



## **TMdrive®-10SPR**

### **Product Application Guide**

Slip Power Recovery Drive System for Wound Rotor Motors

metals

cranes

mining

testing

oil & gas

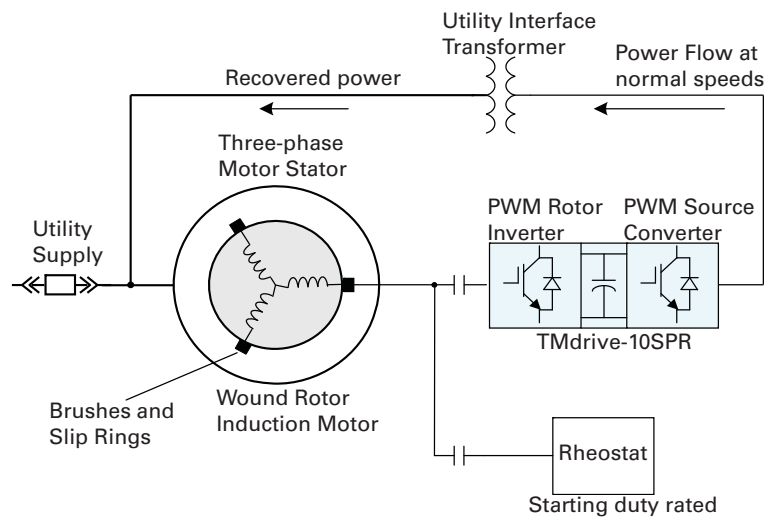
renewable  
energy

power  
generation

cement

With the TMdrive-10SPR, wound rotor motor drives have entered the 21st century, offering:

- PWM converters
- High power factor operation
- High reliability
- Low cost of ownership



## Features

## Benefits

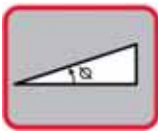


### Based on Standard Drive

Standard TMEiC low voltage drive hardware is applied for use as a wound rotor motor drive.

### Reliable Drive Hardware & Available Spare Parts

The TMdrive-10 drive hardware is in production. No modifications to the hardware are required for use as a slip power recovery drive.



### High Power Factor, Low Harmonic Utility Interface

Source converter feeding power back into utility operates at unity power factor.

### Reduction of Current to Motor and Reduced Harmonics

Higher PF operation means reduced reactive power demands and better voltage stability. Reduced harmonics result in no filtering on utility supply.



### Low Harmonic Currents in Rotor Circuit

PWM converter connected to rotor provides sinusoidal current to rotor

### Negligible Rotor Heating and Smooth Motor Torque

Sinusoidal current in rotor circuit results in negligible rotor heating and torque pulsations.



### Latest Drive Control Technology

Based on current production drive control hardware and firmware.

### Intelligent Drive Control

Using modern drive control provides the latest in drive communications, operating accuracy, and diagnostics.



### Heat Pipe Cooling Technology

The cabinet-based IGBT power bridges use heat pipe cooling technology.

### Reduces Footprint and Lowers Audible Noise

This cooling system reduces the space required for effective IGBT cooling. It also lowers the speed of the cooling air, thereby reducing audible noise.



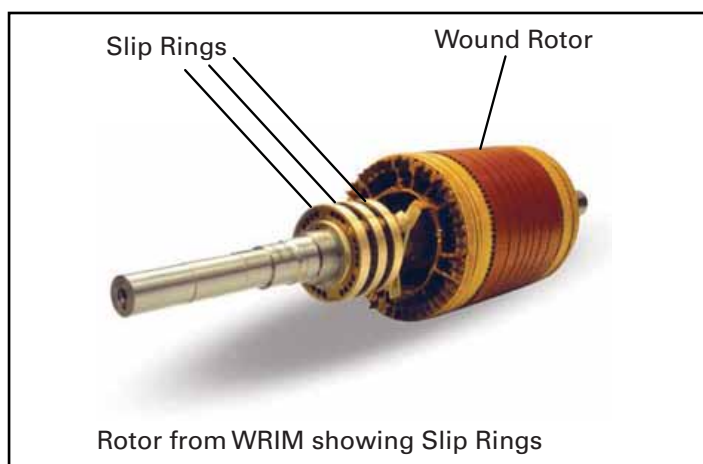
### Precise control of wound rotor motor while not wasting energy

- Drive controls motor torque (rotor current) directly; motor does not have to increase slip (slow down) to increase torque
- Slip power is recovered and fed back to power system when the motor is operating below synchronous speed

## Slip Power Recovery

Wound rotor induction motors have been popular in some industries, particularly cement, for decades. Until about 1985, a wound rotor induction motor (WRIM) was the only large ac motor that allowed controlled starting characteristics and adjustable speed capability.

