TMdrive®-30

Product Application Guide

Medium Voltage 3-Level IGBT System Drive

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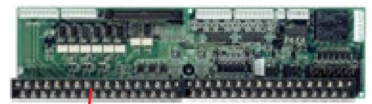
A Look Inside

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

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

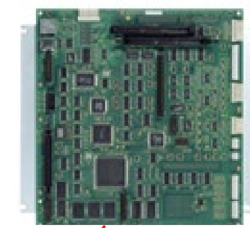
I/O Board
The I/O board supports an encoder, 24 V dc I/O, 115 V ac inputs, and analog I/O, standard. In addition, a resolver interface option can be provided. All I/O are terminated to a two-piece modular terminal block for ease of maintenance.

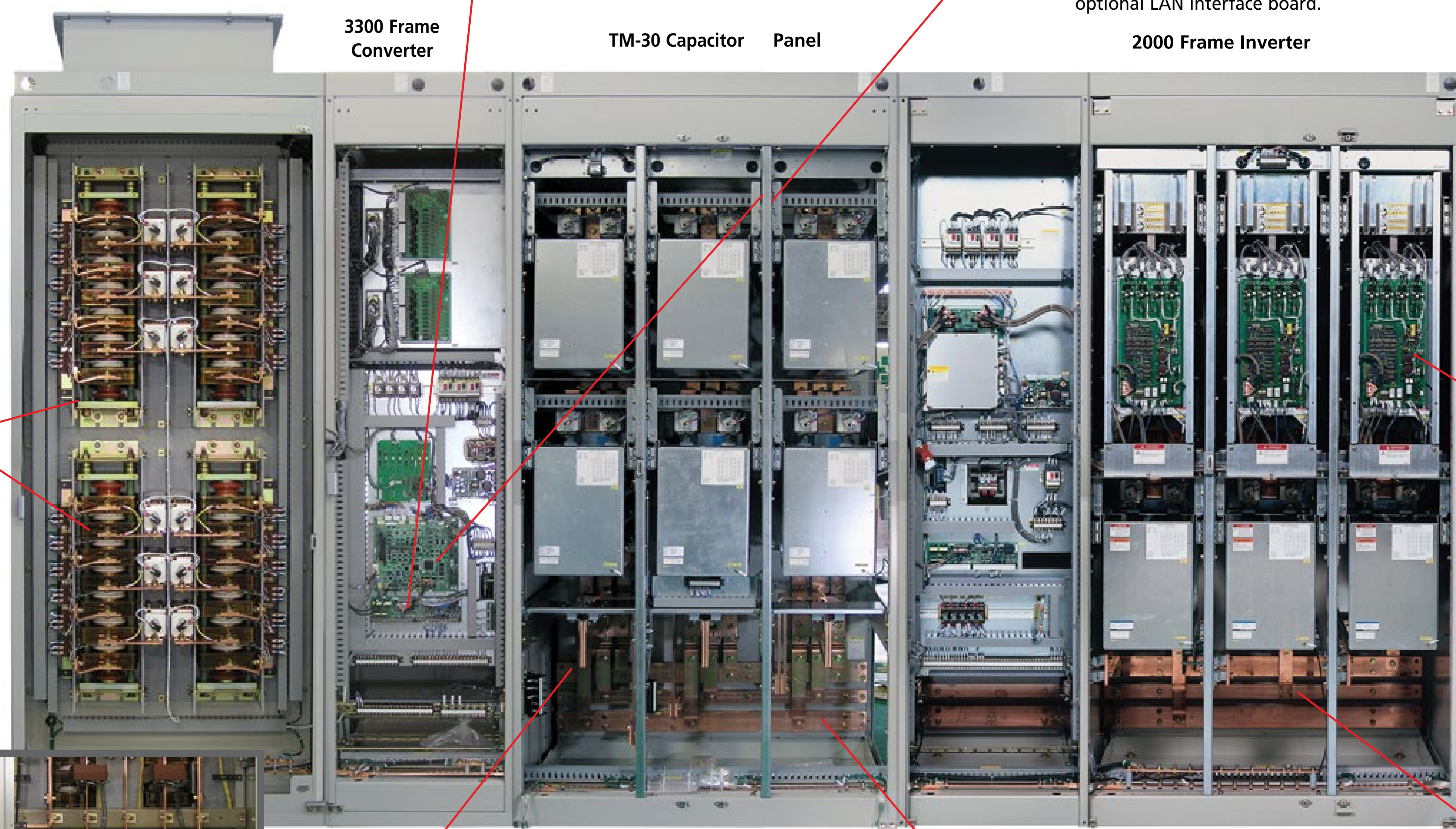


Control Functions
Each inverter and regenerative converter shares a common set of control boards. The primary control board performs several functions:

- Speed and torque regulation
- Sequencing
- I/O mapping
- Diagnostic data gathering

A mounting bracket is provided for an optional LAN interface board.





Thyristor Bridge
A 12-pulse input section provides good harmonic performance for the thyristor converter. Forward and reverse conducting devices allow both motoring and regenerative operation. The converter also provides smooth charging and discharging of the dc bus to control inrush and enhance safety.

Incoming Power (Main and Control)
The converter in each lineup is fed 6-phase ac power. Main power connections are located in the rear of the TMdrive-T30 converter. Only bottom access entry is supported. In addition, 3-phase ac control power is fed to each converter and inverter control cabinet. A control power disconnect is provided in each cabinet.

Capacitor and Bus Interface Panel
The TMdrive-30 capacitor panel is used to provide an electrical interface with the TMdrive-30 inverter. Remotely mounted dc link reactors are wired between these connections. In addition, each TMdrive-30 inverter phase leg has a set of capacitors that are housed in a modular draw-out unit for ease of maintenance.

