TMdrive-30™ Product Application Guide

Medium Voltage 3-Level IGBT System Drive
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.

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.

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.
Panel

2000 Frame Inverter

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.

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.

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

3400 Frame

670 V ac

670 V ac

Control

Power

Transient Suppression

Fuses

Internal dc Link Reactors

DC Bus Charging Circuit

Control

Circuit Breaker

TMdrive–T30™ Regenerative Thyristor Converter

3300 Frame

900 V ac

900 V ac

Current and Voltage Sensors

Circuit Breaker

Capacitor panel integral with inverter lineup

External dc Link Reactors

Capacitor Panel Integral with Inverter Lineup

Internal Load Sharing Reactors

Circuit Breaker

900 V ac

900 V ac

Optional Reversing Thyristor Stack On Second Bank

Control

TMdrive–P30™ Regenerative IGBT

2000 Frame

1100 V ac

Control

Circuit Breaker

Optional ac Link Reactor

Control Power

1100 V ac

Optional ac Link Reactor

Control

1100 V ac

Control

1100 V ac

Express
Converter

Initial Charging Circuit

TMdrive–30 IGBT Inverter

Optional Configuration using Three-phase Induction Motor

Optional Motor Isolation Switches

Combining Output Reactor

Optional ac Link Reactor

Control Power Circuit Breaker

1100 V ac

1250 V ac

1250 V ac

1250 V ac

1100 V ac

1100 V dc

1100 V ac

Converter

TMdrive–50™ Regenerative IGBT

500, 1500 and 2000 Frame

3000 and 4000 Frame

Circuit
### Non-Regenerative Diode (TMdrive-D30)

<table>
<thead>
<tr>
<th>Frame</th>
<th>Weight kg (lbs)</th>
<th>Full Load Losses kW</th>
<th>Control Power Va</th>
<th>Converter Output Power kW (hp)</th>
<th>Current A ac</th>
<th>Current A dc</th>
<th>Allowable Overload %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3400</td>
<td>2200 (4840)</td>
<td>15</td>
<td>800</td>
<td>3300 (4424)</td>
<td>1496</td>
<td>1895</td>
<td>150-60s</td>
</tr>
</tbody>
</table>

### Regenerative Thyristor (TMdrive-T30)

<table>
<thead>
<tr>
<th>Frame</th>
<th>Weight kg (lbs)</th>
<th>Full Load Losses kW</th>
<th>Control Power Va</th>
<th>Converter Output Power kW (hp)</th>
<th>Current A ac</th>
<th>Current A dc</th>
<th>Allowable Overload %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3300</td>
<td>3000 (6600)</td>
<td>21</td>
<td>1500</td>
<td>3300 (4424)</td>
<td>1496</td>
<td>1833</td>
<td>150-10s</td>
</tr>
</tbody>
</table>

### Regenerative IGBT (TMdrive-P30)

<table>
<thead>
<tr>
<th>Frame</th>
<th>Weight kg (lbs)</th>
<th>Full Load Losses kW</th>
<th>Control Power Va</th>
<th>Converter Output Power kW (hp)</th>
<th>Current A ac</th>
<th>Current A dc</th>
<th>Allowable Overload %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1600 (3520)</td>
<td>25</td>
<td>1000</td>
<td>1733 (2323)</td>
<td>929</td>
<td>963</td>
<td>150-60s</td>
</tr>
</tbody>
</table>

### 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.

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

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

\[ I_{dc\ Converter} = \frac{kW_{Shaft} \times 1000}{Eff_{Motor} \times Eff_{inv} \times V_{dc\ Bus} \times 2} = \frac{1500 \times 1000}{0.954 \times 0.98 \times 900 \times 2} = 891 \text{ amps} \]

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.