A WRIM is a machine with a 3-phase wound stator that is usually connected directly to the power system. The rotor also has a 3-phase winding, usually connected in a wye (or star) circuit. The three terminals of the rotor winding are connected to separate slip rings, which are normally connected to a liquid rheostat or resistor bank. Changing rotor resistance changes the motor speed. In the past the power in the resistor was lost as heat. The slip power recovery drive, TMdrive-10SPR, is used to vary the motor speed by varying the power taken off the rotor and returned to the utility supply.



Wound rotor motors continue to be applied in some industries, especially in ore processing, cement, and water/wastewater. Speed control of wound rotor motors has traditionally employed slip power recovery (SPR) drives for cost and energy efficiency reasons. Older implementations of SPR technology saved energy, but had disadvantages of low power factor operation and torque pulsations.

The use of state-of-the-art low voltage PWM converters eliminates these disadvantages while retaining all the energy savings. This new implementation builds on the standard line of TMEIC low voltage induction motor drives used in process industries such as metal processing and paper machines. Therefore the hardware is very reliable and familiar. The TM-10SPR is appropriate for new motors or existing motors.



SAG Mill for grinding ore



Large pumps in a Water Treatment Plant



Cement Plant



## Application 1. Slip Power Recovery Drive System for a water treatment plant

Eight large vertical pumps handling wastewater at this Canadian water treatment plant were driven by 4 kV wound rotor induction motors. Four of the motors were 3050 HP, and four were 5158 HP, all controlled by 1975 vintage variable speed controls using diode rectifiers and thyristor converters. Oil-filled rheostats on each motor provided start and speed control.

### The Customer Need

The oil-filled rheostats posed a fire hazard, and parts and service for the old thyristor controls were hard to obtain. The municipality decided to purchase new controls for the original motors and pumps, and narrowed the choice down to two systems, a medium voltage drive supplying the WRIM, or a low voltage slip power recovery drive (SPR) connected to the WRIM rotor slip rings, (example on page 5). The new controls were required to fit in the foot print of the old drives.

### The Best Solution: TMdrive-10SPR for each pump

- The SPR drive carrying slip power is much smaller and less expensive than an MV drive carrying all the motor power at full speed (4 kV voltage)
- The SPR drive has a smaller footprint than a large stator supply drive
- Inherent fault tolerance - a failure of the SPR drive will not prevent the motor's operation
- The SPR drive can work with any stator-rated voltage, but an MV drive can be difficult to match with the motor.
- The SPR drive can offer higher overall system efficiency, thus saving energy, and can perform additional VAR compensation.
- Running at or above synchronous speed is possible if the motors are rated for the higher speeds.
- The new drive footprint featured a back-to-back configuration to line up with the existing cable and conduits buried in the concrete floor.
- The HMI has one button to switch from English to French displays
- CSA approval required a special inspection for this non-standard panel



One of eight pumps

## Application 2. Slip Power Recovery Drive System for a grinding mill

This new \$250 M ore processing facility in Papua New Guinea can process up to 4.7 million tons of ore per year, resulting in about 275,000 ounces of annual gold production. This variable speed drive application is a dual-pinion SAG mill driven by two 5,000 kW wound rotor induction motors. Two TMdrive-10SPRs control motor speed by recovering rotor current and returning the power to the utility supply.

### The Customer Need

Reliability, power dependency and logistics were a challenge for this project. Limited access to the mine's extremely remote location required power recovery and stellar reliability in its operations.