Common DC Bus
The dc converter 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 copper bus bar system located in the bottom of the cabinets. This design allows multiple inverters to be powered from a single converter.

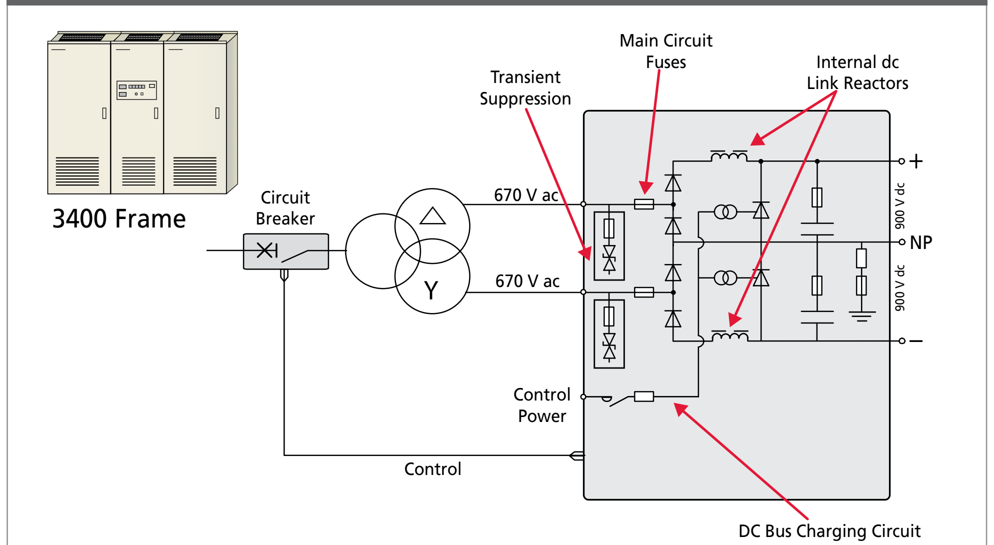
IGBT Three-Level Phase-leg Assembly
The inverters and IGBT-based sources have modular three-level phase leg assemblies. Each phase leg includes:

- IGBTs with flyback diodes
- Heatpipe assembly
- IGBT gate driver circuit board
- Heavy-duty slides that allow easy access for maintenance activities
- High-speed fuses

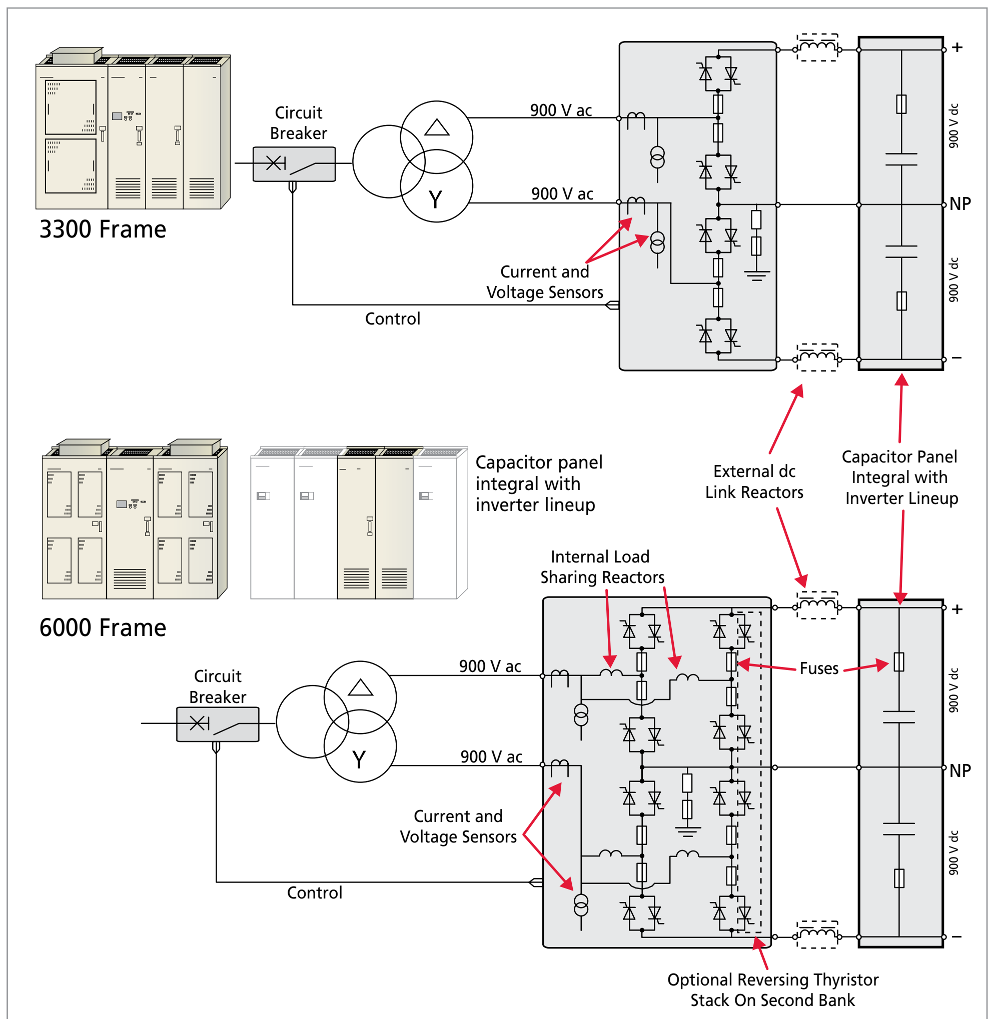
Motor Bus Tabs
Each phase leg has a motor bus tab located at the bottom of the modular phase leg.

