Drive Solutions for the Global Mining Industry
Variable Frequency Drives in the Mining Industry

Every step of the way, from the mine to the finished product, variable frequency drives (VFDs) are used to smoothly start large motors and continuously adjust the speed as required by the machine or process. Induction and synchronous motors driving excavators, conveyors, mills, fans, and pumps use VFDs to provide high power and speed control, as well as generate significant associated energy and maintenance savings.

- Large draglines and shovels require drives to provide high power to all the motors running the machine with controlled torque and speed.
- Long conveyors require drives for starting and running, in particular to provide controlled starting torque to avoid belt slip, and the ability to adjust speed to match processing needs.
- The TMdrive®-10/30/50/70 family of drives and TMEIC motors are also well-suited for mine hoist applications.
- Drives are useful in soft starting large mill motors. Motor life is extended by eliminating inrush currents. Low currents at start also benefit the power delivery system by reducing voltage dips.
Why Use Electrical Variable Frequency Drives?

Here are some of the reasons to use VFDs in the mining industry:

<table>
<thead>
<tr>
<th>Reason</th>
<th>Pages</th>
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<tbody>
<tr>
<td>Increased Reliability</td>
<td>4, 5, 9</td>
</tr>
<tr>
<td>Variable frequency motor-drive systems are more reliable than traditional mechanical approaches such as using throttling valves, gears, or turbines to control speed and flow. Because electric drives have no moving parts, they provide very high reliability.</td>
<td></td>
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<tr>
<td>Good Control over Earth Moving Machines</td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>Responsive speed and position control of large machines with mechanical functions such as hoist, swing, and drag, require powerful variable frequency drives. Long conveyors also require accurate torque and speed control provided by VFDs.</td>
<td></td>
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<tr>
<td>Significantly Less Maintenance</td>
<td>8, 19</td>
</tr>
<tr>
<td>Mine equipment demands high system availability. Electric variable frequency drive systems have no moving parts, and are very low maintenance. This is in sharp contrast to speed control devices such as pumps, valves, gears, and turbines that do require extensive periodic maintenance with associated downtime.</td>
<td></td>
</tr>
<tr>
<td>Soft Starting One or Multiple Mill Motors, and Improved Power Factor</td>
<td>8, 9</td>
</tr>
<tr>
<td>When electric drives soft start large motors, starting inrush current with associated heating and thermal stress is eliminated. This removes limitations on motor frequency of starts, reduces insulation damage, and provides extended motor life. With synchronization logic, one drive can soft start multiple motors. Finally, large variable frequency drives can improve overall system power factor.</td>
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Why TMEIC Drives Make Sense

<table>
<thead>
<tr>
<th>Feature</th>
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<tr>
<td>Choose TMEIC, a Global Supplier</td>
<td>18</td>
</tr>
<tr>
<td>TMEIC manufactures, sells and services drive systems worldwide, supported by engineering and service offices in North &amp; South America, Europe, Asia, Japan and Australia.</td>
<td></td>
</tr>
<tr>
<td>We've got you covered! A Complete Family of Drives</td>
<td>19</td>
</tr>
<tr>
<td>Our family of low and medium voltage (LV and MV) drives covers all your needs from 450 hp up to 12,000 hp (335 kW to 8,950 kW) and beyond, with a wide output voltage range up to 11 kV, and a line of dc drives and motor generator controls to meet your requirements.</td>
<td></td>
</tr>
<tr>
<td>Engineering Expertise</td>
<td>11</td>
</tr>
<tr>
<td>TMEIC drive and motor application engineers bring an average of 25 years of practical industry experience to your application. After analyzing your system requirements, they can recommend the most cost effective solution and design the complete drive system for you.</td>
<td></td>
</tr>
<tr>
<td>Configuration Software</td>
<td>19, 20</td>
</tr>
<tr>
<td>The world-class software configuration tool is used on all TMEIC drives. Live block diagrams and tune-up wizards streamline commissioning and maintenance activities.</td>
<td></td>
</tr>
</tbody>
</table>
Drive Applications for Draglines, Shovels, Conveyors, Mills, and Pumps

AC and DC variable frequency drives are used to control the speed of draglines, conveyors, mills, hoists and pumps in the mining industry. The following pages describe four typical applications and present the reasons why electrical drives were chosen.

Application 1. Advanced Control for MG Set Draglines and Shovels

DC-EXX MG Set Control

The DC-EXX is TMEIC’s motor generator control for mining excavators. This control is a high-performance, innovative, hardware-software system built on proven technology and over 50 years of experience.

The system is designed for multiple dc generators and motors used in large machines. Common-bus dc rectifiers feed IGBT (Insulated Gate Bipolar Transistors) field exciter-regulators, while a single high-speed PLC provides precise control and enables high excavator productivity.