### The Best Solution: TMdrive-10SPR for each mill motor

- The TMdrive-10SPR has high reliability and a good track record.
- Configured in a twin motor arrangement, the motors share load in the tandem mill. The first motor provides speed control, the second motor provides torque control
- Continuously recovers an estimated 770 kW
- Inherent fault tolerance - a failure of the SPR drive will not prevent the motor's operation
- The SPR drive offers high overall system efficiency, thus saving energy, and can perform additional VAR compensation



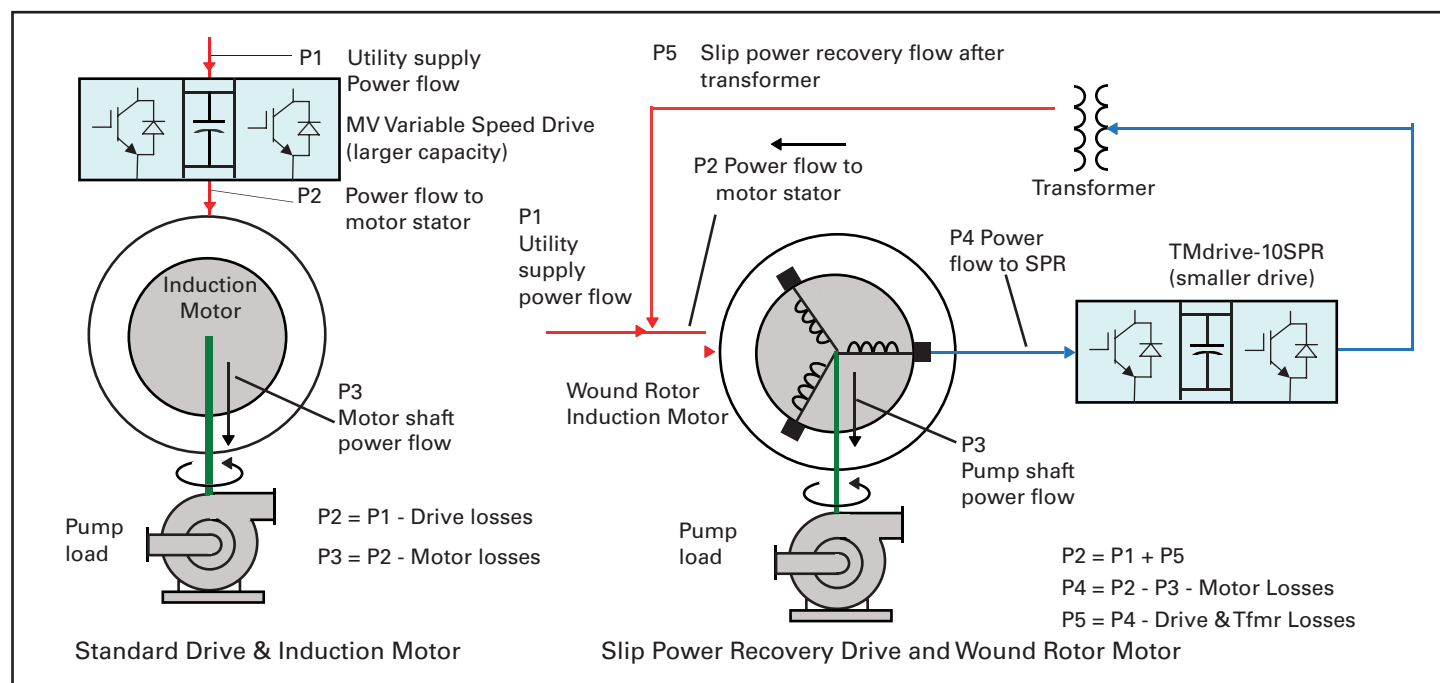
SAG Mill and Motor

### Application 3. Energy Savings using Slip Power Recovery Drive System

The example below compares the case of an induction motor driven by a large standard drive, with the case of a WRIM controlled by a small SPR drive, and calculates the energy savings. In the larger standard drive system, all the motor power passes through the drive. With the SPR drive, only a fraction of the motor power passes through the drive.

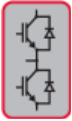
For a rated pump load of 5,000 hp, running at 90% speed, the power saving using the SPR drive is 88 kW. With an electrical cost of 7¢/kWh, the annual savings amount to \$53,960. At lower speeds the savings are even higher.

Compared to a WRIM using only a rheostat to control speed, where all of the slip power is wasted as heat, the SPR drive saves \$176,000 annually.



