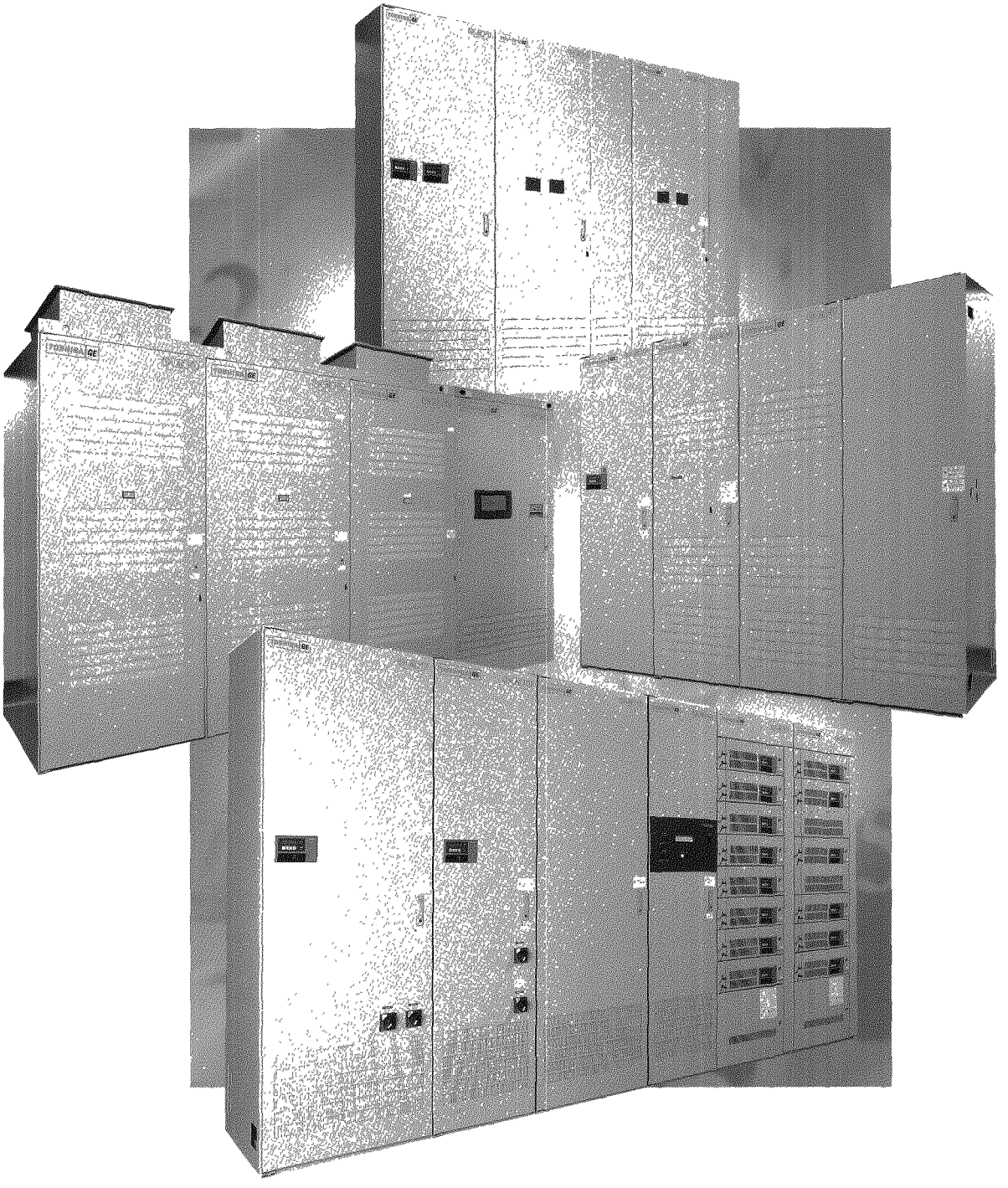
TOSHIBA GE

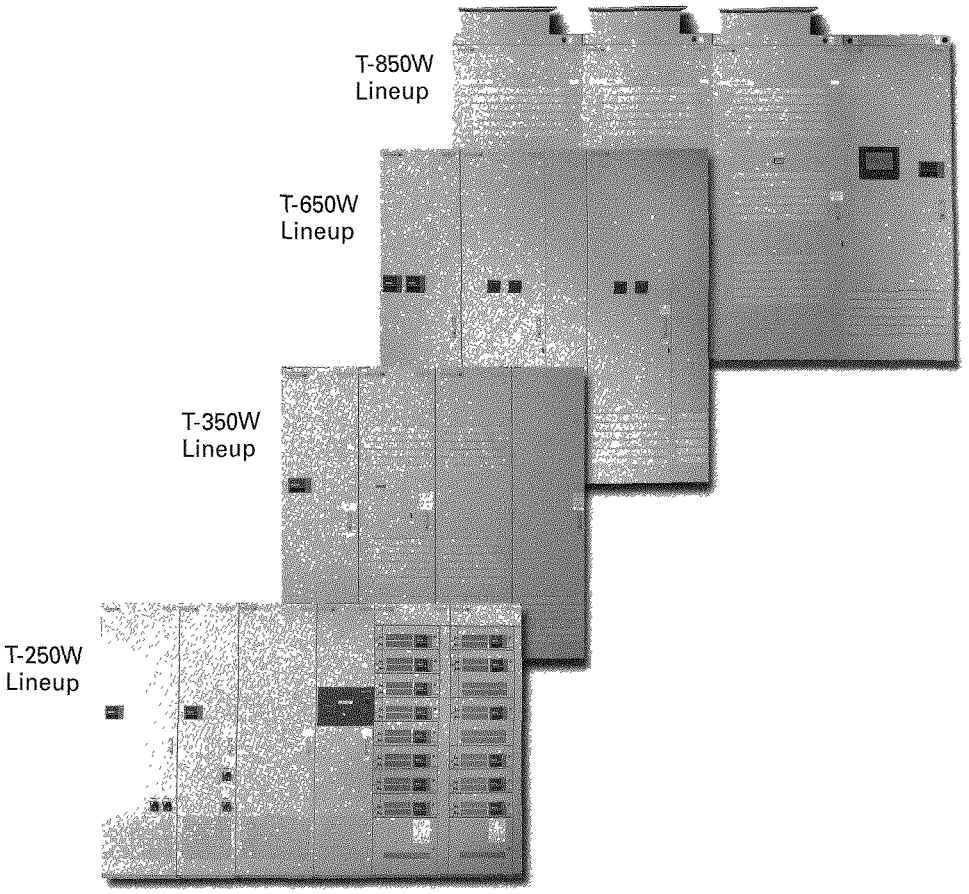


GE TOSHIBA AUTOMATION SYSTEMS

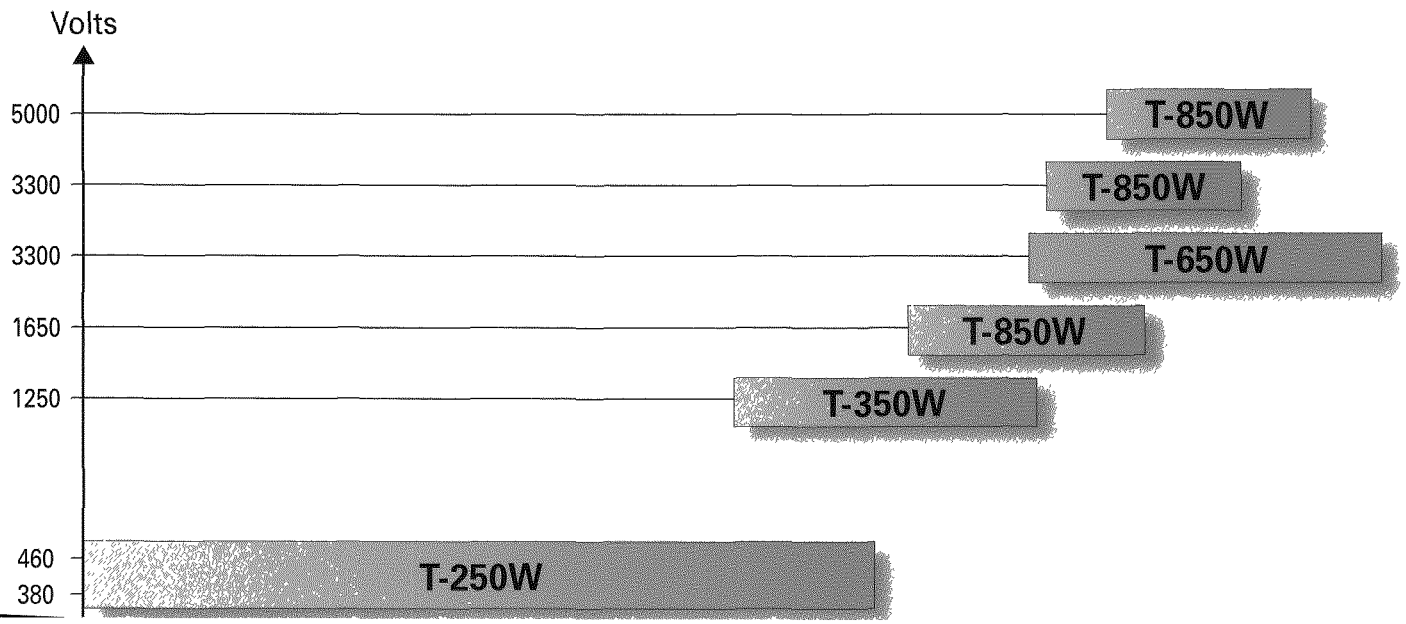
IP7_024292

GE and Toshiba have joined forces to develop a family of TOSVERT ac system drives, targeted at specific customer requirements for:

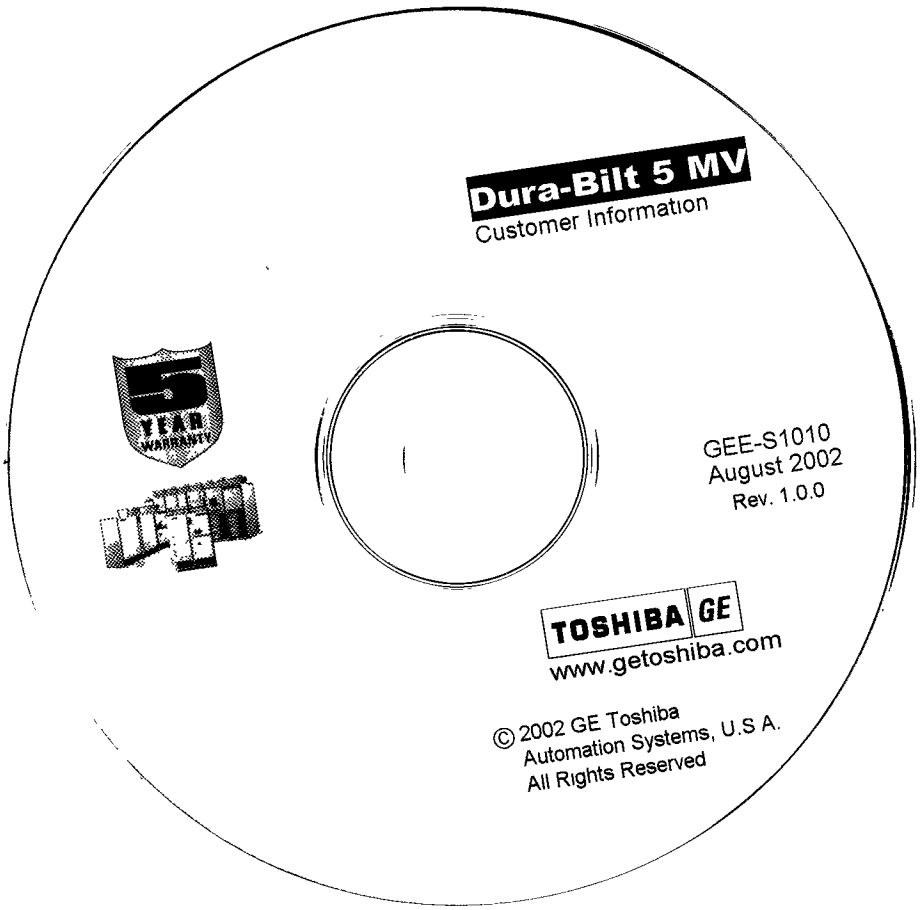
- High reliability
- Simple configuration and maintenance
- Low cost of ownership



TOSVERT System Drives Have Complete Coverage



IP7_024293


Dura-Bilt 5 MV
Customer Information
5
YEAR
WARRANTY
GEE-S1010
August 2002
Rev. 1.0.0
TOSHIBA GE
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IP7_024294

Intermountain Power

VFD Technologies

Overview of our time together

- Introductions, agenda
- GE-Toshiba background
- Drive Topology Comparisons
- GE – Toshiba MV drive experience + overview of latest technology.
- Intermountain Power job specifics
- Technology & $ tradeoffs for IP project for viable technologies.
- Discussion time & conclusions

IP7_024295

GE's Long History in Medium Voltage Drives

The Dura-Bilt5 MV is the newest drive in a long line of Medium Voltage (MV) drives. GE began supplying variable frequency MV drives in the late 1970's.

LCI [Load Commutated Inverter] Late 70's
The first drives were for synchronous motors using LCI (Load Commutated Inverter) technology, thyristors as switching devices – they are still the drive of choice for the very largest of Synchronous motor drive application.

GTO Based IMD [Induction Motor Drive]
In the mid 80's, a new series of drives was introduced for induction motors using GTO based current source technology [CCI].
The GTO has been updated to a device called an ~~IGBT~~ SGCT or IGCT but this technology, though leading edge in the the 80's, has now been replaced by voltage source PWM technology. *more*

Medium Voltage Drives History - 2

Innovation Type G [Medium Voltage IGBT] Mid 90's
The Innovation Series™ of MV drives (Type G) were introduced in the mid 90's using MV IGBT technology and GE's industry leading Toolbox programming tool.
Unfortunately, this product offering required transformers to be separately mounted and wired by the customer, adding cost and installation time.

•Innovation Type H [Low Voltage IGBT power cells]
In the late 90's, the Innovation Series Type H drives were introduced. These drives used integrated transformers and provided state of the art harmonic elimination.
Unfortunately, these drives utilized multiple LV IGBT devices, which due to the very high number of parts used, have an inherently higher potential for failure.

Medium Voltage Drives History - 3

Dura-Bilt5 MV – Medium Voltage IGBT, Integrated Transformer

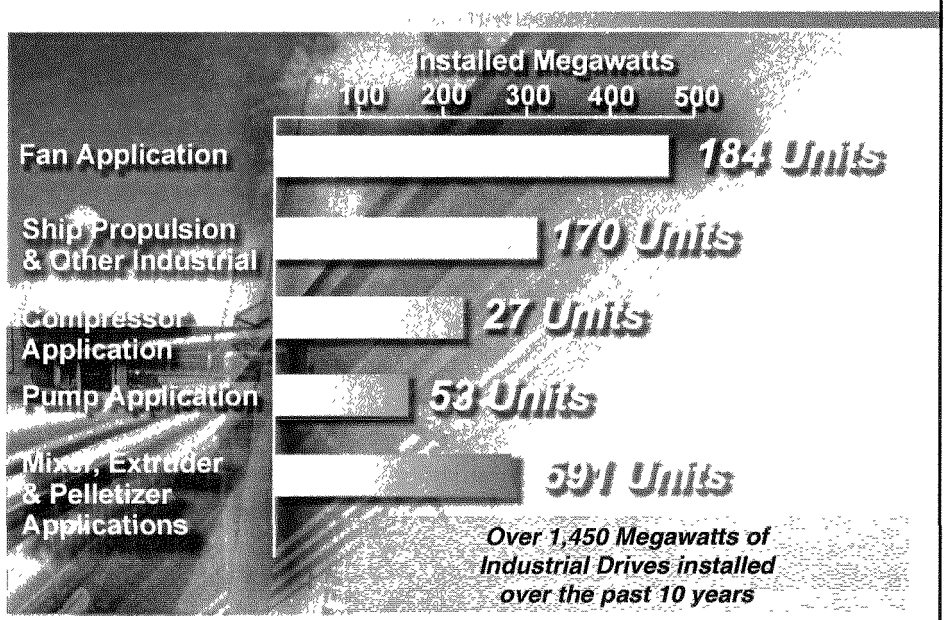
Using the very latest in compact packaging, forced air heat-plate cooling, and power devices, The GE Toshiba Dura-Bilt5 MV drive was developed. With the introduction of the Dura-bilt5 MV Series, GE Toshiba has created a product that combines the best attributes of years of drives experience to deliver the most reliable, most compact, and easiest to install drive system available today.

The Dura-Bilt5 MV

Competitive
Compact
Reliable by Design
5 year Warranty
Backed by GE and Toshiba

GE Medium Voltage Drive Experience

Output Volts	Technology	Quantity
2300	Various	134
3300	Various	10
4160	Various	108
6600	IGCT	12
2300, 4160	LCI Drives	288
2300	LCI Turbine Starters	428



Power Plant/ Utility Applications

Existing Drives or Typical / Traditional:

- **Boiler Feed Pumps**
- **Induced Draft (ID) Fans**
- **Forced Draft (FD) Fans**

New Drives Opportunities:

- **Adding Fan capacity for air quality and more power**
- **Adding pump capacity for growing power demands**

Intermountain Power Specifics

- Black and Veatch scope
- IPP's purposes
- IPP's concerns
- Existing Equipment
- Physical and Environmental Concerns
- Budget Constraints
- Drive Technology tradeoffs

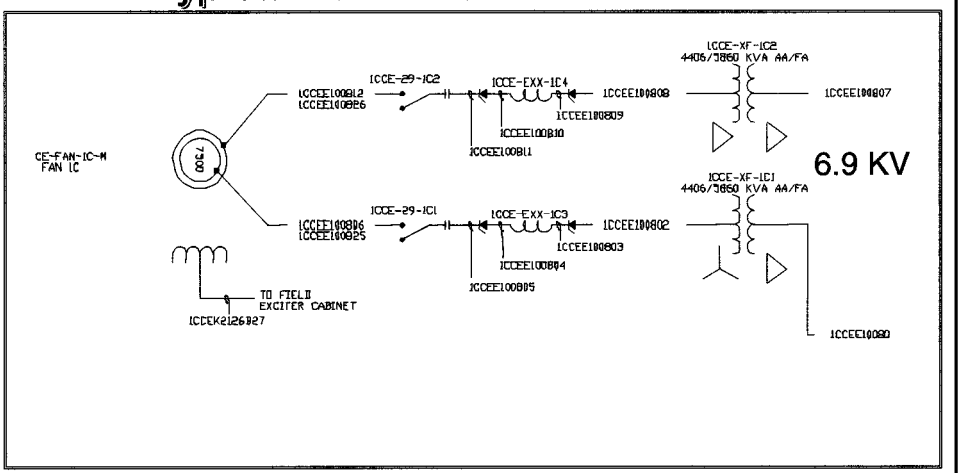
Perceived Purposes & "CTQs"

- Extend available service life
- Modernize to improve potential reliability, assure parts availability
- Uprate Fan Output
- Look at available technologies to get best fit.
- Possibly: improve power system impact.
- Re-use existing motors – replace other equipment if/as needed or recommended.
- Other..

Existing Equipment

- Motors – 2 winding, 1980's Westinghouse design for LCI application
- LCI Drives ~~[& heat exchangers if liquid cooled]~~ AIR COOLED.
- Transformer[s]
- LCI drive DC Link reactors
- Switchgear
- Control interface

Typical LCI Drive One-Line at IPP



Existing Motors – LCI 2-winding

- Low inductance design needed for LCI – would probably need series L if used on voltage source drive
- Two- winding construction, 30 degrees phase shifted – cannot parallel for single connection on PWM.

8 ID Fan Motors at IP Facility

Frame size	B2611S90
Motor Type	Synchronous
Enclosure	WPII
Horsepower	**7415/4596**
Voltage	**3876/3876**
Power factor	0.90
Full load amperes	**472/538**
Hertz	**63.6/53.93**
Phase	**6/3**
Exciter field amperes	44
Service factor	1.0
Application	AFAC Fan Drive
Load wk^2 lb-ft^2	347,700
Motor wk^2 lb-ft^2	35,000
Poles	
Speed	**954/809**

Rotation	4 motors CW, 4 motors CCW
Insulation class	F
Ambient	45 C
Altitude	**4676 feet**
Temperature rise	75 C
Breakdown/pull-out torque	200%
Sound level	80 dBA @ 1 meter
Manufacturer	Westinghouse
Accessories	
Differential current transformers (800:5)	Motor space heater 4500 watts
Exciter space heater 5000 watt	Stator RTD's six 10 ohm @ 25 C copper
Bearing TC Type E	

IP ID Fan Motor Questions

- Rating needed for process: uprate possible.
  - RPM & Loading per winding
- Rewind or overhaul planned?
- NOT Reconnectable for 2300 volts.
- Motor loading summary:

Motor	NP	NP	Needed HP?
HP	4596	7415	10000
V	3786	3786	3876
RPM	809	954	1054
Freq	53.9	63.6	70.2

IP7_024302

Motor & Operational Details

- Dual rated – for dual LCI 12 pulse – 12 pulse feed with operation above base speed [954 RPM, 7415 HP] with 2 channels, below base speed [809 RPM, 4596 HP], with single channel.
- Redundant operation used today.
- Fan HP for Generation Uprate & redundancy for today & future?
- Desire is for one completely redundant fan system.

IP ID Fan Motor Questions

- Rating needed for process: uprate possible.
  - RPM & Loading per winding
  -
- Rewind or overhaul planned?
- NOT Reconnectable for 2300 volts.

Transformers & Switchgear

- Transformer Age & rating concerns.
- Voltages, connections and kVA ratings.
- Location of present transformers.
- Switchgear presently needed and to be required.
- Alternate arrangements with different technologies.

Environmental & Physical Factors

- Physical sizes of old equipment
- Environment for cooling
  - ❖ Present drive: air or liquid cooled?
  - ❖ Replacement drive – liquid for LCI, air for PWM
- Electrical environment: PF & harmonic concerns.

Commercial Areas

- Black & Veatch's role – specify, procure or both.
- Budget constraints vs equipment package
- Project funding?
- Present feedback: buy [1] system 12/02 a second in June 03, start both in 2004.
- Two per year commissioned until all complete.
- Selection process details?

Potential Technologies - 1

- PWM, voltage source drives
  - Example: Dura-Bilt5i MV, 4160 volts, up to 5400 HP per channel, air cooled.
  - Sync or induction motor
  - Potential issues:
    - ✓LCI dual winding = phase shift transformers, reactors, or reduced output [3-phase motor rating]
    - ✓Low inductance may require reactor

Potential Technologies - 2

- Current source drive
  - GE GTO IMD, AB Power-Flex
  - Not suitable for sync motor
- LCI drive
  - GE innovation LCI
  - Possible Best Fit with existing motor
  - Innovation LCI overview
  - Constraints

Potential Technologies - 3

- T650 Voltage Source
  - IEGT rugged steel mill drive
  - 3300 volt output, 8 MVA
  - ~17 sold, 4-5 started, 2 sold in USA
  - Active front end, IEEE compliant w/o filters, 0.95 Power factor
  - Water cooled, sealed heat exchanger
  - Very compact.

Summary: Drives for IPP ID Fan

Motor	GTA Innovation LCI	GTA T650 PWM	GTA Dura-Bilt5i MV
Existing W Sync	2 Channel, 4160 V	NO, due to motor Limitations	NO, due to motor Limitations
New Induction	NO	YES 3300 V	YES, 4160 V
New Sync	2 Channel, Voltage TBD	YES, 3300 V	YES, 4160 V

IP7_024307

Critical Items of IPP Drive Solution

Critical Area [CTQ]	IPP's Value [1 to 5, 5 = Most Important]
System Power Quality	
Channel Redundancy	
Remote Diagnostic & Support	
Experience Factors	
Footprint	
House Heat Load	
Overall Efficiency	
Technology Life Cycle	
Total Cost	

IP7_024308

Conclusions and Discussion

- How can GE-Toshiba help
  - ❖ Black & Veatch
  - ❖IPP directly
- Discussion

Thank You!

IP7_024310

Presentation Overview

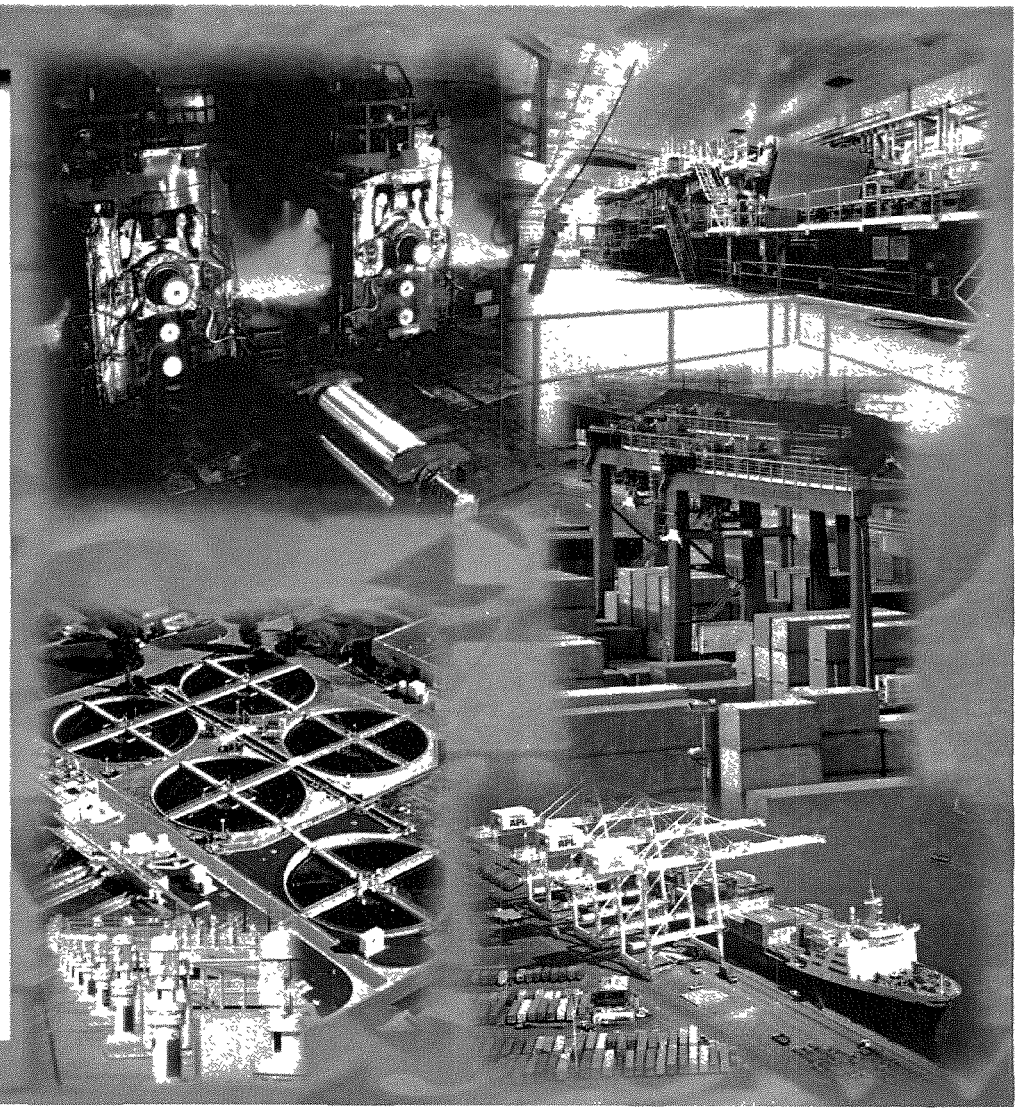
- Purposes today
- GE-Toshiba
- GE MV Drive History
- MV Drive Topology Comparisons
- Dura-Bilt5 MV Drive, with Q&A
- Application Specifics for Project
- Commercial: Timing, next steps

IP7_024311

TOSHIBA GE

GE TOSHIBA AUTOMATION SYSTEMS

As a highly experienced, energized and committed global industrial systems integrator, Toshiba GE Automation Systems Int'l will create solutions with customers that improve their productivity and enhance their product quality.



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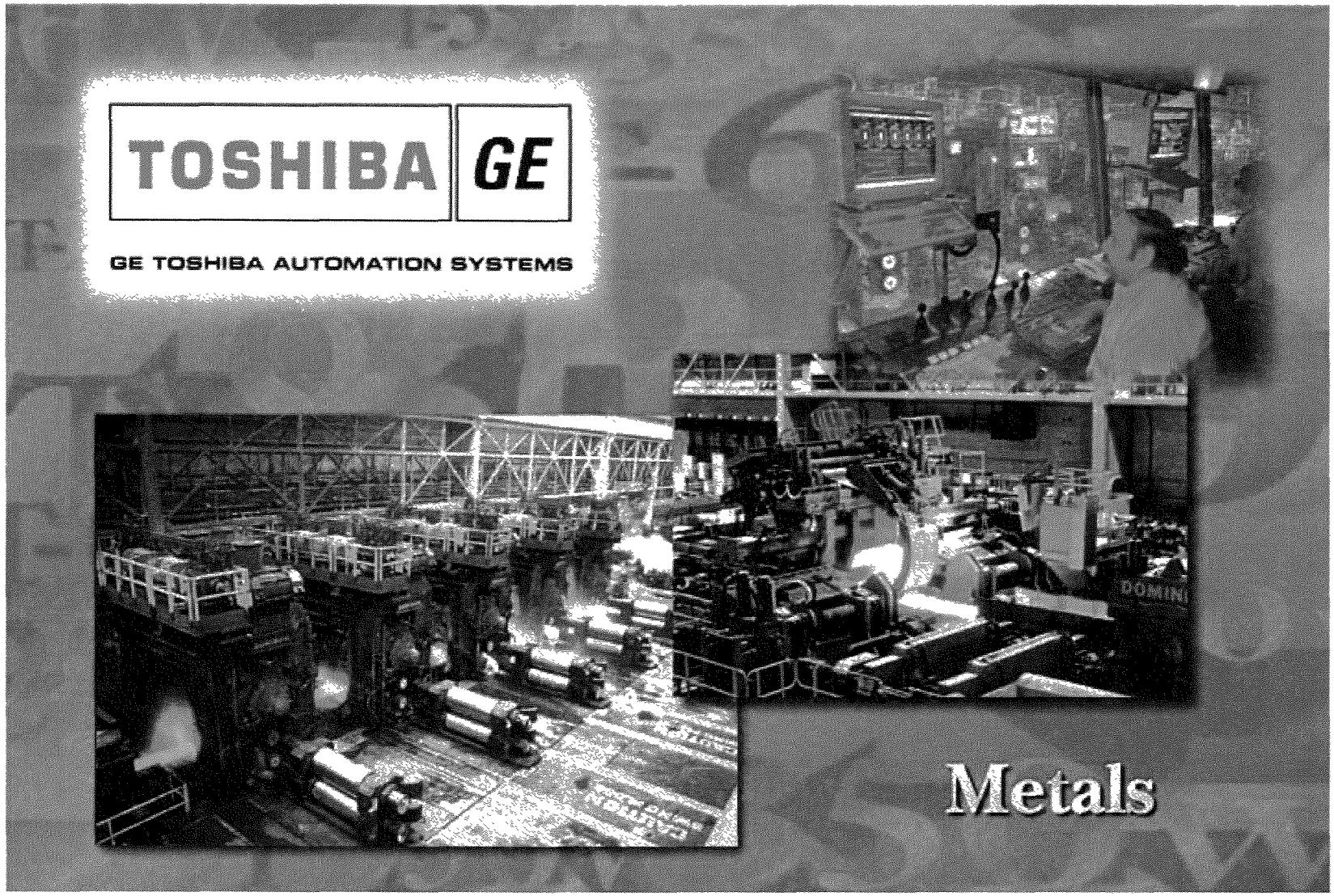

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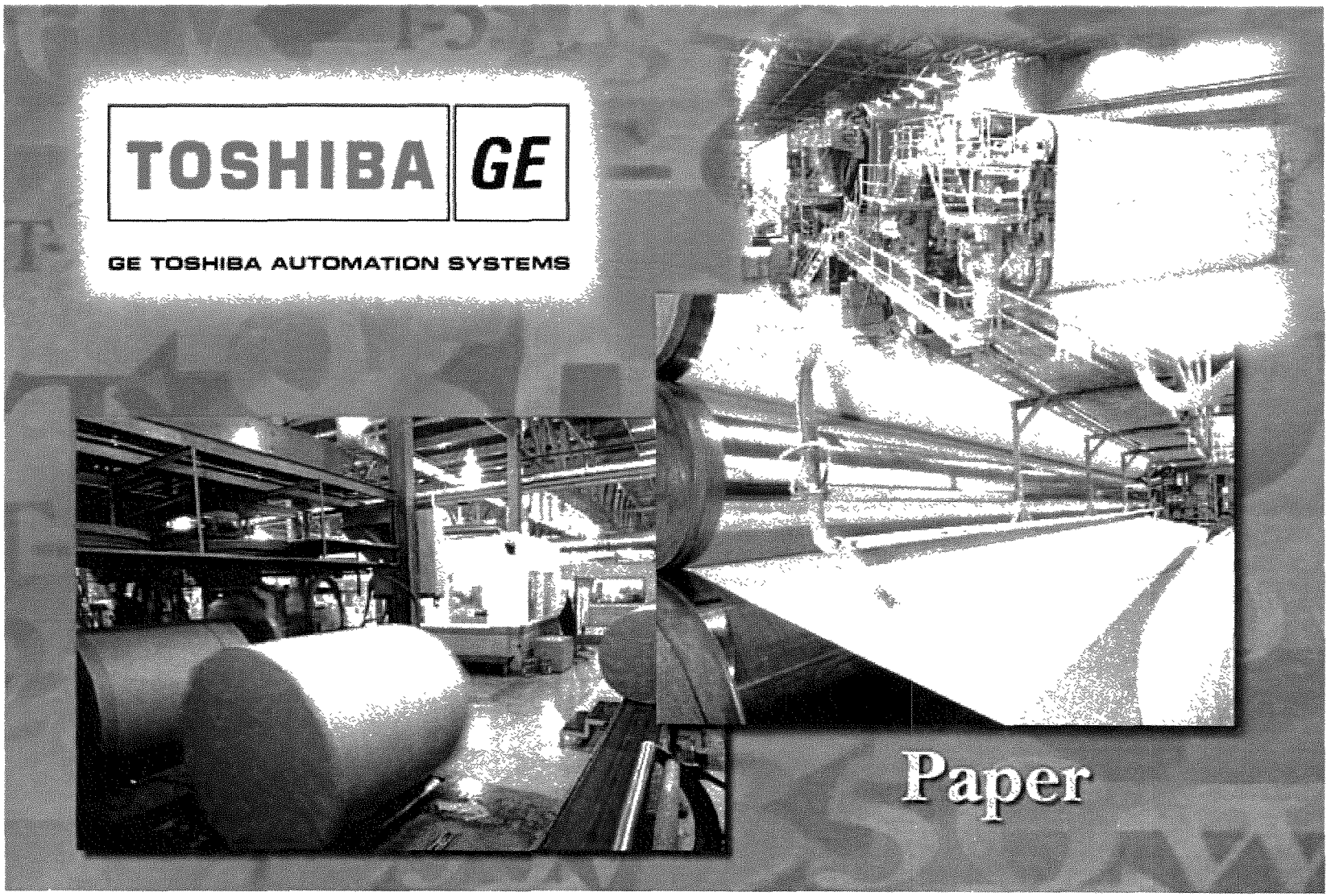

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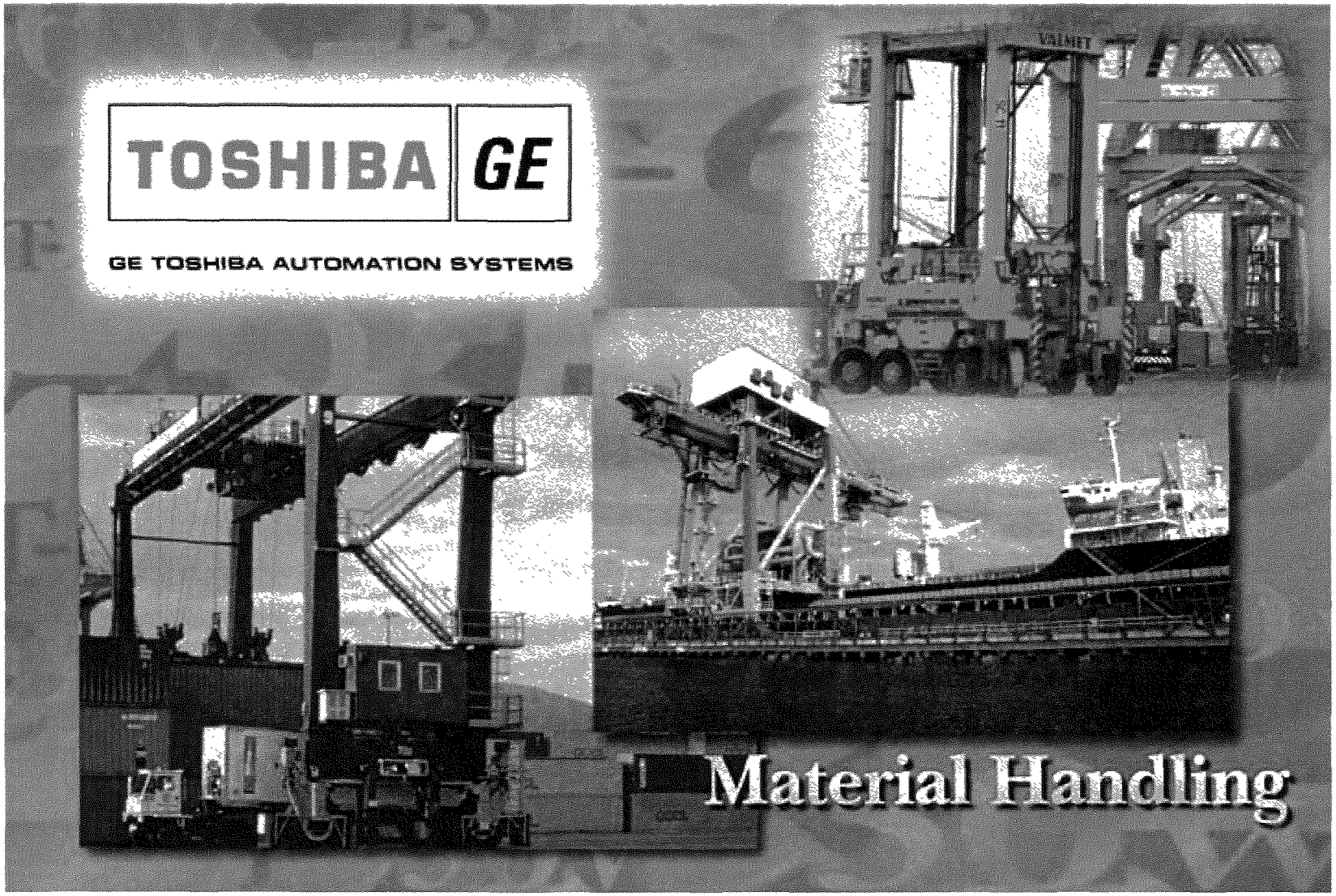
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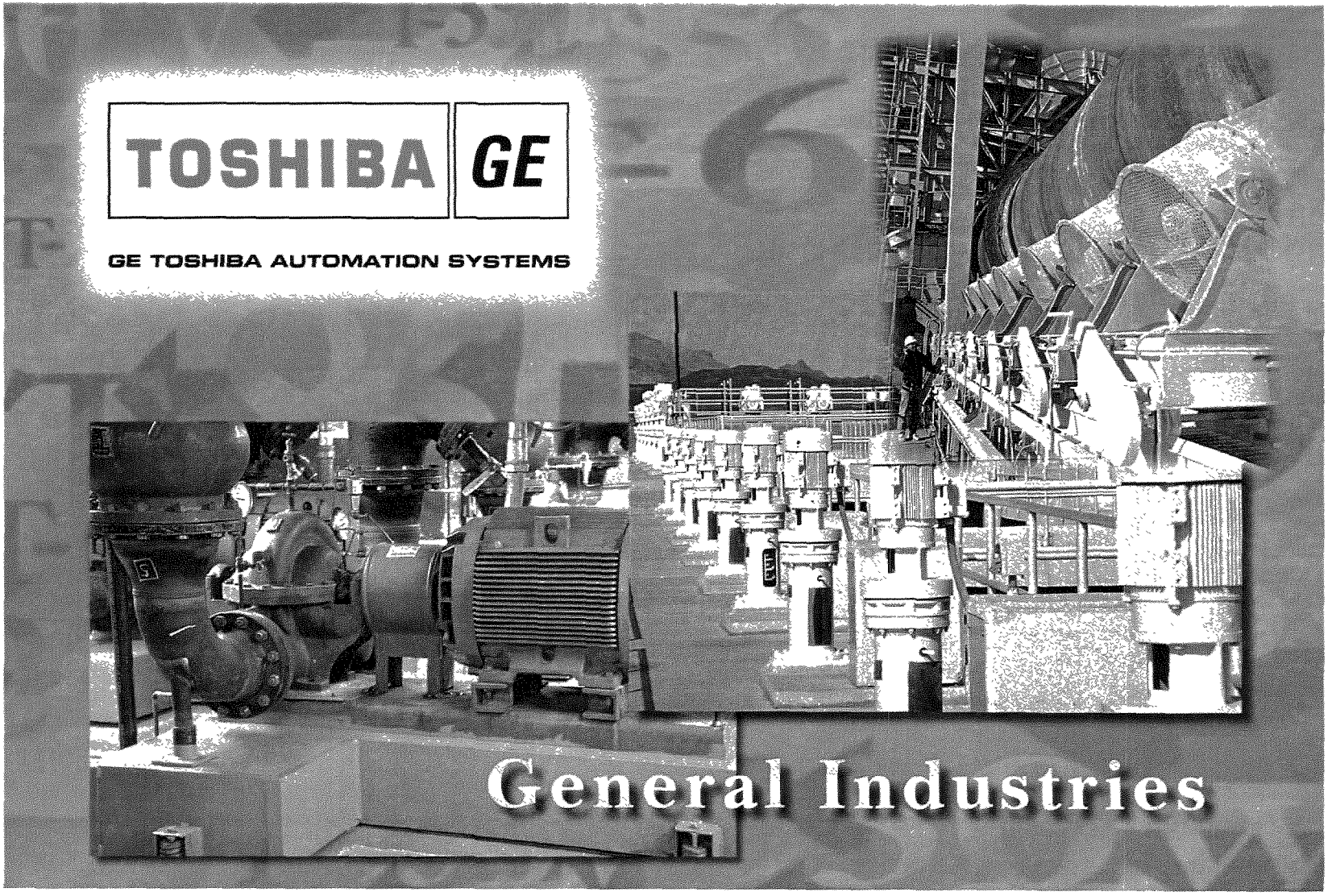
GE TOSHIBA AUTOMATION SYSTEMS
Material Handling

IP7_024315


TOSHIBA GE
GE TOSHIBA AUTOMATION SYSTEMS
General Industries

IP7_024316

Company Info

Our History

- Share Holders - GE and TOSHIBA Corporations
- Date Created - October 1st, 2000
- Structure: Joint Venture between GE and TOSHIBA
  Two Companies formed: GE TOSHIBA Automation Systems LLC (North America) (GTAU)
  TOSHIBA GE Automation Systems Corp (Japan) (TGAJ)

Our Business

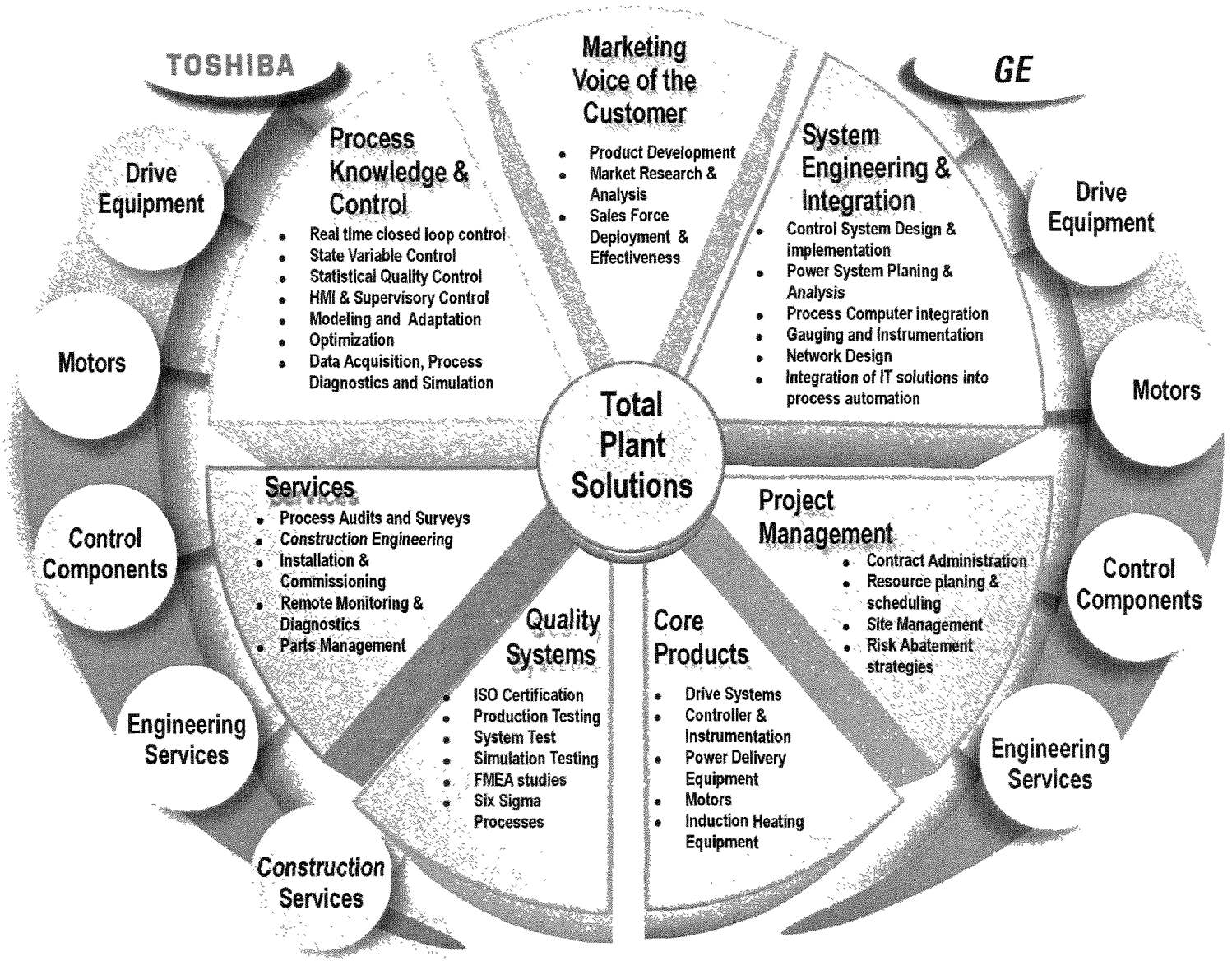
- Scope of Business: Global System Integrator and Supplier of Process Automation
- Annual Sales: $500 MM
- Employees: 600 Engineers and Technicians world wide
- Engineering Skills: System Design, Integration, and Commissioning of Automation Systems
- Products: Core products sourced from both TOSHIBA and GE

Support

Sales & Service: Dedicated Sales and Service in Japan
Service Infrastructure supported by GE and TOSHIBA parent companies globally
GE Solutions Sales Force: Exclusive User Sales Representative in North America

IP7_024317

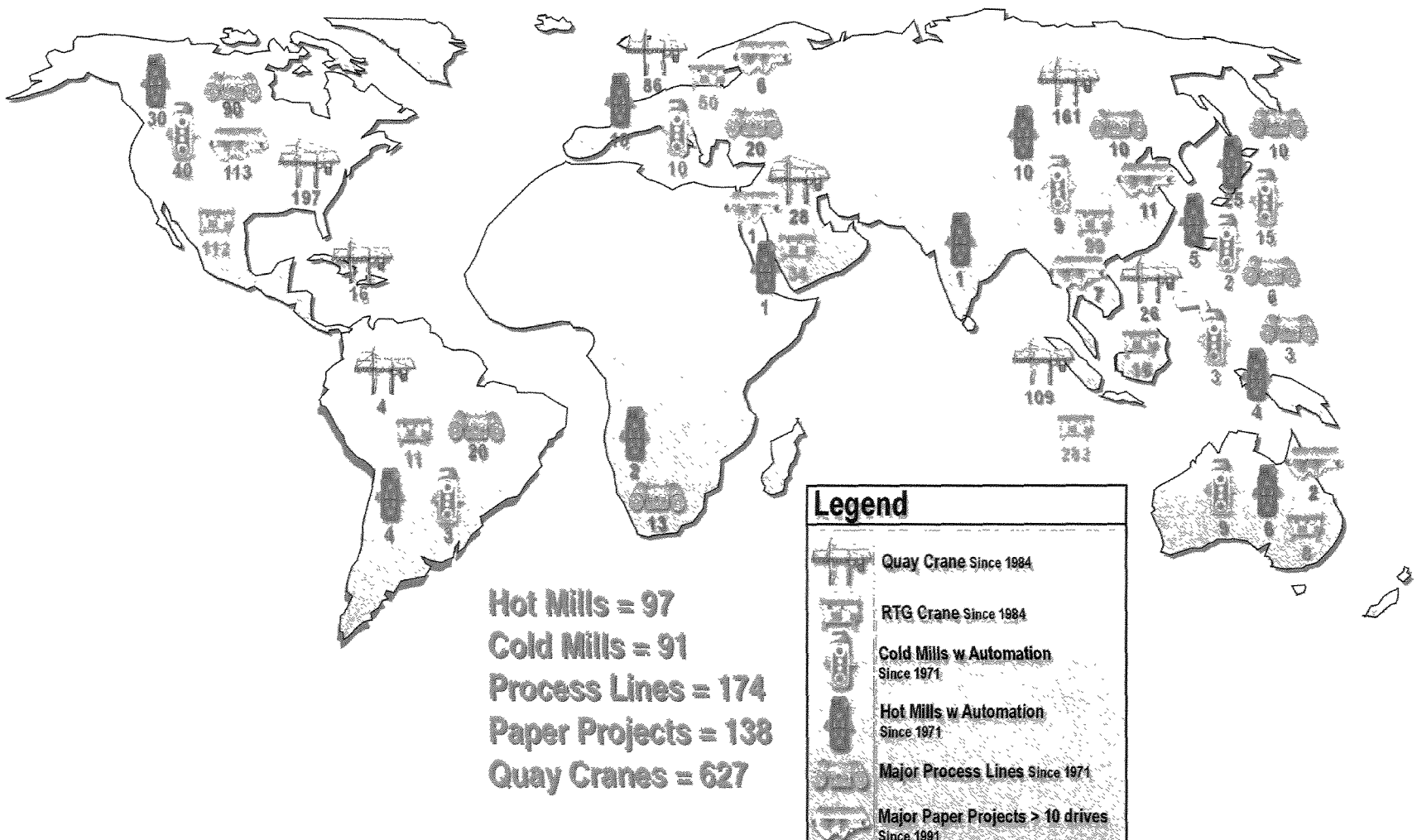
The Value We Bring



IP7_024318

Our Experience Base

Company info



Hot Mills = 97
Cold Mills = 91
Process Lines = 174
Paper Projects = 138
Quay Cranes = 627

IP7_024319

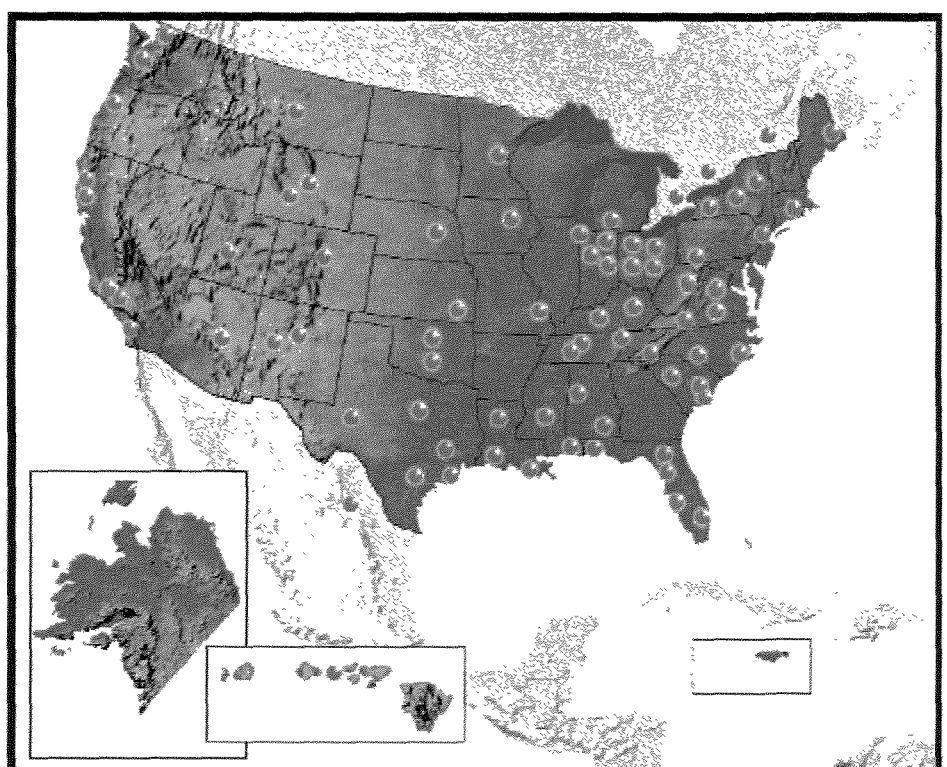
Global Sales and Service

IP7_024320

GE Service Support Network

After sales service by GE Engineering Services in North America

- *The Largest Network of Field Engineers in North America*
- *Supported Globally by GE and Toshiba international service organizations*



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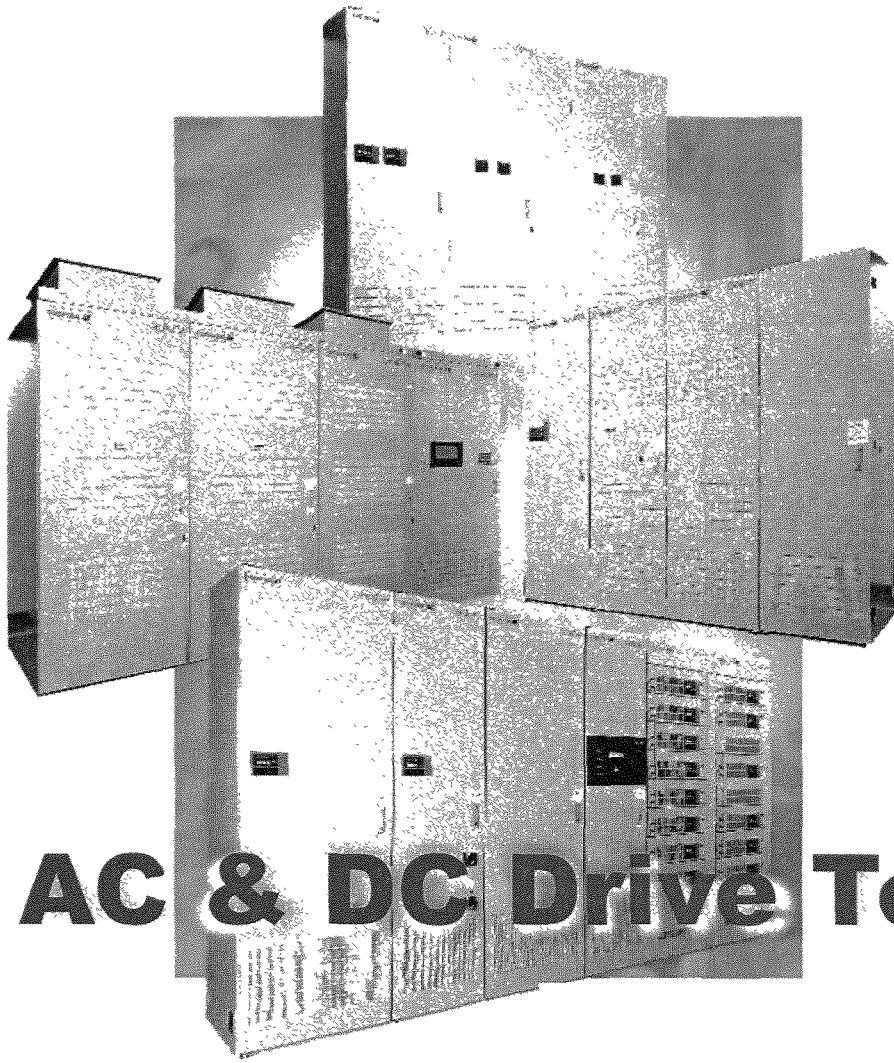
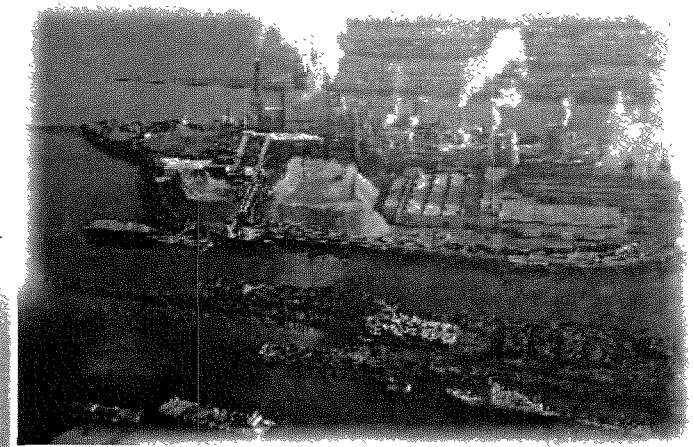
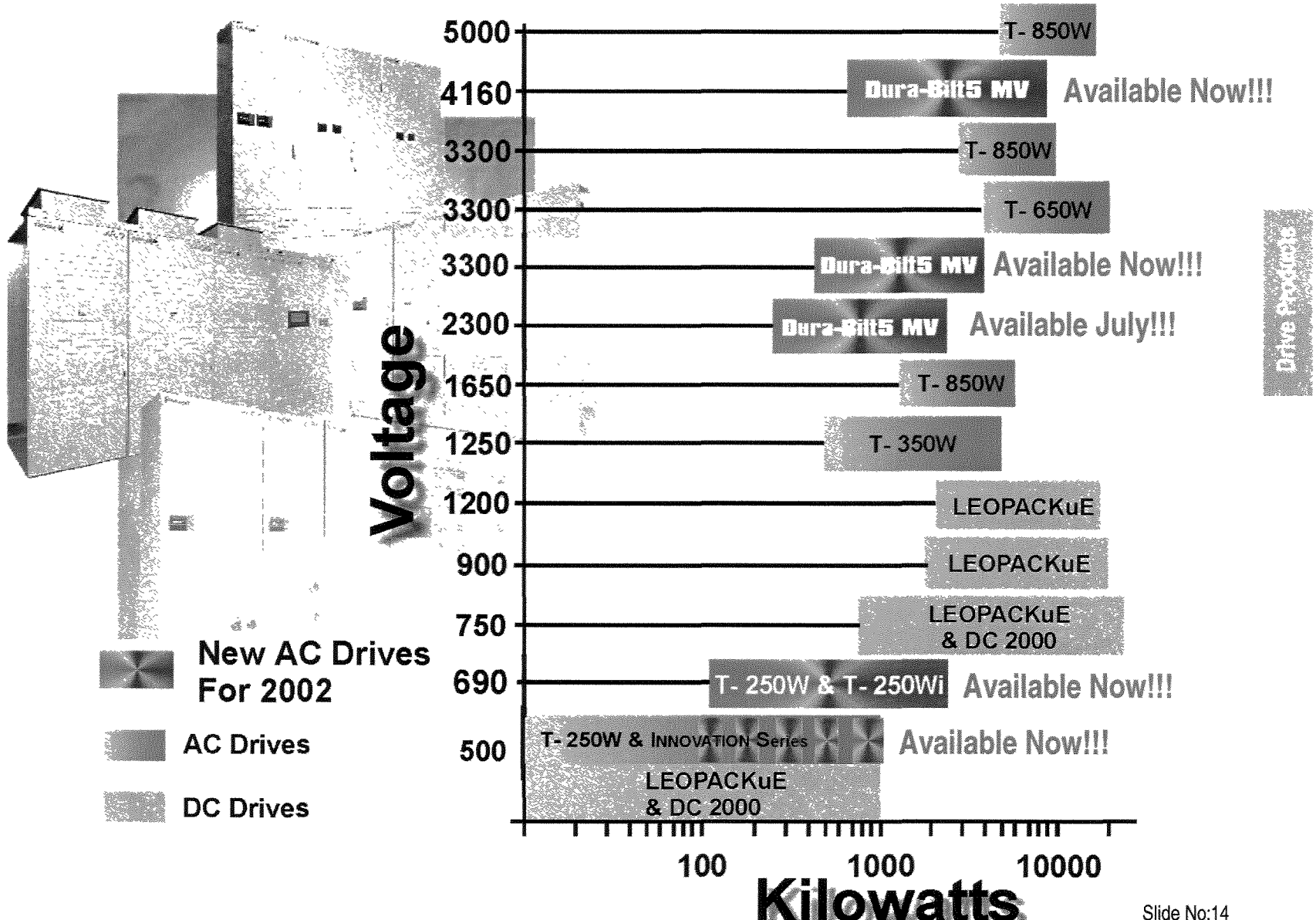




AC & DC Drive Technology

IP7_024322


Voltage
5000
4160
3300
3300
3300
2300
1650
1250
1200
900
750
690
500
T- 850W
Dura-Bilt5 MV
Available Now!!!
T- 850W
T- 650W
Dura-Bilt5 MV
Available Now!!!
Dura-Bilt5 MV
Available July!!!
T- 850W
T- 350W
LEOPACKuE
LEOPACKuE
LEOPACKuE & DC 2000
T- 250W & T- 250Wi
Available Now!!!
T- 250W & INNOVATION Series
Available Now!!!
LEOPACKuE & DC 2000
100
1000
10000
Kilowatts
New AC Drives For 2002
AC Drives
DC Drives

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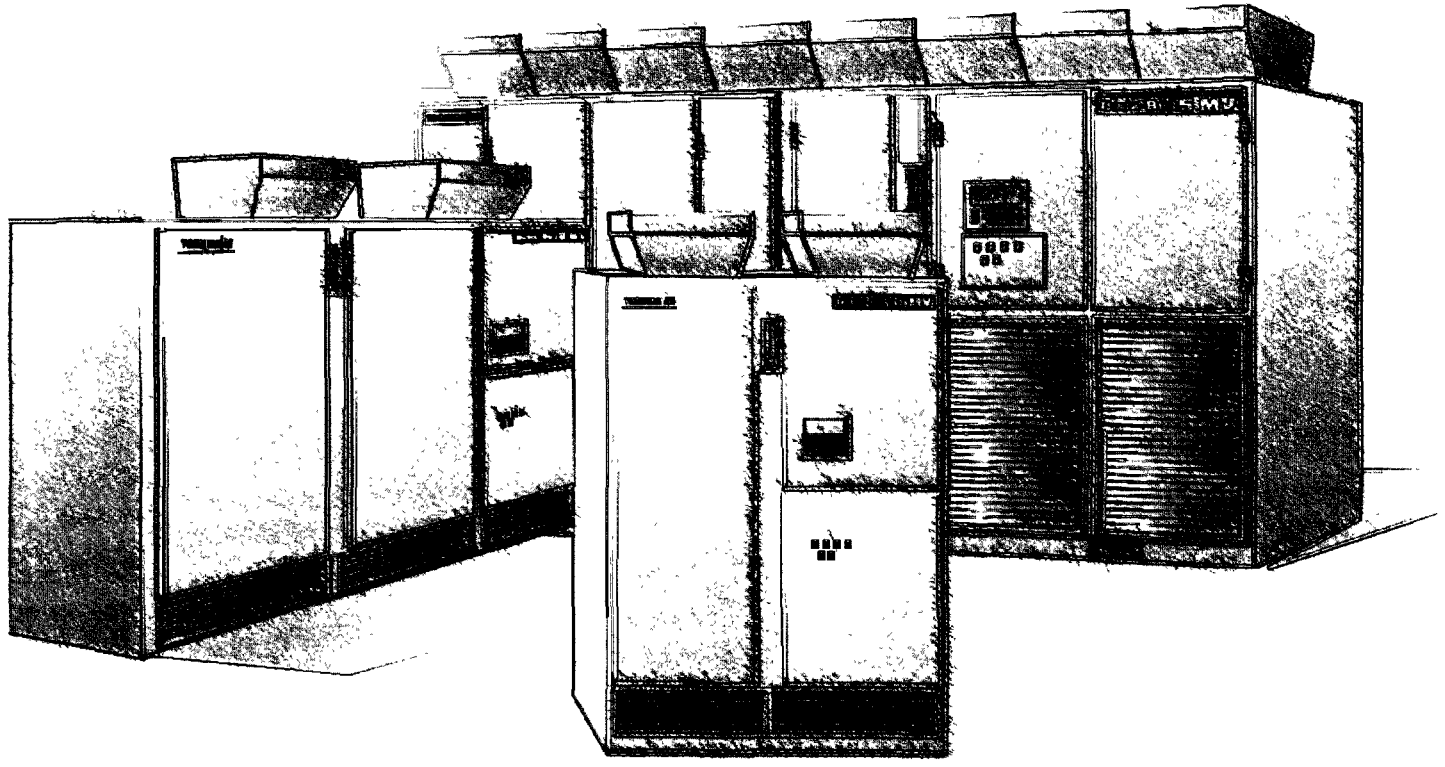

A New Family of MV Drives For a New Century

IP7_024324

Updated 10/01/02

GE-Toshiba Automation Systems

Medium Voltage Drive Experience Lists

Drives Shipped Counter:

Output Volts	Quantity
2300	134
3300	10
4160	125
6600	12
7200	0
LCI	288
LCI Turbine Starters	428

IP7_024325

Medium Voltage Drives (4160 Vac IGBT)

Customer	Location	Application	Rating (hp)	Date	Qty	Type
Cementos Cruz Azul	Mexico	Cement Induced Draft Fan	600	Mar-98	1	G
Cementos Cruz Azul	Mexico	Cement Seperator	400	Oct-98	2	G
Cementos Cruz Azul	Mexico	Cement Induced Draft Fan	700	Nov-98	1	G
Cementos Cruz Azul	Mexico	Cement Induced Draft Fan	1000	Nov-98	2	G
Cementos Cruz Azul	Mexico	Cement Induced Draft Fan	1750	Nov-98	1	G
San Paulo Water	Brazil	Water Pumping	1100	Oct-98	1	G
Farrell / Allied Signal	Virginia	Extruder	1000	Dec-98	2	G
Phil. Mixer / Allied Signal		Mixer	700	Dec-98	3	G
Berstorft / Allied Signal		Extruder	400	Dec-98	1	G
Arizona Portland Cement	AZ	Kiln ID Fan	4000	May-99	1	H
Caribbean Cement	Jamaica	ID Fan	1250	Jun-98	1	G
Cruz Azul	Tepeaca, Mexico	Fan	900	Oct-98	2	G
Cruz Azul	Tepeaca, Mexico	Fan	350	Dec-98	2	G
Midland Cogen. Venture	Michigan	Boiler Feed Pumps	1250	Dec-98	6	G
Cruz Azul	Tepeaca, Mexico	Fan	1500	Jan-99	1	G
Cemco Cement	South America	ID Fan	3000	Jun-99	1	H
TXI Midloathian Cement	Texas	Fan	6500	Aug-99	1	H
TXI Midloathian Cement	Texas	Fan	2250	Aug-99	1	H
TXI Midloathian Cement	Texas	Fan	1500	Aug-99	1	H
TXI Midloathian Cement	Texas	Fan	1500	Aug-99	1	H
TXI Midloathian Cement	Texas	Fan	1250	Aug-99	1	H
Cytec Chemical	Lousiana	Pump	900	Jul-99	1	H
RC Cement	Chatanooga, TN	Fan	1250	Dec-99	2	G
RC Cement	Chatanooga, TN	Fan	2000	Dec-99	1	G
Equipo De Control	Dominican Republic	Fan	2250	Dec-99	1	H
Formosa Plastics	Texas	Extruder	1600	Mar-00	1	H
Cruz Azul	Mexico	Fan	800	Jan-00	1	H
Cruz Azul	Mexico	Fan	600	Mar-00	1	G
Cruz Azul	Mexico	Fan	600	Mar-00	1	G
Cruz Azul	Mexico	Fan	800	Mar-00	1	G
Blue Circle Cement	Tulsa, OK	Fan	800	Dec-99	2	H
Fort James	Wisconsin	ID Fan	1750	Mar-00	1	G
Coperion	New Jersey	Extruder	1500	May-01	1	H
Atofina Chemical	PA	Extruder	1500	Jun-01	1	H
Techint		Fan	3000	Sep-01	1	H
Ashgrove Cement	Oregon	Fan	1500	Jan-02	1	DB5
Petro Canada	Canada	Pump	600	Feb-02	2	DB5
Wheelabrator	Connecticut	ID fans	600	Feb-02	6	DB5
Cruz Azul	Mexico	Various Fans	261	Mar-03	2	DB5i
Cruz Azul	Mexico	Various Fans	2413	Mar-03	3	DB5i
Cruz Azul	Mexico	Various Fans	992	Mar-03	3	DB5i
Krupp Rubber	USA	Mixer	2120	Jan-02	1	DB5i
Georgia Pacific	Wisconsin	Fan	1750	Dec-02	2	DB5
				TOTAL	**69**	

IP7_024326

Medium Voltage Drives (4160 Vac GTO)

Customer		Application	Rating (hp)	Date	Quantity	Type
Sierra Pacific Power Co.		Boiler Feed Pump	2000	Feb-86	1	GTO-IMD
Oklahoma Gas & Electric		Boiler Fan FD	5000	Mar-86	2	GTO-IMD
American Electric Power		River Water Pump	1000	Jul-86	1	GTO-IMD
Stone Container Corp.		Hi Pressure Pump	350	Aug-86	2	GTO-IMD
Nucor Steel		Jump Mill	2500	Aug-86	1	GTO-IMD
Lehigh Portland Cement		ID Fan	600	Sep-86	1	GTO-IMD
Lehigh Portland Cement		ID Fan	700	Sep-86	1	GTO-IMD
Alberta Energy Company		Pipeline Pump	3500	Oct-86	1	GTO-IMD
Giant Cement		ID Fan	600	Jan-87	1	GTO-IMD
So. California Edison		FD Fan	7200	May-87	2	GTO-IMD
Lakehead Pipeline Co		Pipeline Pump	2500	Jun-87	1	GTO-IMD
Sierra Pacific Power Co.		Gas Recirc Fan	1250	Aug-87	1	GTO-IMD
AEC Pipeline		Pipeline Pump	5000	Mar-88	1	GTO-IMD
Weyerhauser		Boiler Feed Pump	3500	Sep-88	1	GTO-IMD
Firestone		Mixer	4000	May-89	1	GTO-IMD
Phelps Dodge		Conveyor	1500	Aug-90	2	GTO-IMD
Phelps Dodge		Conveyor	3000	Aug-90	4	GTO-IMD
U.S. Steel		Fan	1500	Jun-91	1	GTO-IMD
Lakehead Pipeline		Pump	2875	Oct-91	1	GTO-IMD
Wahington Public Power		React Resurge Pumps	10000	Jan-92	2	GTO-IMD
Lakehead Pipeline		Pump	3000	Apr-94	1	GTO-IMD
Tippins Steel		Descaling Pump	5000	Jan-95	1	GTO-IMD
Portland GE		ID Fan	4000	Mar-95	2	GTO-IMD
Enron		Compressor	5000	May-95	3	GTO-IMD
Houston Fuel Oil		Pump	4600	Jul-95	1	GTO-IMD
GEVISA		Mill	1750	Sep-95	2	GTO-IMD
Midwest Power		Boiler Feed Pump	6300	Sep-95	2	GTO-IMD
Cemex		Kiln ID Fan	3000	Oct-96	2	GTO-IMD
Werner & Phleiderer		Extruder	4000	Jan-97	1	GTO-IMD
Caribbean Cement		ID Fan	1250	Dec-97	1	GTO-IMD
Cruz Azul - Cement		Fans	370	Mar-98	2	GTO-IMD
Cruz Azul - Cement		Fans	670	Mar-98	1	GTO-IMD
Cruz Azul - Cement		Fans	1000	Mar-98	2	GTO-IMD
Cruz Azul - Cement		Fans	1750	Mar-98	1	GTO-IMD
Midland Cogeneration Venture		Boiler Feed Pumps	1250	Nov-98	6	GTO-IMD
				TOTAL	**56**	

IP7_024327

Load Commutated Inverters for Synchronous Motors

Customer	Application	Qty	Rating (hp)	Date	Pulse	Voltage	Cooling
GE-GTSS	Starter	1	1340	Jun-79	6	2300	Air
Tampa Electric	Boiler Fan (FD)	2	3000	Oct-79	12	2300	Air
Tampa Electric	Boiler Fan (ID)	2	6000	Oct-79	12	4160	Air
GE-Noryl	Compressor	1	10000	Jan-80	12	4160	Air
Weyerhaeuser	Boiler Fan (PA)	1	1000	Sep-80	6	1200	Air
Weyerhaeuser	Boiler Fan (FD)	1	1250	Sep-80	6	1200	Air
Ohio Edison	Boiler Fan (ID)	5	1500	Sep-80	6	2300	Air
Weyerhaeuser	Boiler Fan (ID)	1	2250	Sep-80	6	2300	Air
Union Camp	Boiler Fan (ID)	2	1500	Feb-81	6	2300	Air
Conoco	Extruder	2	2000	Feb-81	6	2300	Air
Houston Light & Power	Boiler Fan (ID)	8	4000	Feb-81	12	2300	Air
Conoco	Mixer	2	4000	Feb-81	6	4160	Air
St. Joe Paper	Boiler Fan (ID)	1	3000	Mar-81	12	2300	Air
Westvaco Corporation	Boiler Fan (ID)	1	1750	May-81	12	2300	Air
Minnesota Power & Light	Boiler Fan (ID)	4	8000	Jun-81	12	4160	Air
Chevron Pipeline Co.	Pipeline Pump	1	2500	Jul-81	6	2300	Air
Gulf	Charge Pump	1	3000	Sep-81	6	4160	
Monsanto for ASARCO	Compressor	2	4000	Sep-81	6	4160	Air
Westvaco Corporation	Boiler Fan (ID)	2	1000	Nov-81	6	1200	Air
Westvaco Corporation	Boiler Pump	2	2000	Nov-81	6	2300	Air
Amoco Chemicals	Compressor	1	4500	Nov-81	6	4160	Air
Fraser Company	Boiler Fan (ID)	1	1100	May-82	6	1200	
Fraser Company	Boiler Fan (ID)	1	1850	May-82	6	2300	
Jacksonville Elect. Auth.	(Standby)	1	2150	May-82	6	2300	Air
Jacksonville Elect. Auth.	(Standby)	1	2150	May-82	6	2300	Air
Jacksonville Elect. Auth.	Boiler Fan (FD)	2	2150	May-82	6	2300	Air
Jacksonville Elect. Auth.	Boiler Fan (FD)	2	2150	May-82	6	2300	Air
Jacksonville Elect. Auth.	Boiler Fan (ID)	4	3800	May-82	12	4160	Air
Jacksonville Elect. Auth.	Boiler Fan (ID)	4	3800	May-82	12	4160	Air
Cleveland Electric Illum.	Boiler Fan (ID)	2	4500	May-82	12	4160	Air
Grand River Dam Authority	Condensate Pump	2	1250	Jun-82	12	2300	Air
Grand River Dam Authority	Boiler Fan (FD)	2	2400	Jun-82	12	1200	Air
Grand River Dam Authority	Boiler Fan (PA)	2	3500	Jun-82	12	2300	Air
Grand River Dam Authority	Boiler Fan (ID)	2	9400	Jun-82	12	4160	Air
CIL	Compr Starter	1	12500	Jun-82	12	4160	
Union Camp	Feedwater Pump	1	3500	Sep-82	6	4160	Air
International Paper	Boiler Fan	2	1550	Oct-82	12	900	Air
International Paper	Feedwater Pump	2	1750	Oct-82	12	900	Air
Monarch Cement	Boiler Mill Fan	1	1750	Jan-83	6	2300	Air
Conoco/Billings	Compressor	1	2000	Feb-83	6	2300	Air
Southwestern Pub. Service	Boiler Fan (FD)	2	3000	Mar-83	12	2300	Air
Public Service of Colo.	Boiler Fan (ID)	2	3000	Mar-83	12	2300	Air
Southwestern Pub. Service	Boiler Fan (ID)	3	6000	Mar-83	12	4160	Air
Lower Colorado River Auth.	Condensate Pump	2	700	Apr-83	6	2300	Air
Lower Colorado River Auth.	Standby	1	700	Apr-83	6	2300	Air
Zululand/SAPPI	Boiler Fan (FD)	1	2800	Apr-83	12	2300	Air
Zululand/SAPPI	Boiler Fan (ID)	2	3350	Apr-83	6	4160	Air
Lower Colorado River Auth.	Boiler Fan (ID)	2	8000	Apr-83	12	4160	Air
Amoco Oil Company	Compressor	1	1600	May-83	6	2300	Air
Alabama Power Company	Boiler Fan FD	2	3000	Jun-83	12	2300	Air
Alabama Power Company	Boiler Fan ID	4	4200	Jun-83	12	2300	Air
Pacific Gas & Electric	High Speed BFP	1	15000	Jun-83	12	4160	Air
GE-Lynn Utilities	Boiler Fan ID	1	500	Aug-83	6	900	Air
Alabama Power Company	Boiler Fan ID	4	6000	Oct-83	12	4160	Air
Koch Refining Company	Compressor	1	2000	Dec-83	6	2300	Air
GE Evandale	Compressor	1	1500	Feb-84	6	1200	Air
Hydro Quebec	Wind Turbine	1	5400	Feb-84	6	4160	
Liquid Carbonic	Compressor	1	3000	Apr-84	12	2300	Air
Duke Power Company	Boiler Fan ID	2	5500	Jul-84	12	4160	Air
Georgia Pacific Corp.	Boiler Fan ID	2	1400	Aug-84	6	1200	Air
New York Power Authority	Circ. Water Pump	6	1250	Sep-84	6	2300	Air
New York Power Authority	Standby	1	1250	Sep-84	6	2300	Air
Weyerhaeuser	Boiler Fan ID	1	2250	Nov-84	6	2300	Air

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Customer	Application	Qty	Rating (hp)	Date	Pulse	Voltage	Cooling
Northern States Power	Boiler Fan ID	4	6590	Nov-84	12	4160	Air
Scott Paper	Boiler Fan ID	1	2600	Apr-85	12	1200	Air
Fuller/Box Crow Cement	Dust Coil Fan	1	1500	Jul-85	6	1200	Air
Cable Belt for LCRA	Conveyor	2	2500	Jul-85	6	2300	Air
Fuller/Box Crow Cement	ID Fan Drive	2	3500	Jul-85	6	2300	Air
Homestake Mining Company	Exhaust Fan	1	3000	Oct-85	6	2300	Air
Elkem Metals Company	Frequency Conv.	1	32000	Oct-85	12	6900	Air
Sandia National Lab	Wind Turbine	1	700	Dec-85	6	900	Air
Chevron USA Refinery	Compressor	1	4000	Jan-86	6	4160	Air
China Steel	Rod Mill	1	8000	Jan-86	12	4000	Air
Louisville Gas & Electric	ID Fan	2	3000	Feb-86	6	2300	Air
Orange County Sanitation	Sewage Pump	5	2500	Jun-86	6	2300	Air
BHEL-Bangalore (India)	Drive Simulator	1		Jun-86	6	2300	Air
BHEL-Ranipet (India)	Fan Test Drive	1	3000	Jul-86	6	4160	
Garden City-Ft. Howard	Boiler Fan ID	2	1000	Sep-86	6	1200	Air
Federal Paper Board	Boiler Fan ID	1	2000	Dec-86	6	2000	Air
BHEL/TATA (India)	Boiler Fan ID	4	2750	Dec-86	12	1200	
Parsons-Cominco	Grinding Mill	2	2000	Feb-87	6	2300	Air
Washington C. Sanitation	Sewage Pump	2	2500	Apr-87	6	2300	Air
HOLEC (Holland)	Test Unit	1	5000	Jul-87	6	3600	
Public Service of Colorado	Boiler Fan ID	2	5400	Jul-87	12	2400	Liquid
BHEL/Vijawada (India)	Boiler Fan ID	2	2150	Sep-87	12	1200	
BHEL/KEB (India)	Frequency Conv	2	20000	Sep-87	12	4400	
Los Alamos National Lab	Static Starter	1	8000	Feb-88	6	4160	Liquid
Voith-USBR	Water Pumps	4	10000	Mar-88	12	4160	Liquid
Werner Pfleiderer-Phil 66	Extruder	1	3000	Apr-88	6	2300	Air
XYZ Company	Grinding Mill	1	3500	Jun-88	6	4160	Air
Farrel-Lucky P	Extruder	1	1250	Jul-88	6	2300	Air
Weyerhaeuser	Boiler Fan ID	2	1500	Jul-88	6	2300	Air
Farrel-Lucky P	Extruder	1	1750	Jul-88	6	2300	Air
New York Power Authority	Boiler Fan ID	2	7000	Sep-88	12	2300	Liquid
Kimberly-Clark	Fan	2	2500	Oct-88	6	2300	Air
US Navy	Electric Drive	2	12500	Nov-88	12	4160	Air
Union Camp	Boiler Feed Pump	1	5000	Jun-89	6	4160	Air
City of San Antonio	Boiler Fan FD	2	2900	Jul-89	12	2300	Liquid
City of San Antonio	Boiler Fan ID	2	9400	Jul-89	12	4160	Liquid
Texas Eastern	Pipeline Compr	1	14000	Aug-89	12	4160	Liquid
US Air Force - Arnold Engr	Wind Tunnel Drive	1	20000	Aug-89	24	4160	Liquid
TBO/Potomac Edison	Static Starter	1	5000	Dec-89	6	4160	Air
Public Service of Colorado	Boiler Fan (ID)	2	7000	Dec-89	12	2300	Liquid
XYZ Company	Grinding Mill	2	700	Jan-90	6	2300	Air
Farrel-Hyundai	Extruder	1	2000	Jan-90	12	2300	Air
XYZ Company	Grinding Mill	1	3500	Jan-90	6	4160	Air
Gotaverken for Westvaco	Boiler Fan (ID)	2	1500	May-90	6	2300	Air
Inland Steel	Rod Mill	1	9100	May-90	12	4000	Air
TBO/Baltimore G&E	Static Starter	1	5000	Dec-90	6	4160	Air
Public Service of CO	Boiler Fan ID	2	7000	Feb-91	12	2300	Liquid
Elkem Metals Company	Freq. Converter	1	32000	Mar-91	12	6900	Air
Texas Eastern Pipeline	Gas Compressor	2	14000	Jun-91	12	4160	Liquid
Kimberly-Clark	Fan	1	2500	Jul-91	6	2300	Liquid
Omai Gold	Sag Mill	1	4000	Aug-91	12	4160	Liquid
TBO/Baltimore G&E	Static Starter	1	5000	Dec-91	6	2300	Air
TVA	Boiler ID Fans	12	7000	Apr-92	6-Dec	4160	Liquid
Texas Eastern	Pipeline Compr.	1	14000	May-92	12	4160	Liquid
Cemex	Fans	2	450	Jun-92	6	4160	Liquid
Cemex	Raw Mill	2	4500	Jun-92	6	4160	Liquid
Commonwealth Edison	Static Starter	1	5000	Jun-92	6	2300	Air
Cemex	ID Fans	2	5500	Jun-92	6-Dec	4160	Liquid
Cemex	Ball Mill	3	8000	Jun-92	6-Dec	4160	Liquid
Elliott/Maraven	Compressor	1	10000	Jun-92	12	4160	Liquid
New York Power Authority	Pump	2	7000	Oct-92	12	2300	Liquid
Public Service of Colorado	Fan	2	8000	Jan-93	12	4160	Liquid
Kunming	Rod Mill	1	8500	May-93	12	4000	Liquid
Cementos de Chihuahua	Fan	1	5000	Aug-93	12	4160	Liquid

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Load Commutated Inverters for Synchronous Motors

Customer	Application	Qty	Rating (hp)	Date	Pulse	Voltage	Cooling
USS/Kobe	Sizing Mill	2	3200	Nov-93	6	2000	Air
USS/Kobe	No Twist Mill	2	9100	Nov-93	12	4000	Air
Texas Eastern	Compressor	1	11000	Feb-94	12	4160	Liquid
Wuhan	Rod Mill	2	8000	May-94	12	4000	Air
Georgia Pacific	Fan	2	3500	Jun-94	6	4160	Air
Medway	Static Starter	1	6000	Jul-94	6	4160	Liquid
Scott Paper Co	Fan	1	2000	Aug-94	6	4160	Liquid
China Light & Power	Static Starter	4	6000	Aug-94	6	4160	Liquid
Scott Paper Co	Fan	1	3000	Sep-94	6	4160	Liquid
EGAT	Static Starter	2	6000	Sep-94	6	4160	Liquid
Dabohl	Static Starter	2	6000	Oct-94	6	4160	Liquid
Citgo	Compressor	1	7500	Jan-95	12	4160	Liquid
Omai Gold	Sag Mill	1	9500	Feb-95	12	2300	Liquid
Fairbanks Gold	Ball/Sag Mill	5	1500	Jun-95	6	2300	Liquid
Raglan Mine	Sag Mill	1	3000	Sep-95	12	2300	Liquid
Disney/Fincantieri	Ship Propulsion	8	12740	Nov-95	12	4160	Liquid
Lihir Gold	Grinding Mill	1	6400	Dec-95	12	2300	Liquid
Barrick Goldstrike	Sag Mill	1	2500	May-96	12	4160	Liquid
Barrick Goldstrike	Sag Mill	1	4000	May-96	12	4160	Liquid
Sulzer/Lagoven	Compressor	2	11200	Feb-97	12	4160	Liquid
Cooper/Northern Border	Compressor	2	16500	Jun-97	12	4160	Liquid
Dresser Rand/Transco	Compressor	1	18500	Aug-97	12	4160	Liquid
Cementos Cruz Azul	Cement Mill	1	3800	Sep-97	12	2300	Liquid
Enron/Cooper	Pipeline	4	3500	Oct-97	6	2300	Liquid
Enron/Brammel	Pipeline	2	7000	Dec-98	12	2300	Liquid
Dresser-Rand/Transco	Compressor	1	18500	Apr-00	12	4160	Liquid
Copper Rolls	Compressor	1	16000	Aug-01	12	4160	Liquid
Shell	Compressor	1	18000	Aug-01	12	4160	Liquid
Fushun	Metals	1	6700	Oct-01	12	2300	Liquid
Dresser-Rand/Williams	Compressor	1	24000	Nov-01	12	4160	Liquid
Solar/Williams	Compressor	1	10000	Mar-02	12	2300	Liquid
Cementos Cruz Azul	Cement Mill	1	3800	Jun-02	12	2300	Liquid
	TOTAL	**288**					