Overall Motor Generator Set System

- Medium voltage ac power from the mine trail cable feeds MG set sync motors and auxiliary transformer.
- Each synchronous motor MG set powers multiple dc generators on a common shaft.
- Diode ac-dc converters on auxiliary power create two 600 volt common dc busses for generator and motor fields

DC-EXX Features

<table>
<thead>
<tr>
<th>Latest Technology</th>
<th>Improved Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Bus - allows field power sharing</td>
<td>Smaller feed transformers and lower cost</td>
</tr>
<tr>
<td>Low harmonics of diode vs. thyristor converters</td>
<td>Less heating &amp; interference, smaller auxiliary transformer</td>
</tr>
<tr>
<td>IGBT power switches vs. thyristors</td>
<td>Faster response, no cell state sensors, fewer devices</td>
</tr>
<tr>
<td>Replace field circuit dc contactors with thyristor</td>
<td>Less maintenance; same field circuit protection &amp; braking</td>
</tr>
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<table>
<thead>
<tr>
<th>More Control Features</th>
<th>Improved Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive PLC sets limits, communication, &amp; operation modes</td>
<td>Simplified supervisory PLC system &amp; real-time monitoring</td>
</tr>
<tr>
<td>PLC master has motion protection &amp; drive settings</td>
<td>Visible functionality for easier monitoring &amp; maintenance</td>
</tr>
<tr>
<td>Complete control during LE (Excitation) stop</td>
<td>Faster motion stop while protecting motors &amp; generators</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Superior Design</th>
<th>Improved Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current but proven technology</td>
<td>Long product life</td>
</tr>
<tr>
<td>Fewer excitation transformers</td>
<td>Less space, simpler, lower cost MCC and ac feeds</td>
</tr>
<tr>
<td>Simpler drive internal controls</td>
<td>Easier troubleshooting and setup</td>
</tr>
<tr>
<td>Small footprint</td>
<td>Better and smaller panel layout and maintenance</td>
</tr>
<tr>
<td>Lower total system cost</td>
<td>Better value</td>
</tr>
</tbody>
</table>
Main Components

• Medium voltage ac power from the mine trail cable feeds MG set synchronous motors and auxiliary transformer.

• Each synchronous motor MG set powers multiple dc generators on a common shaft.

• Diode ac-dc converters on auxiliary power create two 600 volt common dc busses for generator and motor fields.

• Exciters use IGBT switches in a dc chopper configuration to feed filtered, controlled current to dc fields.

• A high-speed drive controller for optimum digging and machine protection.

• Dragline ac incoming Power Factor is maintained by synchronous motor exciters fed from the dc motor common bus.

• Machine supervisory PLC controls and protects excavator and communicates through operator and maintenance displays.

• Profibus line to drives used for commands and monitoring.

• Static switches in the generator and motor fields provide field protection and controlled emergency stopping.

Ruggedized DC-EXX Modules

DC Converter

• 220-440 V ac 3-phase input

• 300-600 V dc output

• 350 or 750 Amp output capacity

Exciter

• 300 or 600 V dc in, 150, 300 and 600 Amp output, output voltage to match field requirement.

• Microprocessor controlled IGBT switches regulate armature voltage and current.

• Film type internal capacitors for wide temperature tolerance.

• Receives operating commands through Profibus input from drive controller.
### Main Components

- **Incoming power from the mine distribution system feeds the TM-30 converter via the onboard transformer.**
- **For three-level output, the TM-30 converter powers two, 900 V dc busses that are available to the entire line-up of the inverters. The PWM converter is fully regenerative and can provide leading VARS for voltage stability.**
- **Each drive inverter is connected to a motor for performing a particular motion of the dragline.**
- **The swing drive feeds the two swing motors (depending on motion HP), while the propel motion is shared with the drag drive. Hoist motors are supplied from dedicated drives.**
- **The number of inverters per converter lineup depends on the peak and RMS power levels and required dragline power and reactive power characteristic needed for mine voltage stability.**
- **A machine supervisory PLC sends references to the drive and controls/protects the dragline while running.**
- **Two touch-sensitive HMI displays are provided for easy maintenance, diagnostics and monitoring.**
- **Communications between the drives and PLC can be provided via industry high-speed standard protocol like Profibus-DP™.**

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### 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
- Heat pipe assembly
- IGBT gate driver circuit board
- Heavy-duty slides allow easy access for maintenance
- High-speed fuses
Application 3. Transporting Ore by Conveyor - Tough Speed and Torque Control

A train transporting ore to a processing plant had become obsolete and unreliable. TMEIC’s solution was to replace the train with a conveyor to transport the ore. The conveyor was segmented into three pieces: Conveyor 1 lifts the ore to the surface, Conveyor 2 moves the ore several miles, and Conveyor 3 moves the ore to the processing plant. The longest segment, Conveyor 2, is detailed below.

