

M2L 3000 Series

Medium Voltage Variable Frequency Drive

4.16 kV Class

300 to 3,000 HP

Patent-pending technology enabling extended separation
of converter and inverter sections

Introducing M2L Series

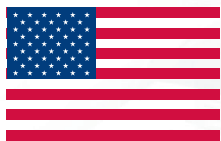
Medium Voltage Variable Frequency Drive

Rugged. Reliable. Ready.

With over 20 years of medium voltage motor controls experience, Benshaw has introduced a new family of medium voltage drives. Our medium voltage drive features a unique technology that allows Benshaw to offer a simple, compact and reliable drive solution. Our innovative topology, coupled with an advanced control architecture, will enable customers to transform the way they do business. Our objective was to not only have one of the best drives in the industry, but to also provide a drive that creates profound value for our customers. The objectives were not only met, but were exceeded with the introduction of our medium voltage variable frequency drive.



The drive design is the result of a collaborative effort between two business units—Benshaw, with a long history of industrial motor control solutions, and APSD, with expertise in power electronics and electromechanical systems.



Developed, designed, and manufactured in the USA. Supported around the globe.



Contents

Key Features

Compact Modular Design

Simplistic component arrangement with minimal total part count

Installation Flexibility

Optimal for retrofits

Arc Resistant

Safety by design—arc flash footprint inherently lower

Energy Efficiency

Inverter efficiency $\geq 99.5\%$

Robust Control Architecture

High performance, reliability and immunity from EMI, through noise tolerant signaling and fiber optic communications

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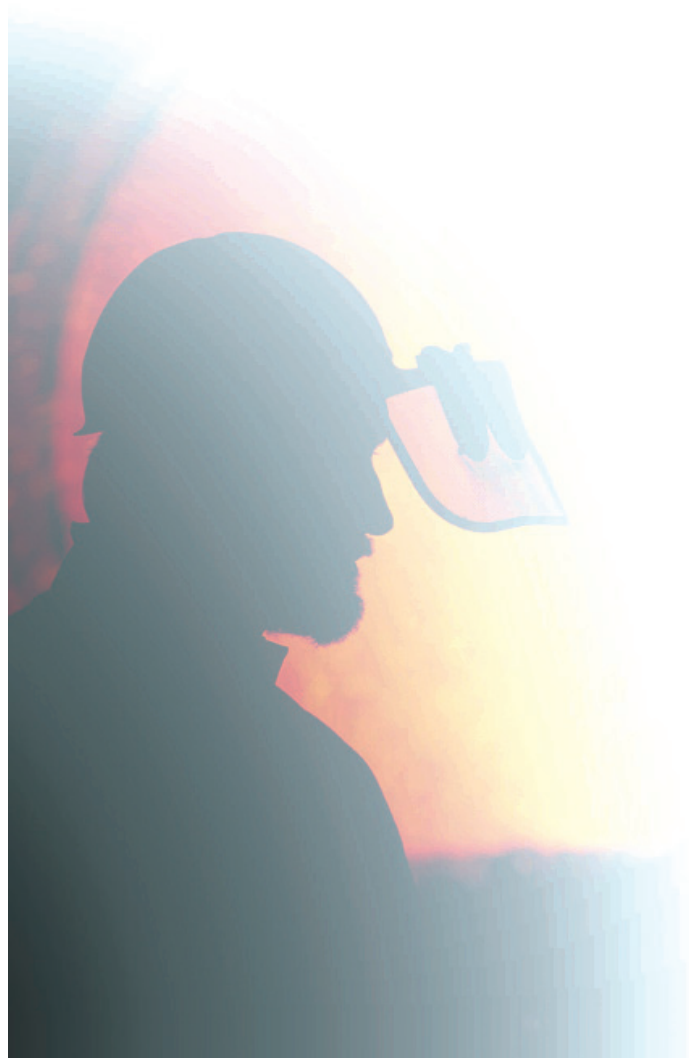
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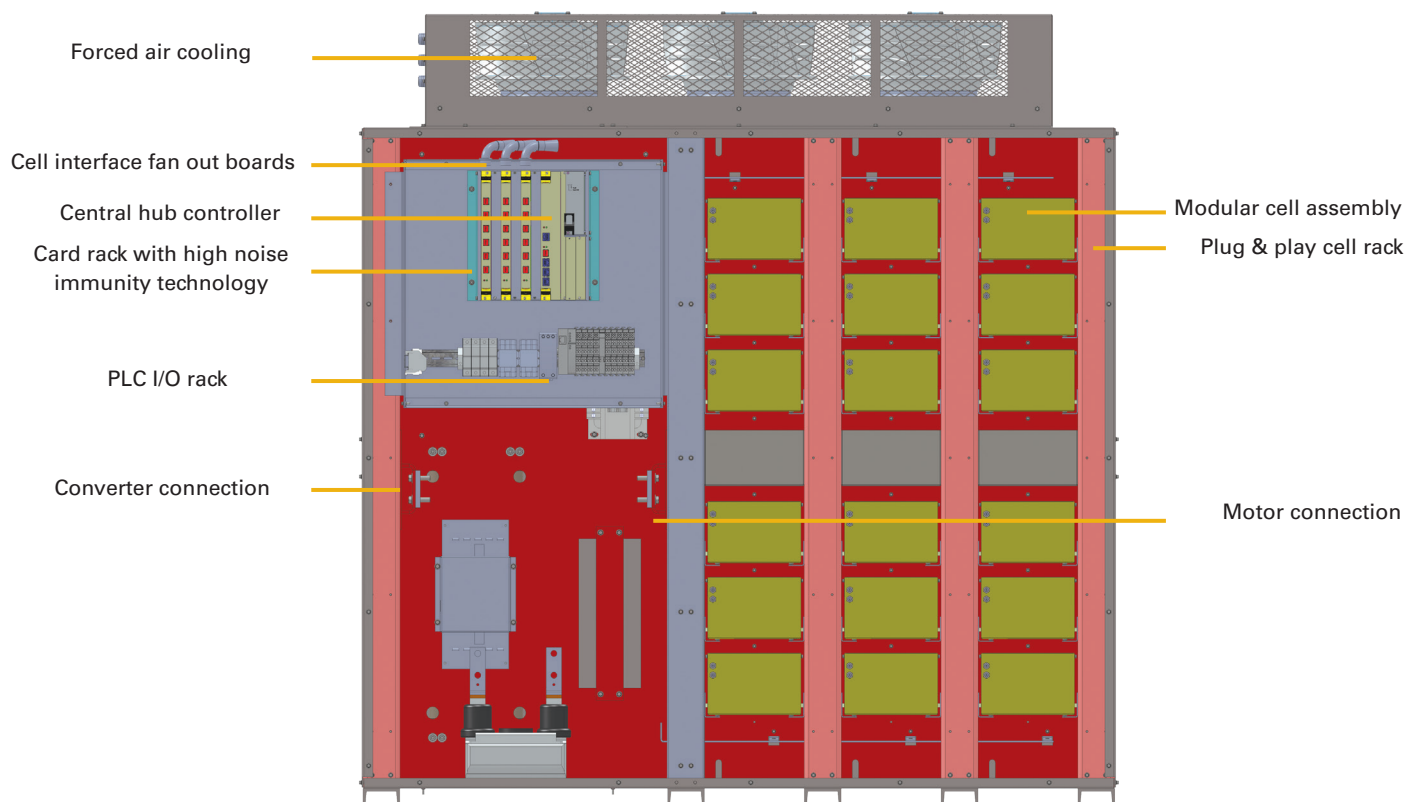