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CUSTOMER	QUANTITY	PRODUCT	DESCRIPTION	BUSINESS	ORDER DATE	DATE SHIPPED
DOW COGEN	1	LCI	LCI 7001 FA	Prime	2/21/2002	9/16/2002
FT MYERS PP1	1	LCI	LCI 7001 FA	Prime	2/26/2002	9/11/2002
SERMIDE	1	LCI	LCI 9001 FA	Prime	2/1/2002	8/9/2002
GILA RVR	1	LCI	LCI 7001 FA	Prime	8/6/2001	8/9/2002
DOW COGEN	1	LCI	LINE UP - MULTIPLE CASE ASSY		2/21/2002	8/8/2002
LAWRENCE	1	LCI	3CI PANEL GT	Prime	8/29/2001	8/8/2002
RIVERSIDE	1	LCI	LCI 7001 FA	Prime	3/7/2002	8/6/2002
CAMPO GRANDE	1	LCI	LCI 7001 FA	Prime	2/14/2002	8/2/2002
BLUE SPRUCE	1	LCI	LCI 7001 FA	Prime	1/24/2002	7/31/2002
HOUSTON	1	LCI	LCI 7001 FA	Prime	1/23/2002	7/31/2002
DOW COGEN	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	2/21/2002	7/30/2002
GOAT ROCK3	1	LCI	A140 LCI PANEL-GT	Prime	3/14/2002	7/29/2002
FT MYERS PP1	1	LCI	LCI 7001 FA	Prime	2/26/2002	7/24/2002
LUNA	1	LCI	LCI 7001 FA	Prime	1/23/2002	7/19/2002
HOUSTON	1	LCI	LCI 7001 FA	Prime	1/23/2002	7/17/2002
HOUSTON	1	LCI	LCI 7001 FA	Prime	1/23/2002	7/15/2002
CHEHALIS	1	LCI	LCI 7001 FA	Prime	3/20/2002	7/10/2002
NELSON	1	LCI	LCI 7001 FA	Prime	11/6/2001	7/10/2002
STANTON	1	LCI	LCI 7001 FA	Prime	1/24/2002	7/8/2002
FAIRLESS	1	LCI	LCI 7001 FA	Prime	2/13/2002	6/28/2002
CALHOUN	1	LCI	LCI	Prime	11/26/2001	6/27/2002
MESQUITE	1	LCI	LCI	Prime	11/29/2001	6/26/2002
SERMIDE	1	LCI	LCI 9001 FA	Prime	2/1/2002	6/24/2002
TIGER CREEK	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	11/5/2001	6/20/2002
RAVENSWOOD	1	LCI	LCI 7001 FA	Prime	4/17/2001	6/20/2002
TERMOACU	1	LCI	LCI 7001 FA	Prime	12/12/2001	6/17/2002
GILA RVR	1	LCI	LCI 7001 FA	Prime	8/6/2001	6/17/2002
SANTURTZI	1	LCI	LCI 9001 FA	Prime	4/18/2002	6/14/2002
EDISON	1	LCI	LCI 9001 FA	Prime	12/12/2001	6/10/2002
RICHMOND	1	LCI	LCI 7001 FA	Prime	2/13/2002	6/5/2002
ENELVEN	1	LCI	LCI 7001 FA	Prime	1/24/2002	5/30/2002
SERMIDE	1	LCI	LCI 9001 FA	Prime	2/1/2002	5/24/2002
ENELVEN	1	LCI	LCI 7001 FA	Prime	1/24/2002	5/23/2002
OTAY MESA	1	LCI	A140 LCI PANEL-GT	Prime	9/21/2001	5/22/2002
DRESDEN	1	LCI	LCI	Prime	11/29/2001	5/21/2002
DRESDEN	1	LCI	LCI	Prime	11/29/2001	5/17/2002
UNION	1	LCI	LCI 7001 FA	Prime	10/3/2001	5/9/2002
DUKE A02	1	LCI	LCI 7001 FA	Prime	11/14/2001	5/8/2002
MERIDEN	1	LCI	LCI 7001 FA	Prime	10/31/2001	5/7/2002
TERMOP	1	LCI	LCI	Prime	11/30/2001	5/3/2002
OSTIGLIA	1	LCI	LCI 9001 FA	Prime	10/29/2001	5/1/2002
CALHOUN	1	LCI	LCI	Prime	11/26/2001	4/29/2002
PIKE	1	LCI	LCI 7001 FA	Prime	11/7/2001	4/24/2002
STANDARD	1	LCI	LCI 7001 FA	Prime	11/5/2001	4/23/2002
EGAT RATCHABURI	1	LCI	R-T-S ITEM		11/21/2001	4/19/2002
CALEDONIA	1	LCI	A140 LCI PANEL-GT	Prime	9/20/2001	4/19/2002
NELSON	1	LCI	LCI 7001 FA	Prime	11/6/2001	4/18/2002
DUKE D02	1	LCI	A140 LCI PANEL-GT	Prime	11/8/2001	4/17/2002
EDISON TERM	1	LCI	R-T-S ITEM LCI9001 FA		9/6/2001	4/15/2002
GILA RVR	1	LCI	LCI 7001 FA	Prime	8/6/2001	4/15/2002
ELIN ANKARA	1	LCI	R-T-S LCI FR 9FA		12/3/2001	4/12/2002
TIGER CREEK	1	LCI	LCI 7001 FA	Prime	11/5/2001	4/10/2002
CASSANO	1	LCI	LCI 9001 FA	Prime	10/24/2001	4/10/2002
OSTIGLIA	1	LCI	LCI 9001 FA	Prime	10/29/2001	4/8/2002
OSTIGLIA	1	LCI	LCI 9001 FA	Prime	10/29/2001	4/5/2002
EDISON TERM	1	LCI	LCI 9001 FA	Prime	9/6/2001	4/5/2002
GREENVILLE	1	LCI	LCI PANEL GT	Prime	11/7/2001	4/1/2002
FRENCH	1	LCI	A140 LCI PANEL-GT	Prime	10/17/2001	4/1/2002
ELIN ANKARA	1	LCI	LCI FR 9FA	BA & OEM	12/3/2001	3/28/2002
TERMOGAUCHA	1	LCI	A140 LCI PANEL-GT	Prime	9/21/2001	3/21/2002
DUKE C02	1	LCI	A140 LCI PANEL-GT	Prime	10/18/2001	3/15/2002
MORRO BAY	1	LCI	LCI 7001 FA	Prime	9/12/2001	3/15/2002
PASTORIA	1	LCI	LCI 7001 FA	Prime	9/12/2001	3/14/2002
FRENCH	1	LCI	A140 LCI PANEL-GT	Prime	10/17/2001	3/13/2002
UNION	1	LCI	LCI 7001 FA	Prime	10/3/2001	3/8/2002
GRAYS HAR	1	LCI	LCI 7001 FA	Prime	9/26/2001	3/8/2002
GOAT ROCK	1	LCI	LCI 7001 FA	Prime	9/25/2001	3/5/2002
HARRISON	1	LCI	A140 LCI PANEL-GT	Prime	9/20/2001	3/4/2002
ALABAMA	1	LCI	LCI 7001 FA	Prime	7/25/2001	2/28/2002
TERMOGAUCHA	1	LCI	A140 LCI PANEL-GT	Prime	9/21/2001	2/26/2002
EGAT RATCHABURI	1	LCI	LCI 4 KV W/C	CM&U	11/21/2001	2/25/2002
IMMINGHAM	1	LCI	LCI 9001 FA	Prime	9/11/2001	2/22/2002
MAGNOLIA	1	LCI	LCI 7001 FA	Prime	7/2/2001	2/22/2002

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CUSTOMER	QUANTITY	PRODUCT	DESCRIPTION	BUSINESS	ORDER DATE	DATE SHIPPED
NEHUENCO	1	LCI	A140 LCI PANEL-GT	Prime	9/21/2001	2/21/2002
MINCIO	1	LCI	KCI 9001 FA	Prime	9/11/2001	2/15/2002
MORRO BAY	1	LCI	LCI 7001 FA	Prime	9/12/2001	2/13/2002
PASTORIA	1	LCI	LCI 7001 FA	Prime	9/12/2001	2/11/2002
CALEDONIA	1	LCI	A140 LCI PANEL-GT	Prime	9/20/2001	2/5/2002
CHIAHUI	1	LCI	LCI 7001 FA	Prime	7/26/2001	1/31/2002
LAWRENCE	1	LCI	LCI PANEL - GT	Prime	8/29/2001	1/29/2002
MEXICALI	1	LCI	LCI 7001 FA	Prime	8/6/2001	1/25/2002
AUTAUGAVILL	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	7/11/2001	1/25/2002
BRIGHTON	1	LCI	LCI 7001 FA	Prime	8/23/2001	1/22/2002
SPALDING	1	LCI	LCI 9001 FA	Prime	8/6/2001	1/22/2002
BRIGHTON	1	LCI	LCI 7001 FA	Prime	8/23/2001	1/18/2002
TARRAGONA1	1	LCI	LCI 9001 FA	Prime	9/7/2001	1/11/2002
FRANKLIN	1	LCI	LCI 7001 FA	Prime	9/4/2001	1/11/2002
GILA RVR	1	LCI	LCI 7001 FA	Prime	8/6/2001	12/28/2001
HUNTERSTOWN 2-3	1	LCI	LCI 7001 FA	Prime	7/19/2001	12/27/2001
OCEAN	1	LCI	A140 LCI PANEL - GT	Prime	10/4/2001	12/21/2001
OCEAN	1	LCI	A140 LCI PANEL GT	Prime	10/4/2001	12/21/2001
VALLEY GEN	1	LCI	LCI 7001 FA	Prime	7/11/2001	12/21/2001
POSSUM	1	LCI	LCI 7001 FA	Prime	7/10/2001	12/21/2001
LINDEN	1	LCI	LCI 7001 FA	Prime	7/2/2001	12/21/2001
BRAZOS	1	LCI	LCI 7001 FA	Prime	7/19/2001	12/19/2001
VALLEY GEN	1	LCI	LCI 7001 FA	Prime	7/11/2001	12/18/2001
BOWLINE	1	LCI	LCI 7001 FA	Prime	6/14/2001	12/18/2001
AUTAUGAVILL	1	LCI	LCI 7001 FA	Prime	7/11/2001	12/14/2001
POSSUM	1	LCI	LCI 7001 FA	Prime	7/10/2001	12/13/2001
ALABAMA	1	LCI	LCI 7001 FA	Prime	7/25/2001	12/10/2001
MAGNOLIA	1	LCI	LCI 7001 FA	Prime	7/2/2001	12/7/2001
REDBUD	1	LCI	LCI 7001 FA	Prime	4/16/2001	12/7/2001
LINDEN	1	LCI	LCI 7001 FA	Prime	7/2/2001	12/6/2001
MTNVIEW	1	LCI	LCI 7001 FA	Prime	7/11/2001	12/3/2001
OXFORD	1	LCI	LCI 7001 FA	Prime	6/20/2001	12/3/2001
MTNVIEW	1	LCI	LCI 7001 FA	Prime	7/11/2001	11/30/2001
FORNEY	1	LCI	R-T-S LCI 7001 FA		6/20/2001	11/28/2001
FORNEY	1	LCI	R-T-S LCI 7001 FA		6/20/2001	11/27/2001
COGEN SOUTH	1	LCI	R-T-S ITEM		6/20/2001	11/26/2001
COGEN SOUTH	1	LCI	LCI 7001 FA	Prime	6/20/2001	11/26/2001
CHIAHUI	1	LCI	LCI 7001 FA	Prime	7/26/2001	11/21/2001
TARRAGONA	1	LCI	R-T-S LCI 9001 FA		5/18/2001	11/20/2001
CONTRA	1	LCI	LCI 7001 FA	Prime	6/4/2001	11/19/2001
COGEN SOUTH	1	LCI	LCI 7001 FA	Prime	6/20/2001	11/16/2001
FORNEY	1	LCI	LCI 7001 FA	Prime	6/20/2001	11/15/2001
FORNEY	1	LCI	LCI 7001 FA	Prime	6/20/2001	11/13/2001
SKS PRAI	1	LCI	LCI 9001 FA	Prime	6/18/2001	11/9/2001
CON ED	1	LCI	LCI 7001 FA	Prime	5/8/2001	11/9/2001
CONTRA	1	LCI	LCI 7001 FA	Prime	6/4/2001	11/7/2001
BAYSIDE 4-7	1	LCI	LCI 7001 FA	Prime	5/8/2001	11/7/2001
ALTAMIRA	1	LCI	LCI 7001 FA	Prime	4/26/2001	11/5/2001
BOWLINE	1	LCI	LCI 7001 FA	Prime	6/14/2001	11/2/2001
OCOTILLO	1	LCI	LCI 7001 FA	Prime	7/26/2001	10/31/2001
PUSAN	1	LCI	LCI 7001 FA	Prime	6/15/2001	10/29/2001
CASTEJON	1	LCI	R-T-S LCI 9001 FA		4/17/2001	10/29/2001
TARRAGONA	1	LCI	LCI 9001 FA	Prime	5/18/2001	10/26/2001
PUSAN	1	LCI	LCI 7001 FA	Prime	6/15/2001	10/25/2001
LAKE WORTH	1	LCI	LCI 7001 FA	Prime	7/5/2001	10/24/2001
CON ED	1	LCI	LCI 7001 FA	Prime	5/8/2001	10/23/2001
AFTON	1	LCI	LCI 7001 FA	Prime	6/14/2001	10/18/2001
AUGUSTA	1	LCI	LCI 7001 FA	Prime	6/11/2001	10/17/2001
ALTAMIRA	1	LCI	LCI 7001 FA	Prime	4/26/2001	10/15/2001
PINE BLUFF2	1	LCI	LCI 7001 FA	Prime	6/14/2001	10/12/2001
AUGUSTA	1	LCI	LCI 7001 FA	Prime	6/11/2001	10/10/2001
LAWRENCE	1	LCI	LCI 9001 FA	Prime	12/1/2000	10/8/2001
NATIONAL	1	LCI	LCI 7001 FA	Prime	4/25/2001	10/5/2001
CASTEJON	1	LCI	LCI 9001 FA	Prime	4/17/2001	10/5/2001
OCOTILLO	1	LCI	LCI 7001 FA	Prime	7/26/2001	9/28/2001
LAKEWOOD2	1	LCI	LCI 7001 FA	Prime	4/26/2001	9/28/2001
FRONT RANGE	1	LCI	LCI 7001 FA	Prime	4/26/2001	9/28/2001
NATIONAL	1	LCI	LCI 7001 FA	Prime	4/25/2001	9/28/2001
ROCK SPRING	1	LCI	LCI 7001 FA	Prime	5/15/2001	9/21/2001
REDBUD	1	LCI	LCI 7001 FA	Prime	4/16/2001	9/21/2001
BAYSIDE 1-2-3	1	LCI	LCI 7001 FA	Prime	3/30/2001	9/21/2001
ARCOS #1	1	LCI	LCI 9001 FA	Prime	3/9/2001	9/19/2001
LIBERTADOR	1	LCI	LCI 9001 FA	Prime	4/11/2001	9/18/2001

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CUSTOMER	QUANTITY	PRODUCT	DESCRIPTION	BUSINESS	ORDER DATE	DATE SHIPPED
ARCOS #1	1	LCI	LCI 9001 FA	Prime	3/9/2001	9/14/2001
FREESTONE	1	LCI	LCI 7001 FA	Prime	2/21/2001	9/14/2001
ZION	1	LCI	LCI 7001 FA	Prime	4/11/2001	9/12/2001
CITRUS	1	LCI	LCI 7001 FA	Prime	4/4/2001	9/10/2001
MCV	1	LCI	LCI 7001 FA	Prime	3/22/2001	9/7/2001
KIAMICHI	1	LCI	LCI 7001 FA	Prime	3/20/2001	9/7/2001
LAWRENCE	1	LCI	LCI 9001 FA	Prime	12/1/2000	9/7/2001
TAFT	1	LCI	LCI 7001 FA	Prime	3/20/2001	9/4/2001
GILA BEND	1	LCI	LCI 7001 FA	Prime	3/22/2001	8/31/2001
TAFT	1	LCI	LCI 7001 FA	Prime	3/20/2001	8/31/2001
GEORGIA-TENASKA	1	LCI	STATIC STARTER	Prime	1/5/2000	8/31/2001
ARCOS #1	1	LCI	LCI 9001 FA	Prime	3/9/2001	8/30/2001
WATERFORD	1	LCI	LCI 7001 FA	Prime	2/27/2001	8/27/2001
HARDEE #3	1	LCI	LCI 7001 FA	Prime	3/15/2001	8/23/2001
TROY	1	LCI	LCI 7001 FA	Prime	1/23/2001	8/22/2001
CUBATO #1	1	LCI	LCI 7001 FA	Prime	3/16/2001	8/20/2001
ARMSTRONG	1	LCI	LCI 7001 FA	Prime	2/21/2001	8/17/2001
HARDEE #3	1	LCI	LCI 7001 FA	Prime	3/15/2001	8/10/2001
KIAMICHI	1	LCI	LCI 7001 FA	Prime	3/20/2001	8/7/2001
EFFINGHAM	1	LCI	LCI 7001 FA	Prime	3/14/2001	8/3/2001
CP&L/SC #1	1	LCI	LCI 7001 FA	Prime	3/9/2001	7/27/2001
DUKE #19	1	LCI	LCI 7001 FA	Prime	2/19/2001	7/25/2001
SANTA ROSA	1	LCI	LCI 7001 FA	Prime	2/23/2001	7/20/2001
CUBATO #1	1	LCI	LCI 7001 FA	Prime	3/16/2001	7/18/2001
APEX #1	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	3/8/2001	7/17/2001
WEST COAST	1	LCI	LCI 7001 FA	Prime	1/22/2001	6/29/2001
APEX #1	1	LCI	LCI 7001 FA	Prime	3/8/2001	6/28/2001
MERCHANT2	1	LCI	LCI 9001 FA	Prime	1/22/2001	6/27/2001
HUNTERSTOWN1	1	LCI	LCI MKV7 FB	Prime	3/8/2001	6/25/2001
ARMSTRONG	1	LCI	LCI 7001 FA	Prime	2/21/2001	6/22/2001
TROY	1	LCI	LCI 7001 FA	Prime	1/23/2001	6/22/2001
COTTONWOOD	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	2/19/2001	6/21/2001
MARCUS #1	1	LCI	A140 LCI	Prime	12/21/2000	6/18/2001
BBE	1	LCI	PANEL-GT	Prime	12/21/2000	6/15/2001
CP&L/CC	1	LCI	LCI 9001 FA	Prime	11/8/2000	6/15/2001
COTTONWOOD	1	LCI	LCI 7001 FA	Prime	2/19/2001	6/14/2001
BAGLAN BAY	1	LCI	R-T-S 4KV LCI		6/26/1997	6/14/2001
SUGAR CREEK1	1	LCI	LCI 7001 FA	Prime	3/6/2001	6/12/2001
DUKE 13	1	LCI	LCI 7001 FA	Prime	12/21/2000	6/12/2001
SUGAR CREEK1	1	LCI	LCI 7001 FA	Prime	3/6/2001	6/8/2001
FREESTONE	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	2/21/2001	6/1/2001
OLEANDER	1	LCI	LCI 7001 FA	Prime	2/19/2001	6/1/2001
CHRISTI	1	LCI	LCI 9001 FA	Prime	11/9/2000	5/30/2001
URQUHART	1	LCI	LCI 9001 FA	Prime	11/6/2000	5/30/2001
DELL	1	LCI	LCI 7001 FA	Prime	1/22/2001	5/25/2001
BBE	1	LCI	LINE UP - MULTIPLE CASE A	Prime	12/21/2000	5/25/2001
PLEASANTS	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	10/20/2000	5/25/2001
OSCEOLA #3	1	LCI	LCI 7001 FA	Prime	2/27/2001	5/24/2001
REDHAWK	1	LCI	A140 LCI PANEL-GT	Prime	12/21/2000	5/18/2001
KYRENE	1	LCI	LCI 9001 FA	Prime	11/6/2000	5/18/2001
OLEANDER	1	LCI	LCI 7001 FA	Prime	2/19/2001	5/14/2001
DUKE 7	1	LCI	LCI	Prime	12/19/2000	5/11/2001
MCADAMS	1	LCI	LCI 9001 FA	Prime	11/6/2000	5/11/2001
MARCUS #1	1	LCI	A140 LCI PANEL-GT	Prime	12/21/2000	5/8/2001
ARLINGTON	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	12/15/2000	5/4/2001
ARCHER	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	6/14/2000	5/4/2001
MOSS LANDING DUKE	1	LCI	LCI 9001 FA	Prime	9/7/2000	5/2/2001
PERRYVILLE 1/2	1	LCI	LCI 9001 FA	Prime	11/7/2000	4/27/2001
LINDSAY HILL TENASKA	1	LCI	LCI 9001 FA	Prime	6/21/2000	4/27/2001
LINDSAY HILL TENASKA	1	LCI	LCI 9001 FA	Prime	6/21/2000	4/27/2001
MERCHANT #1 ONETA	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	7/17/2000	4/24/2001
WATERFORD	1	LCI	LCI 7001 FA	Prime	2/27/2001	4/20/2001
HOLLAND #1	1	LCI	LCI 9001 FA	Prime	10/13/2000	4/20/2001
DUKE #20	1	LCI	LCI 9001 FA	Prime	1/26/2001	4/18/2001
TRIMBLE	1	LCI	LCI 9001 FA	Prime	11/8/2000	4/17/2001
MERCHANT #1 ONETA	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	7/17/2000	4/17/2001
REFAP	1	LCI	LCI 9001 FA	Prime	11/9/2000	3/30/2001
BASTROP	1	LCI	LCI 9001 FA	Prime	10/13/2000	3/30/2001
DUKE #15	1	LCI	LCI 7001 FA	Prime	12/7/2000	3/29/2001
IBIRITE	1	LCI	LCI 9001 FA	Prime	11/6/2000	3/27/2001
ZEELAND	1	LCI	LCI 9001 FA	Prime	10/13/2000	3/26/2001
PLEASANTS	1	LCI	LCI 9001 FA	Prime	10/20/2000	3/23/2001
NEWINGTON	1	LCI	LCI 7001 FA	Prime	10/3/2000	3/20/2001

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CUSTOMER	QUANTITY	PRODUCT	DESCRIPTION	BUSINESS	ORDER DATE	DATE SHIPPED
NOGALES	1	LCI	LCI 9001 FA	Prime	8/14/2000	3/16/2001
HOLLAND #1	1	LCI	LCI 9001 FA	Prime	10/13/2000	3/14/2001
CARVILLE	1	LCI	LCI 9001 FA	Prime	9/7/2000	3/14/2001
SEI KENDALL	1	LCI	LCI 9001 FA	Prime	9/7/2000	3/13/2001
GOLDENDALE	1	LCI	LCI 9001 FA	Prime	11/3/2000	3/9/2001
OUACHITA	1	LCI	LCI 9001 FA	Prime	9/7/2000	3/8/2001
SEI MOBILE	1	LCI	LCI 9001 FA	Prime	9/7/2000	3/6/2001
COYOTE SPRINGS	1	LCI	LCI 9001 FA	Prime	8/29/2000	3/6/2001
MOSS LANDING DUKE	1	LCI	LCI 9001 FA	Prime	9/7/2000	3/2/2001
IZMIR	1	LCI	LCI 9001 FA	Prime	9/18/2000	2/23/2001
OUACHITA	1	LCI	LCI 9001 FA	Prime	9/7/2000	2/22/2001
ELK HILLS	1	LCI	LCI 9001 FA	Prime	8/29/2000	2/16/2001
NOGALES	1	LCI	LCI 9001 FA	Prime	8/14/2000	2/16/2001
GEPS UNIVERSITY	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	11/1/2000	2/9/2001
KENDALL	1	LCI	LCI 9001 FA	Prime	8/1/2000	2/9/2001
LINDEN 7	1	LCI	LCI 9001 FA	Prime	8/14/2000	2/6/2001
PASCO	1	LCI	LCI 9001 FA	Prime	8/29/2000	1/26/2001
MEDWAY	1	LCI	LCI 9001 FA	Prime	7/26/2000	1/26/2001
IBERDROLA	1	LCI	STATIC STARTER	Prime	4/10/2000	1/26/2001
PASCO	1	LCI	LCI 9001 FA	Prime	8/29/2000	1/19/2001
KENDALL	1	LCI	LCI 9001 FA	Prime	8/1/2000	1/19/2001
SANTEE COOPER 3&4	1	LCI	WATER COOLED 4KV LCI	Prime	6/24/1999	1/12/2001
PASCO	1	LCI	LCI 9001 FA	Prime	8/29/2000	1/10/2001
SANFORD-FP&L	1	LCI	R-T-S ITEM		9/16/1999	1/5/2001
IZMIR	1	LCI	LCI 9001 FA	Prime	9/18/2000	12/28/2000
SANFORD-FP&L	1	LCI	STATIC STARTER	Prime	9/16/1999	12/22/2000
BERGEN(PSE&G)	1	LCI	LCI 9001 FA	Prime	7/26/2000	12/12/2000
BERGEN(PSE&G)	1	LCI	LCI 9001 FA	Prime	7/26/2000	12/8/2000
SANFORD-FP&L	1	LCI	STATIC STARTER	Prime	9/16/1999	12/4/2000
INDIAN TRAIL	1	LCI	LCI 9001 FA	Prime	8/9/2000	11/30/2000
SANFORD-FP&L	1	LCI	STATIC STARTER	Prime	9/16/1999	11/21/2000
GEBZE	1	LCI	LCI 9001 FA	Prime	5/4/2000	11/20/2000
ADAPAZARI	1	LCI	LCI 9001 FA	Prime	9/7/2000	11/16/2000
LIBERTY 1&2	1	LCI	STATIC STARTER	Prime	3/30/2000	11/16/2000
REDHAWK #1	1	LCI	LCI 9001 FA	Prime	6/14/2000	11/8/2000
OSCEOLA	1	LCI	LCI 9001 FA	Prime	6/6/2000	11/6/2000
LIBERTY 1&2	1	LCI	STATIC STARTER	Prime	3/30/2000	11/6/2000
TULSA-COGENTRIX	1	LCI	STATIC STARTER	Prime	12/31/1999	10/19/2000
SKYGEN BROAD RIVER	1	LCI	STATIC STARTER	Prime	4/18/2000	10/17/2000
LANSING SOCO	1	LCI	STATIC STARTER	Prime	1/20/2000	10/17/2000
GEBZE	1	LCI	LCI 9001 FA	Prime	5/4/2000	10/13/2000
SANFORD-FP&L	1	LCI	STATIC STARTER	Prime	9/16/1999	10/5/2000
GORDON EVANS PHASE 2	1	LCI	STATIC STARTER	Prime	11/29/1999	9/22/2000
GEORGIA-TENASKA	1	LCI	STATIC STARTER	Prime	1/5/2000	9/20/2000
TULSA-COGENTRIX	1	LCI	STATIC STARTER	Prime	12/31/1999	9/15/2000
ELLWOOD II	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	4/18/2000	9/14/2000
RICHMOND-CP&L	1	LCI	STATIC STARTER	Prime	11/29/1999	9/12/2000
ROWAN-CP&L	1	LCI	STATIC STARTER	Prime	11/29/1999	9/8/2000
ELLWOOD II	1	LCI	STATIC STARTER	Prime	4/18/2000	9/1/2000
FPL/MARTIN	1	LCI	STATIC STARTER	Prime	3/21/2000	8/25/2000
FPL/MARTIN	1	LCI	STATIC STARTER	Prime	3/21/2000	8/25/2000
WANSLEY SO. SC.	1	LCI	STATIC STARTER	Prime	1/20/2000	8/25/2000
WANSLEY SO. SC.	1	LCI	STATIC STARTER	Prime	1/20/2000	8/25/2000
RICHMOND-CP&L	1	LCI	STATIC STARTER	Prime	11/29/1999	8/25/2000
ROWAN-CP&L	1	LCI	STATIC STARTER	Prime	11/29/1999	8/25/2000
GOAT ROCK SO. SC.	1	LCI	STATIC STARTER	Prime	1/20/2000	7/31/2000
ODESSA	1	LCI	STATIC STARTER	Prime	12/1/1999	7/31/2000
BAJIO-CFE	1	LCI	STATIC STARTER	Prime	11/29/1999	7/25/2000
LADYSMITH	1	LCI	STATIC STARTER	Prime	3/13/2000	7/21/2000
RELIANT #1-3	1	LCI	STATIC STARTER	Prime	1/19/2000	7/21/2000
ODESSA	1	LCI	STATIC STARTER	Prime	12/1/1999	6/30/2000
CS&W NORTHEAST STATION	1	LCI	STATIC STARTER	Prime	2/7/2000	6/28/2000
MICHIGAN-SEI	1	LCI	STATIC STARTER	Prime	12/31/1999	6/23/2000
RATHDRUM-COGENTRIX	1	LCI	STATIC STARTER	Prime	12/7/1999	6/23/2000
MICHIGAN-SEI	1	LCI	STATIC STARTER	Prime	12/31/1999	6/22/2000
MONTERREY ENRON	1	LCI	STATIC STARTER	Prime	2/8/2000	6/20/2000
ST VRAIN#3	1	LCI	STATIC STARTER	Prime	10/8/1998	6/15/2000
SANTEE COOPER	1	LCI	STATIC STARTER	Prime	7/13/1999	6/12/2000
DOSWELL-FP&L	1	LCI	STATIC STARTER	Prime	12/31/1999	6/6/2000
MIDWEST ENRON	1	LCI	STATIC STARTER	Prime	2/8/2000	5/26/2000
GEORGIA-TENASKA	1	LCI	STATIC STARTER	Prime	1/5/2000	5/26/2000
DEARBORN-ROUGE RIVER	1	LCI	STATIC STARTER	Prime	12/7/1999	5/26/2000
ROCKGEN 2	1	LCI	STATIC STARTER	Prime	3/21/2000	5/23/2000

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CUSTOMER	QUANTITY	PRODUCT	DESCRIPTION	BUSINESS	ORDER DATE	DATE SHIPPED
ROCKGEN 2	1	LCI	STATIC STARTER	Prime	3/21/2000	5/19/2000
BAJIO-CFE	1	LCI	STATIC STARTER	Prime	11/29/1999	5/18/2000
RELIANT #1-3	1	LCI	STATIC STARTER	Prime	1/19/2000	4/28/2000
LINDEN #6	1	LCI	STATIC STARTER	Prime	1/5/2000	4/28/2000
GRIFFITH-DUKE	1	LCI	STATIC STARTER	Prime	11/5/1999	4/28/2000
WHITING-AMOCO	1	LCI	STATIC STARTER	Prime	11/5/1999	4/20/2000
GRIFFITH-DUKE	1	LCI	STATIC STARTER	Prime	11/5/1999	4/19/2000
FP&L	1	LCI	STATIC STARTER	Prime	1/20/1999	4/14/2000
DUKE HINDS	1	LCI	STATIC STARTER	Prime	10/5/1999	3/31/2000
DUKE KAUFMAN	1	LCI	STATIC STARTER	Prime	10/5/1999	3/31/2000
JEA BRANDY BRANCH	1	LCI	R-T-S LINEUP MULTIPLE CAS		3/18/1999	3/31/2000
CANE ISLAND3	1	LCI	STATIC STARTER	Prime	8/25/1999	3/29/2000
CMS TENASKA	1	LCI	STATIC STARTER	CM&U	10/5/1999	3/24/2000
SEI 3B	1	LCI	STATIC STARTER	Prime	10/19/1999	3/17/2000
GATEWAY	1	LCI	STATIC STARTER	Prime	10/5/1999	3/15/2000
GATEWAY	1	LCI	STATIC STARTER	Prime	10/5/1999	3/10/2000
PITTSBURG #1-ENRON	1	LCI	STATIC STARTER	Prime	10/21/1998	3/10/2000
CONOCO-SABINE	1	LCI	STATIC STARTER	Prime	9/29/1999	3/3/2000
JEA BRANDY BRANCH	1	LCI	R-T-S STATIC STARTER		3/18/1999	3/1/2000
BARRY #7 SOCO	1	LCI	STATIC STARTER	Prime	9/10/1998	2/23/2000
DUKE MCCLAIN	1	LCI	WATER COOLED 4KV LCI	Prime	8/30/1999	2/22/2000
EASTEX PROJECT	1	LCI	STATIC STARTER	Prime	9/29/1999	2/16/2000
PANDA ERCOT 2	1	LCI	STATIC STARTER	Prime	1/28/1999	2/11/2000
SUNRISE - TEXACO	1	LCI	STATIC STARTER	Prime	4/16/1999	2/10/2000
SKYGEN	1	LCI	STATIC STARTER	Prime	10/4/1999	2/7/2000
PANDA ERCOT 2	1	LCI	STATIC STARTER	Prime	1/28/1999	1/28/2000
JEA BRANDY BRANCH	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	3/18/1999	1/27/2000
JEA BRANDY BRANCH	1	LCI	STATIC STARTER	Prime	3/18/1999	1/27/2000
PINE BLUFF	1	LCI	STATIC STARTER	Prime	7/13/1999	12/31/1999
DABHOL 2	1	LCI	STATIC STARTER	Prime	7/1/1999	12/31/1999
FP&L	1	LCI	STATIC STARTER	Prime	1/20/1999	12/31/1999
DABHOL 2	1	LCI	STATIC STARTER	Prime	7/1/1999	12/10/1999
DANIEL - SOCO	1	LCI	STATIC STARTER	Prime	4/29/1999	12/6/1999
HSIN TAO POWER	1	LCI	STATIC STARTER	Prime	6/3/1999	12/1/1999
DABHOL 2	1	LCI	STATIC STARTER	Prime	7/1/1999	11/12/1999
DABHOL 2	1	LCI	STATIC STARTER	Prime	7/1/1999	11/12/1999
WESTBROOK POWER	1	LCI	STATIC STARTER	Prime	4/29/1999	11/5/1999
PANDA ERCOT	1	LCI	STATIC STARTER	Prime	1/27/1999	10/22/1999
VEPCO 1&3	1	LCI	STATIC STARTER	Prime	11/18/1998	10/22/1999
CATAULA/SONAT 3&4	1	LCI	R-T-S STATIC STARTER		11/17/1998	10/1/1999
CATAULA/SONAT 3&4	1	LCI	R-T-S STATIC STARTER		11/17/1998	10/1/1999
CATAULA/SONAT 1&2	1	LCI	R-T-S STATIC STARTER		11/17/1998	10/1/1999
CATAULA/SONAT 1&2	1	LCI	R-T-S STATIC STARTER		11/17/1998	10/1/1999
HSIN TAO POWER	1	LCI	STATIC STARTER	Prime	6/3/1999	9/30/1999
DANIEL - SOCO	1	LCI	STATIC STARTER	Prime	4/29/1999	9/23/1999
SOCO-THEODORE	1	LCI	STATIC STARTER	Prime	3/18/1999	9/23/1999
TECO/POLK COUNTRY	1	LCI	STATIC STARTER	Prime	3/11/1999	9/21/1999
SEI #4 TEXAS	1	LCI	R-T-S LINEUP		9/25/1998	9/21/1999
SEI #4 TEXAS	1	LCI	R-T-S STATIC STARTER		9/25/1998	9/21/1999
COBISA	1	LCI	READY TO SHIP-STATIC STAR		2/25/1999	9/16/1999
RUMFORD/EMI	1	LCI	STATIC STARTER	Prime	2/25/1999	9/14/1999
PANDA ERCOT	1	LCI	R-T-S STATIC STARTER		1/27/1999	9/14/1999
SEI WISCONSIN #1	1	LCI	READY TO SHIP LINEUP		9/25/1998	9/8/1999
SEI WISCONSIN #1	1	LCI	READY TO SHIP LINEUP		9/25/1998	9/8/1999
GREAT YARMOUTH	1	LCI	STATIC STARTER	Prime	3/11/1999	9/3/1999
ROCKGEN PROJECT	1	LCI	R-T-S STATIC STARTER		6/28/1999	8/20/1999
ROCKGEN PROJECT	1	LCI	STATIC STARTER	Prime	6/28/1999	8/20/1999
ROCKGEN PROJECT	1	LCI	R-T-S STATIC STARTER		6/28/1999	8/20/1999
ROCKGEN PROJECT	1	LCI	STATIC STARTER	Prime	6/28/1999	8/20/1999
PANDA ERCOT	1	LCI	STATIC STARTER	Prime	1/27/1999	8/20/1999
BAGLAN BAY	1	LCI	4KV LCI	Prime	6/26/1997	8/20/1999
BUCKSPORT/CHAMPION	1	LCI	STATIC STARTER	Prime	3/11/1999	8/13/1999
VEPCO 1&3	1	LCI	R-T-S STATIC STARTER		11/18/1998	8/2/1999
SEI #4 TEXAS	1	LCI	LINE UP - MULTIPLE CASE ASSY	Prime	9/25/1998	7/23/1999
CP&L LEE #3/4	1	LCI	STATIC STARTER	Prime	9/24/1998	7/23/1999
JEA	1	LCI	READY TO SHIP-STATIC STAR		6/29/1998	7/15/1999
TETO PARSONS CROATIA	1	LCI	R-T-S STATIC STARTER		2/25/1999	7/7/1999
TETO PARSONS CROATIA	1	LCI	R-T-S STATIC STARTER		2/25/1999	7/7/1999
TIVERTON / EMI	1	LCI	STATIC STARTER	Prime	12/23/1998	6/25/1999
SEI #4 TEXAS	1	LCI	STATIC STARTER	Prime	9/25/1998	6/25/1999
CP&L LEE #1/2	1	LCI	STATIC STARTER	Prime	9/24/1998	6/25/1999
VEPCO 1&3	1	LCI	STATIC STARTER	Prime	11/18/1998	6/21/1999
COBISA	1	LCI	STATIC STARTER	Prime	2/25/1999	6/18/1999

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TETO PARSONS CROATIA	1	LCI	STATIC STARTER	Prime	2/25/1999	6/18/1999
TETO PARSONS CROATIA	1	LCI	STATIC STARTER	Prime	2/25/1999	6/18/1999
CATAULA/SONAT 3&4	1	LCI	STATIC STARTER	Prime	11/17/1998	6/11/1999
TENASKA	1	LCI	READY TO SHIP-STATIC STAR		8/31/1998	6/1/1999
TENASKA	1	LCI	READY TO SHIP STATIC STRT		8/31/1998	6/1/1999
CATAULA/SONAT 3&4	1	LCI	STATIC STARTER	Prime	11/17/1998	5/21/1999
CATAULA/SONAT 1&2	1	LCI	STATIC STARTER	Prime	11/17/1998	5/21/1999
CATAULA/SONAT 1&2	1	LCI	STATIC STARTER	Prime	11/17/1998	5/21/1999
SEI WISCONSIN #1	1	LCI	WATER COOLED 4KV LCI	Prime	9/25/1998	5/21/1999
SEI WISCONSIN #1	1	LCI	STATIC STARTER	Prime	9/25/1998	5/21/1999
CITY OF TALLAHASSEE	1	LCI	STATIC STARTER	Prime	8/27/1998	5/19/1999
DUKE - HIDALGO	1	LCI	STATIC STARTER	Prime	10/21/1998	5/17/1999
TENASKA	1	LCI	STATIC STARTER	Prime	8/31/1998	4/26/1999
TENASKA	1	LCI	STATIC STARTER	Prime	8/31/1998	4/23/1999
JEA	1	LCI	STATIC STARTER	Prime	6/29/1998	4/23/1999
CP&L - ASHEVILLE #4	1	LCI	STATIC STARTER	Prime	12/21/1998	3/26/1999
LG&E GREGORY	1	LCI	STATIS STARTER	Prime	11/17/1998	3/25/1999
DUKE - CASCO BAY, ME	1	LCI	STATIC STARTER	Prime	10/21/1998	3/25/1999
LG&E GREGORY	1	LCI	STATIC STARTER	Prime	11/17/1998	3/12/1999
SAN ANTONIO/CPS	1	LCI	STATIC STARTER	Prime	9/4/1998	2/22/1999
SOUTHERN COMPANY-BARRY	1	LCI	STATIC STARTER	Prime	7/24/1998	12/11/1998
ELWOOD/DOMINION #3	1	LCI	STATIC STARTER	Prime	9/21/1998	11/23/1998
ELWOOD	1	LCI	STATIC STARTER	Prime	7/10/1998	11/13/1998
CSW	1	LCI	STATIC STARTER	Prime	5/4/1998	10/23/1998
TRI ENERGY	1	LCI	STATIC STARTER	Prime	3/27/1998	9/24/1998
OCCIDENTAL 1&2	1	LCI	STATIC STARTER	Prime	3/25/1998	9/11/1998
POLSKY	1	LCI	STATIC STARTER	Prime	3/25/1998	8/24/1998
CAROLINA P&L	1	LCI	WATER COOLED 4KV LCI	Prime	1/29/1998	6/25/1998
ROSARITO	1	LCI	STATIC STARTER	Prime	2/20/1998	6/19/1998
FORT ST VRAIN 2	1	LCI	WATER COOLED 4KV LCI	Prime	1/28/1998	6/12/1998
MUSTANG 1-3	1	LCI	WATER COOLED 4KV LCI	Prime	12/22/1997	6/5/1998
RIO BRAVO	1	LCI	WATER COOLED 4KV LCI	Prime	12/22/1997	5/19/1998
CENTRAL PUERTO #1/2	1	LCI	WATER COOLED 4KV LCI	Prime	6/26/1997	5/13/1998
CENTRAL PUERTO #1/2	1	LCI	WATER COOLED 4KV LCI	Prime	6/26/1997	5/12/1998
ENRON COOPER ENERGY	1	LCI	WATER COOLED 4KV LCI		12/11/1996	5/1/1998
ENRON COOPER ENERGY	1	LCI	WATER COOLED 4KV LCI		12/11/1996	4/24/1998
ENRON SUTTON BRIDGE	1	LCI	READY TO SHIP AGREEMENT		6/26/1997	4/22/1998
ENRON SUTTON BRIDGE	1	LCI	READY TO SHIP AGREEMENT		6/26/1997	4/22/1998
ENRON COOPER ENERGY	1	LCI	W/C NI LCI DR 8250HP 6P		12/11/1996	3/20/1998
ENRON COOPER ENERGY	1	LCI	W/C NI LCI DR 8250HP 6P		12/11/1996	3/20/1998
TRANSCO DRESSER RAND	1	LCI	WATER COOLED 4KV LCI		8/1/1997	3/9/1998
TRANSCO DRESSER RAND	1	LCI	WATER COOLED 4KV LCI		8/1/1997	3/9/1998
ENRON SUTTON BRIDGE	1	LCI	WATER COOLED 4KV LCI	Prime	6/26/1997	12/30/1997
ENRON SUTTON BRIDGE	1	LCI	WATER COOLED 4KV LCI	Prime	6/26/1997	12/30/1997
SULZER LAGOVEN	1	LCI	WATER COOLED 4KV LCI		2/27/1997	12/11/1997
SULZER LAGOVEN	1	LCI	WATER COOLED 4KV LCI		2/27/1997	11/28/1997
EGAT RATCHABURI	1	LCI	WATER COOLED 4KV LCI	Prime	3/27/1997	9/26/1997
EGAT RATCHABURI	1	LCI	WATER COOLED 4KV LCI	Prime	3/27/1997	9/25/1997
EXXON BATON ROUGE	1	LCI	W/C 7 FA ST STR	Prime	3/25/1997	8/29/1997
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	12/20/1996
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	12/20/1996
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	12/20/1996
CHINA L&P CPPC	1	LCI	B&H W/C 9F ST STR DRIV		3/17/1993	10/23/1996
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	9/27/1996
CHINA L&P CPPC	1	LCI	WATER COOLED 4KV LCI	Prime	3/17/1993	6/28/1996
CHINA L&P CPPC	1	LCI	WATER COOLED 4KV LCI	Prime	3/17/1993	6/28/1996
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	9/28/1995
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	8/29/1995
DABHOL POWER	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	6/22/1994	5/1/1995
DABHOL POWER	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	6/22/1994	4/25/1995
CHINA L&P CPPC	1	LCI	B&H W/C 9F ST STR DR 4KV		3/17/1993	3/8/1995
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	10/20/1994
CHINA L&P CPPC	1	LCI	W/C 9F ST STR DRIVE 4KV	Prime	3/17/1993	9/2/1994
	428					
Entries Returned: 428						
Total Items: 428						

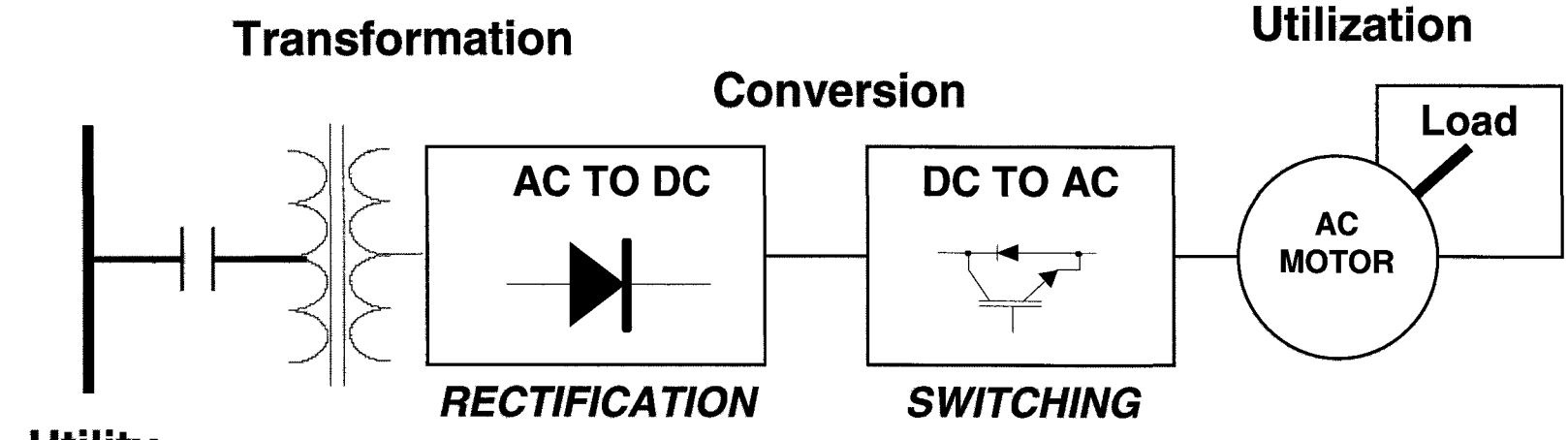
IP7_024336

Medium Voltage AC Drive Topology

Comparisons & Feature-Benefits

IP7_024337

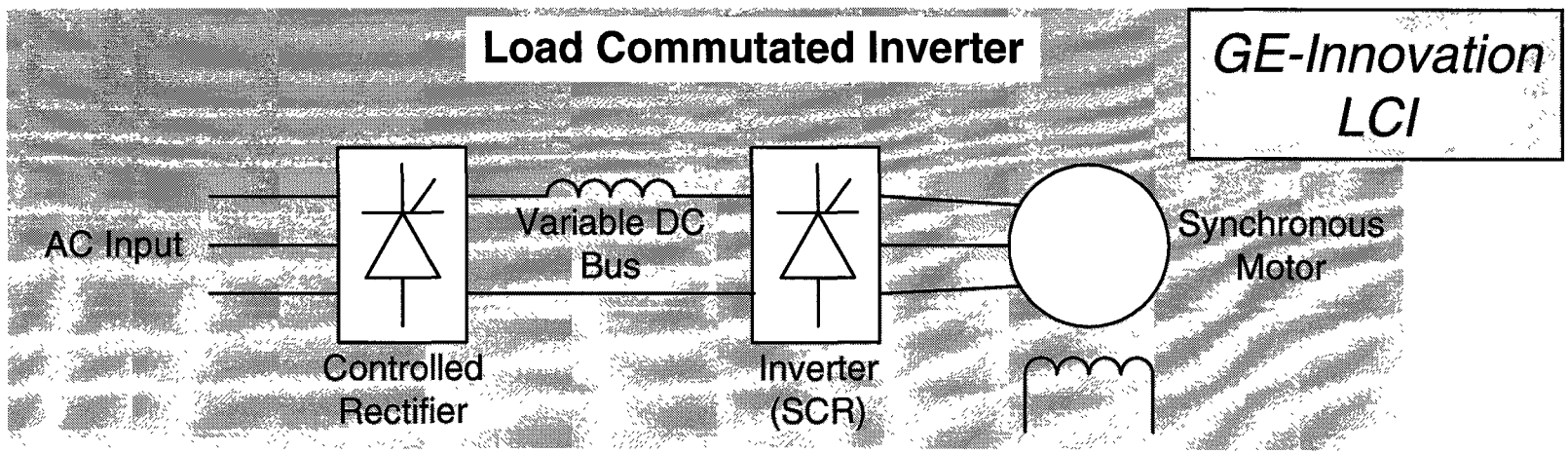
Power Conversion
AC Inverter



AC Inverter Technology
Up To 97% Efficiency

TOSHIBA GE

GE Toshiba Automation Systems



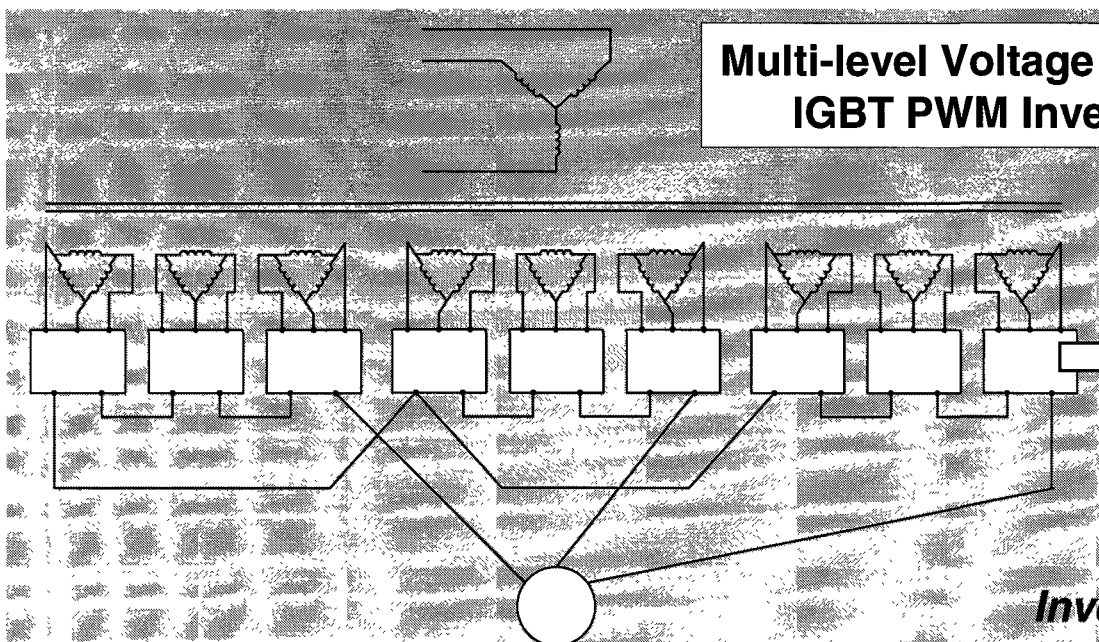
Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Load-commutated Current source SCR Inverter	• Low Parts Count • Full Regen is inherent • Rugged • Economical High HP	• Requires a controlled front end High motor current THD Slow transient response • Narrow motor frequency range Reduced Starting Torque • Limited low speed performance • Synchronous Motors Only • Poor PF, high harmonics unless multiple channels used.	Above 6 MW

IP7_024339

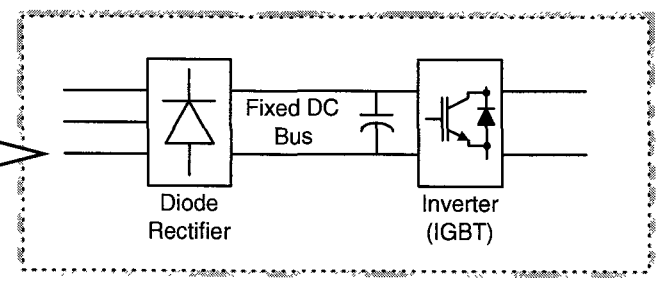
TOSHIBA GE

GE Toshiba Automation Systems



Multi-level Voltage Source IGBT PWM Inverter

GE Innovation Type H



Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Multi-level Voltage Source IGBT PWM Inverter	• Low motor current THD • Low motor insulation stress • Partial N+1 redundancy available • Fast transient response • Wide motor frequency range • High power factor	• No regen or DB possible • Large parts count • Reduced efficiency (many LV IGBTs and diodes) • Special transformer required • Larger footprint in high HP • Electrolytic capacitors degrade with time and are sensitive to overvoltage	0.5 - 7 MW

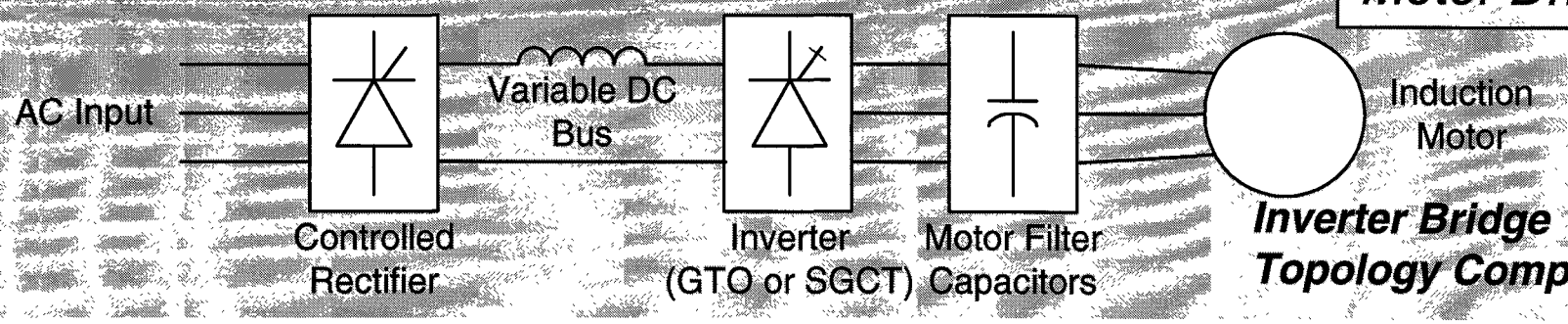
IP7_024340

TOSHIBA GE

GE Toshiba Automation Systems

Current Source PWM GTO or SGCT Inverter

GE-IMD Induction Motor Drive

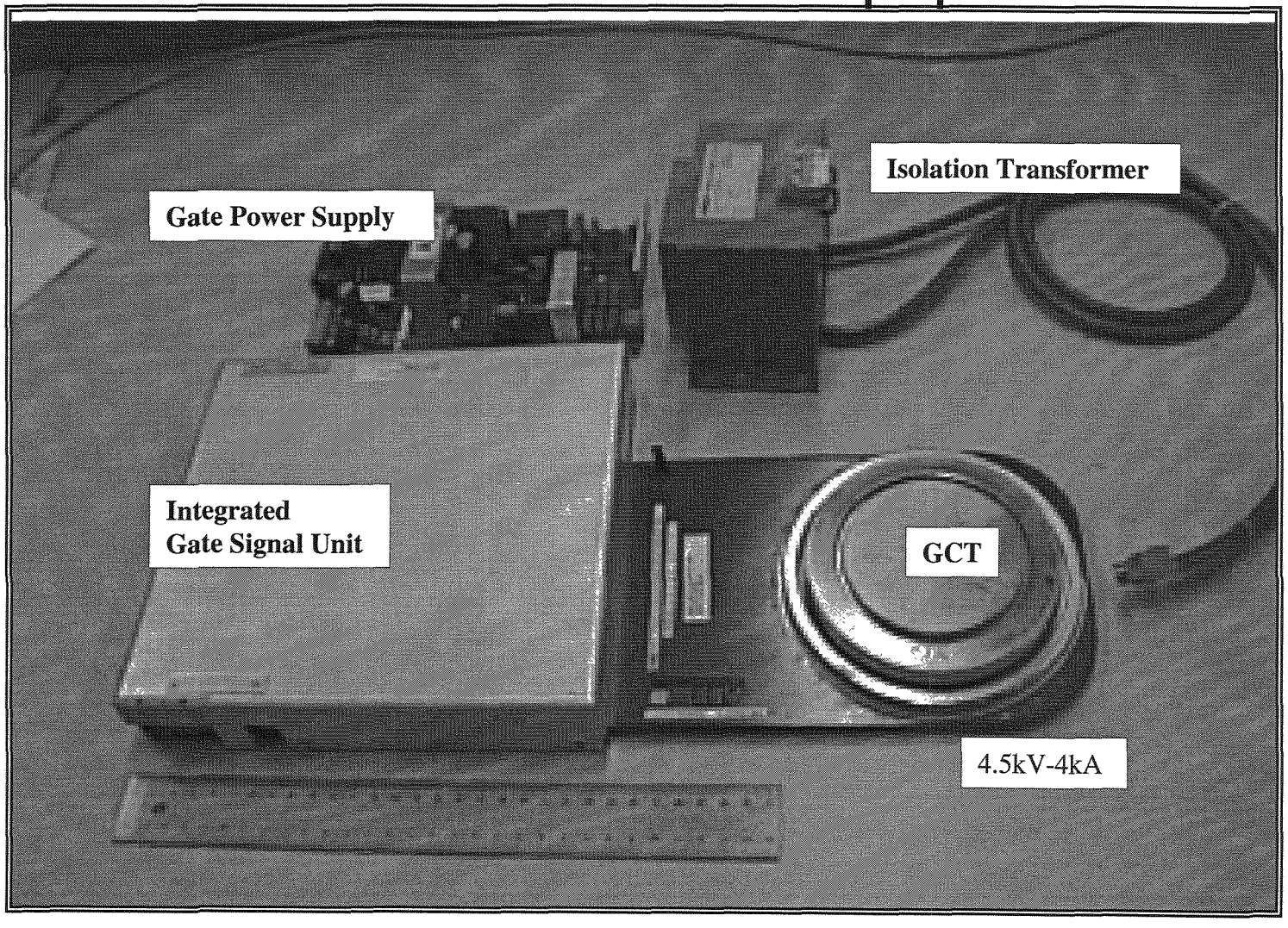


Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Current Source GTO or SGCT PWM Inverter GTO = Gate Turn Off Thyristor SGCT = Symmetrical Gate-Controlled Thyristor	• Low power device (GTO/SGCT) parts count • Low motor THD • Low motor insulation stress when isolation transformer is used	• Requires a controlled front end • Poor input power factor, with SCR front end • Slow transient response • Narrow speed range • Potential resonance between motor & caps • Limited availability of power devices • Complex firing circuit	2 - 15 MW

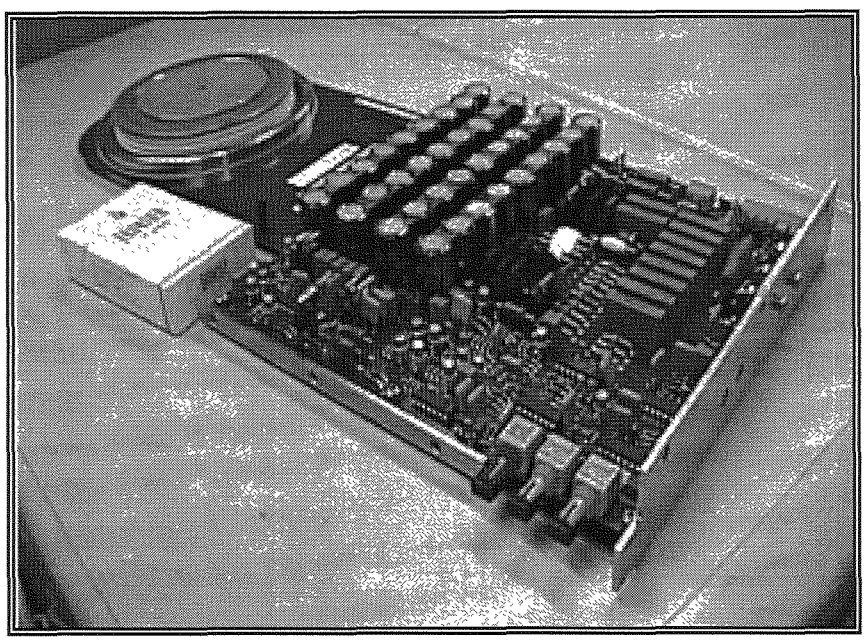
IP7_024341

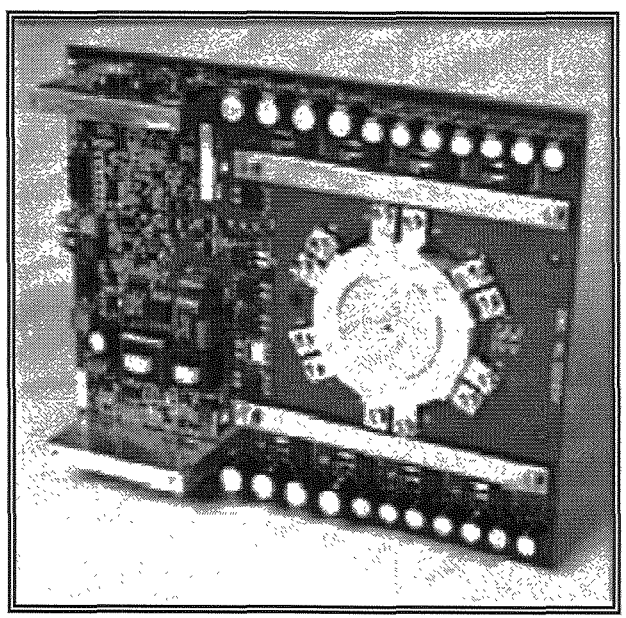
GCT Gate Driver Equipment



IP7_024342

GCT Gate Driver Board Technology Examples





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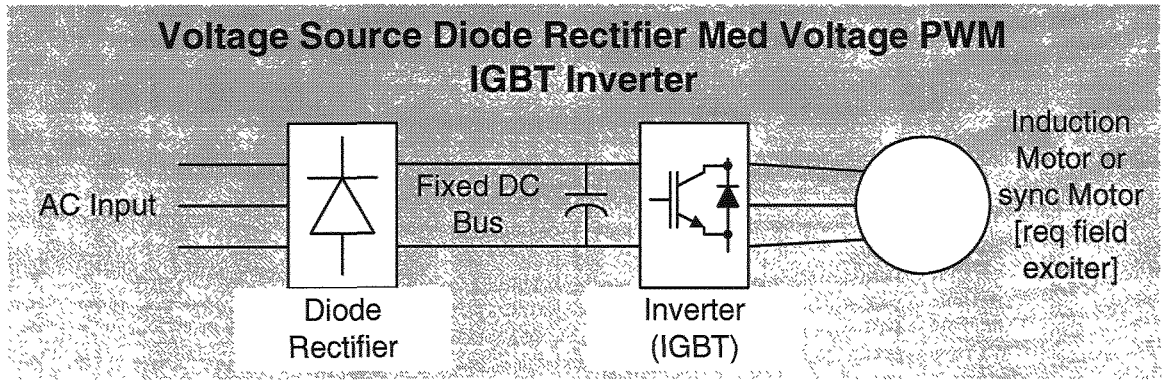


GE-Toshiba **Dura-Bilt5i MV** & GE Innovation Type G

Inverter Bridge Topology Comparison

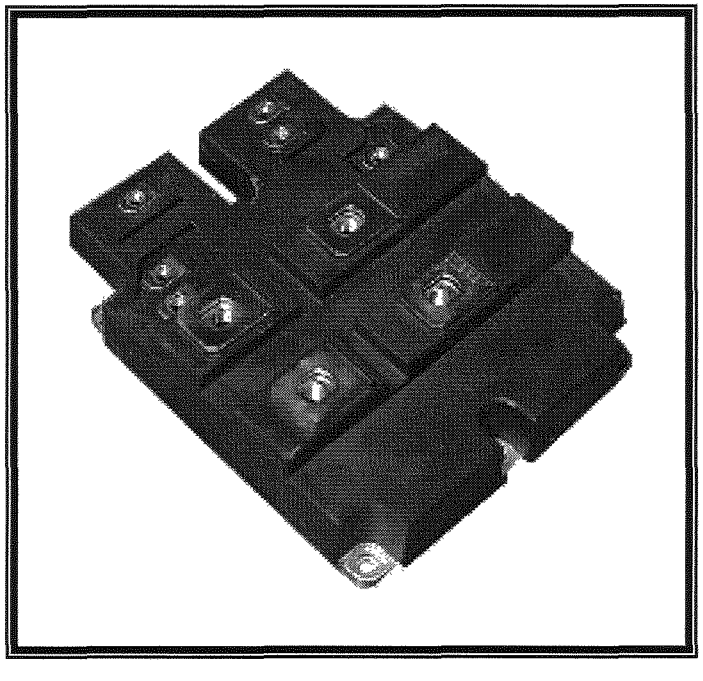
Inverter Topology	Advantages	Drawbacks	Practical Power Range
Three / Five Level Voltage Source IGBT PWM Inverter Medium Voltage IGBT = Insulated Gate Bipolar Transistor	• Minimum parts count for voltage rating • Simple firing circuit. • High efficiency • Low motor current THD • Easy repair • Fast transient response • Wide motor frequency range • Smooth low speed operation • 24 pulse rectifiers for reduced AC line harmonics • Air cooled	• No regen • Fast rise time IGBT switching may require dv/dt output filter in some cases	0.5 – 4.8 MVA per inverter, air cooled 4.8 – 9.6 MVA, dual channel

IP7_024344

Simple IGBT Gate Driver Circuit

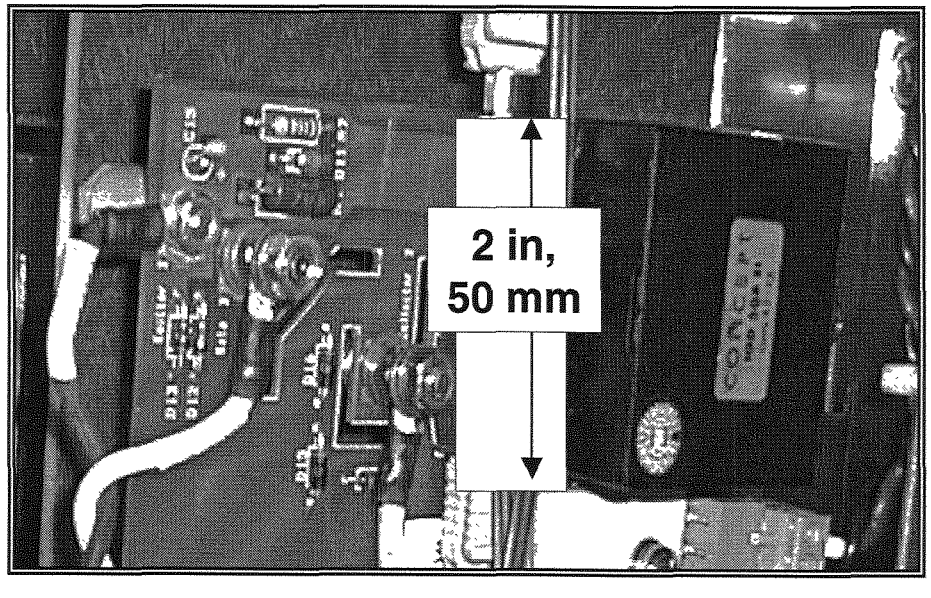
IGBT

Dual package – larger ratings have 1/package



Dura-Bilt5 Gate Driver

Each board has 2 drivers, & fires 2 IGBT's

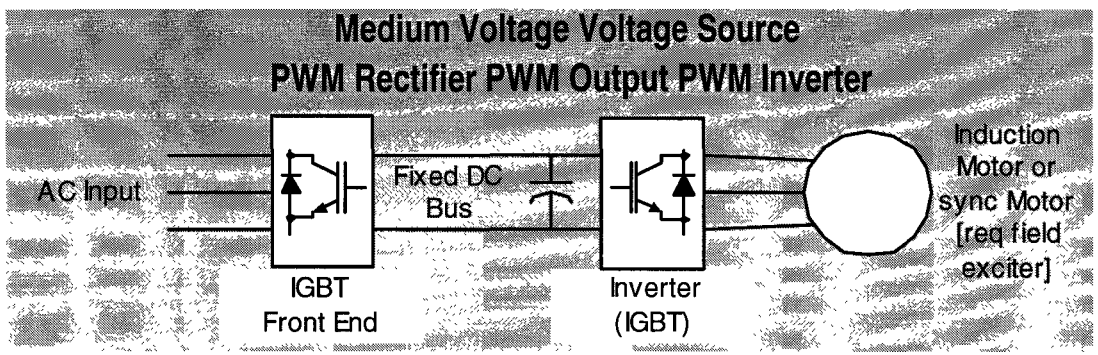


IP7_024345

TOSHIBA GE

GE Toshiba Automation Systems

GE-Toshiba
T350



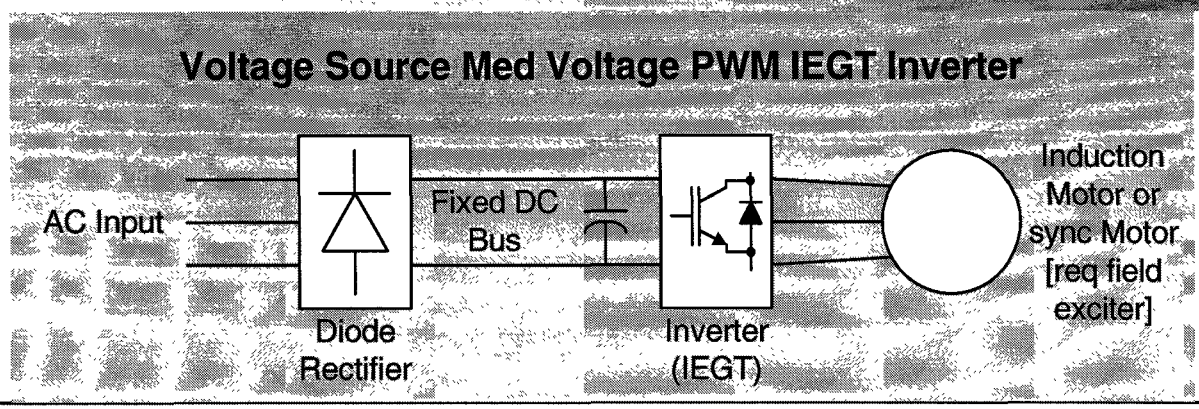
Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Three Level Voltage Source IGBT PWM Inverter IGBT = Insulated Gate Bipolar Transistor	• Minimum parts count for voltage rating • Full regen • High efficiency •Simple firing circuit. • Low motor current THD • Easy repair • Fast transient response • Wide motor frequency range • Smooth low speed operation • Active Front End for low harmonics, Regeneration, Unity PF	• Fast rise time IGBT switching – may require dv/dt output filter in some cases	1.2 – 3.2 MW, water cooled T350, 1250 volt, 3-level

IP7_024346

TOSHIBA GE

GE Toshiba Automation Systems



GE-Toshiba T650 Diode Source

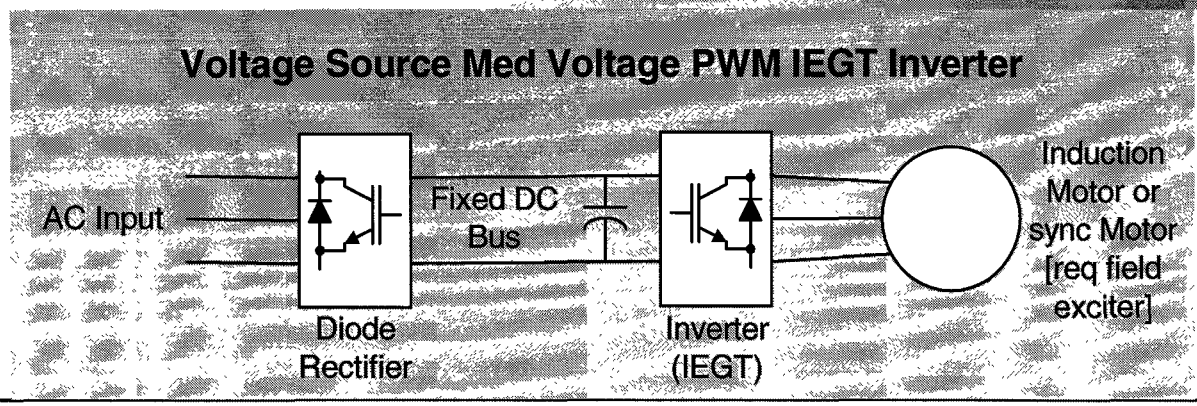
Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Three Level Voltage Source IEGT PWM Inverter IEGT = Injection Enhanced Gate Transistor	• Minimum parts count for voltage rating • High efficiency • Simple firing circuit. • Low motor current THD • Easy repair • Fast transient response • Wide motor frequency range • Smooth low speed operation	• IEGT device limits allow 3300 volt motor output [European and Asian Standard] • 3300 volts is not as common as 4160 volts in North American applications.	6 to 26 MW, water cooled, one or two channel At 3300 volts

IP7_024347

TOSHIBA GE

GE Toshiba Automation Systems



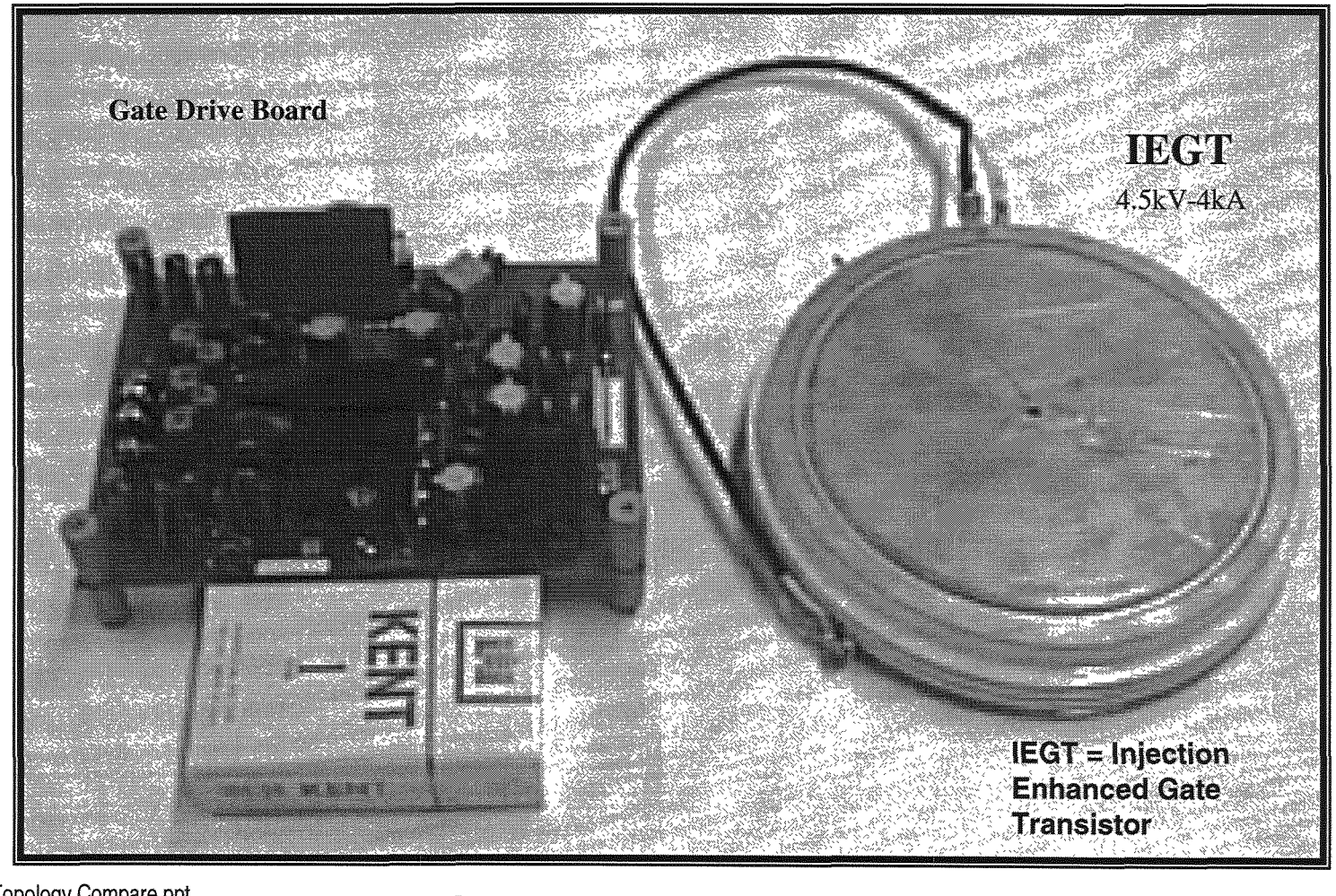
GE-Toshiba T650 with Active IEGT Source

Inverter Bridge Topology Comparison

Inverter Topology	Advantages	Drawbacks	Practical Power Range
Three Level Voltage Source IEGT PWM Inverter IEGT = Injection Enhanced Gate Transistor	• Minimum parts count for voltage rating • High efficiency • Simple firing circuit. • Low motor current THD • Easy repair • Fast transient response • Wide motor frequency range • Smooth low speed operation • Active Front End for low harmonics, Regeneration, Unity PF	• IEGT device limits allow 3300 volt motor output [European and Asian Standard] • 3300 volts is not as common as 4160 volts in North American applications.	6 to 26 MW, water cooled, one or two channel At 3300 volts

IP7_024348

IEGT Gate Driver Equipment



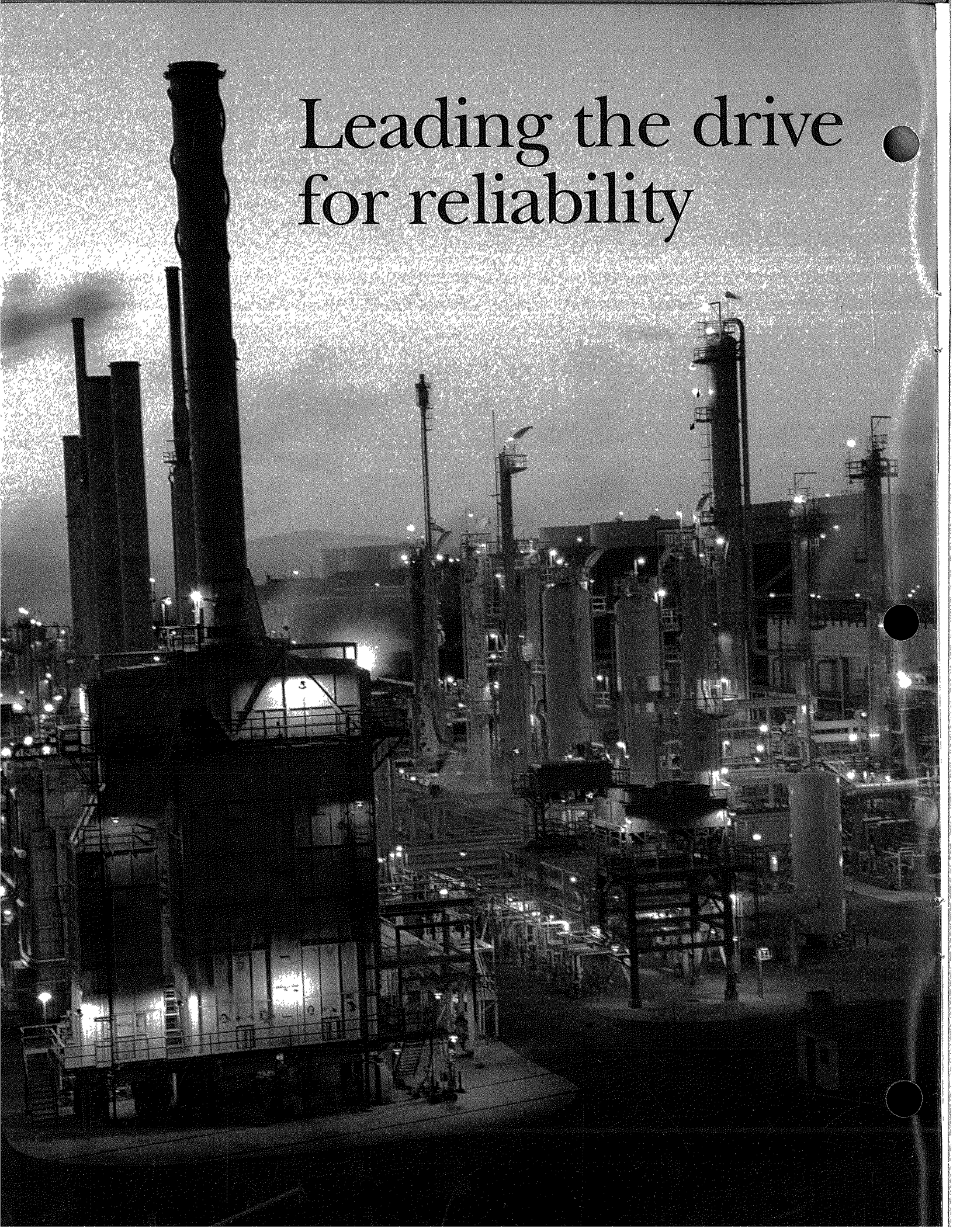
IP7_024349

The INNOVATION™ Series
LCI Load Commutated Inverter

GE Industrial
Control Systems

IP7_024350

Leading the drive for reliability



IP7_024351

GE's highly successful LCI Load Commutated Inverter was one of the first commercially available large ac drives. It earned a well deserved reputation for being "motor friendly." Today many of these units have been in service for more than fifteen years driving fans, pumps, and compressors; and they can be found in ore grinding applications, rod and bar mills, and marine propulsion systems throughout the world. GE LCI products have enabled owners to realize their system's full potential with historical performance of 99.76% availability. The design objectives of the INNOVATION™ LCI product were focused on advancing product reliability and diagnostics intelligence to build on this impressive record and to offer our customer new levels of competitive performance.

During the past decade, ac drives have become an essential part of the industrial drive spectrum. Heavy industries, power suppliers, and motor manufacturers have come to recognize the energy savings and important benefits they can provide.

Now GE gives you more...

You can get higher drive reliability and control performance and better fault avoidance with the INNOVATION™ Series Load Commutated Inverter. This new LCI from GE features a floating point digital signal processor control that provides twenty times more processing power than the previous generation controls. The result — better performance and more comprehensive, higher quality protection and diagnostics.

Immunity to electrical noise is increased. Fiber optics are used to galvanically isolate control signals from high voltage circuitry for noise immunity and safety. Control circuitry has been simplified. The number of control circuit cards has been reduced, so there are fewer connections. Repairs have been simplified and there are fewer spare parts to stock.

It is the simplest, most efficient and most reliable ac adjustable speed drive technology available, and is the drive of choice for large, new synchronous motor applications which require speed control. The LCI is designed to be able to operate continuously at rated torque from near zero to rated speed. Its high starting and accelerating torque capability make it ideal for large conveyors, metal processing, rod, bar, and wire mills, as well as various extrusion, mixing, grinding and compressor applications.

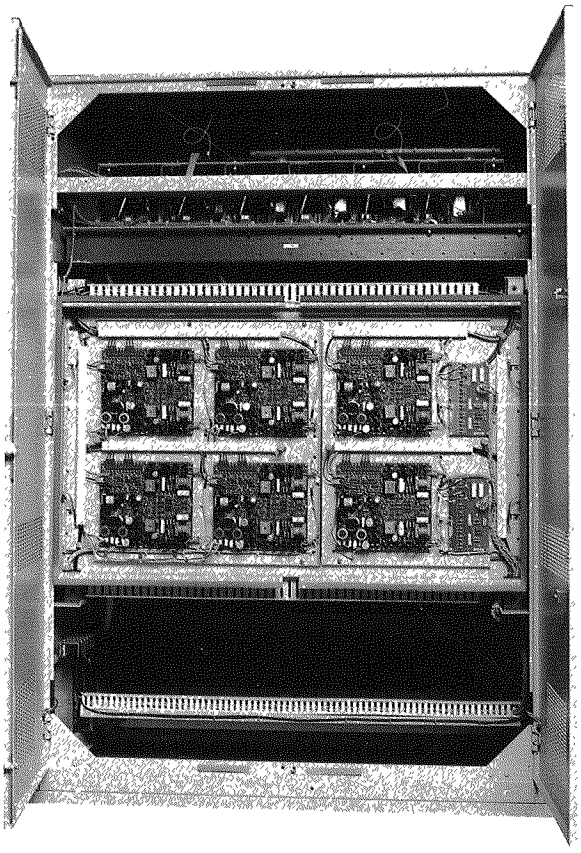
The advantages you need to keep ahead

High Efficiency

Today there are still many processes using a constant speed motor with mechanical flow control. This has been compared to a driver driving with the emergency brake engaged. The LCI enables process operators to adjust the speed of the motors, drawing only the power necessary to attain the required output. The result is a significant increase in efficiency, especially at low levels of flow or output.

Precise Process Control

The LCI controls both the motor current and power factor to control torque and speed. The digital accuracy of the equipment enables the system to provide the speed regulation required for many critical process operations.



Extended Motor Life

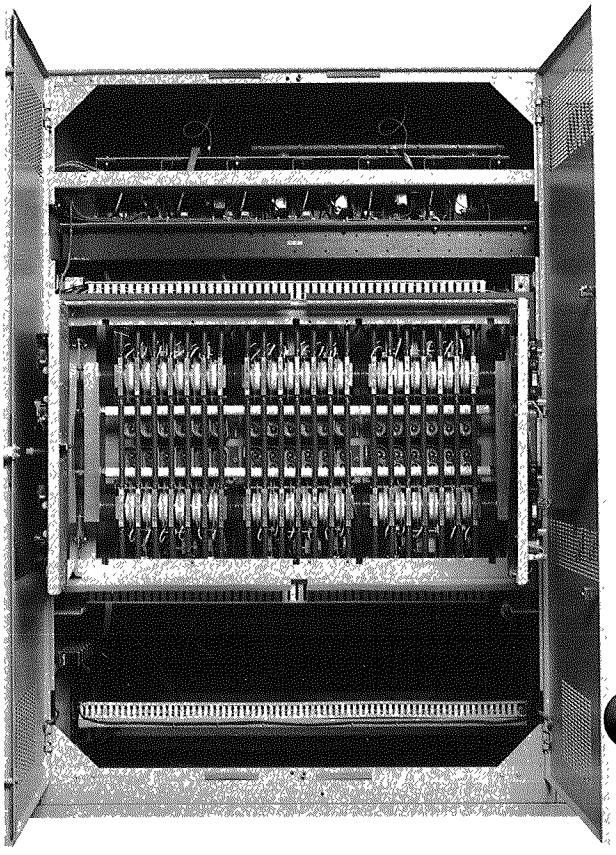
The motor current is always under control. No locked rotor starting currents, excessive temperatures, or mechanical stresses are put on the motor. With constant speed motors, the driven equipment is subjected to hard starts; and the heat, caused by the starting current, degrades the motor insulation and shortens its life. Controlled motor current also means that motor heating will not limit the quantity or frequency of motor starts.