Operating Conditions	Power Flow	Standard Drive & Induction Motor	Slip Power Recovery Drive & Wound Rotor Motor
Pump Load at Full Speed, shaft kW	–	3730 kW (5,000 hp)	3730 kW (5,000 hp)
Pump load at 90% speed, shaft kW	P3	2720 kW	2720 kW
Utility supply power flow	P1	2980 kW	2892 kW
Power flow to motor stator	P2	2863 kW	3180 kW
Power flow to Slip power recovery drive	P4	0	300 kW
Slip power recovery after transformer	P5	0	288 kW
Difference in utility power flows	–	–	88 kW
P1 (Induction motor) - P1 (WRIM)	–	–	\$53,960 per year
SPR system savings with 7¢/kWh electrical power	–	–	

## A Look Inside



### Two-Level Phase Leg Assembly

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

- IGBTs with flyback diodes
- Heat pipe assembly
- IGBT gate driver circuit board

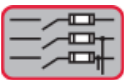


### Control Functions

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.

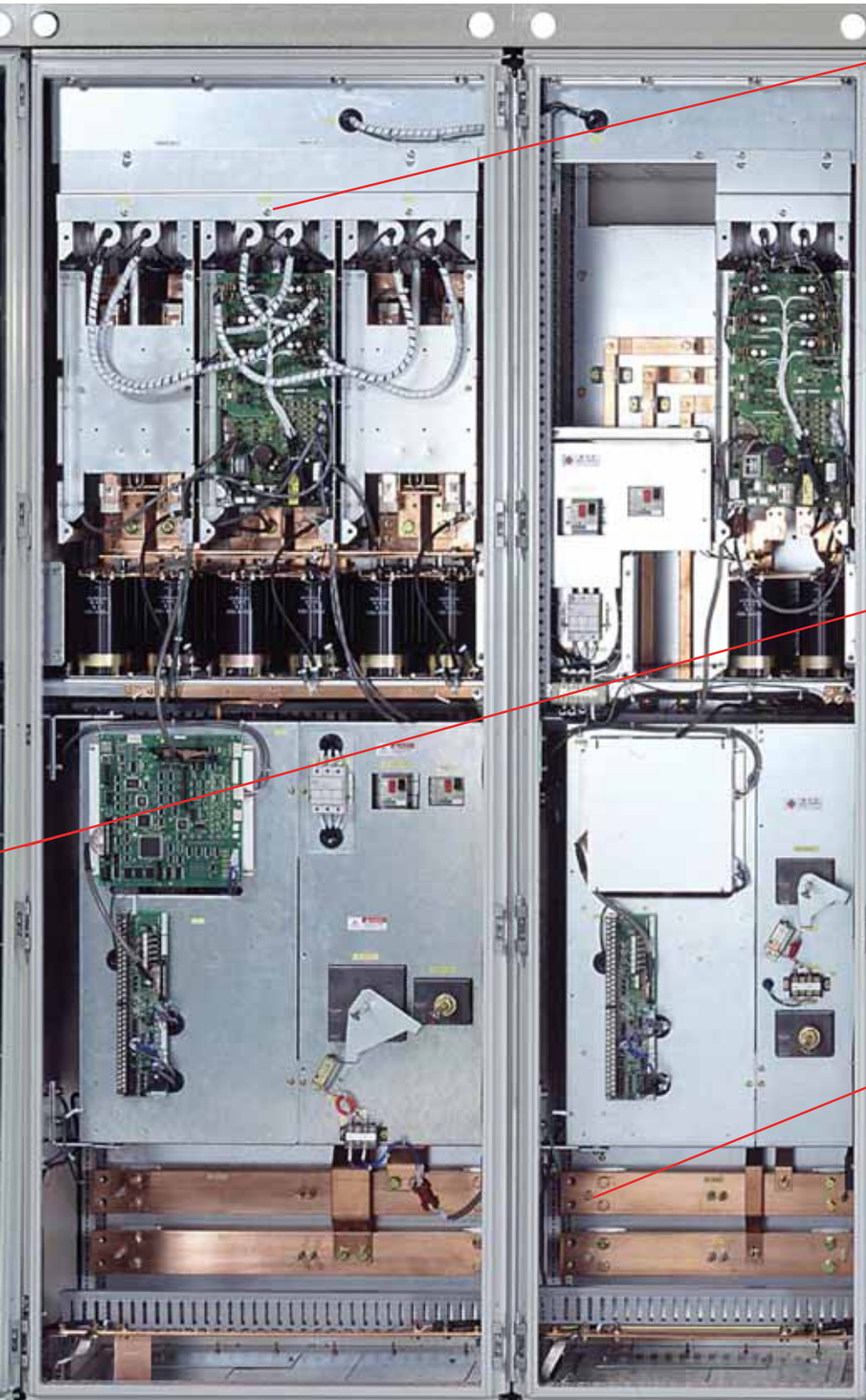


### Incoming Power

The converter in each lineup is fed 3-phase ac power. In addition, 3-phase ac control power is fed to each converter and inverter in the lineup. A control power disconnect is provided in each cabinet.