Features & Benefits

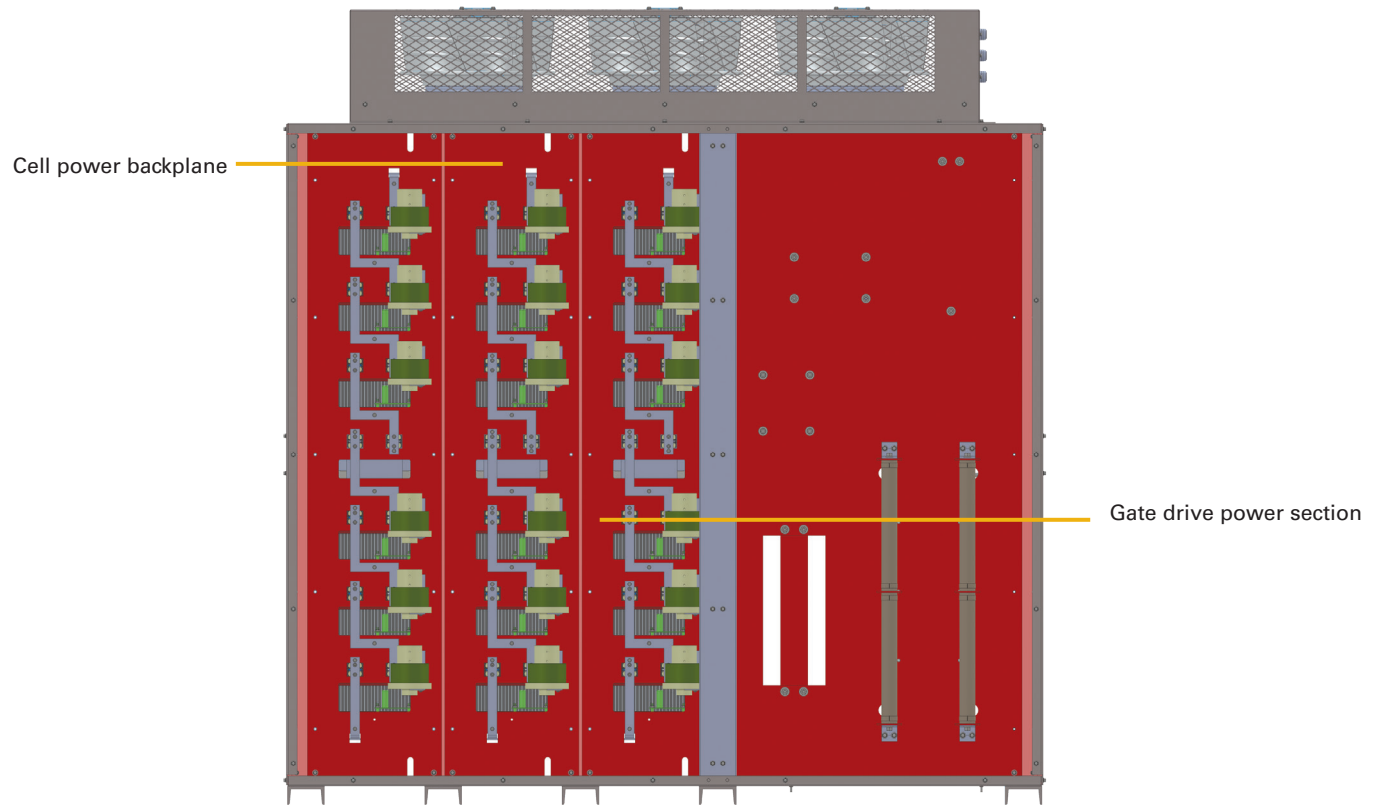
Compact Modular Design

- Simplistic component arrangement with minimal total part count, compared to competitive offerings
- Unique modular power inverter
 - Voltage requirements met by configuring standard IGBT cells
 - Self-healing film capacitors that do not need reforming and are superior to common electrolytics
 - Field maintenance and repair using pre-assembled, pre-tested power cells
 - Internal communication through high-speed fiber optics using Ethernet protocol for high noise immunity and high bandwidth