A Wide Variety of Power Bridges for Every Application

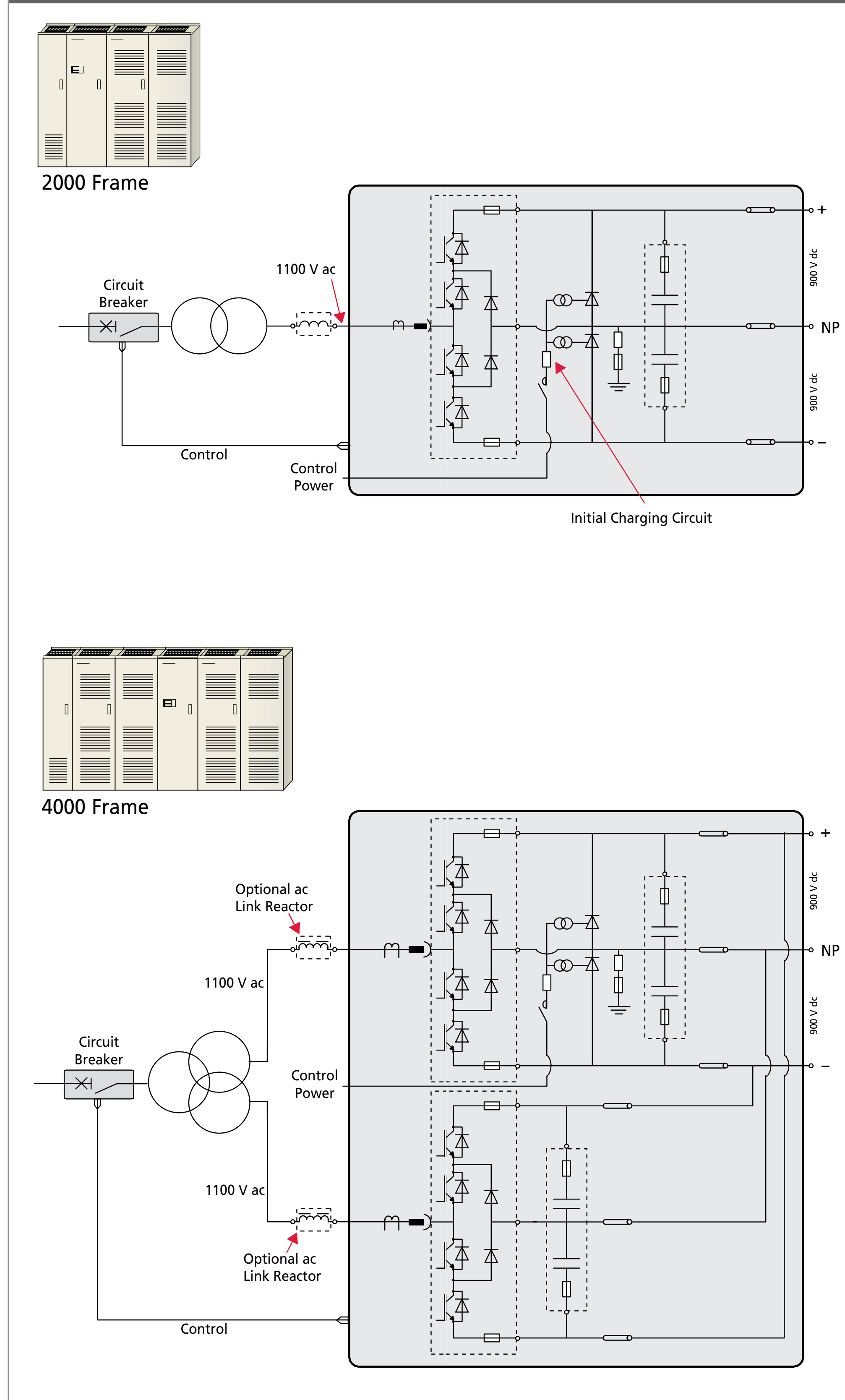
TMdrive–D30 Non-Regenerative Diode Converter