Conveyor 2 Design Challenges

Motor Challenges: The system required:
- Motor powers up to 2250 hp with high starting torque
- Wide speed range

Motor Solution: 2.3 kV induction motors with separate cooling air system supplied by the user.

Drive Challenges: The drives must be:
- Reliable for continuous service
- Energy efficient
- Low maintenance

Drive Solution: TMEIC ac drives for 2300 volt operation, with 3-level PWM inverters and 18-pulse rectifiers.

Control Challenges: The system required:
- Precise torque for belt tension control
- Head to tail tension coordination
- Variable speed operation of any motor.

Control Solution: An Innovation Series controller for torque programming.

Power Challenges: The system required long power feeds, and needed to avoid capacitance-created resonance at high order harmonics.

Power Solution: The power system employs:
- 3-level inverters with IEEE 519 compliant, 18-pulse converters
- High frequency filters to eliminate cable resonance at 19th harmonic

Benefits of ac Drive System

Very reliable system. Replacing the train with the conveyor and variable frequency drive system resulted in:
- High reliability
- Reduction in maintenance & down time

Variable speed brings benefits. Conveyor speed control resulted in several benefits:
- Energy savings
- Reduced friction
- Reduced belt wear

Technical risks avoided. Careful design avoided failure potentials such as slippage and stretch of the miles-long total belt length driven by 9,000 hp at the head end (four motors of 2,250 hp each).
Customer installations at this plant use variable frequency drives for a number of applications. Four motors ranging from 250 to 2,400 hp are driven by TMEIC medium voltage drives. There are three large mill motors, each one requiring a medium voltage motor of 4,000 hp size.

The customer had several requirements when selecting the three large mill motors, associated drives and controls, including:

- Ability to soft start any of the motors from any drive and reduce the impact on the power system.
- Ability to synchronize the motors with the utility supply and run some or all of the motors on the utility supply at constant speed.
- Ability to run one motor at variable frequency to allow grinding process optimization.
- Use synchronous motors, because they can supply leading VARs to the power supply system to help correct poor plant power factor.

After reviewing alternatives, the customer decided to install a medium voltage Load Commutated Inverter (LCI) to individually soft start the three mill motors.

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**Benefits of Variable Speed Drive and Synchronous Motors**

**Cost savings.** The customer’s analysis indicated excellent savings by using synchronous motors because they correct the power factor for the whole plant, and they have a high efficiency. In this location the utility charges users a penalty for low power factor operation.

**High reliability.** The medium voltage LCI has a proven history of high reliability over the past 20 years:

- N+1 SCR redundancy allows continued operation even if a SCR fails
- Water cooled power modules
- SCRs can be changed without opening the cooling circuit
- The MTBF based on plant operation is over 15 years

**Smooth motor starting.** The drive controls the rotor field (through the exciter) and the stator current to provide a smooth starting profile without exceeding rated volts and amps, thereby protecting the motor against overheating. Controlling the motor current is also important where power system grids are weak or the plant is at the end of a long transmission line. In addition to starting, the drive provides smooth motor synchronizing with the supply.
Synchronous Transfer
The drive is responsible for the actual phase and voltage matching for the final transfer of the motor to utility operation. This transition is coordinated to within a few milliseconds that eliminate damaging torques or loss of motor synchronization.

Soft Starting
The drive keeps the motor starting currents below full load amps at all times. Starting the motor across the line without the drive, the starting inrush current is six times full current. Using the drive, motor stress is significantly reduced and motor life is extended.

Shared Drive Starting System is Cost Effective
All three grinding mills are driven by synchronous motors of identical ratings. One drive can start any of the three motors in any desired sequence as shown by the blue lines in the figure above. Once the synchronous motor is started, the drive synchronizes the motor with the supply to operate directly across the line.

As soon as the first mill motor is started and bypassed to the line, the drive is available to start the second mill. The same process is repeated to make the drive available for starting the third mill.

All three mills can operate directly across the line, or one can remain connected to the drive for variable frequency operation if required. Because of the sharing, this system minimizes the customer’s capital cost.
Application 5. Slip Power Recovery Drive System for Grinding Mill

This ore processing facility in Papua New Guinea can process up to 4.7 million tons of ore per year. The variable frequency drive application is a dual-pinion SAG mill driven by two 5,000 kW wound rotor induction motors (WRIM). Two TMdrive-10SPRs control motor speed by recovering rotor current and returning the power to the utility supply. Configured in a twin motor arrangement, the motors share load in the tandem mill.