Reduced Bus Impact

The LCI possesses characteristics that can increase the load carrying capability of an auxiliaries' system bus with a given switchgear rating.

The characteristics contributing to this are:

- Starting currents that are low in magnitude and of relatively high power factor when compared to across-the-line starting of conventional, squirrel-cage induction and synchronous motors. This characteristic eliminates significant voltage dips during the starting of large adjustable speed drives.



IP7_024353

- Normally there is no LCI contribution to short circuit current. This characteristic permits a reduction in the auxilliary transformer's impedance. This results in improved system voltages at a given load condition or permits greater load carrying capability.

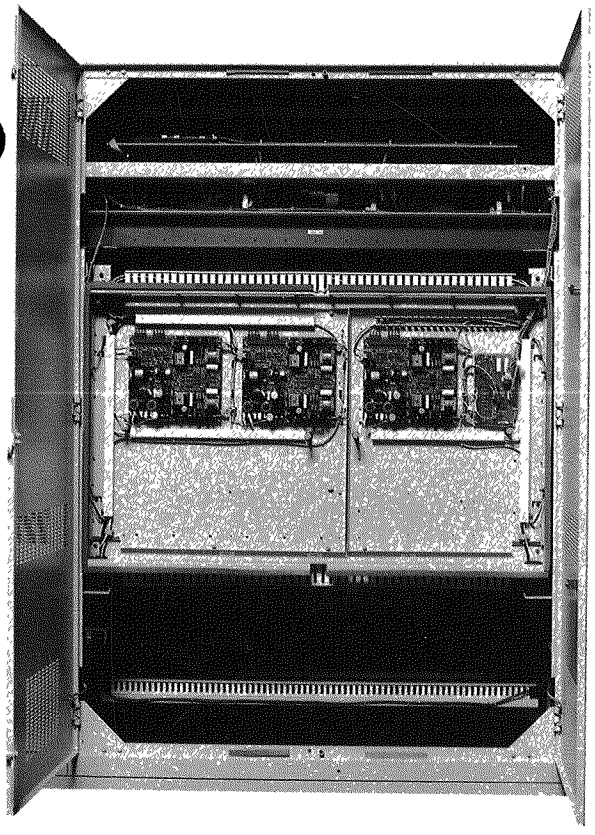
The reduced starting current and lack of short circuit contribution also allows an increase of the total motor load that can be applied to a piece of switchgear. For an existing system there is a reduced voltage dip during motor starting and lower short circuit duty.

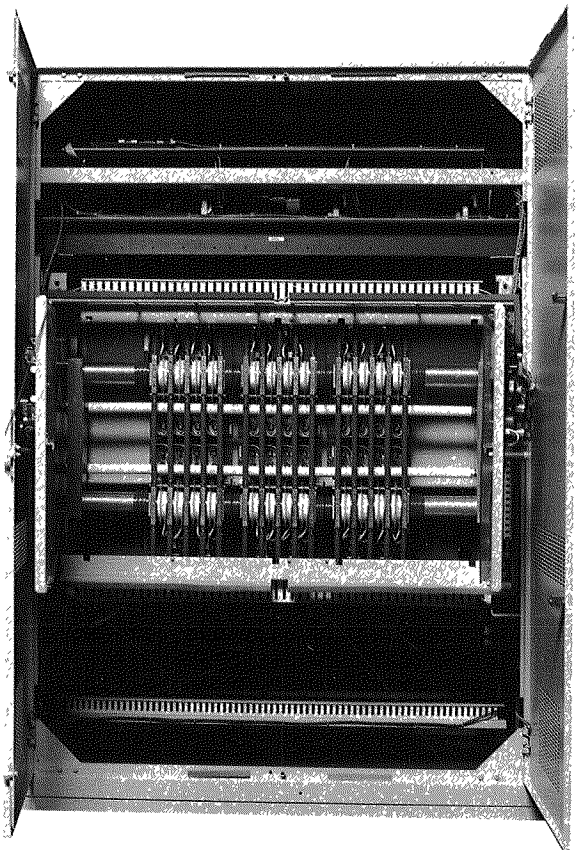
Bus Voltage Variation Resistant

Since the LCI motor is buffered from the power bus, it is less sensitive to voltage fluctuation. If there is a momentary dip in voltage the LCI will continue to produce torque or coast (depending upon the magnitude of the dip) until voltage is returned. It will then re-accelerate to the desired speed. The LCI motor will not pull out of step like a fixed speed motor, but will continue to operate. As a result, the LCI is ideal for power plant applications where bus switching is a common occurrence.

Regenerative

A synchronous motor can also be a generator. When a large inertial load is driven by an LCI with a synchronous motor, the inertia can be used to drive the motor as a generator, slowing the motor and load inertia, feeding the generated power back into the ac line. Line regeneration is an effective, cost efficient way to provide braking of a large inertia load.





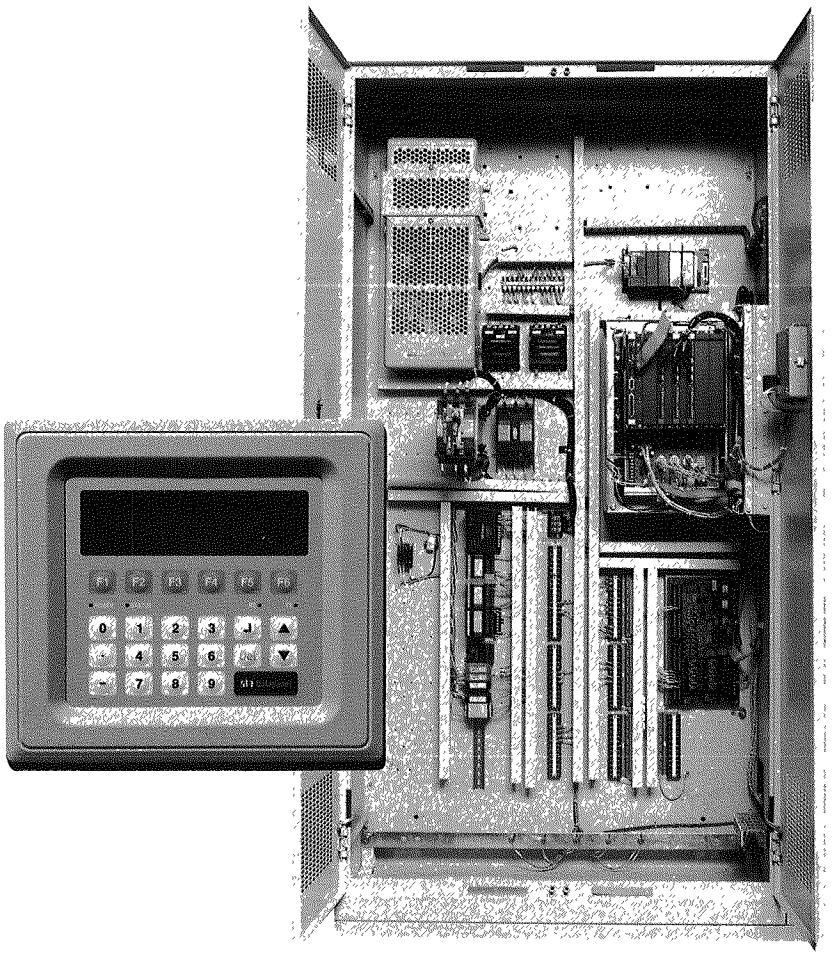
Keeping you in control

Digital Performance and Accuracy

To optimize performance, a floating point Digital Signal Processor (DSP) is used on all systems. This processor has twenty times more processing power than those used in previous generations of controls. The result is higher drive reliability and control performance, more comprehensive, higher-quality protection, and better fault avoidance.

Simpler Design

Control cards are mounted in a VME rack, designed for simplified maintenace in rugged industrial applications. The number of control cards has been minimized. The rack-based design drastically reduces wiring and connectors which means there are less opportunities for faults to develop. Best of all fewer spare parts need to be stocked and repair time has been reduced.



Bridge Control Functions

Drive parameters and control functions are scaled on a per unit basis to match the motor to be controlled. Control signal circuitry is isolated from high voltage circuitry and utilizes fiber optic cabling to provide electrical noise immunity. Drive configuration and tune-up data are retained in non-volatile memory and can be backed-up with a personal computer.

All bridge control functions are performed in the DSP module. These include:

Speed regulation
Current regulation
Flux regulation
Source converter thyristor firing
Load converter thyristor firing.

The bridge control features hardware which is independent of the DSP operation. This protects against over-current in source or load bridges. No power fuses are necessary. There is a DSP independent customer signal path which disables power bridge gating useable for external interlocks.

The use of a high-current, low-voltage thyristor gating strategy with dc output ensures positive, noise immune gating for the SCRs.

System Control Functions

System interfaces for command input, sequencing and interlocks, and status feedback are provided through an expandable Programmable Logic Controller (PLC). The PLC can be a GE-Fanuc 90-30 external to the bridge control module or a GE Industrial Control Systems UC2000 processor integrated into the bridge control module. Either PLC uses GE-Fanuc Field I/O modules hosted on a local Genius® Bus as expandable customer and system I/O.

The use of a standard PLC provides for a wealth of drive communications options which include Ethernet™, DLAN+, Genius® Bus, SNP, Modbus®, Interbus-S™, and others. The field I/O modules offer a DIN rail-mounted, expandable I/O system to handle application specific interface needs.

IP7_024355

Extended Self Diagnostics

The control is designed with extensive test features which are able to isolate problems to a replaceable unit. All bridge control boards feature loop-back test capability which allows the processor to test the board operation without requiring motor operation. All cables are monitored for continuity.

All thyristors are individually monitored for proper conduction status. In drives with optional redundant thyristors, safe operation of the drive can continue with one or more shorted devices until maintenance is performed.

The control is also capable of running a test on the entire drive where current is circulated through the bridges but bypasses the motor, allowing proof of drive readiness without requiring power on the motor.

Help is as Near as Your Modem

GE's OnSite™ remote monitoring, diagnostics and service program is available from GE Engineering Services. It provides 24-hour diagnostic services and software support anywhere in the world. This program is provided by skilled GE installation and service engineering personnel familiar with your application and equipment.

One single contact can provide service, parts and training to keep you up and running.

Cooling System

All major heat producing components in the LCI are liquid cooled. The enclosure is convection cooled and requires only a small amount of air conditioning in the control room. The cooling fluid in the LCI is cooled either by a liquid-to-air heat exchanger or a liquid-to-liquid heat exchanger. Liquid cooling provides a compact drive with maximum rating available from the SCRs.

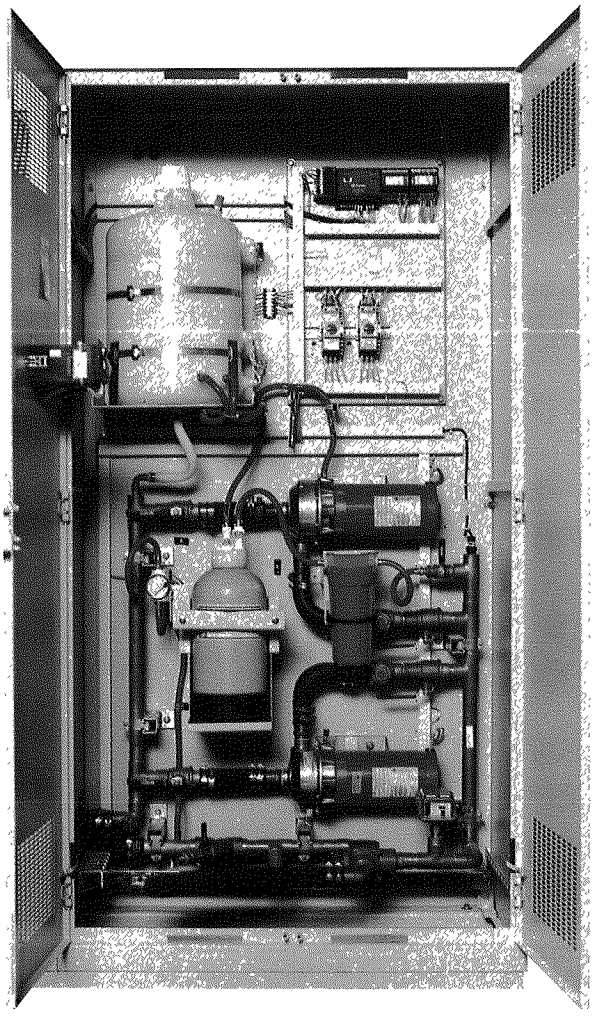
Tachometer (Optional)

A tachometer is available for specialized low speed and constant speed applications when required. For most applications, the motor speed is regulated by comparing the speed reference from the process controller to the feedback derived from the motor terminal voltage.

Initialization

Upon application of power to the drive the following checks are performed to prevent an abnormal microprocessor condition, and to prevent improper drive operation.

CPU test
PROM check sum
RAM test



Drive Control Strategy

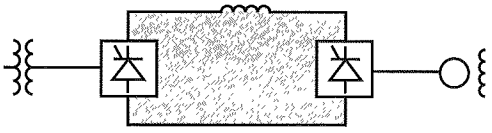
The Load Commutated Inverter's theory of operation is simple and reliable. It uses load-commuted, phase-controlled power technology to supply power to the stator windings of the synchronous machine.

The power circuit has a source converter, connected to the power supply and a load converter connected to the motor. When motoring, power flows from the power source to the motor.

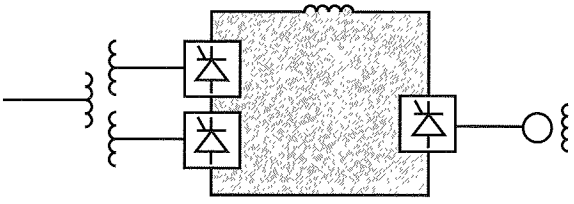
The LCI controls motor torque to regulate motor speed. Motor torque is controlled through the dc link current. In most operating conditions, the source converter controls the link current by changing the voltage across the link reactor.

The link reactor also limits ripple current that flows between the source and the load converters. Properly sized, the link reactor will prevent SCR failures when a commutation failure occurs on the load converter. Under these circumstances, the LCI can continue to operate without tripping off-line.

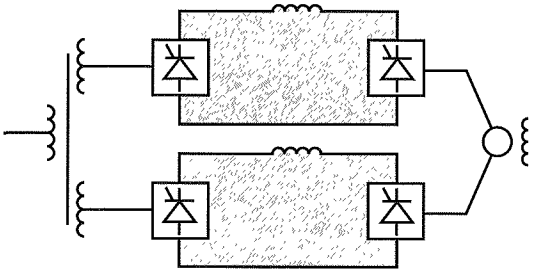
System Configurations:



6 PULSE / 6 PULSE



12 PULSE / 6 PULSE



12 PULSE / 12 PULSE

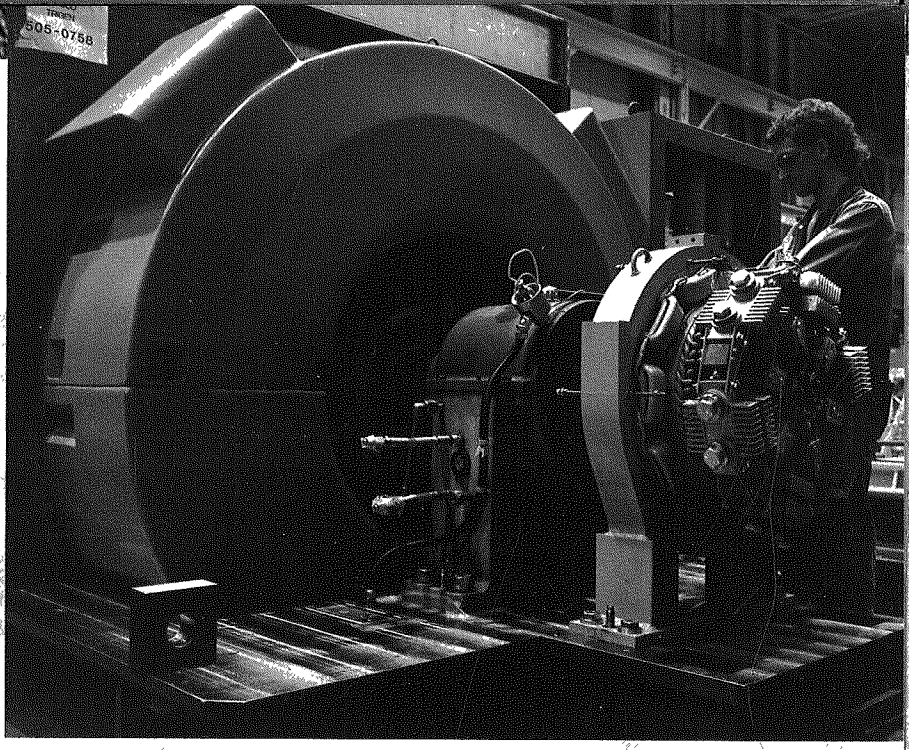
Ratings

VOLTS	PULSES Source	PULSES Load	DIMENSIONS meters W x	D x	H	WEIGHT	kW @ 50°C 50% Antifreeze	kW @ 35°C
2300	6	6	4.0	1.4	2.3	4400	5000	5250
2300	12	12	5.6	1.4	2.3	7400	10000	10500
4160	6	6	5.6	1.4	2.3	7400	12000	14200
4160	12	6	5.6	1.4	2.3	7400	12000	14200

** Additional voltages and ratings can be provided by special request to meet application requirements*

For 2300 volt applications requiring a 12-pulse dual channel LCI configuration, a more effective single line-up is offered as shown above. This compact design has a single control and cooling system.

Motor Design



The LCI is designed as a system. Both the control and the motor are coordinated and designed to work together. GE's motor design engineers and drive engineers work together to assure system compatibility. GE's long experience in motor design and manufacturing means every LCI system will provide a very high degree of reliability.

The synchronous motor for the LCI has several design differences not found in a standard synchronous motor.

Construction

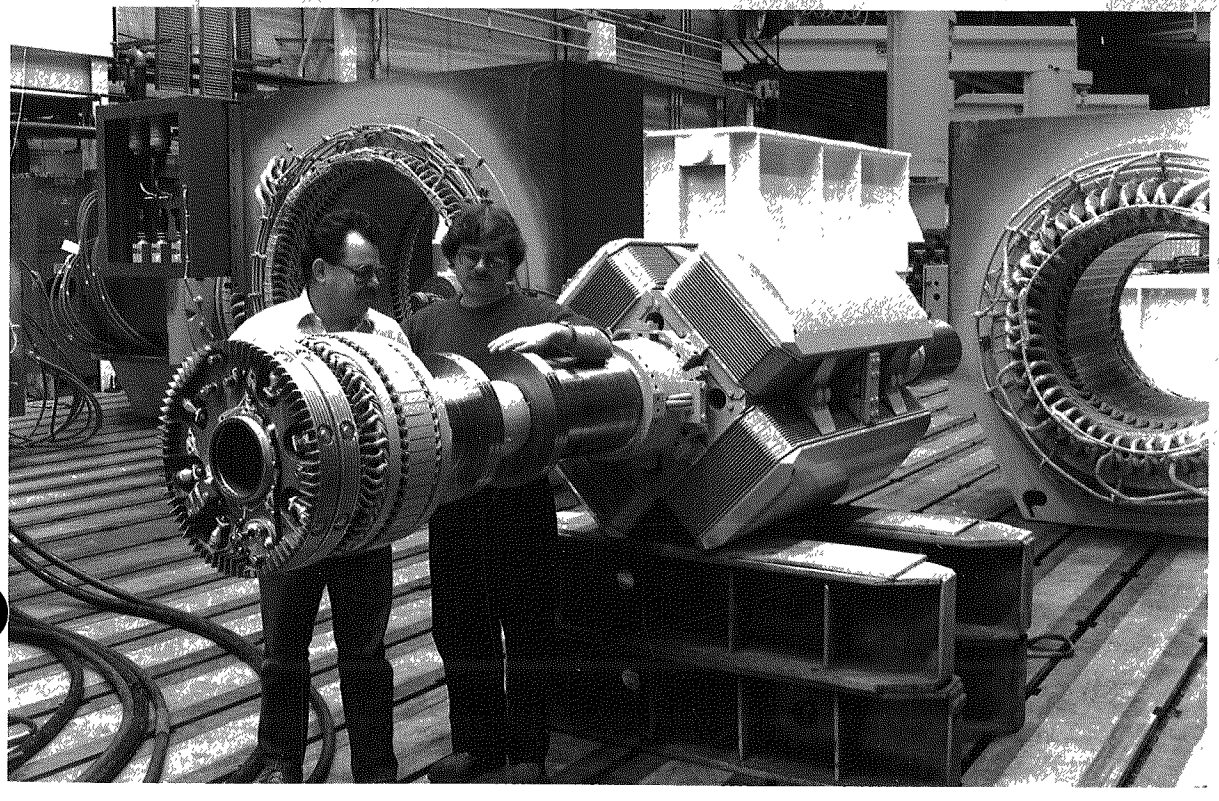
The ammortisseur windings in the LCI motor are designed to minimize the losses caused by the harmonic content of the drive current waveform. The design of these bars is such that the LCI synchronous motor cannot be started across the line. For twelve-pulse operation the motor has two windings that are 30 electrical degrees apart.

Excitation

Brushless field exciters are standard, however slip rings are also available. The LCI control sets the flux of the machine to best suit the application and deliver the highest power factor and efficiency over the entire speed range.

Motor Power Factor

The LCI synchronous motor operates at leading power factor to provide the reactive power required to commutate the inverter thyristors. This operation is a fundamental difference between the LCI and other ac drive technologies.

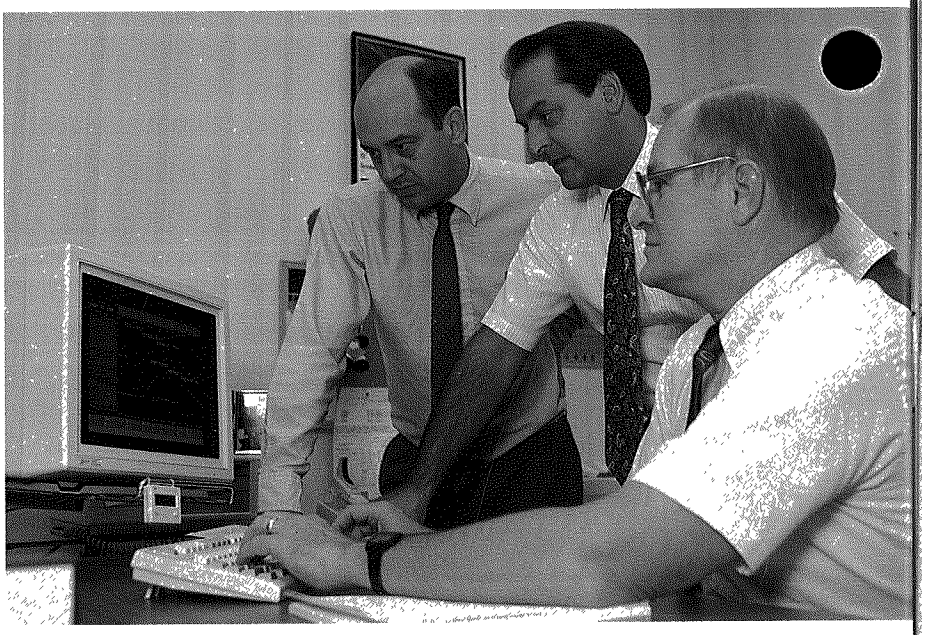


Getting Started

Installation and Startup Supervision

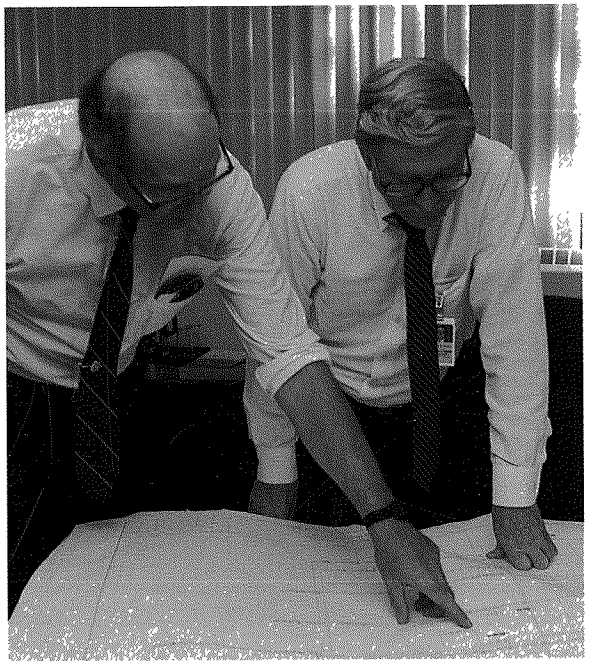
The world-wide GE service network is available for turnkey installation, startup supervision, and service.

GE's OnSite™ remote monitoring and diagnostics system provides on-line support from a team of engineers who have strong application experience and ac drive and motor knowledge. They are available 24 hours a day to support your team in the event of an outage or equipment instability. When you telephone, they can tie into your system to provide quick assistance to pinpoint system problems and identify potential solutions. Think of OnSite™ as a team of experts, poised to help you quickly resume profitable production.



Parts Support

Spare parts are readily available from GE Engineering Services Renewal Parts Operation in Salem, Virginia or through the worldwide network of renewal parts distributors. Emergency phone service is provided 24 hours a day. Most renewal parts are filled from stock and shipped within 24 hours.



Training

Training courses tailored to your needs are available for both operating and maintenance personnel right on your site, or at the GE Training Center in Salem, Virginia.

Project Management

GE provides single point system responsibility. From the application analysis to the final installation, a GE engineer is your point of contact. Knowledge of your system, experience, application expertise, competence, and integrity make your GE engineer a valuable asset.

Commitment

GE is committed to providing our customers with the most up-to-date, proven technology available. We strive to help solve your problems and to provide an exceptionally dependable system manufactured to Six Sigma quality standards. These standards are designed to effectively eliminate all defects from every product, process and transaction in which GE engages around the globe. It is based on the statistical measurement defined as fewer than 3.4 defects per million opportunities. With GE, you know that we will be available throughout the life of your equipment. Best of all, you can be confident that you are working with a company that has the resources, knowledge and experience to do the best job.

IP7_024359

Technical Data

Control Features:

- Forced Commutation Below 10% of Rated Speed
- Load Commutation Above 10% of Rated Speed
- Torque Regulated Speed Control
- Volts / Hz Control
- Field Excitation Control
- 10-160% of Rated Speed Control Range
- 3 Programmable Acceleration / Deceleration Ramps (Max Rate of 10% / Sec)
- Smooth Reversal of Motor Rotation Through Zero Speed

	No Tachometer	Tachometer
Max Starting Torque (From Standstill)	.75 PU	2.0 PU
Max Forward Speed	1.0 PU	1.0 PU
Max Reverse Speed	0.5 PU	1.0 PU
Constant Horsepower Speed Range	Base to Top	Base to Top
Constant Torque Speed Range	0.1 PU to Base	1.5-Hz to Base

Impact Loading

- Below Base Speed 1.0 PU Torque/Sec 3.0 PU Torque/Sec
- Above Base Speed 0.5 PU HP/Sec 1.5 PU HP/Sec

Short Circuit Bracing:

30,000 Amps Symmetrical

Cooling Media:

- Deionized Water
- 50°C Max Inlet Water Cooling Temperature (Water-to-Water Heat Exchanger)
- Optional Addition of Antifreeze (Requires Derating Drive)
- Operating Ambient Air Range (0-50°C)

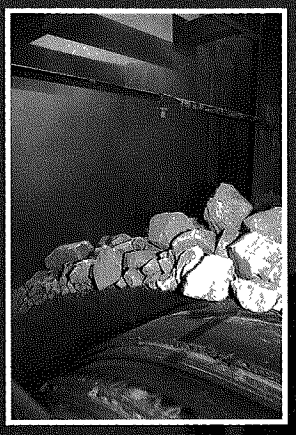
Manufacturing Standards:

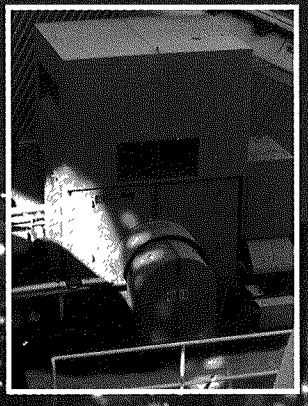
- UL508C
- IEC 146-1-2
- NEMA ICS 7-1993
- CSA C22.2
- UL347A
- EN50178

Manufacturing Quality System:

- ISO9001
- ISO9000-3

GEA-10816D
CADMUS
971020





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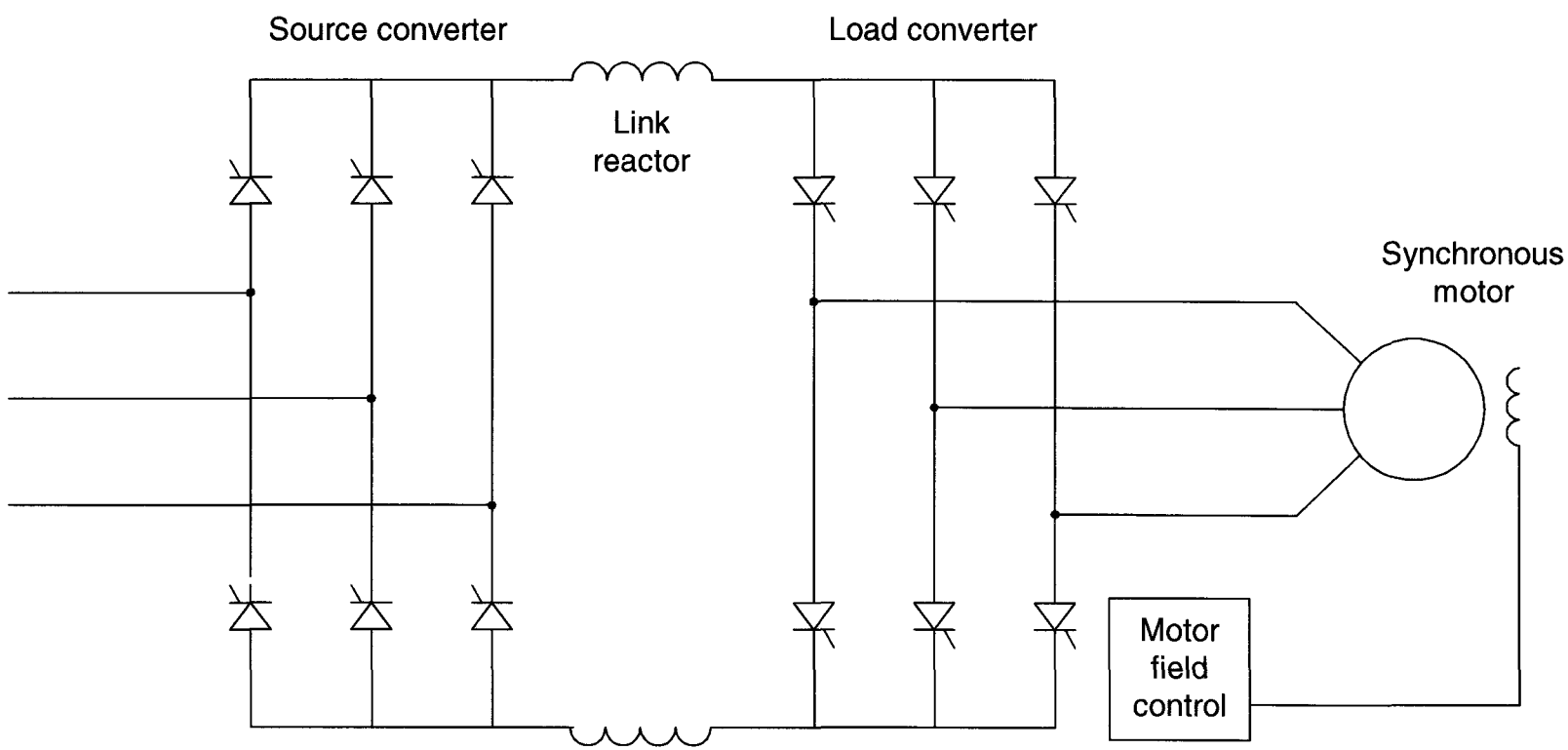
IP7_024361

GE Innovation LCI

IP7_024362

LCI Circuit Diagram



IP7_024363

LCI Concepts

- Current source drive
  - Uses link reactor with significant inductance
  - Variable voltage DC link - matches motor voltage
  - Link current is primary control variable - current is controlled to produce torque, which is regulated to control speed
- Isolation transformer required
- SCR source and load converters
- Regeneration capability inherent in circuit
- Load inverter is commutated by the motor
  - Synchronous motor operates at 0.9 pf leading almost all times
  - Motor must have field current at all times
  - SCR inverter is locked to motor frequency because the motor commutates inverter

IP7_024364

LCI Concepts

Source side characteristics

- Looks much like DC drive to power system
- SCR rectifier draws lagging VARs from system that vary with link voltage
- Low pf at low speeds, but kVAR demand depends on torque delivered by motor
- High pf (0.92) at full motor voltage
- Fixed frequency harmonics injected in power system; 6p $\pm$ 1 characteristic harmonics
  - phase shifting reduces 6 pulse harmonics
- No fault current contribution to bus from LCI

IP7_024365

LCI

Motor Characterictics

- Operates at 0.9 pf leading on LCI
- Base frequency is usually 40 - 60 Hz
- Harmonic currents and torques are multiples of motor fundamental frequency

Transformer Characterictics

- Must be capable of operation with rectifier harmonics
- Phase displacement between secondaries provides harmonic reduction (12 pulse operation)
  - requires dual secondary transformer or two separate transformers
- Can be air or oil cooled - depends on location

IP7_024366

LCI Concepts

Performance

- Good for low dynamic performance drives
- Air gap torque ripple can be high at low motor speeds
- Converter loss about 1.5% at full load - use IEEE Std 995 to calculate
- Starting through an output transformer requires special strategies with high inertia loads

IP7_024367

GE LCI Experience

- Developed first LCI in late '70's
- Water cooled units developed in '85
- Three different generations of controls
- >1,000,000 installed HP in more than 250 drives

IP7_024368

Innovation LCI

- All new hardware, but using proven control strategies
- Output voltage: 2.3 kV or 4 kV
  - selected to match motor output
- Several different converter configurations to meet different requirements
  - 6 pulse source/6 pulse load
  - 12-p source/6-p load
  - 12-p source/12-p load

IP7_024369

Innovation LCI

New LCI Converter

- New bridge structure with single clamp for 2 stacks of thyristors (maximum 36)
- Optical gating isolates control from medium voltage
- Thyristor status feedback to control
- Upgraded leg reactance to accommodate shielded cable capacitance and longer cables
- DC gating of thyristors
- More maintainable

IP7_024370

Innovation LCI

New LCI Control

- New 60 MHz DSP main controller
- Reduced number of circuit boards
- Boards mount in VME rack
- Operator panel in control compartment door
- Extensive diagnostics and self-test capability
- External control interface - 2 options
  - GE Fanuc 90-30 PLC
  - GE UC 2000 unit control

IP7_024371

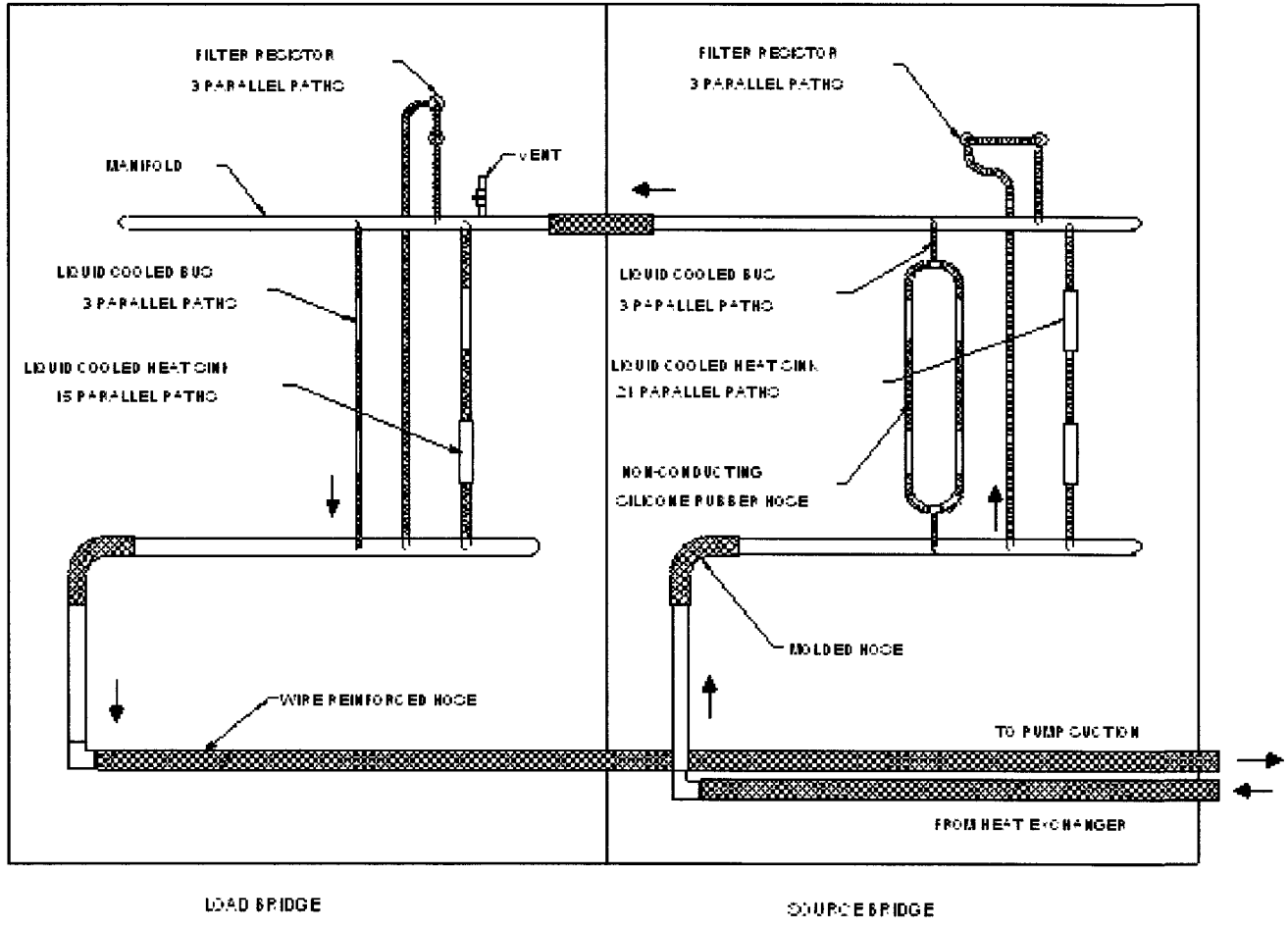
Innovation LCI

LCI Cooling System

- Liquid cooled SCR's and power components
  - Self contained deionized water system
  - Glycol is used as antifreeze when needed
  - Water/air or liquid/liquid heat exchanger
  - Redundant pumps
  - Deionizer and filter can be changed while the LCI is running

IP7_024372

Cooling System Diagram



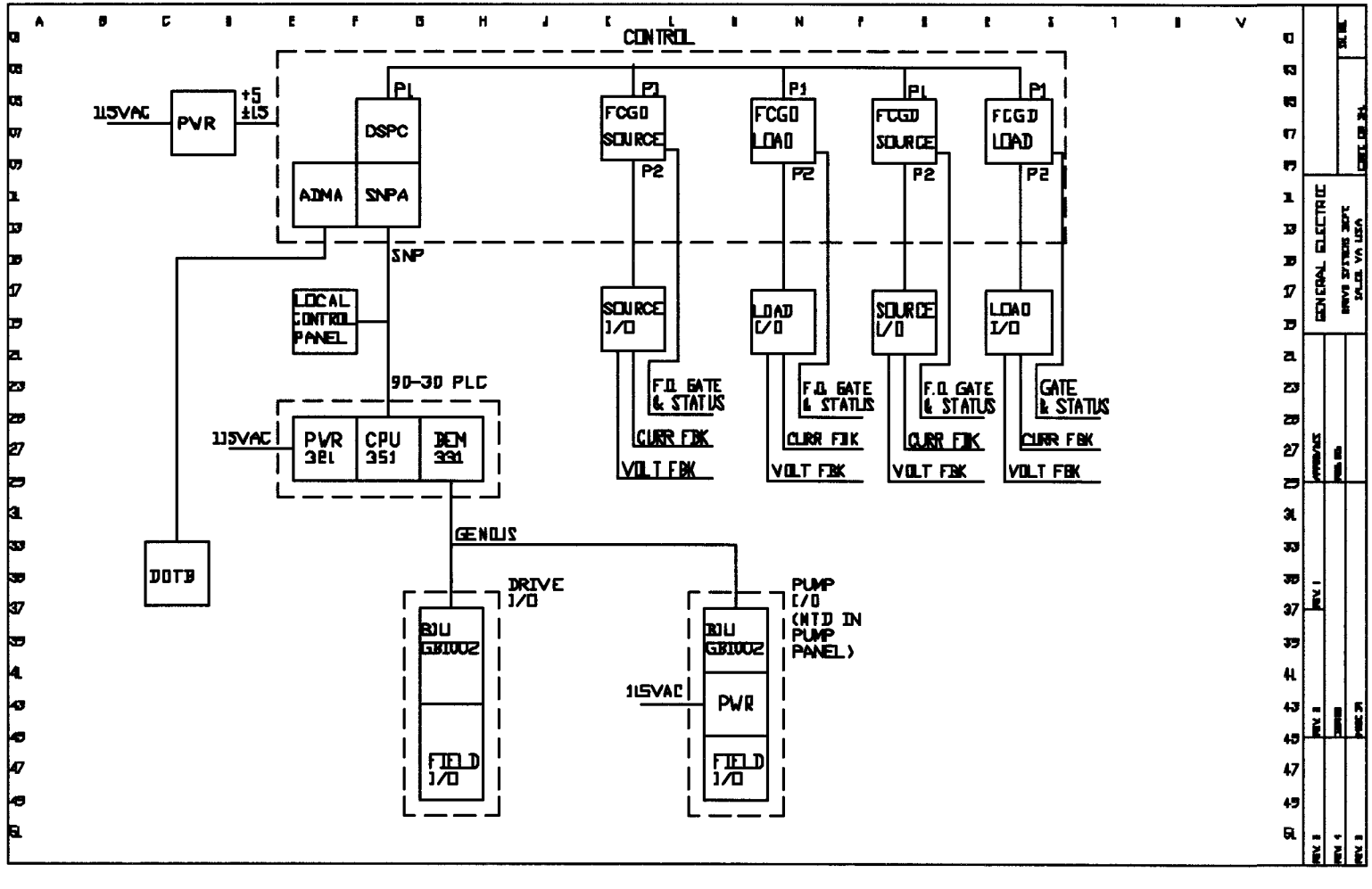
IP7_024373

Innovation LCI

GE Industrial Systems

LCI Control

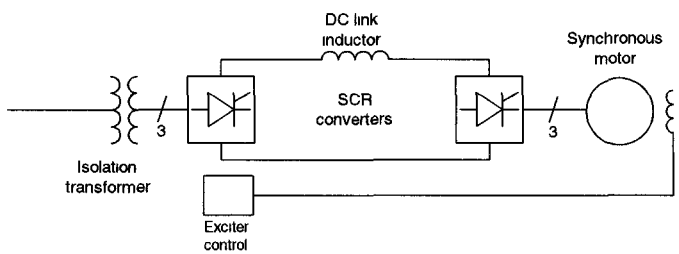
LCI CONTROL BLOCK DIAGRAM



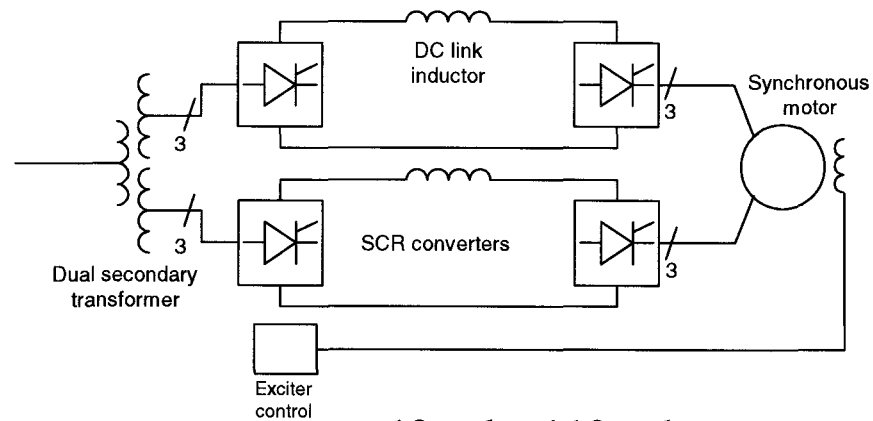
IP7_024374

System Diagrams

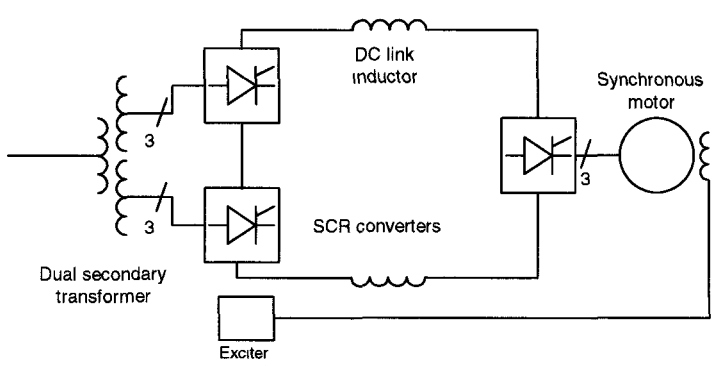
GE Industrial Systems



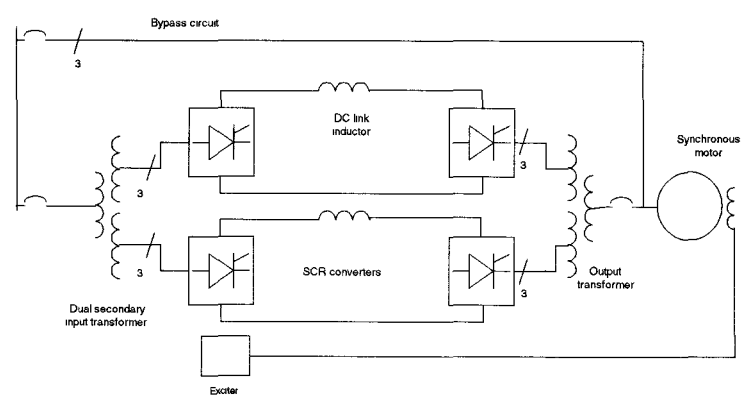
6 pulse / 6 pulse



12 pulse / 12 pulse



12 pulse / 6 pulse



12 pulse / 12 pulse
with bypass circuit

IP7_024375

LCI Models and Ratings

LCI Model	Motor voltage	Source, load config	Rating (HP)	Dimensions (mm) L-D-H [in]	Weight (lbs)
BN	2300	6-p, 6-p	7,000/6,000	4000 x 1400 x 2500 [110 x 55 x 100]	7500
BDN	2300	12-p,12-p	14,000/12,000	5600 x 1400 x 2500 [173 x 55 x 100]	9000
E6+, N	4160	6-p,6-p	19,000/16,000	5600 x 1400 x 2500 [173 x 55 x 100]	9500
E12+, N	4160	12-p,6-p	19,000/16,000	5600 x 1400 x 2500 [173 x 55 x 100]	9500

Notes:
1. In LCI model, + denotes (n+1) cells; N denotes n cells.
2. Rating is based on 40°C water or 40°C water-glycol mixture.
3. Dimensions based arrangement with pump panel and control at opposite ends of lineup. Subtract 1200 mm [47 in] from length if pump panel is placed behind control. This arrangement has no space for field exciter.

IP7_024376

Dual Channel LCI

GE Industrial Systems

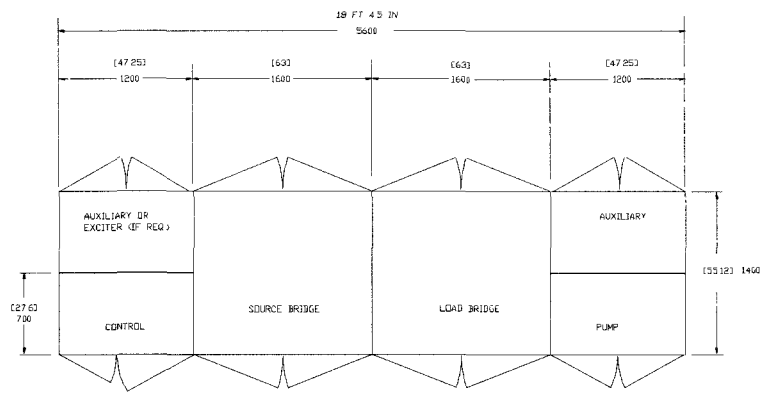
Typical outline

GENERAL ELECTRIC COMPANY

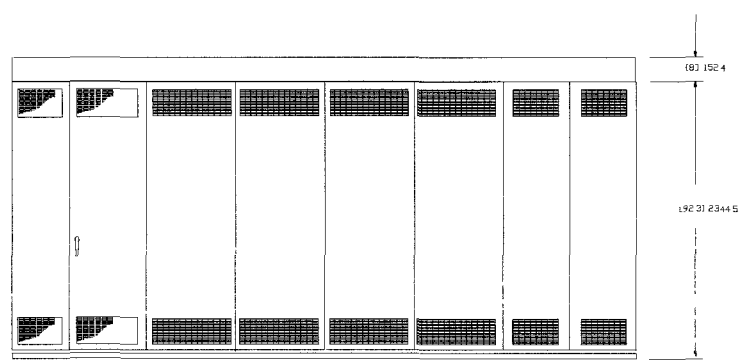
259B1430 CONT ON SHEET 3 SH NO 2

TITLE LCI LINEUP

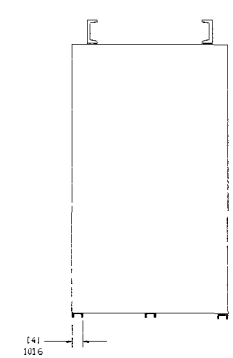
FIRST MADE FOR LCI



1 ESTIMATED WEIGHT 10,000 lbs. (4536 Kg.)
2 LIFTING BEAMS ARE REMOVABLE AFTER INSTALLATION
3 HEAT EXCHANGER TO BE MOUNTED REMOTELY.
4 DC LINK REACTOR TO BE MOUNTED REMOTELY
5 ALL DIMENSIONS IN MILLIMETERS
[ ] = DIMENSIONS IN INCHES



FRONT VIEW



RIGHT SIDE VIEW

REVISIONS		
9-2-97 JWC Changed control door size	1	

DRAWN BY	C HYLTON
MADE BY	R.L. ASHWORTH
ISSUED	1/24/97

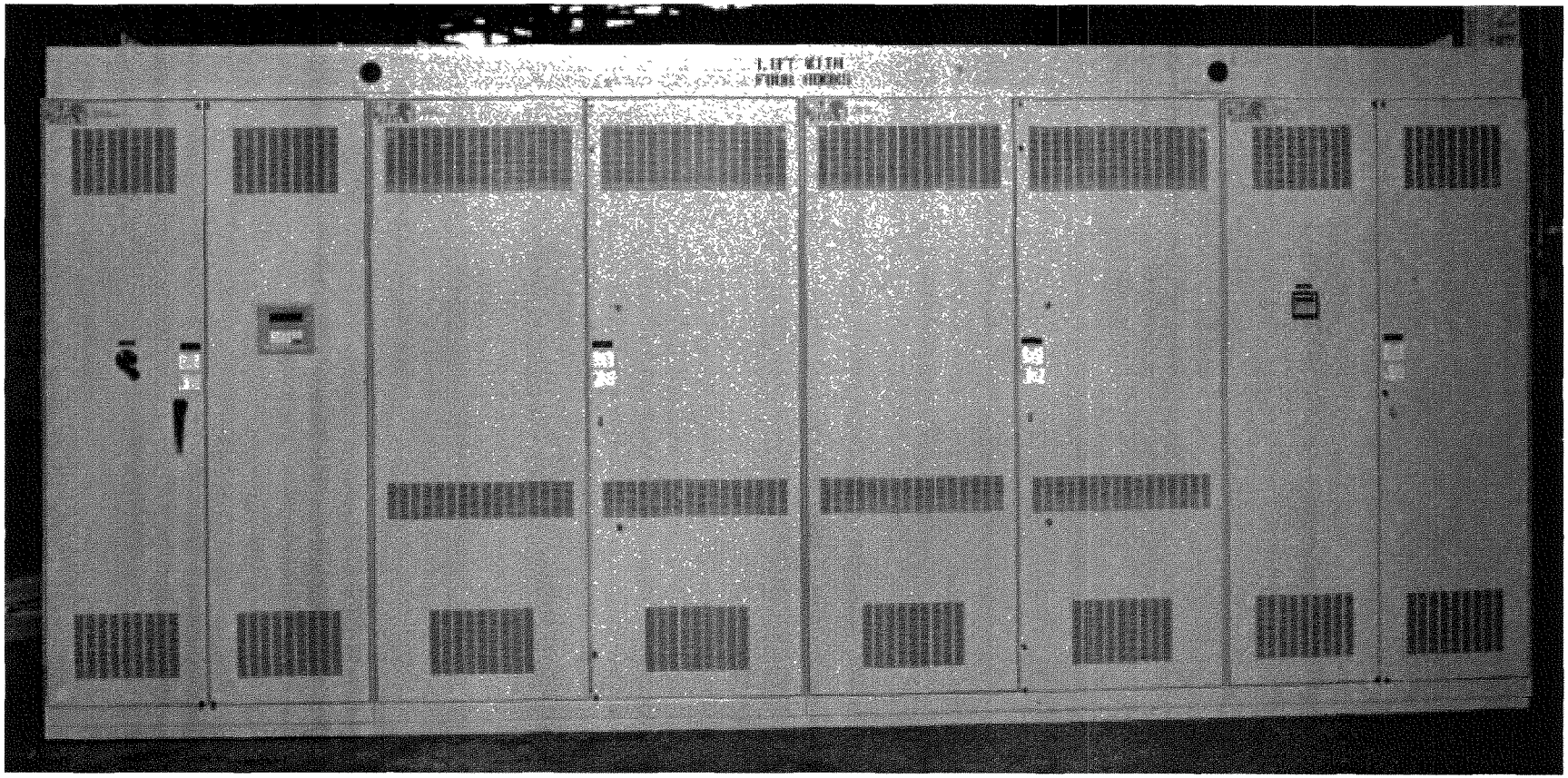
GE DRIVE SYSTEMS SALEM, VA.

259B1430 CONT ON SHEET 3 SH NO 2

IP7_024377

LCI Lineup

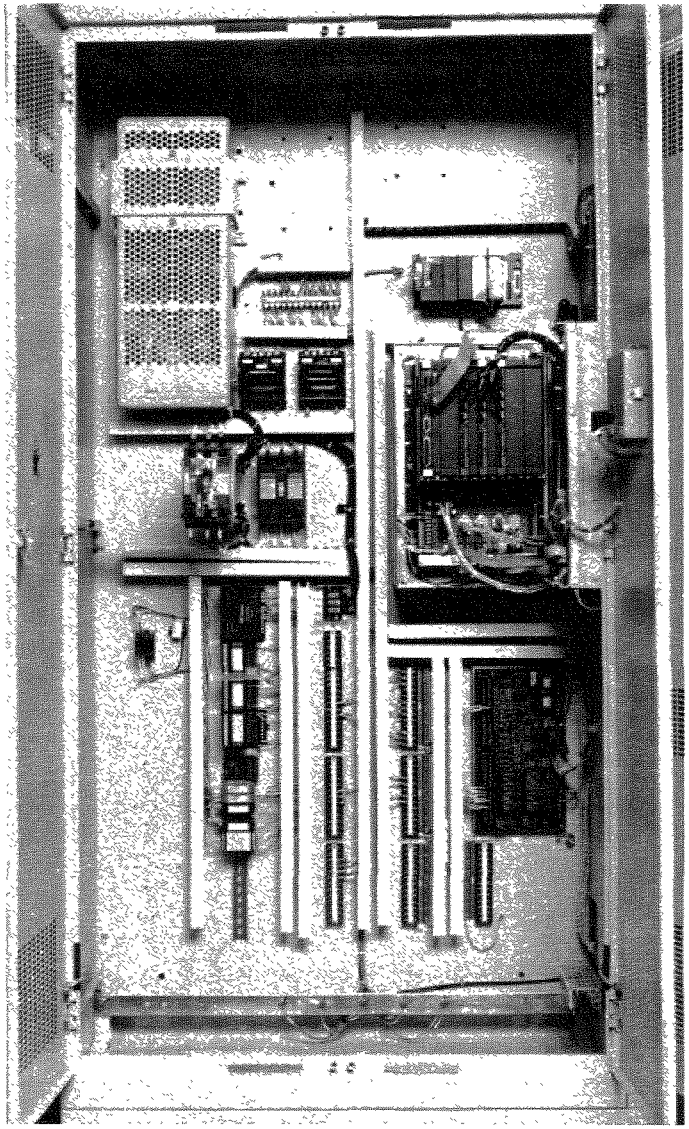
GE Industrial Systems



IP7_024378

LCI Control Panel

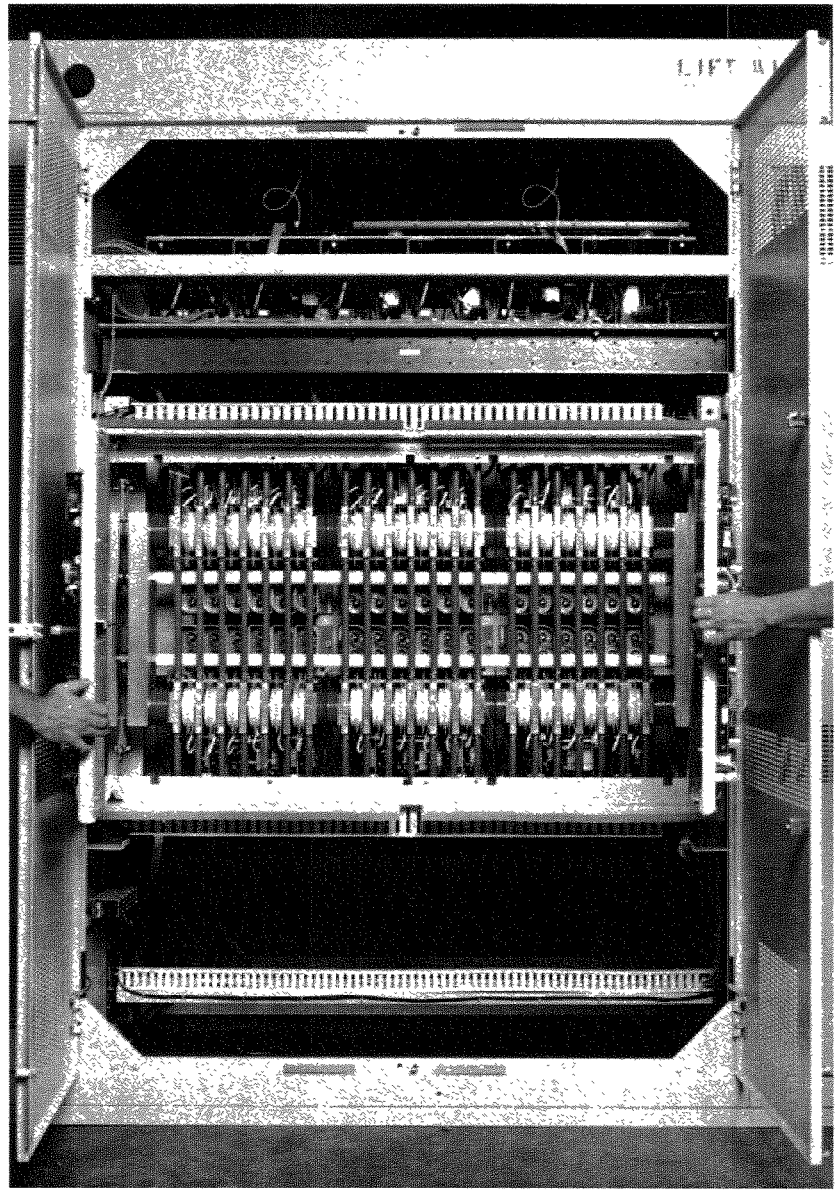
GE Industrial Systems



IP7_024379

LCI Source Converter

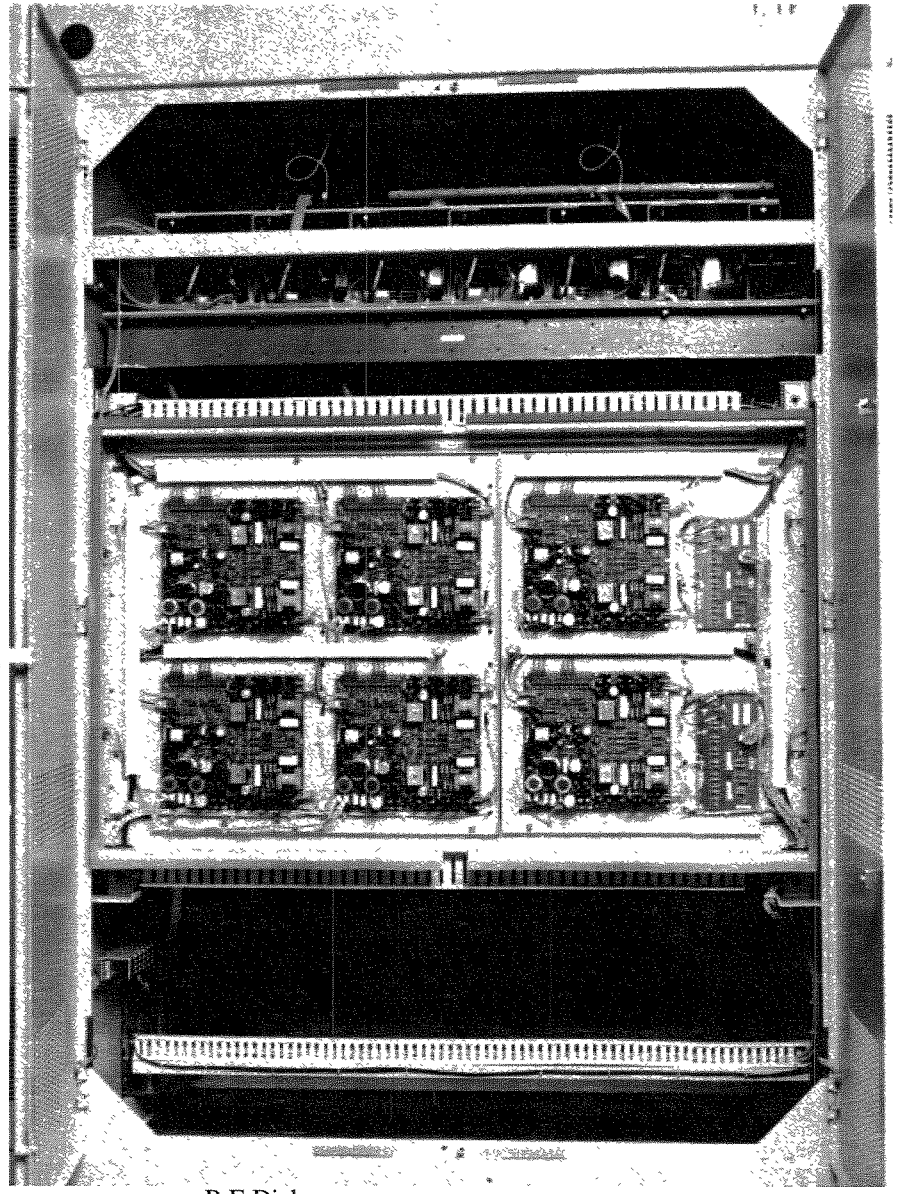
GE Industrial Systems



IP7_024380

LCI Load Converter

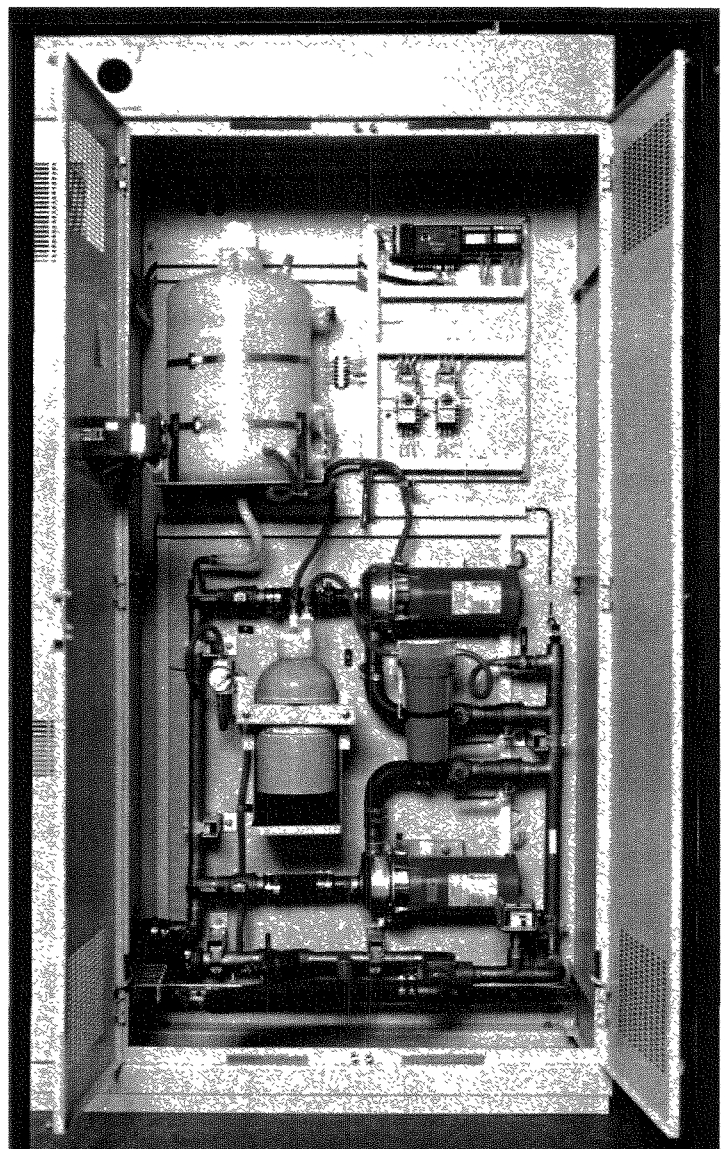
GE Industrial Systems



IP7_024381

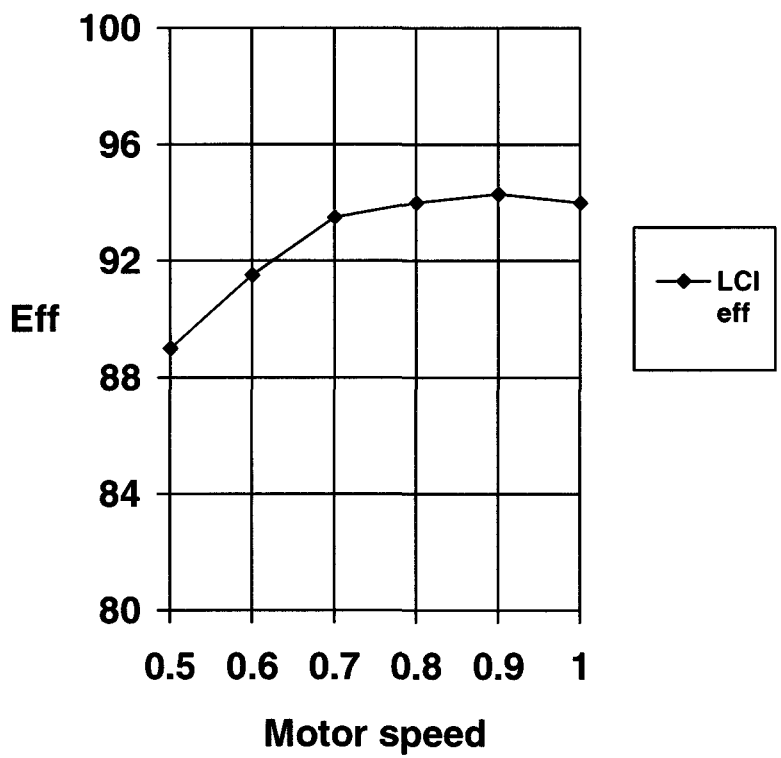
LCI Pump Panel

GE Industrial Systems



IP7_024382

LCI system efficiency



- Typical *system* efficiency
  - includes motor and transformer
  - variable torque loads

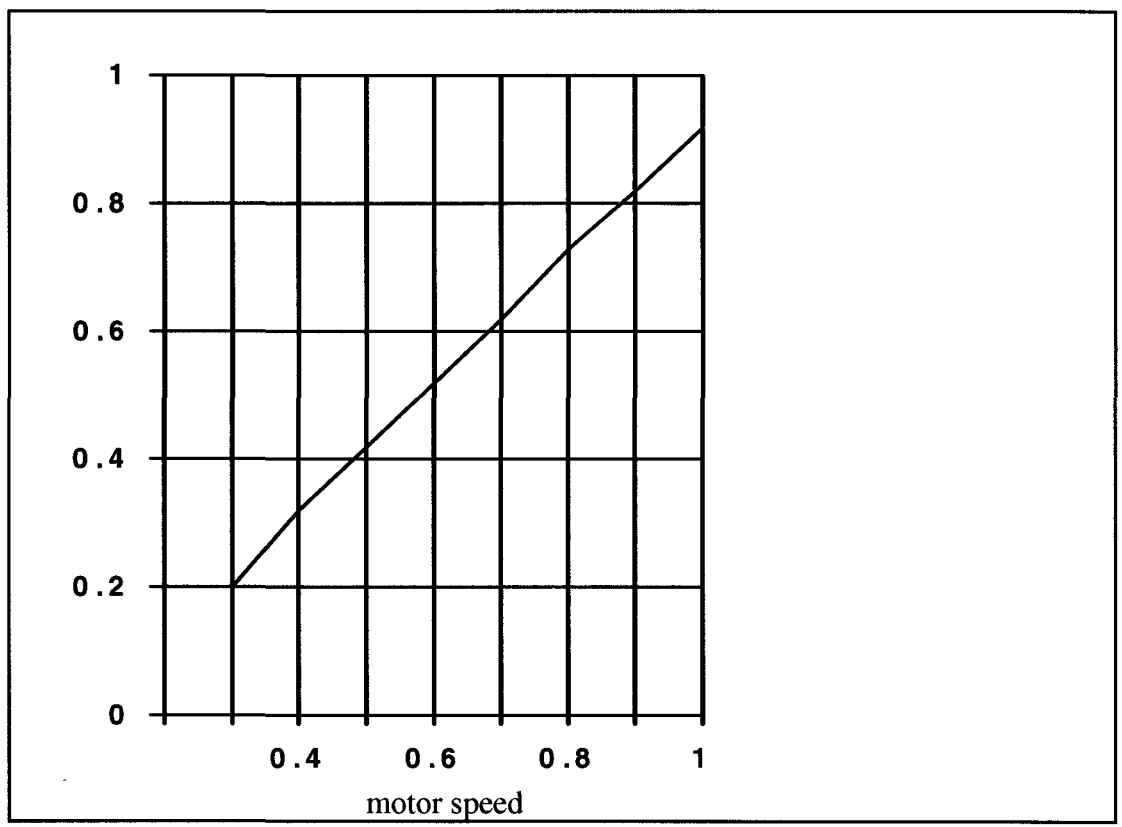
IP7_024383

LCI Power Factor

- SCR rectifier draws lagging VARs under all operating conditions
- Constant torque loads may require compensation, unless operated over a small speed range
- Every application is unique

IP7_024384

LCI Power factor



IP7_024385

LCI Harmonics

- Harmonic reduction with transformer connections
  - 12 pulse instead of 6 pulse harmonics
  - Near elimination of 5th and 7th harmonics
  - Achieved with delta-delta and delta-wye windings
- Harmonic filters
  - Also provide reactive compensation
  - Tuned filters or high pass type filters can be used
  - Design on a small, isolated power system is critical
  - Flicker due to notching can be reduced with right filter
  - A filter large enough to provide reactive compensation will usually filter harmonics very well

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TOSHIBA GE

GE TOSHIBA AUTOMATION SYSTEMS

1501 ROANOKE BOULEVARD, SALEM VA 24153

The GE Toshiba Innovation Series
LOAD COMMUTATED INVERTER (LCI) SYSTEM
Product Description

I. Introduction

The LCI is an ac adjustable-speed drive used to control the speed of synchronous machines (motor or generator. The drive consists of static power conversion and microprocessor-based control equipment. The LCI is available in bridge configurations to deliver a variety 6 and 12 pulse combinations for different applications and power requirements. The basic LCI is a 6-pulse drive configuration that consists of two functional sections: a **power converter** assembly and a **control** assembly. Figure 1 is a simplified one-line diagram of a typical single channel LCI showing major components.

The synchronous motor field is usually excited by a brushless exciter coupled to the motor shaft. The brushless exciter is a wound rotor induction motor. Its rotor voltage is rectified to supply field current to the synchronous motor. The LCI control panel includes a **static excitation voltage controller** to supply stator voltage for the brushless exciter. The LCI's electronic **control** module gates/controls this voltage controller. Thus it controls the excitation to produce the required machine flux. It also provides field over/ undercurrent protection. For applications with slip-ring excitation, the LCI control supports the option of operating an external exciter bridge.

II. Power Converter

The LCI power converter is made up of a **rectifier** that feeds an **inverter** through a **dc link reactor**. A **transformer** isolates the LCI from the ac system bus and provides the correct voltage at the LCI's rectifier terminals. Additionally, the transformer's internal impedance limits the magnitude of any bus faults. The **rectifier** is a line commutated, phase-controlled thyristor bridge that functions as a **source** converter. Its microprocessor-controlled gating produces a variable dc voltage output to the **dc link reactor.** The reactor smoothes the current and keeps it continuous over the system's operating range. The reactor output is fed to the **inverter**, which is a load commutated thyristor bridge. The inverter is also microprocessor-controlled and functions as a **load** converter. The inverter produces a variable frequency ac output to a **synchronous motor**'s stator terminals.

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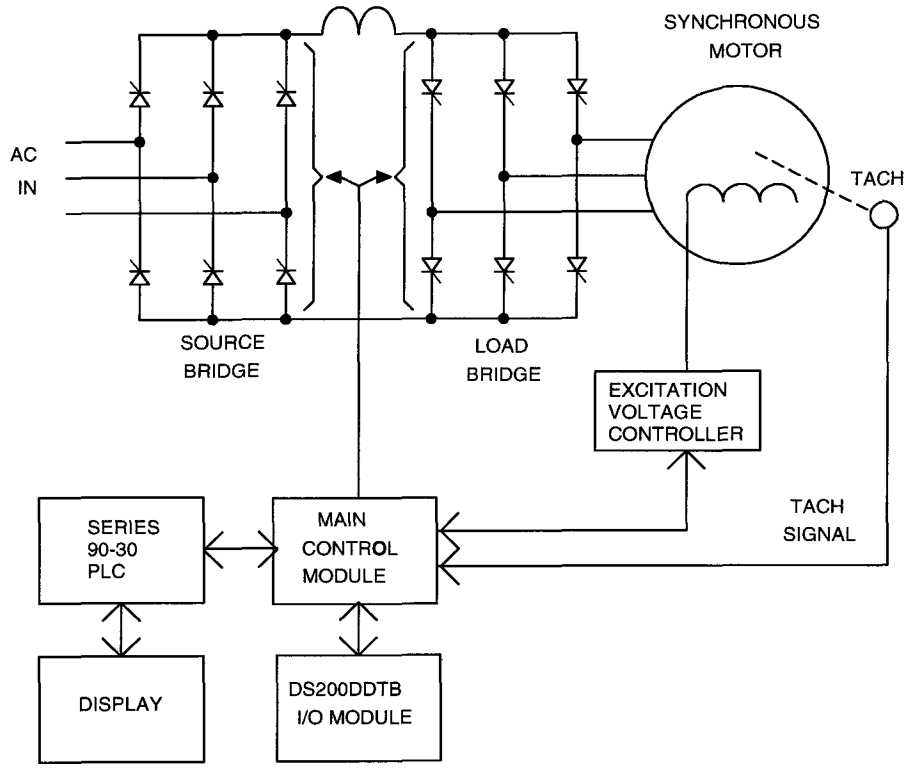

Figure 1: LCI Components

III. Operating Parameters

A. Ratings

VOLTS	PULSES Source	PULSES Load	DIMENSIONS meters W X D X H			WEIGHT	kW @ 50°C 50% Antifreeze	kW @ 35°C
2300	6	6	4.0	1.4	2.3	4400	5000	5250
2300	12	12	5.6	1.4	2.3	7400	10000	10500
4160	6	6	5.6	1.4	2.3	7400	12000	14200
4160	12	6	5.6	1.4	2.3	7400	12000	14200

For 2300 volt applications requiring a 12-pulse dual channel LCI configuration, an effective single line up is offered that has a single control and cooling system.

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B. Basic Design Type

Design Feature	*Type/Value*
Power thyristors	Silicon-controlled rectifiers
Line supply unit	6-pulse or series 12-pulse bridge
Bridge construction	Heatsink/SCR dual-stack
Cooling	Liquid cooling loop
Supply voltage:	
6-pulse converter	2300, 4160, or 6600 V ac
12-pulse converter	2080 or 3300 V ac each
Supply frequency	50 or 60 Hz
Supply phase	3-phase
Output voltage	0 – 2300, 4160, or 6600 V ac *{future}*

C. Control Features:

- Forced Commutation Below 10% of Rated Speed.
- Load Commutation Above 10% of Rated Speed.
- Torque Regulated Speed Control.
- Volts / Hz Control.
- Field Excitation Control
- 10-160% of Rated Speed Control Range.
- 3 Programmable Acceleration / Deceleration Ramps (Max Rate of 10% / Sec)
- Smooth Reversal of Motor Rotation Through Zero Speed.
- Full four-quandraunt operation
- Two Speed regulator settings for adjustment during operation
- Logic is provided to prevent operating in the reverse direction

D. Regulation:

	No Tachometer	Tachometer
Max Starting Torque (From Standstill)	.75 PU	2.0 PU
Max Forward Speed	1.0 PU	1.0 PU
Max Reverse Speed	0.5 PU	1.0 PU
Constant Horsepower Speed Range	Base to Top	Base to Top
Constant Torque Speed Range	0.1 PU to Base	1.5-Hz to Base

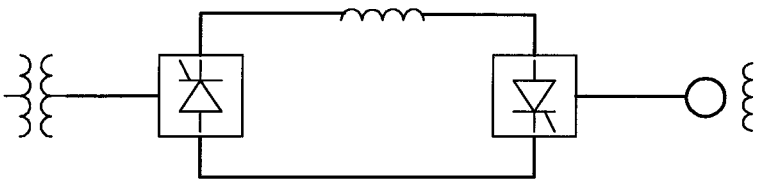
Steady state speed regulation: @ 0.1% of rated maximum speed without tach
Steady state speed regulation: @ 0.01% of rated maximum speed with tach

Impact Loading

- Below Base Speed 1.0 PU Torque / Sec 3.0 PU Torque / Sec
- Above Base Speed 0.5 PU HP / Sec 1.5 PU HP / Sec

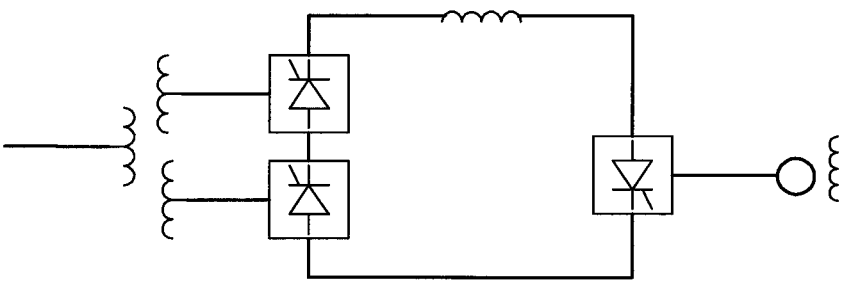
E. System Configurations:

The LCI base configuration is a 6 pulse source and load bridge arrangement.



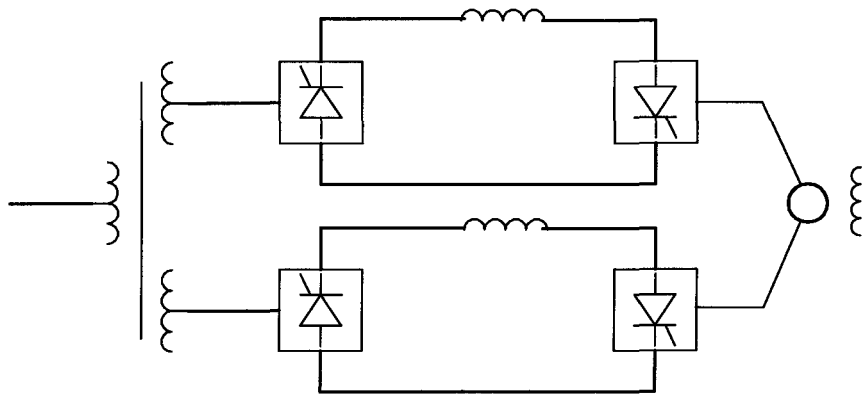
6 PULSE / 6 PULSE (E6, F6)

A 12 Pulse Source Inverter can be supplied with a 6 Pulse Load Inverter using a common control.



12 PULSE / 6 PULSE (E12)

Full twelve-pulse operation is like two identical separate 6-pulse drives operating from a common source at the same firing angle, with the firing reference angles shifted by 30 degrees by the isolation transformer. The configuration allows two motor to combined into one frame. The Twelve-Pulse construction uses a common magnetic frame and a common field.



12 PULSE / 12 PULSE (BD)

IV. Codes and Standards

The drive is designed and manufactured to be in accordance with UL508C, IEC 146-1-2 and NEMA ICS 7-1993 standards where applicable. CSA (C22.2) and CE certification are available for select applications. Consult your local Factory Representative for availability for your particular requirements.

Occupational Safety and Health Administration (OSHA) regulations require the employer to provide a place of employment free from recognized hazards. OSHA standards include requirements of the National Electric Code. Ultimate compliance with OSHA and other interpretive codes remains the responsibility of the user.

V. Service Conditions

The equipment is designed for operation in utility and industrial environments under the following conditions:

A. Temperature

Indoor equipment is designed to be installed in a relatively clean, dry environment with an ambient temperature range of 0⑤C to 50⑤C with a relative humidity of 95% maximum, non-condensing.

- Maximum transient thermal changes of ⑥ 5⑤C per minutes.
- Maximum linear ⑥ 15⑤C per hour changes.
- Outdoor equipment is designed for an ambient temperature range of -25⑤C to 50⑤C with a relative humidity of 95% maximum.
- All equipment is designed for a non-operating (storage) temperature range of -25⑤C to 70⑤C.

B. Elevation

- 3300 feet above mean sea level maximum.
- Higher elevations can be accommodated by derating the drive.

C. Vibration

The equipment has been designed for operation when subjected to the following vibration:

Vertical Axis:

- Single amplitude vibration displacement profile from 10 mils at 16 Hz to 1 mil at 50 Hz corresponding to a constant level of 0.25 G.
- Constant single amplitude vibration displacement of 10 mils between the frequencies of 4 to 15 Hz corresponding to G loads from 0.02 G to 0.25 G.

Transverse Axis:

- One-half of vertical axis displacement

D. Seismic

The equipment has been designed to be capable of meeting the Common Building Code Seismic Zone IV requirements.

VI. AC Power Source

A. Input Power

- Maximum steady state voltage variation ⑥10%
- System frequency 5060 hertz with maximum permissible deviation of ⑥5%
- Maximum phase unbalance ⑥2%

The LCI will operate at reduced torque with momentary bus voltages of 70%-90%. Below 70% bus voltage, the motor will be allowed to coast. If bus voltage is restored within an adjustable time of 1 to 5 seconds the system will automatically shut down and trip the source breaker A. manual operator reset of the drive and source breaker is required before starting.

B. Auxiliary Power

Required 380/460 Vac ⑥10%, 3 phase, 50/60 Hertz ⑥1% preferred source by the Buyer. The KVA required is dependent on the size drive supplied but can be approximated by the following:

As available options, the following auxiliary power can be used.

- 460VAC ⑥10%. 3 phase, 60 Hz ⑥1%
- 230VAC ⑥10%. 3 phase, 60 Hz ⑥1%
- 120VAC ⑥10%, 1 phase, 60 Hz ⑥1% for control only.
- 380VAC ⑥10%, 3 phase, 50 Hz ⑥ 1%
- 120VAC ⑥ 10%, 1 phase, 50Hz ⑥ 1% for control only

Specific component power requirements are,

- Control power, 2kVA, 1 phase
- Auxiliary power, 5kVA - 12kVA, 3 phase
- Field exciter, 30kVA to 60kVA 3 phase

The drive will continue to operate when control power is interrupted by a disturbance not exceeding 8 milliseconds. If longer disturbances are expected, a UPS can be supplied with the drive.

VII. Drive Controller

The control hardware consists of the main control module, firing control and bridge interface boards.

A. Main Controller

The main control module is made up of printed wiring boards in a VME rack. These boards contain programmable microprocessors with companion circuits, and the LCI software. This module connects with the control panel I/O terminal board, the exciter voltage controller, and the user interfaces.

Module connections are made through plugs located at the board front connectors. Fiber-optic cables connect to the power converter bridge. The module requires +5, ±15, and 24 V dc, which are provided by a base-mounted power supply. The main control panel contains a module of boards built into a VME rack plus an auxiliary I/O board. Additional boards in the power converter panel provide interface functions for the power conversion.

B. Programable Logic Controller

There are two options available for the LCI control architecture: either the Series 90-30 Programmable Logic Controller (PLC) or the UC2000V Unit Controller.

The PLC-based LCI configures its bridge control hardware and software in a VME rack mounted in its **control cabinet**. This configuration requires only free-convection cooling up to 50 °C (122 °F) ambient.

The UC2000V-based LCI differs from the PLC-based version in two ways:

- It adds the UCVA processor board to replace the PLC
- It eliminates the SNPA daughterboard

This configuration is used for higher performance applications that require a faster data flow as seen in coordinated drive applications like Rod and Bar Mills. The DSPC remains the VME bus master, controlling up to five power bridges. The AFE Datapanel display option is not available with the UC2000V-based LCI.

C. User Interfaces

The LCI includes three user interfaces that connect to the control:

- Programmable Logic Controller (PLC, GE Fanuc Series 90™-30)
- Diagnostic/display module (AFE Datapanel Model K)
- Serial Communications Monitor terminal

The PLC is used to customize I/O, sequencing, and speed references per application requirements. It connects to the LCI control through the Series 90 Protocol (SNP) serial link.

The AFE Datapanel display is a local interface, typically mounted on the control panel door and connected to the PLC. It allows the user to display and modify regulator and logic variables and regulator constants.