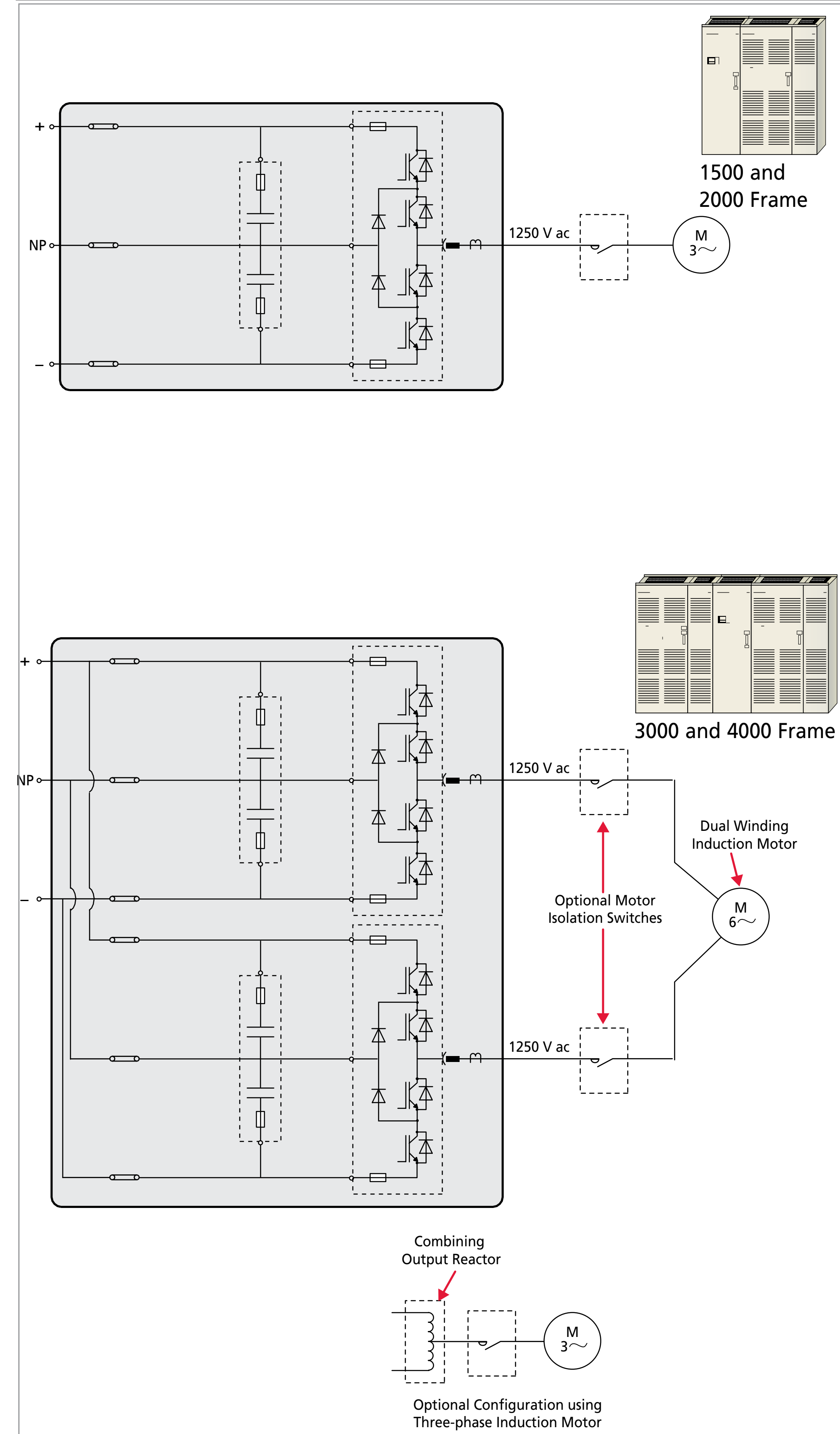
TMdrive–T30 Regenerative Thyristor Converter



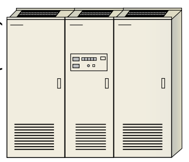
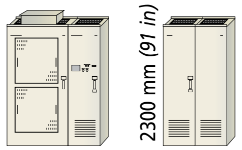
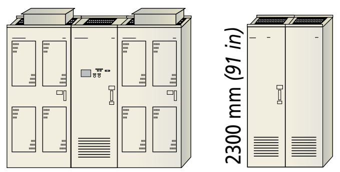
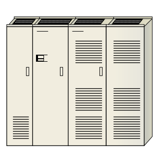
TMdrive–P30 Regenerative IGBT Converter



TMdrive–30 IGBT Inverter



Converter Specifications

	Frame	Weight kg (lbs)	Full Load Losses kW	Control Power va	Converter Output Power kW (hp)	Current A ac	Current A dc	Allowable Overload %
Non-Regenerative Diode (TMdrive-D30)								
	3400	2200 (4840)	15	800	3300 (4424)	1496	1895	150-60s
						1316	1613	175-60s
						1182	1448	200-60s
						972	1191	250-60s
						807	989	300-60s
Regenerative Thyristor (TMdrive-T30)								
	3300	3000 (6600)	21	1500	3300 (4424)	1496	1833	150-10s
						1426	1747	200-10s
						1253	1535	250-10s
						1110	1360	300-10s
						1496	1833	150-60s
						1236	1515	200-60s
						1044	1280	250-60s
						898	1100	300-60s
	6000	3300 (7260)	41	2400	6000 (8043)	2720	3333	150-10s
						2566	3144	200-10s
						2255	2763	250-10s
						2007	2460	300-10s
						2720	3333	150-60s
						2225	2727	200-60s
						1877	2300	250-60s
						1616	1980	300-60s
Regenerative IGBT (TMdrive-P30)								
	2000	1600 (3520)	25	1000	1733 (2323)	929	963	150-60s
						796	825	175-60s
						697	722	200-60s
						557	577	250-60s
						465	482	300-60s
	4000	2600 (5720)	50	2000	3465 (4645)	1858	1925	150-60s
						1593	1650	175-60s
						1394	1444	200-60s
						1115	1155	250-60s
						929	963	300-60s

Non-Regenerative Converter (TMdrive–D30) Example

When specifying a converter, start from the process requirements and work through the motor to the inverter, and then the associated converter. The following example illustrates this process (continuation of inverter application example on page 9).

1 Compute the operating voltage of the dc bus. It is assumed that the converter is dedicated to the inverter specified in the application example on page 9.

$$V_{dc\ Bus} = 1.35 \times V_{Converter\ line\text{-}to\text{-}line}$$
$$= 1.35 \times 700$$
$$= 900\ V$$

2 Compute the continuous dc current requirement of the converter based on its power requirement.

$$I_{dc\ Converter} = \frac{kW_{Shaft} \times 1000}{Eff_{Mtr} \times Eff_{Inv} \times V_{dc\ Bus} \times 2}$$
$$= \frac{1500\ kW \times 1000}{0.954 \times 0.98 \times 900 \times 2}$$
$$= 891\ amps$$

3 Scan the specifications in the non-regenerative converter table above for a frame where the continuous current rating exceeds 891 amps. The **3400 frame** meets this criterion *(1895 amps)*, thus is the appropriate non-regenerative converter for this application.