<table>
<thead>
<tr>
<th>Current dc</th>
<th>Overload – Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1895</td>
<td>150% – 60s</td>
</tr>
<tr>
<td>1613</td>
<td>175% – 60s</td>
</tr>
<tr>
<td>1448</td>
<td>200% – 60s</td>
</tr>
<tr>
<td>1191</td>
<td>250% – 60s</td>
</tr>
<tr>
<td>989</td>
<td>300% – 60s</td>
</tr>
</tbody>
</table>
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.

\[
\text{kW}_{\text{dc}} = \frac{\text{kW}_{\text{ShdB}}}{} \times \text{Eff}_{\text{Mtr}} = 1500 \text{ kW} \times 0.954 = 1580 \text{ kW}
\]

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

\[
I_{\text{ac \, Converter}} = \frac{\text{kW}_{\text{dc}} \times 1000}{\sqrt{3} \times V_{\text{Converter \, line-to-line \, voltage}} \times \text{Eff}_{\text{Converter}} \times \text{Eff}_{\text{Inverter}}}
\]

\[
= \frac{1580 \text{ kW} \times 1000}{\sqrt{3} \times 1100 \text{ V} \times 0.985 \times 0.98 \times 2} = 430 \text{ amps}
\]

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

\[
\text{kW}_{\text{dc}} = \text{kW}_{\text{Shaft}} \times \text{Eff}_{\text{Mtr}} \times \text{Eff}_{\text{Inverter}}
\]

3. Scan the regenerative converter table for entries that exceed 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.

<table>
<thead>
<tr>
<th>Current</th>
<th>Overload – Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1858</td>
<td>150% – 60s</td>
</tr>
<tr>
<td>1593</td>
<td>175% – 60s</td>
</tr>
<tr>
<td>1394</td>
<td>200% – 60s</td>
</tr>
<tr>
<td>1092</td>
<td>250% – 60s</td>
</tr>
<tr>
<td>929</td>
<td>300% – 60s</td>
</tr>
</tbody>
</table>

Miscellaneous

<table>
<thead>
<tr>
<th>Main Circuit Input Voltage Variation</th>
<th>± 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Frequency</td>
<td>50/60 Hz ±20%</td>
</tr>
<tr>
<td>TMdrive-P30 Input Chopping</td>
<td>1.5 kHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Power</th>
<th>180-220 V ac, 50 Hz 3-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement Power Factor (at all loads)</td>
<td>TMdrive-D30 - 0.98</td>
</tr>
<tr>
<td></td>
<td>TMdrive-T30 - 0.71 to 0.98 depending on application</td>
</tr>
<tr>
<td></td>
<td>TMdrive-P30 - Unity power factor</td>
</tr>
</tbody>
</table>

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 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 impedance 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 converter 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.
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.

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

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

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.

**Inverter Example**

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).

\[
I_{ac, \text{Inverter}} = \frac{kW_{\text{Shaft}} \times 1000 \times SF_{\text{Mtr}}}{\text{Eff}_{\text{Mtr}} \times \text{PF}_{\text{Mtr}} \times \sqrt{3} \times V_{\text{Motor rated voltage}}}
\]

\[
= \frac{1500 \times 1000 \times 1.15}{0.954 \times 0.765 \times \sqrt{3} \times 1200 \text{ V}}
\]

\[
= 1138 \text{ amps}
\]

---

### IGBT Inverter (TMdrive-30)

<table>
<thead>
<tr>
<th>Frame (mm)</th>
<th>Weight (kg)</th>
<th>Full Load Losses kW</th>
<th>Control Power VA</th>
<th>Inverter Output KVA</th>
<th>Motor Output Power kW (hp)</th>
<th>Motor Current A ac</th>
<th>Allowable Overload %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2406 (95 in)</td>
<td>2000</td>
<td>1300 (2860)</td>
<td>25</td>
<td>1000</td>
<td>2000</td>
<td>1615 (2165)</td>
<td>924</td>
</tr>
<tr>
<td>3000 (118 in)</td>
<td>4000</td>
<td>2300 (5060)</td>
<td>50</td>
<td>2000</td>
<td>4000</td>
<td>3230 (4330)</td>
<td>1848</td>
</tr>
</tbody>
</table>