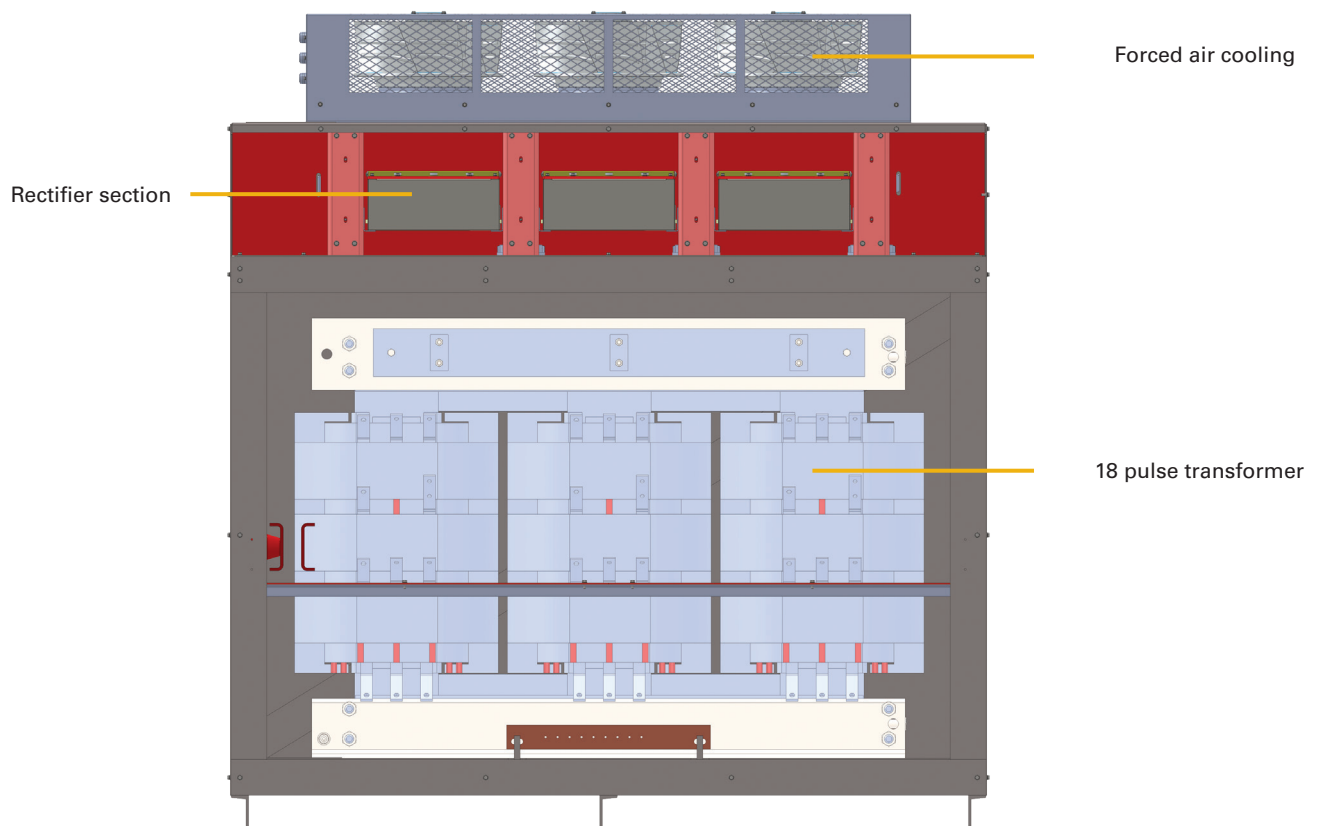
Typical 1,000 HP / 4,160 Vac output Inverter front



Inverter rear



Converter front

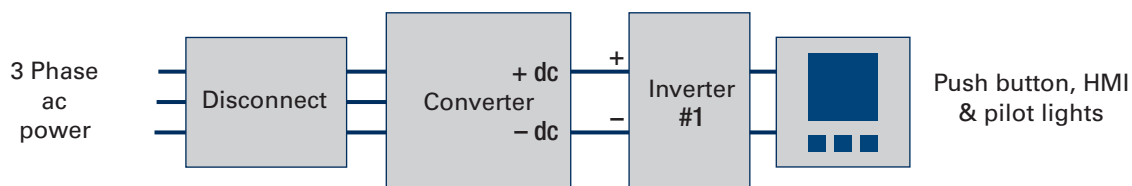


Features & Benefits

Installation Flexibility

- Patent-pending topology enabling extended separation of converter and inverter sections
- Uses a standard input transformer in the converter that can accommodate a wide range of input voltages (480V–13.8 kV)
- Interconnection using standard high-voltage cable (no limits on length)
- Reduced heat load and space requirements in environmentally conditioned equipment rooms — remotely located converter
- Customer sourcing of the transformer (per Benshaw's specification)
- Operation directly from customer's dc bus (per Benshaw's specification)
- Remote mounted HMI and optional controls