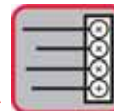






#### **Heat Pipe Cooling Technology**

The cabinet style inverters and regenerative converters use heat pipes 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 dramatically reducing the audible noise.



#### **I/O Board**

All TMdrive-10 products share a common 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.



#### **DC Bus**

The 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 solid copper bus near the bottom of the cabinets. Tin-plated bus may be used.

## Operator Interface

### 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

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

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

## How to Apply SPR

Application of the TMdrive-10SPR starts with the motor speed range, the rated rotor current, the rated rotor voltage (at standstill), and any overload requirements. The speed range and the rotor voltage determine the maximum operating voltage of the TMdrive-10SPR. The rotor voltage is at rated value at standstill and reaches zero at synchronous speed. Therefore, the voltage at minimum controlled speed is:

$$V_c = V_{rated} * (100 - N_{min}), \text{ where}$$

$$V_{rated} = \text{rated rotor voltage, and}$$

$$min = \text{minimum controlled speed in percent}$$

The rated rotor current and overloads determine the required inverter current capacity. The inverter continuous current rating must be equal to the rated rotor current and must be rated for any overloads.

The rating of the converter is determined from the speed range and the power to be recovered from the rotor. For a variable torque load (pump or fan), the maximum regenerated power is 15% of the motor rating. By contrast, the power regenerated from a motor powering a constant torque load is equal to motor rating times the speed range in percent.

As an example, consider a 3000 HP motor with a 4 kV stator, a rotor voltage of 1200V, rotor current of 1150 A, speed range of 70 – 96%, and no overloads exceeding 150% for 60 sec, driving a fan. The maximum rotor voltage is 360 V, so a 460 V inverter is applicable. The inverter size is a 1000 frame with a current rating of 1506 amps. The regenerated power is 335 kW, so the line converter is a 700 frame. Other components such as the utility interface transformer and rotor contactors must also accommodate these ratings.



## Specifications

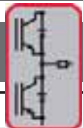
### Inverter Specifications for models without DC disconnects

Frame	Weight kg (lbs)	Full Load Loss (kW)	460 V ac	Allowable Overload %	575 / 690 V ac
			Rotor Current A ac		Rotor Current A ac
400	395 (869)	6.3	528	100 - 150	352
			469	175	302
			411	200	264
500	400 (880)	7.5	753	100 - 150	486
			669	175	417
			586	200	365
700	405 (892)	9.3	960	100 - 150	586
			861	175	502
			753	200	440
900	410 (902)	13.5	1130	100 - 150	720
			969	175	617
			848	200	540
1000	800 (1760)	14.9	1506	100 - 150	972
			1339	175	883
			1171	200	729
1400	810 (1782)	18.6	1920	100 - 150	1172
			1721	175	1005
			1506	200	879
1800	820 (1804)	27	2260	100 - 150	1440
			1937	175	1234
			1695	200	1080

### Source Converter Specifications

Frame	Weight kg (lbs)	460 V ac			575/690 V ac			
		Loss kW	Power kW	Current A ac	Allowable Overload	Power at 575 V ac	Power at 690 V ac	Current A ac
300	475	3.7	236	308	150	196	235	205
	(1045)			290	200			180
700	680	8.5	533	697	150	445	534	465
	(1496)			697	200			407
900	795	11	709	926	150	590	709	617
	(1749)			895	200			540
1400	1330	17	1067	1394	150	890	1067	929
	(2926)			1394	200			813
1800	1560	27	1417	1852	150	1180	1416	1235
	(3432)			1790	200			1080

## Inverter Specifications



### Inverter Power Output

Output Voltage	0-460 V, 0-690 V
Output Frequency	0 - 200 Hz 0 - 400 Hz Optional Continuous operation below 0.4 Hz requires derate
Output Chopping Frequency	1.5 kHz for 200-1800 frames 2 kHz for 4-125 frames Up to 6 kHz available with derating
Inverter Type Modulation	Two-level voltage converter Pulse Width Modulation (PWM)
Power Semiconductor Technology	Insulated Gate Bipolar Transistor (IGBT)