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

Grinding Mill Design Challenges

| Motors: Two, 5,000 kW Wound Rotor Induction Motors |
| Twin motor application |
| One motor provides speed control, one provides torque control |
| Motors share the load in the tandem mill |

Drive Challenges: The drives must be:
- Reliable for continuous service
- Energy efficient and Low maintenance

Drive Solution: TMdrive-10 SPR drive for each motor
- Two, 690 VACTMdrive-10SPR line-ups with 1800 frame converters and inverters
- Drive power level is only 750 kW

Control Challenges: The system required:
- Speed range 85% - 110% rated speed
- Variable speed operation of motors

Control Solution: 1800 frame Toshiba V Series PLCs

Power Challenges:

| Power Solution: Slip Power Recovery. |
| TMdrive-10SPR Slip Power Recovery drives |
| Continuously recovers an estimated 770 kW |

Benefits of Slip Power Recovery Drive

Very reliable system. Standard low voltage drive hardware, with a proven track record for performance and reliability.
- High reliability is suitable for the remote location
- Reduction in maintenance and down time
- Inherent fault tolerance - a failure of the SPR drive will not prevent the motor’s operation

Energy efficient
- The SPR drive offers high overall system efficiency, thus saving energy and lowering operating costs
- Can perform additional VAR compensation utilizing extra capacity in the converters

Latest Drive Technology
- Modern drive control provides the latest drive communications, operating accuracy, and diagnostics
- Standard TMEIC low voltage drive hardware is applied for use as a wound rotor motor drive
- The TMdrive-10 drive hardware requires no modifications in the slip power recovery drive application

Precise control of wound rotor motor while conserving energy
- Soft starts the mill motors
- Drives control motor torque (rotor current) directly; motors do not have to increase slip (slow down) to increase torque, providing faster control response than Liquid Rheostat Control
- Slip power is recovered and fed back to power system, saving energy

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SPR Operation

The TMdrive-10SPR takes power out of the rotor to reduce the motor speed. At reduced speeds, power flows out of the rotor through the SPR to the transformer and back into the supply, instead of being dissipated in the rheostat.

The SPR provides the highest efficiency VFD configuration because only a fraction of the motor power goes through the drive, in this case only 750 kW, out of 5,000 kW motor power. During startup the rheostat is connected to the rotor and the SPR is disconnected. Once up to minimum speed, the SPR drive is connected and the rheostat disconnected. The motor speed is then controlled by the SPR.

SAG Mill Operator’s Screen (HMI)

The SAG mill operator’s control screen shown illustrates the two wound rotor motors M1 and M2. Liquid rheostat starters on the right are switched in before starting and switched out when the motor reaches SPR regulating speed.

Recovered slip power from the rotor flows to the left through the slip power recovery drives and out through the transformers to the supply.

Motor speeds up to 110% of synchronous speed are possible, if torque and horse power limitations are observed.

Electric power savings using Slip Power Recovery are considerable. An example calculation is shown on the next page.
Calculating Recovered Energy Savings

**Energy Efficiency**

Energy efficiency of the components are estimated as follows:
- SPR drive efficiency = 0.97
- Transformer efficiency = 0.99
- Motor efficiency = 0.95
- Slip power from the rotor (est.), P4: Full Load x Slip % = 373 kW

**Basic Equations**

For the slip power recovery case above, the basic energy flow equations are:
- \( P1 = \text{Motor Power} - \text{Recovered Power} \)
- \( P2 = P3 + \text{Motor Losses} + \text{Rotor Power} \)
- \( P5 = P4 \times \text{Drive Efficiency} \times \text{Transformer Efficiency} \)

**Operating Conditions**

<table>
<thead>
<tr>
<th>Power Flow</th>
<th>Wound Rotor Motor (WRM) with Rheostat</th>
<th>WRM with Slip Power Recovery Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill Load at Full Speed, shaft kW</td>
<td>3730 kW (5,000 hp)</td>
<td>3730 kW (5,000 hp)</td>
</tr>
<tr>
<td>Mill load at 90% speed, shaft kW</td>
<td>3357 kW (assume linear)</td>
<td>3357 kW</td>
</tr>
<tr>
<td>Power flow from Slip Rings (est.)</td>
<td>373 kW (to rheostat)</td>
<td>373 kW (to SPR drive)</td>
</tr>
<tr>
<td>Power flow to motor (95) efficient</td>
<td>3906 kW</td>
<td>3906 kW</td>
</tr>
<tr>
<td>Slip power recovery after transformer</td>
<td>0 kW</td>
<td>358 kW</td>
</tr>
<tr>
<td>Utility supply power flow</td>
<td>3906 kW</td>
<td>3548 kW</td>
</tr>
</tbody>
</table>

**Difference in utility power used**

\( P1(\text{WRM}) - P1(\text{SPR}) = 358 \text{ kW} \)

**SPR System Annual Savings** with 7¢ electrical power $200,480 per year (8000 hours)
Project Engineering

General Industries Team

Experienced Drive Engineering Team
The drive engineering team’s experience in the mining industry was gained through years of working in mines with technicians and mechanical suppliers. This engineering background, coupled with state-of-the-art technology, enables TMEIC to consistently meet the very demanding requirements of the industry.