Installation Flexibility

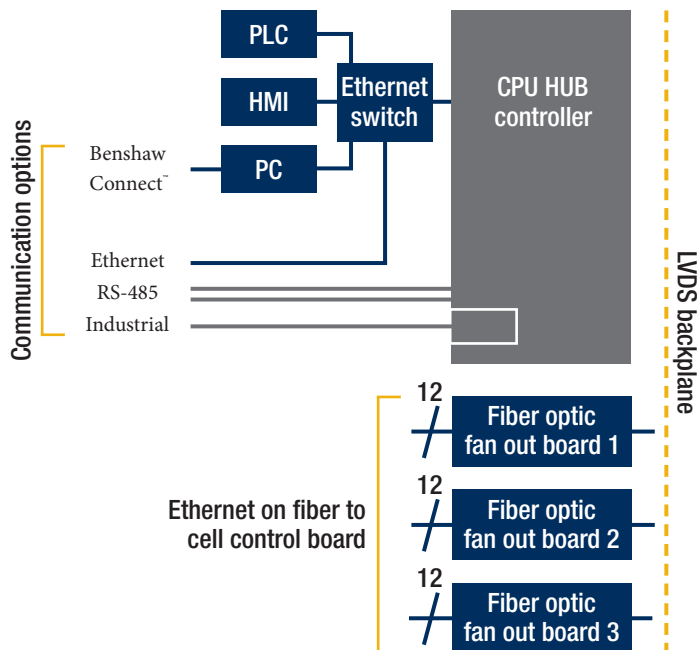


Robust Control Architecture

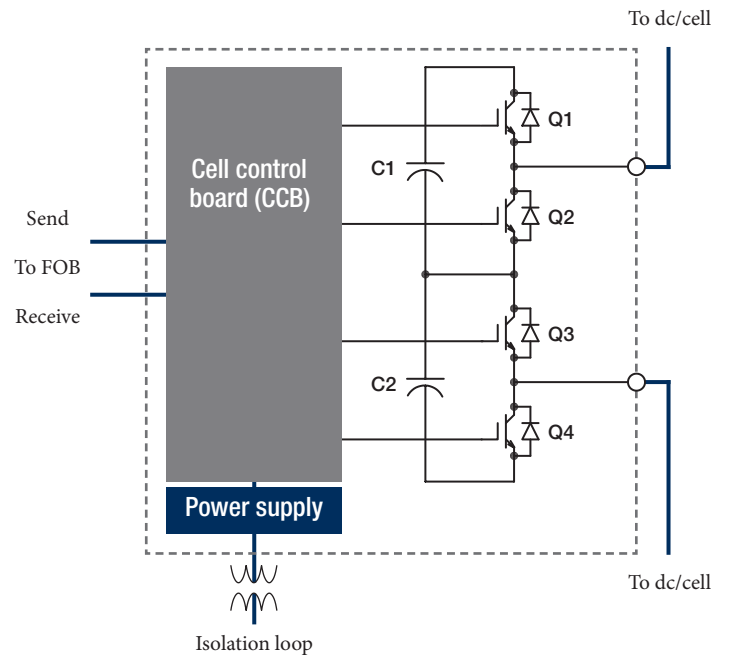
Modern control platform

- Distributed control with intelligent power cells
- Ultra-fast CPU core for high-speed processing and expansion capability
- Industry-standard card cage
 - Front access for easy removal and replacement
 - Low Voltage Differential Signaling backplane—EMI resistant
- Standard PLC I/O
 - User I/O modules for every application possibility
 - Industrial process control using ladder logic
- Industry-standard field buses and communication protocols
 - Profibus DP, Modbus TCP/IP, embedded web server, Ethernet IP, DeviceNet
- Benshaw Connect™ for monitoring, parameter setting and data logging at the drive or over the internet
- Wireless connectivity available for safe and secure communication

Card Rack



Cell Circuit Configuration



Features & Benefits

Arc Flash Resistant—Safety by Design

- Arc flash footprint inherently lower
 - Utilizes distributed energy storage
 - No centralized bulk storage capacitors
 - Optical arc flash detection in each power cell to instantaneously de-energize the drive
 - Offending cell is immediately reported to the control system
- Fault currents greatly reduced compared to other VFDs
 - Converter will not feed energy into faults
- Increased user safety work envelope
 - Remote control via Bluetooth® connection, or serial communication, using HMI, PC or intelligent handheld device
- Motorized disconnect switch (option) with remote control

Secured gateway ready to facilitate wireless / internet connection

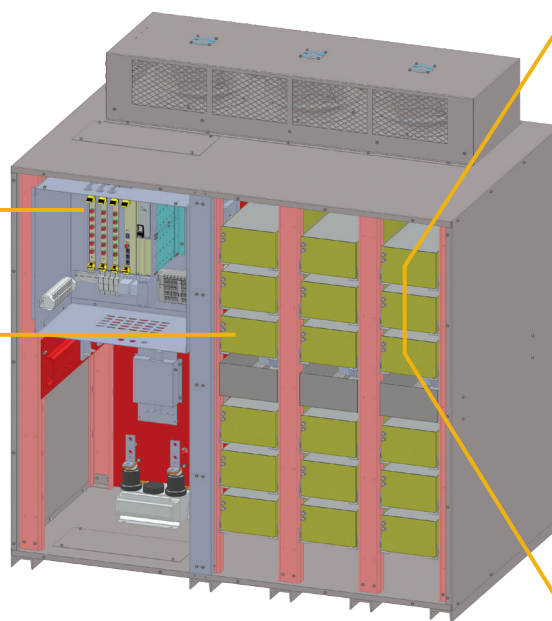


Cell arc flash detection

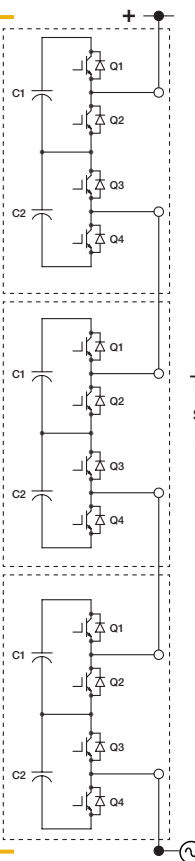


Remote monitoring and control

Safety by Design



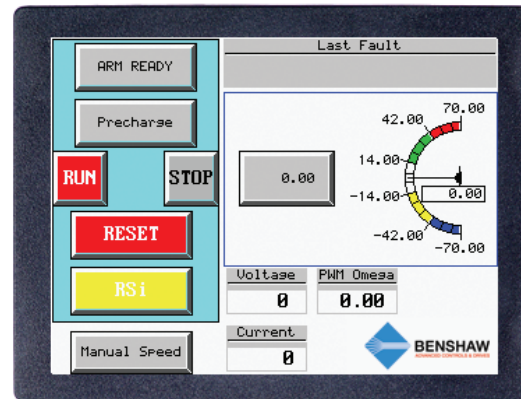
Upper leg cell configuration



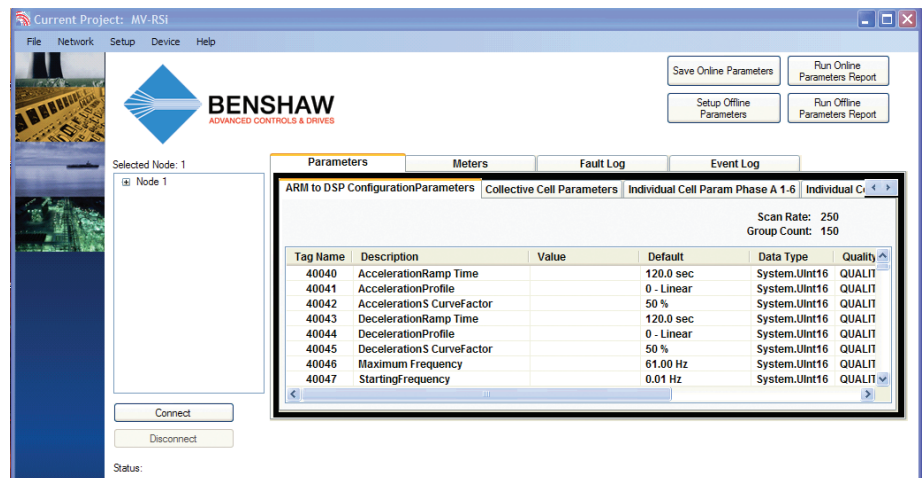
Topology supports cell fault isolation

User Interface

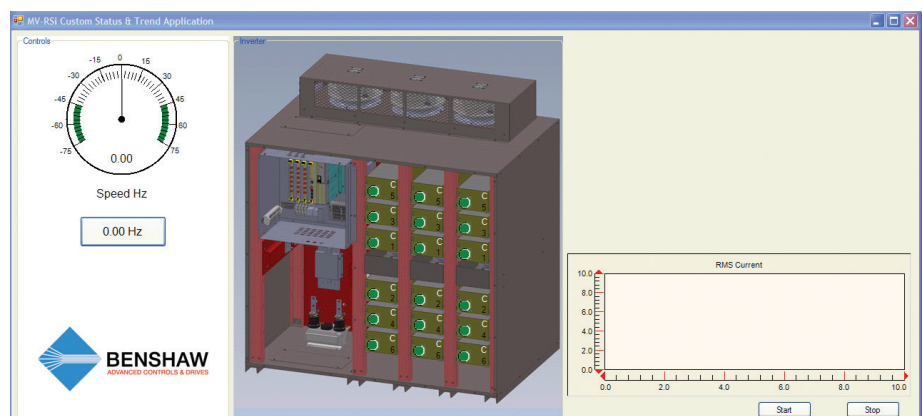
- Intuitive, user-friendly TCP/IP touch screen easily customizable for specific process control use
- No need to remember multi-use key assignments used on other low-end digital operators