Current dc	Overload – Time
1895	150% – 60s
1613	175% – 60s
1448	200% – 60s
1191	250% – 60s
989	300% – 60s

Regenerative Converter (TMdrive–P30) Example

When specifying a converter, start from the process requirements and work through the motor to the inverter, and then the associated converter. The following example illustrates this process (continuation of inverter application example on page 9):

1 Compute kW requirements into the inverter. It is assumed that the converter is dedicated to the inverter specified in the application example on page 9. It is also assumed that the converter is controlled to unity power factor.

$$kW_{dc} = \frac{kW_{Shaft}}{Eff_{Mtr}}$$
$$= \frac{1500\ kW}{0.954}$$
$$= 1580\ kW$$

2 Compute continuous ac current requirement of the converter based on its power requirements.

$$I_{ac\ Converter} = \frac{kW_{dc} \times 1000}{\sqrt{3} \times V_{Converter\ line\text{-}to\text{-}line\ voltage} \times Eff_{Converter} \times Eff_{Inverter}}$$
$$= \frac{1580\ kW \times 1000}{\sqrt{3} \times 1100\ V \times 0.985 \times 0.98 \times 2}$$
$$= 430\ amps$$

Note: For sizing systems with peak powers in regenerative mode, a different equation is used to compute power requirements.

$$kW_{dc} = kW_{Shaft} \times (Eff_{Mtr} \times Eff_{Inverter})$$

3 Scan the regenerative converter table for entries that exceeds your overload (175%), time **(60 sec)** and continuous current requirements (430 amps). In this case the 2000 frame TMdrive-P30 meets the requirement and is appropriate for this application.

Current A ac	Overload – Time
1858	150% – 60s
1593	175% – 60s
1394	200% – 60s
1115	250% – 60s
929	300% – 60s

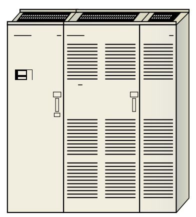
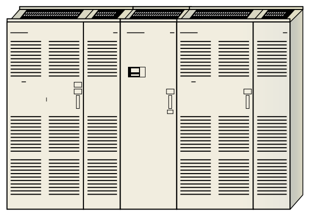
Miscellaneous

Main Circuit Input Voltage Variation	± 10%
Input Frequency	50/60 Hz ±20%
TMdrive-P30 Input Chopping	1.5 kHz
Control Power	180-220 V ac, 50 Hz 3-phase 198-242 V ac, 60 Hz 3-phase
Displacement Power Factor (at all loads)	TMdrive-D30 - 0.98 TMdrive-T30 - 0.71 to 0.98 depending on application TMdrive-P30 - Unity power factor

Converter Notes

1. TMdrive-D30 and TMdrive-P30 converters and TMdrive-T30 capacitor panels are 800mm (32in) in depth. TMdrive-T30 thyristor panels are 1000mm (40in) in depth.
2. Allocate a minimum of 500mm (20 in) above the cabinet for an maintenance. All equipment requires a steel support of at least 50mm (2 in) under the panel which is not included in these dimensions.
3. The specified current ratings are continuous to which the referenced overload can be applied. Refer to the application example.
4. All TMdrive-30 equipment supports bottom cable entry standard. Top cable entry is support with adjacent auxiliary cabinets.
5. All TMdrive-30 equipment requires 3-phase control power and the kVA requirements shown in the rating tables are continuous. In addition, TMdrive-D30 and TMdrive-P30 converters have additional transient bus charging requirements of 30 amps peak.
6. All TMdrive-30 converters require an external circuit breaker.
7. TMdrive-T30 converters require external dc link reactors. TMdrive-P30 converters require external ac link reactors or high impendence transformer.
8. TMdrive-30 converters pull air in the front and exhaust out the top of cabinets.
9. TMdrive-30 dc common bus is limited to 1640 amps.
10. TMdrive-P30 and TMdrive-T30 require ac-phase rotation to match system elementaries.
11. There are no restrictions on the total dc bus length or the minimum capacitance connected to any of these converters. For maximum capacitance consult the factory when the combined capacity of all connected inverters exceeds 1 times the rating of the TMdrive-P30 converters or 2.5 times the rating of the TMdrive-D30 converter. There are no maximum capacitance restrictions for the TMdrive-T30 converter.
12. TMdrive-D30 and TMdrive-T30 losses are proportional to load current. TMdrive-P30 losses are 40% fixed with the remaining losses proportional to current. Converter efficiency can be estimated at any load by properly combining static and load related losses.
13. The maximum shipping split for TMdrive-30 equipment is 3 m (118 in).
14. TMdrive-P30 converters require 1300mm (51 in) minimum front access and 50 mm (3 in) back clearance. Other converters require 1050 mm (41 in) minimum access front and back.
15. TMdrive-P30 converters require isolation transformers with single or dual secondaries and optional ac reactor for total impedance of 12%.
16. High temperature current derating: -2.5% per °C above 40 °C for TMdrive-T30 and TMdrive-D30 converters. No high temperature derating for TMdrive-P30 converters.
17. Low temperature current derating: -1.75% per °C below 0 °C for TMdrive-P30 converters. No derating for TMdrive-T30 or TMdrive-D30 converters.