Experienced drive engineers jointly define the drive equipment and control strategy with your engineers and the OEM. This is followed by detailed design of the system, control logic, and configuration of the drives.

Local Commissioning Team Ensures Knowledgeable Ongoing Service
Our globally-based field organization has extensive experience in the industry providing you with a strong service presence for startup and ongoing service work.

Project Life Cycle Process Minimizes Risk

We understand that delay in your equipment commissioning is very expensive, so we take steps to hold our startup schedule. Our project engineering is based on the Project Life Cycle Process illustrated above and described in the following pages.

- Project management provides a single point of contact from initial order to final commissioning.
- Complete factory tests are conducted including applying power to the drive bridges and exercising the control system using motor and load simulators.
- The local commissioning engineers are included in the project team, allowing a seamless transition from the factory to your mine.
The Medium Voltage VFD System

TMEIC application engineers consider the system from the medium voltage switchgear to the adjustable speed drive and motor, sizing and selecting required equipment for the optimal drive solution. A typical MV VFD system is shown below.

**Instrumentation** for equipment metering, monitoring, protection and control is selected:
- Amp transducer and ammeter
- Watt and Watt-hr transducers
- Phase CTs and phase overcurrent relay
- Ground sensor CT and relay
- Power quality monitor

**Selection of optional drive associated equipment**
- Heat exchangers if required
- Air conditioned equipment house if required
- Switchgear if motor is to be synchronized with the line
- PLC for logic control
- Reactor for use with an LCI

**Selection of the motor**
- Induction, synchronous, wound rotor or dc motor
- Motor specs including power, torque, voltage, current, and speed
- Selection of exciter for sync motor
- Required motor protection devices
- Optional tachometer
- Optional Torsional analysis

**MV Switchgear** is selected for the application considering:
- The type, such as vacuum or SF6
- The size for the current and voltage
- The CTs, PTs, and protective relays to operate the breaker
- The enclosure for outdoor or indoor
- The environment, such as temperature and humidity

**Drive Isolation transformers, input and output**, are selected for the application considering:
- The type, such as dry or liquid filled
- Size for the kVA and voltage
- Cooling, if required
- The enclosure for outdoor or indoor
- The environment, such as temperature and humidity

**Selection of the best adjustable speed drive** for the application:
- Continuous and overload torque and power requirements
- Type of load, including constant or variable torque, regenerative
- Drive and motor voltage
- Power system compatibility
- Overall efficiency of the ASD and motor combination
- Harmonic analysis
During all phases of your project planning, TMEIC assists you by supplying information, training, guide-form specifications, and general advice. Experienced drive application engineers prepare a technical proposal that includes:

- Customized system architecture for your project.
- Detailed equipment specifications for the drives, motors, exciters, transformers, switchgear, and housings.
- Thorough description of the PLC and other control functions.
- Formal bid documentation.

Based on the proposal specification, the project engineering team proceeds with four main tasks:

- **Control Software Design.** Control engineers configure the drives and PLC controller logic, if a PLC is required for the application. The illustration shows a typical toolbox logic function diagram in Relay Ladder Diagram format. The software tool is used for drive configuration, tuning, sequencing, and drive diagnostics.

- **Optional HMI Screen Design.** Interface screens for maintenance and drive control can be configured. For example, the configurable keypad shown here provides real-time drive data and operator interaction.

- **Hardware Design.** All equipment is specified to meet the project requirements, and a complete set of elementary diagrams, layout, and outline drawings is created.

- **Component Procurement.** We work with our parent and partner suppliers to source the most cost effective system components for your application.
Understanding the importance of a thorough drive and system test, the TMEIC engineering team conducts factory tests before shipment. Drive tests in the factory typically include:

- Full voltage and current check of power cells, insulation, and control circuits.
- Acceleration and run test with unloaded motor.
- Full current test into a reactor (ac drives).
- Validation of all I/O interfaces.
- Validation of the drive test modes and any special logic, or optional PLC using motor and load simulator.

In the commissioning phase, the TMEIC team includes the field engineers you know and trust, alongside the engineer who designed and tested the system. This overlap of teams between engineering design and the site ensures a smooth and on-schedule startup.

The TMEIC service engineer, who is responsible for startup and commissioning, and for any future service required at the site, is part of the project team and participates in the factory system test to become familiar with the system. Commissioning is supported by TMEIC design and service engineers.