- Benschaw Connect™ Tool Suite
 - Applications allow for seamless connectivity between a PC and the drive
 - Easy to use configuration and diagnostics tool
 - Windows-based tool for use on XP and Windows 7



- Custom managed applications for process control, diagnostics and trending



Features & Benefits

Energy Efficiency

- Unique modular inverter design has improved efficiency over Cascaded H-Bridge and Neutral Point Clamped (NPC) inverter designs
- Uses the latest in efficient IGBT designs for minimum losses and maximum performance
- Inverter efficiency $\geq 99.5\%$ over a wide speed range and wide load range
- The modular inverter design allows the input converter to operate more efficiently than other inverter designs reducing losses
- No efficiency reducing output transformers or output filters are required
- Input power supply power factor of ≥ 0.95 minimizes losses in the power supply and input wiring

Full Load Efficiency	Benshaw	Others
Inverter	99.5%	99%
Input Converter and Transformer	98%	97–98%
Total Efficiency	98%	96–97%

Energy Savings

- Shaft power of motor driven equipment (fans, pumps, blowers) is proportional to the cube of the rotational speed
- By design, variable frequency drives (VFDs) improve efficiency at a low speed
- Considerable energy savings can be achieved by outfitting motors with VFDs; the speed can then be adjusted to match the required load

Energy Saving Formulas

Power Consumption with Damper Control

$$P_d (\text{kW}) = \frac{P_0}{\eta_{f0} \eta_{m0}}$$

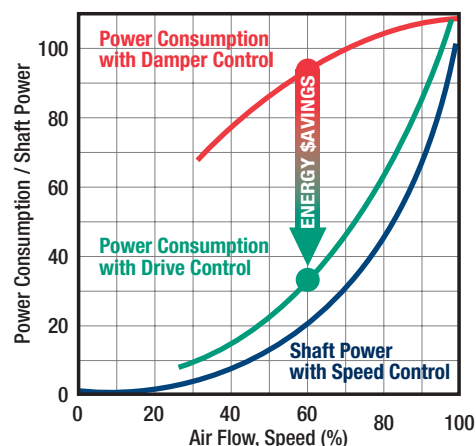
P_0 : Motor rated power
 η_{f0} : Fan rated efficiency
 η_{m0} : Motor rated efficiency

Power Consumption with Drive Control

$$P_i (\text{kW}) = \frac{\left(\frac{Q}{Q_0}\right)^3}{\eta_f \eta_m \eta_i} P_0$$

Q/Q_0 : Ratio of air flow to fan rating
 P_0 : Motor rated power
 η_f : Fan efficiency
 η_m : Motor efficiency
 η_i : Drive efficiency

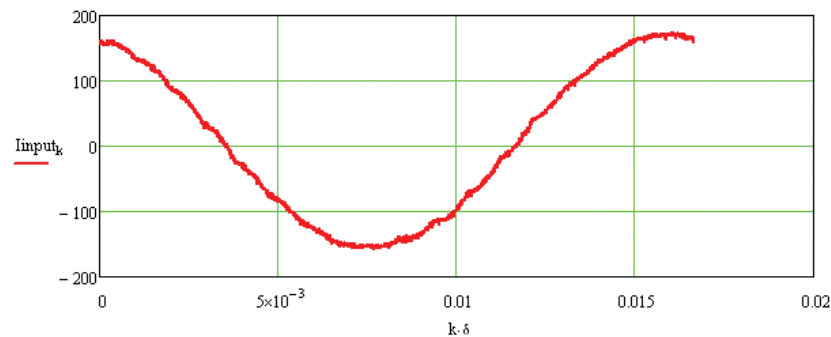
Power Consumption Curve



Minimized Harmonics

Converter Input

Input Current Waveform



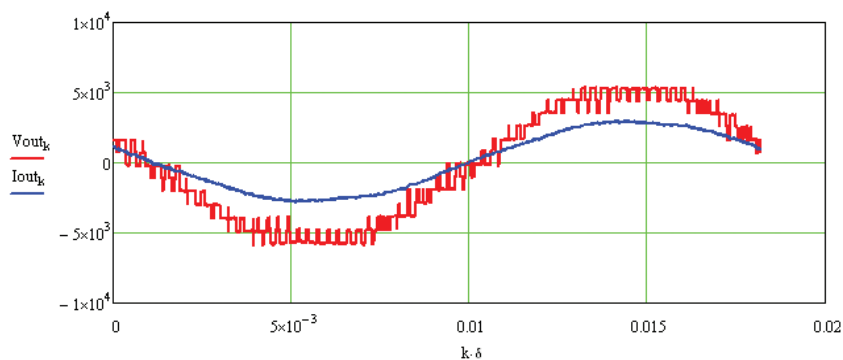
Typical Input Current Harmonics (at full load)

	5th	7th	11th	13th	17th	19th	23rd	25th	THD
Benshaw	0.78%	0.33%	0.085%	0.19%	1.45%	1.1%	0.14%	0.089%	2.28%
IEEE-519	4%	4%	2%	2%	1.5%	1.5%	0.6%	0.6%	5%

The near sinusoidal input current with minimal harmonics easily meets IEEE-519 recommended standards without the need for any extra input filters or harmonic compensation. This minimizes installation and site issues.