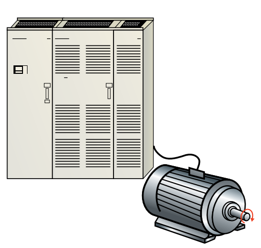
Inverter Specifications

	Frame	Weight kg (lbs)	Full Load Losses kW	Control Power va	Inverter Output KVA	Motor Output Power kW (hp)	Motor Current A ac	Allowable Overload %
IGBT Inverter (TMdrive-30) AC								
 2406 mm (95 in) / 1800 mm (71 in)	2000	1300 (2860)	25	1000	2000	1615 (2165)	924	150
							792	175
							693	200
							554	250
							462	300
 2406 mm (95 in) / 3000 mm (118 in)	4000	2300 (5060)	50	2000	4000	3230 (4330)	1848	150
							1584	175
							1386	200
							1109	250
							924	300

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} = 1500 kW *(2000 hp)*

The motor delivers constant torque from zero to base speed of 900 rpm and 1500 kW *(2000 hp)*.

Duty cycle requires 175% for 10 sec. but has rms duty cycle of 1500 kW *(2000 hp)*.

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

- 1500 kW *(2000 hp)*
- 900 rpm, 1200 V
- Efficiency = 0.954
- Power factor = 0.765
- Service factor = 1.15

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

$$I_{ac\ Inverter} = \frac{kW_{Shaft} \times 1000 \times SF_{Mtr}}{Eff_{Mtr} \times PF_{Mtr} \times \sqrt{3} \times V_{Motor\ rated\ voltage}}$$

$$= \frac{1500 \times 1000 \times 1.15}{0.954 \times 0.765 \times \sqrt{3} \times 1200\ V}$$

= 1138 amps

4 Select inverter based on continuous current and overload requirements.

Scan the 175% entries in the inverter tables for a frame where the continuous current rating exceeds 1138 amps. The **3000 frame** meets this criterion (**1188 amps**) and is appropriate for this application.

Current A ac	Allowable Overload %
1386	150
1188	175
1040	200
832	250
693	300

Inverter Power Output

Output Voltage	0-1250 V
Output Frequency	0-120 Hz Continuous operation below 0.4 Hz requires derate
Output Chopping Frequency	1.5 kHz
Inverter Type Modulation	3-level voltage converter Pulse Width Modulation (PWM)
Power Semiconductor Technology	Insulated Gate Bipolar Transistor (IGBT)

Mechanical (Inverters and Converters)

Enclosure	NEMA 1 (IP20) IP32 or IP31 optional
Cable Entrance	Bottom is standard Top with optional auxiliary cabinet
Wire Colors	Per CSA/UL and CE
Short Circuit Ratings	100 kA for ac and dc buswork 10 kA for control power
Acoustic Noise	≤ 68 dB
Mean Time to Repair	30 minutes to replace power bridge phase-leg
MTBF	> 41,000 hours
Code Conformance	Applicable IEC, JIS, JEM, UL, CSA and NEMA standards

Motor Control

With Speed Sensor (Resolver or Encoder)
- Speed regulator accuracy: +/- 0.01%
- Maximum speed response: 60 rad/sec
- Torque linearity: +/- 3% with temperature sensor; +/- 10% without temperature sensor
- Maximum Torque current response: 1000 rad/sec
- Torque range: 0-400% of rated motor torque
- Maximum flux control range: 20%-100%

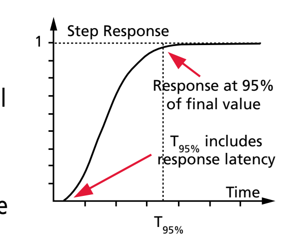
Without Speed Sensor
- Speed regulator accuracy: +/- 0.1% with temperature sensor; +/- 0.2% without temperature sensor (Using 1% slip motor at rated flux)
- Maximum speed regulator response: 20 rad/sec
- Minimum continuous speed: 3%
- Torque linearity: +/-10%
- Maximum Torque current response: 1000 rad/sec
- Torque range: 0-150% of rated motor torque
- Maximum flux control range: 75%-100%

Environmental (Inverters and Converters)

Operating Temperature	0 to 40°C (32 to 104°F) at rated load -20 to 50°C (-4 to 122°F) with derating
Storage Temperature	-25 to 55°C (-13 to 131°F)
Humidity	5 to 95% relative humidity Non-condensing
Altitude	0 to 5000 m (16,400 ft) above sea level Derate voltage 2.25% per 200 m (656 ft) above 1800 m (5905 ft) Derate TMdrive-30 and TMdrive-P30 current 1% per 200 m (656 ft) above 3500 m (11,480 ft) Derate TMdrive-T30 and TMdrive-D30 current 1% per 200 m (656 ft) above 1000 m (3280 ft)
Vibration	10-50 Hz, <4.9 m/s^2 (0.5 G)

Inverter Notes

1. All cabinets shown are 800 mm (32 in) in depth. All equipment requires a steel support at least 50 mm (2 in) under the panel (not included in these dimensions).
2. A minimum of 500 mm (20 in) should be reserved above cabinets for fan maintenance. No back access is required. Reserve 1300 mm (50 in) front clearance for maintenance.
3. Motor power ratings based assume 150% overloads, motor efficiency of 95%, motor power factor of 0.85, ambient temperature 0-40˚C *(32-104˚F)*, and altitude below 1000 m *(3280 ft)* above sea level. Use actual motor data for final inverter selection.
4. The specified current ratings are continuous to which indicated overload can be applied for a maximum of 60 seconds. Refer to application on page 8.
5. Inverters support bottom cable entry. For 1500 and 2000 frames, top cable entry is supported with one auxiliary cabinet 600 mm (24 in). For 3000 and 4000 frames two auxiliary cabinets are required.
6. Each of the inverters require 3-phase control power.
7. For high-performance torque regulation, a temperature sensor is mounted in the motor.
8. Speed and current regulator responses are computed per the adjacent figure in radians/s. Speed regulator responses shown are maximum available. Actual response will be limited by drive train mechanical conditions. Accuracy and linearity specifications shown are as measured under controlled conditions in our lab and while typical may not be achievable in all systems.