**Complete & Detailed System Documentation**

Along with the hardware and software, TMEIC delivers complete system documentation:

- An electronic instruction book with all the prints on CD with a hyperlink index;
- Recommended wiring and grounding procedures;
- Renewal parts list; and
- Standard third-party vendor documentation.
- Validation of the drive test modes and any special logic, or optional PLC using motor & load simulator.
Global Customer Support Network

Comprehensive technical service is provided by our Customer Support Organization, staffed by TMEIC service engineers with offices and spare parts depots across the globe.

In North and South America
Customers are supported by the TMEIC Corporation service personnel, design engineers and Spare Parts Depot in Virginia, and the TMEIC Factory in Japan.

In Europe
TMEIC service engineers service all drive systems in Europe, supported by the European TMEIC Spare Parts Depot.

In Asia and the Pacific Rim
TMEIC services drive systems throughout China, India and the Pacific Rim, supported by multiple Field Engineers, Spare Parts Depots, and the TMEIC factory in Japan.

Remote Drive Diagnostics
TMEIC supports drive customers through the Remote Connectivity Module (RCM), a remote diagnostic service link with the TMEIC design and service engineers in Roanoke, Virginia. The RCM enables seamless integration between your drives and our engineers.

Remote System Diagnostics
TMEIC’s remote system diagnostics tool, included in level 1 software, offers a quick path to problem resolution. System faults are automatically identified, and provide an integrated view of product, process and system information. TMEIC design and service engineers in Roanoke, Virginia, can analyze the data and provide steps for resolution.

Drive Training at our Training Center or in Your Facility

Customer engineers, maintenance and operations personnel are trained on the drives and control system at the TMEIC Training Center in Virginia. This world-class facility features large classrooms and fully-equipped training labs.

Classroom and hands-on training consists of 50% class time and 50% hands-on lab time. Topics include:

- Overview of the drive system
- Function of the main assemblies
- Technical details of the components
- Drive and control system tools
- System diagnostics and service

As an alternative to the standard factory training in Virginia, TMEIC can offer a course tailored to your project and held at your location. In this case, a project engineer trains your operators, maintenance technicians and engineers in your facility.
A Family of Drives up to 11 kV

TMEIC’s Family of AC and DC System Drives

Over 50 years of Drive Experience. Starting with dc drives, we later introduced ac drives, such as the new technology Tosvert, Dura-Bilt 5i MV, and TMdrives. Since 1979 over 2 million hp of TMEIC ac drives have been installed and are in service, representing the largest installed base of MV drives of any manufacturer.

AC drive Voltages up to 11 kV. The family of ac drives offers voltages from 380 V with the TMdrive-10 up to 11 kV with the TMdrive-MVG. The dc drive family covers 230 to 1200 vdc

Significant Investment in Drive Technology. TMEIC’s Dura-Bilt and TMdrive products represent a large investment in LV and MV drive technology, including development of semiconductor devices such as the IEGT and GCT.

The Highest Reliability. TMEIC drives provide the highest reliability based on field experience and customer satisfaction survey results.

Configuration Software. The TMdrive Navigator world-class configuration software is used on all TMEIC drives. Live block diagrams and tune-up wizards streamline commissioning and maintenance activities.

Spare Parts Stock. TMEIC’s parts depots stock the line of LV and MV drive parts to provide rapid delivery to your facility anywhere in the world.
The TMdrive-10 family of low voltage ac system drives has an integral dc bus structure with a wide variety of inverters (dc to ac) and converters (ac to dc) to match diverse needs. There are four voltage levels – 440, 460, 575, and 690 V ac.

Converter power level ranges are:
- Non-regenerative, 150 kW – 3600 kW
- Regenerative, 100 kW – 1417 kW

Inverter power level ranges are:
- With dc disconnects, 3.1 kW – 1182 kW
- Without dc disconnects, 141 kW – 1454 kW

Draw-out Inverter trays stack eight to a 32-inch wide cabinet. The power level ranges are:
- Single high trays, 3.1 kW – 63 kW
- Double high trays, 101 kW – 106 kW

Inverter power bridges use Insulated Gate Bipolar Transistors (IGBT). The type of modulation is two-level voltage using pulse width modulation (PWM).

### TMdrive®-10SPR Slip Power Recovery for Wound Rotor Motors

The Slip Power Recovery (SPR) version of the TMdrive-10 provides speed control of a wound rotor motor and efficient recovery of slip power from the rotor. This is discussed in Application 4 on page 10. Features of the SPR include:
- Significant energy savings and low cost of ownership
- The highest efficiency adjustable speed drive
- Pulse width modulated converter
- Reliability
- High power factor operation
- High MV Motor: for wound rotor motors, from pulse width modulated converter 1,000 – 10,000 hp

**Speed Range:** depends on rotor voltage; super synchronous speed operation is available

**I/O, LAN Interface, & Cabinet Size:** same as TMdrive-10.

**SPR Operation**
The TMdrive-10SPR takes power out of the rotor to reduce the motor speed. At reduced speeds, power flows out of the rotor through the SPR to the transformer and back into the supply, instead of being dissipated in the rheostat.