---

**TMdrive-30 Inverter Specifications**
### Inverter Power Output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>0-1250 V</td>
</tr>
<tr>
<td>Output Frequency</td>
<td>0-120 Hz</td>
</tr>
<tr>
<td>Continuous operation below 0.4 Hz requires derate</td>
<td></td>
</tr>
<tr>
<td>Output Chopping Frequency</td>
<td>1.5 kHz</td>
</tr>
<tr>
<td>Inverter Type Modulation</td>
<td>3-level voltage converter</td>
</tr>
<tr>
<td>Pulse Width Modulation</td>
<td>(PWM)</td>
</tr>
<tr>
<td>Power Semiconductor Technology</td>
<td>Insulated Gate Bipolar Transistor (IGBT)</td>
</tr>
</tbody>
</table>

### 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%

### Mechanical (Inverters and Converters)

- **Enclosure**: NEMA 1 (IP20) IP32 or IP31 optional
- **Cable Entrance**: Bottom is standard 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

### Environmental (Inverters and Converters)

- **Operating Temperature**: 0 to 40°C (32 to 104°F) at rated load
- **Temperature Derating**: -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/s² (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.
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)

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

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

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

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

Non-Regenerative Converters (TMdrive–D30)

Controls
- Precharge circuit
- “On/Off” switch
- “Reset/Fault” switch

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

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 the local toolbox connection

Interlock button disables the drive

Bus Charged Indicator

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
A Common Control To Reduce Cost Of Ownership

Control Functions

Instrumentation Interface

I/O Interface

LAN Interface Options

TOSLINE-S20

- Supports run-time control (6 words in and 10 words out) from an Innovation Series controller or V Series controller
- Drives can directly exchange data between themselves (4 words)
- Fiber-optic bus in a star configuration
- 2 Mbps peer-to-peer protocol; bus scan time based on the number of nodes:

<table>
<thead>
<tr>
<th>Quantity of Nodes</th>
<th>Bus Scan Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3</td>
<td>1 ms</td>
</tr>
<tr>
<td>4-5</td>
<td>2 ms</td>
</tr>
<tr>
<td>6-8</td>
<td>4 ms</td>
</tr>
<tr>
<td>9-64</td>
<td>25 ms</td>
</tr>
</tbody>
</table>

iBUS

- Supports both run-time control (10 words in and 10 words out) and Toolbox configuration/monitoring using the Innovation Series controller as a gateway between the iBUS and Ethernet
- RS-485 or optional fiber-optic bus in a synchronous ring configuration
- 5 Mbps master/follower (drive is the follower) protocol using copper or fiber; bus scan time based on the number of nodes:

<table>
<thead>
<tr>
<th>Quantity of Nodes</th>
<th>Bus Scan Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4</td>
<td>1 ms</td>
</tr>
<tr>
<td>5-8</td>
<td>2 ms</td>
</tr>
<tr>
<td>6-16</td>
<td>4 ms</td>
</tr>
<tr>
<td>17-32</td>
<td>8 ms</td>
</tr>
</tbody>
</table>

Modbus

- Supports run-time control (fixed 10 words in/out) from a Modbus-RTU controller
- RS-485 copper bus
- 1.2 kbps to 57.6 kbps master/follower protocol; update rates up to 20 ms/node possible at the highest baud rate
- Number of notes: 127 max per LAN

MELPLAC™ Net

- Supports run-time control (8 words in and out) from MELPLAC Net master controller
- Fiber-optic bus
- 1 Mbps peer-to-peer protocol, cyclic transmission
- Number of nodes: 128 local station max

Profibus-DP™

- Supports run-time control (6 words in and 10 out) from a Profibus-DP master controller
- Copper bus in a daisy-chain configuration
- 9.6 kbps to 12 Mbps master/follower protocol; bus scan time based on the number of nodes

DeviceNet™

- Supports run-time control (4 words in and 10 words out) from a DeviceNet master controller
- Copper bus in a daisy-chain configuration
- 125 kbps to 500 kbps master/follower protocol; bus scan time based on the number of nodes

Note: 1 word = 16 bits