Output Waveform

Line-to-Line Voltage Output



- Multiple PWM output levels provide a near sinusoidal output
- Multiple PWM output levels reduce output voltage dv/dt over other MV inverter designs and are similar to low voltage variable frequency drive levels
- Minimal output voltage and current harmonic distortion maximizes motor efficiency
- Clean output makes it possible to use existing motors and cables without the need for extra output filters or other additional components

Protective Functions

Motor and Drive Protections

DC Bus Overvoltage	Detects an overvoltage condition on the DC bus
DC Bus Undervoltage	Detects an undervoltage condition on the DC bus
Output Phase Loss	Detects an open phase on the drive output
Drive Thermal Overload	Drive overload protects the drive hardware from overheating
Motor Overcurrent	During normal operation can protect against a motor overcurrent condition
Motor Thermal Overload	User adjustable electronic motor overload with speed and cooling type compensation
Motor Undercurrent	During normal operation can protect against a loss of load
Ground Fault	Trips drive when a ground fault condition in the motor or motor cables is detected
Drive Output Short Circuit Protection	Protects drive against short on the drive's output
Transformer Overtemperature	Trips drive when a transformer overtemperature condition is detected
Control Card Fault	Occurs when a problem with the control hardware is detected

Power Cell Protections

Cell Overcurrent	Detects a current level inside the cell above the cell specified overcurrent level
Cell Overvoltage	Detects an overvoltage condition on one of the cell's capacitors
IGBT Overtemperature	Detects an overtemperature condition of a cell's IGBT
IGBT Switching Fault	Detects incorrect switching of a cell's IGBTs
Cell Parameter Initialization Error	Indicates that initialization parameters for a cell were not valid
Cell Initialization Offset Error	Indicates that the initialization check for current sensing circuitry did not pass
Cell Arc Flash Detected	Indicates that an arc flash condition with detected within the cell enclosure
Cell Power Supply Fault	Indicates that one of the cell's power supply voltages is out of range
Cell Communication Fault	Indicates that communications with the cell have been disrupted

NOTE: Not all functions are listed.

Software Features

Software Features

Start and Stop Functions

Speed Search Starting	Catches a spinning motor and brings it to the commanded frequency
Brake then Start	Applies high slip / dc brake before starting motor
Controlled Fault Stop	If enabled and selected faults occur, allows drive to complete deceleration or braking before shutting down, reduces instances of water hammer, etc.

Speed Functions

Multiple Acceleration and Deceleration Profiles	Linear, S- Curve and U-curve
Optimal Deceleration	Allows the motor to slow down at the maximum rate without excessive regeneration and resultant bus overvoltage trips
Skip Frequencies	Three user-selectable frequencies that can be used to avoid machine resonance problems by preventing continuous operation at these speeds
Dwell Frequency	During acceleration and/or deceleration holds a specific frequency to allow process specific actions to occur (such as opening valves, etc.)
Maximum Frequency Limit	Sets the maximum frequency that the drive will output to prevent potential motor overspeed situations

Motor Control Functions

Sensorless Vector Control	Implements a sensorless vector control algorithm for optimal motor control
Volts-to-Hertz Control	Provides V/Hz control for situations that require V/Hz control
Slip Compensation	When in V/Hz mode provides compensation of slip to provide desired motor shaft speed
Multiple Flux Profiles	Provides linear flux, squared flux and user-defined flux profile
Automatic and Manual Torque Boost	Provides low frequency torque boost in selected control modes
Motor Autotuning Function	Using user-provided motor nameplate data and detected motor parameters, the drive calculates the motor information needed for the sensorless vector control algorithm

Metering Functions

Extensive Metering Functions	Display applied motor voltage, phase currents, motor power factor, output power, dc link voltage, IGBT temperatures
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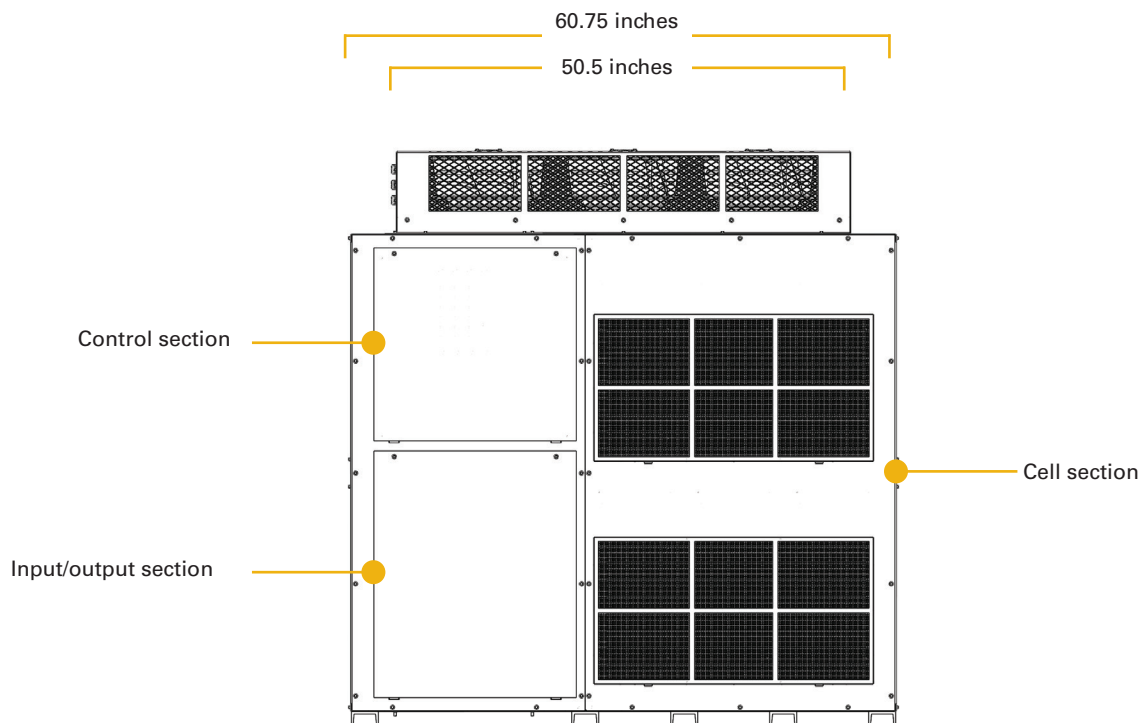
Logging Functions

Fault Log	Logs faults, time and date, and a snapshot of meter data at the time of a fault condition to provide fault resolution
Event Log	Logs event, time and date of drive events (such as starts and stops)