The serial communications Monitor is an operator interface program for reading and modifying the LCI's tuneup values and diagnostic tests. It is accessed by connecting a compatible display/terminal to the LCI control.

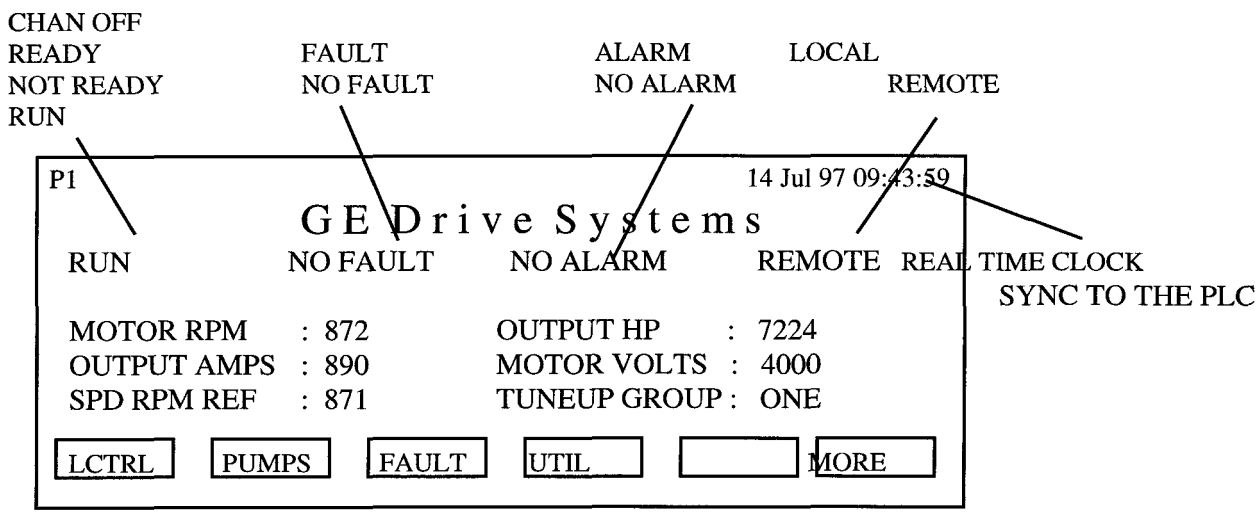
Panel mounted meters and manual switches are available as options.

D. Local Control Panel

The Datapanel allows the operator to interface with the drive. The interface includes controlling the pump panel, viewing faults and alarms, resetting faults and alarms, real time motor values, and local/remote drive control.

MAIN SCREEN

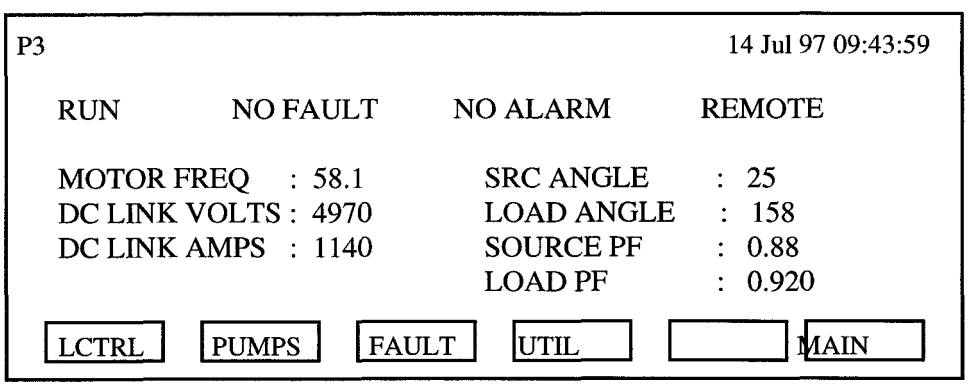
The main screen appears on power-up or can be reached from other screens by pressing the "MAIN" function key



MAIN AFE SCREEN (TYPICAL)

The main screen displays drive status (CHANNEL OFF, READY, NOT READY or RUN), fault status (FAULT or NO FAULTS), alarm status (ALARM or NO ALARM) and control status (REMOTE or LOCAL). Real time quantities are updated once per second for rpm, amps, speed reference, horse power (or KW) and motor volts. The software tune-up group (ONE, TWO, THREE or FOUR) currently used is also displayed.

Additional real time information is provided on the second Main Screen page.



MAIN AFE SCREEN (second page)

The second page of the main screen displays additional real time quantities such as: motor frequency, dc link volts, dc link amps, source firing angle, load firing angle, source power factor and load power factor.

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LOCAL CONTROL

Local control allows the operator to start/stop and control the speed of the LCI using the AFE datapanel.

The six function keys in the main local control screen perform the following functions:

ONOFF : Channel on/off, active in local or remote mode will stop the LCI from running.
LC/RM : Toggles between local and remote mode, this function may not be allowed while the drive is running.
START : Active only in local mode, used to start the LCI.
STOP : Active only in local mode, used to stop the LCI.
MORE : Additional local control functions.
EXIT : Returns user to main screen.
RAISE : Active in local mode only, will raise speed in 5 RPM increments.
LOWER : Active in local mode only, will lower speed in 5 RPM increments
START : Active in local mode only, will start the LCI.
STOP : Active in local mode only, will stop the LCI.
SETREF : Active in local mode only, allows setting the RPM reference with the datapanel keypad.
BACK : Returns user to main page of the local control screens.

When transiting from remote to local the datapanel will preset the local speed reference to the actual RPM of the motor.

PUMP CONTROL

Pump control allows the operator to select the lead pump, lead blower and view the coolant system status. The three keys in the pump panel control screen perform the following functions:

PUMP : Toggles the lead pump between one and two.
BLWR : Toggles the lead blower between one and two.
MAIN : Returns datapanel to the main menu.

ALARM & FAULT SCREENS

The alarm and fault screens allows the operator to view all active alarm and faults. The fault/alarm main menu displays the time the first fault or alarm occurred.

DETAIL FAULT INFORMATION

Some fault screens have a detail option which gives more information on the indicated fault.

VIII. Faults and Alarms

A. Introduction

All drive fault and alarm conditions are displayed on the drive control data panel. The following sections lists these faults and alarms along with a brief explanation.

In the event of a fault condition, the LCI will shut down and a fault diagnostic message will appear on the data panel located on the control panel door. If more than one fault occurs the first fault will be indicated with the flashing letters "FLT" preceding the diagnostic message.

Alarm conditions will not shut down the LCI but may indicate a pending problem which requires action.

The time at which the first fault and/or alarm occurred is displayed on the main fault/alarm screen. To reset the control after a fault or alarm condition, the user must first view all alarm and fault diagnostic messages. Once all the messages have been viewed the "reset" button on the data panel will become active and the user may reset the alarm/faults.

Consult the system elementary ladder diagram for a complete list of faults and alarms. Most of the faults are standard and are defined in the following paragraphs, along with suggested corrective action. Some fault messages have a detail option which gives more information on the indicated fault.

B. Alarms:

NO FLD INPT VLTS: Indicates the source voltage to the field exciter has dropped below specified nominal value. This function will also detect single phasing of the exciter and a problem with the FCGE pll(phase lock loop).

ROTOR POS NOT FND: Indicates the control has failed to detect machine stator flux feedback after the exciter energizes the field. This means the control is unable to determine the electrical position of the machine rotor.

SHORTED CELL(S): Indicates the control has detected one or more shorted SCRs. Because of the n-1 feature, the LCI will continue to run with up to one shorted SCR in each leg.

EE POWERUP: Indicates a configuration problem has occurred in the EE prom or a change was made in the EE prom which does not become effective until the drive is re-booted.

GATE SUPPLY UV: Indicates the FGPA gate power supply monitor has detected an under voltage.

PC AC FAIL: Indicates the AC power to the VME control power supply has failed.

MTR VOLT UNBAL: Indicates an unbalance has been detected in the motor voltage feedback. The alarm threshold is adjustable with an EE prom variable..

SOURCE UNDERVLTS: Indicates a momentary dip of the source voltage to less than 70%(typical, adjustable) of nominal.

LOSS OF SPD CTRL: Indicates that speed is not following the speed reference. This usually occurs because the drive is overloaded and in current limit.

TACH FEEDBACK: Indicates the tach based drive speed does not match the flux zero crossing based drive speed.

FCGD MISOP: Indicates a problem has occurred on one of the FCGD boards or a device which communicates with the FCGD.

COOLANT TEMP: Indicates coolant water has exceeded the alarm setting, normally 155 F or the main cooling fan has failed.

COOLANT RESIST: Indicates the coolant resistivity has decreased below the alarm level setting, normally 1 meg ohm - cm

COOLANT PRESS: Indicates low differential coolant pressure across power converter bridges or loss of both pump starters.

COOLANT LEVEL: Indicates coolant is below the low level float switch in the coolant reservoir. Add coolant and check for leaks.

PCR OVERTEMP: This alarm indicates high ambient temperature in the drive control house or room. When used, the signal originates from an external thermostat.

DSPC ALARMS: Indicates the DSPC has reported an alarm. DSPC alarms include loss of field exciter input volts, rotor position not found, shorted cell, EE power up, gate supply uv, ps ac fail, motor volt unbal, source uv, loss of speed control, tach feedback nok and FCGD misops.

RUN/START PERM: This is an optional alarm indication that the run or start permissive contact supplied by the user is open.

BLOWN FILTER FUSE: Indicates that protective fuses for ac or dc bus R-C filters are blown.

TRANSFORMER NOK: Composite indication of a transformer alarm. Typical transformer alarms are over temperature, low oil level, and pressure relief.

LINK REACTOR OT: Indication of an inductor over temperature as sensed by a thermal switch in the link inductor coil(s).

4-20MA REF LOSS: Indicates that the 4-20 ma speed reference(if used) has dropped below 4ma.

MOTOR OVERTEMP: This is an optional alarm indication of motor over temperature from an externally supplied monitor.

C. Faults:

AC EXC CUR UNBAL: Indicates an unbalanced load is applied to the AC field exciter.

EXCITER OVERCUR: Indicates exciter current has exceeded the EE prom setting.

GATE SUPPLY UV: Indicates the FGPA gate power supply monitor has detected an under voltage.

SOURCE OVERCURR: Indicates an over current as detected by the source bridge CTs.

LOAD OVERCURR: Indicates an over current as detected by the load bridge LEM modules.

LOAD CUR > SRC: Indicates a misfiring of the source bridge resulting in a diametric commutation fault on the source side of the dc link.

SRC CUR > LOAD: Indicates a misfiring of the load bridge resulting in a diametric commutation fault on the load side of the dc link.

EXCITER PLL: Indicates the exciter phase lock loop has lost lock with the exciter source voltage feedback..

SOURCE PLL: Indicates the source phase lock loop has lost lock with the source voltage feedback.

LOAD PLL: Indicates the load phase lock loop has lost lock with the load voltage feedback.

DC EXC OVERVOLT: Used only in dc field exciters. Indicates the exciter output has exceeded 1.25 times Edo (Edo=maximum exciter dc volts).

HIGH SPD RESTART: This fault is normally enabled for static starters and other applications where top speed is much higher than base speed for the LCI.

FAIL TO START: For applications using a tachometer, this fault indicates rotation has not occurred 5 seconds after application of stator current.

SOURCE OVERVOLT: Indicates source voltage is excessive (EE prom setting typically set at 1.2 pu). Recheck tune up settings.

MOTOR OVERVOLT: Indicates load voltage is excessive (EE prom setting typically set at 1.2 pu). Recheck tune up settings.

MOTOR OVERSPEED: An indication of over frequency derived from the load voltage feedback. Normally set to 1.05 pu of maximum drive frequency.

DDTB HRDWRE JUMP: Indicates the hardware has detected opening of the DDTB hardware jumper.

FCGD KILL GATING: If any one of the FCGD or FCGE watchdog timer (8 ms) times out the FCGD(E) will stop its gating and open the source or load contactor.

M/S CURRENT UNBAL: On drives with a series 12 pulse source, this fault indicates an unbalance between the source bridge currents.

FIELD LOSS: Indicates exciter current has fallen below the EE prom setting for field loss.

GROUND FAULT: Indicates a ground somewhere between (and including) the source isolation transformer and the ac output busses including the motor.

ADMA A/D NOT OK: Indicates a failure on the ADMA daughter board mounted on the DSPC or a failure of the ADMA to communicate with the DDTB.

FCGD FIRE FAULT: Indicates there is an overflow of the pending register usage on one of the FCGD or the FCGE board.

SHORTED CELL(S): Indicates the control has detected more than one shorted SCRs in a SCR leg.

DSPC MISOP: Indicates the DSPC has reported a fault.

HARDWARE FAULT: Indicates one of the FCGDs or FCGE has reported a hardware fault.

COOLANT TEMPER: Indicates coolant water has exceeded the fault setting, normally 170 F or both cooling fans have failed.

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COOLANT RESIST: Indicates the coolant resistivity has decreased below the fault level setting, normally 0.2 meg ohm - cm.

COOLANT PRESS: Indicates low differential coolant pressure across power converter bridges or loss of both pump starters for an extended period of time (adjustable with EE prom set point).

COOLANT LEVEL: Indicates coolant is below the low - low level float switch or above the high level float switch in the coolant reservoir.

SOURCE UNDERVOLT: Indicates the source voltage has dropped below the uv set point for an excessive period of time.

LOAD ISOLATOR: In the case where an output isolator is supplied and controlled by the drive, this fault indicates that the isolator has failed to close after having been commanded to do so.

DSPC FAULTS: Indicates the DSPC has reported a fault.

START FAULT: Indicates the LCI has taken an excessive time to reach self commutated mode (mode 4) during start up.

FILTER FUSE: Indicates that protective fuses for ac or dc bus R-C filters are blown.

TACH FEEDBACK: Indicates a failure has occurred in the motor tachometer (if used).

FCGD MISOPERATION: Indicates a problem has occurred on one of the FCGD boards or a device which communicates with the FCGD.

EXCITER MISOP: Indicates a problem has occurred on the FCGE board or a device which communicates with the FCGE.

IX. Drive Monitor

A. Introduction

Access to tuneup values and diagnostic test is accomplished through a serial communitication monitor. It is designed to be run on a simple terminal, like a ASCII terminal or common emulator on a personal computer with ANSI support. The Monitor program resides in memory on the LCI's DS200DSPC board. It is accessed by connecting board's serial communications port to the operator terminal.

B. Monitor Functions

The LCI Monitor provides the following functions:

HELP: On-line Help

TABLE DISPLAY: Data table configuration utility

PEEK/POKE: Allows examination and changing memory contents

CAPTURE: Support diagnostics by storing data based on selected features

ANALOG OUTPUT: Contains six voltage output D/A converters for diagnostics display

FLASH MEMORY: The DSPC board contains Flash memory for non-volatile program storage. Also used to upload
contents of flash memory to the Monitor port.

PRODUCT SPECIFIC: The standard set of functions are extended to invoke custom test functions.

The Monitor provides the following Test modes:

TEST MODE TERMINATE: Used to halt test in progress

SIMULATOR: Embedded simulations are used to test system without drive operation

CROW BAR TEST: Makes the source bridge regulate dc link current through a diametrics (gate shorted) on the load bridge. Test the power bridges without applying power to motor.

GATE TESTEITHER gates celss in sequence, or gates a given cell string periodically.

CELL STATUS: Monitors the conduction status of each SCR in all primary power bridges.

EXCITER ONLY: Operate the integrated exciter with the source and load bridges turned off.

HARDWARE OVERCURRENT: Confirms operation of the protective function on each FCGD board

BRIDGE ALPHA: Tests open loop commands the bridge firing alpha angle

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SPEED LOOP: Allows regulator testing by injecting square wave reference into existing speed reference.

CURRENT LOOP: Allows regulator testing by injecting square wave reference into existing current reference.

FLUX LOOP: Allows regulator testing by injecting square wave reference into existing flux reference.

C. Tune-Up

Having a digital control system permits fast field tune-up by allowing regulator gains and time constants to be changed by changing a variable in memory. Software tune-up constants that may be changed include:

- Current regulator
- Speed regulator
- Flux regulator
- Field current
- System protection
- Speed ramps
- Scaling factors
- Data logging list

D. Diagnostics

Initialization

Upon application of power to the drive the following checks are performed to prevent an abnormal microprocessor condition, and to prevent improper drive operation.

- CPU test
- PROM check sum
- RAM test
- Writing/ reading to each board on the microprocessor bus

Extended Self Diagnostics

The control is designed with extensive test features which are able to isolate problems to a replaceable unit. All bridge control boards feature loop-back test capability which allows the processor to test the board operation without requiring motor operation. All cables are monitored for continuity.

All thyristors are individually monitored for proper conduction status. In drives with redundant thyristors this allows safe operation of the drive to continue with one or more shorted devices until maintenance is performed.

The control is capable of running a test on the entire drive where current is circulated through the bridges but bypasses the motor, allowing proof of drive readiness without requiring power on the motor.

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X. Communication

The use of a standard PLC provides for a wealth of drive communications options which include,

- Ethernet,
- DLAN+,
- Genius Bus,
- SNP,
- Modbus,
- Interbus-S,.

The Field I/O modules offer a DIN rail mounted expandable I/O system to handle application specific interface needs.

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XI. Cooling System

The drive uses a liquid coolant to transfer heat from heat producing devices (such as SCRs and high wattage resistors) to a remote heat exchanger. The cooling system is a closed-loop system with a covered reservoir for makeup coolant (see Figures 3). Coolant circulates from the pump discharge, to the heat exchanger, to the power conversion bridges, and returns to the pump. A portion of the coolant bypasses to a deionizer system to maintain the coolant resistivity.

The cooling system has the following features:

- Self-venting, closed-loop cooling system using a water/propylene glycol mixture
- Full-capacity coolant circulation pump
- Redundant circulation pumps with automatic changeover and isolation valves for maintenance
- Full capacity heat exchanger, either remote liquid-to-liquid or liquid-to-air with cooling blower and optional redundant heat exchanger blowers with automatic changeover
- Purity alarm monitor with digital resistance and temperature display and contacts for alarm and trip
- Translucent coolant storage reservoir with cover and contacts for overflow alarm, low-level alarm and low-level trip
- Deionizer system with isolation valve for maintenance
- Differential pressure switch across bridge
- Temperature switch
- Drain valves
- Temperature-regulating valve
- Deionized Water Cooling Media: 50°C Max Inlet Water Cooling Temperature (Water to Water Heat Exchanger)
- Operating Ambient Air Temperature Range (0-50°C with 95% Max Relative Humidity, Non-Condensing)
- Optional Addition of Antifreeze (Requires Derating Drive)

A. Coolant

The drive's normal operating environment temperature ranges from 0 to +50 °C (32 to 104 °F). The coolant is a water/propylene glycol mixture that prevents freezing with lower outside ambient temperatures. The system should initially be charged with a mixture of distilled, de-mineralized, or deionized water and pure propylene glycol. Makeup coolant must be a similar mixture to maintain the desired freeze protection. Although both materials are approved for use, propylene glycol is superior to ethylene glycol because of higher electrical resistance and longer de-ionizer life. Contamination caused by mixing these two fluids is of minor consequence, but a residual of no more than 10% ethylene glycol and water solution should be the goal when changing over to propylene glycol.

B. Coolant Circulation System

Redundant pumps circulate the coolant. The differential pressure switch and interlocking pump motor starters provide automatic transfer to the backup pump at 7 psi. Normal differential pressure is 15 to 40 psi. Isolation valves allow the pumps to be changed online without draining the system.

The liquid-to-air heat exchanger option includes redundant cooling blowers. A coolant temperature switch and interlocking blower motor starters provide automatic transfer to the backup blower. A liquid-to-liquid heat exchanger for remote mounting may be supplied as an option. This option does not use cooling blowers. The circulating system is self-venting. During normal operation, it does not require air venting or purging. The outlet side of the power conversion bridge contains a manual vent.

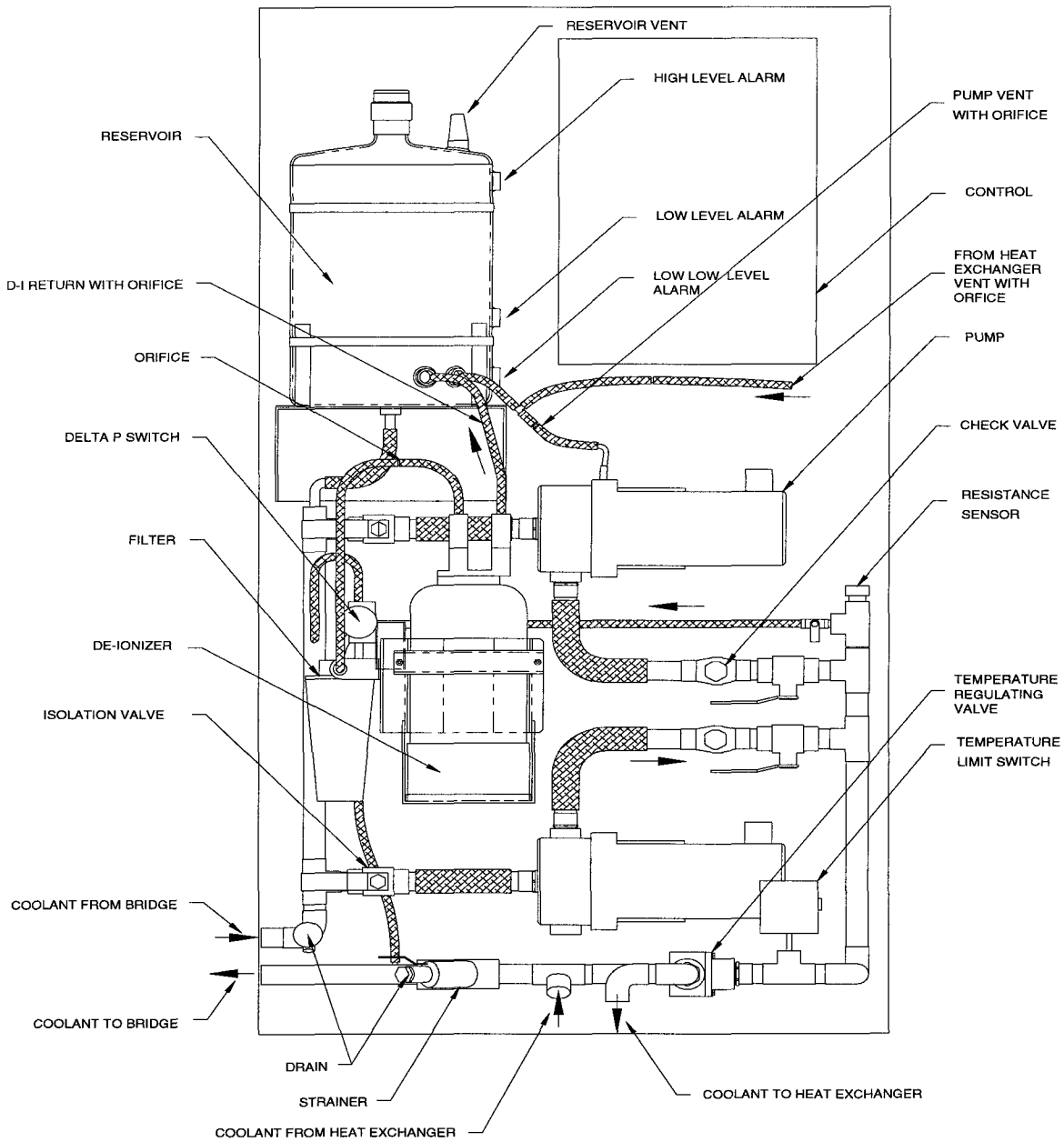


Figure 3. Liquid Cooling System for LCI

C. Coolant Temperature

A temperature regulating valve similar to an automotive engine thermostat controls coolant temperature entering the bridge to a minimum of 27 °C (80 °F) within an 10 °C (18 °F) band. If there is no bridge dissipation, this temperature may be lower. If outside ambient or cooling service water temperature is higher, then the coolant temperature will rise above 27 °C.

When a liquid-to-liquid heat exchanger is used, a Robertshaw valve may be installed in the heat exchanger service water inlet line with a sensing bulb in the drive coolant line. This serves the additional function of conserving cooling water.

IP7_024403

D. Standard Heat Exchanger Elevation

The heat exchanger is normally mounted with its base at or below the elevation of the drive.

E. Elevation Limit

The heat exchanger can be mounted higher than the drive, including on the roof above the drive. The limitation is the reservoir vent that must be above the elevation of the highest point in the cooling system.. The elevation should be kept to a minimum. In no case can the top of the heat exchanger or any other piping be higher than 26 feet above the base of the drive (about 20 feet above the reservoir).
Heat exchanger performance is reduced above 5000 ft. altitude and requires a special design.

F. Liquid-to-Air Heat Exchanger Option

Do not obstruct heat exchanger airflow and do not locate the equipment so that it intakes hot air exhausted from some other equipment. Provide at least 1 1/2 fan diameters of clearance to the heat exchanger inlet and exhaust it away from walls that might cause the air to re-enter. Locate the blower above anticipated snow level.

G. Liquid-to-Liquid Exchanger Option

If a Robertshaw temperature regulating valve is supplied for remote mounting, install it as shown in drawing 238B4861, Sheet 2 for liquid-to-liquid heat exchangers. The dimensions shown for the sensing bulb are for the thermowell supplied with the valve. The use of a thermowell is recommended so that the coolant does not have to be drained if the sensing bulb has to be removed.
The sensing bulb can be installed in any position from vertical to horizontal. If the bulb is installed away from vertical, the arrow and/or UP markings on the positioning disk must point UP. The top (threaded end) should be approximately the same elevation as the valve actuator.

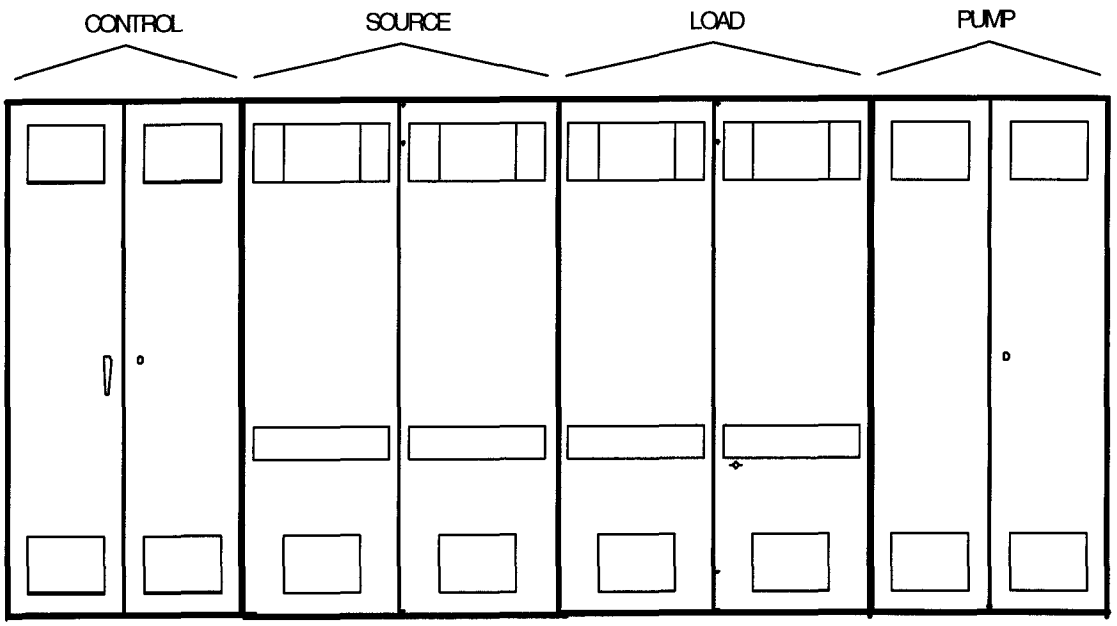
H. Local Control Panel Control

Under normal conditions, the liquid cooling system operates without human intervention. Cooling system status can be determined through the Datapanel™ user interface.

XII. Equipment Enclosures

The drive controller is supplied in a factory assembled and tested, free standing enclosure. The transformer, DC link inductor, heat exchanger are supplied in separately from the drive enclosure. The drive controller is supplied in a NEMA Type 1 ventilated enclosure for indoor mounting. The enclosure has a rigid steel frame enveloped by sheet steel with a minimum 12-gauge thickness. The enclosure is painted ANSI-70 light gray.The control cabinet has a hinged access door held in the closed position with a three point latching device and a padlockable handle. Power conversion cabinets have hinged covers which require a tool for opening and equipped with a padlock hasp for locking the cover in the closed position. Rear sections requiring access only for high voltage bus connections are covered by bolted on panels.

IP7_024404



[5600 mm L X 1400 mm D X 2334.5 mm H]

Figure 3: Enclosure

IP7_024405

XIII. DC Link Inductor

One DC link inductor is supplied with each 6 pulse channel. Electrically the DC link inductor is at the output of the source converter and the input of the load inverter.

A. Features

- Air core, dry type
- Aluminum enclosure with removable access panels.
- Aluminum conductors with drilled, plated aluminum terminals for connections. Optional copper conductors can be supplied on some designs.
- Outdoor enclosure with screened louvered openings for convection cooling.
- Optional indoor enclosure with screened openings for convection cooling.
- Vacuum and pressure impregnated in a double dip process using 200⑤ C polyester solventless resin.
- Outdoor, ANSI-70 gray paint
- Field replaceable over temperature sensor with normally closed contacts rated 240Vac, .5A embedded in the windings.
- Two 120V, 1 amp space heaters wired to a single terminal board are supplied.
- Class H insulation system.
- 5kV class coils tested to a 12kV Hipot.
- BIL rating for specific voltage
    - 1200V 10kV BIL
    - 2520V 20kV BIL
    - 4160V 30kV BIL
- Top or Bottom cable entry.

B. Standards

The reactor meets the applicable requirements of ANSI C57.12.01 for construction and materials and meets the audible sound level requirements of NEMA standard TR-27.

IP7_024406

TOSHIBA GE

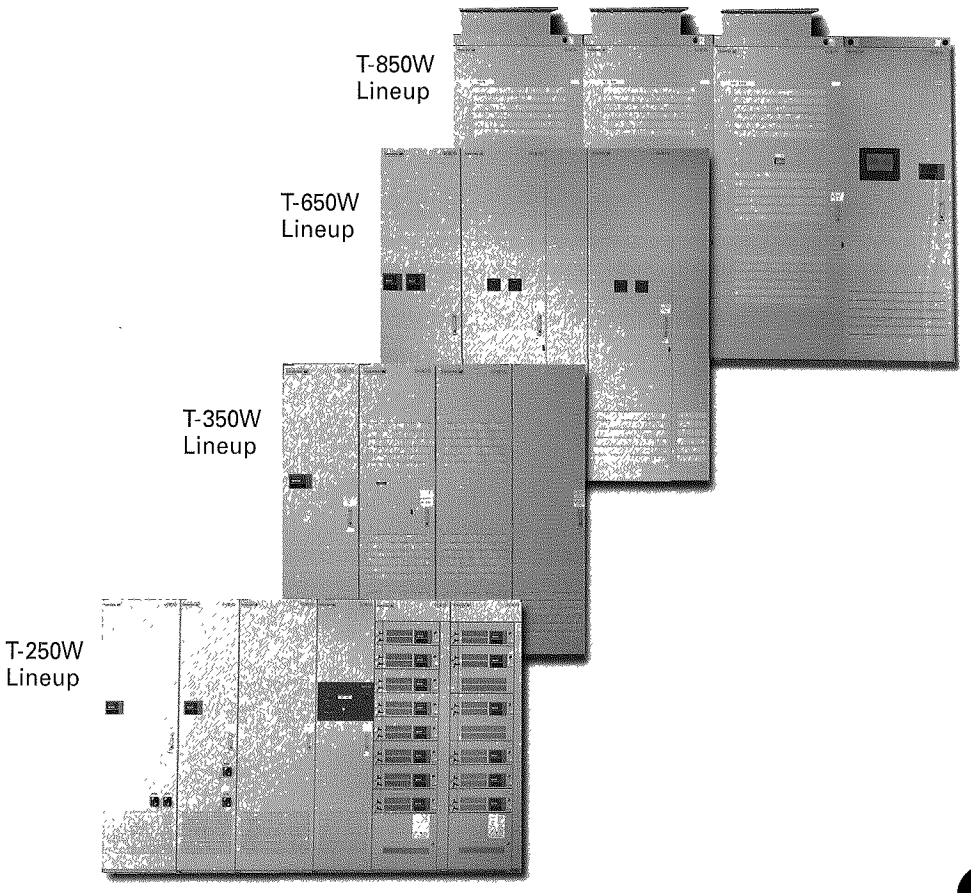
GE TOSHIBA AUTOMATION SYSTEMS

TOSVERT™ System Drives Application Guide

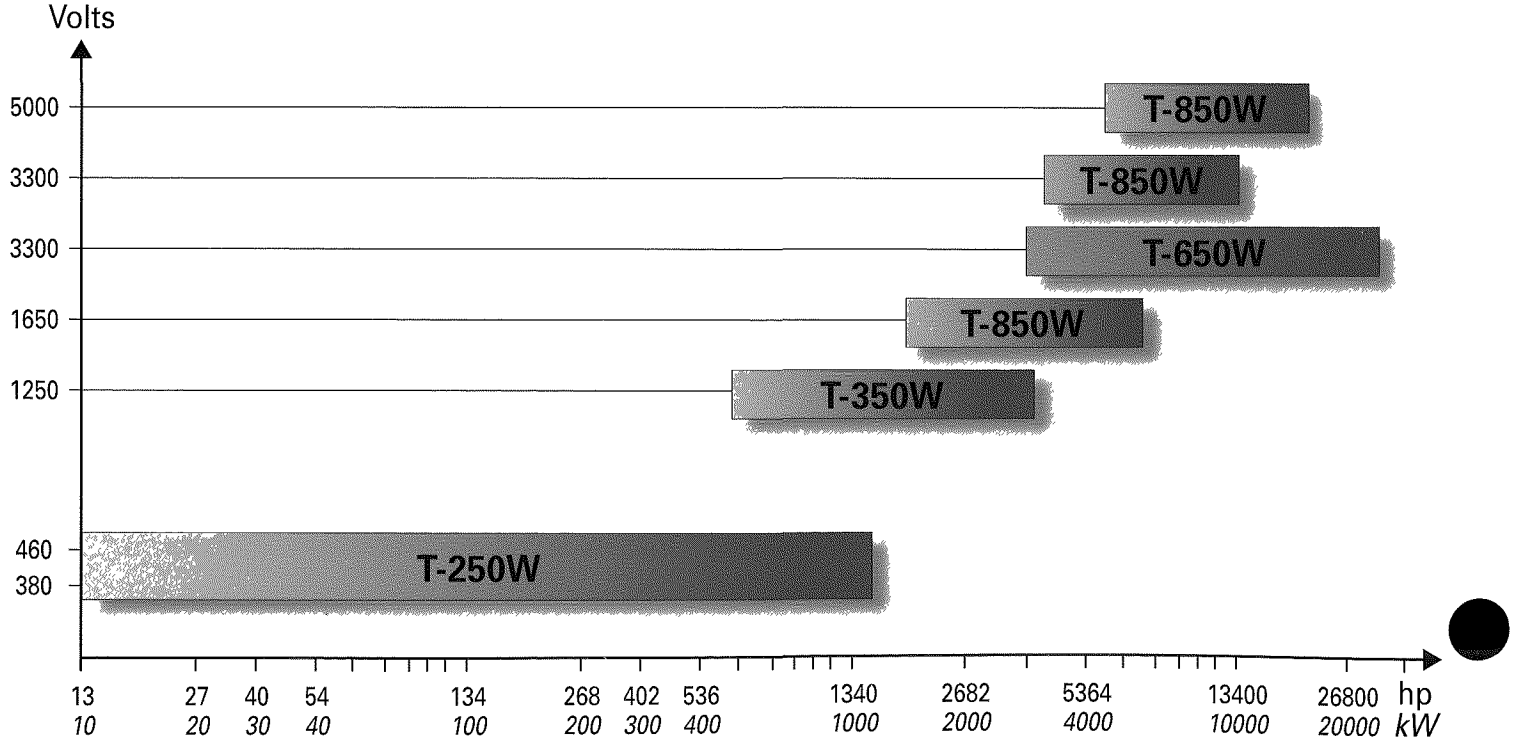
IP7_024407

GE and Toshiba have joined forces to develop a family of TOSVERT ac system drives, targeted at specific customer requirements for:

- High reliability
- Simple configuration and maintenance
- Low cost of ownership



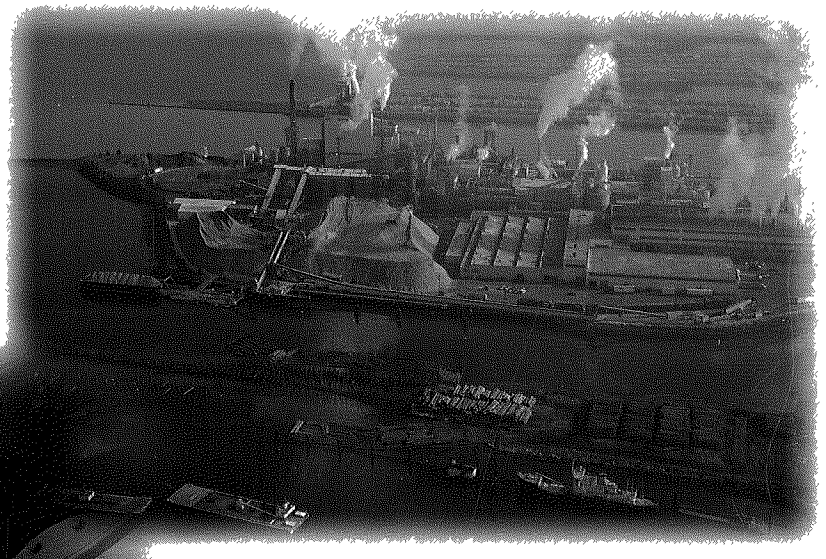
TOSVERT System Drives Have Complete Coverage



IP7_024408

Bringing Reliable Control To System Applications

In the pulp and paper industry, uninterrupted operation is priority one. The robust design of the T-250W heatpipe-based power bridges provide superior reliability and maintainability for paper mill applications.



Coordinated drive systems are an integral part of numerous manufacturing processes in the metals industry. TOSVERT system drives address all of these applications with a common Microsoft® Windows®-based Control System Toolbox (toolbox) featuring animated block diagrams, integrated trending window, and local or remote connectivity. This intuitive tool is invaluable in drive system and process analysis.

In the automation of dock side cranes, tight integration between the system drives and the controller is a requirement. The high performance ISBus™ provides this synchronization with:

- Run time control at 1-8 ms
- Remote connectivity for toolbox configuration and monitoring

IP7_024409

An Open Architecture For Both New

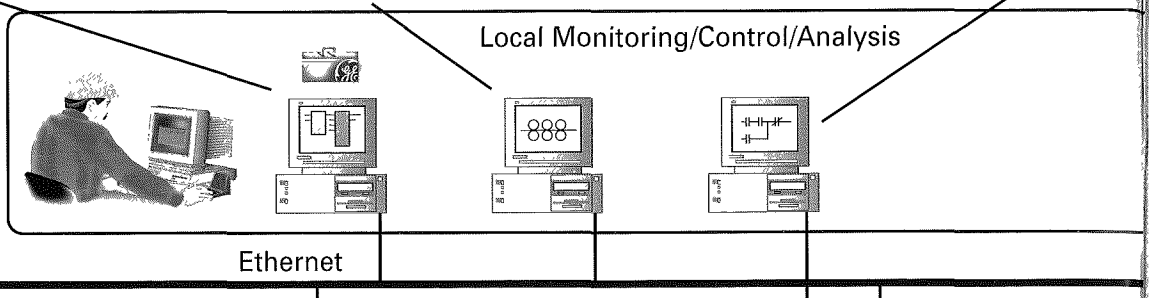
Control System Toolbox - Windows-based application for configuration and monitoring:

- TOSVERT system drives
- Innovation Series™ drives
- AC/DC2000 drives
- AV-300i™ drives
- Innovation Series controllers

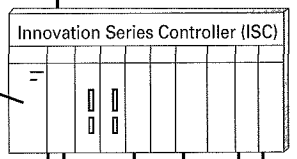
Microsoft Certified Solution Provider

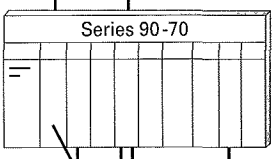
CIMPLICITY HMI - Windows-based applications for monitoring and control of the process. Additional process specific applications are included for advanced diagnostics and reporting.

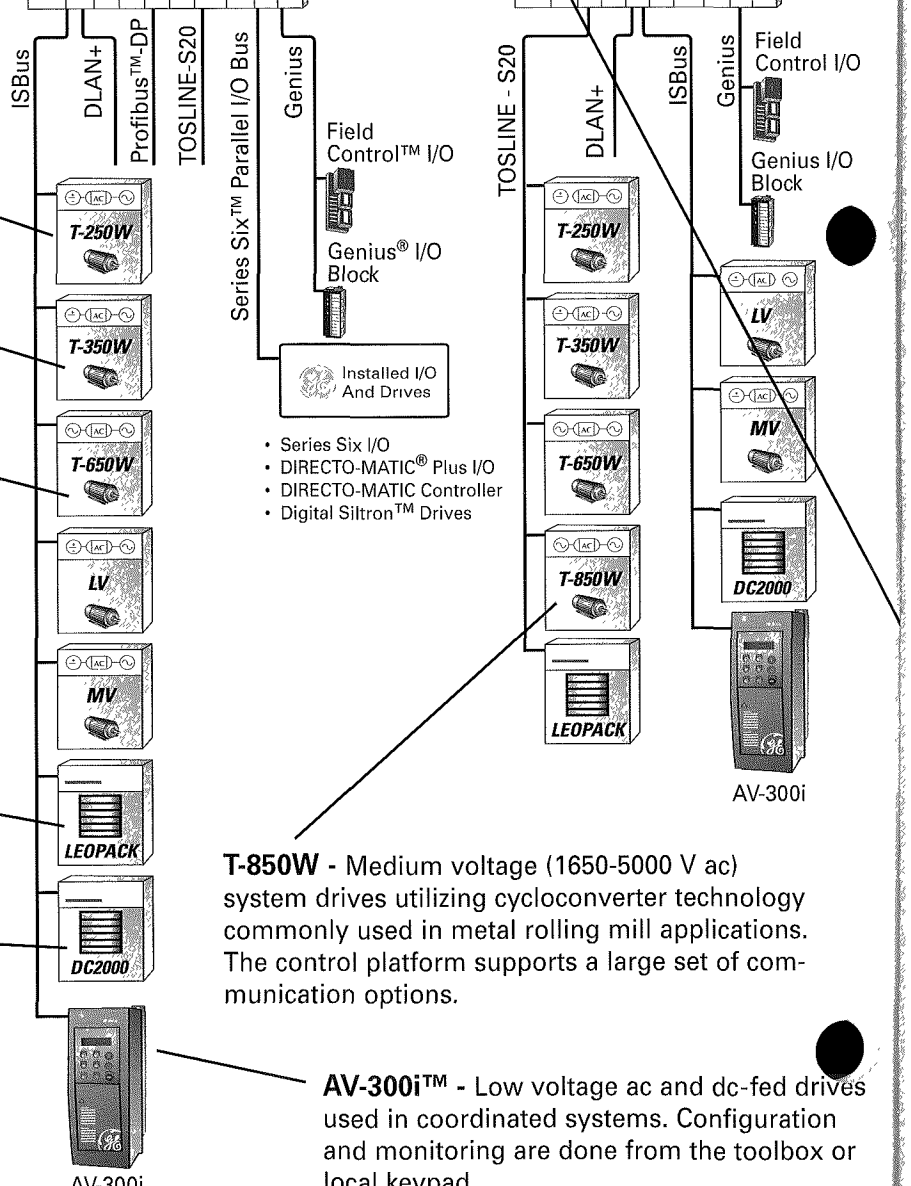
VersaPro™ - Windows-based application for configuration and monitoring of the GE Fanuc Series 90™-70 and Series 90-30 PLCs.



Innovation Series Controllers (ISCs) - Set of pre-emptive multi-tasking controllers (VME, 3U, and panel-mount) that are specifically designed for application in large integrated drive systems. Configuration and monitoring are done from the toolbox.







T-250W - Low voltage (380-460 V ac) system drives that share a common control platform with the T-350W, T-650W, and LEOPACK™.

T-350W - Medium voltage (1250 V ac) system drives that share a common control platform with the T-250W, T-650W, and LEOPACK.

T-650W - A set of medium voltage (3300 V ac) system drives utilizing Injection Enhanced Gate Transistor (IEGT) power switch technology commonly used in metal rolling mill applications. The source and inverter share a common control platform with the T-250W, T-350W, and LEOPACK.

LEOPACK - DC drive products for application in coordinated drive systems. They share a common control platform with the T-250W, T-350W, and T-650W drive products.

DC2000 - DC drive products for application in coordinated systems.

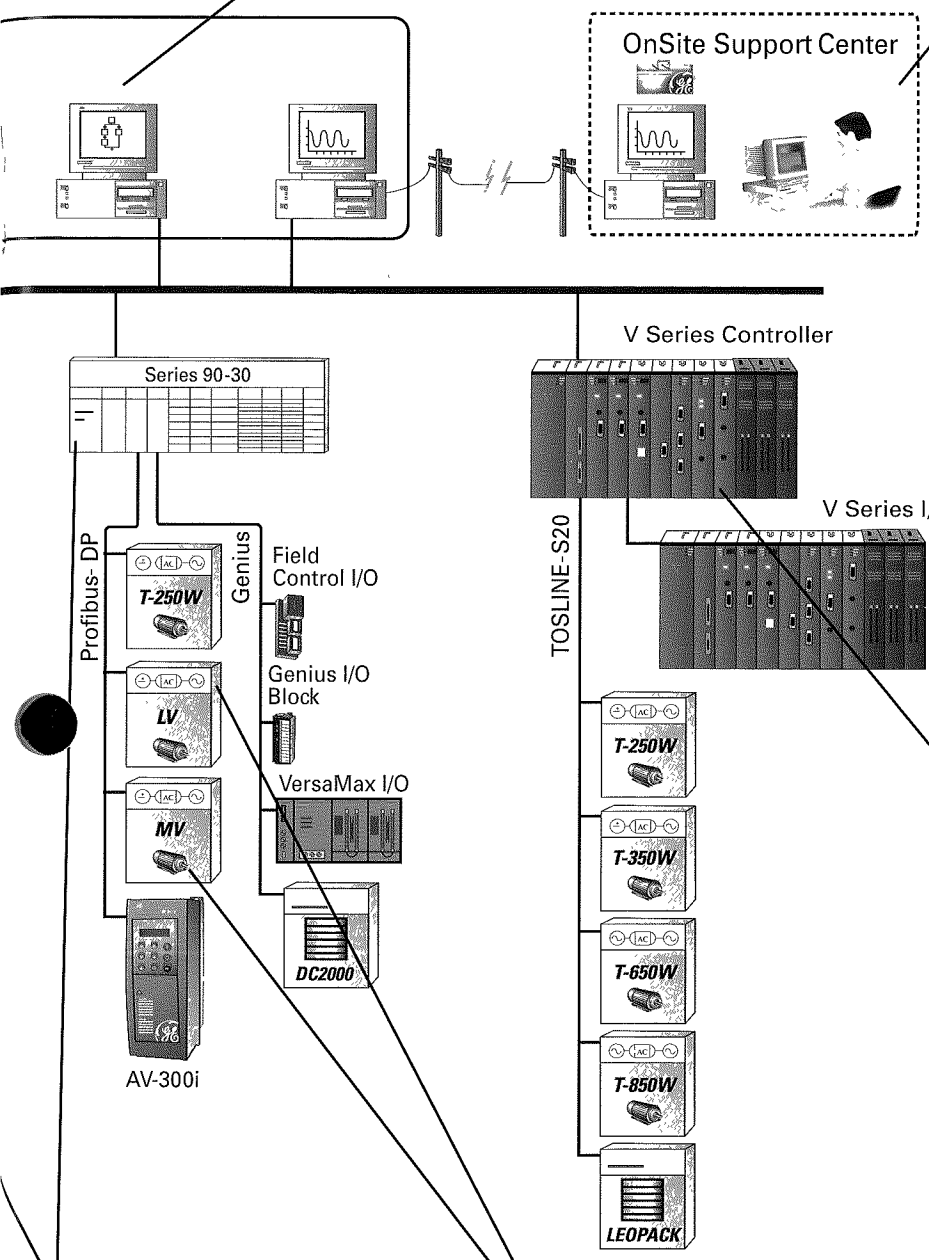
T-850W - Medium voltage (1650-5000 V ac) system drives utilizing cycloconverter technology commonly used in metal rolling mill applications. The control platform supports a large set of communication options.

AV-300i™ - Low voltage ac and dc-fed drives used in coordinated systems. Configuration and monitoring are done from the toolbox or local keypad.

IP7_024410

And Existing Systems

V Tool - Windows-based application for configuration and monitoring of the Toshiba V Series PLCs.



OnSite Support[SM] - Engineering services available 24 hours a day to help reduce downtime for your process. To facilitate this service, our coordinated drive system architecture has several features:

- Integrated flight recorder (Message View application with Modelogger service) that logs events in the system for future local or remote analysis
- Single-point local or remote connectivity that allows the toolbox to monitor and configure any drive and/or controller from one location
- A common trend window in the toolbox for both the Innovation Series controllers and system drives

V Series Controllers - Family of controllers and I/O systems from Toshiba for application in coordinated drive systems. Control logic is configured in any combination of the five IEC 61131-3 languages:

- Relay ladder diagrams (RLD)
- Function block diagrams (FBD)
- Sequential function charts (SFC)
- Instruction list (IL)
- Structured text (ST)

Full support of today's TOSVERT system drives is provided, as well as support for legacy TOSVERT system drives.

Series 90-70 and 90-30 PLCs - PLCs that address a wide range of industrial control applications. The Series 90-70 is VME rack-based, which allows the integration of the Innovation Series controller along with other third party VME boards. Configuration and monitoring are done with the VersaPro.

Innovation Series Drives - Family of low and medium voltage ac system drives that share a common control rack with an option slot for an integral 3U controller or communications module. Configuration and monitoring are done from the toolbox or local keypad.

- Low Voltage (380-575 V ac) dc-fed set of drive products for application in a coordinated system
- Medium Voltage Type G (2300-4160 V ac) ac-fed non-regenerative drives for industrial applications
- Medium Voltage Type H (2400-6600 V ac) ac-fed non-regenerative drives for industrial applications
- Medium Voltage SP (3300/6600 V ac) ac regenerative drives for mill stand applications

Control System Toolbox– A Common

Several years ago, GE introduced the Control System Toolbox (toolbox), a powerful Windows-based application for configuring drives and controllers. The tradition continues with full support of the TOSVERT system drives.

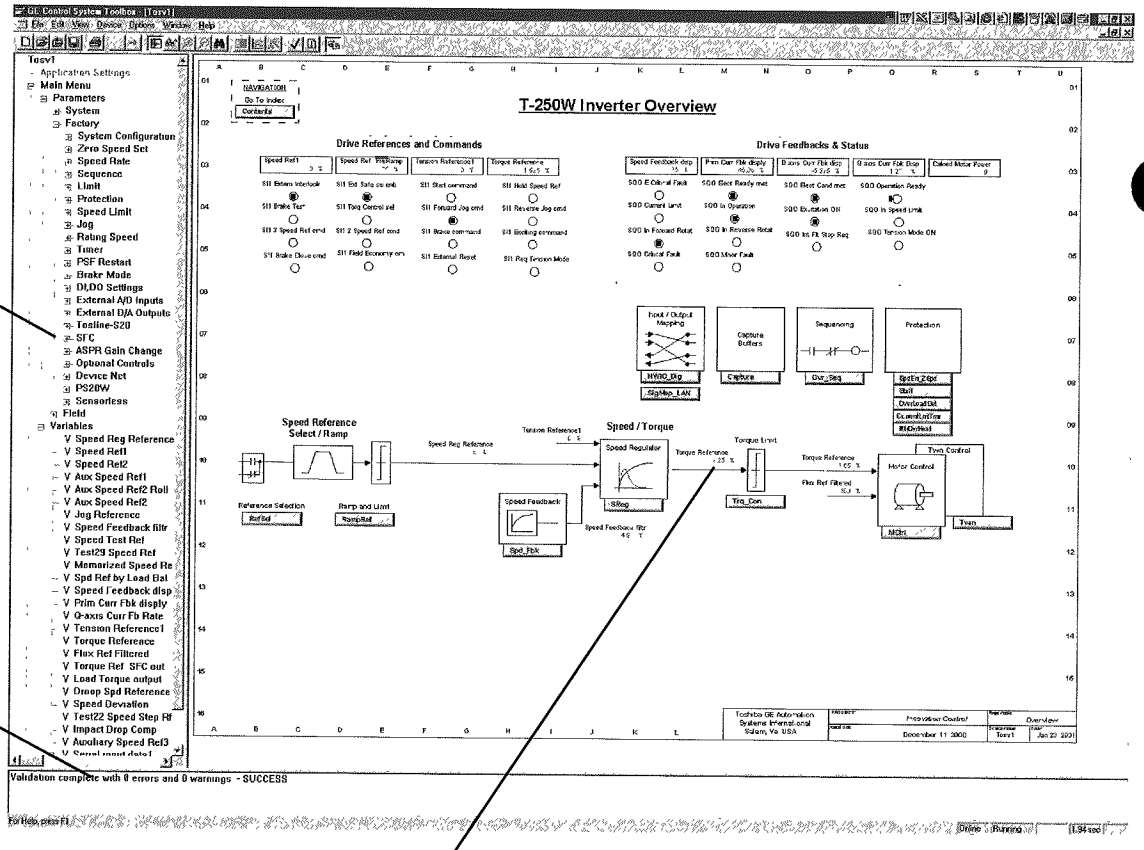
Drive Configuration With Animated Function Block Diagrams

TOSVERT drive functions are detailed in a set of graphical block diagrams with associated configuration parameters and variables. To access a given parameter, simply click on its name within the diagram. Help on drive functions and related parameters is a key (F1) away.

Animated relay ladder diagrams (RLD) brought dramatic productivity improvements to digital control in a PLC. Now, animated function block diagrams bring the same improvements to system drive control.

Outline View
Functionally organized parameters and related variables allow quick access to a given function.

Log View
Provides status of commanded operations.



Animated Block Diagrams
The control functions for each of the TOSVERT system drives are detailed in a set of function block diagrams. Embedded in each diagram are the configuration parameters and variables associated with the function. Hyperlinks are provided to parameter editing and related function block diagrams. When online, the diagrams are animated with the actual value of variables shown in green. Digital logic is displayed in ladder logic format with animation of the contacts and coils. Additional animation is provided in the Summary View shown above with key drive feedback and status variables.

IP7_024412

Tool For All Of Our System Drive Products

Drive Commissioning With An Integrated Trend Window

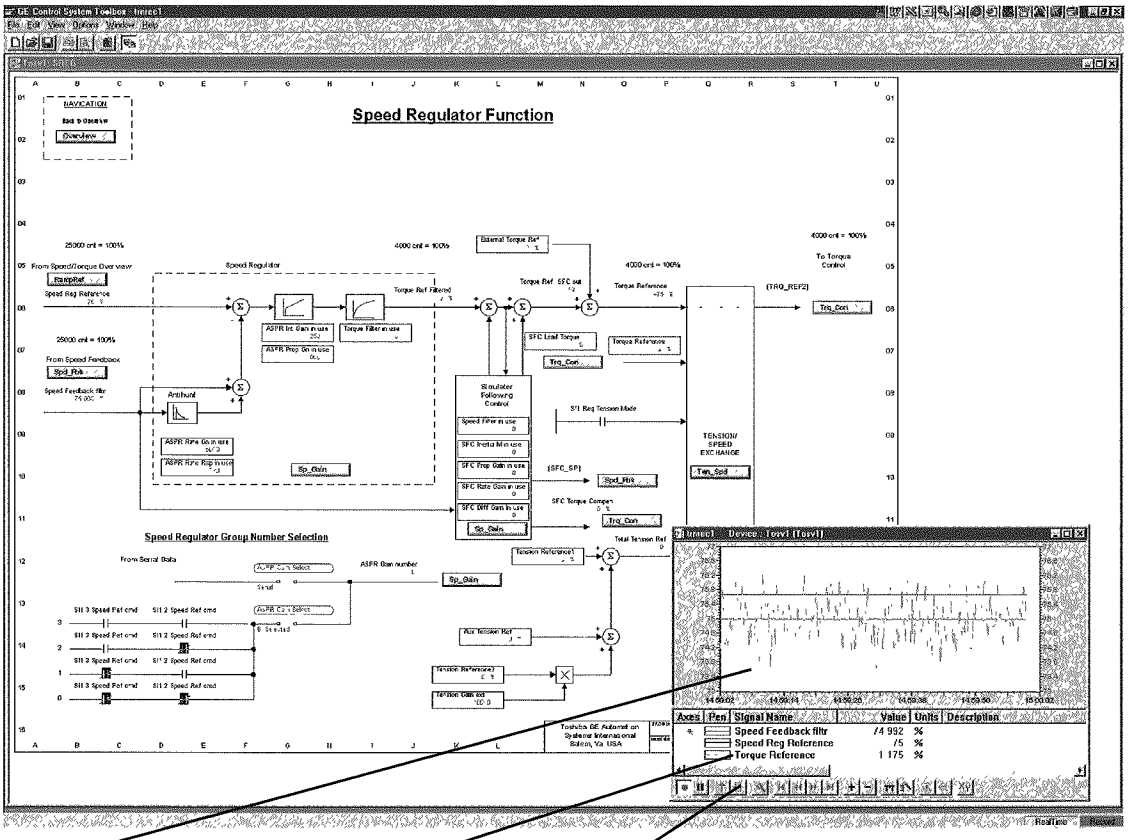
The toolbox application has an integrated trend window for the trending of drive and related process variables. Our development team of experienced control engineers has built a very practical tool for the analysis of a coordinated drive system.

Configuration

- Define the trend with drag-and-drop of variables from function block diagrams or select the variables from a list box
- Conduct online real-time trending with the drive or upload the capture buffers in the drive for trending. For historical trending, define a link with integrated historian database.

Display/Analysis

- Quickly define a display with the auto-scaling toolbar button
- Analyze a specific time frame with the zoom in/out toolbar buttons
- Create different views using variable hiding
- Analyze specific times with cross-hairs
- Perform frequency-based analysis of the trend using the Fast Fourier Transform (FFT) function.



Time-based trend of drive variables

List of variables being trended

Trend window toolbar

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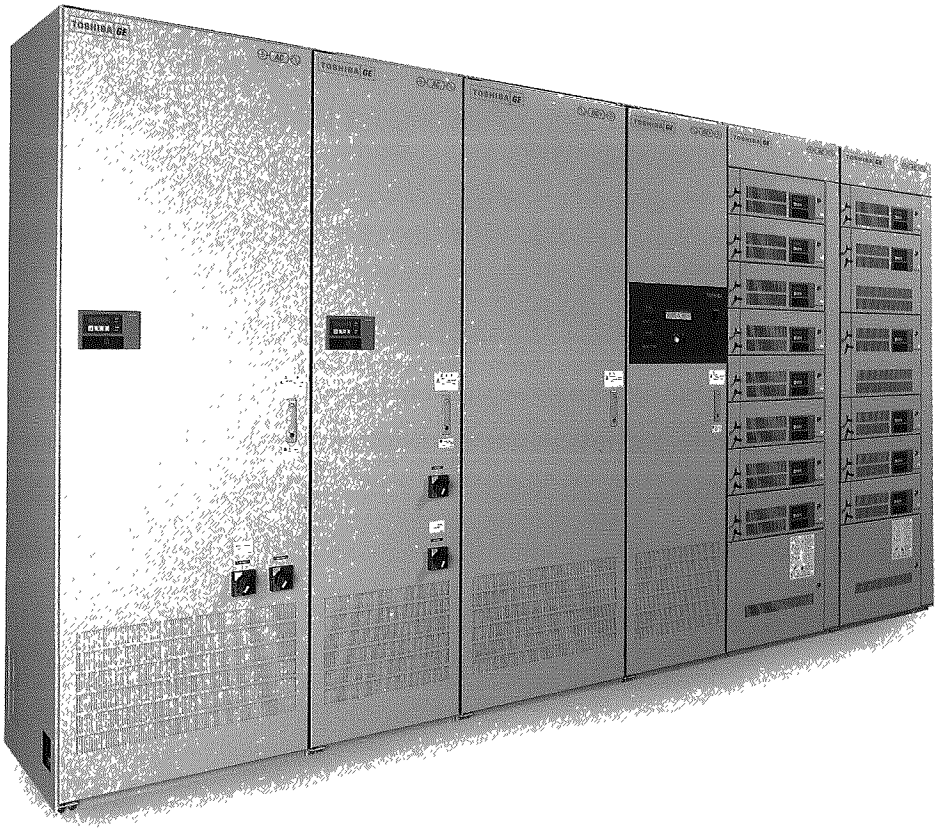
IP7_024413

System Maintenance With A Common Tool For All Of Our System Drives

The productivity of the toolbox spans all of our system drive products and controllers.

System Drive Product		Toolbox Feature Set						
		Animated Block Diagrams	Online Trending	Capture Buffer Trending	Integrated Parameter Help	Serial Interface	Ethernet-ISBus Connectivity	Ethernet-DLAN+ Connectivity
TOSVERT Drive Products	T-250W	✓	✓	✓	✓	✓	✓	
	T-350W	✓	✓	✓	✓	✓	✓	
	T-650W	✓	✓	✓	✓	✓	✓	
	T-850W	✓	✓	✓	✓	✓		
	LEOPACK	✓	✓	✓	✓	✓	✓	
Innovation Series Drive Products	Low Voltage	✓	✓	✓	✓	✓	✓	
	Medium Voltage	✓	✓	✓	✓	✓	✓	
AV/DV-300 Drive Products	AV-300i AV-300 DV-300	✓	✓	✓	✓	✓	✓	
AC/DC2000 Drive Products	AC2000 DC2000	✓	✓	✓	✓	✓	✓	✓
Innovation Series Controller		✓	✓	✓	✓		✓	✓

IP7_024414



A standard for reliability

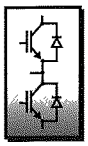
in low voltage system drive applications

T-250W

Features	Benefits
Heatpipe Cooling Technology The cabinet-based IGBT power bridges use heatpipe cooling technology.	**Reduces Footprint and Lowers Audible Noise** Reduces the footprint of the drive, saving valuable floor space. In addition, lowers the required cooling-air speed, significantly reducing the associated audible noise.
Toolbox-Based Configuration The toolbox is used to configure, install and maintain the T-250W drives.	**Common Tool Across All System Drives** This common tool for all of our system drive products and the Innovation Series controller is a source of productivity for the life of the system.
LAN Options: • ISBus • Profibus-DP • DeviceNet™ • TOSLINE-S20	**Multiple Controller Platforms Supported** For virtually all controller platforms, these LAN options provide seamless integration with the rest of your factory. The ISBus provides both run-time control services and configuration/diagnostic support for the toolbox.

IP7_024415

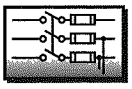
T-250W—Take A Look



Two-Level Phase Leg Assembly

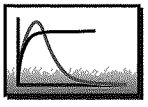
The cabinet-style inverters have modular two-level phase leg assemblies. Each phase leg includes:

- IGBTs with flyback diodes
- Heatpipe assembly
- IGBT gate driver circuit board



Incoming Power (Main and Control)

The source in each lineup is fed 3-phase 460 V ac power. This particular source uses an external ac circuit breaker with an associated set of control signals. In addition, 3-phase 220 V ac control power is fed to each source and inverter in the lineup. A control power disconnect is provided in each cabinet.

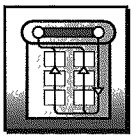


Control Functions

Each inverter and PS20W regenerative source share a common set of control boards. The primary control board performs several functions:

- Speed and torque regulation
- Sequencing
- I/O mapping
- Set of capture buffers

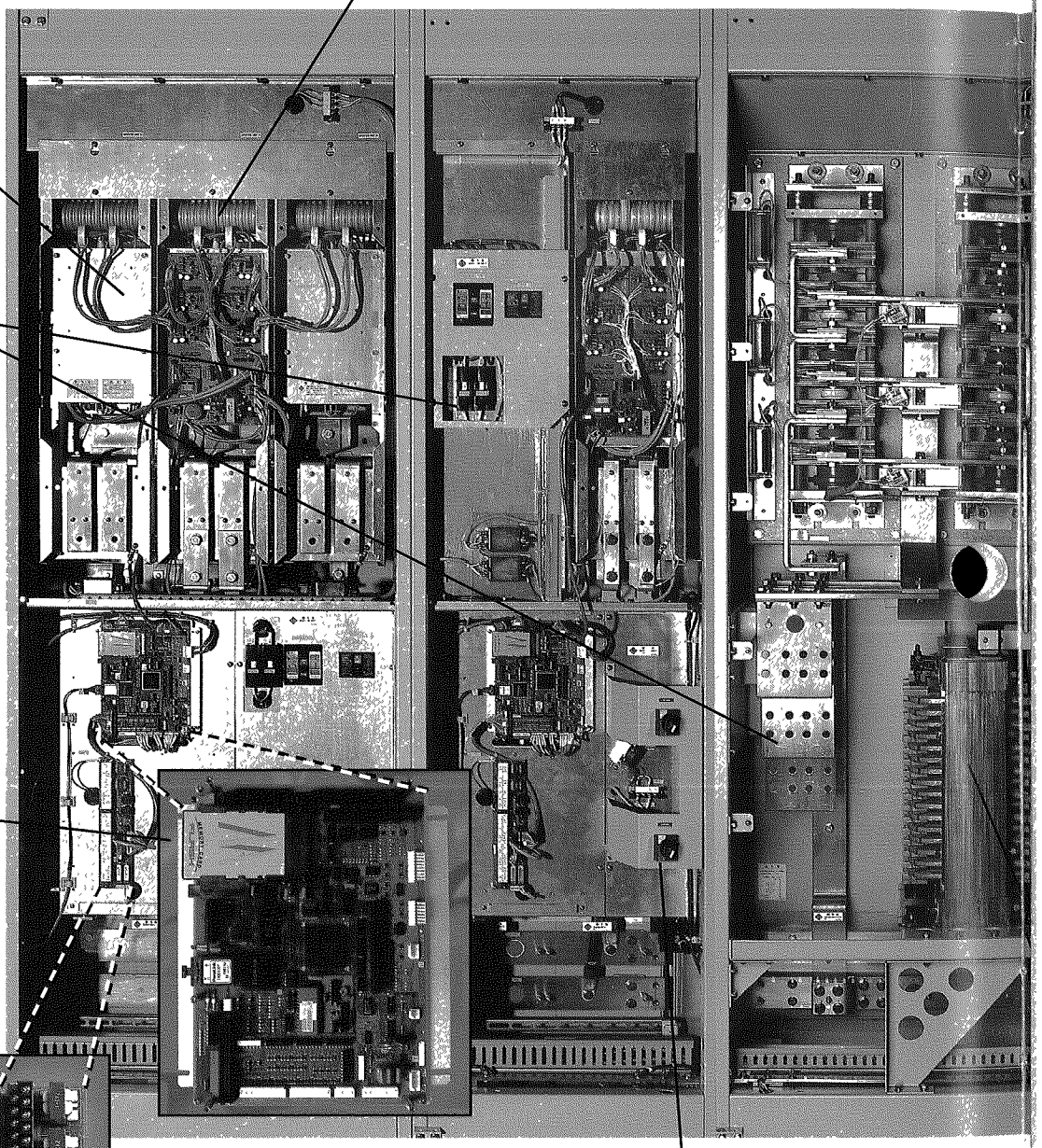
A mounting bracket is provided for an optional LAN interface board. In addition, parameters and diagnostic data are stored on a removable non-volatile PCMCIA card.

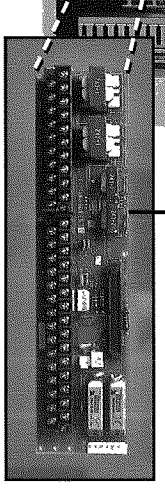


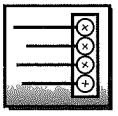
Heatpipe Cooling Technology

The IGBT cabinet-based power bridges use heatpipe cooling technology. This technology reduces the footprint of the drive, saving valuable floor space. In addition, reduces the required cooling air speed, dramatically lowering the associated audible noise.

650 Frame Inverter **325 Frame Inverter** **2000 Frame Non-R**







I/O Board

A resolver or encoder board is available with the inverters and PS20W regenerative sources. Both of the boards also contain 24 V dc digital and analog I/O. All I/O is terminated to a two-piece modular terminal block for ease of maintenance.

Inverter DC Bus Disconnect

Each inverter has a set of dc power disconnect switches that are mechanically interlocked to properly charge the bus.

IP7_024416

Reliable low voltage ac system drive technology designed to **reduce cost of ownership:**

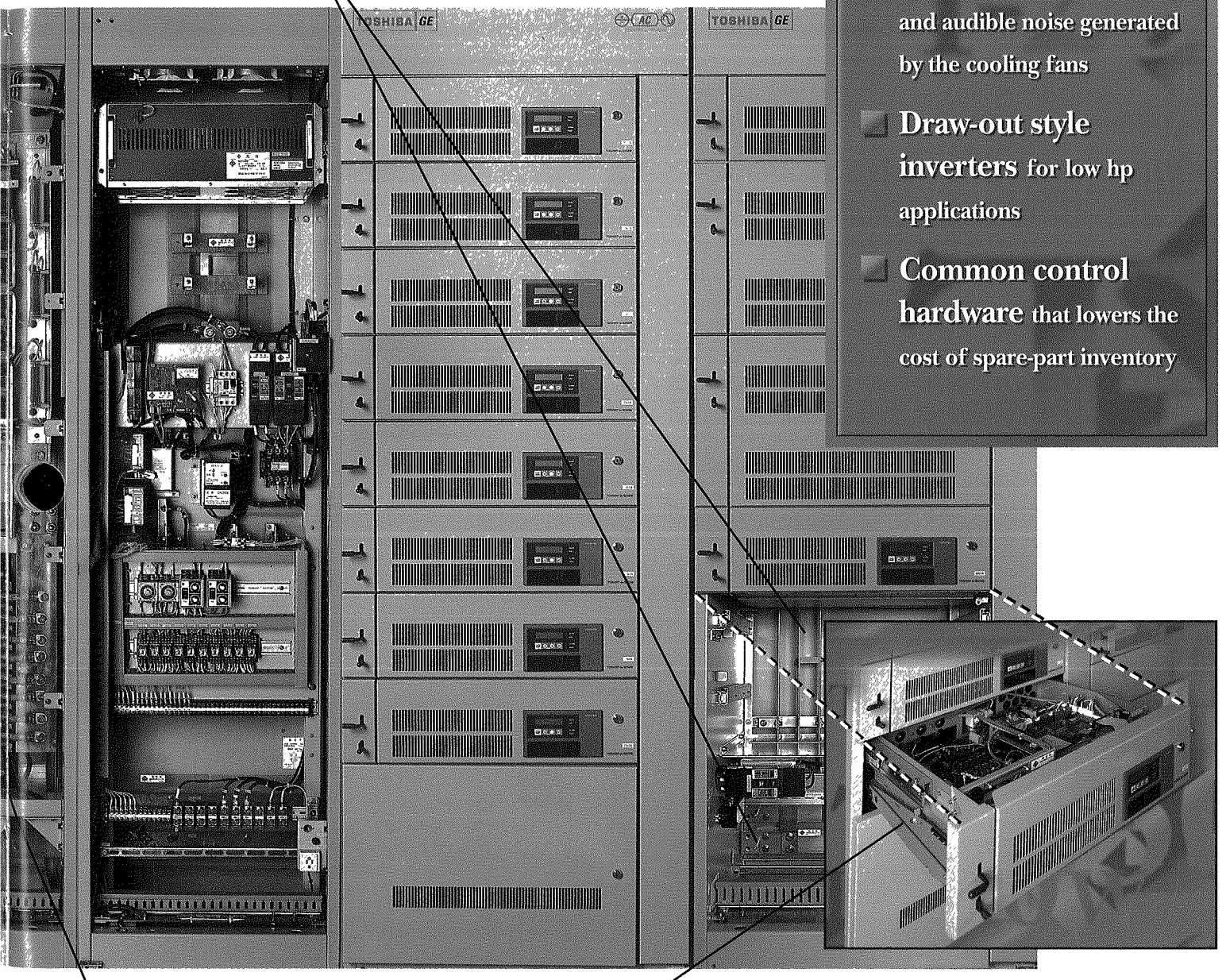
- **Heatpipe cooling technology** that reduces the size of the power bridge and audible noise generated by the cooling fans
- **Draw-out style inverters** for low hp applications
- **Common control hardware** that lowers the cost of spare-part inventory

DC Bus

The dc source in each lineup generates dc power for each of the inverters. The inverters then create variable frequency ac power to control the induction motors. This dc power for the lineup is conveyed on a solid-copper bus mounted in the bottom of the cabinets.

Regenerative Diode Source

Draw-Out Style Inverters



DC Link Reactor

The dc link reactor smoothes any current ripples (di/dt) on the dc bus, to provide steady power for the inverters in the lineup.

Draw-Out Style Inverters

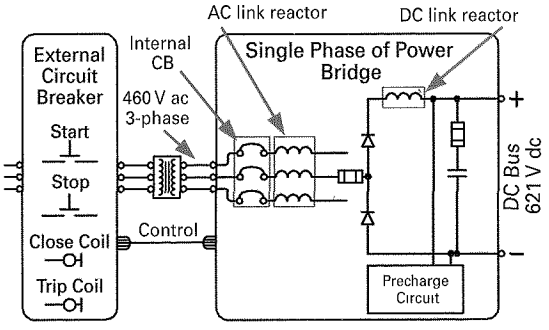
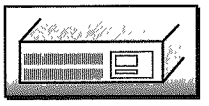
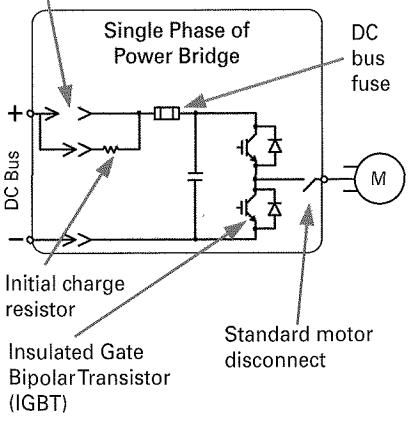
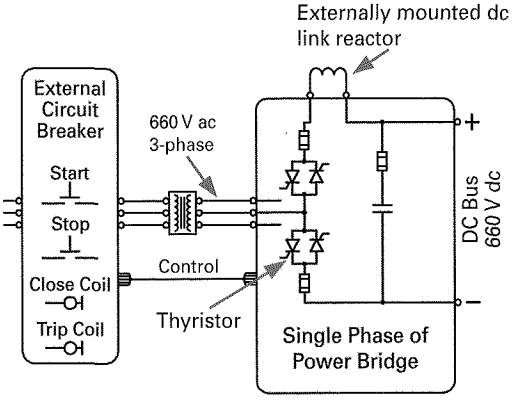
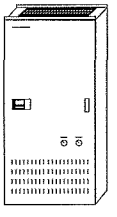
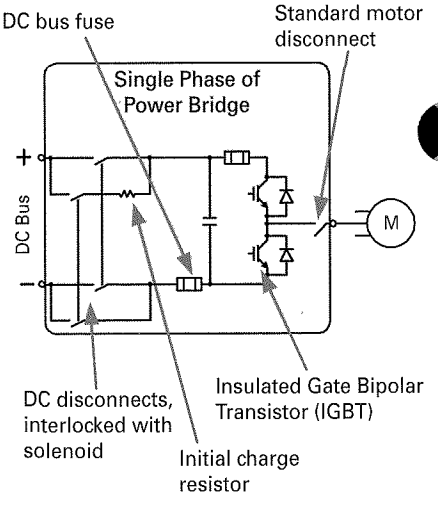
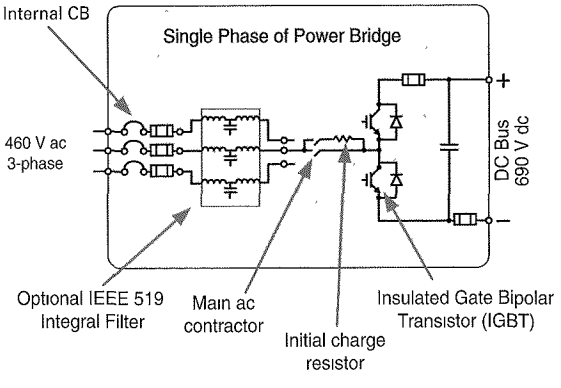
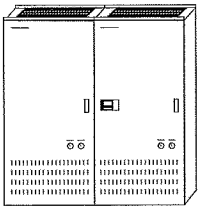
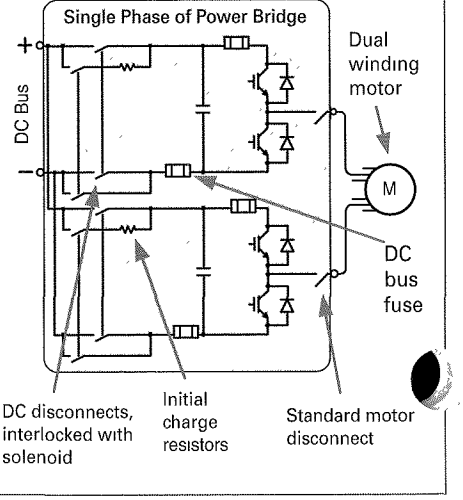
For applications up to 140 hp *(106 kW)*, a draw-out style inverter is available in a very compact package. Draw-out inverters are mounted on heavy-duty slides with staggered dc bus connectors on the back that connect with the bus when slid into the cabinet. Motor cables are terminated at a common terminal block in the bottom of the cabinet. I/O wiring is mounted to a modular terminal block for ease of maintenance.

IP7_024417

A Low Voltage Power Bridge Topology To Fit Your Application

T-250W Source Topologies

T-250W Inverter Topologies

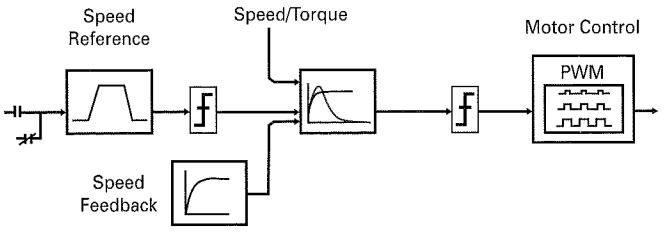
Frame	Power Switch Technology	Inverter Frame AC Amps	Inverter Topology
PS20D 250 830 2000 2x2000	Non-Regenerative Diode-Based Power Bridge  250 and 830 frames have ac link reactor and internal CB. 2000 and 2x2000 frames have dc link reactor and external CB. 2x2000 frame is a 12-pulse power bridge with load sharing reactor provided.	 Draw-Out Construction 20 35 70 95 160	
PS20E 600 1200 2400	Regenerative Thyristor-Based Power Bridge  - 600 and 1200 frames have fusing on ac side - 2400 frame has fusing on dc side (shown above)	 325 650 900	
PS20W 225 640 850 2x640 2x850	Regenerative with Power Factor Correction IGBT-Based Power Bridge  	 1300 1800	

IP7_024418

A Common Control To Reduce Cost Of Ownership

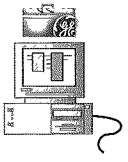
Control Functions

Feedback And Status | I/O Mapping | Capture Buffer | Sequencing



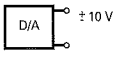
Instrumentation Interface

Toolbox



- RS-232C electrical interface
- 9.6 kbps maximum
- ISBus-Ethernet® option using Innovation Series controller as gateway

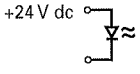
Analog Outputs



- Quantity 5 configurable, ±10V
- Motor current A and B, ±10V
- Configurable gain and offset
- 8-bit resolution

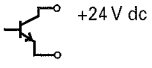
I/O Interface

Digital Inputs



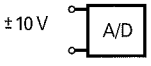
- Opto-coupled, 10 mA
- Quantity 7 configurable mapping
- Quantity 1 dedicated

Digital Outputs



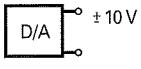
- Open collector, 70 mA maximum
- Quantity 4 configurable mapping

Analog Inputs



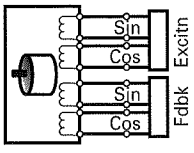
- Quantity 2, ±10V
- 12-bit resolution
- Configurable mapping

Analog Outputs



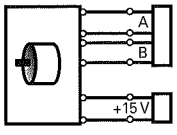
- Quantity 2, ±10V
- Configurable gain, offset, and mapping
- 8-bit resolution

Speed Feedback Resolver Input



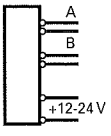
- Excitation freq of 1 kHz
- Preferred source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp

Speed Feedback Tach Input



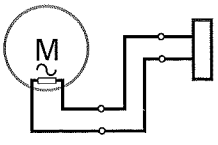
- Maximum freq of 10 kHz
- Drive provides 15 V dc

Speed Tach Follower Output



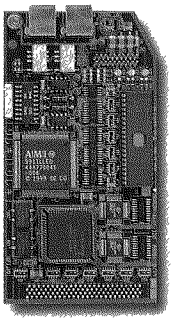
- Maximum freq of 10 kHz
- External 12-24 V dc is required

Motor Temperature Feedback



- Enhanced torque regulation motor temperature feedback
- 1k ohm platinum resistor or 100 ohm platinum RTD (RTD uses analog input with signal conditioner)

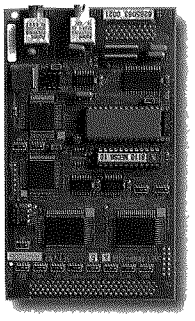
LAN Interface Options



ISBus

- Supports both run-time control (12 bytes in and 20 bytes out) and tool box configuration/monitoring using the Innovation Series controller as a gateway between the ISBus and Ethernet
- RS-485 or optional fiber-optic bus in a synchronous ring configuration
- 5 Mbps master/slave (drive is the slave) protocol using copper or fiber, bus scan time is based on the number of nodes

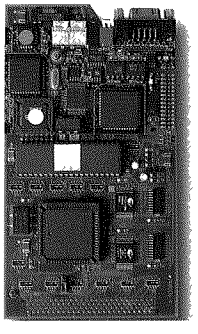
Quantity of Nodes	Bus Scan Time
2-4	1 ms
5-8	2 ms
6-16	4 ms
17-32	8 ms



TOSLINE-S20

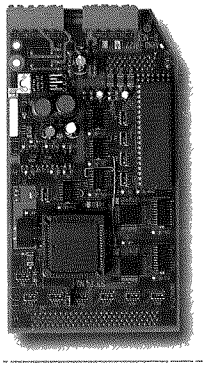
- Supports run-time control (12 bytes in and 20 bytes out) from an Innovation Series controller, Series 90-70 PLC, or V Series controller
- Drives can also exchange data between themselves
- Fiber-optic bus in a star configuration
- 2 Mbps peer-to-peer protocol, bus scan time is based on the number of nodes

Quantity of Nodes	Bus Scan Time
2-3	1 ms
4-5	2 ms
6-8	4 ms
9-64	25 ms



Profibus-DP

- Supports run-time control (16 Booleans and 5 integers in and out) from a Profibus-DP master controller
- Copper bus in a daisychain configuration
- 9.6 kbps to 12 Mbps master/slave protocol, bus scan time is based on the number of nodes

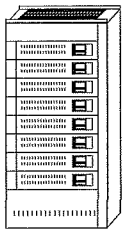
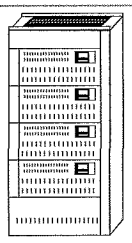
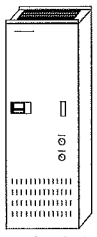
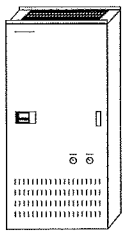
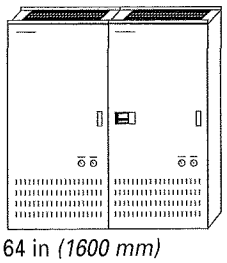


DeviceNet

- Supports run-time control (16 Booleans and 3 integers in and out) from a DeviceNet master controller
- Copper bus in a daisychain configuration
- 125 kbps to 500 kbps master/slave protocol, bus scan time is based on the number of nodes

IP7_024419

T-250W Inverter Specifications

	Frame	Heat Loss *kW*	Weight lbs *(kg)*	CT Mtr Shaft 150% for 60 sec @ 460 V ac: hp *(kW)*	Current Ratings AC Amps: Required %Overload	Continuous Current (with 120 sec overloads)
 94 in *(2375 mm)* 32 in *(800 mm)*	20	*0.8*	68 *(31)*	17 *(13)*	100-150 175 200 250 300	20 17 15 12 10
	35	*1.0*	71 *(32)*	34 *(25)*	100-150 175 200 250 300	39 34 30 24 20
	70	*1.4*	75 *(34)*	62 *(46)*	100-150 175 200 250 300	72 62 54 43 36
	95	*1.7*	80 *(36)*	85 *(63)*	100-150 175 200 250 300	98 84 74 59 49
 94 in *(2375 mm)* 32 in *(800 mm)*	160	*2.0*	126 *(57)*	141 *(106)*	100-150 175 200 250 300	164 141 123 98 82
 94 in *(2375 mm)* 24 in *(600 mm)*	325	*3.5*	595 *(270)*	283 *(211)*	100-150 175 200 250 300	299 (328 for 10-60 sec) 270 (281 for 10-60 sec) 246 197 164
 94 in *(2375 mm)* 32 in *(800 mm)*	650	*6.5*	915 *(415)*	566 *(422)*	100-150 175 200 250 300	656 562 492 394 328
	900	*8.9*	1125 *(510)*	793 *(591)*	100-150 175 200 250 300	919 787 689 551 459
 94 in *(2375 mm)* 64 in *(1600 mm)*	1300	*13.5*	1830 *(830)*	1132 *(844)*	100-150 175 200 250 300	1312 1125 984 787 656
	1800	*18.3*	2249 *(1020)*	1585 *(1182)*	100-150 175 200 250 300	1837 1575 1378 1102 919

IP7_024420

Inverter Power Output

Output Voltage	0-460 V
Output Frequency	0-120 Hz
Output Chopping Frequency	1.5 kHz for 325-1800 frames 2 kHz for 20-160 frames
Inverter Type Modulation	Two-level voltage source pulse-width-modulation (PWM)
Power Semiconductor Technology	Insulated Gate Bipolar Transistor (IGBT)

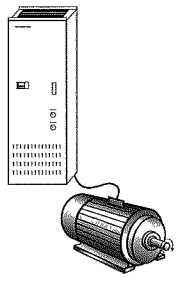
Motor Control

Resolver/Pulse Tachometer Speed Feedback	
Speed regulator accuracy	± 0.01%
Speed regulator response	42 rad/s
Torque regulator accuracy with motor temperature sensor	± 3%
Torque regulator accuracy without motor temperature sensor	± 30%
Torque regulator response	628 rad/s
Sensorless (Single Motor)	
Speed regulator accuracy	± 0.5%
Speed regulator response	20 rad/s

Inverter Example

When specifying an inverter, start from the process requirements and work through the motor to the inverter. The following example illustrates this process:

1 Define process requirements.



kW_{Shaft} = 200 hp *(150 kW)*

The motor delivers constant torque from zero to base speed of 900 rpm at 460 V ac.