The SPR is the highest efficiency VFD because only a fraction of the motor power goes through the drive. During startup the rheostat is connected to the rotor and the SPR is disconnected. Once up to minimum speed, the SPR drive is connected and the rheostat disconnected. The motor speed is then controlled by the SPR.

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The Dura-Bilt5i MV delivers simple operation in a robust and compact design, providing a cost effective solution for a broad range of medium voltage applications.

The Dura-Bilt5i MV delivers value through low cost of ownership and high reliability. Dual drive configurations are possible; power levels available include:

- **2000 Series** – 2,300 Volts Out, 200 to 3,000 hp
- **3000 Series** – 3,300 Volts Out, 300 to 4,000 hp
- **4000 Series** – 4,160 Volts Out, 400 to 10,000 hp
- **4000 MTX Series** - 4160 Volts Out, NEMA 3R Outdoor enclosure for 0 to 50° C ambient

Rugged design features for high reliability include:

- Inverter heat pipe cooling for largest size
- Diode rectifier converter with 24-pulse circuit for low input current distortion
- Neutral point clamped pulse width modulated inverter using medium voltage IGBTs

**Cabinet Size:**
- 900 hp drive is 74 in. (1,880 mm) long
- 6,000 hp drive is 222 in. (5,639 mm) long
- Cabinet height is 104 in. (2,642 mm)

**Integral Transformer:** Copper wound transformer with electrostatic shield, rated for 115° C rise.

**DC Bus Capacitors:** Bus capacitors are oil-filled for long life.

**Synchronization:** Closed transfer synchronizing control.

**Access:** Roll out inverter phase leg assemblies.

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**Features**

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium voltage IGBTs</td>
<td>Rock-solid reliability</td>
</tr>
<tr>
<td>Each inverter uses 3,300 Volt Insulated Gate Bipolar Transistors (IGBTs).</td>
<td>High power IGBTs allow a simpler, more reliable inverter design with fewer power switches.</td>
</tr>
<tr>
<td>24-pulse converter</td>
<td>Power system friendly</td>
</tr>
<tr>
<td>Each phase leg of the converter includes a 24-pulse diode rectifier.</td>
<td>The converter produces less Total Harmonic Distortion (THD) than the IEEE 519-1992 specification, without requiring filters.</td>
</tr>
<tr>
<td>Heat pipe cooling technology</td>
<td>Compact Quiet Design</td>
</tr>
<tr>
<td>Each of the three inverter legs use heat pipe cooling for the IGBTs.</td>
<td>The heat pipe cooling system maintains good semi-conductor working temperature, reduces fan noise, and saves valuable floor space in your plant.</td>
</tr>
<tr>
<td>Windows-Based configuration and maintenance tool</td>
<td>Faster commissioning and maintenance</td>
</tr>
<tr>
<td>• Animated block diagrams</td>
<td>This world-class software tool improves productivity in commissioning and maintenance and can be used on all TMEiC drive products.</td>
</tr>
<tr>
<td>• Drive tune up wizards</td>
<td></td>
</tr>
<tr>
<td>• Integrated trend window</td>
<td></td>
</tr>
</tbody>
</table>
The TMdrive-MVG is a medium voltage, ac fed drive designed for high efficiency and motor-friendly operation in a broad range of industrial applications.

High reliability, low harmonic distortion, and high power factor operation are designed into the MV drive. Modular drawable cell inverters minimize the time required for any maintenance activities.

The TMdrive-MVG is available in these voltage classes:
- **3.3 kV Voltage class**: 3,000 – 3,300 V ac
- **6.6 kV Voltage class**: 6,000 – 6,600 V ac
- **10.0 kV Voltage class**: 10,000 V ac
- **11.0 kV Voltage class**: 11,000 V ac

Five Cabinet Sizes are available for each class, some examples:
- **3.3 kV**: 200-400 kVA, 83 in wide, 106 in. high, 36 in. deep
  - 2400-3000 kVA, 182 in wide, 114 in. high, 52 in. deep
- **6.6 kV**: 400-800 kVA, 126 in wide, 106 in. high, 36 in. deep
  - 4800-6000 kVA, 248 in wide, 114 in. high, 56 in. deep

### Features

**A clean wave input converter**

Using the multiple winding input transformer, the TMdrive-MVG has a multi-pulse rectification and more than meets the requirements of IEEE-519 (1992). This reduces the harmonic voltage distortion on the power source and protects the other equipment in the plant.

**A clean output wave**

As a result of the multilevel PWM control, the output waveform is close to a sine wave, and the heat loss caused by harmonics is negligible. In addition, harmonic currents in the motor are minimized so there is negligible torque ripple on the output shaft and very little risk of torsional load resonance.