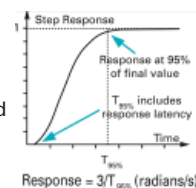
### Motor Control

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 fad/sec
Torque range:	0-150% of rated motor torque
Maximum flux control range:	75%-100%

### Inverter Notes

1. All inverter cabinets are 605 mm (24 in.) in depth. All equipment requires a steel support of at least 50 mm (2 in) under the panel (not included in these dimensions). All shipping splits are 2.4 m maximum. Reserve an additional 115 mm (5 in.) in height for equipment requiring a debris hood (UL).
2. A minimum of 500 mm (20 in) should be allocated above cabinet for fan maintenance. No back access is required. Reserve 800 mm (32 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), an altitude below 2000 m (3280 ft) above sea level. Use actual motor data for final inverter selection.
4. The specified current ratings are continuous to which the referenced overload can be applied for a maximum of 60 seconds. Refer to application example on the previous page.
5. Inverters support bottom cable entry. Top cable entry is supported with one 600 mm (24 in) auxiliary cabinet between every two inverter cabinets.
6. Each of the inverters requires 2-phase control power.
7. For high-performance torque regulation, a temperature sensor is mounted in the motor.
8. Speed and current regulator responses are computer 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 current capacity of 2000 amps.
11. High temperature current derating: all frames -2.5% per °C below 0 °C above 40° C.
12. Inverter doors are electrically interlocked with controls to inhibit gating when the doors are open.
13. Low temperature current derating: frames 200 to 1800 -1.75% per °C except frame 400 which is -2.5% per °C below 0 °C all other frames no derating.
14. 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.



### 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 current ratings: 1% per 200m (656ft) altitude above 1000 m (3280 ft) Derate voltage 2.25% per 200 m (656 ft) for 460 V inverters above 4000 m (13120 ft) for 575 V inverters above 3000 m (9840 ft) for 690 V inverters above 2000 m (6560 ft)
Vibration	10-50 Hz, <4.9 m/s <sup>2</sup> (0.5 G)



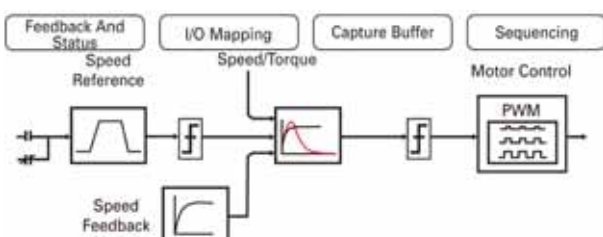
### Mechanical (Inverters and Converters)

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 (entire lineup extra cost option)

# Control Functions

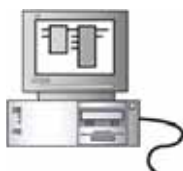


## Control Functions



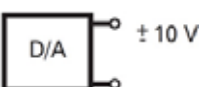
## Instrumentation Interface

### Configuration



- RJ-45 Ethernet interface
- 10 Mbps maximum
- Toolbox option of ISBus to Ethernet using Innovation Series controller as gateway

### Meter Outputs

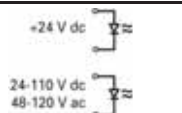


- Motor current A and B,  $\pm 10$  V
- Quantity 5 configurable,  $\pm 10$  V, 8-bit resolution



## I/O Interface

### Digital Inputs



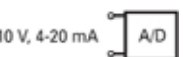
- Opto-coupled 20 mA
- Quantity 6 configurable mapping
- Opto-coupled 10 mA
- Quantity 1 configurable mapping
- Quantity 1 dedicated mapping

### Digital Outputs



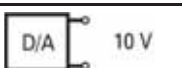
- Open collector 70 mA
- Quantity 6 user defined

### Analog Inputs



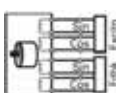
- Quantity 2  $\pm 10$  V or 4-20 mA
- Differential  $8 \Omega$  input impedance
- 12 bit resolution
- Optional Quantity 2  $\pm 10$  V
- 12 bit resolution (Optional for Inverters only)

### Analog Outputs



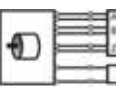
- Quantity 3  $\pm 10$  V, 10 mA max
- User defined
- 8-bit resolution

### (Optional) Speed Feedback Resolver Input



- Excitation frequency of 1 or 4 kHz
- Source for resolvers is Tamagawa: [www.tamagawa-seiki.co.jp](http://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 of 15 V dc at 200 mA supply