Duty cycle requires 200% for 10 sec, but has an rms duty cycle of 200 hp *(150 kW)*.

2 Select motor based on process requirements and compute required inverter kVA.

- 200 hp (150 kW)
- 900 rpm
- Efficiency = 0.954
- Power factor = 0.765

$$kVA_{Inverter} = \frac{kW_{Shaft}}{Eff_{Mtr} \times PF_{Mtr}} = \frac{150\ kW}{0.954 \times 0.765} = 206\ kVA$$

3 Compute continuous current requirements for the inverter, based on the selected motor.

$$I_{Inverter\ Phase\ Current} = \frac{kVA_{Inverter} \times 1000}{\sqrt{3} \times V_{Inverter\ line\text{-}to\text{-}line\ voltage}} = \frac{206\ kVA \times 1000}{\sqrt{3} \times 460\ V} = 259\ amps$$

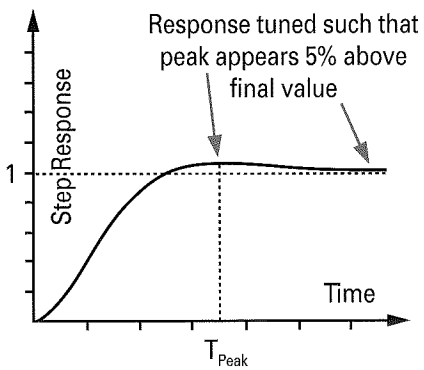
4 Select inverter based on continuous current and overload requirements.

Scan the 200% entries in the inverter tables for a frame where the continuous current rating exceeds 259 amps. The **650** frame meets this criteria (492 amps), and is appropriate for this application.

Required %Overload	Continuous Current (with 120 sec overloads)
100-150	656
175	562
200	492
250	394
300	328

Inverter Notes

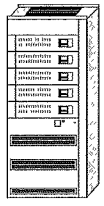
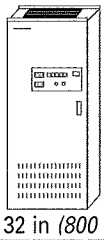
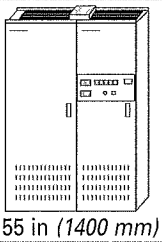
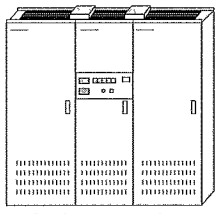
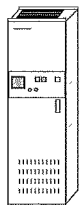
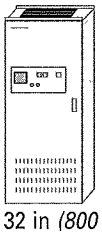
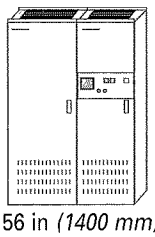
1. All cabinets are 26 in *(650 mm)* in depth, height shown does not include required 2 in (50 mm) channel base.
2. A minimum of 20 in *(500 mm)* should be allocated above cabinet for fan maintenance.
3. Continuous Torque (CT_{Shaft}) power rating data assumes a motor efficiency of 95%, motor power factor of 0.85, ambient temperature of 32-104 °F *(0-40 °C)*, altitude up to 3300 ft *(1000 m)* above sea level.
4. The specified current ratings are continuous, to which the referenced overload can be applied. Refer to application example on this page.
5. Each of the inverters support bottom cable entry. Top cable entry is supported with an auxiliary cabinet.
6. Inverters require 3-phase 220 V 50/60 Hz control power.
7. Torque regulation is limited to 5-100% of speed range when using a pulse tachometer for speed feedback. Torque can be regulated at zero speed with the use of a resolver for speed feedback.
8. For high performance torque regulation, a temperature sensor is mounted in the motor. A 1K ohm platinum resistor or 100 ohm platinum RTD (RTD uses analog input with signal conditioner).
9. Speed and current regulator response is computed per the adjacent figure in rad/s (assumes a Type 2 regulator with a 5% overshoot).
10. Air is pulled in through the doors and out the top for all cabinets.
11. The dc bus for the lineup has a maximum current capacity of 2000 amps.



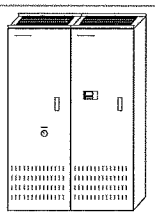
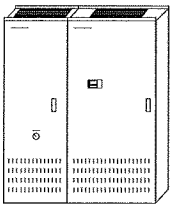
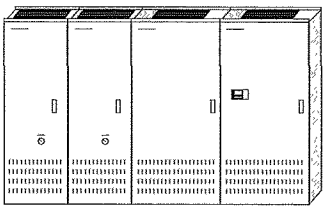
Drive Frequency Response = π / T_{Peak} (rad/s)

IP7_024421

T-250W Source Specifications

		Frame	Heat Loss *kW*	Weight lbs *(kg)*	Power 150% for 60 sec @ Rated Voltage hp *(kW)*	Current Ratings DC Amps: Required %Overload	Continuous Current (with 60 sec overloads)	Continuous Current (with 120 sec overloads)
Non-Regenerative Diode-Based Sources (PS20D)	 94 in *(2375 mm)* 32 in *(800 mm)* Source	250 Includes ac input reactor	*3.1*	406 *(185)*	*198* *(148)*	100-150 175 200 250 300	250 220 197 162 135	242 212 185 147 125
	 94 in *(2375 mm)* 32 in *(800 mm)*	830 Includes ac input reactor	*9.8*	601 *(274)*	*657* *(490)*	100-150 175 200 250 300	830 730 655 539 448	805 705 614 489 415
	 98 in *(2475 mm)* 55 in *(1400 mm)*	Top-mounted pre-charge resistor 2000 Includes dc link reactor	*15*	2409 *(1100)*	1582 *(1180)*	100-150 175 200 250 300	2000 1760 1580 1300 1080	1940 1700 1480 1180 1000
	 98 in *(2475mm)* 87 in *(2200 mm)*	Top-mounted pre-charge resistor 2x2000 Includes dc link reactor	*28*	4161 *(1900)*	3165 *(2360)*	100-150 175 200 250 300	4000 3510 3160 2600 2160	3800 3400 2960 2360 2000
Regenerative Thyristor-Based Sources (PS20E)	 94 in *(2375 mm)* 24 in *(600 mm)*	600	*4*	876 *(400)*	531 *(396)*	100-150 175 200 250 300	600 530 470 380 320	600 582 510 444 354
	 94 in *(2375 mm)* 32 in *(800 mm)*	1200	*5*	1205 *(550)*	1062 *(792)*	100-150 175 200 250 300	1200 1060 950 780 650	1160 1020 890 710 600
	 94 in *(2375 mm)* 56 in *(1400 mm)*	2400	*10*	2190 *(1000)*	2124 *(1584)*	100-150 175 200 250 300	2400 2400 2230 1870 1600	2328 2020 1776 1416 1200

IP7_024422

Regenerative IGBT-Based Sources (PS20W)	Frame	Heat Loss kW	Weight lbs (kg)	Power 150% for 60 sec @ Rated Voltage hp (kW)	Current Ratings AC Amps @ 2 kHz, 460 Vac: Required %Overload	Continuous Current (with 60 sec overloads)	Continuous Current (with 120 sec overloads)
 94 in (2375 mm) 47 in (1200 mm)	225	1.8	1041 (475)	242 (181)	100-150	229	208
					175	196	186
					200	172	172
					250	388	137
					300	115	115
 94 in (2375 mm) 55 in (1400 mm)	640	5.5	1490 (680)	684 (510)	100-150	647	618
					175	555	545
					200	485	485
					250	388	388
					300	323	323
	850	7.3	1742 (795)	909 (678)	100-150	859	844
					175	736	736
					200	644	644
					250	515	515
					300	429	429
 94 in (2375 mm) 110 in (2800mm)	2x640	11.6	2913 (1330)	1369 (1021)	100-150	1294	1236
					175	1110	1090
					200	970	970
					250	776	776
					300	646	646
	2x850	15.1	3417 (1560)	1817 (1355)	100-150	1718	1688
					175	1472	1472
					200	1288	1288
					250	1030	1030
					300	858	858

Source Notes

1. All cabinets are 26 in *(650 mm)* in depth, height shown does not include required 2 in (50 mm) channel base.
2. A minimum of 20 in *(500 mm)* should be allocated above cabinet for fan maintenance.
3. The specified current ratings are continuous, to which the referenced overload can be applied. Refer to application example on next page.

   Each of the sources support bottom cable entry. Top cable entry is supported with an auxiliary cabinet.
5. Sources require 3-phase 220 V 50/60 Hz control power.
6. PS20D frames 250 and 830 have an internal circuit breaker.
7. PS20D frames 2000 and 2x2000 require an external circuit breaker on the primary side of the transformer.
8. All PS20E sources require an external circuit breaker.
9. All PS20W sources have an internal circuit breaker and require a dedicated isolation transformer.
10. Air is pulled in through the doors and out the top for all cabinets.
11. The 2x2000 PS20D frame is a 12-pulse power bridge with an integral load-sharing reactor.
12. Power rating data for the PS20D sources assumes negligible input impedance.

IP7_024423

T-250W Specifications

Source Input Power

Input Voltage Variation	± 10%
Input Frequency	50/60 Hz ±2 Hz
Voltage Dip/Ride Through	PS20D 460 V ac ±10% PS20E 660 V ac ±10% PS20W 460 V ac ±10%

Control Power	220 V ac ±10% 3-phase 50/60 Hz
Displacement Power Factor	PS20D - 0.99 PS20E - 0.71 PS20W - Utility power factor

Non-Regenerative Source (PS20D) Example

When specifying a source, start from the process requirements and work through the motor to the inverter, and then the associated source. The following example illustrates this process (continuation of inverter application example on page 15):

1 Compute the dc bus voltage requirements of the inverter. It is assumed that the source is dedicated to the inverter specified in the application example on page 15.

$$V_{dc\ Bus} = 1.35 \times V_{Source\ line\text{-}to\text{-}line} \times (1 - Z_{pu})$$
$$= 1.35 \times 460 \times (1 - 0.05)$$
$$= 590\ V$$

Assumptions:
- Per unit transformer impedance of 5% (Z_{pu})
- Source is at 100% of its current rating.
- Transformer is properly sized for the source.

2 Compute the dc current requirements of the source.

$$I_{dc\ Source} = \frac{kW_{Shaft} \times 1000}{Eff_{Mtr} \times Eff_{Inv} \times V_{dc\ Bus}}$$
$$= \frac{150\ kW \times 1000}{0.954 \times 0.98 \times 590}$$
$$= 272\ amps$$

3 Scan the 200% for 10 sec entries in the non-regenerative source tables for a frame where the continuous current rating exceeds 272 amps. The **830** frame meets this criteria (655 amps), thus is the appropriate non-regenerative source for this application.

Required %Overload	Continuous Current (with 60 sec overloads)
100-150	830
175	730
200	655
250	539
300	448

Regenerative Source (PS20W) Example

When specifying a source, start from the process requirements and work through the motor to the inverter, and then the associated source. The following example illustrates this process (continuation of inverter application example on page 15):

1 Compute kW requirements of the inverter. It is assumed that the source is dedicated to the inverter specified in the application example on page 15. It is also assumed that the source is controlled to unify power factor.

$$kW_{Inverter} = \frac{kW_{Shaft}}{Eff_{Mtr}}$$
$$= \frac{150\ kW}{0.954}$$
$$= 158\ kW$$

2 Compute the kW requirements of the source.

$$kW_{Source} = \frac{kW_{Inverter}}{Eff_{Inverter}}$$
$$= \frac{158\ kW}{0.98}$$
$$= 161\ kW$$

3 Compute continuous current requirements for the source, based on its power requirements.

$$I_{Source\ Phase\ Current} = \frac{kW_{Source} \times 1000}{\sqrt{3} \times V_{Source\ line\text{-}to\text{-}line\ voltage} \times Eff_{Source}}$$
$$= \frac{161\ kW \times 1000}{\sqrt{3} \times 460\ V \times 0.985}$$
$$= 205\ amps$$

Note: For sources that are ALWAYS in a regenerative mode, a different equation is used to compute its power requirements.

$$kW_{Source} = kW_{Shaft} \times Eff_{Mtr} \times Eff_{Inverter}$$

4 Scan the 200% for 10 sec entries in the regenerative source tables for a frame where the continuous current rating exceeds 205 amps. The **640** frame meets this criteria (485 amps), thus is the appropriate regenerative source for this application.

Required %Overload	Continuous Current (with 60 sec overloads)
100-150	647
175	555
200	485
250	388
300	323

IP7_024424

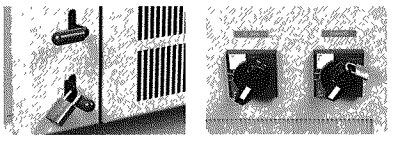
Environmental

Operating Temperature	32 to 104 °F *(0 to 40 °C)* at rated load 32 to 122 °F *(0 to 50 °C)* with derating
Storage Temperature	-13 °F to 131 °F *(- 25 °C to +55 °C)*
Humidity	5 to 95% Relative humidity, Non-Condensing
Altitude	Normal Operation: 0 to 3280 ft *(0 to 1000 m)* above sea level Derated Operation: 5% per 3280 ft *(1000 m)* altitude above 3280 ft *(1000 m)*
Vibration	10-50 Hz, <0.5 G

Mechanical

Enclosure	NEMA 1 (IP20)
Cable Entrance	Bottom is standard, top with auxiliary cabinet option
Acoustic Noise	20-160 Frame, ≤67 dB @100% load 325 Frame, ≤59 dB @100% load 650-900 Frame, ≤63 dB @100% load
Mean Time to Repair	30 minutes to replace power bridge phase leg
Dimensions	Refer to pages 14, 16, and 17
Tilt	Inverters and sources that utilize the heatpipe technology can operate up to 3 degrees from vertical standard and up to 15 degrees from vertical optionally.

Inverters Lockout



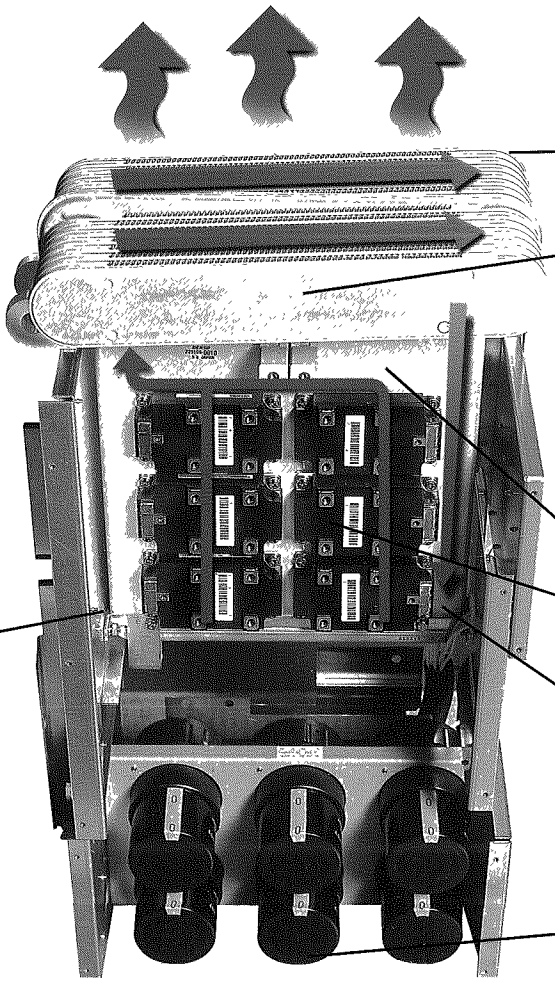
Draw-Out Style Cabinet Style

Heatpipe Technology
Used In T-250W And T-350W

This dramatic advance in power bridge design cooling technology provides:

- Significant Reduction in the footprint of the power bridge
- Lower audible noise

Awarded:
Mechanical Engineers Medal of Technology



1 Condensate To Vapor

The thermal cycle starts with the refrigerant in condensate form at the bottom of the chill plate. IGBT power switches are mounted to the multi-channeled chill plate. The heat being generated by these IGBTs vaporizes (heats) the refrigerant, moving it up through the chill plate to the bottom of the condensing unit.

1 2 3 Thermal Cycle

Condensing unit with several fins for the flow of refrigerant

2 Vapor To Condensate

The refrigerant cools while moving through the condensing unit. Cooling air is pulled vertically through the power bridge and then the condensing unit by both convection and fans mounted in the top of the cabinet.

Multi-channeled chill plate

IGBT power switches that require cooling

3 Return Of Condensate

The condensate (refrigerant in liquid form) returns to the bottom of the multi-channeled chill plate for the beginning of another thermal cycle.

Capacitors associated with the power bridge

IP7_024425

T-250W And T-350W Operator Interfaces

All Inverters And IGBT-Based Regenerative Sources

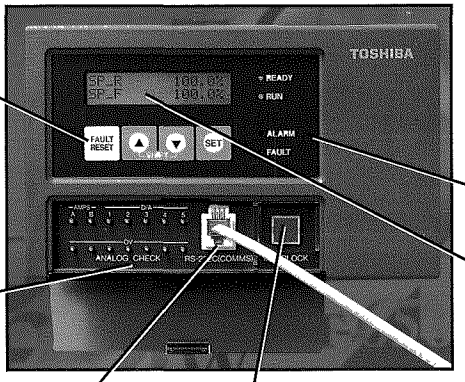
Keypad Operation

- Fault Reset button completes the clearing of an active fault condition in the drive
- Up/Down arrow buttons index the display through key variables
- Set button toggles the display between a cyclic and constant set of variables

Instrumentation Interface

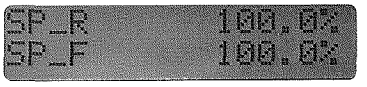
- Five analog outputs can be mapped to variables for external data logging and analysis
- Two analog outputs are dedicated to motor current feedback
- RS-232C port for local toolbox connection

All Inverters and IGBT-based Sources



Interlock button

- Interlock button disables the drive

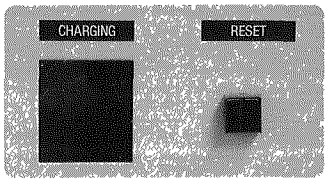


Example of variables (speed reference and speed feedback) that can be displayed in Ready/Run state

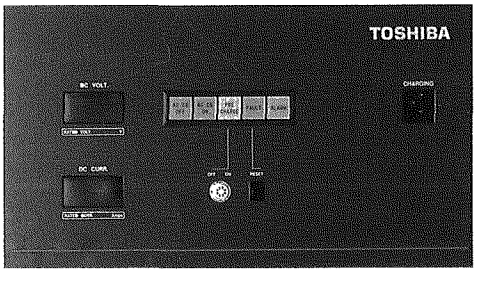
The status of the drive is indicated by the four LEDs

Status	Display
Ready/Run	Eight key variables, display two at a time, using the Up/Down buttons
Alarm	Alarms display in the order of occurrence, two at a time
Fault	Faults display in the order of occurrence, two at a time

Non-Regenerative Diode-Based Sources



PS20D 250 Frame



PS20D 830—2x2000 Frames
PS30D 1800 Frame

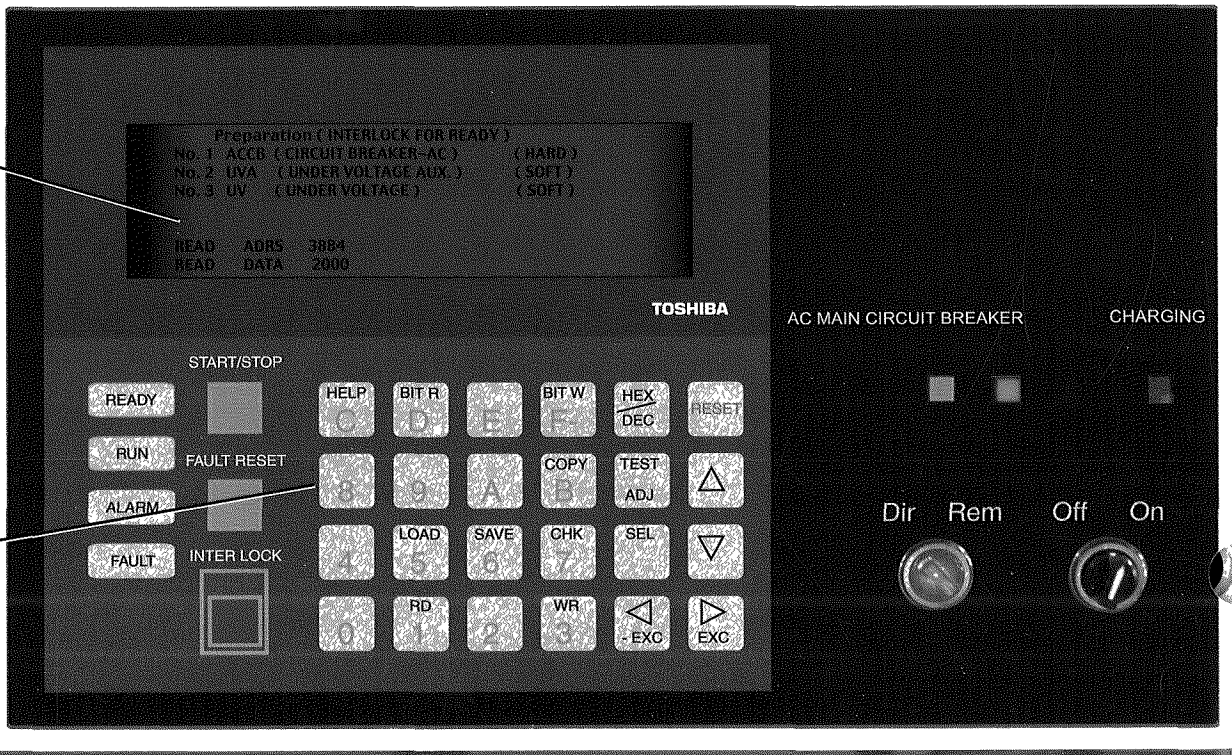
Regenerative Thyristor-Based Sources

Display Functions

- Trending
- Speed/Current response
- Digital monitoring of data
- Fault history

Keypad Functions

- Parameter editing
- PCMCIA memory card operation
- Local control



IP7_024426

DC-fed medium voltage technology

T-350W

Features

Three-Level Power Bridge

The T-350W inverters and sources have a three-level IGBT-based power bridge.

Toolbox-Based Configuration

The T-350W uses the toolbox for PC-based configuration and maintenance.

Benefits

Motor And Power System Friendly

This type of power bridge produces a smoother sine wave output, reducing:

- High frequency harmonics
- Torque ripple
- Cost of motor cabling

Animated Graphical Interface For Drive Functions

The toolbox application contains several functions that reduce the cost of commissioning and maintenance:

- Intuitive block diagrams allow the user to quickly analyze operation of the drive.
- An integrated trend window provides a more flexible tool for real-time trending than traditional strip-chart recorders.
- Several methods for parameter editing reduces the time required for drive tuneup and maintenance functions.

IP7_024427

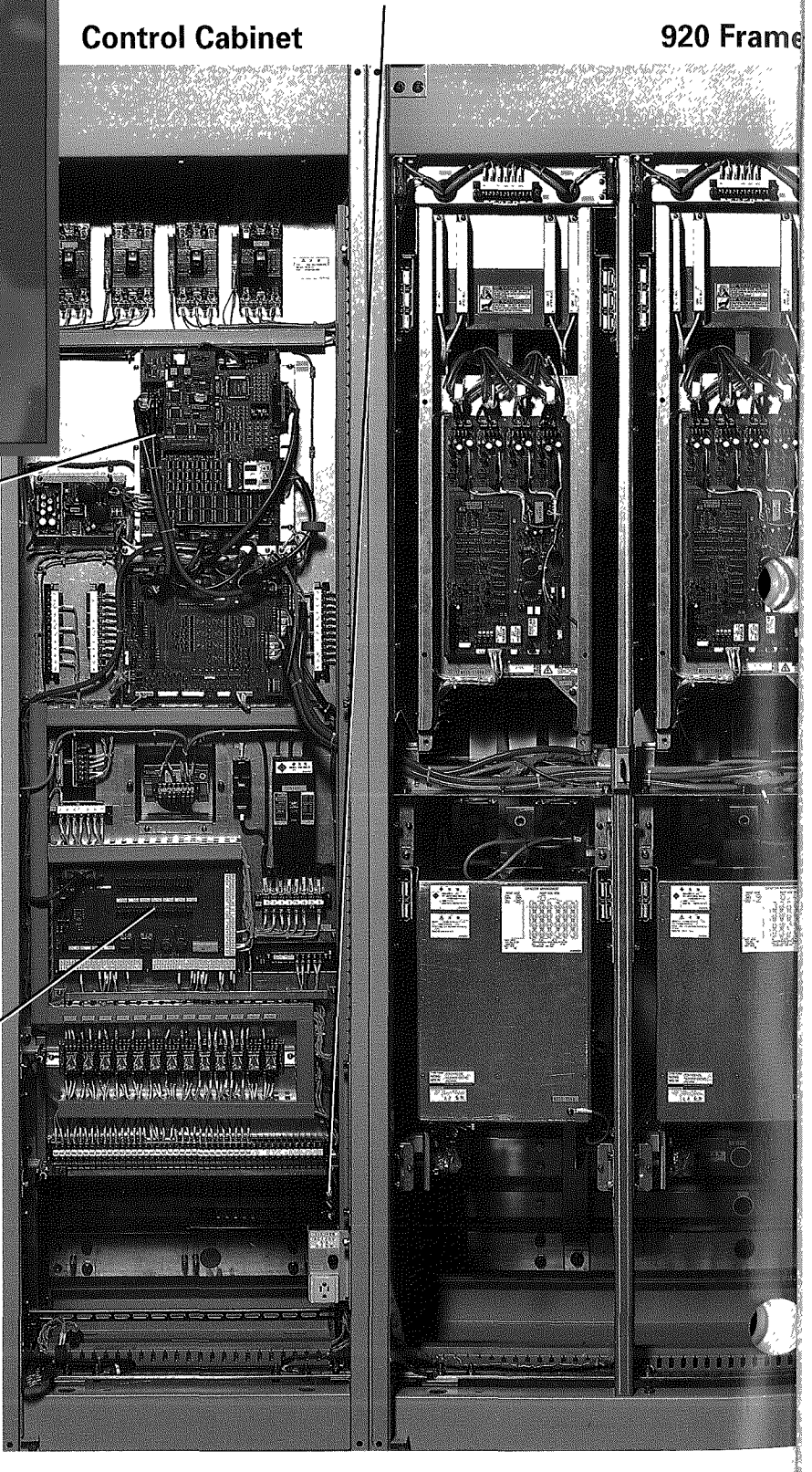
T-350W—Take A Look

Reliable medium voltage dc-fed system drive technology for high power applications:

- Modular phase-leg assemblies mounted on heavy-duty slides that **reduce the time required for maintenance**
- Heatpipe cooling technology that **reduces the size of the power bridge and audible noise generated by the cooling fans**
- Common control hardware that **lowers the cost of spare part inventory**

Incoming Control Power

The source in each lineup is fed 3-phase ac power (refer to figures on page 24 for exact voltages). The source is not shown in this particular lineup. Each source and inverter in the lineup requires a 3-phase 220 V ac control power feed. A control power disconnect is provided in each cabinet.



Control Functions

Each inverter and PS30W regenerative source share a common set of control boards. The primary control board performs several functions:

- Speed and torque regulation
- Sequencing
- I/O mapping
- Set of capture buffers

A mounting bracket is provided for an optional LAN interface board. In addition, parameters and diagnostic data are stored on a removable non-volatile PCMCIA card.

Below the control board is a circuit board that provides an interface with the gate drivers located in each phase-leg.

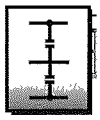
To the left of the control board is a dc power supply.

I/O Board

A resolver or encoder board is available with the inverters and PS30W regenerative sources. Both of the boards also contain 24 V dc digital and analog I/O. All I/O is terminated to a two-piece modular terminal block for ease of maintenance.

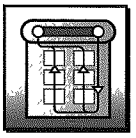
In this application, interposing relays are installed below the I/O circuit board. All field wiring is tied to the terminal block below these interposing relays.

IP7_024428



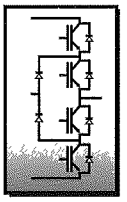
Phase Leg Capacitor Assembly

Each phase leg has a set of capacitors across the dc bus that are housed in a modular draw-out unit for ease of maintenance.



Heatpipe Cooling Technology

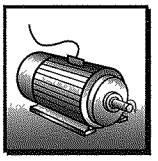
The inverters and regenerative sources utilize heatpipes to cool the IGBT power switches and capacitors. This technology reduces the footprint of the power bridge, as well as the airflow requirements, saving valuable floor space and reducing the audible noise.



IGBT Three-Level Phase-leg Assembly

The inverters and IGBT-based sources have modular three-level phase leg assemblies. Each phase leg includes:

- IGBTs with flyback diodes
- Heatpipe assembly
- IGBT gate driver circuit board with a high-speed fiber link to the controls for isolation
- Heavy-duty slides that allow easy access for maintenance activities



Motor Bus Tabs

Each phase leg has a motor bus tab located at the bottom of the modular phase leg.

DC Bus

The dc source in each lineup generates dc power for each of the inverters. The inverters then create variable frequency ac power to control the induction motor. This dc power for the lineup is conveyed on a solid copper bus mounted in the bottom of the cabinets.

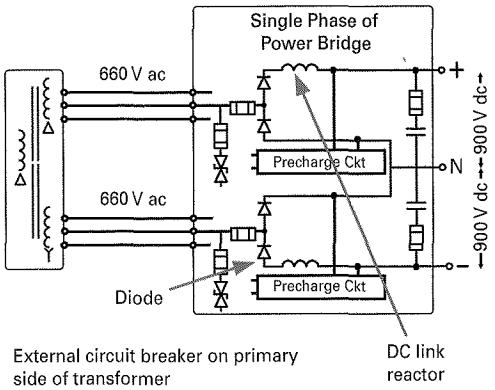
Note:
The source for this T-350W lineup is not included in this picture.

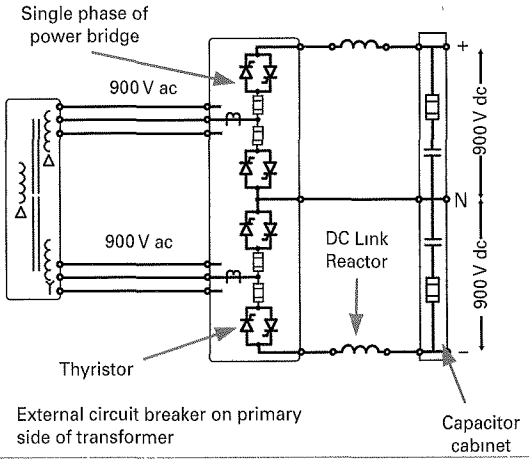
IP7_024429

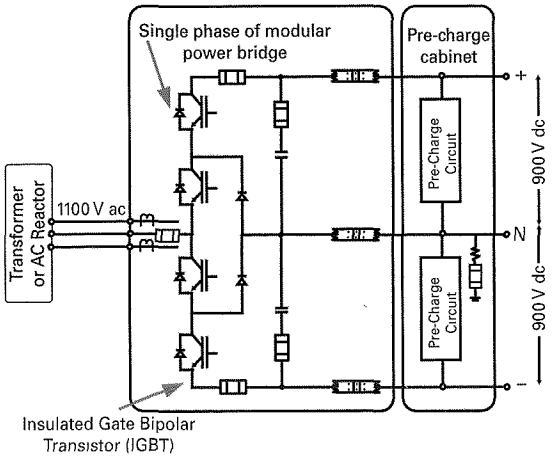
T-350W – A Medium Voltage Topology To Meet Your Application

Source Topologies

Frame (A)	Power Switch Technology
PS30D 1800	Non-Regenerative Diode-Based Power Bridge
PS30E 1800 3300	Regenerative Thyristor-Based Power Bridge
PS30W SINGLE 690 830 920 TWIN 2 x 690 2 x 830 2 x 920	Regenerative With Power Factor Correction IGBT-Based Power Bridge

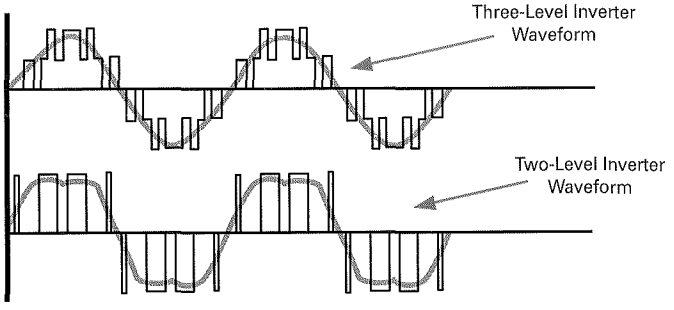


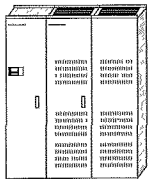




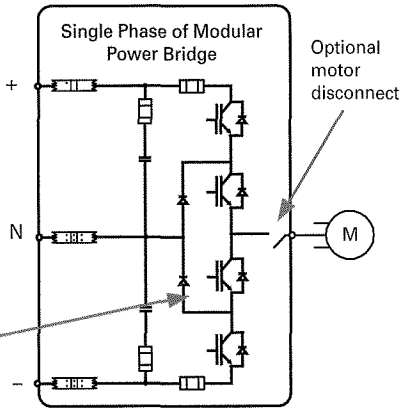
Inverter Topology (Three-Level)

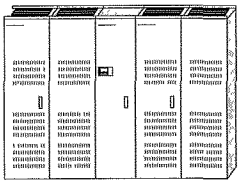
Three-level provides reduced harmonics and torque ripple applied to motor



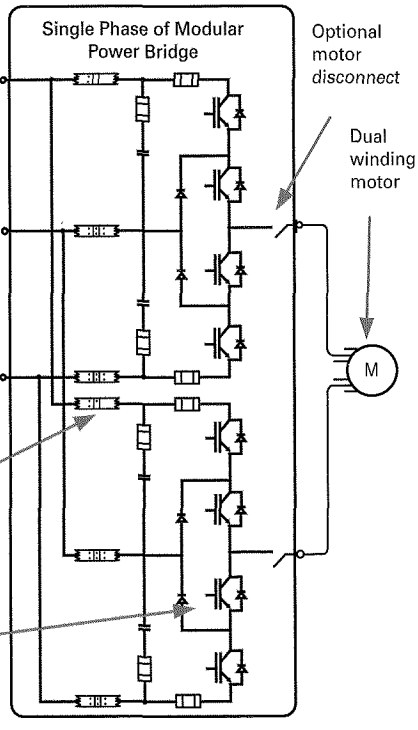


690
830
920





2 x 690
2 x 830
2 x 920

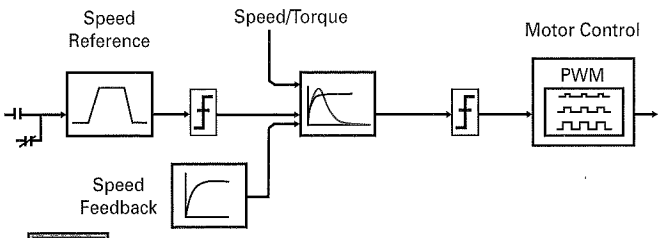


IP7_024430

A Common Control To Reduce Cost Of Ownership

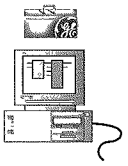
Control Functions

Feedback And Status | I/O Mapping | Capture Buffer | Sequencing



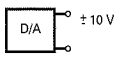
Instrumentation Interface

Toolbox



- RS-232C electrical interface
- 9.6 kbps maximum
- ISBus-Ethernet option using Innovation Series controller as gateway

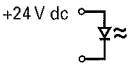
Analog Outputs



- Quantity 5 configurable, ±10 V
- Motor current A and B, ±10 V
- Configurable gain and offset
- 8-bit resolution

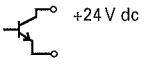
I/O Interface

Digital Inputs



- Opto-coupled, 20 mA
- Quantity 26 dedicated

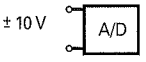
Digital Outputs



- Open collector, 40 mA maximum
- Quantity 6 configurable mapping
- Quantity 6 dedicated

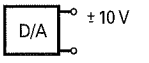
- Dry contact, 1.5 A @ 120 V ac
- Quantity 1 configurable mapping
- Quantity 3 dedicated

Analog Inputs



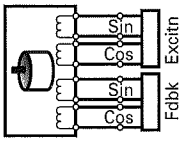
- Quantity 2, ±10 V
- Configurable mapping
- 12-bit resolution

Analog Outputs



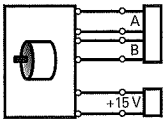
- Quantity 4, ±10 V
- Configurable gain, offset, and mapping
- 12-bit resolution

Speed Feedback Resolver Input



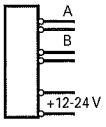
- Excitation freq of 1 kHz
- Preferred source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp

Speed Feedback Tach Input



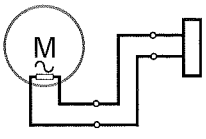
- Maximum freq of 10 kHz
- Drive provides +15 V dc

Speed Tach Follower Output



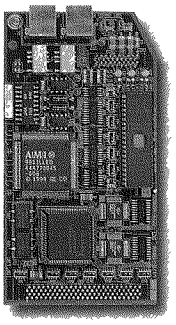
- Maximum freq of 10 kHz
- External 12-24 V dc is required

Motor Temperature Feedback



- Enhanced torque regulation motor temperature feedback
- 100 ohm platinum RTD (uses analog input with signal conditioner)

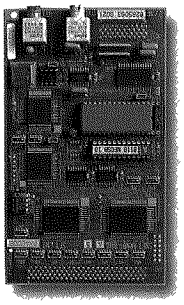
LAN Interface Options



ISBus

- Supports both run-time control (12 bytes in and 20 bytes out) and toolbox configuration/monitoring using the Innovation Series controller as a gate way between the ISBus and Ethernet
- RS-485 or optional fiber-optic bus in a synchronous ring configuration
- 5 Mbps master/slave (drive is the slave) protocol using copper or fiber, bus scan time is based on the number of nodes

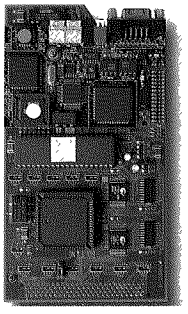
Quantity of Nodes	Bus Scan Time
2-4	1 ms
5-8	2 ms
6-16	4 ms
17-32	8 ms



TOSLINE-S20

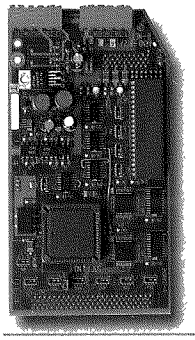
- Supports run-time control (12 bytes in and 20 bytes out) from an Innovation Series controller, Series 90-70 PLC, or V Series controller
- Drives can also exchange limited data between themselves
- Fiber-optic bus in a star configuration
- 2 Mbps peer-to-peer protocol, bus scan time is based on the number of nodes

Quantity of Nodes	Bus Scan Time
2-3	1 ms
4-5	2 ms
6-8	4 ms
9-64	25 ms



Profibus-DP

- Supports run-time control (16 Booleans and 5 integers in and out) from a Profibus-DP master controller
- Copper bus in a daisychain configuration
- 9.6 kbps to 12 Mbps master/slave protocol, bus scan time is based on the number of nodes



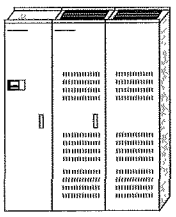
DeviceNet

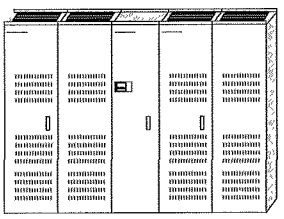
- Supports run-time control (16 Booleans and 3 integers in and out) from a DeviceNet master controller
- Copper bus in a daisychain configuration
- 125 kbps to 500 kbps master/slave protocol, bus scan time is based on the number of nodes

IP7_024431

T-350W Inverter Specifications

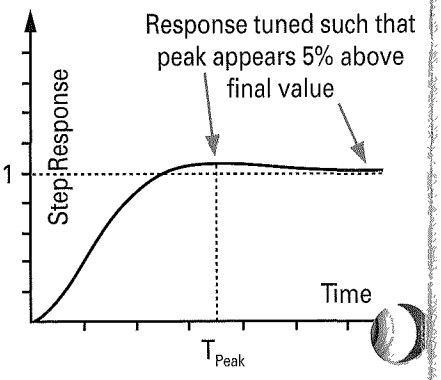
Frame	Heat Loss kW	Weight lbs (kg)	$CT_{Mtr\ Shaft}$ 150% for 60 sec @ 1250 V ac hp (kW)	Current Ratings AC Amps: Required %Overload	Current Ratings AC Amps: Continuous Current (with 120 sec overloads)
690	19	2870 (1300)	1625 (1212)	100-150 175 200 250 300	693 594 520 416 346
830	23	2870 (1300)	1948 (1453)	100-150 175 200 250 300	831 713 624 499 416
920	25	2870 (1300)	2166 (1615)	100-150 175 200 250 300	924 792 693 554 462
2x690	38	5080 (2300)	3249 (2423)	100-150 175 200 250 300	1386 1188 1040 832 692
2x830	45	5080 (2300)	3896 (2906)	100-150 175 200 250 300	1662 1426 1248 998 832
2x920	50	5080 (2300)	4333 (3231)	100-150 175 200 250 300	1848 1584 1386 1108 924





Inverter Notes

1. All cabinets are 32 in *(800 mm)* in depth. Height shown does not include required 2 in (50 mm) channel base.
2. A minimum of 20 in *(500 mm)* should be allocated above cabinet for fan maintenance.
3. Continuous Torque (CT_{Shaft}) power rating data assumes a motor efficiency of 95%, motor power factor of 0.85, ambient temperature of 32-104 °F *(0-40 °C)*, altitude up to 3300 ft *(1000 m)* above sea level.
4. The specified current ratings are continuous, to which the referenced overload can be applied.
5. Each of the inverters support bottom cable entry. Top cable entry is supported with an auxiliary cabinet.
6. Inverters require 3-phase 220 V 50/60 Hz control power.
7. Torque regulation is limited to 5-100% of speed range when using a pulse tachometer for speed feedback. Torque can be regulated at zero speed with the use of a resolver for speed feedback.
8. For high performance torque regulation, a temperature sensor is mounted in the motor. A 100 ohm platinum RTD uses analog input with a signal conditioner.
9. Speed and current regulator response is computed per the adjacent figure in rad/s (assumes a Type 2 regulator with a 5% overshoot).
10. Air is pulled in through the doors and out the top for all cabinets.
11. Door-mounted operator interface devices are detailed on page 20.
12. Equipment requires 48" (120 mm) of front access clearance for maintenance. No back access is required.



Drive Frequency Response = π / T_{Peak} (rad/s)

IP7_024432

Inverter Power Output

Output Voltage	0-1250 V
Output Frequency	0-120 Hz
Output Chopping Frequency	1.5 kHz
Inverter Type Modulation	Three-level voltage source pulse-width-modulation (PWM)
Power Semiconductor Technology	Insulated Gate Bipolar Transistor (IGBT)
Power Semiconductor	4000 V Isolation Isolation from Control

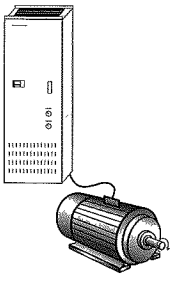
Motor Control

Resolver / Pulse Tachometer Speed Feedback	
Speed regulator accuracy	± 0.01%
Speed regulator response	42 rad/s
Torque regulator accuracy with motor temperature sensor	± 3%
Torque regulator accuracy without motor temperature sensor	± 30%
Torque regulator response	628 rad/s
Sensorless	
Speed regulator accuracy	± 1.0%
Speed regulator response	10 rad/s

Inverter Example

When specifying an inverter, start from the process requirements and work through the motor to the inverter. The following example illustrates this process:

1 Define process requirements.



kW_{Shaft} = 1200 hp *(895 kW)*

The motor delivers constant torque from zero to base speed of 900 rpm at 1250 V ac.

Duty cycle requires 200% overload for 10 sec, but has an rms duty cycle of 1200 hp *(895 kW)*.

2 Select motor based on process requirements and compute inverter kVA.

- 1200 hp *(895 kW)*
- 900 rpm
- Efficiency = 0.954
- Power factor = 0.765

$$kVA_{Inverter} = \frac{kW_{Shaft}}{Eff_{Mtr} \times PF_{Mtr}} = \frac{895\ kW}{0.954 \times 0.765} = 1226\ kVA$$

3 Compute continuous current requirements for the inverter, based on the selected motor.

$$I_{Inverter\ Phase\ Current} = \frac{kVA_{Inverter} \times 1000}{\sqrt{3} \times V_{Inverter\ line\text{-}to\text{-}line\ voltage}} = \frac{1226\ kVA \times 1000}{\sqrt{3} \times 1250\ V} = 566\ amps$$

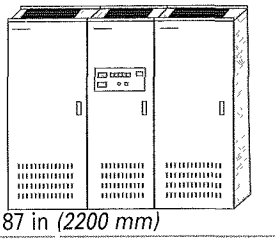
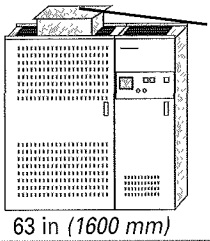
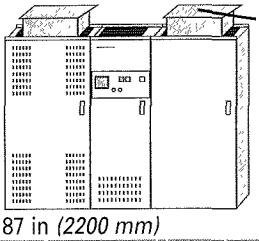
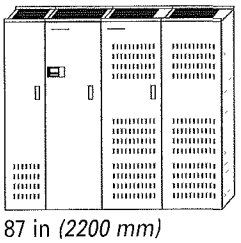
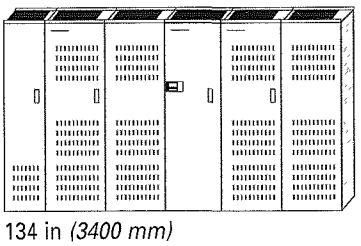
4 Select inverter based on continuous current and overload requirements.

Scan the 200% for 10 sec entries in the inverter tables for a frame where the continuous current rating exceeds 566 amps. The **830** frame meets this criteria (624 amps), thus is the appropriate inverter for this application.

Required %Overload	Continuous Current (with 120 sec overloads)
100-150	831
175	713
200	624
250	499
300	416

IP7_024433

T-350W Source Specifications

	Frame	Heat Loss kW	Weight lbs (kg)	Power 150% for 60 sec @ Rated Voltage hp (kW)	Current Ratings Amps: Required %Overload	Current Ratings Amps: Continuous Current (with 60 sec overloads)	
Non-Regenerative Diode-Based Source (PS30D)	 94 in (2375 mm) 87 in (2200 mm) 1800	15	4850 (2200)	4424 (3299)	100-150 175 200 250 300	1833 1613 1448 1191 989	DC Amps
Regenerative Thyristor-Based Source (PS30E)	 Fan assembly 103 in (2600 mm) 63 in (1600 mm) 1800 Optional capacitor cabinet is 1200 mm in width and 800 mm in depth	21.5	5100 (2300)	4424 (3299)	100-150 175 200 250 300	1833 1660 1510 1290 1100	DC Amps
	 Fan assembly 103 in (2600 mm) 87 in (2200 mm) 3300 Optional capacitor cabinet is 1200 mm in width and 800 mm in depth	41.5	5700 (2600)	8048 (6001)	100-150 175 200 250 300	3334 2990 2720 2300 1980	DC Amps
Regenerative IGBT-Based Source (PS30W)	 95 in (2406 mm) 87 in (2200 mm) 690	19	3520 (1600)	1912 (1426)	100-150 175 200 250 300	693 594 520 416 346	AC Amps
	830	23	3520 (1600)	2293 (1710)	100-150 175 200 250 300	831 713 624 499 416	AC Amps
	920	25	3520 (1600)	2550 (1901)	100-150 175 200 250 300	924 792 693 554 462	AC Amps
	 95 in (2406 mm) 134 in (3400 mm) 2x690	38	5720 (2600)	3824 (2852)	100-150 175 200 250 300	1386 1188 1040 832 692	AC Amps
	2x830	45	5720 (2600)	4586 (3420)	100-150 175 200 250 300	1662 1426 1248 998 832	AC Amps
	2x920	50	5720 (2600)	5099 (3803)	100-150 175 200 250 300	1848 1584 1386 1108 924	AC Amps

IP7_024434

Non-Regenerative Source (PS30D) Example

When specifying a source, start from the process requirements and work through the motor to the inverter, and then the associated source. The following example illustrates this process (continuation of inverter application example on page 27):

1 Compute dc bus voltage requirements of the inverter. It is assumed that the source is dedicated to the inverter specified in the application example on page 27.

$$V_{dc\ Bus} = 1.35 \times V_{Source\ line\text{-}to\text{-}line} \times (1 - Z_{pu})$$
$$= 1.35 \times 660 \times (1 - 0.05)$$
$$= 846\ V\ dc$$

Assumptions:
- Per unit transformer impedance of 5% (Z_{pu})
- Source is at 100% of its current rating.
- Transformer is properly sized for the source.

2 Compute the dc current requirements of the source.

$$I_{dc\ Source} = \frac{kW_{Inverter} \times 1000}{Eff_{Inv} \times V_{dc\ Bus} \times 2}$$
$$= \frac{895\ kW / 0.954 \times 1000}{0.985 \times 846 \times 2}$$
$$= 563\ dc\ amps$$

3 Scan the 200% for 10 sec entries in the non-regenerative source tables for a frame where the continuous current rating exceeds 563 amps. The **1800** frame meets this criteria (1448 amps), thus is the appropriate non-regenerative source for this application.

Required %Overload	Continuous Current (with 60 sec overloads)
100-150	1833
175	1613
200	1448
250	1191
300	989

Regenerative IGBT Source (PS30W) Example

When specifying a source, start from the process requirements and work through the motor to the inverter, and then the associated source. The following example illustrates this process (continuation of inverter application example on page 27):

1 Compute kW requirements of the inverter. It is assumed that the source is dedicated to the inverter specified in the application example on page 27. It is also assumed that the source is controlled to unify power factor.

$$kW_{Inverter} = \frac{kW_{Shaft}}{Eff_{Mtr}}$$
$$= \frac{895\ kW}{0.954}$$
$$= 938\ kW$$

2 Compute the kW requirements of the source.

$$kW_{Source} = \frac{kW_{Inverter}}{Eff_{Inverter}}$$
$$= \frac{938\ kW}{0.98}$$
$$= 957 kW$$

3 Compute continuous current requirements for the source, based on its power requirements.

$$I_{Source\ Phase\ Current} = \frac{kW_{Source} \times 1000}{\sqrt{3} \times V_{Source\ line\text{-}to\text{-}line\ voltage} \times Eff_{Source}}$$
$$= \frac{957\ kW \times 1000}{\sqrt{3} \times 1100\ V \times 0.98}$$
$$= 513\ ac\ amps$$

4 Scan the 200% for 10 sec entries in the regenerative source tables for a frame where the continuous current rating exceeds 513 amps. The **690** frame meets this criteria (520 amps), thus is the appropriate regenerative source for this application.

Required %Overload	Continuous Current (with 60 sec overloads)
100-150	693
175	594
200	520
250	416
300	346

Source Notes

1. PS30D and PS20W sources are 32 in *(800 mm)* in depth, the PS30E sources are 40 in *(1000 mm)* in depth.
2. A minimum of 20 in *(500 mm)* should be allocated above cabinet for fan maintenance. All dimensions do not include required 2 in (50 mm) channel base.
3. The specified current ratings are continuous, to which the referenced overload can be applied. Refer to application example on this page.
4. Each of the sources support bottom cable entry. Top cable entry is supported with an auxiliary cabinet.
5. Each of the sources require 3-phase 220 V 50/60 Hz control power.
6. All sources require an external breaker on the primary side of the transformer.
7. Air is pulled in through the doors and out the top for all cabinets.
8. Current ratings for the PS30D and PS30E sources are in dc amps.
9. The PS30E requires 24 in (600 mm) back access clearance for maintenance.
10. Door-mounted operator interface devices are detailed on page 20.
11. Current ratings for the PS30W sources are in ac amps.

IP7_024435

T-350W Specifications

Source Input Power

Input Voltage Variation	PS30D - ±10% PS30E - ±10% PS30W - +10%, -0%
Input Frequency	50/60 Hz ±2 Hz
Voltage Dip/Ride Through	PS30D 700 V ac ±10% PS30E 900 V ac ±10% PS30W 1100 V ac ±10%
Control Power	220 V ac ±10% 3-phase 50/60 Hz
Displacement Power Factor	PS30D - 0.99 PS30E - 0.71 PS30W - Unity Power Factor

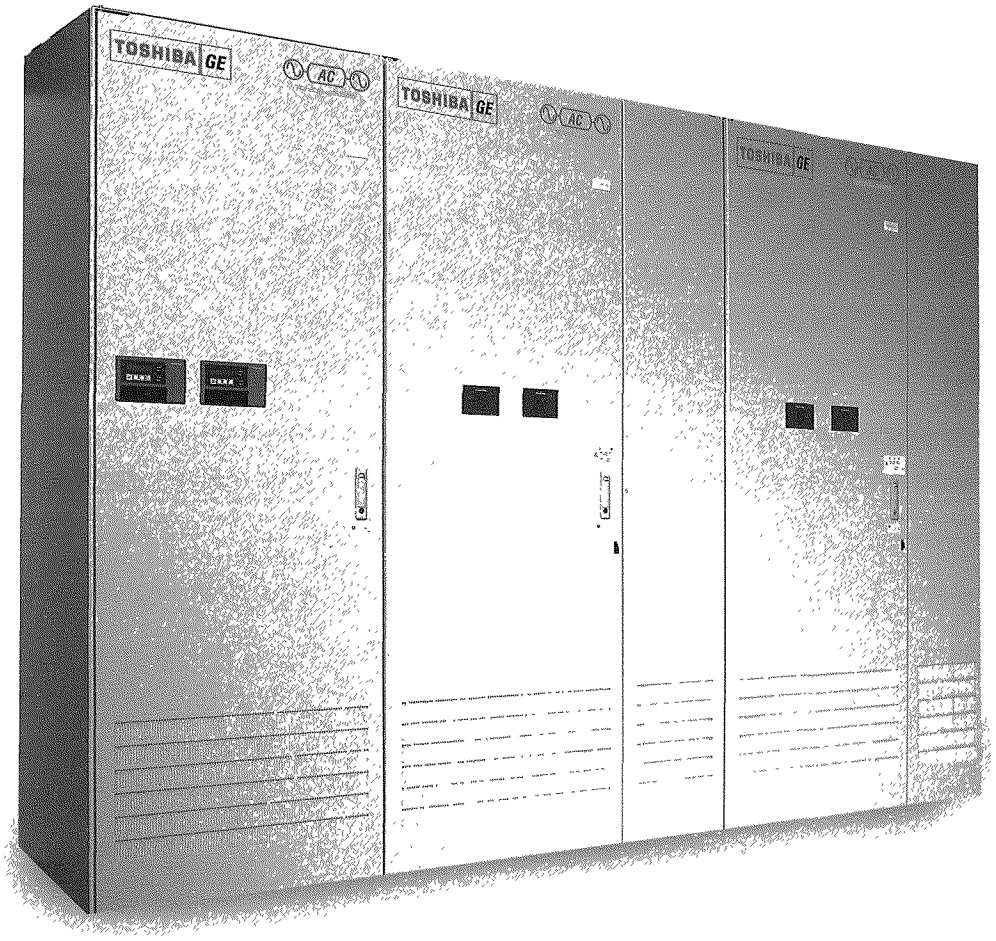
Environmental

Operating Temperature	32 to 104 °F *(0 to 40 °C)* at rated load 32 to 122 °F *(0 to 50 °C)* with derating
Storage Temperature	-13 °F to 131 °F *(- 25 °C to +55 °C)*
Humidity	5 to 95% Relative Humidity, Non-Condensing
Altitude	Normal Operation: 0 to 3280 ft *(0 to 1000 m)* above sea level Derate 5% per 3280 ft *(1000 m)* altitude above 3280 ft *(1000 m)*
Vibration	10-50 Hz, <0.5 G

Mechanical

Enclosure	NEMA 1 (IP 20)
Cable Entrance	Bottom is standard, top with auxiliary cabinet
Acoustic Noise	66-68 dB @ 150% OL, 39 in *(1 m)* from cabinet in all directions, 59 in *(1.5 m)* in height above the floor
Dimensions	Refer to pages 26 and 28
Mean Time to Repair	30 minutes to replace power bridge phase leg
Tilt	Inverters and sources that utilize the heatpipe technology can operate up to three degrees from vertical standard and up to 15 degrees from vertical optionally.

IP7_024436



High performance in MV applications

T-650W

Features

IEGT-Based Power Bridge
High power Injection Enhanced Gate Transistors (IEGTs) are used in the power bridge for both the inverter and source.

Common Modular Phase Leg Assembly
A common modular phase assembly is used for both the inverter and source.

Water-Cooled Power Bridge
Integral and stand-alone forms of water-cooling technology are offered for the various T-650W power bridge configurations.

Benefits

Regenerative At Unity Power Factor
Fully regenerative topology provides bi-directional power flow for your process at unity power factor without the traditional harmonic filters or var-compensation equipment.

Wide Range Of Power Capacity
In the three power bridge configurations, the T-650W can control large induction or synchronous motors from 4000 hp *(3000 kW)* to 34500 hp *(25725 kW)*.

Reduced Maintenance Expense
This common phase leg assembly reduces the cost of training, spare parts, and mean time to repair.

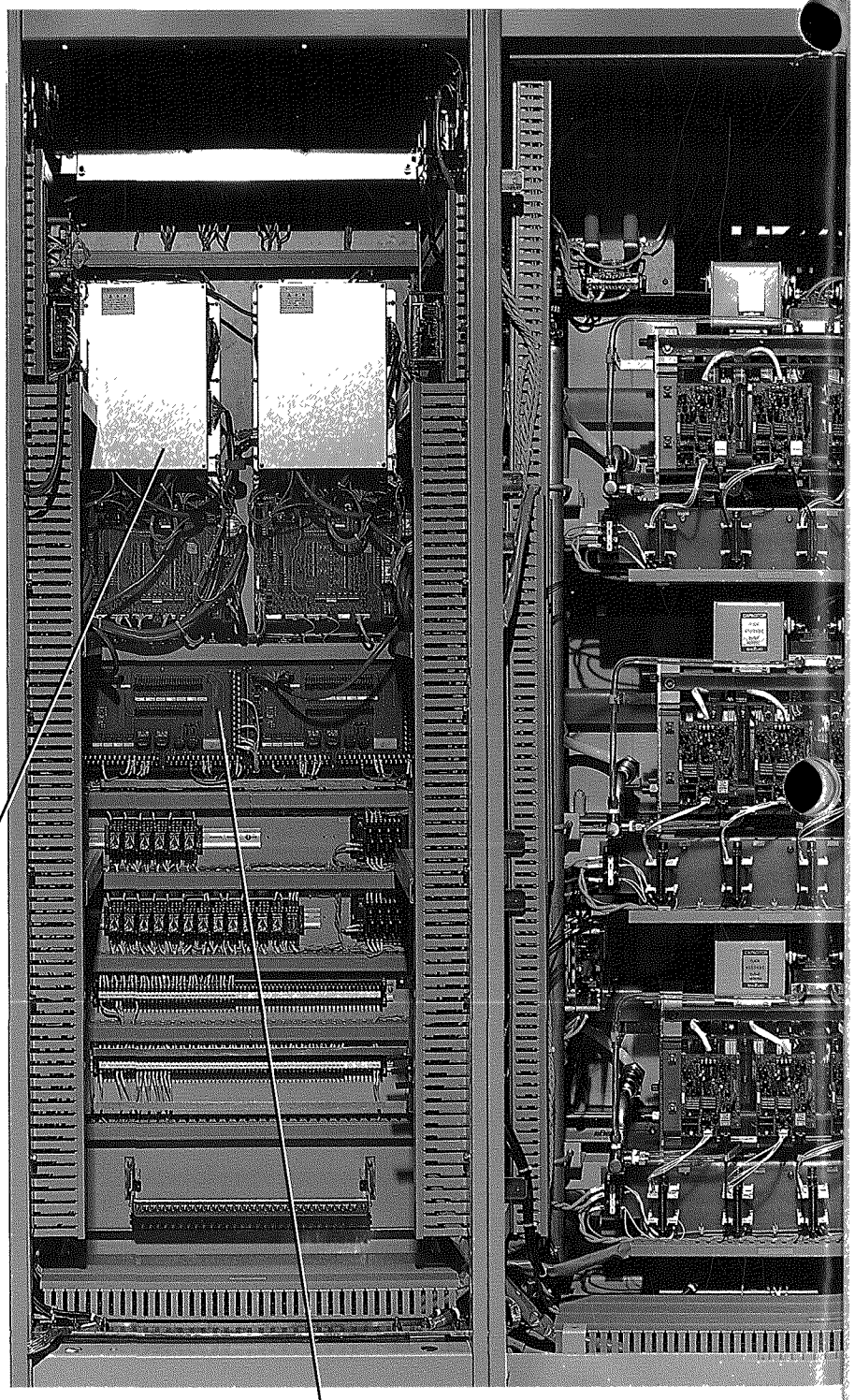
Smaller Footprint
This form of cooling technology reduces the footprint of the equipment, lowering the associated building infrastructure cost.

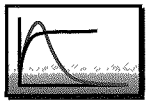
IP7_024437

T-650W – Take A Look

State-of-the-Art Technology:

- Injection Enhanced Gate Transistor (IEGT)-based source and inverter provides power to the process at unity power factor with minimum harmonic distortion
- Water-cooling technology for the power bridge reduces the footprint of the equipment saving valuable space in your factory
- Modular design for power bridge minimizes the time required for any maintenance activities





Control Functions

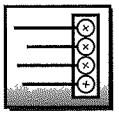
The inverter and regenerative source share a common set of boards.

The primary control board performs several functions:

- Speed and torque regulation
- Sequencing
- I/O mapping
- Set of capture buffers

A mounting bracket is provided for an optional LAN interface board. In addition, the parameters and diagnostic data are stored on a removable non-volatile PCMCIA board.

Below the control board is a circuit board that provides a fiber interface with the gate drivers located in each phase leg.



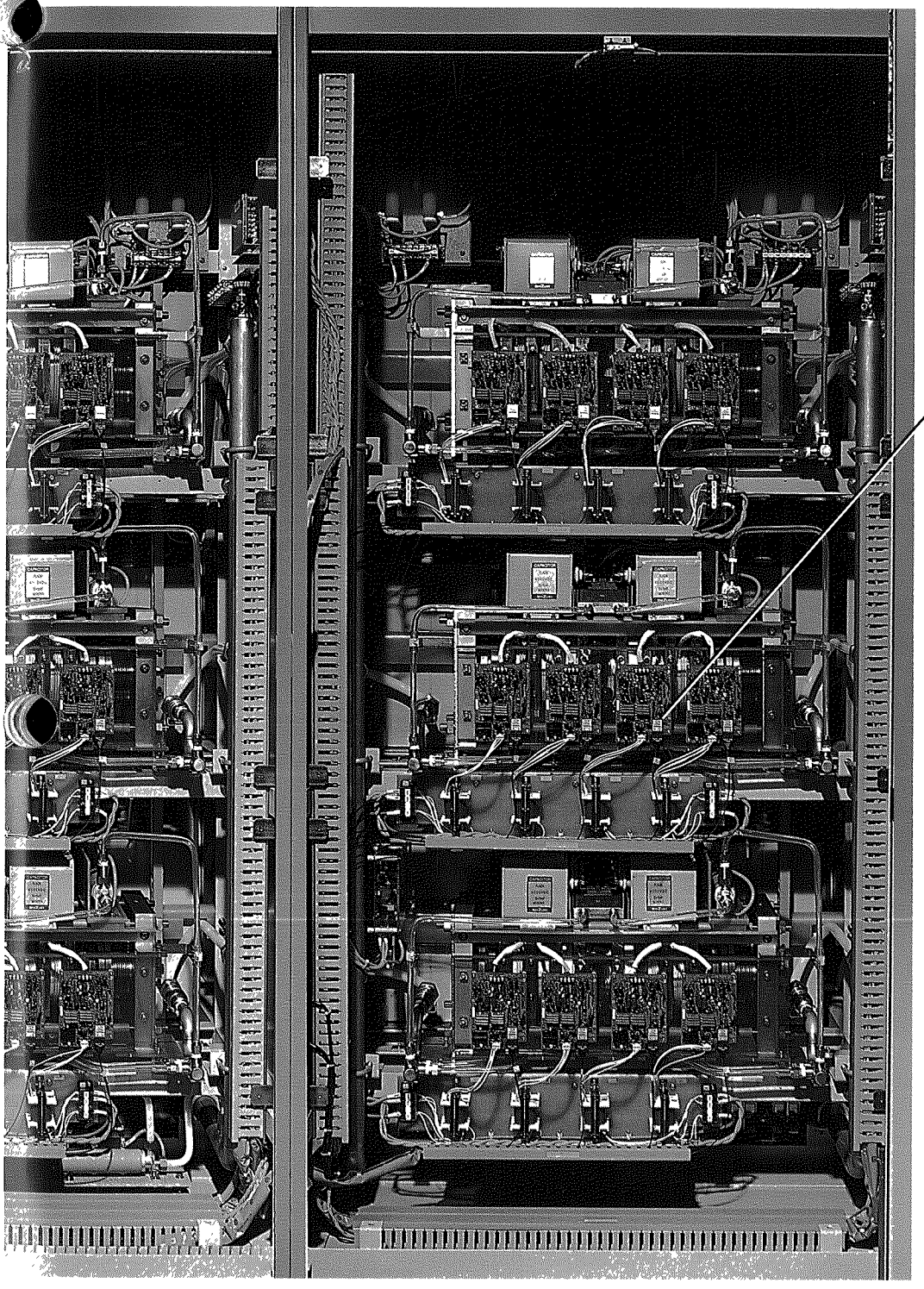
I/O Board

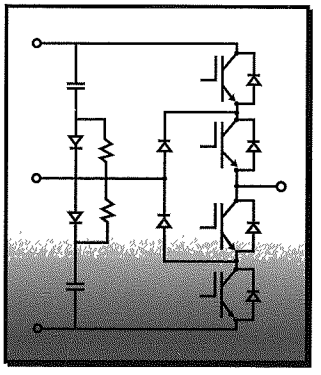
A resolver or encoder board is available with the inverter and regenerative source. Both of the boards contain 24 V dc digital and analog I/O. All I/O is terminated to a two-piece modular terminal block for ease of maintenance.

In this application, interposing relays are installed below the I/O circuit board. All field wiring is tied to the terminal block below these interposing relays.

IP7_024438

Inverter



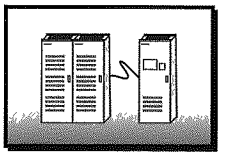


IEGT Three-Level Phase Leg Assembly

The drive has a total of six identical Injection Enhanced Gate Transistor (IEGT) phase leg assemblies in the source and inverter.

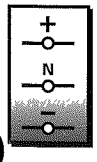
The modular draw-out assembly includes:

- Four IEGT power semiconductors with integrated flyback diodes
- Neutral-point clamp diodes
- Water-cooled piping assembly with quick disconnect fittings
- IEGT gate driver circuit board
- Feedback control circuitry
- DC clamp snubber mounted on top



Remote Control

Modular construction allows the power converter and control cabinets to be installed up to 100 m apart. This optimizes the use of space in your equipment room.



DC Bus

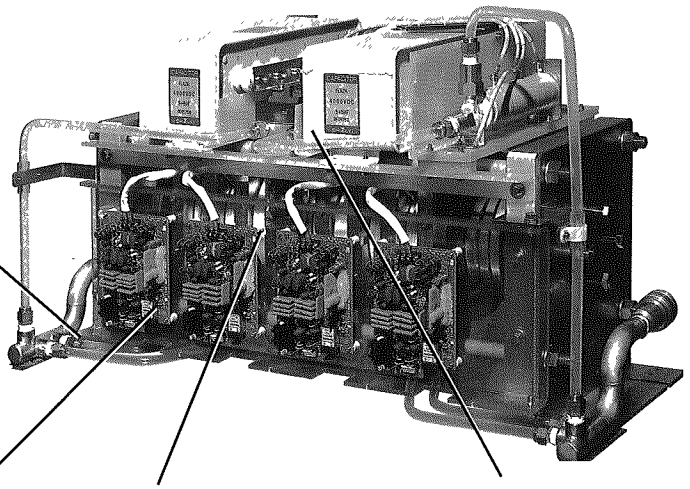
The source generates dc power for the inverter. The inverter then creates variable frequency ac power to control the induction or synchronous motor. The dc power between the source and inverter is conveyed on a solid copper bus behind the phase leg assemblies in both cabinets.

Note:
Required water-conditioning equipment is not shown in this lineup.

IP7_024439

T-650W– Three-Level IEGT Source/Inverter Topology

Three-Level Phase Leg Assembly For Both Source And Inverter

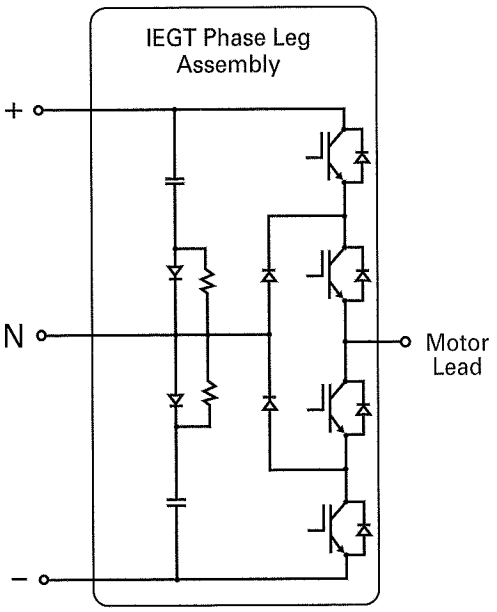


Quick disconnect fittings for the cooling system reduces mean time to repair.

Compact gate driver assemblies due to low power switching requirements of the IEGT devices

IEGT devices with integral forward and clamp diodes allowing a very compact phase leg stack, reducing the footprint versus previous technology

DC clamp snubber circuit used to absorb the energy generated in turning off the IEGTs



IEGT Technology Dramatically Lowers Cost of Ownership

The Injection Enhanced Gate Transistor (IEGT) is a breakthrough in power switch technology. The following set of features and associated benefits detail how this device lowers your cost of ownership versus previous main drive technology.

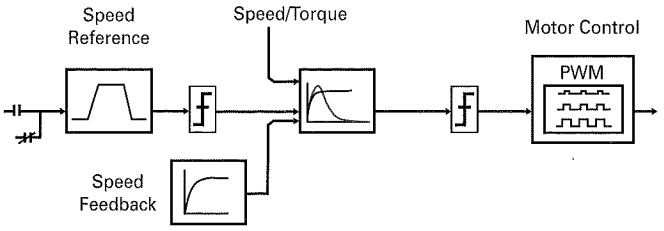
Features	Benefits
Low Voltage Gate Drive Given that the IEGT is a MOS structure, it can be gated (turned on/off) with ±15 V.	**High Efficiency And Small Size** A very compact phase leg assembly is achieved with: • A reduction in snubber circuitry • Integral forward diodes • Integral clamp diodes
Minimal Snubber Circuitry With the high dV/dt capability of the IEGT, there is only need for a small dc clamp snubber circuit.	**Higher Performance** The reduction in snubber circuitry allows a higher chopping frequency, lowering the torque ripple applied to the motor and harmonics fed back into the power system.
High-Speed Switching The IEGT is switched at a rate of 500 Hz in this application.	**Motor And Power System Friendly** The high-speed switching coupled with the three-level power bridge design delivers a smooth sine wave to the motor and power system.

IP7_024440

A Common Control To Reduce Cost Of Ownership

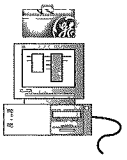
Control Functions

Feedback And Status | I/O Mapping | Capture Buffer | Sequencing



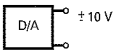
Instrumentation Interface

Toolbox Serial Interface



- RS-232C electrical interface
- 9.6 kB maximum

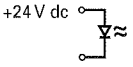
Analog Outputs



- Quantity 5 configurable, ±10 V
- Motor current A and B, ±10 V
- Configurable gain and offset
- 8-bit resolution

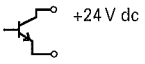
I/O Interface

Digital Inputs



- Opto-coupled, 20 mA
- Quantity 26 dedicated

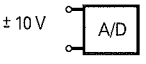
Digital Outputs



- Open collector, 40 mA maximum
- Quantity 6 configurable mapping
- Quantity 6 dedicated

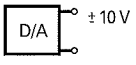
- Dry contact, 1.5 A @ 120 V ac
- Quantity 1 configurable mapping
- Quantity 3 dedicated

Analog Inputs



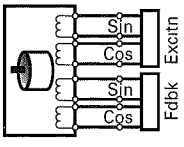
- Quantity 2, ±10 V
- 12-bit resolution

Analog Outputs



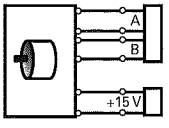
- Quantity 4, ±10 V
- Configurable gain and offset
- 12-bit resolution

Speed Feedback Resolver Input



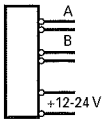
- Excitation freq of 1 kHz
- Preferred source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp

Speed Feedback Tach Input



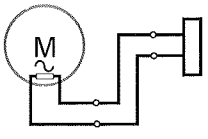
- Maximum freq of 10 kHz
- Drive provides +15 V dc

Speed Tach Follower Output



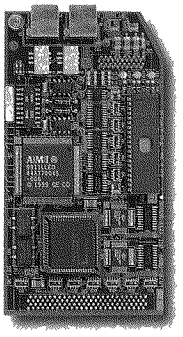
- Maximum freq of 10 kHz
- External 12-24 V dc is required.

Motor Temperature Feedback



- Enhanced torque regulation motor temperature feedback
- 100 ohm platinum RTD (uses analog input with signal conditioner)

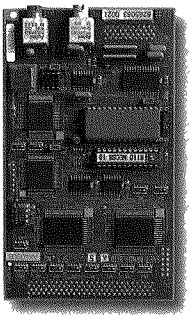
LAN Interface Options



ISBus

- Supports both run-time control (12 bytes in and 20 bytes out) and toolbox configuration/monitoring using the Innovation Series controller as a gateway between the ISBus and Ethernet
- RS-485 or optional fiber-optic bus in a synchronous ring configuration
- 5 Mbps master/slave (drive is the slave) protocol using copper or fiber, bus scan time is based on the number of nodes

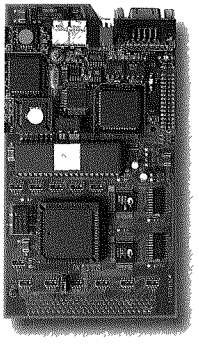
Quantity of Nodes	Bus Scan Time
2-4	1 ms
5-8	2 ms
6-16	4 ms
17-32	8 ms



TOSLINE-S20

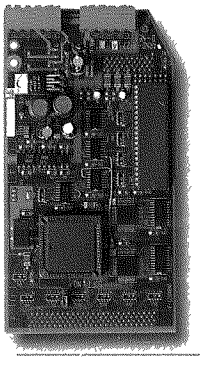
- Supports run-time control (12 bytes in and 20 bytes out) from an Innovation Series controller, Series 90-70 PLC, or V Series controller
- Drives can also exchange data between themselves
- Fiber-optic bus in a star configuration
- 2 Mbps peer-to-peer protocol, bus scan time is based on the number of nodes

Quantity of Nodes	Bus Scan Time
2-3	1 ms
4-5	2 ms
6-8	4 ms
9-64	25 ms



Profibus-DP

- Supports run-time control (16 Booleans and 5 integers in and out) from a Profibus-DP master controller
- Copper bus in a daisychain configuration
- 9.6 kbps to 12 Mbps master-slave protocol, bus scan time is based on the number of nodes



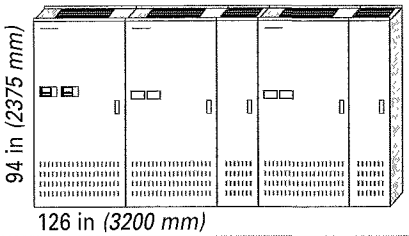
DeviceNet

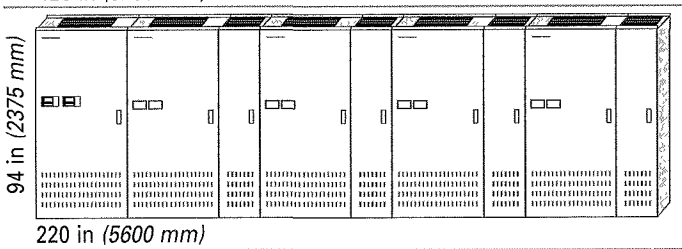
- Supports run-time control (16 Booleans and 3 integers in and out) from a DeviceNet master controller
- Copper bus in a daisychain configuration
- 125 kbps to 500 kbps master/slave protocol, bus scan time is based on the number of nodes

IP7_024441

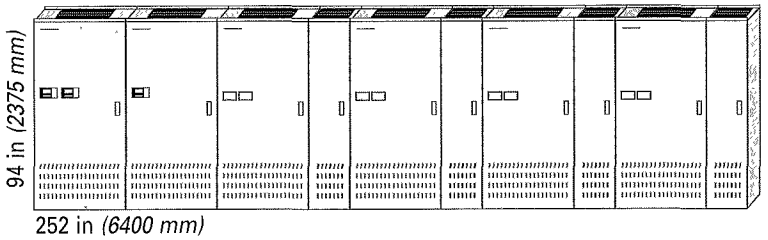
T-650W Rating Data

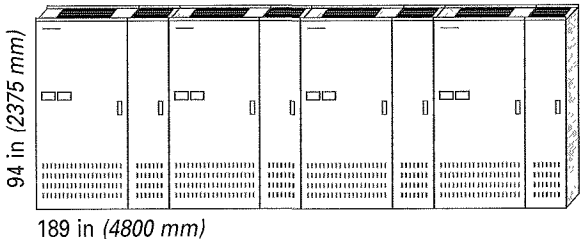
Frame	Weight lbs (*kg*)	$CT_{Mtr\ Shaft}$ 150% for 60 sec @ 3300 V ac hp (*kW*)	Current Ratings AC Amps @ 500 Hz, 3300 Vac: Required %Overload	Continuous Current (with 120 sec overloads)
1400	8600 (*3900*)	8665 (*6462*)	100-150 175 200 250	1400 1200 1050 840
2800	16540 (*7500*)	17330 (*12923*)	100-150 175 200 250	2800 2400 2100 1680
5600	33070 (*15000*)	34660 (*25847*)	100-150 175 200 250	5600 4800 4200 3360





Dual-winding motor or external AC output reactors





Dual-winding motor and external AC output reactors

Water-Conditioning Equipment

Item	Capacity (*kW*)	Width in (*mm*)	Depth in (*mm*)	Height in (*mm*)	Weight lbs (*kg*)	Notes
Integral to lineup	(*100*)	39 (*1000*)	63 (*1590*)	94 (*2375*)	3530 (*1600*)	Capacity for one source/inverter, 350 l/min
Integral to lineup	(*200*)	48 (*1200*)	63 (*1590*)	94 (*2375*)	4410 (*2000*)	Capacity for two sources/inverters, 700 l/min
Separate cabinet	(*100*)	78 (*2000*)	78 (*2000*)	99 (*2500*)	3300 (*1500*)	Plant water required, 350 l/min
Separate cabinet	(*200*)	78 (*2000*)	78 (*2000*)	99 (*2500*)	3960 (*1800*)	Plant water required, 700 l/min
Separate cabinet	(*400*)	118 (*3000*)	78 (*2000*)	99 (*2500*)	5500 (*2500*)	Plant water required, 1400 l/min
Separate cabinet	(*800*)	118 (*3000*)	78 (*2000*)	99 (*2500*)	6270 (*2850*)	Plant water required, 2800 l/min
Separate cabinet	(*1000*)	118 (*3000*)	78 (*2000*)	99 (*2500*)	7700 (*3500*)	Plant water required, 3500 l/min

IP7_024442

T-650W Specifications

Power Input

Input Voltage Variation	±10%
Input Frequency	50/60Hz
Voltage Dip/Ride Through	±5%
Control Power	220 V ac ±10% 3-phase 50/60 Hz
Displacement PF	Will maintain unity power factor and optionally provide leading or lagging vars

Power Output

Output Voltage	0 -3140 V (synchronous motor) 0 -3300 V (induction motor)
Output Frequency	0 - 60 Hz
Output Chopping Frequency	500 Hz
Inverter Type Modulation	Three-level voltage source Pulse Width Modulation (PWM)
Power Semiconductor	Injection Enhanced Gate Transistor (IEGT)

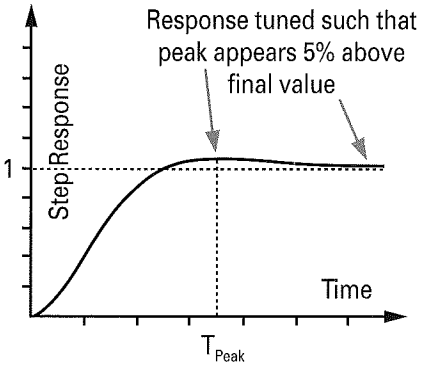
Motor Control

Resolver/Pulse Tachometer Speed Feedback

- Speed regulator accuracy ±0.01%
- Speed regulator response 42 rad/s
- Torque regulator accuracy with motor temperature sensor ±3%
- Torque regulator response 628 rad/s

Notes

1. Power bridge cabinets are 65 in *(1650 mm)* in depth. Control cabinets are 28 in *(700 mm)* in depth. Dimensions do not include required 2 in (50 mm) channel base.
2. A minimum of 20 in *(500 mm)* should be allocated for fan maintenance.
3. Continuous Torque (CT_{Shaft}) power rating data assumes a motor efficiency of 95%, motor power factor of 0.85, ambient temperature of 32-104 °F *(0-40 °C)*, altitude up to 3300 ft *(1000 m)* above sea level.
4. The specified current ratings are continuous, to which the referenced overload can be applied.
5. Dimensions shown are for induction motor control only. Synchronous motor control requires additional 32 in (800 mm) or 48 in (1200 mm) field exciter cabinet (ratings as shown on page 45).
6. Each of the inverters require 3-phase 220 V 50/60 Hz control power.
7. Torque regulation is limited to 5-100% of speed range when using a pulse tachometer for speed feedback.
8. For high performance torque regulation, a temperature sensor is mounted in the motor. A 100 ohm platinum RTD that uses an analog input with signal conditioner.
9. Speed and current regulator response is computed per the adjacent figure in rad/s (assumes a Type 2 regulator with a 5% overshoot).
10. Air is pulled in through the doors and out through the top for all cabinets.
11. All T-650W cabinets require back access for maintenance.
12. The required water-conditioning equipment is not included in the lineups shown on page 36.
13. Water-cooling equipment temperature specifications:
    Inlet 32 to 90 °F *(0 to 32 °C)*
    Outlet 32 to 97 °F *(0 to 36 °C)*
14. Power bridge cabinets require 32 in (800 mm) of rear access clearance for maintenance.
15. Water connections to water cooling unit are near the floor in the rear of the power converter cabinets. The flange is 150 mm JIS-10K50A. Stainless piping to water-conditioning equipment is required.



Drive Frequency Response = π / T_{Peak} (rad/s)

IP7_024443

T-650W Specifications

Environmental

Operating Temperature	32 to 104 °F *(0 to 40 °C)* at rated load 32 to 122 °F *(0 to 50 °C)* with derating
Storage Temperature	-13 °F to 131 °F *(- 25 °C to +55 °C)*
Humidity	5 to 95% Relative humidity, Non-Condensing
Altitude	Normal Operation: 0 to 3280 ft *(0 to 1000 m)* above sea level Derate 5% per 3280 ft *(1000 m)* altitude above 3280 ft *(1000 m)*
Vibration	10-50 Hz, <0.5 G

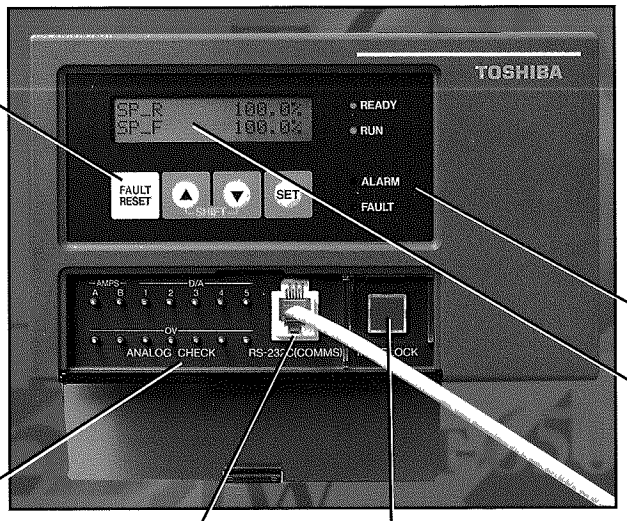
Mechanical

Enclosure	NEMA 1 (IP 20)
Cable Entrance	Top or Bottom entry
Acoustic Noise	66-68 dB @ 150% OL, 39 in *(1 m)* from cabinet in all directions, 59 in *(1.5 m)* in height above the floor
Dimensions	Refer to page 36
Mean Time to Repair	60 minutes to replace power bridge phase leg

T-650W Operator Interface

Keypad Operation

- Fault Reset button completes the clearing of an active fault condition in the drive
- Up/Down arrow buttons index the display through key variables
- Set button toggles the display between a cyclic and constant set of variables



Example of variables (speed reference and speed feedback) that can be displayed in Ready/Run state

The status of the drive is indicated by the four LEDs.