**A higher efficiency than conventional drives**

Actual factory load tests show the drive efficiency is approximately 97% (design efficiency is approximately 97% design value). This high efficiency is a result of:

- Lowest number of switching semiconductors by using 1700 V IGBTs.
- Lower switching frequencies using multilevel PWM control reduce the switching loss of each IGBT.
- Direct connection of 6 kV motor without an output transformer.
The TMdrive-30 is a medium voltage, dc-fed system drive for high power applications. The drive is available in two voltage levels – 1100 V and 1250 V ac.

Benefits of the TMdrive-30 include:
- Non-regenerative, 3300 kW
- Regenerative (Thyristor), 3300 – 6000 kW
- Regenerative (IGBT), 1733 – 3465 kW

Converter power level ranges are:
- IGBT, 2000 – 4000 kVA

Inverter power level ranges:
- Common dc bus circulates motoring and regen power on the drive dc bus for optimum use of conversion equipment and power factor control.
- TMdrive-30’s ruggedized design enables application in demanding environments like draglines and is suited for cyclic loads.
- Rack out power modules facilitate fast inspection and maintenance.
The TMdrive-50 is designed for high-power applications
High-power, precision-controlled processes are ideally suited for the TMdrive-50 with its efficient high current IGBT power devices and control cards common to the drive family. Flexible arrangement of converter, inverter and cooling units allows for maximum power density, resulting in minimum floor space and installation cost.

3,000 – 6,000 Frame: 3,300 Volts out, motor power 2,000 – 6,000 hp

Cabinet Size: 79 inches (2,000 mm) long, 94 inches (2388 mm) high.

Design features for high reliability:
- Water cooling technology for the power bridge reduces footprint
- Medium Voltage Insulated Gate Bipolar Transistor (IGBT) provides power at unity power factor and low harmonics
- Modular Design for power bridges minimizes maintenance time
- Control signal is voltage, not current. IGBT requires very low power to switch.
- High switching speeds less than 2 μ second - low switching losses and accurate control
- Simple switching circuitry - gate driver hardware is compact.

The TMdrive-70 is designed for high-power applications
High reliability, design simplicity and high efficiency, the TMdrive-70 is perfect for compressor, fan and pumping applications. It provides accurate speed control and high efficiency while eliminating the need for high maintenance mechanical flow control devices.

Design features for high reliability:
- Water cooled, draw-out phase leg assemblies with quick disconnect fittings reduce drive footprint
- Converter and inverter use medium voltage IEGT power semiconductors with high-speed switching to provide near unity power factor to the load
- Regenerative IEGT converter available
- Pulse Width Modulation using fixed pulse pattern control reduces switching losses
- Modular design - power bridge assemblies are draw-out modules. Quick disconnects minimize maintenance time.
- Motor and power-system friendly - high speed switching (500 Hz) coupled with the three-level bridge design delivers a smooth sine wave to the motor and power system.

<table>
<thead>
<tr>
<th>Frame Size</th>
<th>Volts Out</th>
<th>Motor Power (hp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000</td>
<td>3,300</td>
<td>5,000-10,000</td>
</tr>
<tr>
<td>10,000</td>
<td>3,300</td>
<td>13,000</td>
</tr>
<tr>
<td>20,000</td>
<td>3,300</td>
<td>26,000</td>
</tr>
<tr>
<td>40,000</td>
<td>3,300</td>
<td>52,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frame Size</th>
<th>Cabinet Length (mm)</th>
<th>Cabinet Height inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000 - 10,000</td>
<td>126 (3,200)</td>
<td>94 (2,388)</td>
</tr>
<tr>
<td>20,000</td>
<td>220 (5,600)</td>
<td>94 (2,388)</td>
</tr>
<tr>
<td>40,000, plus a second cabinet</td>
<td>252 (6,400)</td>
<td>94 (2,388)</td>
</tr>
<tr>
<td></td>
<td>189 (4,800)</td>
<td>94 (2,388)</td>
</tr>
</tbody>
</table>

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Medium Voltage Motor and Drives Systems School

TMEIC is pleased to offer its tuition-free MV Motor and Drives Systems School to its customers. These schools are offered regularly in Roanoke, Virginia, and other cities.

Course Topics:

- Medium Voltage (MV) induction and synchronous motors
- Fundamentals of variable frequency drives
- MV drive characteristics, payback, and specifications
- MV power systems design concepts
- MV switchgear, starters, transformers, reactors, and substations
- MV system protection
- Real-world industrial application stories from the mining, cement, oil & gas, petrochemical and water & waste water industries
- Equipment demonstrations

For details and registration for our next school, please visit our Web site at www.tmeic.com.

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