Response = $3/T_{95\%}$ (radians/s)

9. Air is pulled in through the front and out the top for all cabinets.
10. The dc bus for the lineup has a maximum capacity of 1640A.
11. Temperature current derating all frames: -1.75% per ˚C below 0˚C. No high temperature derating.
12. Maximum shipping split for the factory is 3 m for this equipment.
13. The ratings shown in green in the inverter table for motor currents and the associated overload percent indicate the maximum peak current that inverter frame can produce.

Operator Interfaces

Standard Display (Inverters and Regenerative Converters)

Optional analog meters can be supplied in addition to either the standard or enhanced display. For cabinet style equipment, four meters are provided.

Three-digit display alternates between speed and current while running, or a fault code when there is an error.

Three LEDs give a quick indication of the status ofthe unit

LED Indication

Ready	On when the unit is ready to run
Running	On when the unit is running
Alarm/Fault	Blinking LED indicates alarm condition, while solid LED indicates a fault

RJ-45 Ethernet™ port is used for local toolbox connection

Interlock button disables the drive

Keypad Option (Inverters and Regenerative Converters)

High Function Display

- LCD backlight gives great visibility and long life
- Bar graphs, icons, menus, and digital values combine to provide concise status information, often eliminating the need for traditional analog meters

Easy-to-understand navigation buttons allow quick access to information without resorting to a PC-based tool

Switch to local mode and operate the equipment right from the keypad

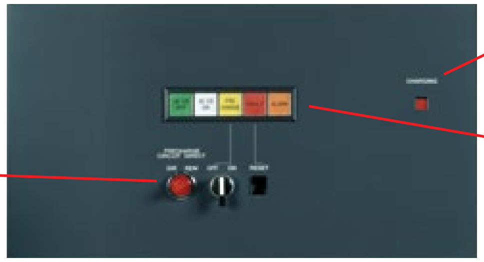
RJ-45 Ethernet port is used for the local toolbox connection

Instrumentation Interface

- Two analog outputs are dedicated to motor current feedback
- Five analog outputs can be mapped to variables for external data logging and analysis

Interlock button disables the drive

Non-Regenerative Converters (TMdrive–D30)



Bus Charged Indicator

Indicating Lamps

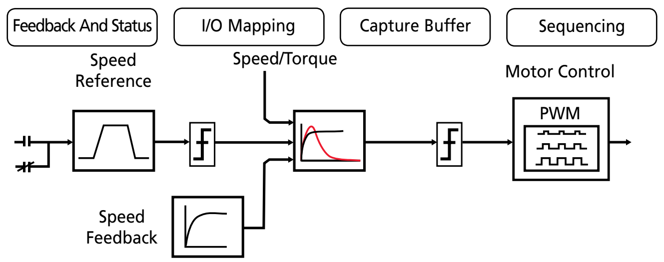
- Green — ac breaker open
- White — ac breaker closed
- Yellow — precharging
- Red — fault
- Orange — alarm

Controls

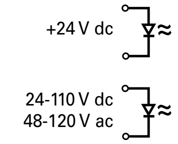
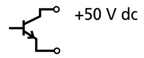
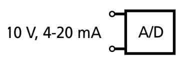
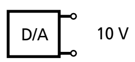
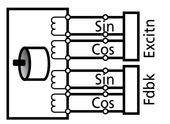
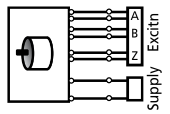
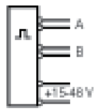
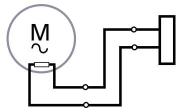
- Precharge circuit
- "On/Off" switch
- "Reset/Fault" switch

A Common Control to Reduce Cost of Ownership

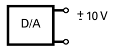
Control Functions



I/O Interface

Digital Inputs		• Opto-coupled 20 mA • Quantity 6 configurable • Opto-coupled 10 mA • Quantity 1 configurable mapping • Quantity 1 dedicated mapping
Digital Outputs		• Open collector 70 mA • Quantity 6 user defined
Analog Inputs		• Quantity 2 ±10 V or 4-20 mA - Differential 8 kΩ input impedance - 12-bit resolution • Optional Quantity 2 ±10 V - 12 bit resolution (Optional for Inverters only)
Analog Outputs		• Quantity 3 ±10 V, 10 mA max • User defined • 8-bit resolution
(Optional) Speed Feedback Resolver Input		• Excitation frequency of 1 or 4 kHz • Source for resolvers is Tamagawa: www.tamagawa-seiki.co.jp
Speed Feedback Encoder Input		• A quad B with marker • Maximum frequency of 100 kHz • Differential 5 or 15 V dc • 5 or 15 V dc at 200 mA supply
Speed Tach Follower Output		• Maximum frequency of 10 kHz • External 15-24 V dc at 100 mA max
Motor Temp. Feedback		• High-resolution torque motor temperature feedback • 1 kΩ positive temperature coefficient RTD or other sensor using optional signal conditioning module