Status	Display
Ready/Run	Eight key variables, display two at a time, using the Up/Down buttons
Alarm	Alarms display in the order of occurrence, two at a time
Fault	Faults display in the order of occurrence, two at a time

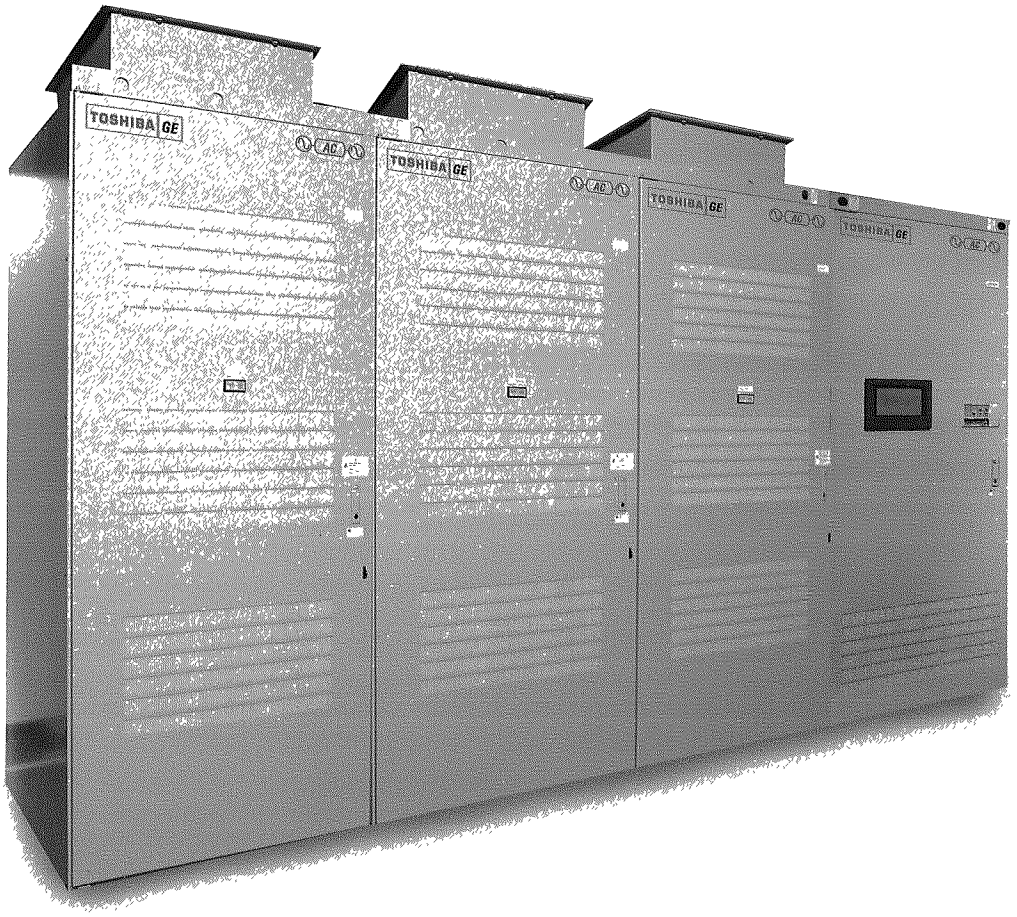
Instrumentation Interface

- Five analog outputs can be mapped to variables for external data logging and analysis
- Two analog outputs are dedicated to motor current feedback
- RS-232C port for local toolbox connection

Interlock button

- Interlock button disables the drive

IP7_024444



A standard for **Reliability** in medium voltage ac system drive applications.

TOSCYCLO drives offer **high power** and **maximum reliability** for your critical duty ac drive needs.

T-850W

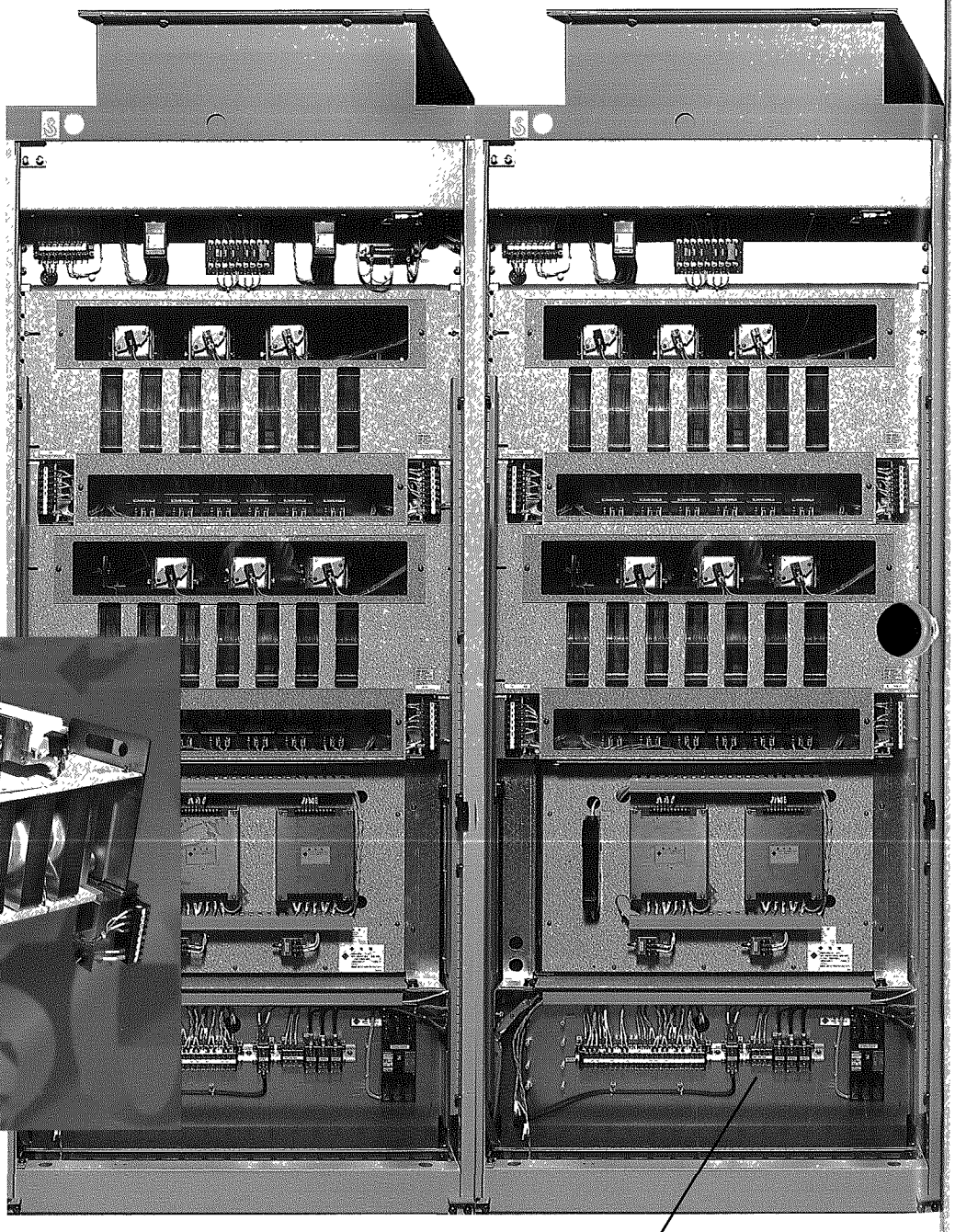
Features	Benefits
Advanced efficiency and power factor regulating technology	Minimizes kvar and kW charges from your utility.
Proven technology	Years of trouble-free operation.
VME-based control	Eases connectivity to third party LANs and controls.
Windows-based Control System Toolbox for configuration and maintenance	Intuitive block diagrams allow the user to quickly analyze operation of the drive. An integrated trend window provides a more flexible tool for real-time trending than traditional strip chart recorders. Several mechanisms for parameter editing reduces the time required for drive tune-up and maintenance functions.
Several LAN Options: • ISBus • Profibus-DP • DeviceNet • TOSLINE-S20	For virtually all controller platforms, these LAN options provide seamless integration with the rest of your factory.

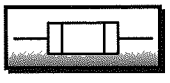
IP7_024445

T-850W —Take A Look

Robust Technology

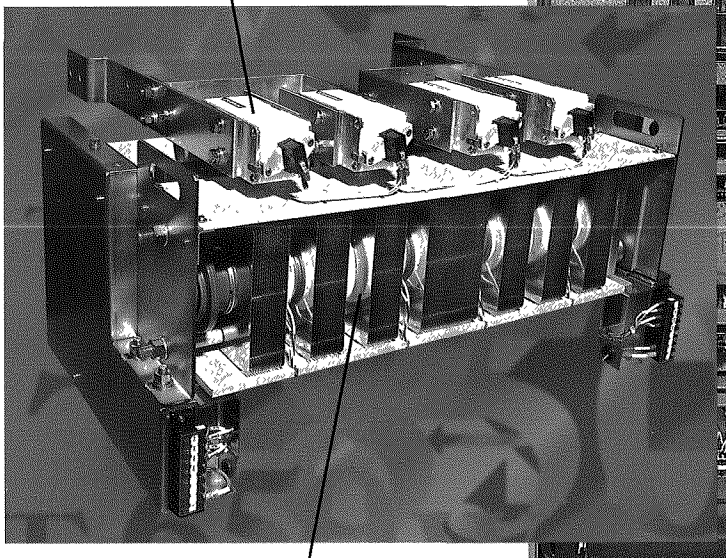
- Thyristor-based highly efficient power conversion in a compact package
- Over 200 systems installed and working around the world

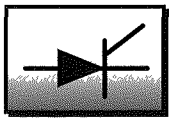




Thyristor Leg Fuses

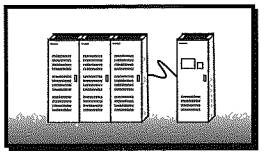
Designed to prevent even the worst faults from being more than a simple component replacement.





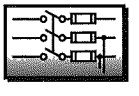
Thyristors

Large capacity power devices result in compact equipment and improved reliability. Conventional electrically triggered thyristors are used for systems with voltages up to 3300 V ac. For higher voltages, light triggered thyristors are supplied.



Remote Control

Modular construction allows the thyristor and control cabinets to be installed up to 200 m apart. This optimizes the use of space in your equipment room.

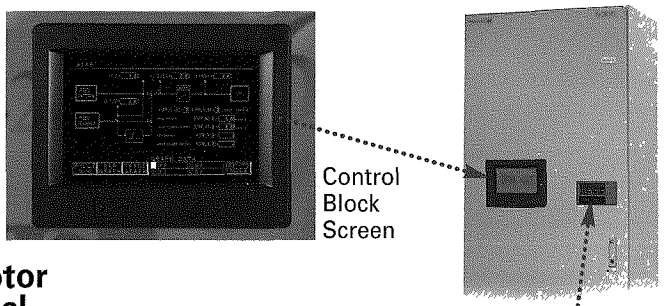


Incoming Power (Main and Control)

3-phase 220 V ac control power is fe to each cabinet in the lineup. A contr power disconnect is provided in each cabinet. All main power connections are made in the rear of each cabinet.

IP7_024446

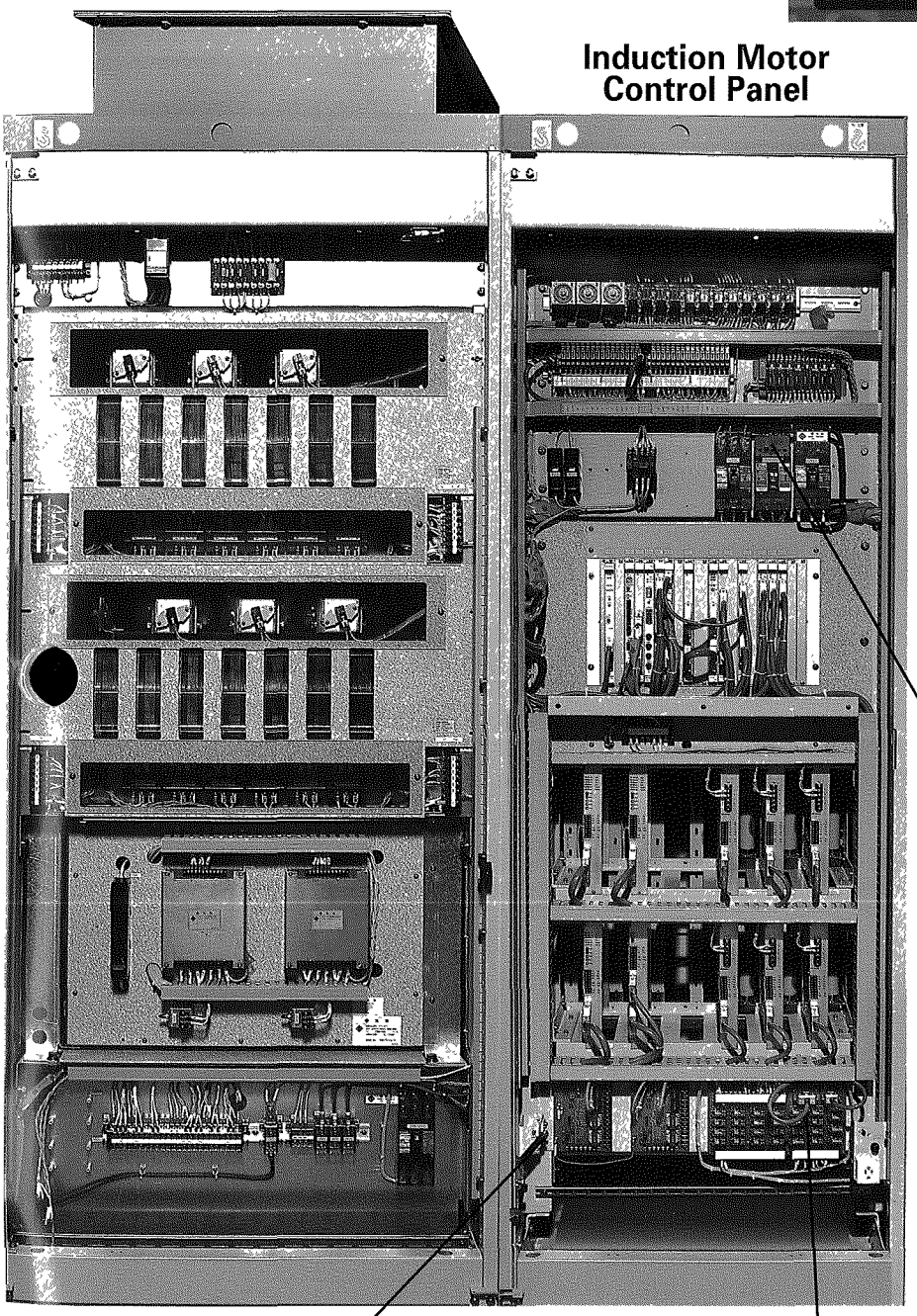
Integrated in the door of the control cabinet is a graphical touch screen display and an efficient local operation panel. These provide access to control block diagrams, control data, settings, and fault information for a quick readout on the status of the system.



Control Block Screen

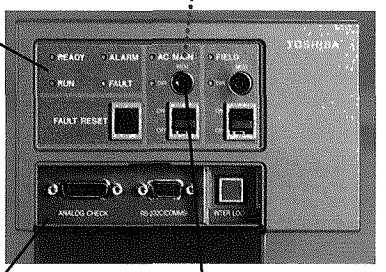
Phase W

Induction Motor Control Panel



Status LEDs

- Ready
- Run
- Alarm
- Fault
- AC Main
- Field

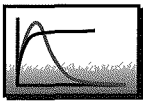


Instrumentation Interface

- Five analog outputs can be mapped to variables for external data logging and analysis
- RS-232C port for local toolbox connection

Local Control

- AC main keyswitch
- AC main on/off switch
- Field keyswitch
- Field on/off switch
- Fault reset switch
- Interlock button that disables the drive



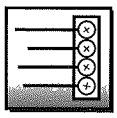
Control Functions

A VME-based control provides primary motor functions:

- Speed and torque regulation
- Sequencing
- I/O mapping
- Set of capture buffers

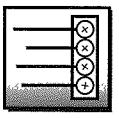
Includes resonance control and impact recovery functions to handle real world systems.

Configuration is performed using the same toolbox as all other drives.



Resolver I/O

A resolver I/O board is provided to interface with the speed sensor. Resolver I/O provides high resolution feedback, even at a very low speed.

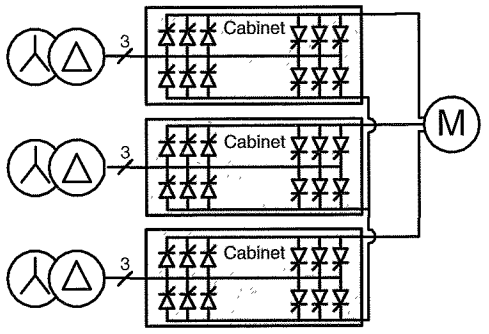
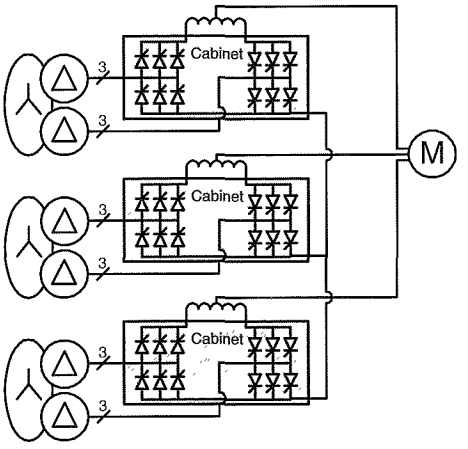
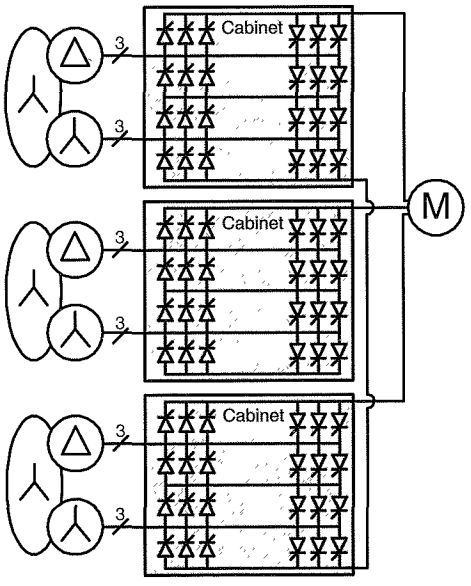
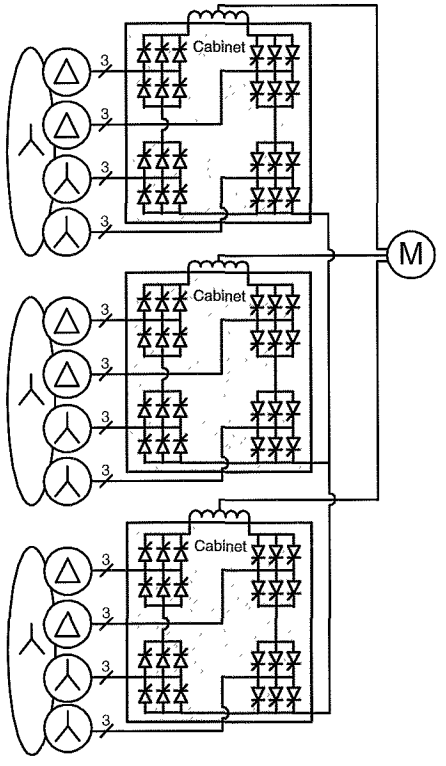


I/O Board

Process I/O boards are provided with every system. The digital I/O board has a removable terminal block for ease of maintenance. The analog I/O board is mounted in the VME rack and has an associated terminal block mounted in the rear of the cabinet.

IP7_024447

A Medium Voltage Power Bridge Topology To Fit Your Application

	Non-Circulating Current	Circulating Current
36-Thyristor System • 1650 V Output		
72-Thyristor System • 3300 V And 5000 V Output		

AC-To-AC Power Conversion

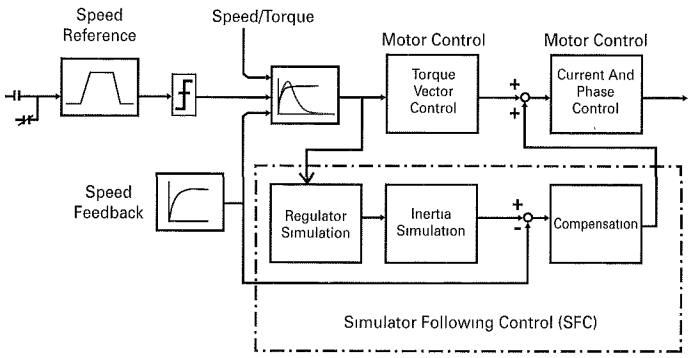
The T-850W line starts with the basic non-circulating current (NCC) cycloconverter. Optimum control of the deadtime between gating of the forward and reverse thyristors allows output frequencies up to 45% of the utility frequency. For applications requiring output frequencies up to 80% of the utility frequency, move up to the circulating current (CC) cycloconverter. The CC cycloconverter uses an interphase reactor, allowing both forward and reverse thyristors to be in conduction at the same time, eliminating deadtime constraints. CC cycloconverters are also used in applications requiring a more sinusoidal output waveform and lower torque ripple. Finally, for the most demanding applications, a 72-thyristor system not only allows for higher voltage and power levels, but also reduces high order current harmonics resulting in nearly zero torque ripple.

IP7_024448

A Control To Reduce Cost Of Ownership

Control Functions

Feedback And Status | I/O Mapping | Capture Buffer | Sequencing



Simulator Following Control (SFC) uses modeling and compensation to dramatically reduce torsional vibration inherent in many mechanical systems. The control injects a torque signal into the load, which has been calculated to cancel vibration caused by the natural resonant frequencies in the load.

I/O Interface

Digital Inputs — +24 V dc
- DC relay coil, 21 mA holding current
- Quantity 32 dedicated

Digital Outputs
- Dry contact, 4.2 amps at 120 V ac, 3.8 amps at 24 V dc
- Quantity 2 configurable
- Quantity 14 dedicated

Analog Inputs — ±10 V, A/D
- Quantity 2, ±10 V, 12-bit, 2 ms
- Quantity 6, ±10 V, 14-bit, 10 ms

Analog Outputs — D/A, ±10 V
- Quantity 4, ±10 V
- Configurable gain and offset
- 12-bit resolution

Speed Feedback Resolver Input — Sin, Cos, Excitn; Sin, Cos, Fdbk
- Excitation freq of 1 kHz
- Preferred source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp

Speed Tach Follower Output — A, B, +12-24 V
- Maximum freq of 10 kHz
- External 12-24 V dc is required

Motor Temperature Feedback — M
- High resolution torque motor temperature feedback
- 100 ohm platinum RTD (RTD uses analog input with signal conditioner)

Instrumentation Interface

Toolbox
- RS-232C serial interface
- 9.6 kbps maximum

Analog Outputs — D/A, ±10 V
- Quantity 4 configurable, ±10 V
- Motor current U,V,W, ±10 V
- Configurable gain and offset
- 12-bit resolution

VME LAN Interface Options

ISBus
- Supports drive control
- 5 Mbps master/slave synchronous protocol using copper or fiber, scan times of 1-8 ms

Modbus
- Supports drive control
- Supports for both Ethernet and serial interface

Ethernet (SRTP and EGD)
- Supports drive control

DLAN+
- Supports drive control

TOSLINE-S20
- Supports drive control from an Innovation Series controller, Series 90-70 PLC, or V Series controller
- Drives can also exchange data between themselves
- Fiber-optic bus in a star configuration
- 2 Mbps peer-to-peer protocol, bus scan time is based on the number of nodes

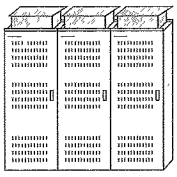
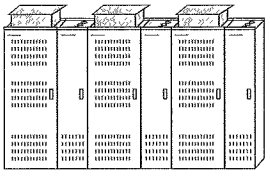
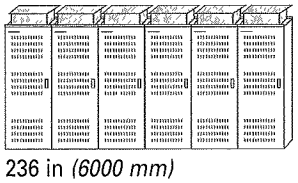
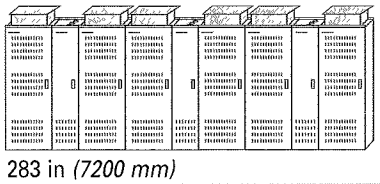
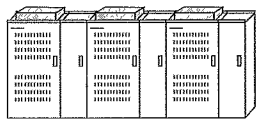
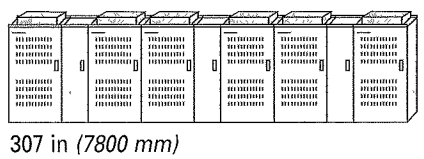
Quantity of Nodes	Bus Scan Time
2-3	1 ms
4-5	2 ms
6-8	4 ms
9-64	25 ms

Profibus-DP
- Supports run-time control (12 bytes in and 20 bytes out) from a Profibus-DP master controller
- Copper bus in a daisychain configuration
- 9.6 kbps to 12 Mbps master/slave protocol, bus scan time is based on the number of nodes

IP7_024449

T-850W Thyristor Cabinet Specifications

AC

	Type	Rated Input Voltage (Volts)	Rated Output Voltage (Volts)	$CT_{Mtr\ Shaft}$ 175% for 60 sec @ Rated Volts hp *(kW)*	Continuous Current Rating Amps @ 60 sec maximum Ambient °F *(°C)*	175%	200%	225%	250%
 102 in *(2600 mm)* 118 in *(3000 mm)* 6600 lbs *(3000 kg)* CP = 5 kVA	NCC 36	1250	1650	4586 *(3420)*	122 *(50)*	1141	1014	912	829
					113 *(45)*	1201	1068	961	873
					104 *(40)*	1260	1120	1008	916
					95 *(35)*	1319	1172	1054	958
					86 *(30)*	1376	1223	1100	999
	CC 36	1250	1650	5949 *(4436)*	122 *(50)*	1488	1316	1180	1069
					113 *(45)*	1562	1382	1239	1123
					104 *(40)*	1634	1446	1296	1174
					95 *(35)*	1705	1509	1352	1225
					86 *(30)*	1775	1570	1407	1275
 102 in *(2600 mm)* 165 in *(4200 mm)* 7260 lbs *(3300 kg)* CP = 5 kVA	NCC 36	1250	1650	6772 *(5050)*	122 *(50)*	1693	1498	1343	1217
					113 *(45)*	1777	1573	1410	1277
					104 *(40)*	1860	1646	1475	1336
					95 *(35)*	1940	1717	1539	1394
					86 *(30)*	2020	1787	1601	1451
 102 in *(2600 mm)* 236 in *(6000 mm)* 13200 lbs *(6000 kg)* CP = 10 kVA	NCC 72	1250	3300	9173 *(6840)*	122 *(50)*	1141	1014	912	829
					113 *(45)*	1201	1068	961	873
					104 *(40)*	1260	1120	1008	916
					95 *(35)*	1319	1172	1054	958
					86 *(30)*	1376	1223	1100	999
	CC 72	1250	3300	11898 *(8872)*	122 *(50)*	1488	1316	1180	1069
					113 *(45)*	1562	1382	1239	1123
					104 *(40)*	1634	1446	1296	1174
					95 *(35)*	1705	1509	1352	1225
					86 *(30)*	1775	1570	1407	1275
 102 in *(2600 mm)* 283 in *(7200 mm)* 13200 lbs *(6000 kg)* CP=10 kVA	NCC 72	1250	3300	10100 *(13544)*	122 *(50)*	1693	1498	1343	1217
					113 *(45)*	1777	1573	1410	1277
					104 *(40)*	1860	1646	1475	1336
					95 *(35)*	1940	1717	1539	1394
					86 *(30)*	2020	1787	1601	1451
 97 in *(2460 mm)* 189 in *(4800 mm)* 10500 lbs *(4800 kg)* CP = 5 kVA	NCC 72	1800	5000	11600 *(1556)*	122 *(50)*	1285	1162	1058	971
					113 *(45)*	1349	1219	1110	1019
					104 *(40)*	1411	1275	1161	1065
					95 *(35)*	1471	1329	1210	1110
					86 *(30)*	1530	1382	1258	1154
13860 lbs *(6300 kg)* • CP = 10 kVA  97 in *(2460 mm)* 307 in *(7800 mm)*	CC 72	1800	5000	19847 *(14800)*	122 *(50)*	1648	1477	1337	1220
					113 *(45)*	1725	1546	1399	1276
					104 *(40)*	1799	1612	1459	1331
					95 *(35)*	1872	1677	1517	1384
					86 *(30)*	1942	1740	1574	1435

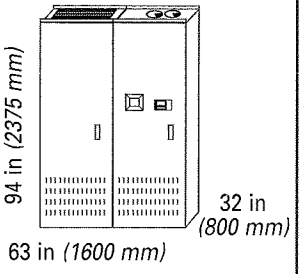
T-850W System Notes

1. CC=Circulating Current, NCC=Non-Circulating Current, 36=36 Thyristor System, 72=72 Thyristor system, CP=Control Power.
2. Continuous Torque (CT_{Shaft}) motor shaft power rating data assumes a motor efficiency of 95%, motor power factor of 1.0, ambient temperature of 104 ° F *(40 °C)*, altitude up to 3300 ft *(1000 m)* above sea level, 175% overloads up to 60 sec and 0.5 Hz as minimum output frequency.
3. The specified current ratings are continuous, to which the referenced overload can be applied.
4. Dimensions of the 3-phase unit shown do not include required control panel or channel base standard height is 2 in *(50 mm)*.
5. To achieve power factors over 0.65, typically requires that power factor correction capacitors be supplied.

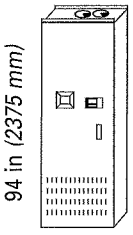
IP7_024450

Control Cabinet with Field Exciter Options

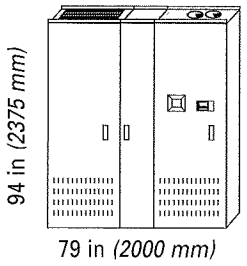
Synchronous Motor Control with 675 V dc, 1200 A field exciter
1760 lbs *(800 kg)*
CP = 2.5 kVA



Type	Overload Time (sec)	Field Exciter Continuous Current Rating, DC Amps											
		50 Hz						60 Hz					
		150%	175%	200%	225%	250%	300%	150%	175%	200%	225%	250%	300%
1200A	10	1320	1200	1100	1010	940	810	1360	1240	1130	1040	960	830
	30	1230	1100	1000	900	820	710	1280	1130	1020	915	845	720
	60	1180	1040	920	830	760	645	1205	1060	945	850	775	660
	120	1120	980	860	760	690	585	1160	1000	885	790	710	590
2100A	10	2376	2160	1980	1818	1692	1458	2448	2232	2034	1872	1728	1494
	30	2214	1980	1800	1620	1476	1278	2304	2034	1836	1647	1521	1296
	60	2124	1872	1656	1494	1368	1161	2169	1908	1701	1530	1395	1188
	120	2016	1764	1548	1368	1242	1053	2088	1800	1593	1422	1278	1062



Induction Motor Control
770 lbs *(350 kg)*
CP = 2.5 kVA



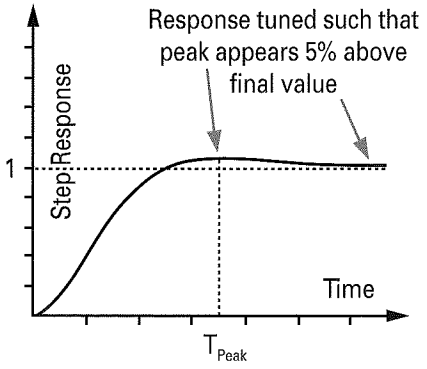
Synchronous Motor Control with 675 V dc, 2100 A field exciter
2420 lbs *(1100 kg)*
CP = 3 kVA

Performance

	Induction Motor		Synchronous Motor	
	Non-Circulating Current System	Circulating Current System	Non-Circulating Current System	Circulating Current System
Maximum output frequency	45% of line freq.	80% of line freq.	45% of line freq.	80% of line freq.
Speed regulator accuracy (%)	0.01	0.01	0.01	0.01
Speed regulator response (rad/s)	28	70	28	70
Field weakening range	1 : 3	1 : 6	1 : 3	1 : 4
Torque ripple (%)	0.2 - 2.0	< 0.1	0.2 - 2.0	< 0.1
Torque regulator response (rad/s)	188	628	188	628
Power factor at rated voltage (%)	0.6 - .75	0.5 - 1.0	0.7 - .85	0.65 - 1.0
Typical Output current distortion (%)	< 4	< 1	< 4	< 1

T-850W System Notes

6. Input voltage is the maximum voltage of transformer secondaries that feed the bridge. Ampacity of this cabling is = (MtrPwr x 12)/(Input Vlts x DeviceCnt) DeviceCnt = 72 or 36 depending on bridge. Input volts is generally selected as Motor Volts x 36 / (1.32 x DeviceCount).
7. Each of the cabinets require 3-phase 220 V 50/60 Hz control power.
8. Circulating current systems require separately mounted interphase reactors. Typical dimensions are 51 in *(1300 mm)* (W) x 44 in *(1100 mm)* (D) x 83 in *(2100 mm)* (H) per phase. Reactor weight per phase may be estimated at 400 kg/MW of motor.
9. Field current overload (%) must be higher than required motor current overload (%).
10. Minimum 48 in *(1200 mm)* clearance is required for access in both the rear and front of thyristor cabinets. Allow 28 in *(700 mm)* minimum clearance for ventilation above cabinets. Control panel requires 800 mm clearance for back access.
11. Speed and current regulator response is computed per the adjacent figure in radians/sec (assumes a Type 2 regulator with a 5% overshoot).
12. Cabinets for 5000 V systems are 51 in *(1300 mm)* deep, all other cabinets are 39 in deep *(1000 mm)*.
13. High performance low speed control requires the use of 4x type resolvers. Control of synchronous motors with other than 8 poles require the use of 1x type resolvers. Some applications will require Tamagawa model TS2062N11E10 resolver with both 1x and 4x type feedback.

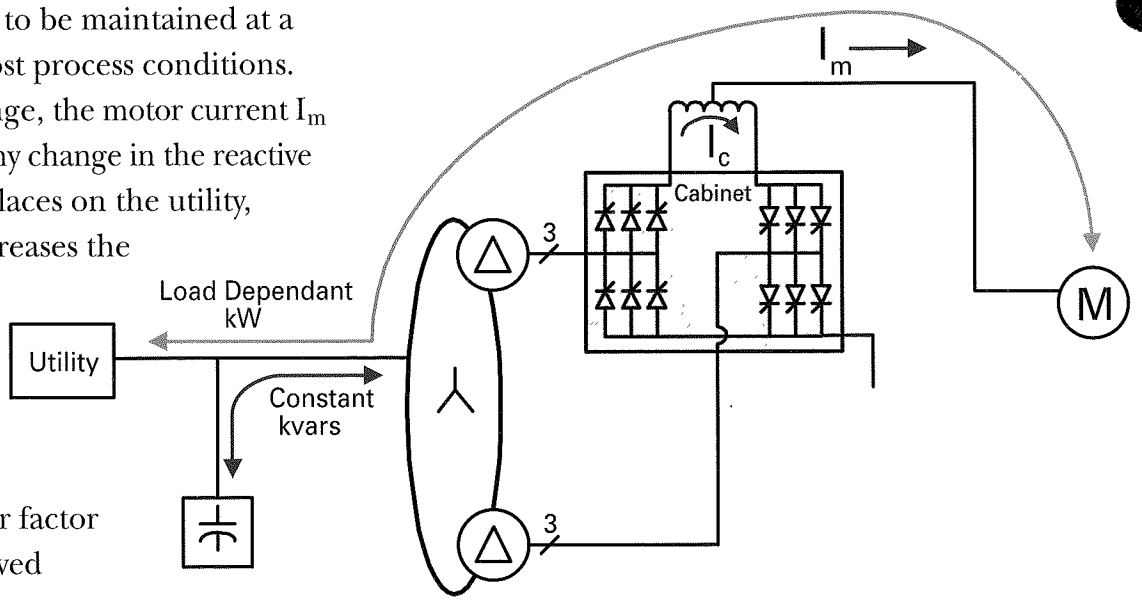


Drive Frequency Response = π / T_{Peak} (rad/s)

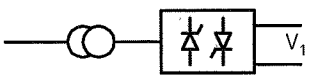
IP7_024451

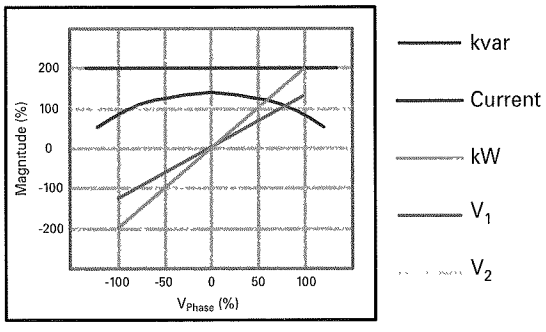
T-850W VAR Control

The flexibility of the Circulating Current (CC) system allows power factor to be maintained at a constant value through most process conditions. As process conditions change, the motor current I_m must respond. To prevent any change in the reactive power demand the system places on the utility, the control increase or decreases the circulating current I_c. The result is a constant reactive power demand, which can be easily compensated for with kvar capacitor banks. Any power factor including 1.0 can be achieved under most circumstances.

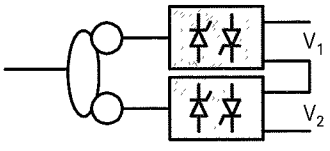


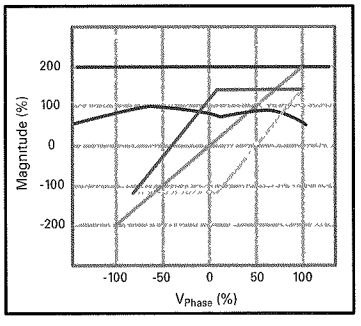
36-Thyristor Systems





72-Thyristor Systems





Cycloconverter systems with 72-thyristors are also controlled to achieve power factors higher than conventional cycloconverters. By coordinating the voltage output of the series bridges, overall var requirements are reduced as compared to 36-thyristor systems (refer to the adjacent figure).

Total Plant Power Quality

Modern utility interfaces require strict control over harmonics and power factor to prevent problems in other areas of your plant and other places on the grid. GE Toshiba Automation Systems have advanced simulation tools to study your power system. They take into account your system impedance, your expected operations and other harmonic filters you may already have in place. The result, an optimum harmonic filter system designed to meet your needs.

IP7_024452

T-850W Specifications

Environmental

Operating Temperature	32 to 104 °F *(0 to 40 °C)* at rated load 32 to 122 °F*(0 to 50 °C)* with derating (Refer to table on page 44)
Storage Temperature	-13 °F to 131 °F *(- 25 °C to +55 °C)*
Humidity	5 to 95% relative humidity, non-condensing
Altitude	Normal Operation: 0 to 11483 ft *(0 to 3500 m)* above sea level Derate current approximately 1% per 328 ft *(100 m)* altitude above 3280 ft *(1000 m)* Derate voltage approximately 0.7% per 328 ft *(100 m)* altitude above 3280 ft *(1000 m)*
Vibration	10-50 Hz, <0.5 G

Input Power

Input Voltage Variation	± 10%
Input Frequency	50/60 Hz ±2 Hz
Control Power	220 V ac ± 10% 3-phase 50/60 Hz
Conversion Efficiency	98.5% at rated load

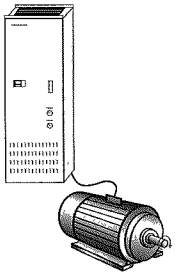
Mechanical

Enclosure	NEMA 1 (IP 20)
Cable Entrance (Utility)	Bottom is standard, top with optional 12 in *(300 mm)* deeper cabinets
Cable Entrance (Motor)	Bottom is standard
Acoustic Noise	80 dB
Lockout Mechanisms	Padlock
Dimensions	Refer to pages 44 and 45
Mean Time To Repair (MTTR)	30 minutes
Mean Time Between Failure (MTBF)	8 years (70000 hours)

Converter Specification Example

When specifying an inverter, start from the process requirements and work through the motor to the inverter. The following example illustrates this process:

1 Define process requirements.



kW_{Shaft} = 3655 hp *(4900 kW)*

The motor delivers constant torque from zero to base speed of 900 rpm.

Duty cycle requires 200% overload for 60 sec, but has an rms duty cycle of 3655 hp *(4900 kW)*. Utility is 60 Hz.

2 Select motor based on process requirements, and compute converter kVA.

- Induction motor (6 pole)
- 1185 rpm @ 60 Hz
- Efficiency = 0.954
- Power factor = 0.765
- 3300 V

$$kVA_{Converter} = \frac{kW_{Shaft}}{Eff_{Mtr} \times PF_{Mtr}} = \frac{4900\ kW}{0.954 \times 0.765} = 6714\ kVA$$

3 Compute continuous current requirements for the converter, based on the selected motor.

$$I_{Phase\ Current} = \frac{kVA_{Converter} \times 1000}{\sqrt{3} \times V_{Motor\ line\text{-}to\text{-}line\ voltage}} = \frac{6714\ kVA \times 1000}{\sqrt{3} \times 3300\ V} = 1176\ amps$$

4 Compute frequency ratio for the converter, based on the selected motor.

$$Freq_{Ratio} = \frac{\text{Motor Rated Freq} \times \text{Required Speed}}{\text{Motor Rated Speed} \times \text{Utility Freq}} = \frac{60\ Hz \times 900}{1185 \times 60\ Hz} = 0.76$$

(Over 0.45 Requires Circulating Current converter)

5 Select converter based on continuous current, overload and maximum frequency requirements.

Scan the 200% for 60 sec entries in the converter tables (page 44) for CC type system where the continuous current rating exceeds 1176 amps, and the voltage is 3300 V. The 3300 V CC-72 system meets this criteria (1446 amps @ 104 °F 40 °C), thus is the appropriate converter for this application.

IP7_024453

OnSite Support℠
Remote Monitoring And Diagnostics Center
Can Make A Difference In Your Productivity

From anywhere in the world, GE OnSite Support Service is only a phone call away. This service gives you direct access to our engineers, 24-hours a day, 365 days a year, to help you reduce downtime and get the most from your process.

The unique single point connectivity of our systems allows the OnSite Support engineers to become one with your process. Years of experience has shown:

- 96% of cases resolved remotely
- Elapsed Time To Repair (ETTR) .85 hour

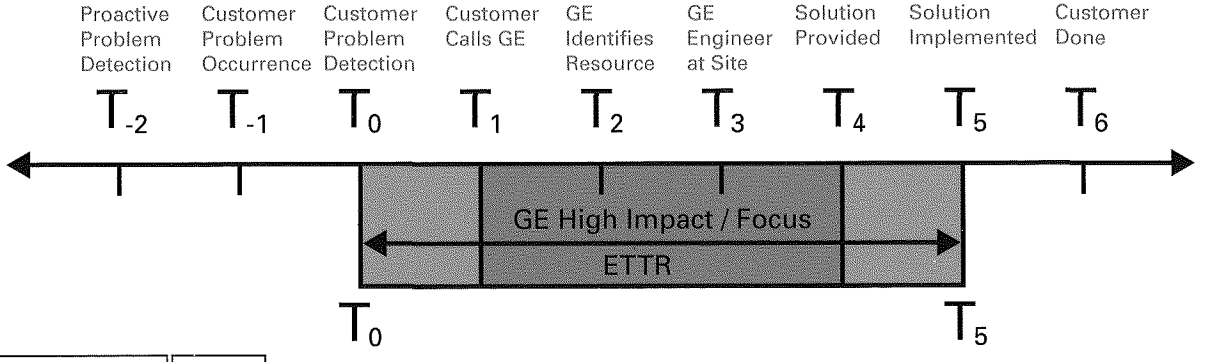
The Screen You See Is The Screen We See

We become a real-time partner with you to:

- Troubleshoot
- Perform drive system analysis
- Provide diagnostic information
- Trend key process variables
- Conduct preventive maintenance

From technical training to our Rapid Response Program for parts and services, GE has what you need to keep your process productive. Ask your GE representative to detail the many benefits our OnSite Support Service can bring to your process.

ETTR Measurement Timeline



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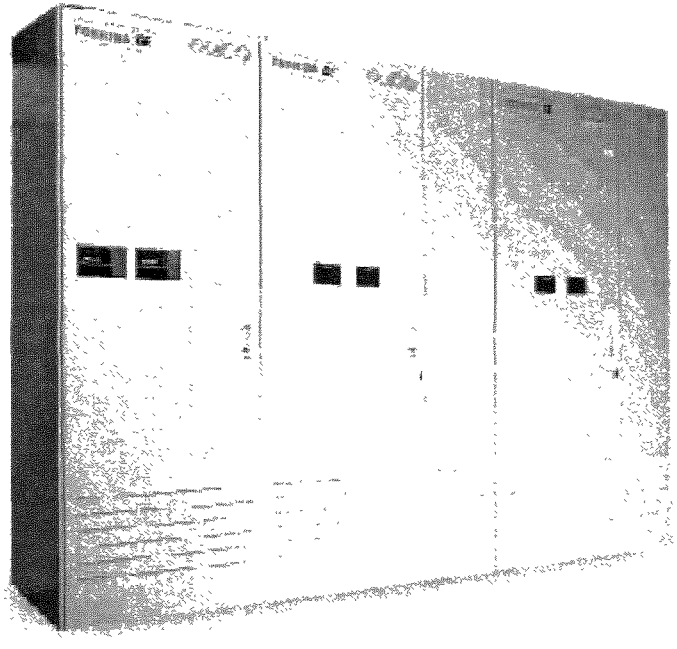
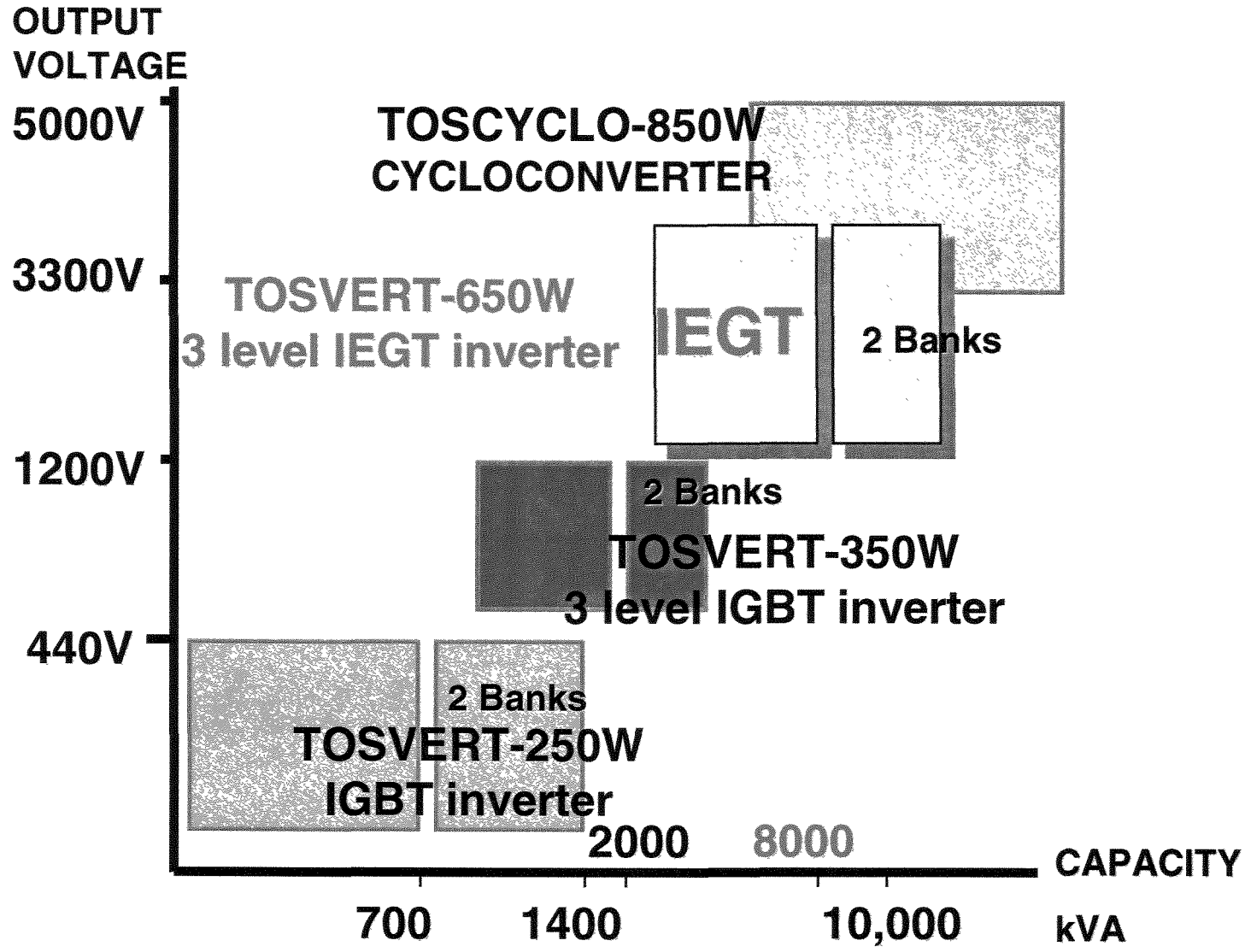
MEDIUM VOLTAGE 3 LEVEL IEGT INVERTER TOSVERT-650W Series



TOSHIBA AC MOTOR DRIVE TOSVERT-W SERIES



IP7_024456

Features of IEGT 3 Level Inverter

- Most Compact Size in the World
  (8MVA- Converter + Inverter 2.4m x 1.6m x 2.3m)
- Very High Efficiency (More Than 98.5%)
- Higher Reliability
  (Reduced Main Circuit Parts : 40% of GTO)
  (No electrolythic capacitors are used.)
- Easy Maintenance
  (No special tools are necessary for IEGT Stack)

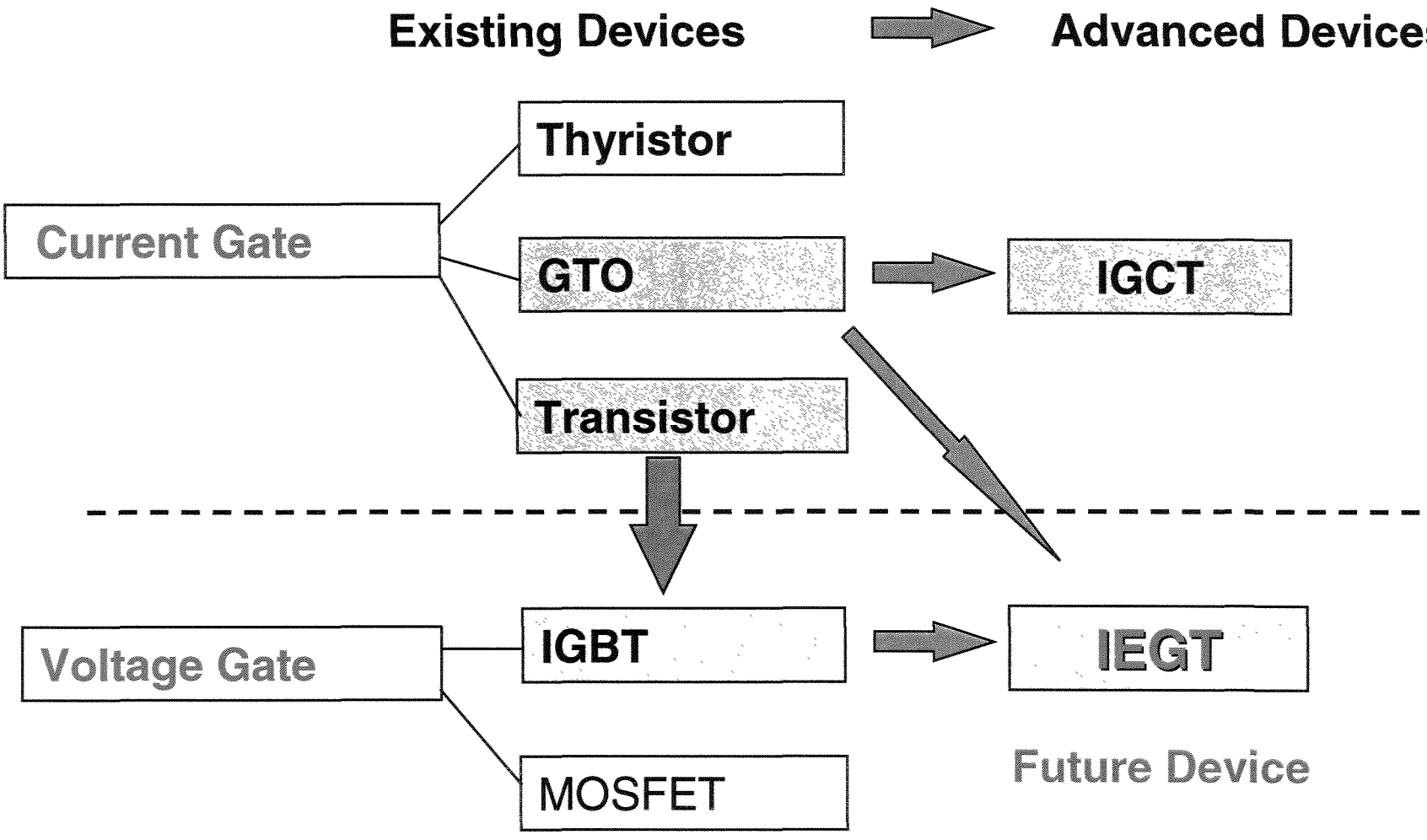
IP7_024457

Features of High Power IEGT

- New power device applied plenty of high voltage IGBT technologies
  (Low ON state voltage, high speed switching)
- Multi-chip structure similar to IGBT which has many practical application
  (Press package type, Module package type)
- Press packaged Multi-chip device is practically used only by TOSHIBA
  (Many application for rolling stock such as SVCs and Linear Motor Cars)

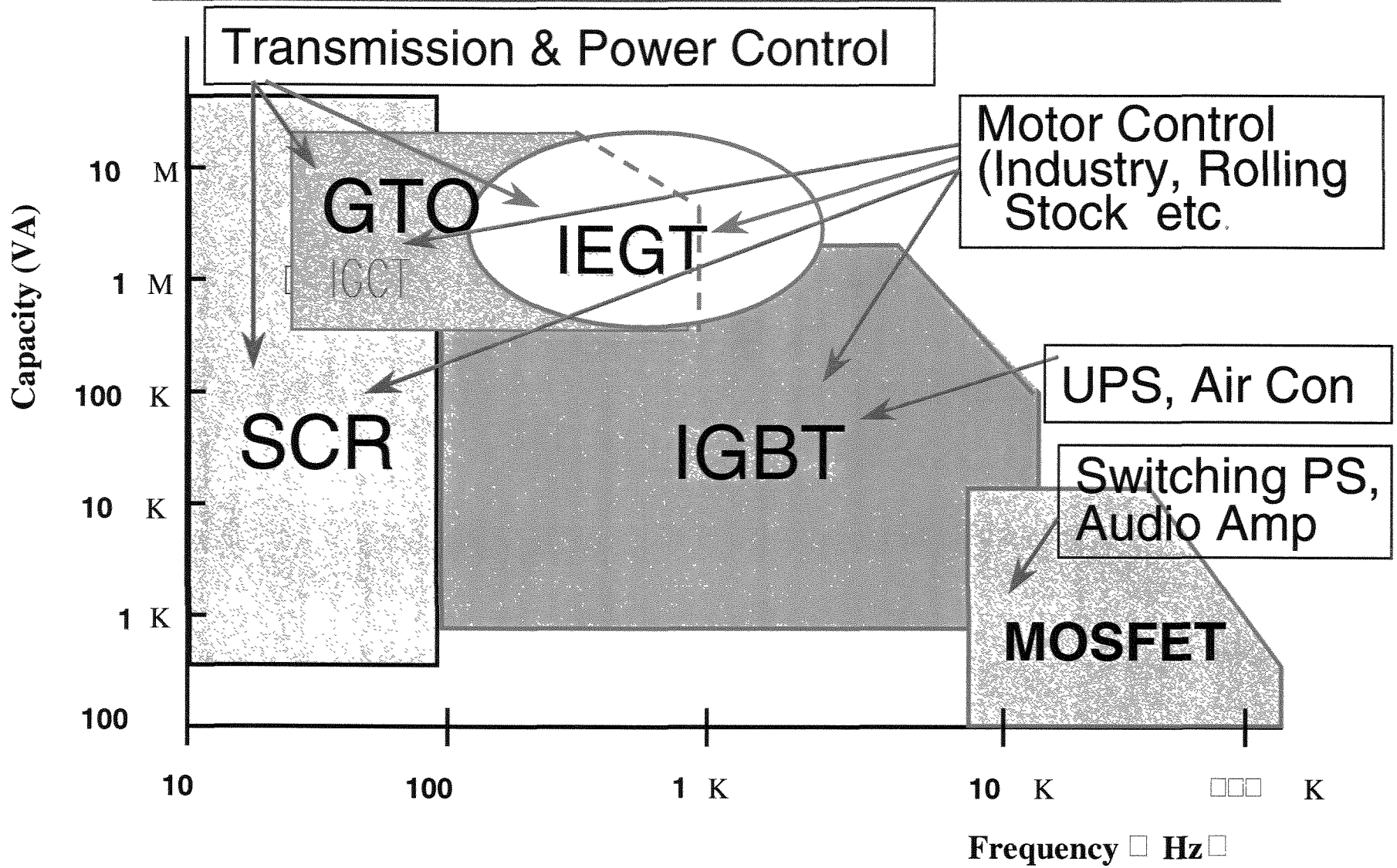
IP7_024458

Progress of Power Devices



IP7_024459

Application for Power Device



Feature of IEGT Inverter

IEGT : New high voltage device controlled by gate voltage signal.

High Voltage, Large Current
4.5kV-4kA

→ **Large Capacity**
8MVA, 2x8MVA, 4x8MVA

Voltage Gate Drive
Voltage : +/-15V

Snubber Less
(Only DC Clamp Snubber)

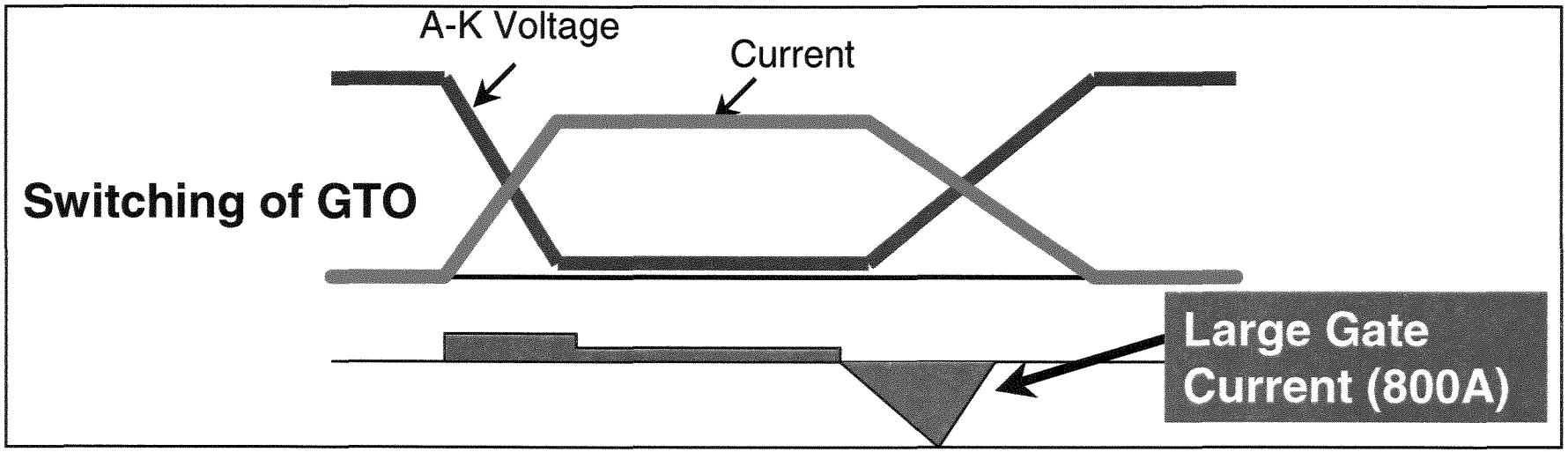
High Speed Switching
Small Loss, Short dead time

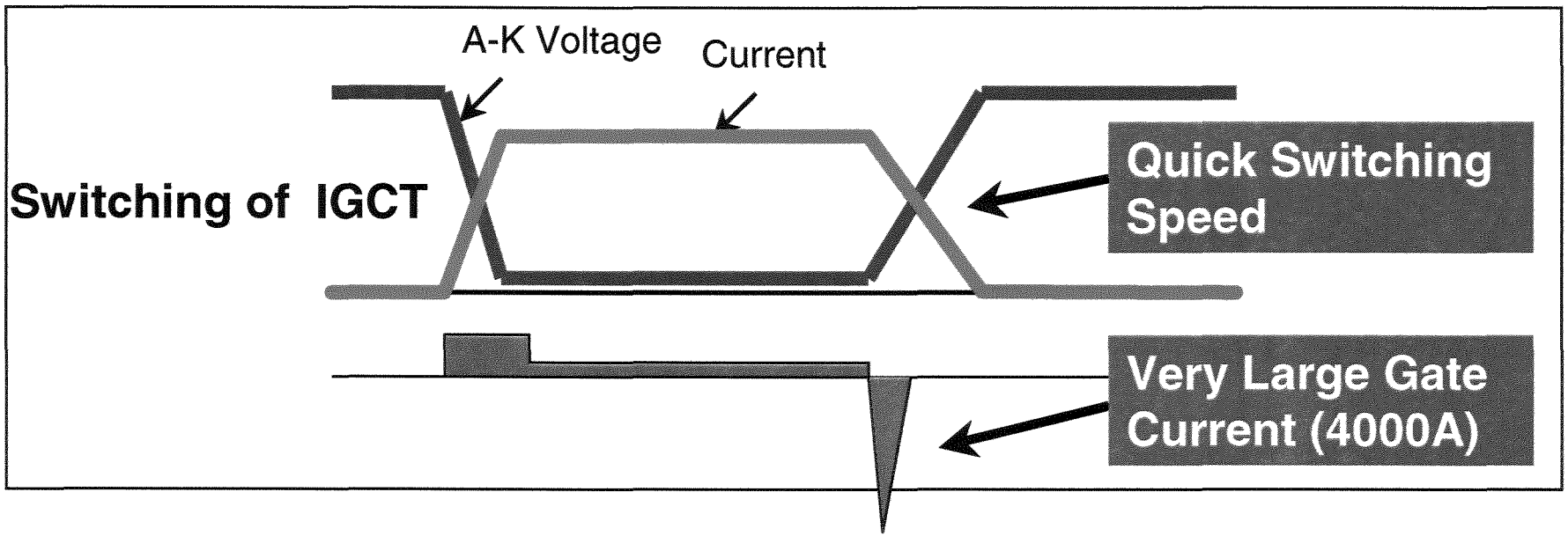
High Efficiency
(>98.5%)

Small Size
(IEGT/GTO=0.55)

Higher Performance
Low Torque Ripple, Low Harmonics

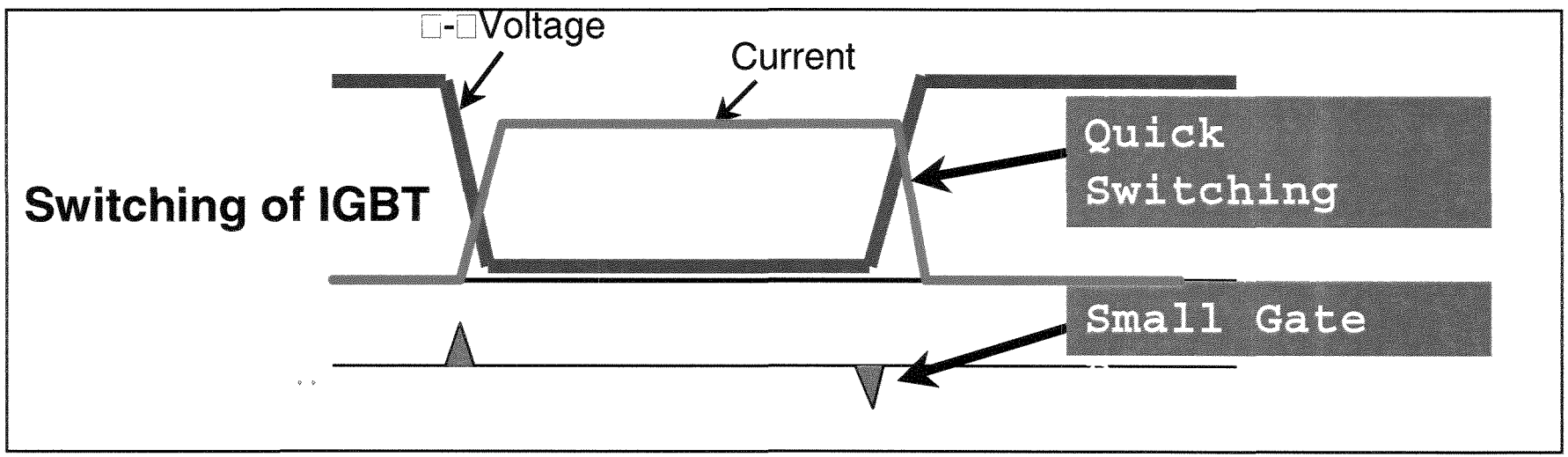
Gate Power of Device

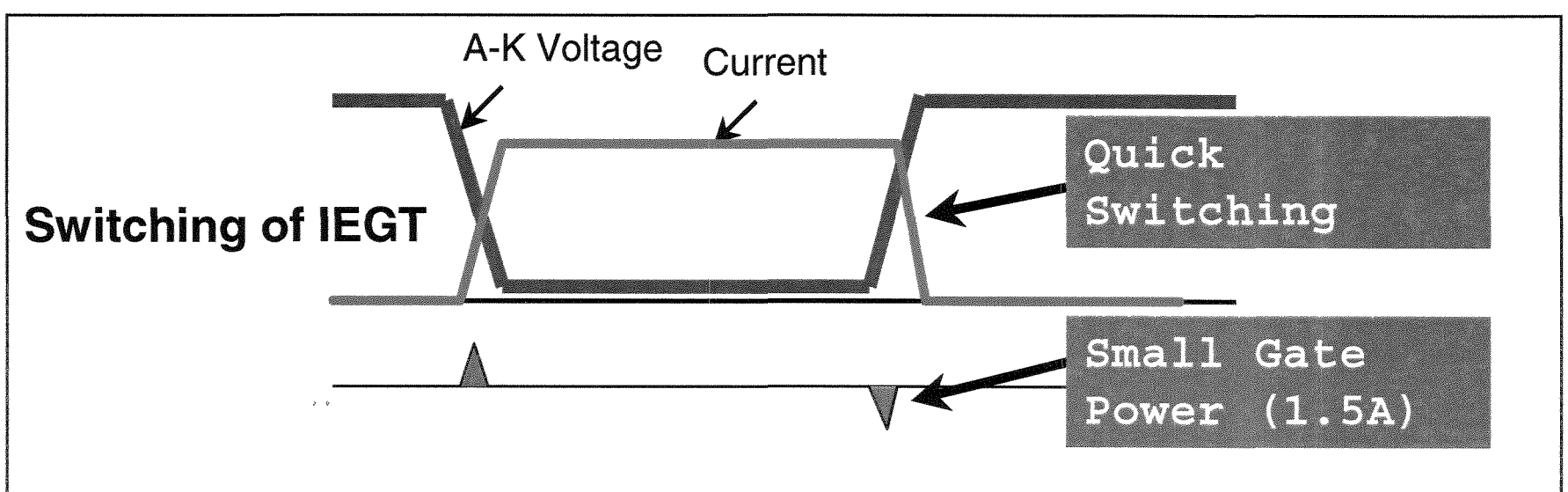




IP7_024462

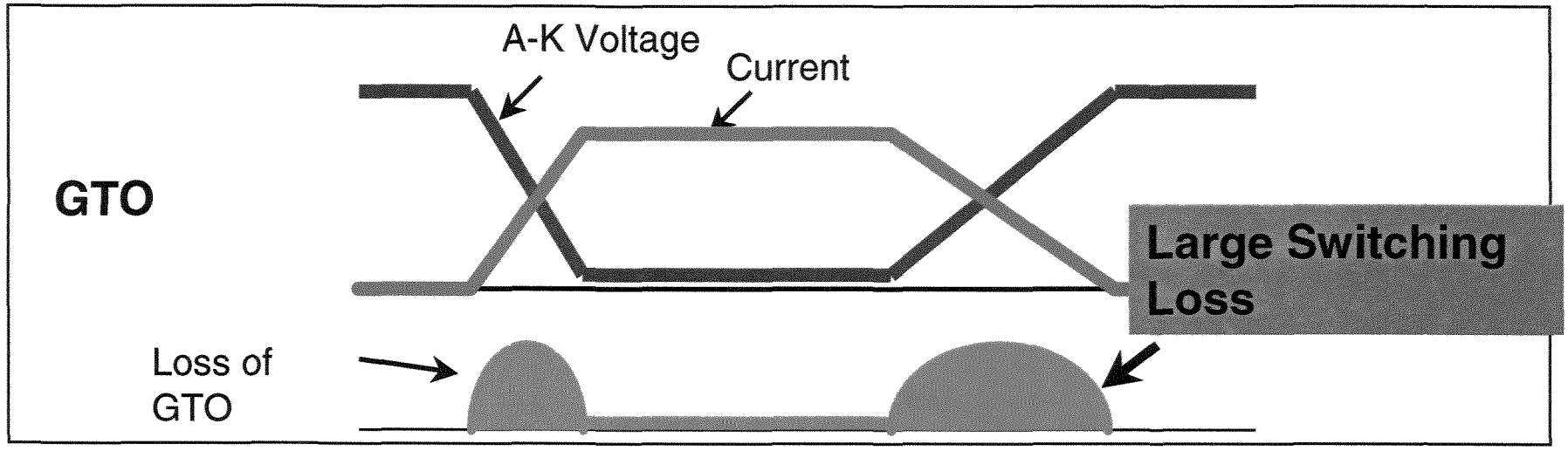
Gate of Device

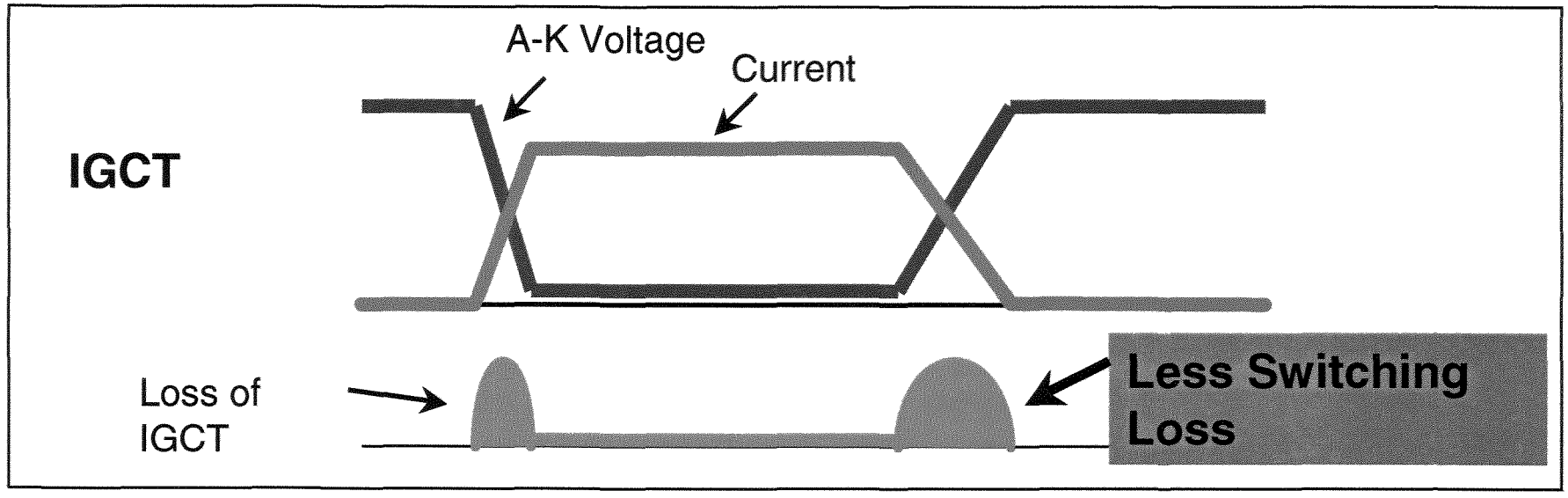




IP7_024463

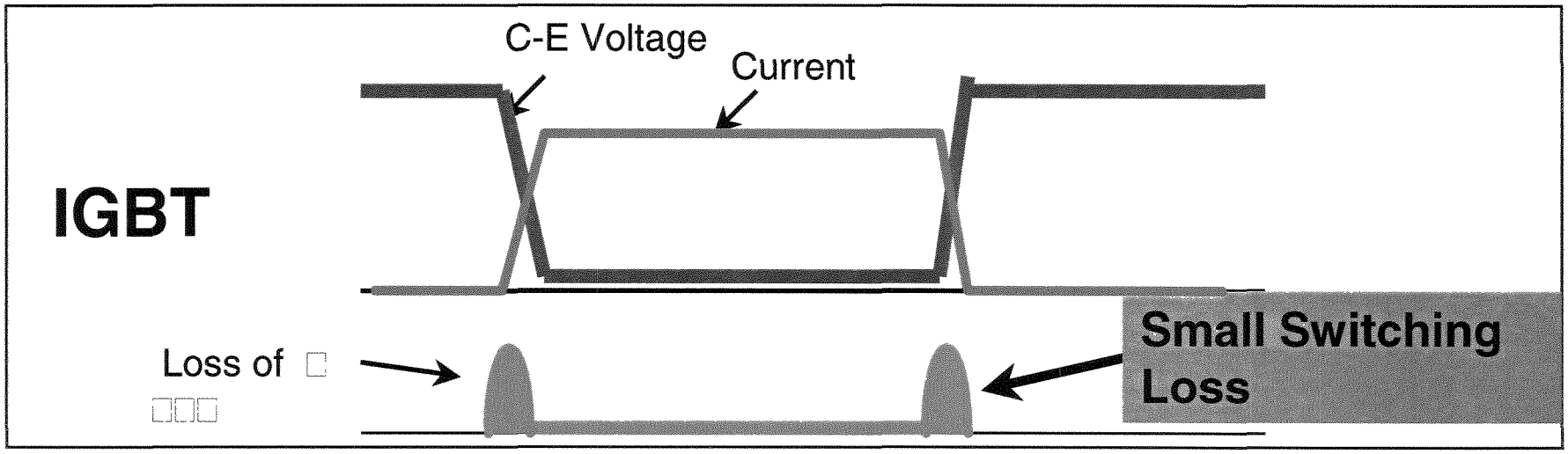
Comparison of loss

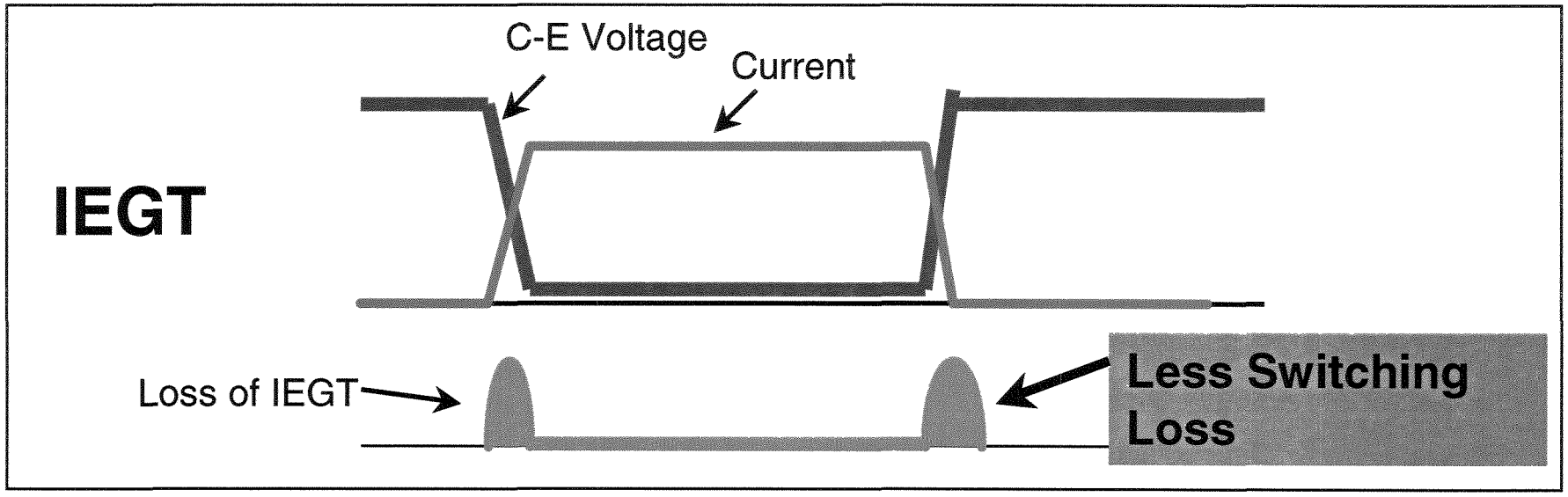




IP7_024464

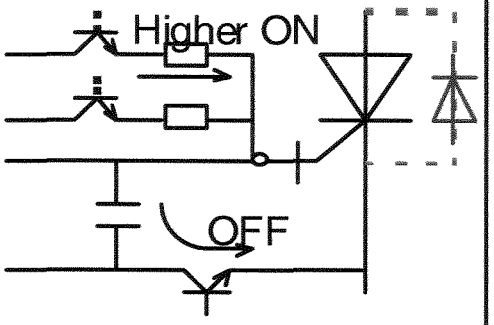
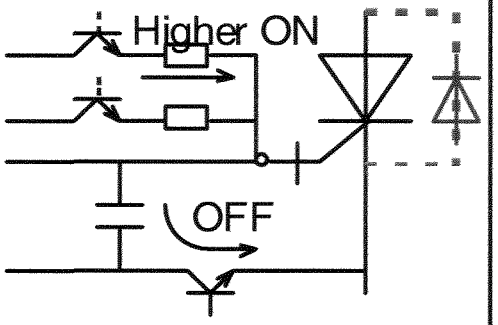
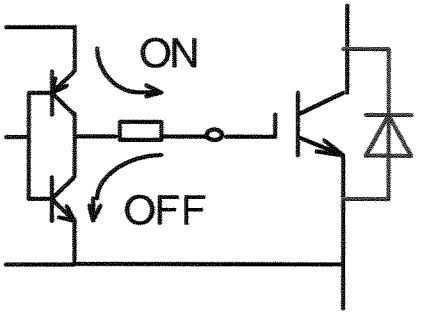
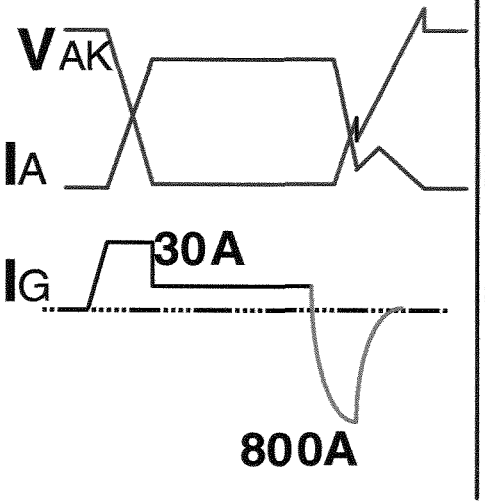
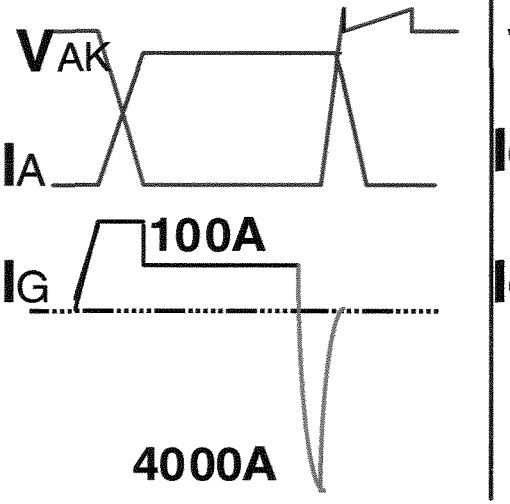
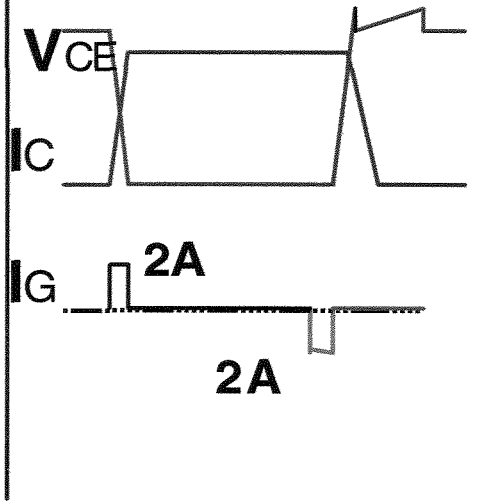
Comparison of loss





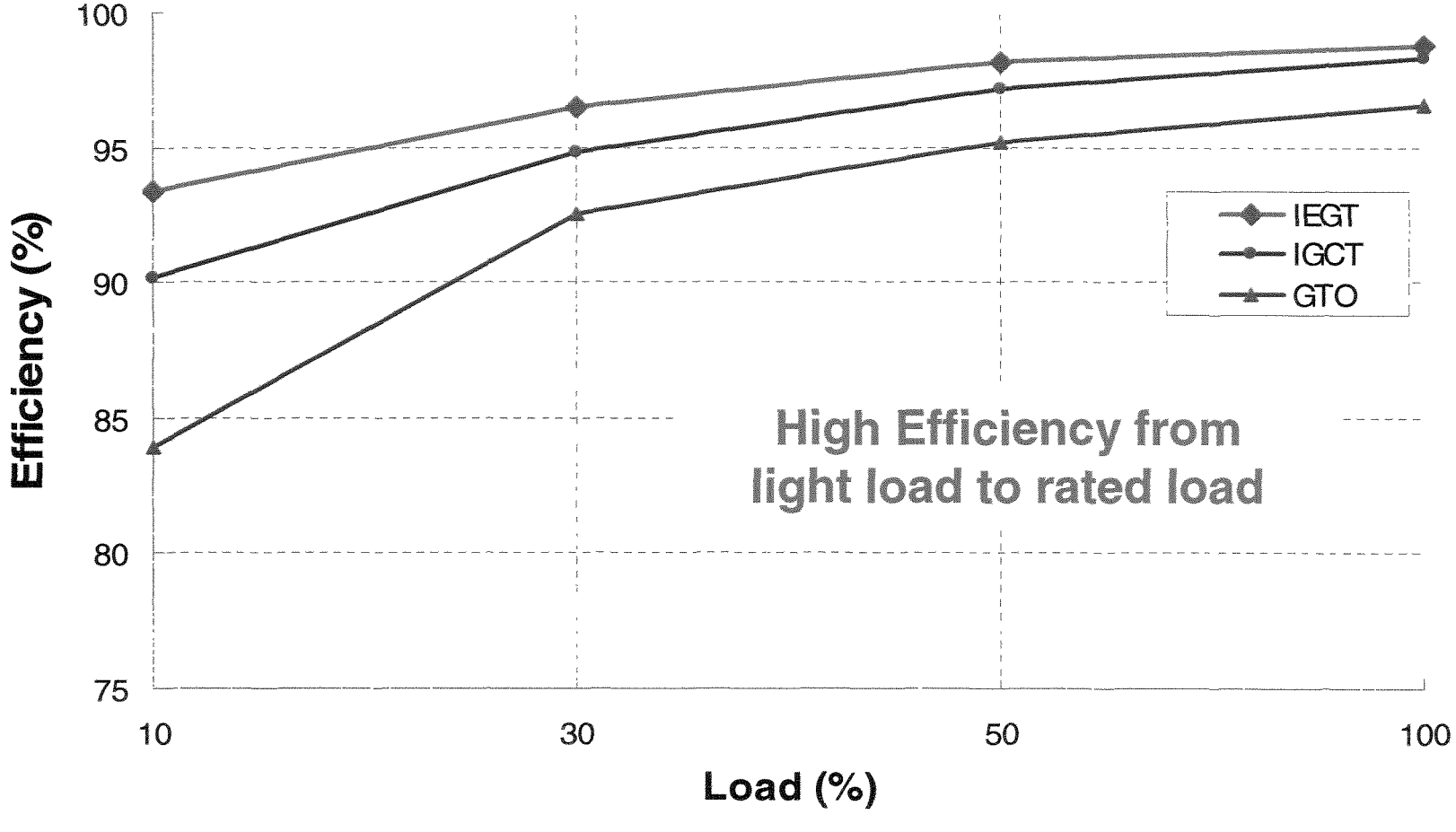
IP7_024465

Operation of GTO and IEGT

	GTO	IGCT	IEGT
Gate Circuit			
Wave form TurnOff 4kA			

IP7_024466

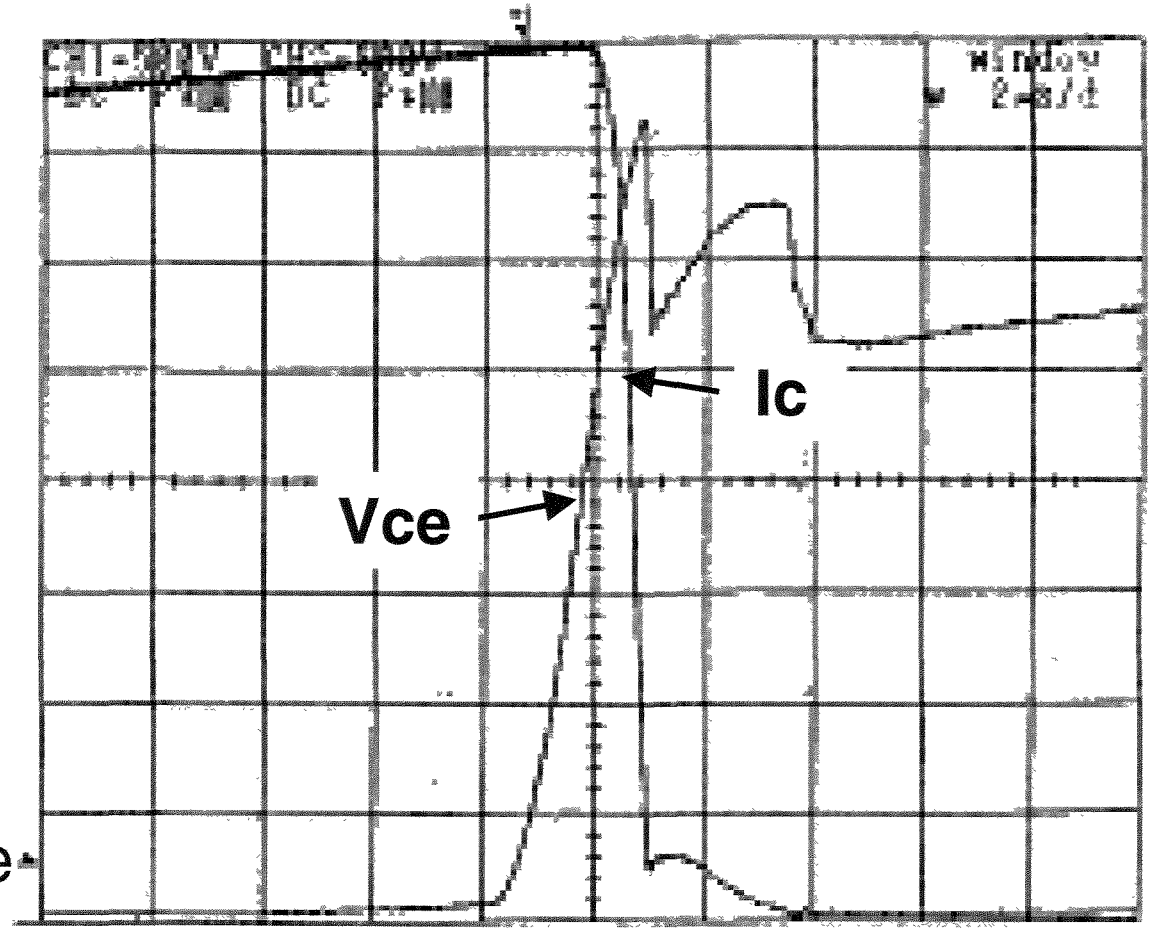
Efficiency of 8MVA CONV/INV (Calculated)