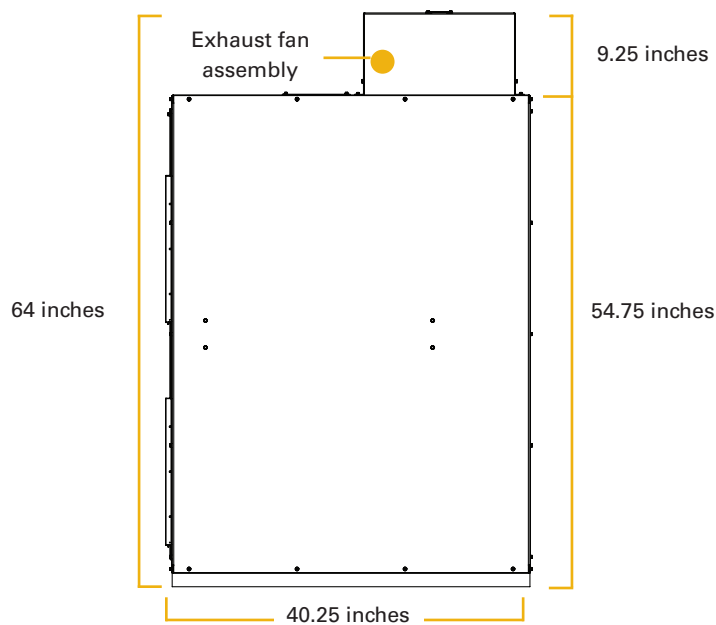
NOTE: Not all functions are listed.

Dimensions

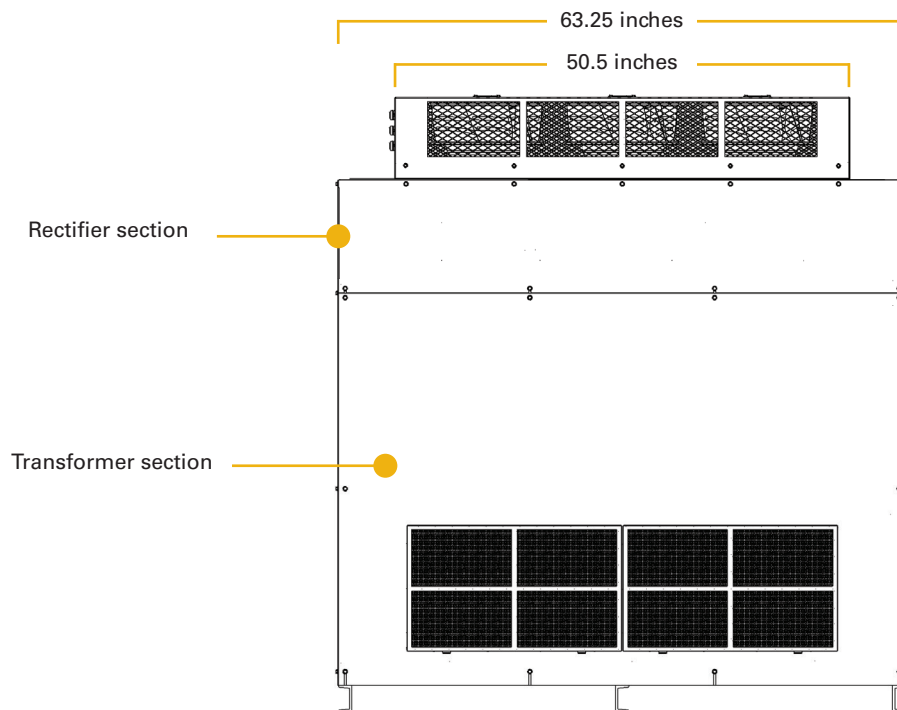
1,000 HP / 4,160 Vac Inverter front/rear



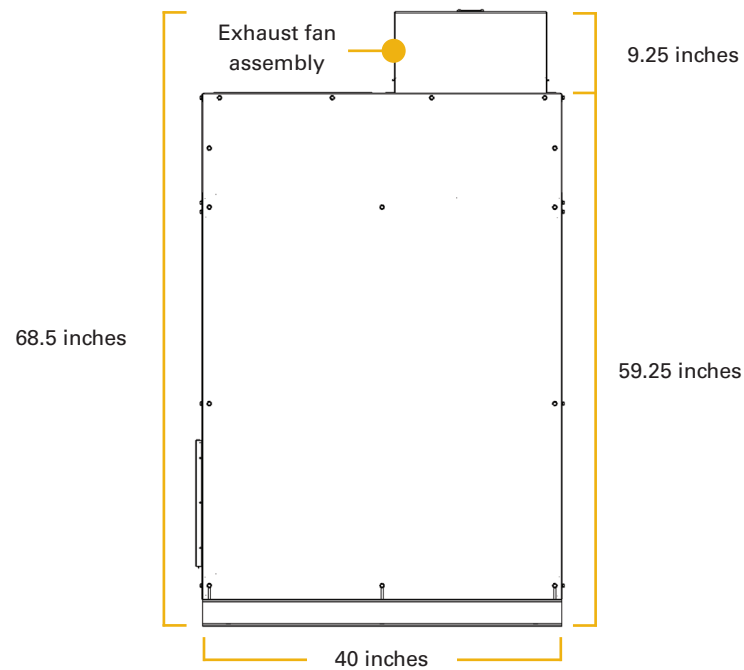
Inverter side



Converter front/rear



Converter side





Specifications

Typical for 1,000 HP

Electrical

Inverter Output—Variable Torque

Rated output power	kW: 746
Output voltage	V: 0–4160
Output frequency min/max	Hz: 0–180
Required auxiliary supply	AC: 208 / 240 V, 50 Hz / 60 Hz, 30 A
Rated output current	A: 0–140 at 60 Hz 0–133 at 120 Hz

Converter Input

Rated supply voltage	V: 480-13.8 kV
Rated system frequency	Hz: 45 – 66
Input distortion	IEEE 519
Rated input current at 4.2 kV	A: 144
Voltage variations	Steady state: $\pm 10\%$ Transient state: +10%, -30% for 30 line cycles
Frequency variations	Steady state: 95–105% Transient state: $\pm 5\%$ / sec.