Instrumentation Interface

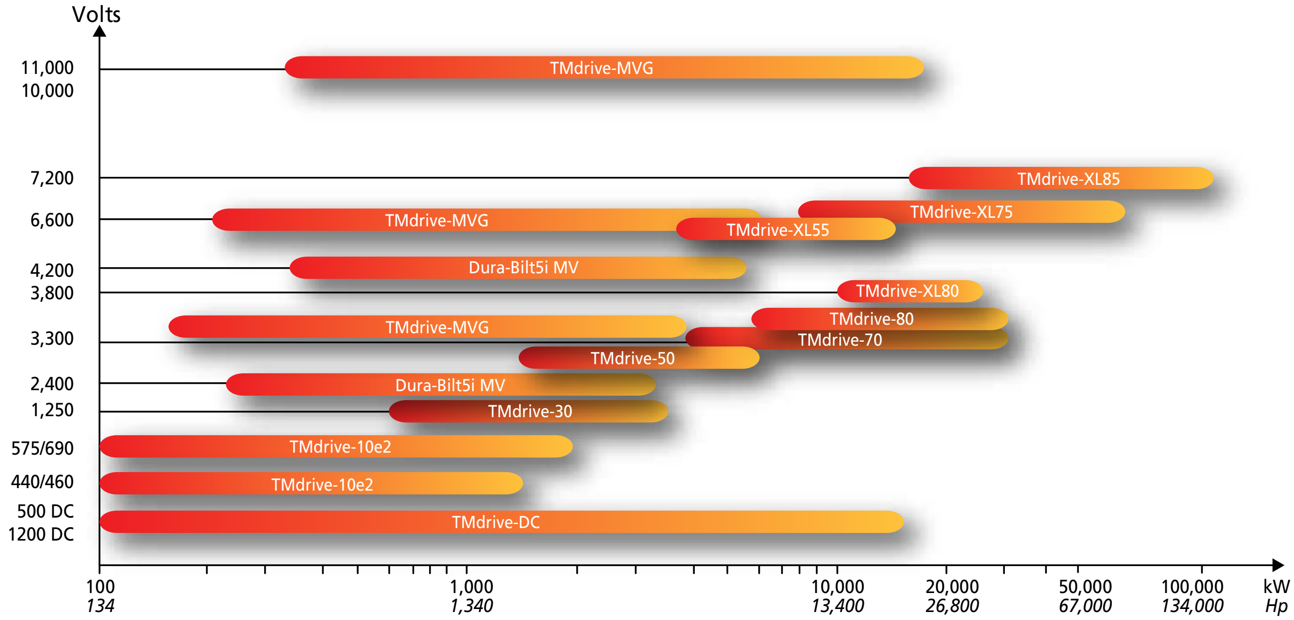
Configuration		• Direct Ethernet connection of TMdrive-Navigator to the drive • Drive Navigator connection to the drive using TC-net via the nv controller
Meter Outputs		• Quantity 5 configurable, ±10 V, 10-bit resolution

LAN Interface Options

TC-net I/O	8 words in/out 10 words in/19 out option
Ethernet Global Data (EGD)	10 words in/out
Profibus-DP	10 words in/out
Modbus RTU	10 words in/out
ControlNet	10 words in/out
DevicNet	4 words in, 10 words out

TOSLINE-S20 and ISBus legacy LANs can also be supported on request. Note: 1 word=16 bits

TMdrive System Drives Offer Complete Coverage



TMEIC Corporation
Office: 1325 Electric Road, Roanoke, VA, 24018, USA
Mailing: 2060 Cook Drive, Salem, VA, 24153, USA
Tel.: +1-540-283-2000; Fax: +1-540-283-2001
Email: info@tmeic.com; Web: www.tmeic.com

TMEIC Corporation - Houston Branch
2901 Wilcrest Dr., Houston, TX 77042, USA
Tel.: +1-713-784-2163; Fax.: +1-713-784-2842
Email: OilGas@tmeic.com; Web: www.tmeic.com

TMEIC Power Electronic Products Corporation
13131 W. Little York Road, Houston, Texas 77041, USA

Toshiba Mitsubishi-Electric Industrial Systems Corporation
Tokyo Square Garden
3-1-1 Kyobashi, Chuo-kyo, Tokyo, 104-0031, Japan
Tel.: +81-0-3327-5511
Web: www.tmeic.co.jp

TMEIC Europe Limited
6-9 The Square, Stockley Park, Uxbridge, Middlesex, United Kingdom, UB7 7LT
Tel.: +44 870 950 7220; Fax: +44 870 950 7221
Email: info@tmeic.eu; Web: www.tmeic.com/Europe

TMEIC Industrial Systems India Private Limited
Unit # 03-04, Third Floor,
Block 2, Cyber Pearl, HITEC City, Madhapur,
Hyderabad, 500081, Andhra Pradesh, India
Tel.: +91-40-44434-0000; Fax: +91-40-4434-0034
Email: inquiry_india@tmeic.com; Web: www.tmeic.in

Toshiba Mitsubishi-Electric Industrial Systems Corp (Beijing)
21/F., Building B, In.do Mansion, 48 Zhichunlu A, Haidian District, Beijing 100098, PRC
Tel.: +86 10 5873-2277; Fax: +86 10 5873-2208
Email: sales@tmeic-cn.com

TMEIC – Sistemas Industriais da América do Sul Ltda.
Av.Paulista, 1439 cj72
Bela Vista, CEP:01311-200
São Paulo/SP, Brasil
Tel: +55-11-3266-6161; Fax: +55-11-3253-0697

For specifications not mentioned here, contact TMEIC

WWW.TMEIC.COM