IP7_024467

IEGT 4kA Turn-off Waveforms

Current



Voltage

500V/div

500A/div

2μS/div

Comparison of 8MVA 3-Level Inverters

Equipment	GTO- INV.	IEGT- INV.
Device rating	6kV-4kA off	4.5kV-4kA off
Panel floor size	100%	55%
Panel weight	100%	55%
Total efficiency	96.5%	> 98.5%
Number of main circuit parts	100%	40%
Number of gate Circuit Parts	100%	33%

IP7_024469

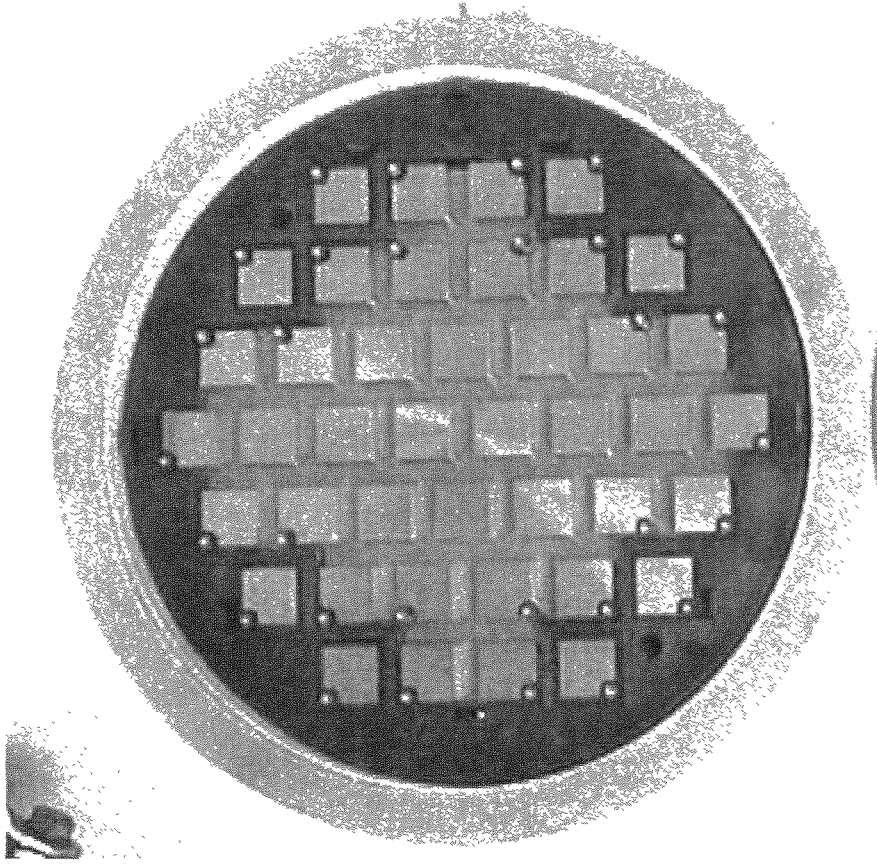
GTO Inverter vs. IEGT Inverter

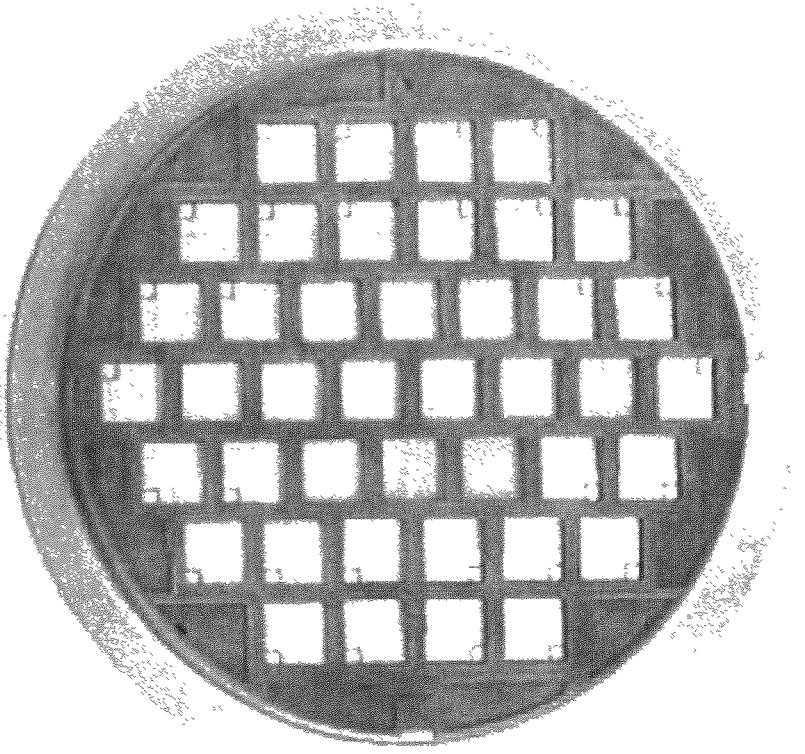
For Reference

		GTO	IEGT	
Output Voltage		AC3.3kV	AC3.3kV	
DC Voltage		3kV	2.7kV	IEGT can output higher voltage than GTO.
Gate Circuit	Parts Q`ty	100%	30%	IEGT gate is very simple.
	Power	Very Large	small	
FWD		Separate	Inside	The FWD circuit is mounted in the IEGT package.
Snubber Circuit	Type	Discharge	Clamp	The energy loss of a clamp type snubber circuit is very small.
	Loss	Large Loss	Small	
	Regen. Circuit	Necessary	Not necessary	The GTO inverter is necessary to equip a re-generative circuit.
Anode reactor		Necessary	Not necessary	
Dimension		100%	63%	The data shows one sample.
Inverter Efficiency		96%	98%	Converter + Inverter

IP7_024470

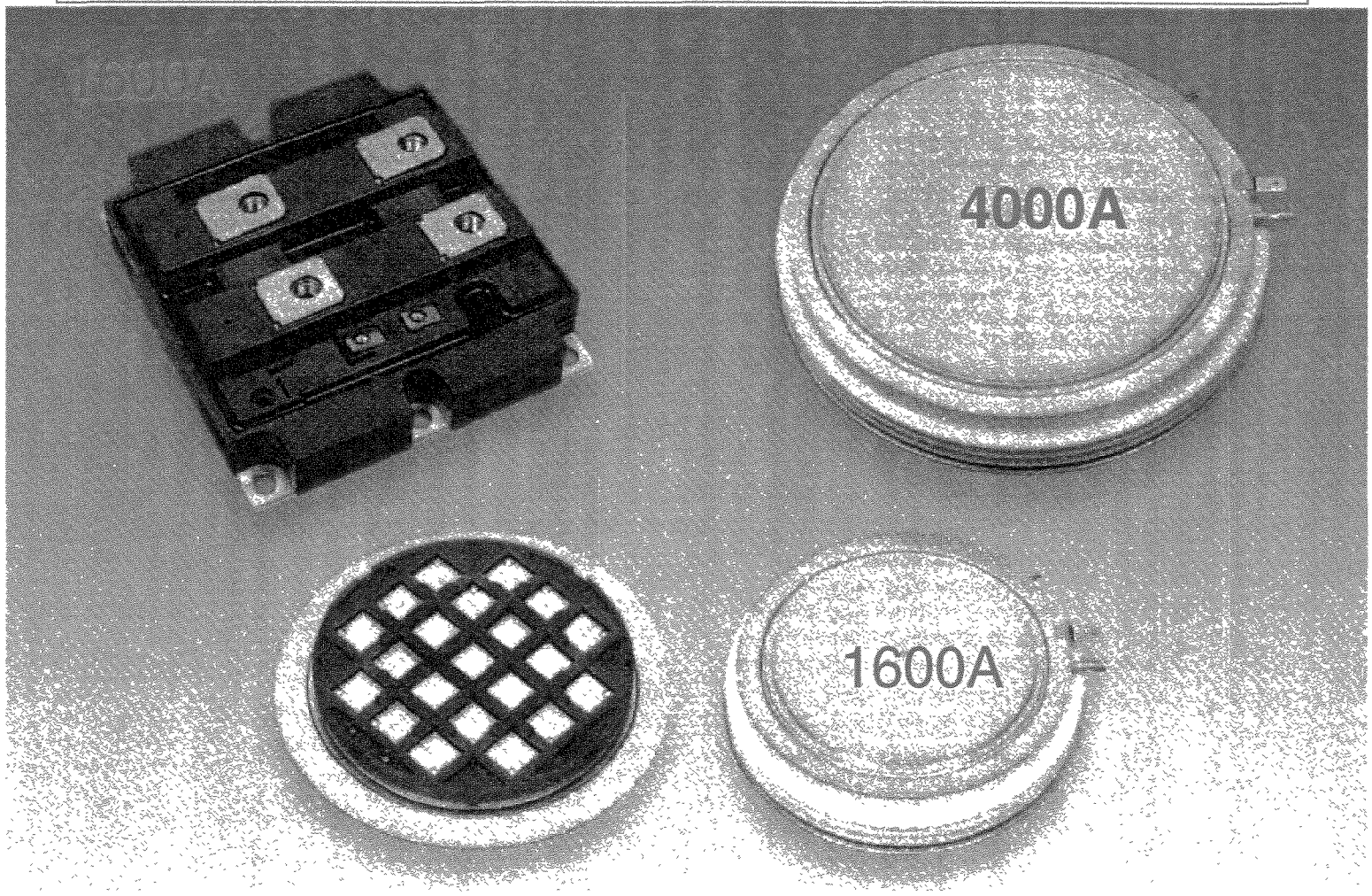
4. 5kV−4kA Turn off
Marlboro
LIGHTS
Marlboro
LIGHTS





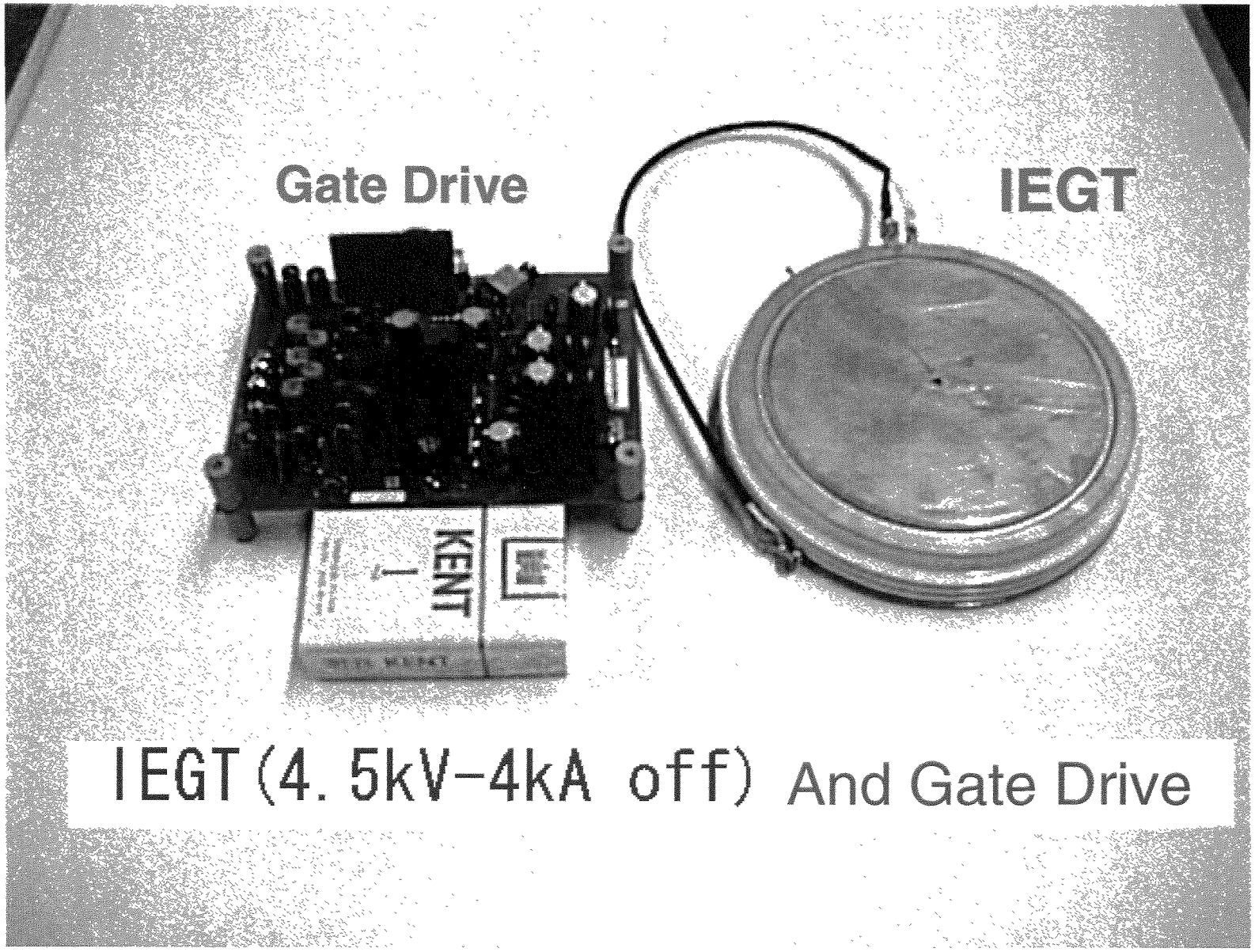
IP7_024472

TOSHIBA IEGT Device Series



4500V series IEGT Devices

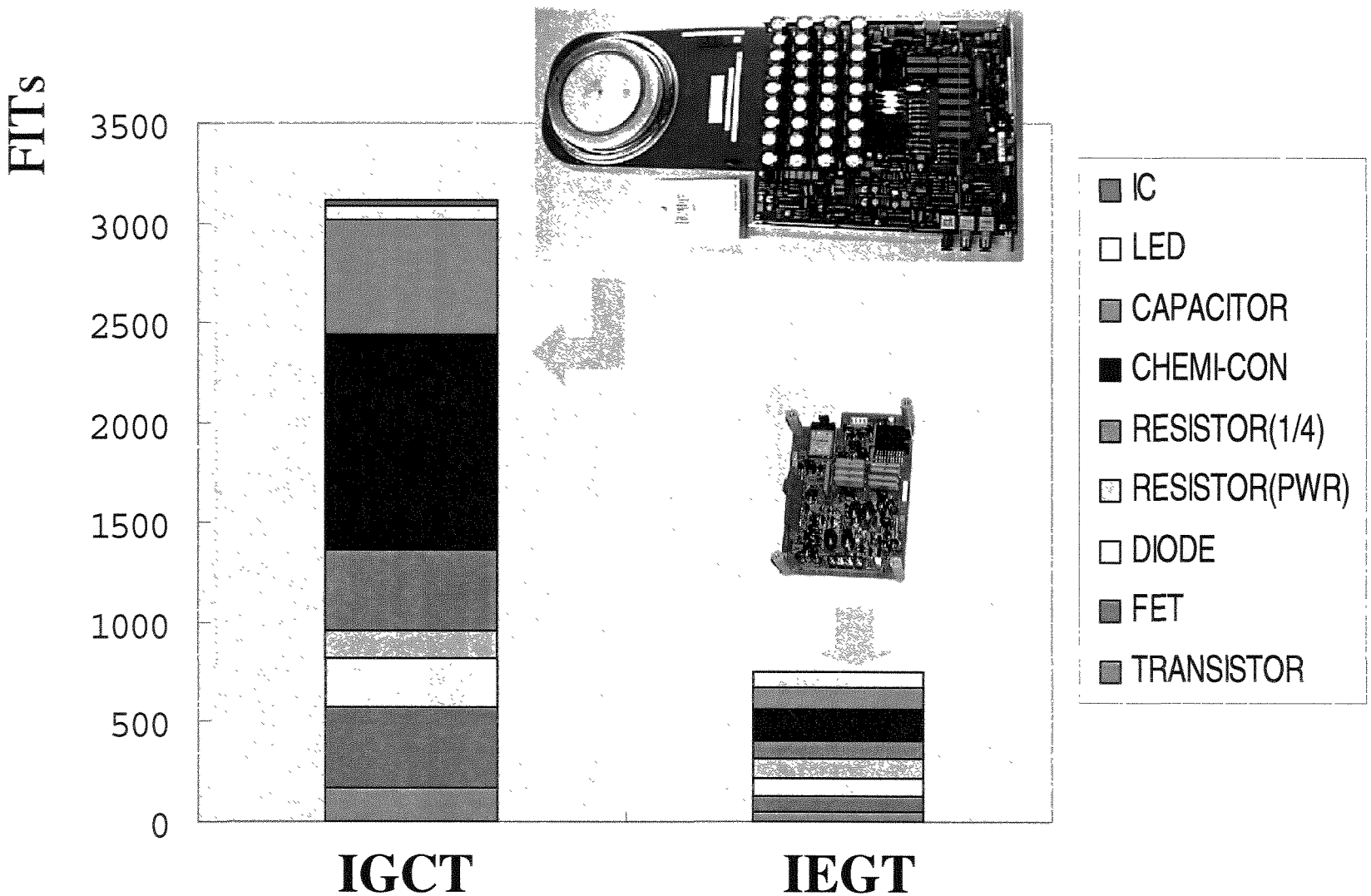
IP7_024473



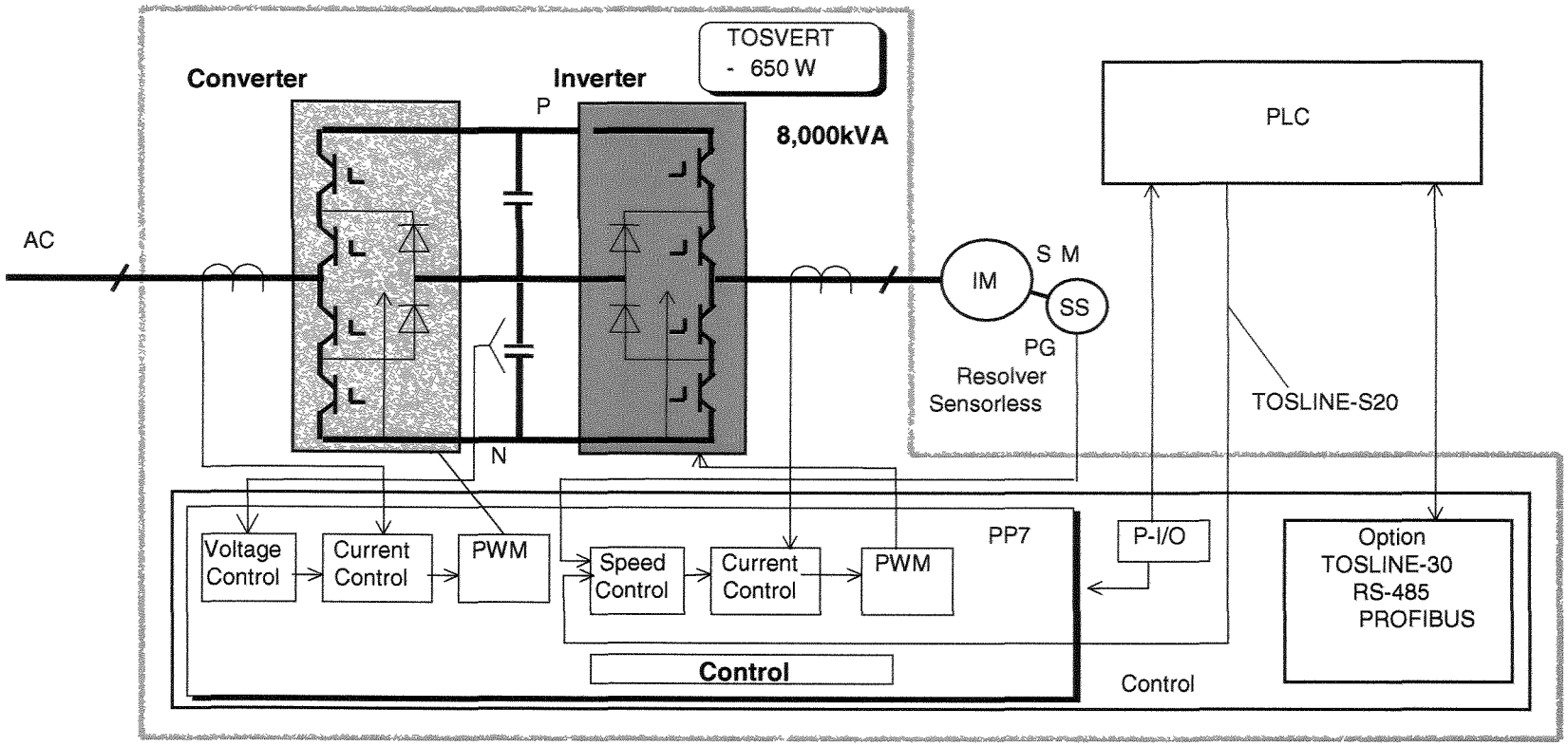
IEGT (4. 5kV-4kA off) And Gate Drive

IP7_024474

Calculated Reliability of Gate Driver

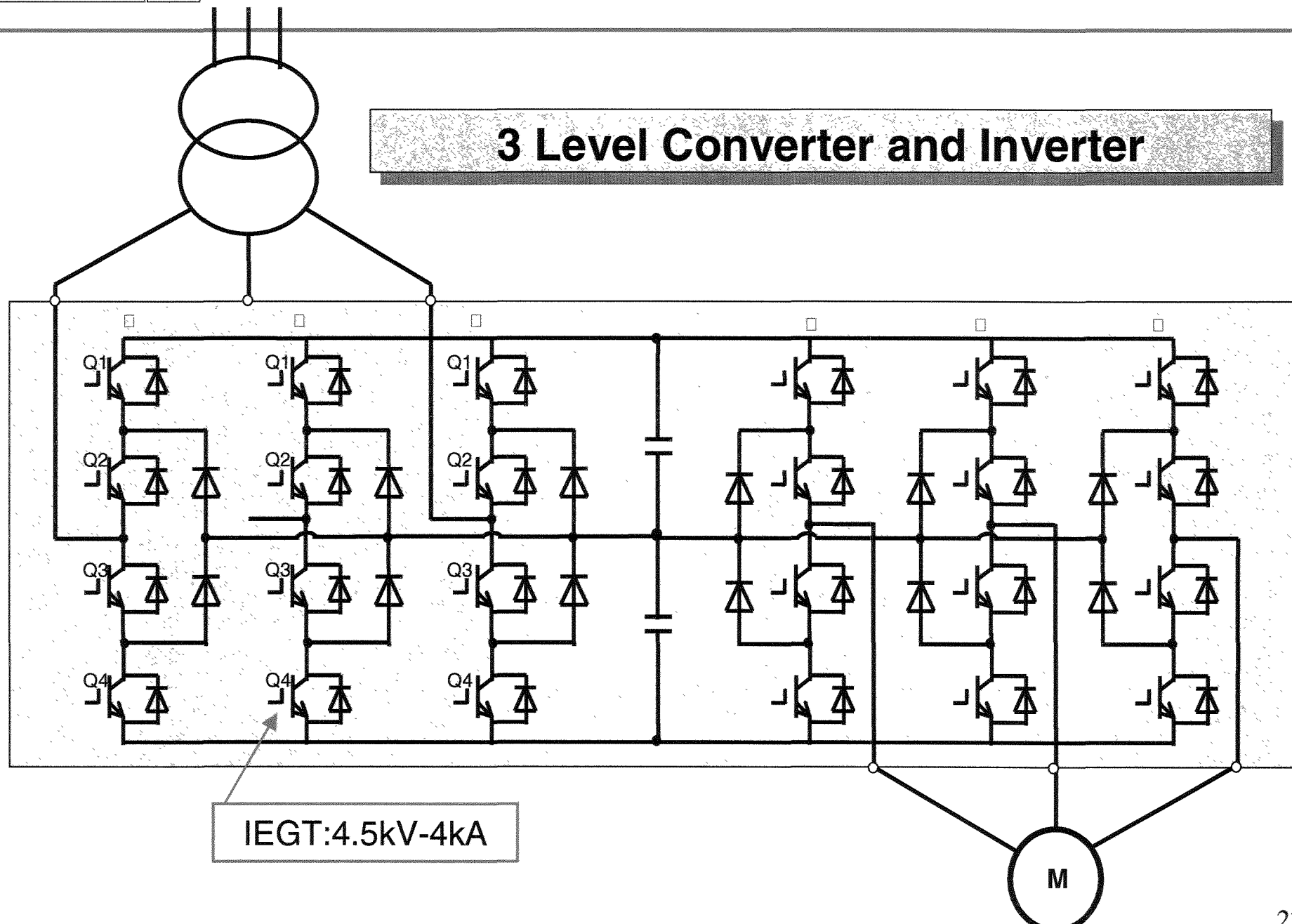


Single Line Diagram of TOSVERT-650W



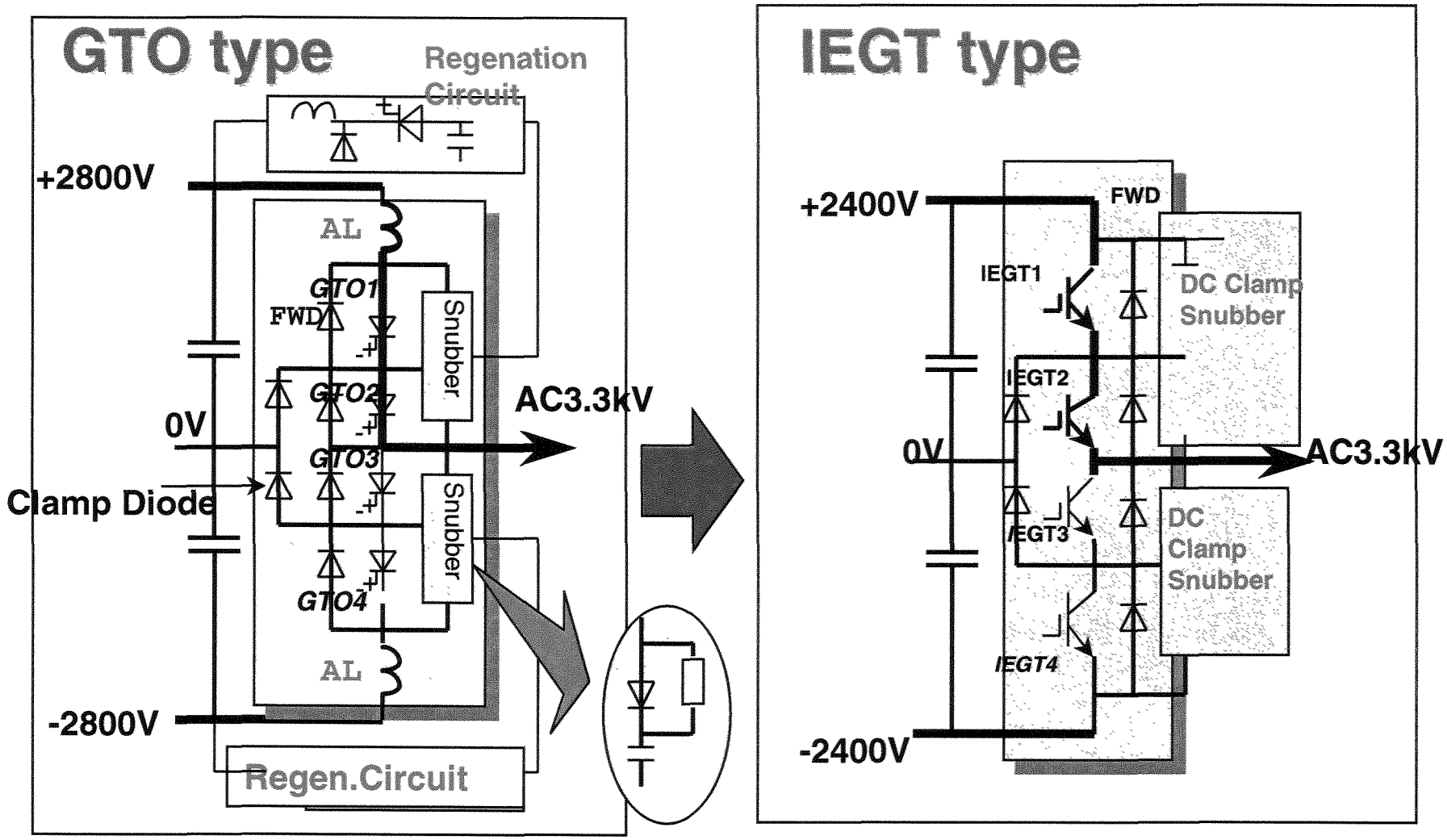
IEGT CONVERTER + INVERTER

3 Level Converter and Inverter



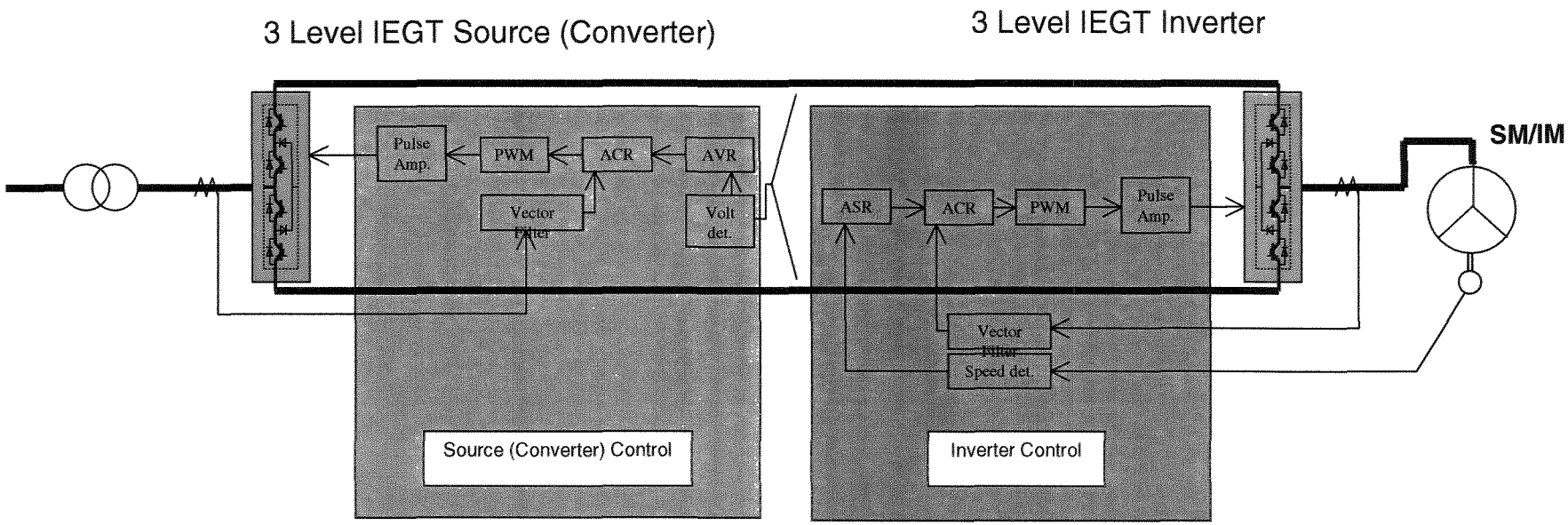
IP7_024477

3 Level Inverter (1 Phase)



IEGT Inverter
TOSVERT-650W

3300V - 8000kVA



IEGT: Injection Enhanced insulated Gate bipolar Transistor

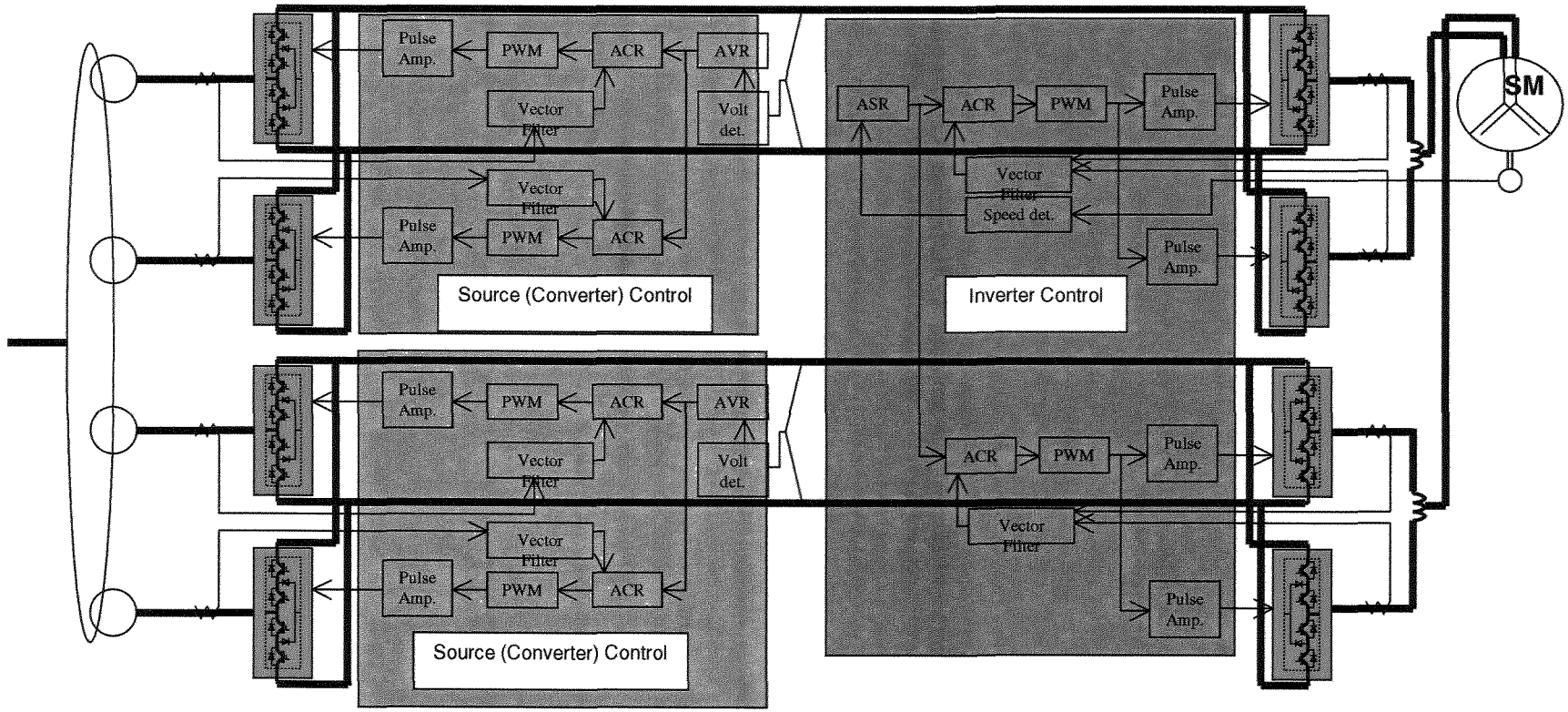
IP7_024479

IEGT Inverter
TOSVERT-650W

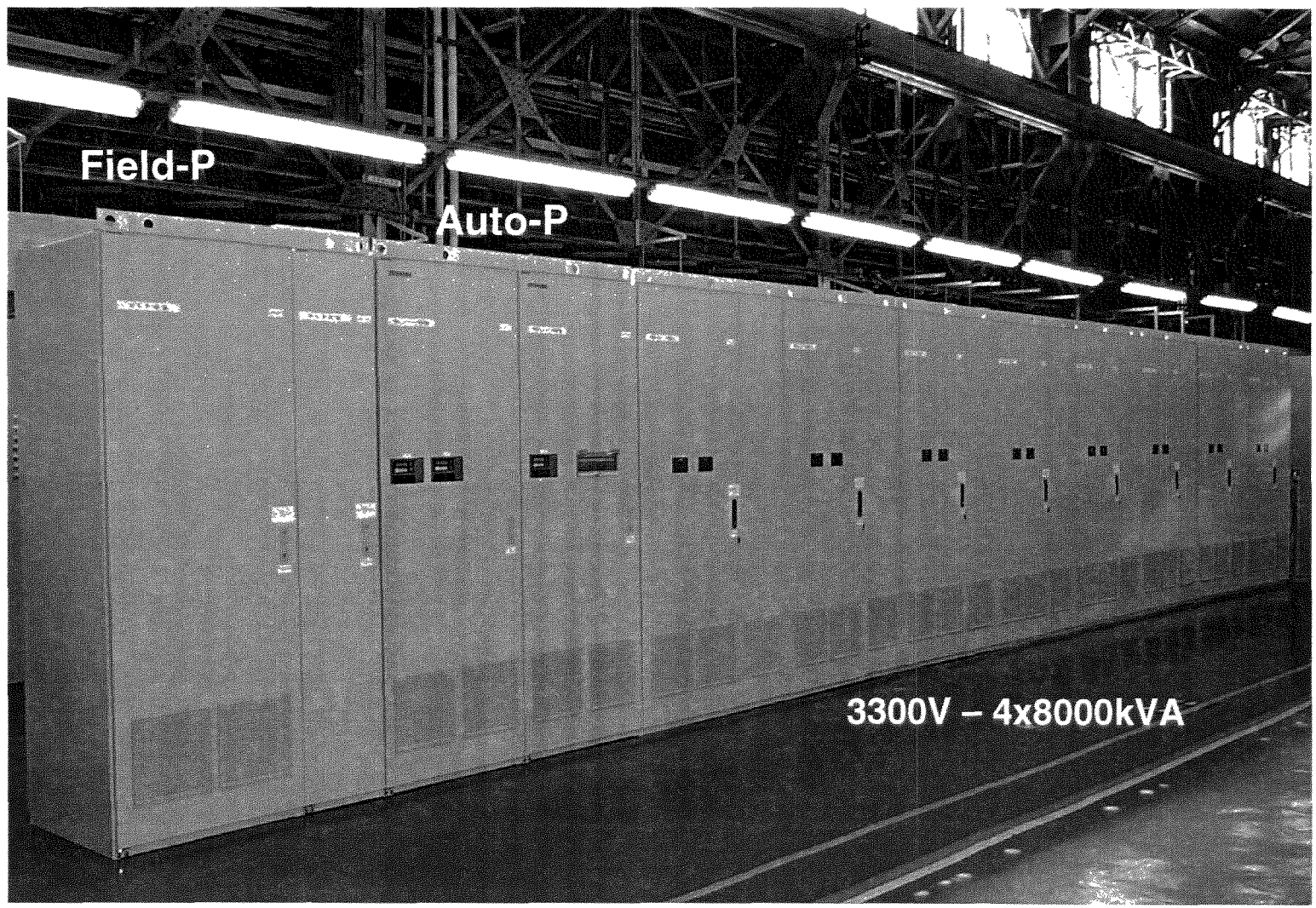
3300V – 4x8000kVA

3 Level IEGT Source (Converter)

3 Level IEGT Inverter



IEGT Inverter
TOSVERT-650W

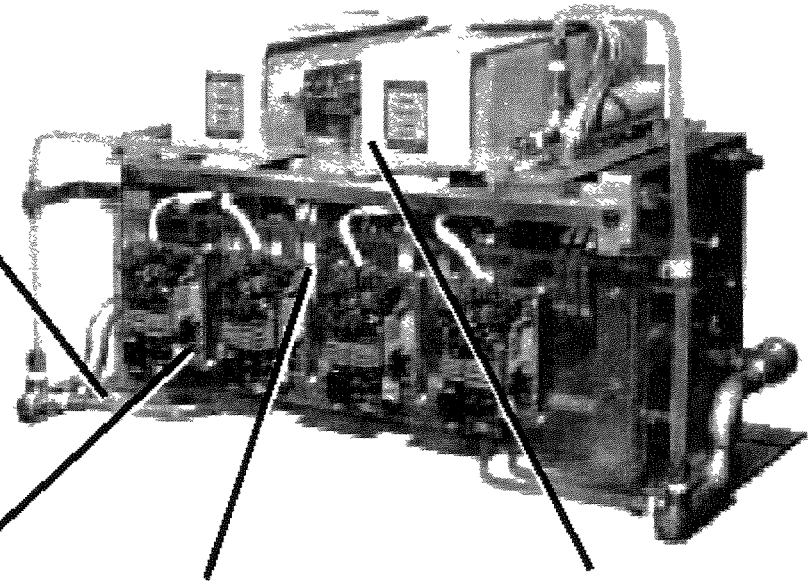


IP7_024481

TOSVERT-650W
Simple Main Stack Structure

- Three-Level Phase-Leg Assembly for Both Source and Inverter

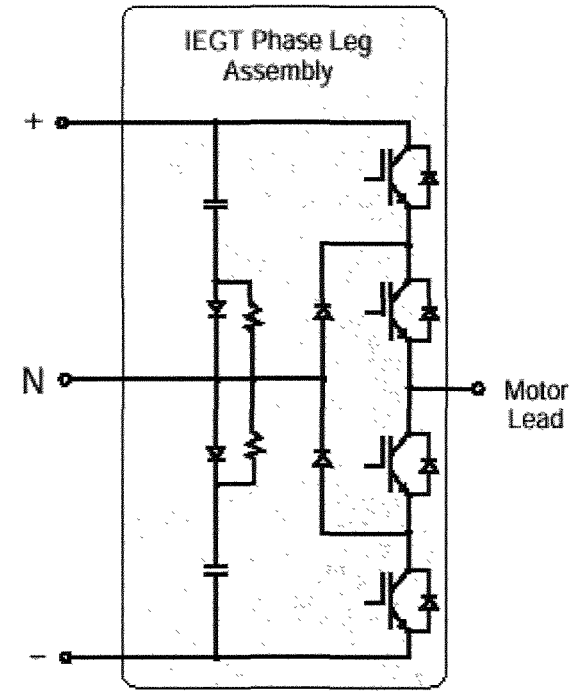
Quick disconnect fittings for the cooling system reduces mean time to repair.



Compact gate driver assemblies due to low power switching requirements of the IEGT devices

IEGT devices with integral forward and clamp diodes allowing a very compact phase leg stack, reducing the footprint versus previous technology

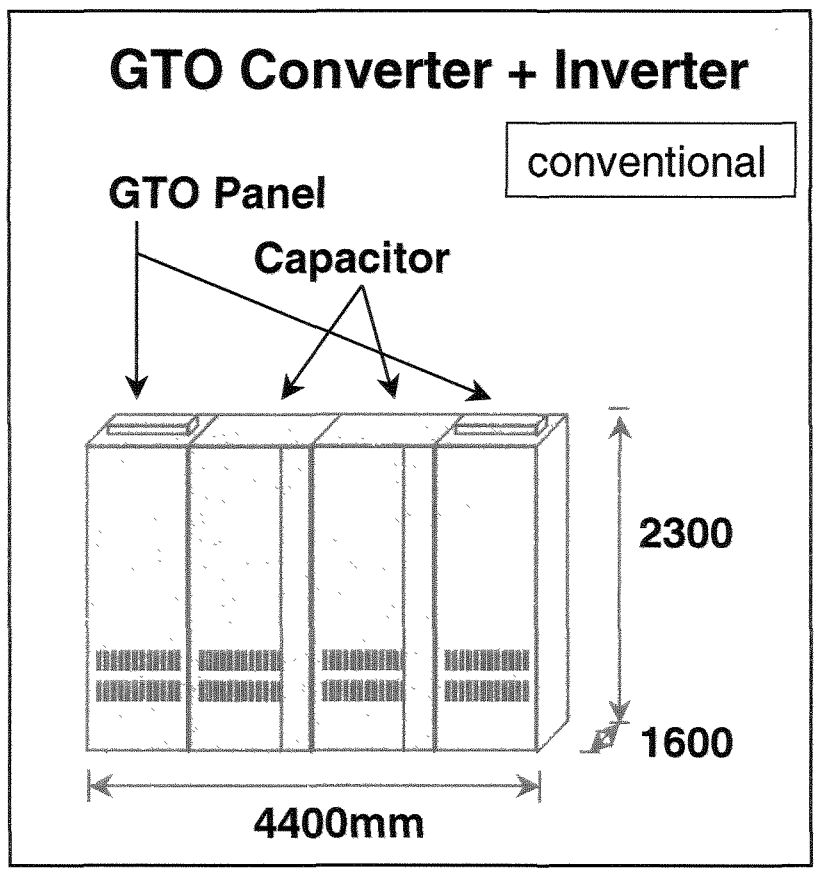
DC clamp snubber circuit used to absorb the energy generated in turning off the IEGTs



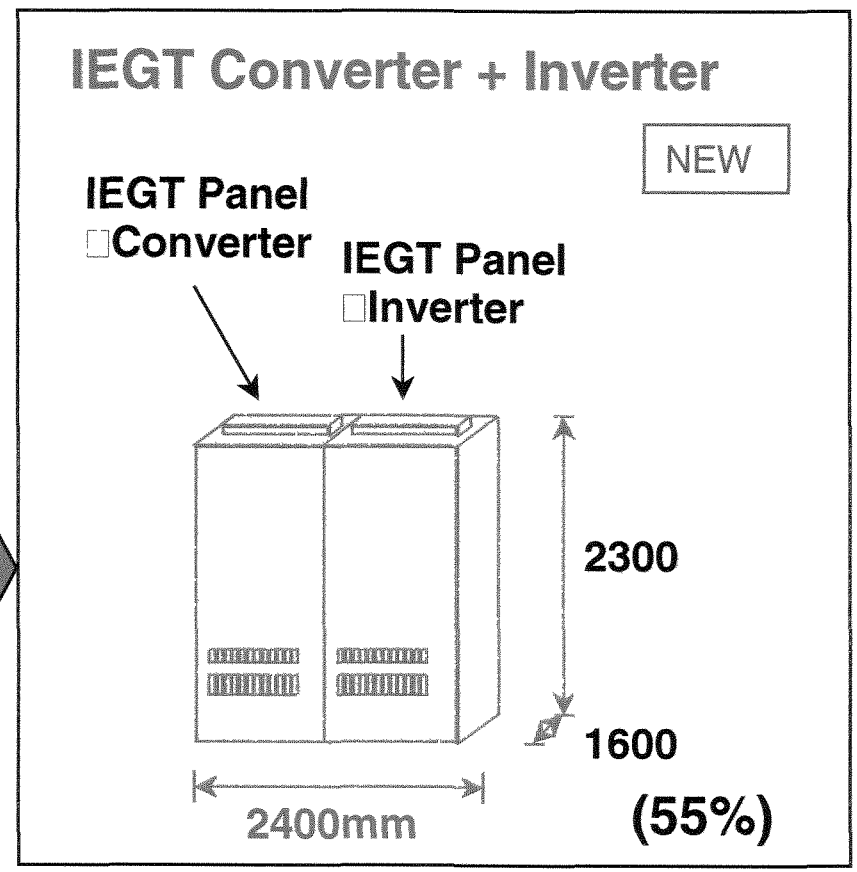
IP7_024482

Floor Space : 1/2

6MVA GTO

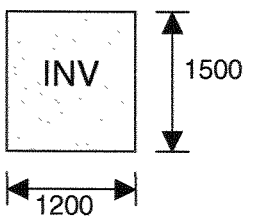


8MVA IEGT

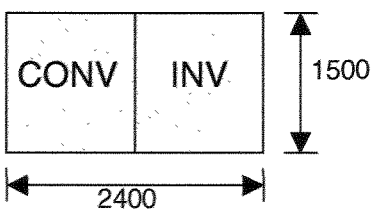


Installation Area of typical IEGT Inverter

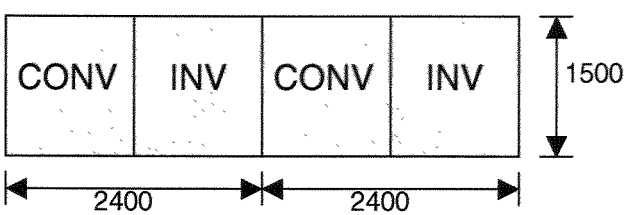
8MVA IEGT Inverter



8MVA IEGT Converter + Inverter

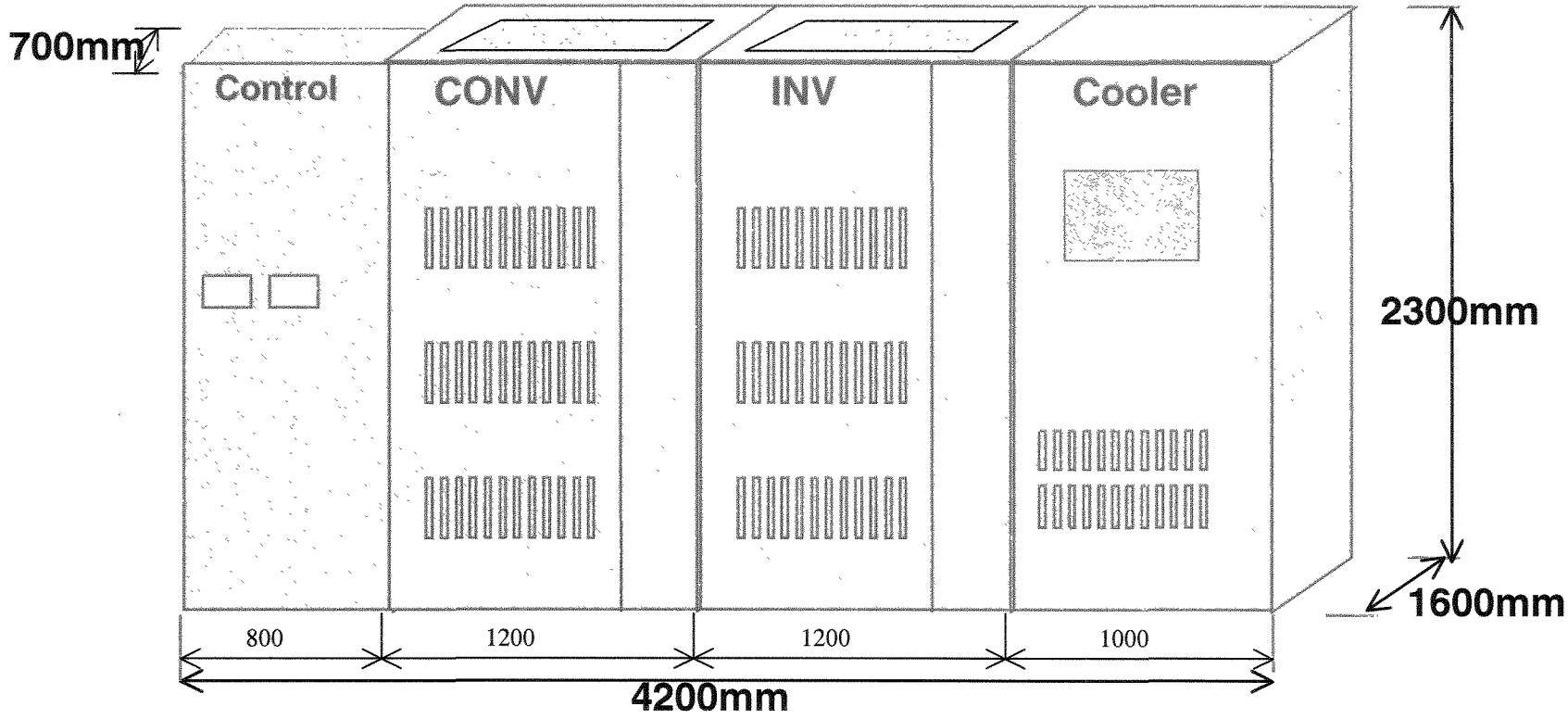


8MVAx2=16MVA IEGT Converter + Inverter



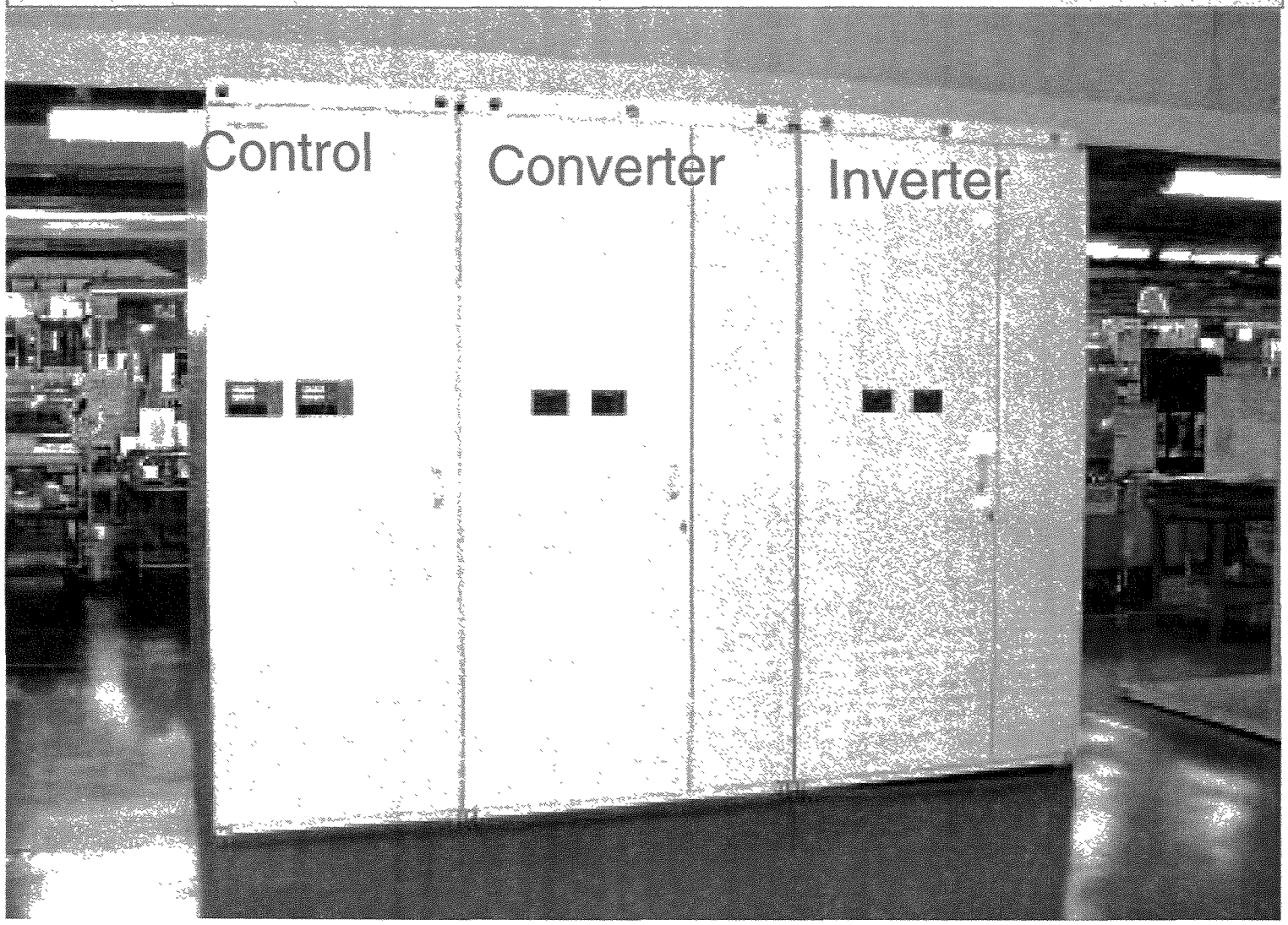
IP7_024484

8MVA-3.3kV IEGT- 3 Level Inverter



IP7_024485

Exterior of IEGT 3 Level Inverter



IP7_024486

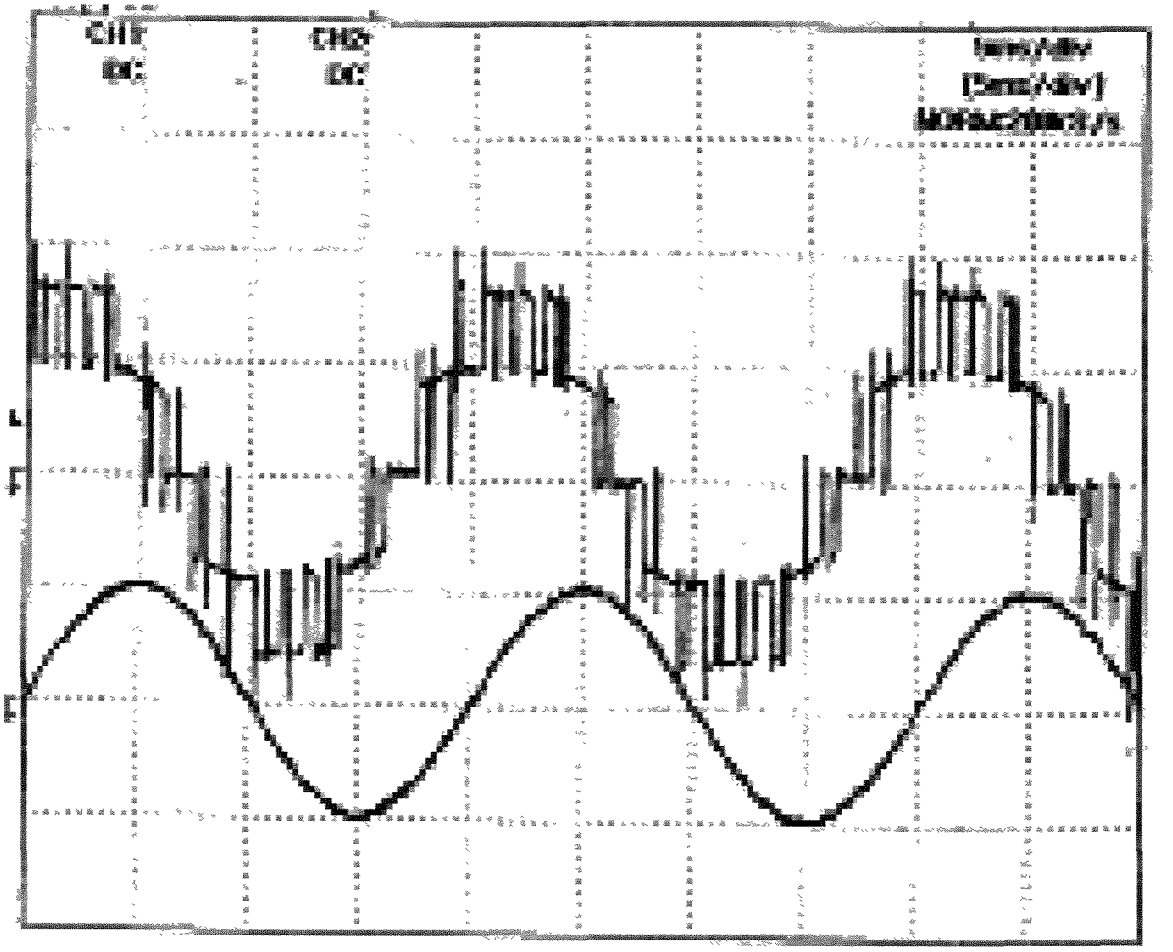
Rolling Mill Main Motor Drive
Feature of 3 Level Inverter

Suitable for Mill Drive	→	**Sine Waveform by 3 Level Inverter** **(Small Torque Ripple)**
Lower Harmonics	→	**Sine Input Waveform by 3 Level Inverter** **Lower Harmonics, Unity P.F or Leading P.F**
HV-AC Motor Drive	→	**Improved Output Waveform** **High Voltage**
Compact size **(Motor, Inverter)**	→	**Compact Size by Water Cooling** **Large Capacity : 8MVA/bank** **High Voltage Output : AC3300V**
Higher Performance	→	Higher Performance Control by Vector Control (Higher Efficiency, Simulator Following Control)

OUTPUT WAVEFORMS

Output Waveform
Voltage
Vuv : 2.5kV/div

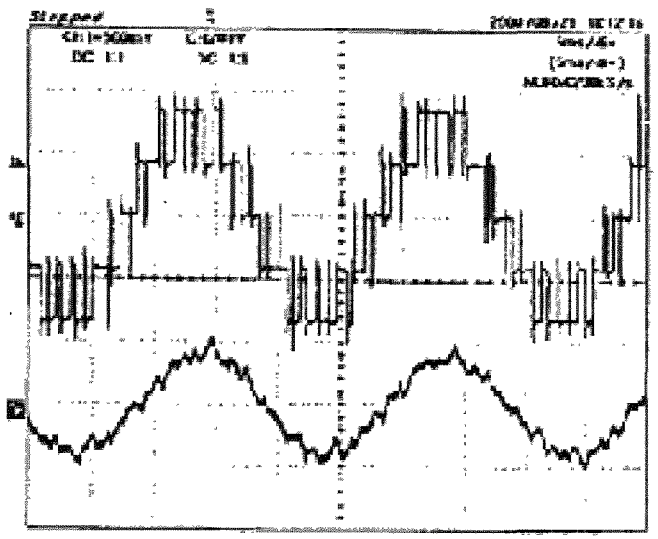
Current
I_L : 2kA/div



IP7_024488

Harmonic Current into AC Distribution System (1)

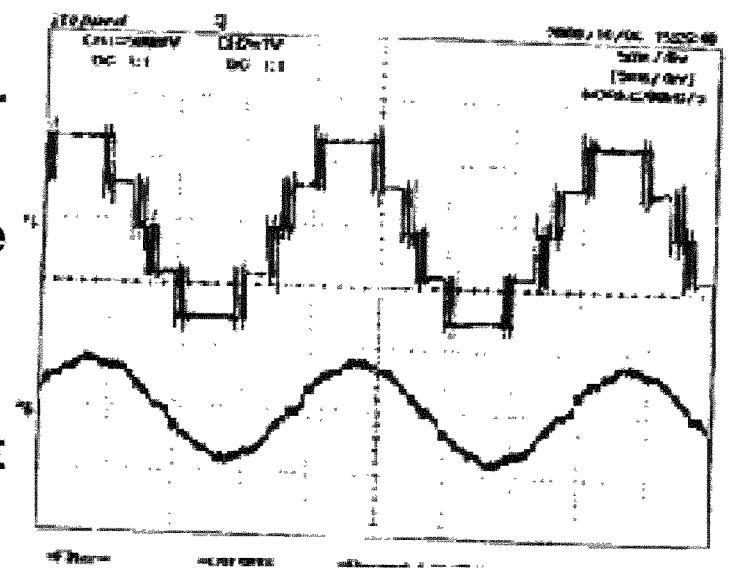
- Carrier Comparison PWM
- FMC (Fixed Modulation Converter)
  - Clear IEEE 519 without harmonic filter



Conventional

Inverter Input Voltage

Line Current

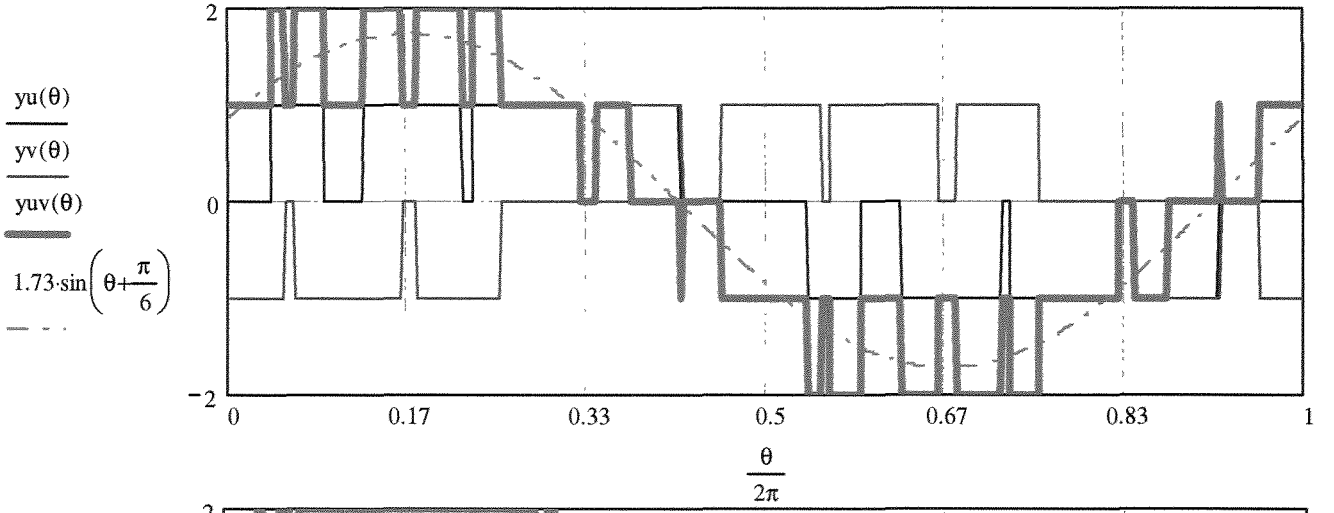


FMC

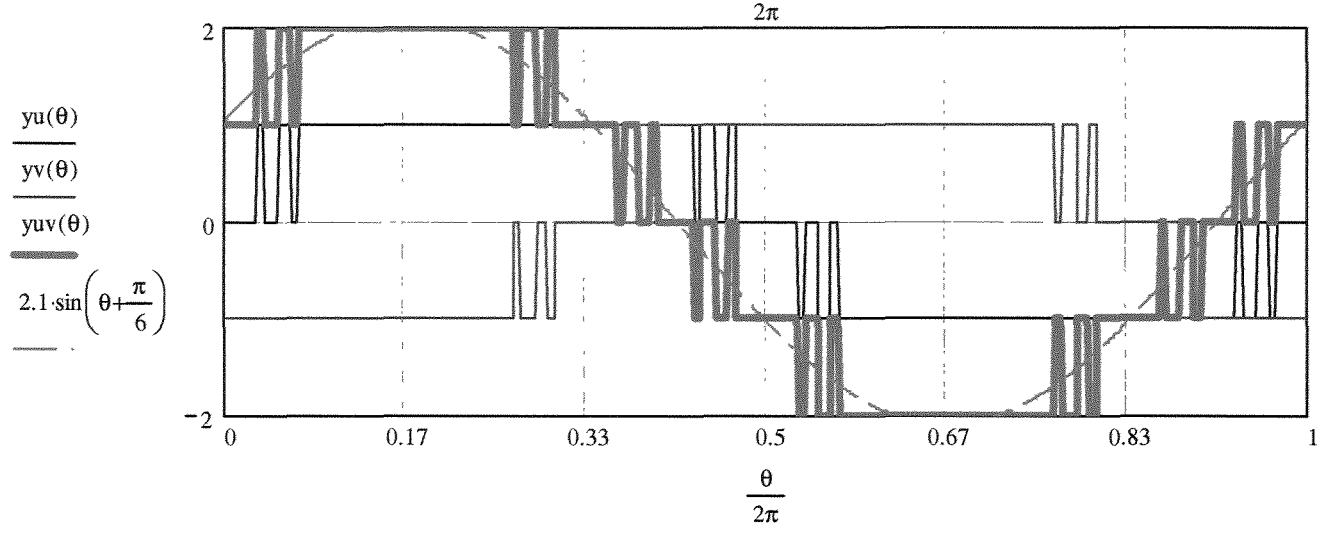
IP7_024489

Harmonic Current into AC Distribution System (2)

Carrier Comparison PWM



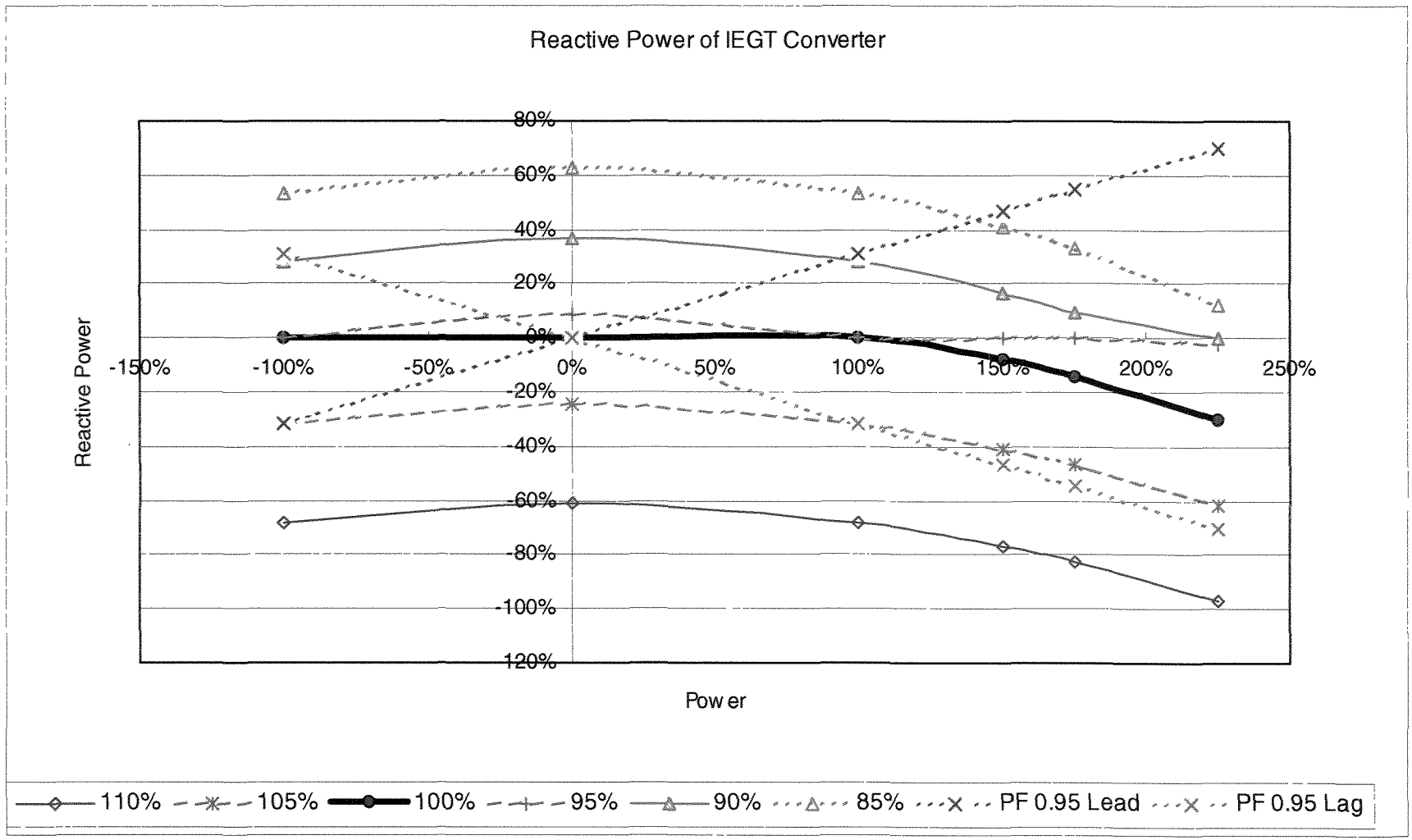
FMC (Fixed Modulation Converter)



IP7_024490

Power Factor of IEGT Converter

Stabilize AC Voltage Deviation



IP7_024491

Comparison of Large Drives

	72 arm Cyclo	3 level GTO Inverter	3 level IGCT Inverter	3 level IEGT Inverter	
Number of Main Devices	THY: 72	GTO: 24 FWD:24 Clamp D:12 Snubber:48	IGCT: 24 FWD:24 Clamp D:12	IEGT: 24 Clamp D:12	Very small number of devices realize compact size and high reliability.
Switching Loss	Very Small	Large	Very Small	Very Small	Excellent switching characteristics as IGCT.
Snubber re-gen. circuit	Not necessary	Must	Not necessary	Not necessary	Snubber re-gen. Circuit is not necessary like IGCT.
Gate Driver	1.5A	600A	6000A	1.5A	The gate power is very small like IGBT.
Power factor	Compensation required	Good	Good	Good	The power factor is same as IGCT.
Cubicle Size	Small	Large	Small	Very Small	Very compact cubicle.
Cooling	Fan	Water	Water	Water	
Total	Good	Possible	Good	Excellent	

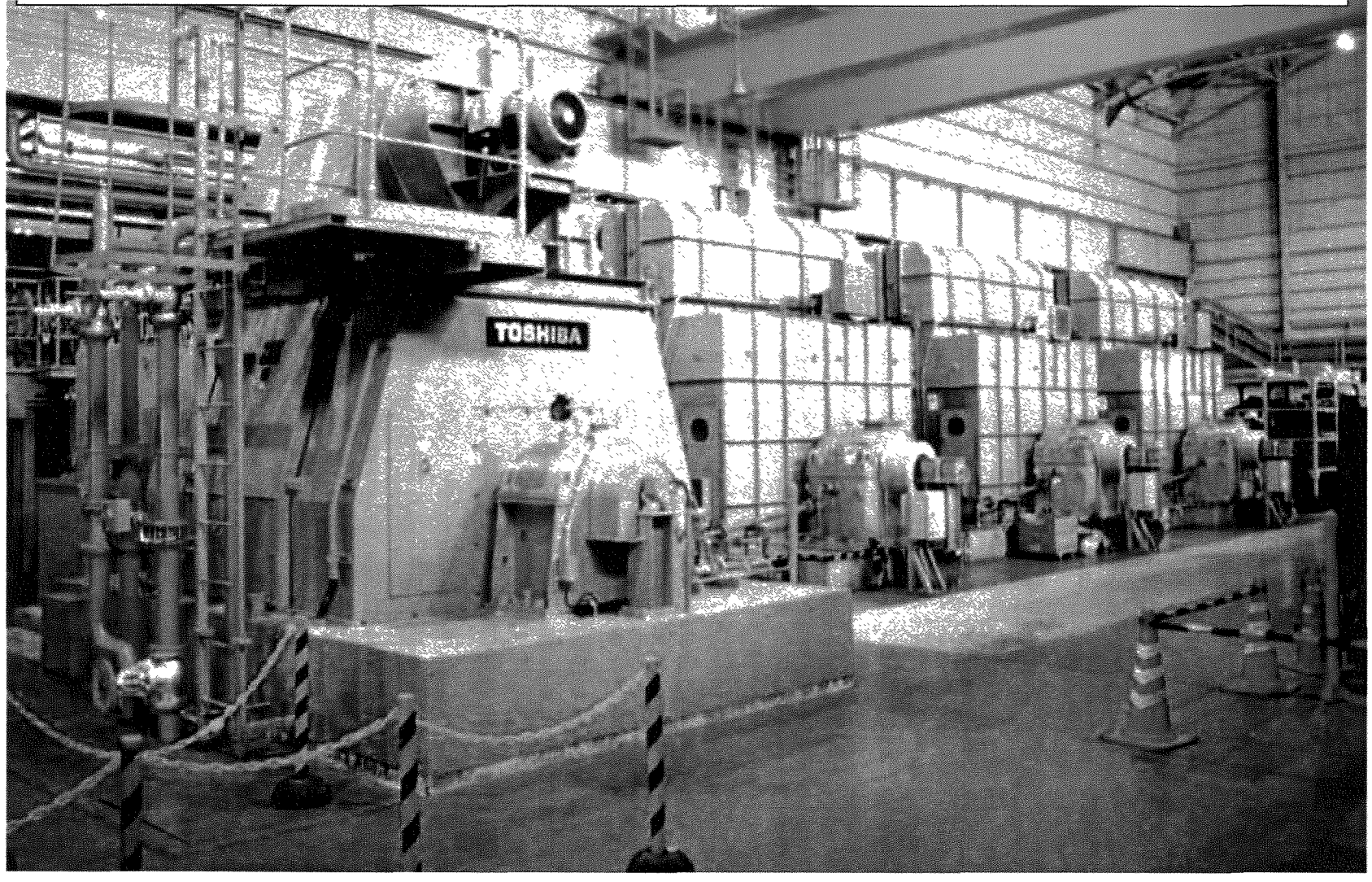
IP7_024492

TOSVERT-μ/S650W Installation and Backlogs

No.	Customer	Application	Motor TYPE	Motor Capacity	Base Speed	Top Speed	Base OL	Bank
				[kW]	[rpm]	[rpm]	[%]	[-]
1	A Certain Co.	NT	IM	4,100			156%	1
2	NKK- Fukuyama	1 Hot R5 Mill	SM	17,000	514	820	225%	4
3	CSI, CA	Hot R5 Mill	IM	5,625	360	360	250%	2
4	NSC- Ohita	Hot R4 Mill	SM	12,000	450	550	250%	4
5	KSC- Mizushima	BD Mill TOP	SM	3,700	30	60	225%	1
6	KSC- Mizushima	BD Mill BOT	SM	3,700	30	60	225%	1
7	CSC	Rod Outlet Mill and Sizing Mill	IM	3,200	850	1700	150%	1
8	POSCO	#2 Wire Rod Mill, Finishing Mill	IM	5,100	600	1080	150%	1
9	POSCO	Billet Mill	IM	2,250	40	100	250%	1
10	NKK- Fukuyama	2 Hot F1	SM	10,000	120	300	175%	2
11	CSC / SMS	Cold, Entry Tension Reel	IM	3,150	301	1125		1
12	CSC / SMS	Cold, Mill Drive	IM	4,200	400	1363		1
13	CSC / SMS	Cold, Exit Tension Reel	IM	3,150	301	1125		1
14	POSCO	PLATE	SM	3,100	45	110	250%	1
15	POSCO	Plate	SM	3,100	45	110	250%	1
16	NSC- Nagoya	TCM #6 TOP	IM	3,500				1
17	NSC- Nagoya	TCM #6 BOT	IM	3,500				1

IP7_024493

5000 kW Induction Motor for Aluminum Rolling Mill



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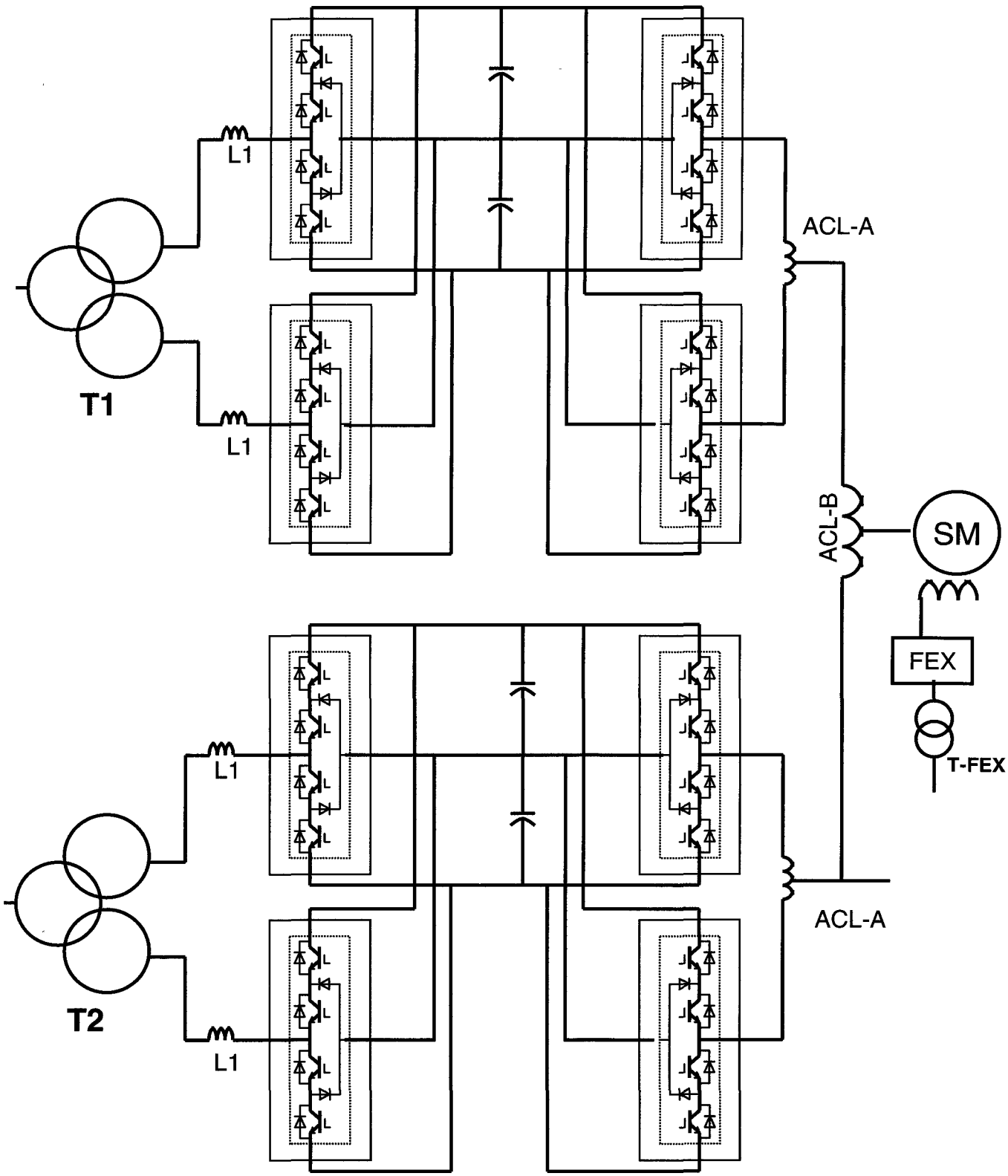


Figure 1 GE-Toshiba T-650 MV Drive
4 - Channel Source, 4-Channel – Single Winding Motor

IP7_024495

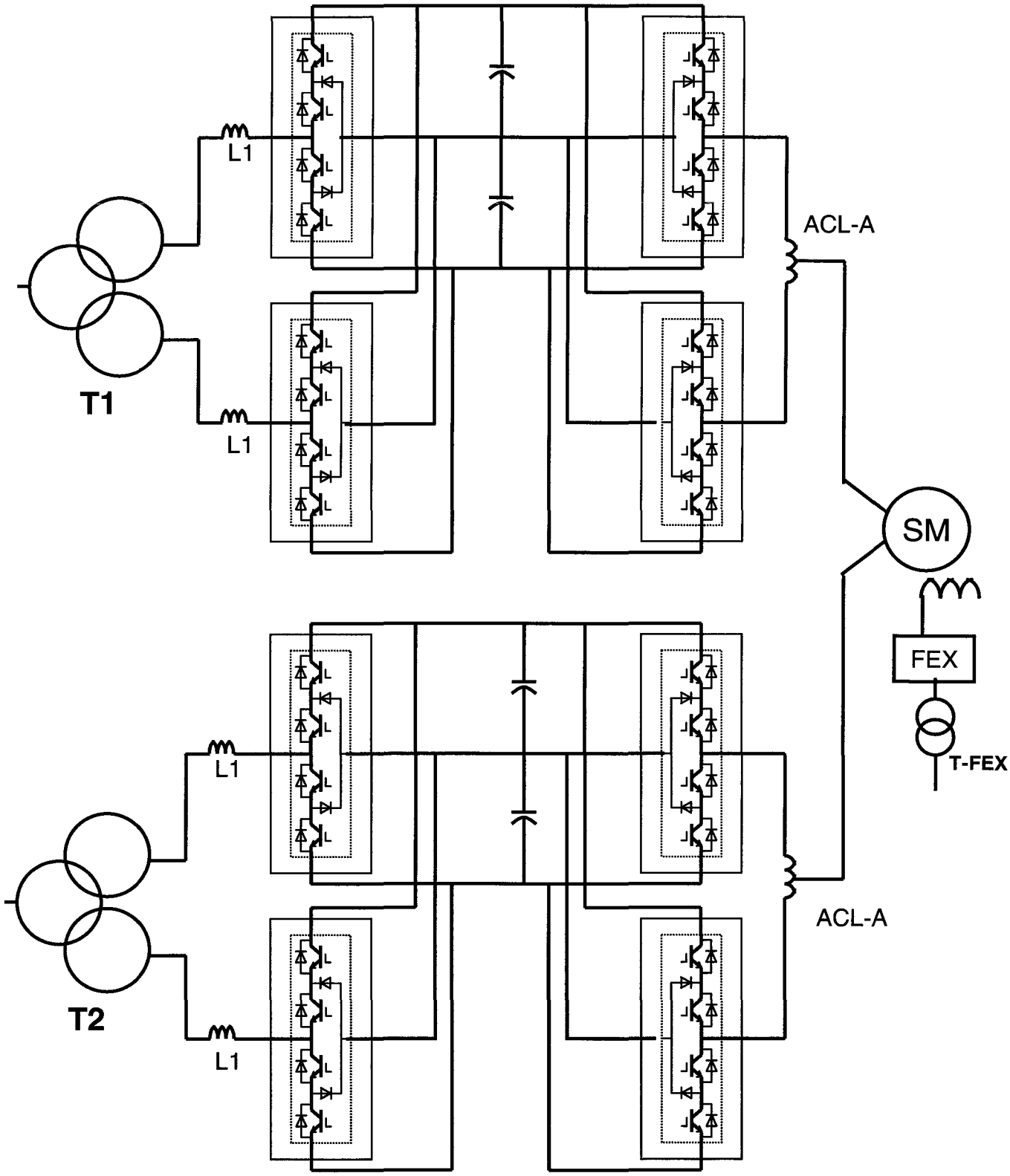


Figure 2 GE-Toshiba T-650 MV Drive
4 - Channel Source, 4-Channel – Dual Winding Motor

IP7_024496

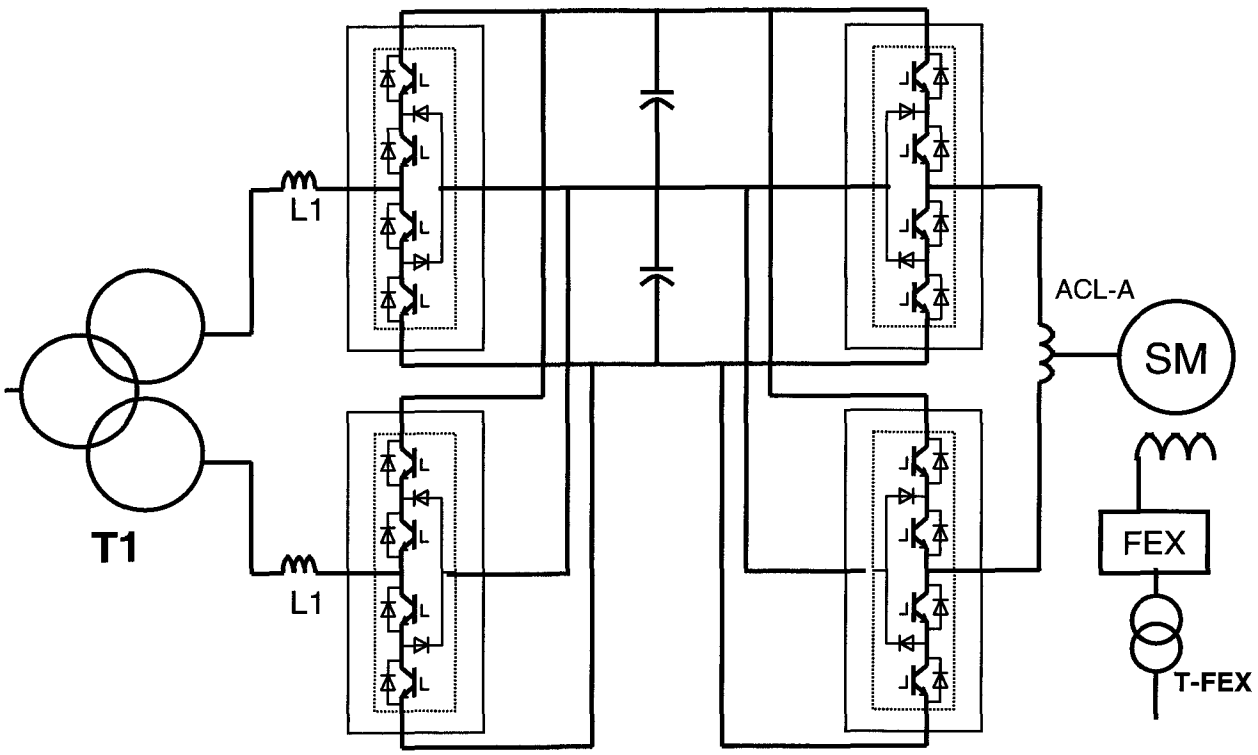


Figure 3 GE-Toshiba T-650 MV Drive
2 - Channel Source, 2 -Channel – Single Winding Motor

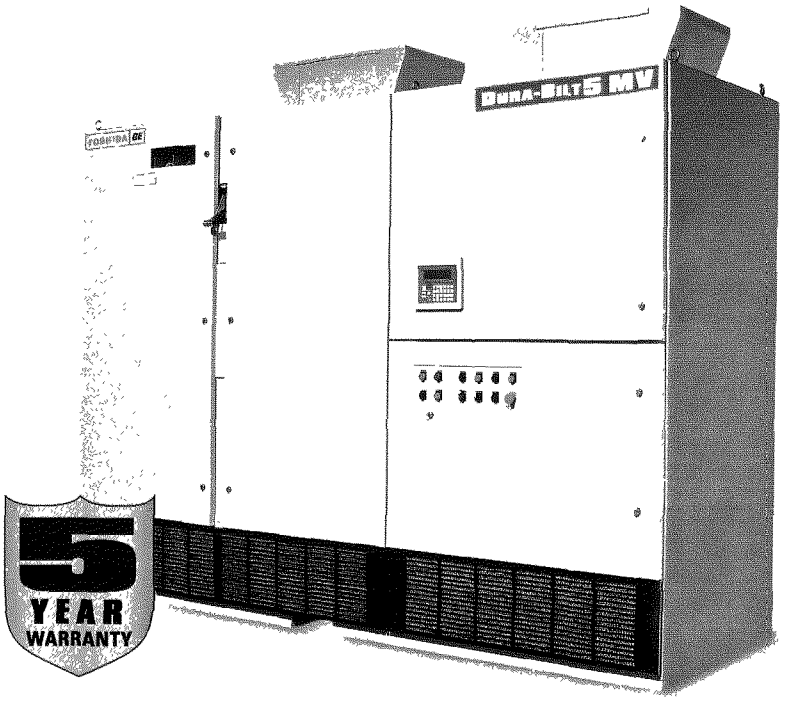
Medium Voltage Drive
400 - 5400 HP*
(300 - 4000 kW*)

The Dura-Bilt5 MV series of medium voltage ac fed drives deliver simple operation in a robust and compact design, providing a cost effective solution for a broad range of applications.