### SpeedTach Follower Output



- Maximum frequency of 10 kHz
- External 15-24 V dc at 100 mA max

### Motor Temperature Feedback



- High-resolution torque motor temperature feedback
- 1 k $\Omega$  positive temperature coefficient RTD or other sensor using optional signal conditioning module

## LAN Interface Options

### ISBus

- 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 ISBus 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:

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

### TOSLINE-S20

- Supports both 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
- 2Mbps peer-to-peer protocol; bus scan time based on the number of nodes:

Quantity of Nodes	Bus Scan Time
2-3	1 ms
9-64	25 ms

### 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 nodes: 127 max per LAN

### 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

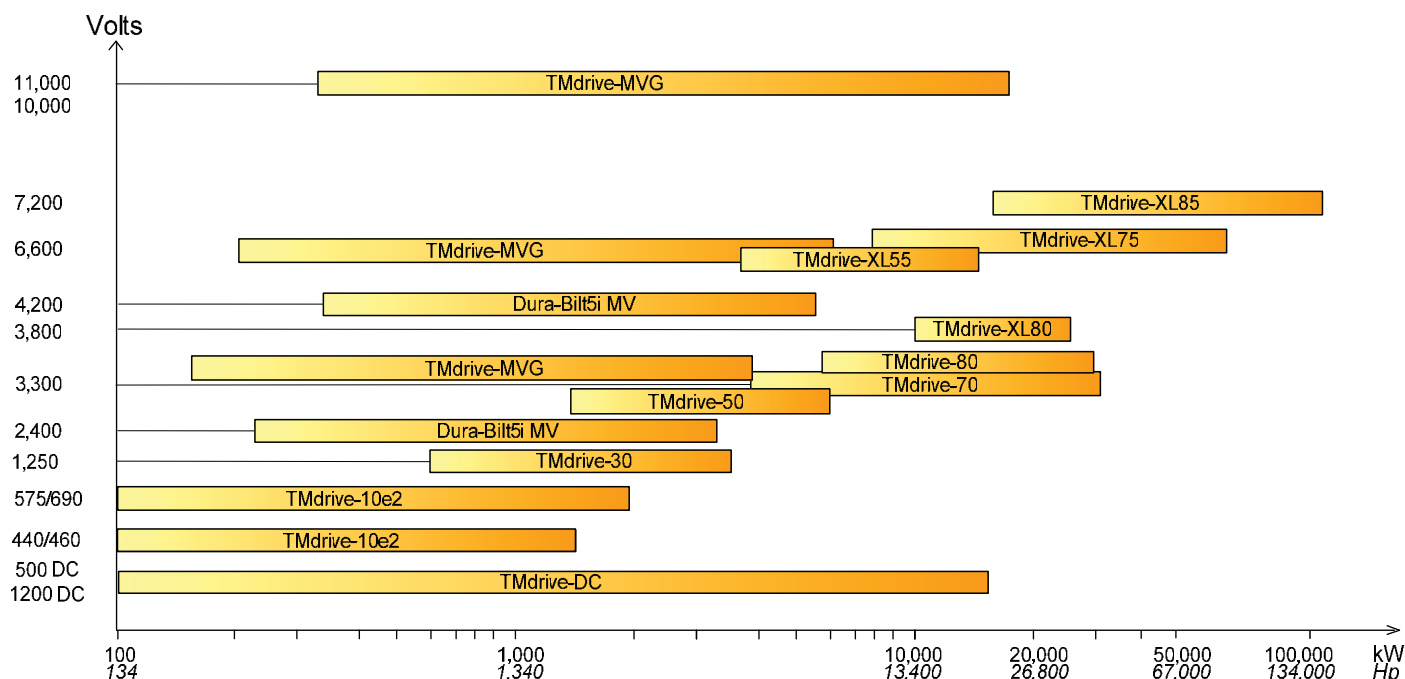
### Ethernet Global Data (EGD)

- Supports run-time control (10 words in/out)
- RJ-45 Ethernet interface
- Update rates up to 20 ms using standard 10 Mbps hardware or rates up to 2 ms with optional 100 Mbps card
- Drives can exchange data directly
- Supports peer-to-peer operation (no master needed)
- No limit to maximum number of nodes

Note: 1 word = 16 bits



# TMEIC AC 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 Dis-  
 trict, 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

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