Environmental Conditions

Ambient temperature	°C: Min. 0 (no frost), Max. 50
Humidity	%: 95, no dripping water, no condensation
Air quality	No corrosive gases
Pollution	IEC 61010-1 and UL 840 Degree 2 IEC 60664-3 (Optional)
Vibration	MIL-STD-810F for 2.5 hours
Seismic	IBC-2006 (3G on stiff soil)
Altitude	meters: 1,000 4,000 derated operation

Cooling System

Cooling method	Inverter/Converter	Forced air
Heat loss at full load	Inverter	kW: 3.7
(max)	Converter	kW: 15

Construction

Power connection entry		Bottom or top
Power connection type	Inverter	Cables
	Converter	Cables
Dimensions	Inverter	height x width x depth
	Converter	
Minimum clearance required:	front x back x side x above	in: 36 x 0 x 0 x 36
Total weight	Inverter	lb: 1,452
	Converter	lb: 6,200
Auxiliary cables entry		Bottom or top
Lifting of cabinets		Channel slots (cabinet bottom)

M2L Series Medium Voltage VFD—Application Checklist

Your name	Date
Customer's name	Quote due date
Project name	Project location
Type of customer: <input type="checkbox"/> OEM <input type="checkbox"/> Distributor <input type="checkbox"/> End User	Project Status: <input type="checkbox"/> Budgetary <input type="checkbox"/> Funded
Est. purchase date	Est. installation / commissioning date
User's country	Competitor(s)
Your ref. no.	Attached documents
Existing Benshaw customer: <input type="checkbox"/> Yes <input type="checkbox"/> No	Quantity of identical drives

Item	Specifications					
1. Name of facility or application						
2. Type of application	Pump	Fan	Blower	Compressor	Extruder	Other
3. Load characteristics	Variable torque	Constant torque	Proportional torque	Constant HP	Motor inertia _____ lb/ft ²	
4. Operating conditions	Annual operating time _____ hours		Actual motor current (If existing motor) _____ A			
5. Motor characteristics	TYPE: Squirrel-cage induction	Synchronous Wound-rotor	Other (describe) _____	REUSE/NEW: motor: mfr. and model #: _____	Retrofit existing motor: mfr. and model #: _____	New motor
6. Motor specifications	Output: _____ kW _____ HP Rated current _____ A		Voltage _____ Vac Poles _____ P Efficiency _____ %		Frequency _____ Hz Speed _____ RPM Power factor _____	
7. Speed control range	Min _____ RPM	Max _____ RPM	or Min _____ Hz	Max _____ Hz		
8. Speed reference	4 to 20 mA		Manual speed potentiometer		Multi-step digital presets	
9. Accel / Decel ramps	Internal accel time _____ sec./ _____ RPM	Decel time _____ sec./ _____ RPM	External (customer control of ramps)		Define:	
10. Overload capacity	Not needed (100% rated output current continuous)		Needed when motoring _____ % rated output current for _____ sec. _____ min.			
11. Drive bypass	TYPE: ATL (Across-the-line)	RVSS (Reduced Voltage Soft Starter)			Combined None	
12. Input power supply specifications	Input power source: Grid Private Variable Transformer	Power Supply Generator	Power supply short-circuit capacity _____ MVA	Input voltage _____ Vac _____ Hz	Control circuit voltage (customer supplied) 208/220V, 50/60Hz, 3-Phase 380V, 50Hz, 3-Phase	
13. Ambient conditions	Outdoor (Enclosure supplied by others) Indoor	Other (Provide details in the "Other required specifications" section on following page)	Air-conditioning facilities: Provided Not provided	Ambient temperature Min _____ °C to Max _____ °C	Humidity _____ % or less, non-condensing	
	Altitude _____ m or less		Cabinet enclosure _____		Atmosphere _____	
14. Enclosure	1. Type _____	2. Dimensional Restrictions: _____ height x _____ width x _____ depth None		3. Cable entry: Input: Top Bottom Output: Top Bottom	4. Cable entry: Output Input	

Specifications

Item	Specifications	
	Standard specification	Optional specification
15. Options		
a. Cabinet paint	Standard color (ANSI 61 Gray)	Non-Standard color Define: _____
b. Incoming wiring location	Bottom	Top
c. Analog outputs	Quantity (8) (4) -10 to +10 Vdc (4) 4 to 20 mA	Quantity / description: 0 to 10 V _____ 0 to 20 mA _____ 4 to 20 mA _____ Resolution: _____ —
d. Digital outputs	Quantity (4) - Relay N.O.	Quantity / description: Relay _____
e. Digital inputs	Quantity (5) - 120 Vac	Quantity / description: 24 Vdc _____ 120 Vac _____ 230 Vac _____
f. Analog inputs	Quantity (5) (1) -10 to +10 Vdc (4) 4 to 20 mA	Quantity / description: 4 to 20 mA _____ 0 to 10 V _____ 10 to 20 V _____ Resolution: _____ —
g. Motor temperature monitor	Without	Motor stator winding temperature Motor stator winding and bearing temperature TYPE: Thermostat Thermister RTD: 100 ohm 10 ohm 120 ohm
h. Communication option	Without	With DeviceNet Profibus-DPV1 Ethernet/IP Modbus TCP Profinet Other: _____ Integrator: _____
i. Recommended spare parts	Without	With
j. Witness test	Without	With
k. Load test	Without	With
k. Type test	Without	Without
Other required specifications:	_____ _____ _____	

* Customer Supplied



24/7 Technical Support

Benshaw is dedicated to providing comprehensive 24-hour-a-day, 7-day-a-week phone support. Benshaw provides repair, spare parts, field engineering, retrofit and training services, when and where you need us. You can count on our experienced team, backed by the latest diagnostics and repair tools and an extensive part inventory to support your operations.

Call 1.800.203.2416

24/7 Hotline Support from our operations in Pittsburgh and Listowel (Canada):

- Technical phone support
- Overnight parts shipment
- 24-hour service dispatch
- Coordination of all service capabilities

Repairs

Repairs are made on Benshaw equipment by trained, experienced personnel, using the latest diagnostic and test equipment.

Field Services are performed on-site by skilled technicians, engineers or complete team if needed, including:

- Start-up commissioning
- Field repairs
- Field analysis/data collection
- Preventative maintenance
- Retrofits

The Benshaw Product Line

A wide range of motor controls and drives is available.

- Solid-state starters fractional up to 30,000HP at 15kV
- LV AC drives to 2,000HP, MV AC drives to 10,000HP
- Electromechanical controls to 800A

Benshaw express is a 24/7 online inventory and order entry system for authorized Benshaw distributors:

- 24/7 shipment
- Air or truck delivery

Visit us online at
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