Backed by its five-year standard warranty, the Dura-Bilt5 MV delivers value through low cost of ownership and high reliability.

The Dura-Bilt5 MV product has a series designation appropriate for the outgoing motor voltage:

2000 Series: 2000–2400 V ac
3000 Series: 3000–3300 V ac
4000 Series: 4000–4200 V ac



Design Feature	Customer Benefit
• High reliability and five-year warranty	• Increased uptime and low ownership cost
• Compact design	• Smaller equipment rooms and easier layout
• Control System Toolbox programming	• Common programming tool across GE Toshiba family of drives
• Integral medium voltage disconnect	• No added space needed up to 7.2 kV
• Power modules with medium voltage IGBTs	• Fewer devices for higher reliability
• 24-pulse ac to dc diode converter	• Power-system friendly, IEEE 519 compliant
• Heat pipe air-cooled inverter	• Extends IGBT life on cyclic loads
• Low velocity air paths	• Quiet operation (<80 dBA)
• Multi-level output voltage waveform	• Motor-friendly
• Sensorless vector control	• Matches drive to process needs
• Roll-out power modules	• Fast repair and maintenance
• Copper wound transformer included as standard	• Cooler operation and small size
• Transformer electrostatic shield and lightning arrestors included as standard	• Reliability and power disturbance tolerance

* 115% Overload (OL) for 60 seconds; other OL ratings available.

TOSHIBA GE

Dura-Bilt5 MV 4000 Series

Dimensions and Weights

HP (kW)	Height Inches (mm)	Width Inches (mm)	Depth Inches (mm)	Est. Weight Pounds (kg)
400-900 (300-670)	104 (2640)	74 (1880)	44 (1118)	7,500 (3402)
1000-2000 (750-1490)	104 (2640)	122 (3098)	44 (1118)	11,500 (5216)
2100-2700 (1566-2014)	104 (2640)	164 (4165)	50 (1270)	18,000 (8165)
2750-3600 (2051-2686)	104 (2640)	174 (4420)	50 (1270)	22,500 (10206)
3650-5400 (2723-4028)	104 (2640)	222 (5639)	50 (1270)	32,500 (14742)

Control I/O Comparison by Model

Control Area	Dura-Bilt5	Dura-Bilt5i
Analog Inputs	(2) ± 10 V, configurable, single-ended	(2) ± 10 V or 4-20 mA, configurable, differential
Analog Outputs	(2) ± 10 V, 8-bit, configurable	(2) ± 10 V, 8-bit, configurable
Digital Inputs	(8) -24 V dc, 4 configurable	(2) 24-120 V ac/dc, (6) 24 V dc, configurable
4-20 mA Inputs	(1) isol. standard, total of (2) available	(2) non isol. standard, up to (2) isol. available
Isolated 4-20 mA Outputs	(1) standard, total of (2) available	(1) standard, total of (2) available
24 V dc Relay Drivers	(4) open collector	(6) open collector, (2) dedicated
Relays Included and Connected to Relay Drivers	(1) dedicated plus (1) ea. on Fault, Ready, Run, and Spare	(1) dedicated plus (1) ea. on Fault, Ready, Run, and Spare
Speed Signals	Resolver or 10 kHz pulse tach input, plus tach follower output	High-resolution tach, 125 kHz, 5 or 15 V dc diff input, A Quad B
LAN Interface	DeviceNet™ and TOSLINE®-S20	Profibus-DP, ISBus, DeviceNet, or TOSLINE-S20
Motor Temperature Sensor	1000 Ω res./100 Ω RTD	1000 Ω res./100 Ω RTD

Display and Diagnostics Comparison by Model

	Dura-Bilt5	Dura-Bilt5i
Software	Control System Toolbox for troubleshooting and programming	
Display Format	Eight LCD lines, 40 characters	LCD, graphic based, animated displays
PC Programming Interface	RS-232	Ethernet 10 Mbps
Keypad Functions	Parameter editing Textual editing	Parameter editing Graphic status Drive control
Instrumentation Test Points	Pins on auxiliary display behind control door	Pins on main display on outside of control door
Other Common Features	Parameter access and edit, 16 level fault sequence display, drive setup capability, backlighting of display	

Technical Specifications

Power System Input
- Voltage: up to 7.2 kV, 3-phase
- Frequency: 60 Hz (50 Hz available)
- Displacement power factor (PF): 0.95 lag
- True PF: greater than 0.95 lag from 10% to 100% load
- Lightning arrestors included as standard
- Top or bottom cable entry

Converter Type
- AC fed 24-pulse diode, non-regenerative

Transformer
- Copper winding is standard
- Electrostatic shield is standard
- 115°C rise
- Insulation class: 220°C
- Cooling: forced air
- Optional fan power winding

Inverter
- Five-level NPC (Neutral-Point-Clamped) configuration
- 3300 V IGBTs for margin, minimum parts count
- Optically isolated control for safety
- Roll-out phase modules for fast maintenance and repair

Applicable Standards
- CUL, UL 347A, NEMA ICS 6, NEMA ICS 7

Safety Features
- Integral MV disconnect, door interlocked
- Door electrical interlocks included as standard
- Optical control isolation from MV circuits

Output
- 3% or less motor current harmonic distortion
- Five-level output for motor-friendly waveform
- Optional integrally mounted output filter
- Top or bottom cable entry

Operating Environment and Needs
- Temperature: 0° to +40°C no derating
  Up to +50°C with derating
- Altitude: Up to 3300 ft/1000 m a.m.s.l. no derating;
  Up to 10,000 ft/3280 m a.m.s.l. with derating
- Heat load: 3000 Watts (10,245 BTU/Hr) per 100 hp output
- Fan and Control Power (by user): 460 V, 3-phase, 60 Hz, 3.5-10 kVA
  (other voltages and 50 Hz available)

Input Power Harmonic Data
- ≤ 3% THD (current distortion)
- Meets IEEE 519-1992 standards without filters

Cooling
- Air-cooled with redundant fan option
- Separate converter and inverter cooling paths
- Inverter utilizes heat pipe technology for long IGBT life, compact size, and low noise

Sound
- Less than 80 dBA, at one meter from enclosure

Control
- Non-volatile memory for parameters
- Vector control with or without speed feedback

Vector Control Accuracy and Response
- Speed regulator: 20 rad/s
- ± 0.01% speed regulation with speed sensor, ± 0.5% without
- Torque response: 500 rad/s
- Torque accurracy: ± 4% with temp sensor, ± 30% without

Protective Functions
- Inverter overcurrent, overvoltage
- Loss of phase and low/loss of system voltage
- Ground fault
- Loss of dc link
- Motor overload
- Temperature

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www.getoshiba.com

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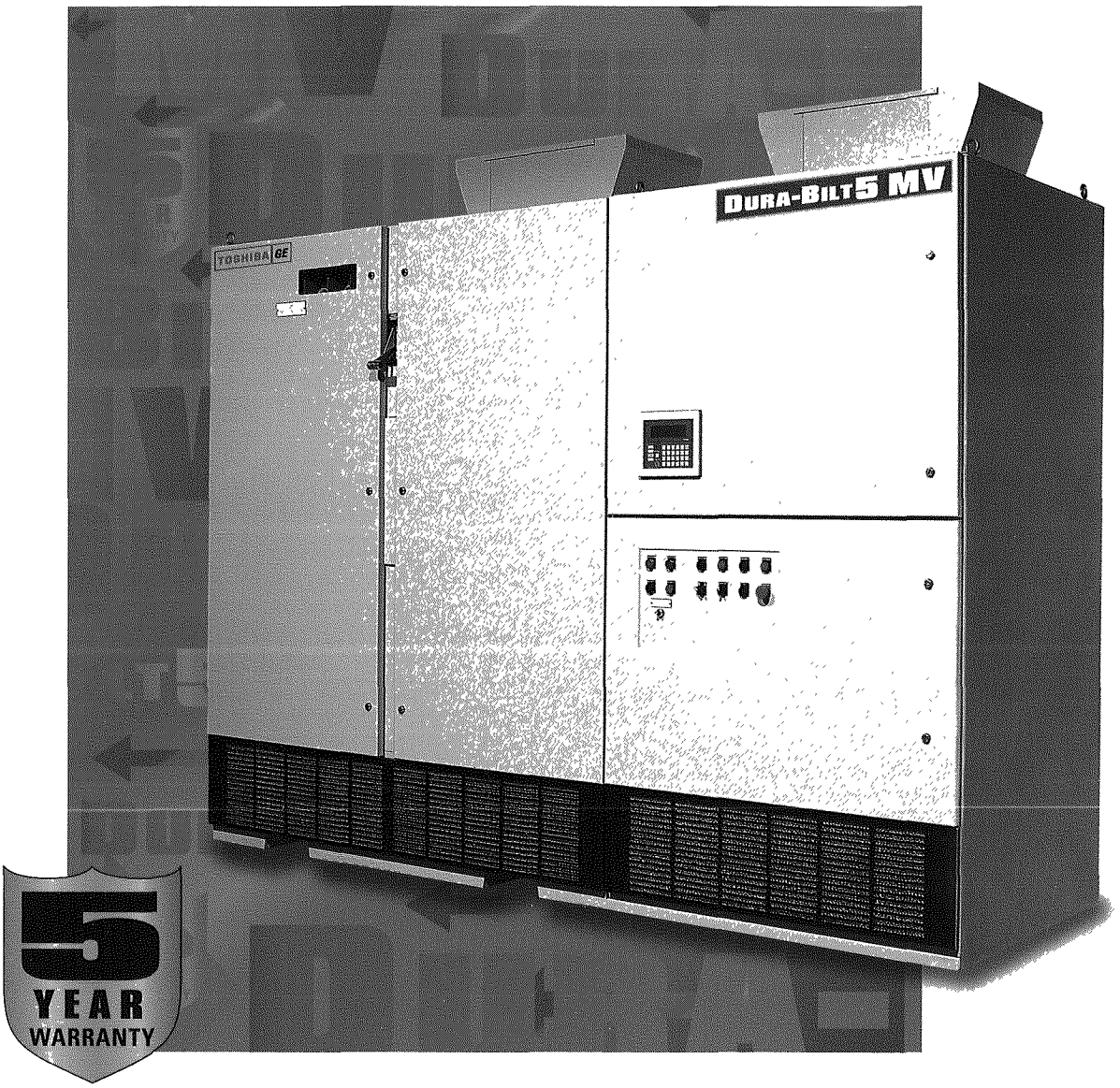
IP7_024499

TOSHIBA GE

TOSHIBA GE AUTOMATION SYSTEMS CORPORATION



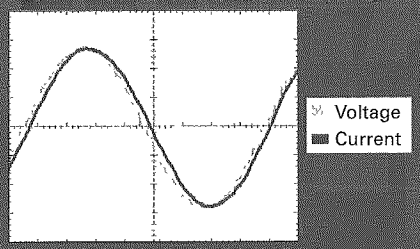
DURA-BILT 5 MV

2000/3000/4000 Series Application Guide

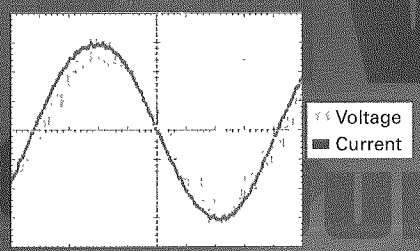
IP7_024500

GE and Toshiba have teamed up to design a family of medium voltage drives focused on **lowering your cost of ownership.**

Power System Friendly



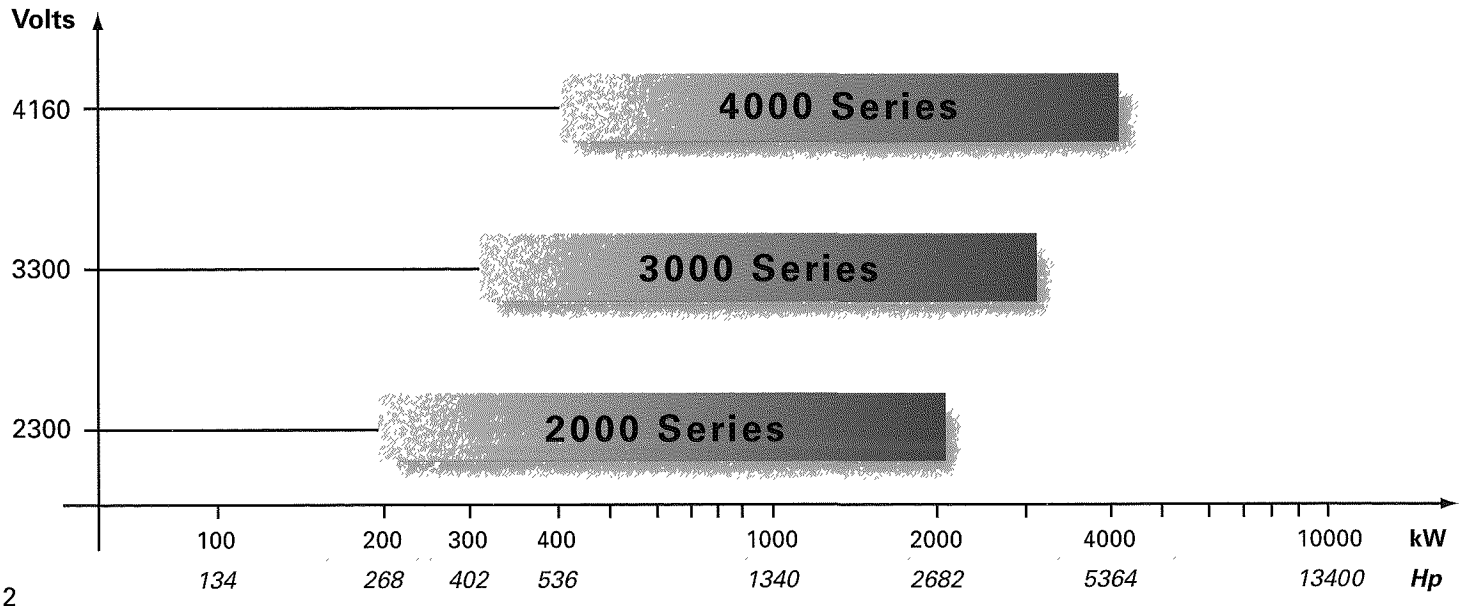
Motor System Friendly



Features	Benefits
Medium Voltage IGBTs Each inverter utilizes medium voltage Insulated Gate Bipolar Transistors (IGBTs).	**Rock Solid Reliability** These high-power IGBTs create a simpler, more reliable inverter design.
24-Pulse Converter Each phase leg of the converter includes a 24-pulse diode rectifier.	**Power System Friendly** This design exceeds the IEEE 519-1992 specification for Total Harmonic Distortion (THD) without requiring filters.
Heat Pipe Cooling Technology Heat pipe cooling technology is used in each of the three inverter phase legs.	**Compact Quiet Design** This form of cooling reduces the ambient noise and saves valuable floor space in your plant.
Windows-Based Configuration & Maintenance Tools For pc-based configuration, the Control System Toolbox features: • Animated block diagrams • Functionally organized parameters • Integrated trend window	**Faster Commissioning & Maintenance** These world-class tools drive productivity in commissioning and typical maintenance activities.

DURA-BILT 5 MV

Covering a broad range of medium voltage drive applications.



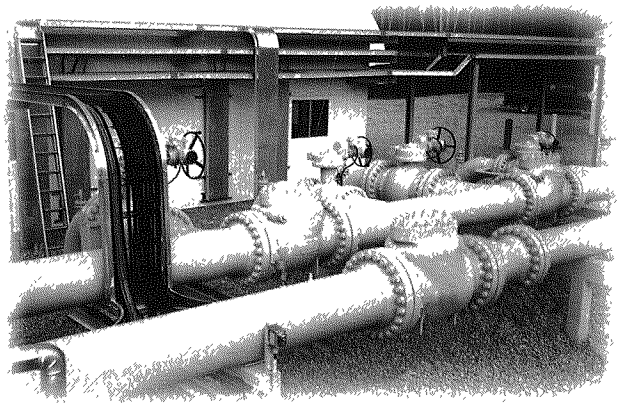
IP7_024501

Bringing Reliable Control To A Wide Variety Of Industries

Cement Plant

The Dura-Bilt5 MVs compartmentalized design streamlines installation, commissioning, and maintenance of medium voltage fans, mills, separators, and kilns. With a Mean Time Between Failure (MTBF) exceeding 16 years, the Dura-Bilt5 MV is engineered to deliver rock solid performance in virtually any application.

The Dura-Bilt5 MV family of drives can be seamlessly integrated with the rest of your pump or compressor station control system. They can be applied to existing motors and cabling, making them an excellent fit in modernization/retrofit applications.

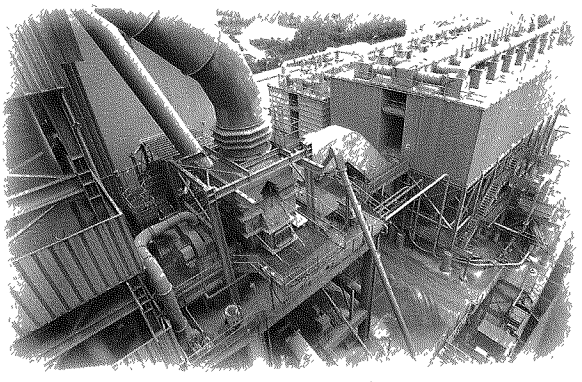


Pump Station

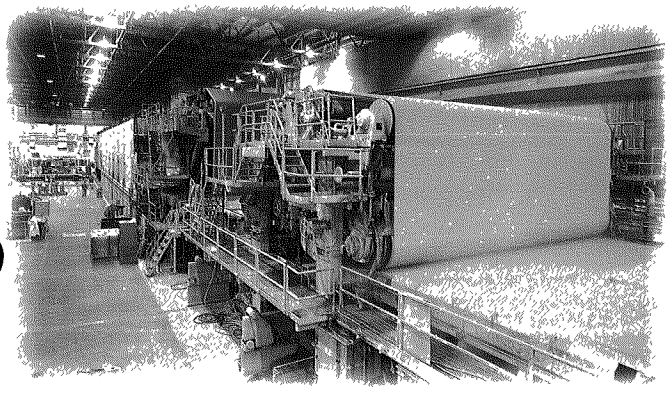
Mining Conveyor

Accurate torque control is a key in controlling large conveyors. The Dura-Bilt5 MV's flux vector algorithm provides the accuracy and response for this demanding application.

Traditional mechanical methods of controlling airflow are inefficient and require considerable maintenance. The Dura-Bilt5 MV provides more accurate and energy efficient control of airflow while eliminating the maintenance associated with dampers or vanes.



Induced Draft (ID) Fan In Cement Plant



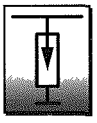
Paper Machine

In configuration and maintenance of coordinated drive systems, common pc-based tools are essential. The Dura-Bilt5 MV shares the same Toshiba GE Control System Toolbox Windows-based application with the entire family of Toshiba GE system drives and Innovation Series™ controllers.

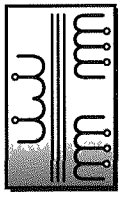
4000 Series 1600 kVA Frame - A Compact

Differentiating Features:

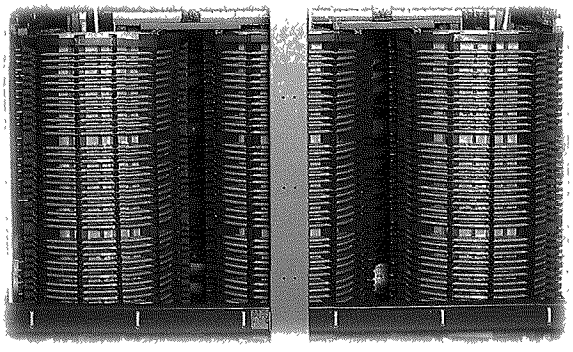
- Compact design saves valuable floor space
- Compartmentalized design provides voltage class segregation and top or bottom cable feeds
- Copper wound integral transformer provides reliable operation and simplifies installation

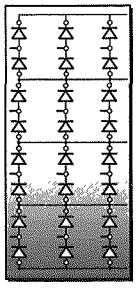


Lightning Arrestors – Standard
Incoming power (top or bottom fed) is protected by distribution class lightning arrestors for suppression of transient surges.

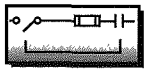


Copper Wound Isolation Transformer – Standard
An integral copper wound transformer is mounted in the rear of cabinet. It meets or exceeds standards established by ANSI/IEEE C57.12.91. Transformer is rated for 239°F *(115°C)* rise and its insulation system is rated at 428 °F *(220°C)*. An electrostatic shield is included for transient resistance.

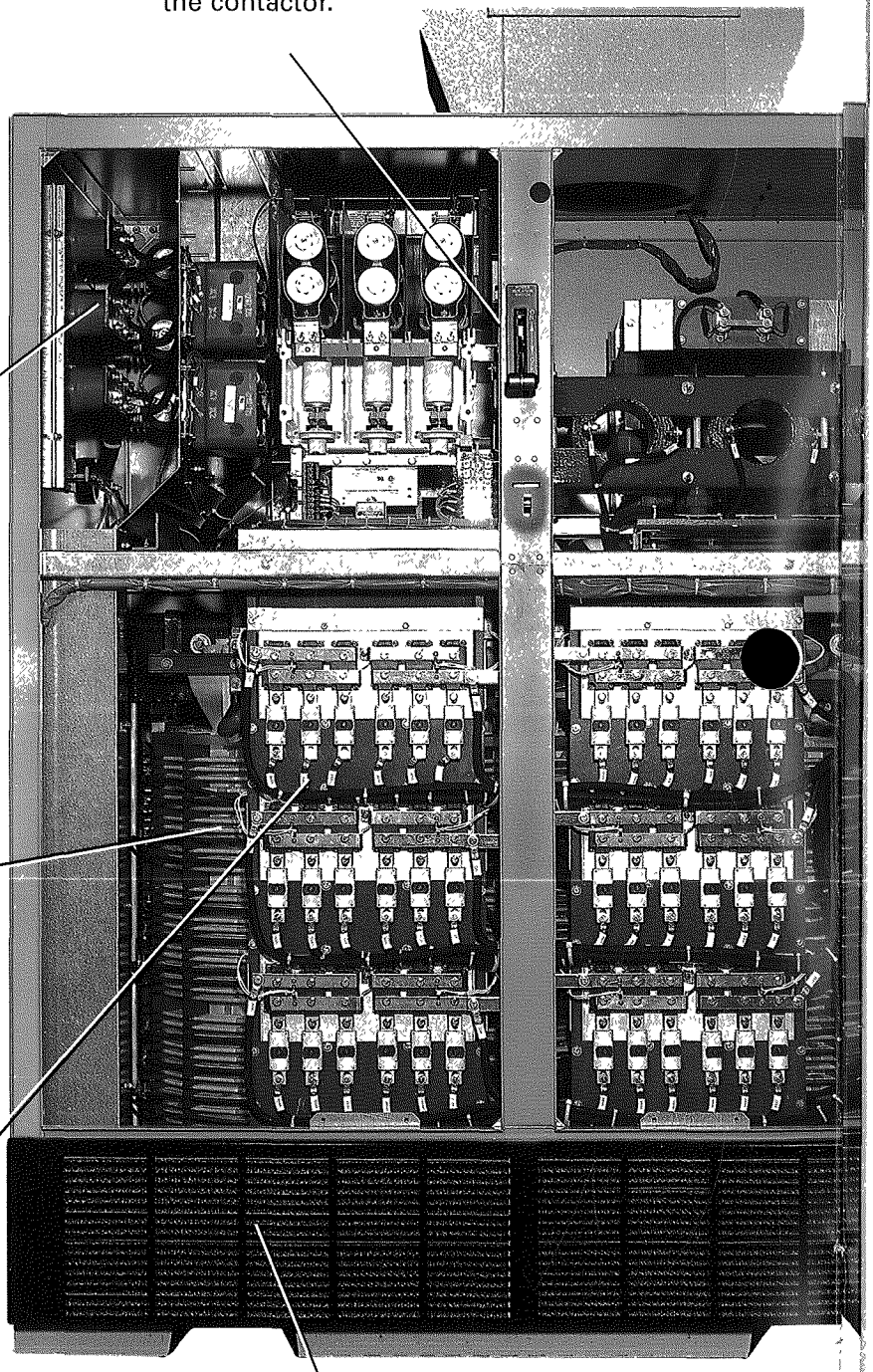


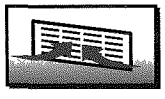


IEEE 519 Compliant 24-Pulse Source
Each phase leg has its own 24-pulse rectifier input. This design exceeds the IEEE 519-1992 stringent guidelines for input voltage and current distortion. The source diodes are mounted to an air-cooled extruded aluminum heat sink with fuse protection. Each fuse has blown fuse indication, and the dc bus is monitored for fuse loss.



Input Power Disconnect – Option
A fused integral 3-phase disconnect option with vacuum contactor allows maintenance personnel to lockout or disable the drive. For additional safety, each of the high voltage doors is mechanically or electrically interlocked with the contactor.





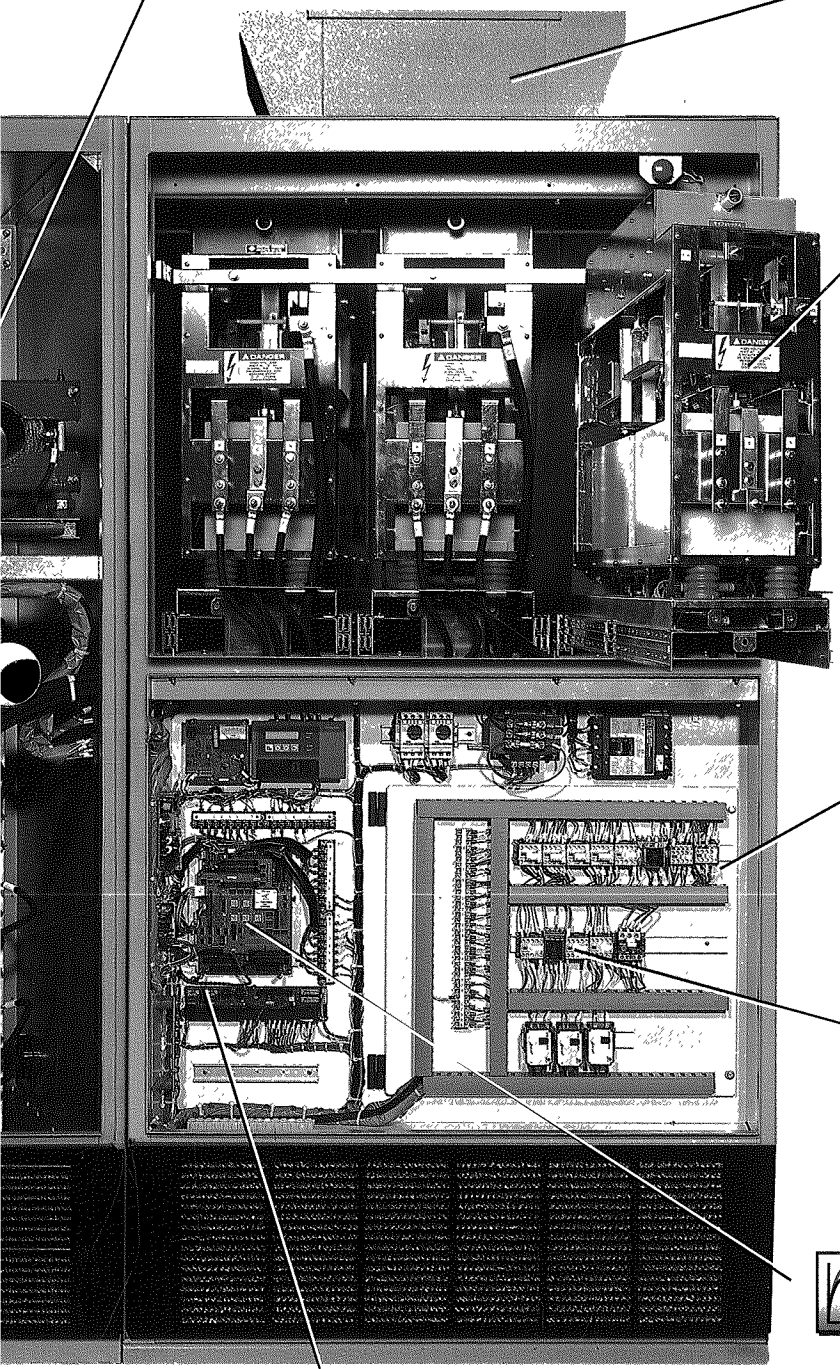
Filtered Air Intake
Washable input air filters have front access for periodic maintenance.

IP7_024503

Design

Integral Pre-Charge AC Reactor
An ac reactor and medium voltage contactor control the charging of the dc bus, minimizing stress on the fusing and power components.

Blower Assemblies
Quiet (<80 dB @ 1 m) backward curved impeller fans circulate air throughout the enclosures, pulling air from the bottom filter assemblies and venting it out the top of the cabinets. Redundant fan assemblies can be provided as an option.



Roll Out Inverter Phase Leg Assemblies
The three modular phase leg assemblies include:
- Neutral point clamped power cell
- Medium voltage IGBTs
- DC bus capacitors, oil-filled for long life
- Gate driver circuit board
- Heat pipe cooling assembly
- 120 V ac to 15 V dc power supply
- Fiber optic link interface circuit board

A phase leg assembly can be easily rolled out (using heavy-duty slides) and replaced in 15 minutes for maintenance.

Motor Cabling Termination
Control panel swings out for access to motor cabling terminations. Both top and bottom motor cabling is supported as a standard.

Application Specific Controls
Each drive is matched to project requirements with custom control components mounted in this area.

Control Functions
Each of the frames is available with either the Dura-Bilt5 or Dura-Bilt5i control boards. In both cases, the primary control board performs several control functions:
- Speed and torque regulation
- Sequencing
- I/O mapping
- Set of capture buffers
- Optional LAN interface board

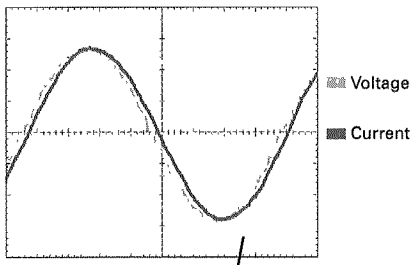
The drive is configured from the Control System Toolbox.

I/O Board
Based on the application, 1 of 2 types of I/O boards is available (refer to page 8 for specifications). All I/O is terminated to a two-piece modular terminal block for ease of maintenance and troubleshooting.

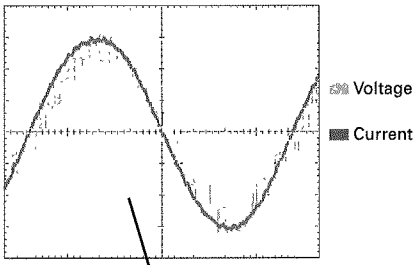
DURA-BILT5 MV Power Bridge Technology

The Dura-Bilt5 MV power bridge design provides advantages over competing medium voltage technology in reliability, footprint, and maintenance.

Dura-Bilt5 MV Input Waveform



Dura-Bilt5 MV Output Waveform



1 of 3 phases shown in detail

C (W)
B (V)
A (U)
Transformer/Source Compartment 24-Pulse Source

C (W)
B (V)
A (U)
Inverter Compartment Phase-Leg Assemblies

Integral pre-charge circuit

Main Power
7.2 kV or below
50-60 Hz

Incoming Power Compartment

3

E

Standard integral lightning arrestor

Sensing potential transformers, 120 V output

Integral disconnect option

460 V ac

Standard E.S. Shield

Control power feed option

Voltage detection module

Optical link module

3

M

Current feedback

Output disconnect option

Auxiliary & Control Power
460 V ac standard, others available

3

460:120

3

1

Redundant fans option

Phase detection module

3

Power Supply (PS1)

+5 V dc
+15 V dc
-15 V dc
0 V dc

Main Controller

Gate Signal Distributor

LAN Interface

Power Supply (PS2)

+24 V dc
0 V dc

External I/O

Control Compartment

Control System Toolbox

3

Input bypass disconnect option

Note: Input bypass and output contactors are mounted in a separate cabinet integral to the line-up.

IP7_024505

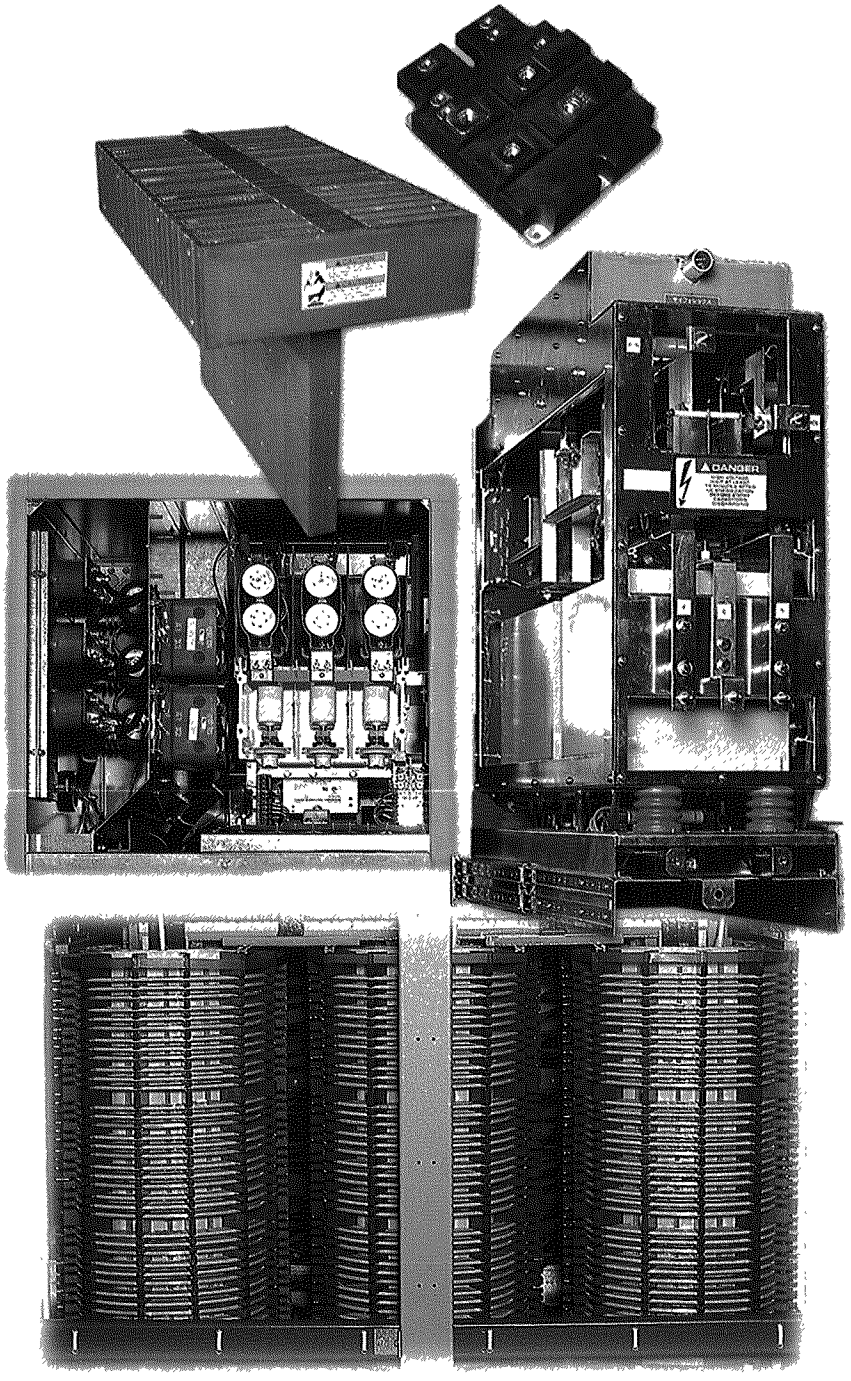
Driving The Five Year Warranty

5 YEAR WARRANTY

The design behind the warranty...

Designed to a Mean Time Between Failure (MTBF) of More than 16 Years

- Medium Voltage rated IGBTs minimizes the component count
- Neutral Point Clamped (NPC) power bridge topology improves motor waveform quality while maintaining efficiency
- Oil filled capacitors instead of limited life electrolytic type
- Copper wound 239°F *(115°C)* rise transformer with electrostatic shield standard
- Built in surge and transient protection
- Minimized transformer connections
- Conservative rating practices used on all components



Minimized Component Count

- Reduced parts count achieved by using medium voltage IGBTs
- Fewer ancillary components compared to SGCT/GTO & IGCT technologies
- No water cooling (deionizers, pumps, heat exchangers)
- Designed to minimize the opportunity for failure (by using fewer parts) rather than distributing failure (by using redundant parts)

A Control Offering To Fit Your Application

	Dura-Bilt5 I/O Offering	Dura-Bilt5i I/O Offering
PC-Based Configuration Tool Interface	• RS-232C interface • 9.6 kbps maximum	• Ethernet 10 Mbps • Single point or multi-drop configuration
Digital Inputs	+24 V dc • Quantity 4 configurable mapping • Quantity 4 dedicated	24-120 V ac/dc, 50/60 Hz • Quantity 1 configurable mapping • Quantity 1 dedicated (hardware disable) +24 V dc • Quantity 6 configurable mapping
Digital Outputs	+24 V dc • Open collector • Quantity 4 configurable mapping	+24 V dc • Open collector • Quantity 4 configurable mapping • Quantity 2 user defined
Analog Inputs	±10 V, A/D • Quantity 2, ±10 V • 12-bit resolution • Configurable mapping	±10 V, 4-20 ma A/D • Quantity 2, ±10 V or 4-20 mA, • Differential 8 kΩ impendence • 12-bit resolution • Configurable mapping
Analog Outputs	D/A ± 10 V • Quantity 2, ±10 V • Configurable gain, offset, and mapping • 8-bit resolution	D/A ± 10 V • Quantity 2, ±10 V • User defined • 8-bit resolution
Speed Feedback	Sin, Cos, Sin, Cos, Excitn, Fdbk **Resolver** • Excitation freq of 1 kHz • Preferred source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp A, B, +15 V **Tachometer** • Maximum freq of 10 kHz • Drive provides 15 V dc A, B, +12-24 V **Speed Tach Follower Output** • Maximum freq of 10 kHz • External 12-24 V dc is required	A, ~A, B, ~B, M, ~M, +15 V **High Resolution Tachometer** • A Quad B with marker • Maximum freq of 125 kHz per channel • Differential 5 or 15 V dc • Drive provides 5 or 15 V dc @ 150 mA
LAN Interface Options	• DeviceNet • TOSLINE-S20	• DeviceNet • Profibus-DP • ISBus • TOSLINE-S20
Motor Temperature Feedback	M • High resolution torque motor temperature feedback • 1 kΩ platinum resistor or 100 Ω platinum RTD (RTD uses analog input with signal conditioner)	

IP7_024507

Between the Dura-Bilt5 and 5i controls, your application requirements are covered. In straightforward applications, the Dura-Bilt5 provides effective control. When advanced control or advanced diagnostic functionality is required, the Dura-Bilt5i can be applied. A few of the key features for these products are summarized below:

			Dura-Bilt5i MV Advanced Control Features				
Medium Voltage Drive Application	Dura-Bilt5 MV Speed Sensor Required	Dura-Bilt5i MV Speed Sensor Required	High Performance Torque Regulation Without Motor Temperature Sensor	Transfer Motor To/From Line	Bumpless Transition From Tach To Tachless Operation	Motor Thermal Overload Class 10/20/30 Protection	Auto-Tune
General Industry							
Pumps							
Centrifugal				✓		✓	✓
Reciprocating	✓					✓	✓
Fans							
Induced Draft				✓		✓	✓
Inline Fan						✓	✓
Compressors							
Centrifugal				✓		✓	✓
Reciprocating	✓					✓	✓
Mining & Cement							
Crushers	✓					✓	✓
Ball Mills	✓			✓		✓	✓
Conveyors	✓		✓	✓		✓	✓
Kilns	✓	✓	✓		✓	✓	✓
Rubber & Plastics							
Extruders	✓		✓			✓	✓
Pelletizers	✓					✓	✓
Mixers	✓	✓	✓		✓	✓	✓
Utilities							
Boiler Feed Pump				✓		✓	✓
ID, FD Fans				✓		✓	✓

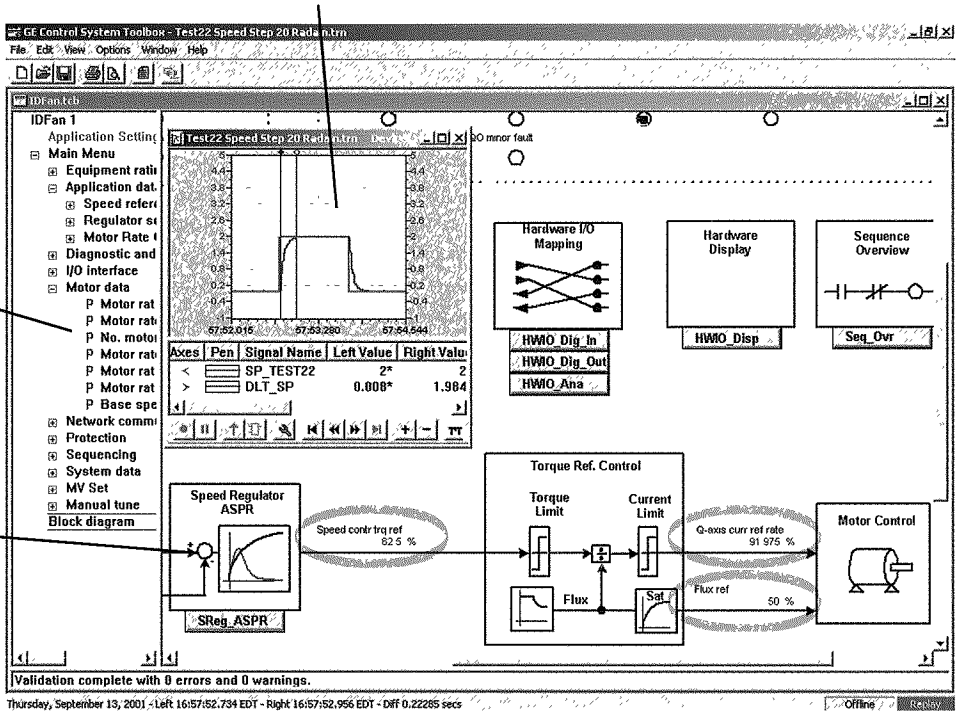
Drive/Motor Monitoring & Analysis

The 5 and 5i keypads, coupled with the Windows-based Control System Toolbox, bring productivity to your commissioning and maintenance activities.

Integrated Trend Window
The toolbox application has an integrated trend window that allows the user to:
- Define a trend with drag-and-drop variables from function block diagrams or select the variables from a list.
- Conduct online real time trending with the drive or upload the capture buffers in the drive for trending. For historical trending, define a link with integrated historian database.
- Quickly define a display with the auto scaling toolbar button.
- Analyze a specific time frame with the zoom in/out toolbar buttons.
- Create different views using variable hiding.
- Analyze specific times with cross hairs.
- Perform frequency-based analysis of the trend using the Fast Fourier Transform (FFT) function.

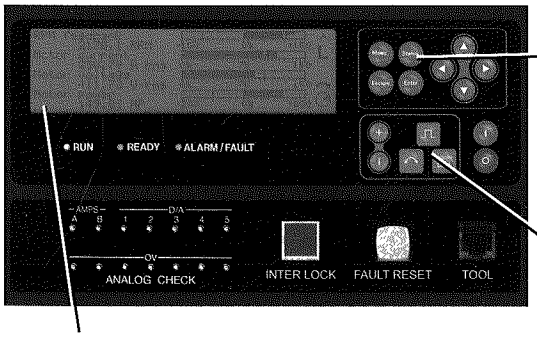
Outline View
Functionally organized parameters and variables allow quick access to any given function.

Animated Block Diagrams
Provides an animated graphical display of drive sequencing and regulation functions. Animated variables are shown in green, and the buttons are used to navigate to associated functions.



Control System Toolbox

Dura-Bilt5i Keypad



Parameter Editing
Intuitive menu interface for parameter editing.

Local Drive Control
Dedicated keys for local control of the drive for commissioning and maintenance activities.

Drive Status
Graphic status screen displays key variables in bar chart format with additional status icons.

Display Functions
- Speed/Current response
- Digital monitoring of data
- Fault history

Keypad Functions
- Parameter editing
- Memory card operation

Dura-Bilt5 Keypad

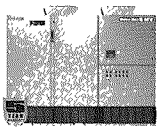
IP7_024509

TOSHIBA GE

Dura-Bilt5 MV-4000 Series Data Sheet

GE and Toshiba have teamed up to create a family of medium voltage drives that feature

- Compact compartmentalized design
- Power system friendly 24-pulse source
- Motor friendly five-level inverter
- Comprehensive 5 year parts and labor warranty



Drive & Transformer	Power Motor Shaft hp (kW)	Rated I_{phase} AC Amps	Weight lbs (kg)
104 in (2634 mm) / 44 in (1102 mm) / 74 in (1880 mm)	400 (298)	51	
	500 (373)	64	7500 (3409)
	700 (522)	90	
	900 (671)	115	
104 in (2634 mm) / 44 in (1102 mm) / 122 in (3099 mm)	1000 (746)	127	
	1250 (933)	158	11500 (5227)
	1500 (1119)	190	
	2000 (1492)	253	
104 in (2634 mm) / 50 in (1257 mm) / 164 in (4166 mm)	2250 (1679)	279	
	2500 (1865)	310	18000 (8182)
	2700 (2014)	334	
104 in (2634 mm) / 50 in (1257 mm) / 174 in (4420 mm)	3000 (2238)	372	
			22500 (10227)
	3500 (2611)	433	
104 in (2634 mm) / 50 in (1257 mm) / 222 in (5639 mm)	4000 (2984)	490	
	4500 (3357)	552	32500 (14773)
	5000 (3730)	613	

Notes

1 kVA [illegible] = (Power [illegible]) / (Mtr PF x Mtr Eff)
I_{phase} = (kVA [illegible]) x (1000) / (1.732) x (V[illegible])

- Mtr PF = 0.87, Mtr Eff = 0.94, Ambient temperature is 32.1-104°F (0-40°C)
- Output Voltage 4160 V ac
- Ratings based on a variable torque load (industrial fans and pumps)
- For constant torque load applications a derate factor should be applied consult the GE Toshiba Application Center
- Altitude above sea level is 0-3300 ft (0-1000 m)

2 An optional bypass cabinet can be integrated into the line up

- For applications up to 2700 hp, add 30 in (762 mm) in width
- For applications greater than 2700 hp, add 72 in (1829 mm) in width

3 A minimum of 24 in (610 mm) above the cabinets should be allocated for air flow, no rear access is required

4 Both incoming power cabling and motor cabling can be either top or bottom entry with no additional cabinets

5 This table presents only a representative sample of voltages and horsepower ratings other options are available, please consult the GE Toshiba Application Center

6 Air is pulled in through the filters in the bottom of cabinets and vented out the top

7 Weights provided in table are estimates and do not include the optional bypass cabinet

8 Options include redundant motor cooling fans and control cabinet space heater, bypass power/control, and dv/dt filter

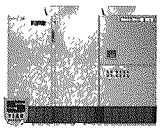
9 For the sizing of cooling equipment use .3 kW/100 hp of output power

TOSHIBA GE

Dura-Bilt5 MV-3000 Series Data Sheet

TOSHIBA GE

Dura-Bilt5 MV-2000 Series Data Sheet



GET S1006 – Dura-Bilt5 MV 2000 Series Data Sheet

GET S1005 – Dura-Bilt5 MV 3000 Series Data Sheet

GET S1004 – Dura-Bilt5 MV 4000 Series Data Sheet

TOSHIBA GE

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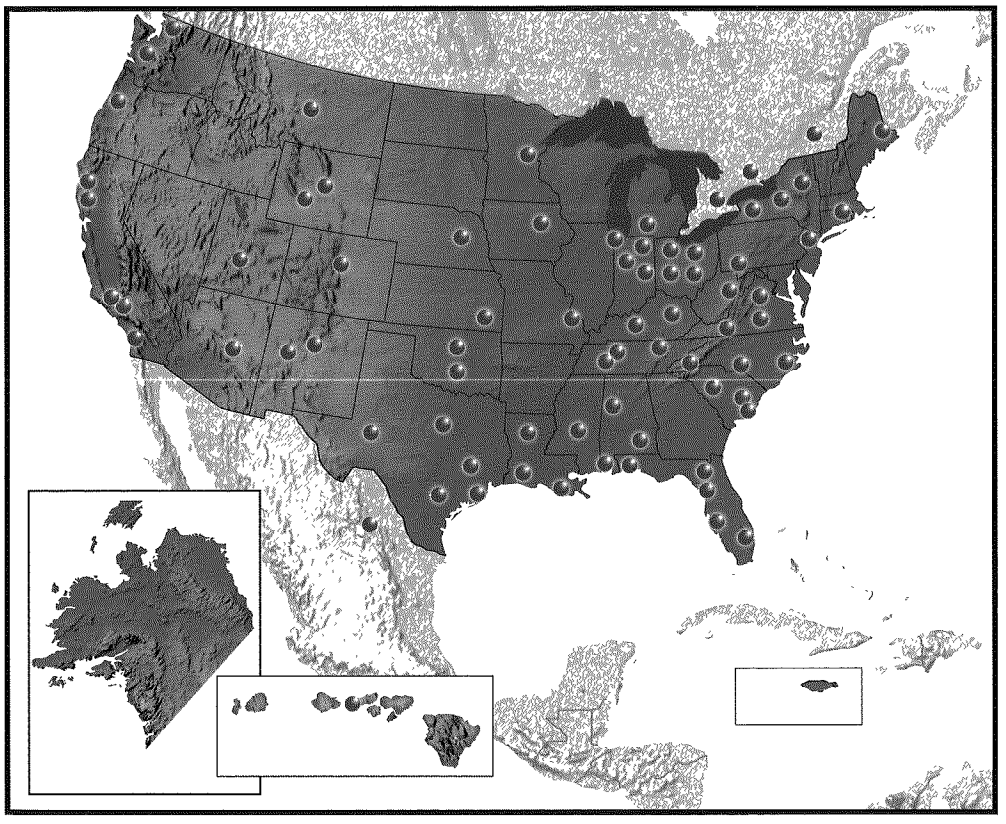
When You Need Service, We Are Right Next Door

Toshiba GE uses the extensive infrastructure of GE service organizations to support its drive products over the long term. By using this network of fully trained personnel, you can be assured that your investment and trust in Toshiba GE products will be preserved for many years to come. GE also provides a full scope of services, ranging from process optimization to asset optimization—focusing on improving productivity and quality of production processes. Asset optimization focuses on the maintenance and management of physical and software assets employed by your business enterprise.

- Installation, Startup, & Commissioning
- Remote Monitoring & Diagnostic (RM&D)
- On-Demand Planned Service
- On-Demand Emergency Service
- Instrument Repair & Calibration
- Technical & Engineering Staffing
- Project Services
- Feasibility Studies
- Documentation
- Maintenance Programs
- Energy Asset Programs (EAP)
- Power Systems Management
- Energy Monitoring
- Engineering & Construction Management
- Projects with Financial Solutions
- Advanced Process Controls
- Custom Panel Design & Build
- Customizations, Modifications & Upgrades
- Tolerance Control
- Scrap Reduction Programs
- Technical Staffing & Training
- Preventative & Condition Based Maintenance
- Renewal Parts
- Parts Management



Over 2000 GE service engineers and technicians deliver improved productivity and cash flow to customers.

TOSHIBA GE

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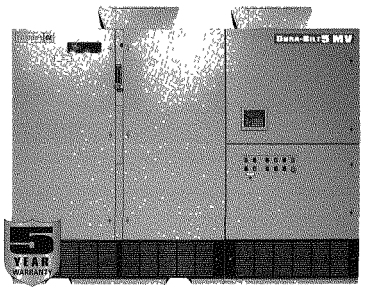
GET-S1003

IP7_024511

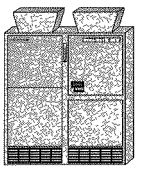
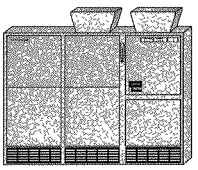
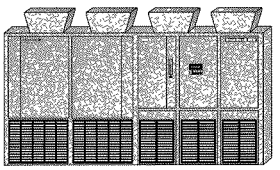
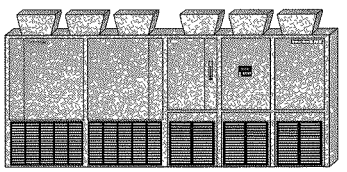
TOSHIBA | GE

DURA-BILT5 MV-2000 Series Data Sheet



GE and Toshiba have teamed up to create a family of medium voltage drives that feature:

- Compact compartmentalized design
- Power system friendly 24-pulse source
- Motor friendly three-level inverter
- Comprehensive 5 year parts and labor warranty

Drive & Transformer	Power$_{\text{Motor Shaft}}$ hp *(kW)*	Rated I_{Phase} AC Amps	Weight lbs *(kg)*
 104 in *(2634 mm)* 44 in *(1102 mm)* 74 in *(1880 mm)*	300 (224)	69	6000 *(2727)*
	400 *(298)*	93	
 104 in *(2634 mm)* 44 in *(1102 mm)* 122 in *(3099 mm)*	500 *(373)*	116	9000 *(4091)*
	750 *(560)*	174	
 104 in *(2634 mm)* 50 in *(1257 mm)* 174 in *(4420 mm)*	1000 *(746)*	229	14000 *(6364)*
	1500 *(1119)*	343	
	1750 *(1306)*	401	
 104 in *(2634 mm)* 50 in *(1257 mm)* 222 in *(5639 mm)*	2000 *(1492)*	448	21000 *(9545)*
	2500 *(1865)*	560	

Notes

1. $kVA_{Inverter}$ = ($Power_{Mtr\ Shaft}$) / (Mtr PF x Mtr Eff)
   I_{Phase} = ($kVA_{Inverter}$) x (1000) / (1.732) x ($V_{Mtr\ Line\ to\ Line}$)
   - Mtr PF = 0.87, Mtr Eff = 0.94, Ambient temperature is 32°F-104°F *(0°C-40°C)*.
   - Output Voltage 2300 V ac.
   - Ratings based on a variable torque load (industrial fans and pumps).
   - For constant torque load applications, a de-rate factor should be applied, consult the GE Toshiba Application Center.
   - Altitude above sea level is 0-3000 ft *(0-1000 m)*.
2. An optional bypass cabinet can be integrated into the line up:
   - For applications up to 1750 hp, add 30 in *(762 mm)* in width.
   - For applications greater than 1750 hp, add 72 in *(1829 mm)* in width.
3. A minimum of 24 in *(610 mm)* above the cabinets should be allocated for air flow, no rear access is required.
4. Both incoming power cabling and motor cabling can be either top or bottom entry with no additional cabinets.
5. This table presents only a representative sample of voltages and horsepower ratings, other options are available, please consult the GE Toshiba Application Center.
6. Air is pulled in through the filters in the bottom of cabinets and vented out the top.
7. Weights provided in table are estimates and do not include the optional bypass cabinet.
8. Options include redundant motor cooling fans and control, cabinet space heater, bypass power/control, and dv/dt filter.
9. For the sizing of cooling equipment, use 3 kW/100 hp of output power.

IP7_024512

Power Input 2200V - 7200V
(Top or Bottom Cable Entry)

Input Voltage Variation	+ 10/-5% continuous operating for main power
Input Frequency	50-60 Hz, ± 5%
Input Power Quality	THD ≤ 3% without filters Exceeds IEEE 519-1992
Surge Protection	Distribution class lightning arrestors are standard
Transformer	Transformer is rated for 239°F *(115°C)* rise and its insulation system is rated at 428°F *(220°C)*. A 3-phase electrostatic shield is standard, forced air cooling, optional control power secondary winding.
Source Type	AC fed 24-pulse diode, non-regenerative
Control Power	460 V ac, three-phase, or optional secondary feed from main power transformer
Control Power Line Dip/Ride Through	100 msec
Operating Displacement Power Factor	≥ 95% (includes transformer)

Motor Control

Speed Regulator Response	20 rad/s
Speed Regulator Error	± 0.01% FS with speed feedback ± 0.5% FS without speed feedback
Torque Regulator Response	500 rad/s
Torque Regulator Accuracy	± 3% FS with motor temperature sensor ± 30% FS without motor temperature sensor

Note: Refer to Dura-Bilt5 MV 2000, 3000, 4000 Series Application Guide (GET S1003) for additional technical information on these products.

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Power Output 2200V - 2400V
(Top or Bottom Cable Entry)

Output Frequency	0-120 Hz
Output Current Total Harmonic Distortion (THD)	≤ 3% Current ≤ 6% Voltage
Inverter Type, Modulation	Voltage source, Pulse Width Modulation (PWM), 3-level Neutral Point Clamped (NPC), modular draw-out phase leg assemblies, optically isolated from control
Power Semiconductor Technology	Medium Voltage Insulated Gate Bipolar Transistor (IGBT)

Environment

Operating Temperature	32°F-104°F *(0°C-40°C)* De-rate 1.5% per °C above 40°C to a maximum of 50°C
Storage Temperature	-13°F-158°F *(-25°C-70°C)*
Altitude	Up to 3300 ft *(0-1000 m)* with no de-rate Above 3300 ft *(0-1000 m)* with 3% de-rate per 1000 ft *(308 m)*
Humidity	≤ 95%, non-condensing
Audible Noise	≤ 80 dBA @ 3.1 ft *(1 m)*
Cooling	• Forced air with redundant cooling fans as an option • Separate source & inverter cooling paths • Inverter uses heat pipe technology for long IGBT life, compact size, and low ambient noise

Other

Efficiency	96.5% @ 60 Hz output frequency, including transformer
Agency Approvals	c UL

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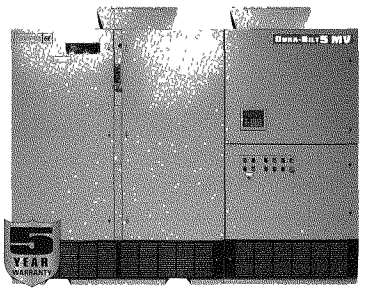
IP7_024513

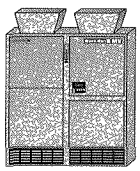
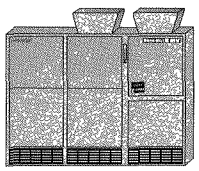
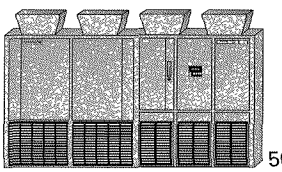
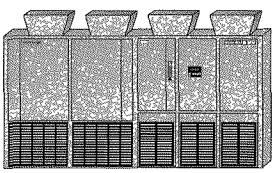
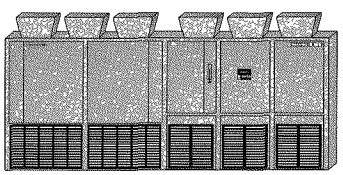
TOSHIBA | GE

DURA-BILT5 MV-3000 Series Data Sheet



GE and Toshiba have teamed up to create a family of medium voltage drives that feature:

- Compact compartmentalized design
- Power system friendly 24-pulse source
- Motor friendly five-level inverter
- Comprehensive 5 year parts and labor warranty

Drive & Transformer	Power Motor Shaft hp *(kW)*	Rated I_{Phase} AC Amps	Weight lbs *(kg)*
 104 in *(2634 mm)*; 44 in *(1102 mm)*; 74 in *(1880 mm)*	400 *(298)*	65	7500 *(3409)*
	500 *(373)*	81	
	700 *(522)*	113	
 104 in *(2634 mm)*; 44 in *(1102 mm)*; 122 in *(3099 mm)*	1000 *(746)*	160	11500 *(5227)*
	1250 *(933)*	199	
	1500 *(1119)*	239	
 104 in *(2634 mm)*; 50 in *(1257 mm)*; 164 in *(4166 mm)*	1750 *(1306)*	279	18000 *(8182)*
	2000 *(1492)*	319	
 104 in *(2634 mm)*; 50 in *(1257 mm)*; 174 in *(4420 mm)*	2250 *(1679)*	351	22500 *(10227)*
	2500 *(1865)*	390	
 104 in *(2634 mm)*; 50 in *(1257 mm)*; 222 in *(5639 mm)*	3000 *(2238)*	468	32500 *(14773)*
	3500 *(2611)*	546	
	4000 *(2984)*	624	

Notes

1. $kVA_{Inverter}$ = ($Power_{Mtr\ Shaft}$) / (Mtr PF x Mtr Eff)
   I_{Phase} = ($kVA_{Inverter}$) x (1000) / (1.732) x ($V_{Mtr\ Line\ to\ Line}$)
   - Mtr PF = 0.87, Mtr Eff = 0.94, Ambient temperature is 32°F-104°F *(0°C-40°C)*.
   - Output Voltage 3300 V ac.
   - Ratings based on a variable torque load (industrial fans and pumps).
   - For constant torque load applications, a de-rate factor should be applied, consult the GE Toshiba Application Center.
   - Altitude above sea level is 0-3000 ft *(0-1000 m)*.
2. An optional bypass cabinet can be integrated into the line up:
   - For applications up to 2000 hp, add 30 in *(762 mm)* in width.
   - For applications greater than 2000 hp, add 72 in *(1829 mm)* in width.
3. A minimum of 24 in *(610 mm)* above the cabinets should be allocated for air flow, no rear access is required.
4. Both incoming power cabling and motor cabling can be either top or bottom entry with no additional cabinets.
5. This table presents only a representative sample of voltages and horsepower ratings, other options are available, please consult the GE Toshiba Application Center.
6. Air is pulled in through the filters in the bottom of cabinets and vented out the top.
7. Weights provided in table are estimates and do not include the optional bypass cabinet.
8. Options include redundant motor cooling fans and control, cabinet space heater, bypass power/control, and dv/dt filter.
9. For the sizing of cooling equipment, use 3 kW/100 hp of output power.

IP7_024514

Power Input 2200V - 7200V
(Top or Bottom Cable Entry)

Input Voltage Variation	+ 10/-5% continuous operating for main power
Input Frequency	50-60 Hz, ± 5%
Input Power Quality	THD ≤ 3% without filters Exceeds IEEE 519-1992
Surge Protection	Distribution class lightning arrestors are standard
Transformer	Transformer is rated for 239°F *(115°C)* rise and its insulation system is rated at 428°F *(220°C)*. A 3-phase electrostatic shield is standard, forced air cooling, optional control power secondary winding.
Source Type	AC fed 24-pulse diode, non-regenerative
Control Power	460 V ac, three-phase, or optional secondary feed from main power transformer
Control Power Line Dip/Ride Through	100 msec
Operating Displacement Power Factor	≥ 95% (includes transformer)

Motor Control

Speed Regulator Response	20 rad/s
Speed Regulator Error	± 0.01% FS with speed feedback ± 0.5% FS without speed feedback
Torque Regulator Response	500 rad/s
Torque Regulator Accuracy	± 3% FS with motor temperature sensor ± 30% FS without motor temperature sensor

Note: Refer to Dura-Bilt5 MV 2000, 3000, 4000 Series Application Guide (GET S1003) for additional technical information on these products.

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Power Output 3200V - 3400V
(Top or Bottom Cable Entry)

Output Frequency	0-120 Hz
Output Current Total Harmonic Distortion (THD)	≤ 3% Current ≤ 6% Voltage
Inverter Type, Modulation	Voltage source, Pulse Width Modulation (PWM), 5-level Neutral Point Clamped (NPC), modular draw-out phase leg assemblies, optically isolated from control
Power Semiconductor Technology	Medium Voltage Insulated Gate Bipolar Transistor (IGBT)

Environment

Operating Temperature	32°F-104°F *(0°C-40°C)* De-rate 1.5% per °C above 40°C to a maximum of 50°C
Storage Temperature	-13°F-158°F *(-25°C-70°C)*
Altitude	Up to 3300 ft *(0-1000 m)* with no de-rate Above 3300 ft *(0-1000 m)* with 3% de-rate per 1000 ft *(308 m)*
Humidity	≤ 95%, non-condensing
Audible Noise	≤ 80 dBA @ 3.1 ft *(1 m)*
Cooling	• Forced air with redundant cooling fans as an option • Separate source & inverter cooling paths • Inverter uses heat pipe technology for long IGBT life, compact size, and low ambient noise

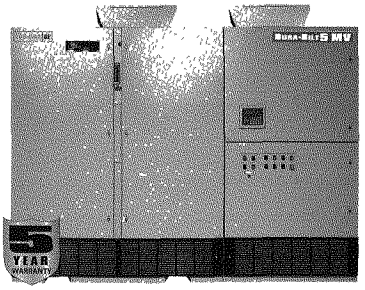
Other

Efficiency	96.5% @ 60 Hz output frequency, including transformer
Agency Approvals	c UL

IP7_024515

TOSHIBA | GE

DURA-BILT5 MV-4000 Series Data Sheet



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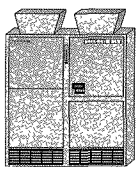
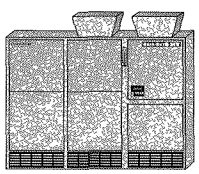
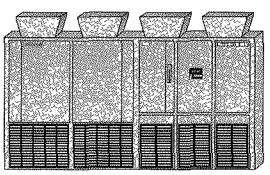
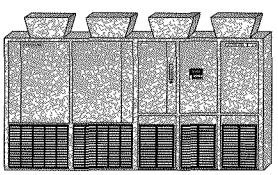
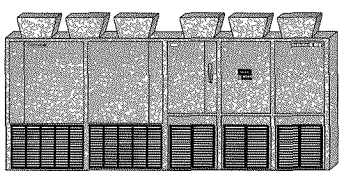
- Power system friendly 24-pulse source
- Motor friendly five-level inverter
- Comprehensive 5 year parts and labor warranty

Drive & Transformer	Power$_{\text{Motor Shaft}}$ hp *(kW)*	Rated I_{Phase} AC Amps	Weight lbs *(kg)*
 104 in *(2634 mm)* 44 in *(1102 mm)* 74 in *(1880 mm)*	400 *(298)*	51	7500 *(3409)*
	500 *(373)*	64	
	700 *(522)*	90	
	900 *(671)*	115	
 104 in *(2634 mm)* 44 in *(1102 mm)* 122 in *(3099 mm)*	1000 *(746)*	127	11500 *(5227)*
	1250 *(933)*	158	
	1500 *(1119)*	190	
	2000 *(1492)*	253	
 104 in *(2634 mm)* 50 in *(1257 mm)* 164 in *(4166 mm)*	2250 *(1679)*	279	18000 *(8182)*
	2500 *(1865)*	310	
	2700 *(2014)*	334	
 104 in *(2634 mm)* 50 in *(1257 mm)* 174 in *(4420 mm)*	3000 *(2238)*	372	22500 *(10227)*
	3500 *(2611)*	433	
 104 in *(2634 mm)* 50 in *(1257 mm)* 222 in *(5639 mm)*	4000 *(2984)*	490	32500 *(14773)*
	4500 *(3357)*	552	
	5000 *(3730)*	613	

Notes

1. kVA_{Inverter} = ($\text{Power}_{\text{Mtr Shaft}}$) / (Mtr PF x Mtr Eff)
   I_{Phase} = (kVA_{Inverter}) x (1000) / (1.732) x ($V_{\text{Mtr Line to Line}}$)
   - Mtr PF = 0.87, Mtr Eff = 0.94, Ambient temperature is 32°F-104°F *(0°C-40°C)*.
   - Output Voltage 4160 V ac.
   - Ratings based on a variable torque load (industrial fans and pumps).
   - For constant torque load applications, a de-rate factor should be applied, consult the GE Toshiba Application Center.
   - Altitude above sea level is 0-3000 ft *(0-1000 m)*.
2. An optional bypass cabinet can be integrated into the line up:
   - For applications up to 2700 hp, add 30 in *(762 mm)* in width.
   - For applications greater than 2700 hp, add 72 in *(1829 mm)* in width.
3. A minimum of 24 in *(610 mm)* above the cabinets should be allocated for air flow, no rear access is required.
4. Both incoming power cabling and motor cabling can be either top or bottom entry with no additional cabinets.
5. This table presents only a representative sample of voltages and horsepower ratings, other options are available, please consult the GE Toshiba Application Center.
6. Air is pulled in through the filters in the bottom of cabinets and vented out the top.
7. Weights provided in table are estimates and do not include the optional bypass cabinet.
8. Options include redundant motor cooling fans and control, cabinet space heater, bypass power/control, and dv/dt filter.
9. For the sizing of cooling equipment, use 3 kW/100 hp of output power.

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Power Input 2200V - 7200V
(Top or Bottom Cable Entry)

Input Voltage Variation	+ 10/-5% continuous operating for main power
Input Frequency	50-60 Hz, ± 5%
Input Power Quality	THD ≤ 3% without filters Exceeds IEEE 519-1992
Surge Protection	Distribution class lightning arrestors are standard
Transformer	Transformer is rated for 239°F *(115°C)* rise and its insulation system is rated at 428°F *(220°C)*. A 3-phase electrostatic shield is standard, forced air cooling, optional control power secondary winding.
Source Type	AC fed 24-pulse diode, non-regenerative
Control Power	460 V ac, three-phase, or optional secondary feed from main power transformer
Control Power Line Dip/Ride Through	100 msec
Operating Displacement Power Factor	≥ 95% (includes transformer)

Motor Control

Speed Regulator Response	20 rad/s
Speed Regulator Error	± 0.01% FS with speed feedback ± 0.5% FS without speed feedback
Torque Regulator Response	500 rad/s
Torque Regulator Accuracy	± 3% FS with motor temperature sensor ± 30% FS without motor temperature sensor

Note: Refer to Dura-Bilt5 MV 2000, 3000, 4000 Series Application Guide (GET S1003) for additional technical information on these products.

TOSHIBA GE

www.getoshiba.com

Power Output 4000V - 4200V
(Top or Bottom Cable Entry)

Output Frequency	0-120 Hz
Output Current Total Harmonic Distortion (THD)	≤ 3% Current ≤ 6% Voltage
Inverter Type, Modulation	Voltage source, Pulse Width Modulation (PWM), 5-level Neutral Point Clamped (NPC), modular draw-out phase leg assemblies, optically isolated from control
Power Semiconductor Technology	Medium Voltage Insulated Gate Bipolar Transistor (IGBT)

Environment

Operating Temperature	32°F-104°F *(0°C-40°C)* De-rate 1.5% per °C above 40°C to a maximum of 50°C
Storage Temperature	-13°F-158°F *(-25°C-70°C)*
Altitude	Up to 3300 ft *(0-1000 m)* with no de-rate Above 3300 ft *(0-1000 m)* with 3% de-rate per 1000 ft *(308 m)*
Humidity	≤ 95%, non-condensing
Audible Noise	≤ 80 dBA @ 3.1 ft *(1 m)*
Cooling	• Forced air with redundant cooling fans as an option • Separate source & inverter cooling paths • Inverter uses heat pipe technology for long IGBT life, compact size, and low ambient noise

Other

Efficiency	96.5% @ 60 Hz output frequency, including transformer
Agency Approvals	c UL

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IP7_024517

From anywhere in the world, GE OnSite Support Service is only a phone call away. This service gives you direct access to our engineers, 24-hours a day, 365 days a year, to help you reduce downtime and get the most from your process.

The unique single point connectivity of our systems allows the OnSite Support engineers to become one with your process. Years of experience has shown:

- 96% of cases resolved remotely
- Elapsed Time To Repair (ETTR) .85 hour

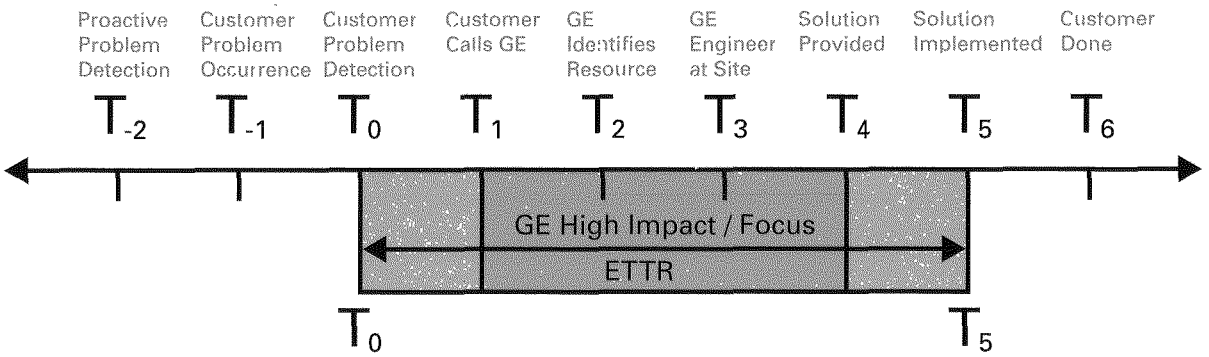
The Screen You See Is The Screen We See

We become a real-time partner with you to:

- Troubleshoot
- Perform drive system analysis
- Provide diagnostic information
- Trend key process variables
- Conduct preventive maintenance

From technical training to our Rapid Response Program for parts and services, GE has what you need to keep your process productive. Ask your GE representative to detail the many benefits our OnSite Support Service can bring to your process.

ETTR Measurement Timeline



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GET S1002
010230
PRO PRT
tSUNAone

IP7_024518

Environmental

Operating Temperature	32 to 104 °F *(0 to 40 °C)* at rated load 32 to 122 °F*(0 to 50 °C)* with derating (Refer to table on page 44)
Storage Temperature	-13 °F to 131 °F *(- 25 °C to +55 °C)*
Humidity	5 to 95% relative humidity, non-condensing
Altitude	Normal Operation: 0 to 11483 ft *(0 to 3500 m)* above sea level Derate current approximately 1% per 328 ft *(100 m)* altitude above 3280 ft *(1000 m)* Derate voltage approximately 0.7% per 328 ft *(100 m)* altitude above 3280 ft *(1000 m)*
Vibration	10-50 Hz, <0.5 G

Input Power

Input Voltage Variation	± 10%
Input Frequency	50/60 Hz ±2 Hz
Control Power	220 V ac ± 10% 3-phase 50/60 Hz
Conversion Efficiency	98.5% at rated load

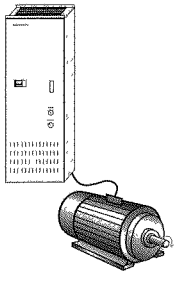
Mechanical

Enclosure	NEMA 1 (IP 20)
Cable Entrance (Utility)	Bottom is standard, top with optional 12 in *(300 mm)* deeper cabinets
Cable Entrance (Motor)	Bottom is standard
Acoustic Noise	80 dB
Lockout Mechanisms	Padlock
Dimensions	Refer to pages 44 and 45
Mean Time To Repair (MTTR)	30 minutes
Mean Time Between Failure (MTBF)	8 years (70000 hours)

Converter Specification Example

When specifying an inverter, start from the process requirements and work through the motor to the inverter. The following example illustrates this process:

1 Define process requirements.



kW_{Shaft} = 3655 hp *(4900 kW)*

The motor delivers constant torque from zero to base speed of 900 rpm.

Duty cycle requires 200% overload for 60 sec, but has an rms duty cycle of 3655 hp *(4900 kW)*. Utility is 60 Hz.

2 Select motor based on process requirements, and compute converter kVA.

- Induction motor (6 pole)
- 1185 rpm @ 60 Hz
- Efficiency = 0.954
- Power factor = 0.765
- 3300 V

$$kVA_{Converter} = \frac{kW_{Shaft}}{Eff_{Mtr} \times PF_{Mtr}} = \frac{4900\ kW}{0.954 \times 0.765} = 6714\ kVA$$

3 Compute continuous current requirements for the converter, based on the selected motor.

$$I_{Phase\ Current} = \frac{kVA_{Converter} \times 1000}{\sqrt{3} \times V_{Motor\ line\text{-}to\text{-}line\ voltage}} = \frac{6714\ kVA \times 1000}{\sqrt{3} \times 3300\ V} = 1176\ amps$$

4 Compute frequency ratio for the converter, based on the selected motor.

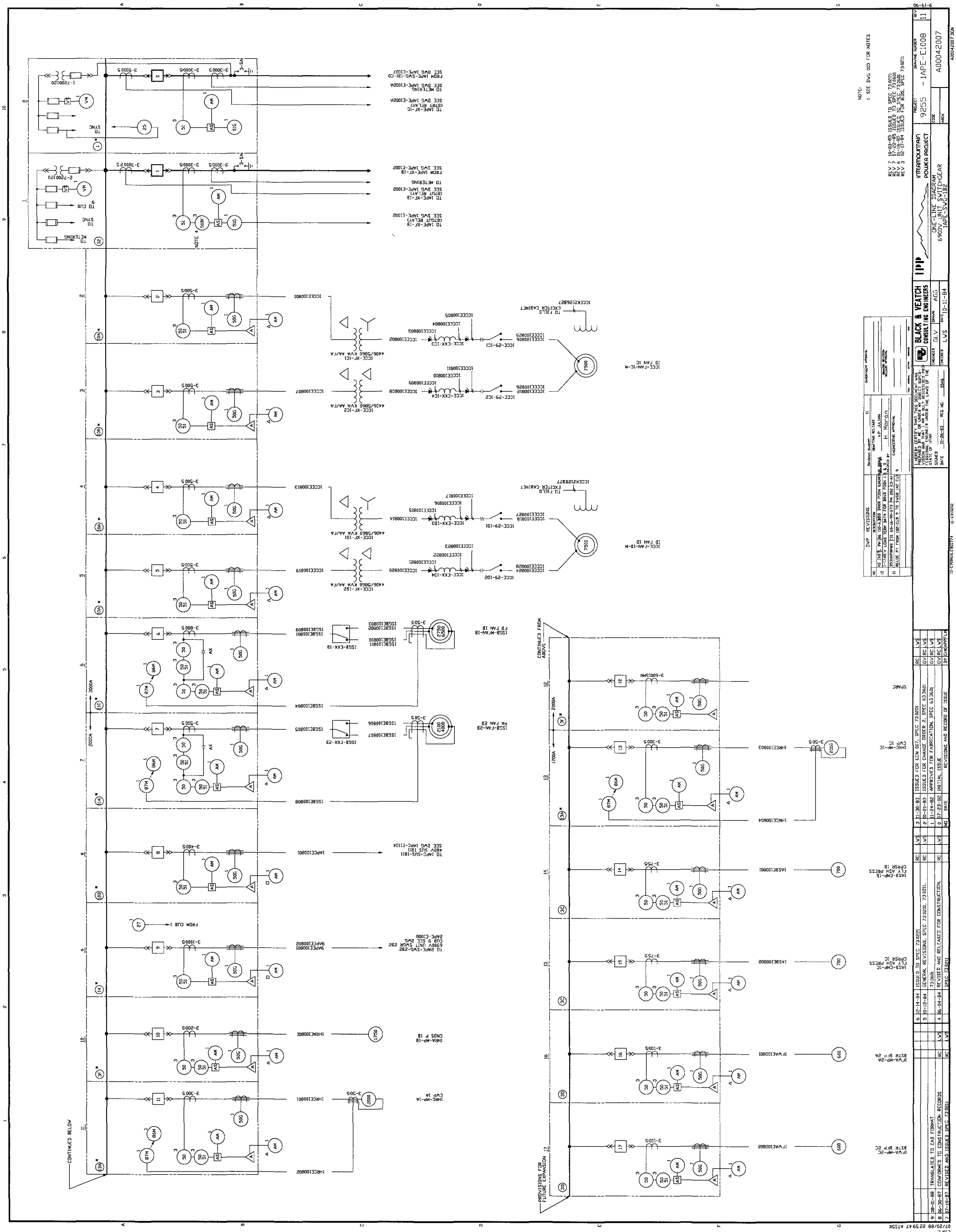
$$Freq_{Ratio} = \frac{Motor\ Rated\ Freq \times Required\ Speed}{Motor\ Rated\ Speed \times Utility\ Freq} = \frac{60\ Hz \times 900}{1185 \times 60\ Hz} = 0.76$$

(Over 0.45 Requires Circulating Current converter)

5 Select converter based on continuous current, overload and maximum frequency requirements.

Scan the 200% for 60 sec entries in the converter tables (page 44) for CC type system where the continuous current rating exceeds 1176 amps, and the voltage is 3300 V. The 3300 V CC-72 system meets this criteria (1446 amps @ 104 °F 40 °C), thus is the appropriate converter for this application.

IP7_024519


BLACK & VEATCH CONSULTING ENGINEERS
INTERMOUNTAIN POWER PROJECT
ONE-LINE DIAGRAM
6900V UNIT SWITCHGEAR
1APE-SWG-1B2
PROJECT 9255 - 1APE-E1008
DRAWING NUMBER A00042007
REV 11
REV 7 10-03-85 ISSUED TO SPEC 730221
REV 7 07-22-85 ISSUED TO SPEC 730601
REV 6 01-18-85 ISSUED TO SPEC 730601
REV 3 02-17-84 ISSUED FOR BIDS, SPEC 730211
NOTE:
1 SEE DWG 005 FOR NOTES
DWP REVISIONS
REVISIONS AND RECORD OF ISSUE
SPEC 730211
REVISED AND RELEASED FOR CONSTRUCTION.
GENERAL REVISIONS, SPEC 730201, 730601
ISSUED TO SPEC 730221
ISSUED FOR ECN 007, SPEC 730201
ISSUED FOR CHANGE ORDER 2, SPEC 630601
APPROVED FOR FABRICATION, SPEC 630601
INITIAL ISSUE
CONFORMED TO CONSTRUCTION RECORDS
TRANSLATED TO CAD FORMAT
REVISED AND ISSUED SPEC 730211
CONTINUED BELOW
CONTINUED FROM ABOVE
PROVISIONS FOR FUTURE EXPANSION
SPARE
CWP 1A
CWP 1C
BSTR BFP 2A
BSTR BFP 2C
CPRSR 1B
CPRSR 1C
FLY ASH PRESS
CNDS P 1B
FD FAN 1B
PA FAN 2B
ID FAN 1C
ID FAN 1D
EXCITER CABINET
TO FIELD
FROM CUB 1
TO 1APE-SUS-1B1 480V SUS 1B1 SEE DWG 1APE-E1104
TO 2APE-SWG-2B2 6900V UNIT SWGR 2B2 CUB 9 SEE DWG 2APE-E1008
TO METERING
TO SYNC
TO CUB 9
FROM 1APE-SWG-1B1-C0 SEE DWG 1APE-E1007
TO 1APE-XF-1C (BYPT RELAY) SEE DWG 1APE-E1002A
TO 1APE-XF-1B (BYOUT RELAY) SEE DWG 1APE-E1002
FROM 1APE-XF-1B SEE DWG 1APE-E1002
TO 1APE-XF-1B (BYOUT RELAY) SEE DWG 1APE-E1002
4406/5860 KVA AA/FA
1CCE-XF-1C1
1CCE-XF-1C2
1CCE-XF-1D1
1CCE-XF-1D2
1CCE-29-1C1
1CCE-29-1C2
1CCE-29-1D1
1CCE-29-1D2
1CCE-EXX-1C3
1CCE-EXX-1C4
1CCE-EXX-1D3
1CCE-EXX-1D4
1CCE-FAN-1C-M
1CCE-FAN-1D-M
1SGB-MFAN-1B
1SGB-FAN-2B
1SGB-EXX-1B
1SGB-EXX-2B
1HRCE-MP-1C
1HRCE-MP-1B
1HRCE-MP-1A
1HRCE-MP-2A
1HRCE-MP-2C
1ASB-CMP-1B
1ASB-CMP-1C
1APCE-SUS-1B1
9APCE-SWG-2B2
1FVAE-MP-2A
1FVAE-MP-2C
I HEREBY CERTIFY THAT THIS DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF UTAH
SIGNED
DATE 01-26-83 REG NO. 3546
ENGINEER GLV
DRAWN AGG
DATE 10-11-84
CHECKED LVS
A00042007.DGN
07/20/88 22:59:47 ATSSK
E10PE

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