BENSHAW
Applied Motor Controls
AN AMCONEX GROUP COMPANY

AC/DC HOTLINE

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# Medium Voltage Drive

2.3 KV – 7.2 KV CLASS VARIABLE FREQUENCY DRIVE WITH PATENTED TECHNOLOGY ENABLING EXTENDED SEPARATION OF TRANSFORMER, RECTIFIER AND INVERTER SECTIONS

***Rapid | Rugged | Global***

## CONTENTS

# Introduction

## *Benshaw's M2L Series Medium Voltage Variable Frequency Drive provides the utmost in performance, reliability, serviceability and safety.*

Benshaw M2L Medium Voltage Variable Frequency Drives feature a unique, patented topology, with independent transformer, rectifier and inverter sections, allowing Benshaw to offer flexible packaging options to accommodate a wide range of project-specific requirements and limitations.

Benshaw's modular, power-cell-based M2L inverters use the most reliable components available … such as low voltage IGBTs and dry-type film capacitors … and they are equipped with the latest in safety features, including a fast and reliable arc flash detection system. This topology, along with the M2L's advanced remote monitoring system, helps minimize down-time and simplify integration with other drive system components.

The M2L family spans a power range from 300 HP to 12,000 HP, operating at industry-standard medium voltages up to 7.2kV and accepting up to a 35kV input. Redundant fans are included in the standard design. Benefits of the M2L series' patented topology include:

- Flexibility of installation
- Industry-leading performance
- Reduced total cost of ownership
- Enhanced reliability and efficiency
- Simplified serviceability
- Dependable safety

# Patented Topology

## *Standard and independent rectifiers, combined with multi-level power-cell-based inverters in one multi-level modular converter (M2LC).*

### Features

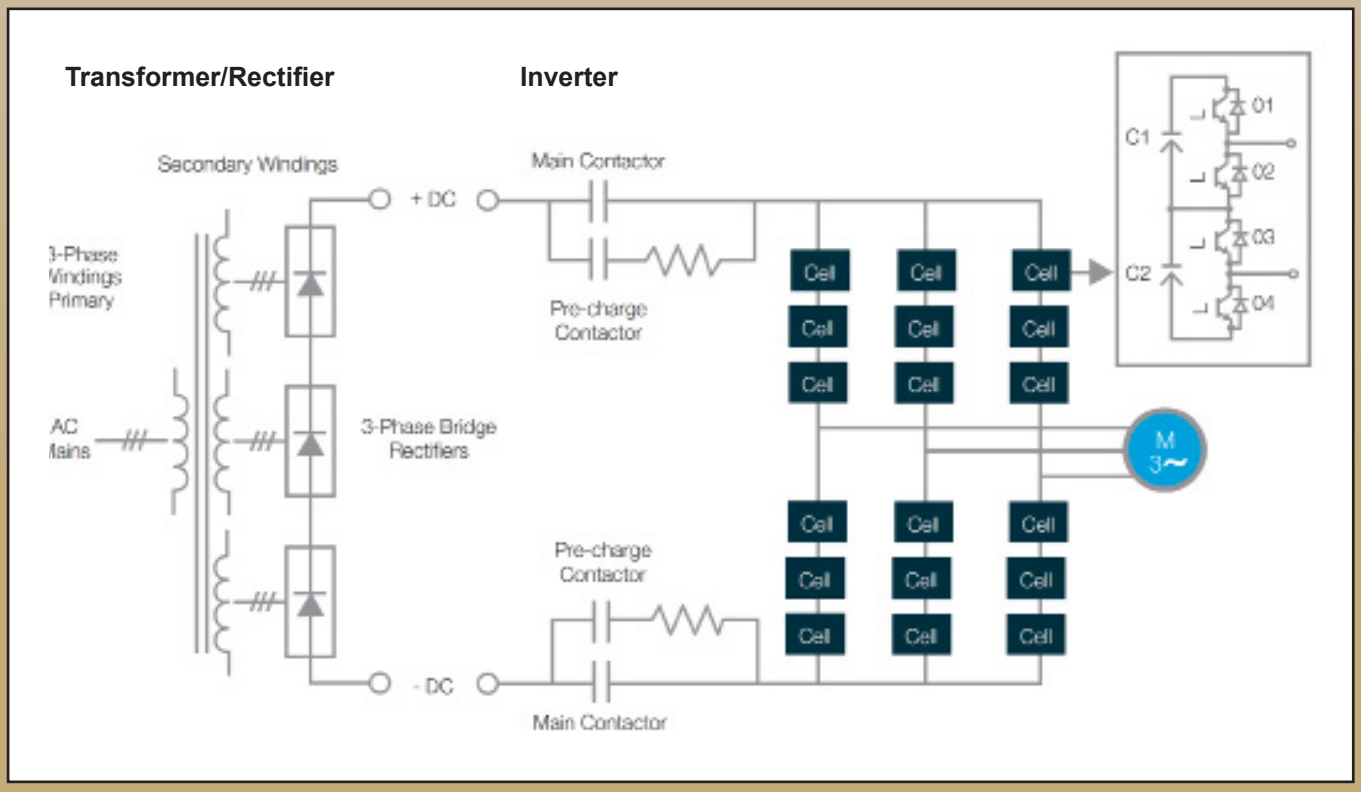
- Extended separation of main components
- Multiple indoor and outdoor installation options
- Inverter power is supplied using only two cables
- Practically no limit on distances (remote transformer and rectifier)
- Use of existing transformer and existing DC supply
- Direct supply (transformerless) from generator

### Benefits

- Smaller environmentally conditioned equipment room (~50–60% reduction)
- Significantly lower required air conditioning (~65–75% reduction in heat-load)
- Maximized safety and smallest arc flash footprint
- ~50% reduction in short-circuit currents

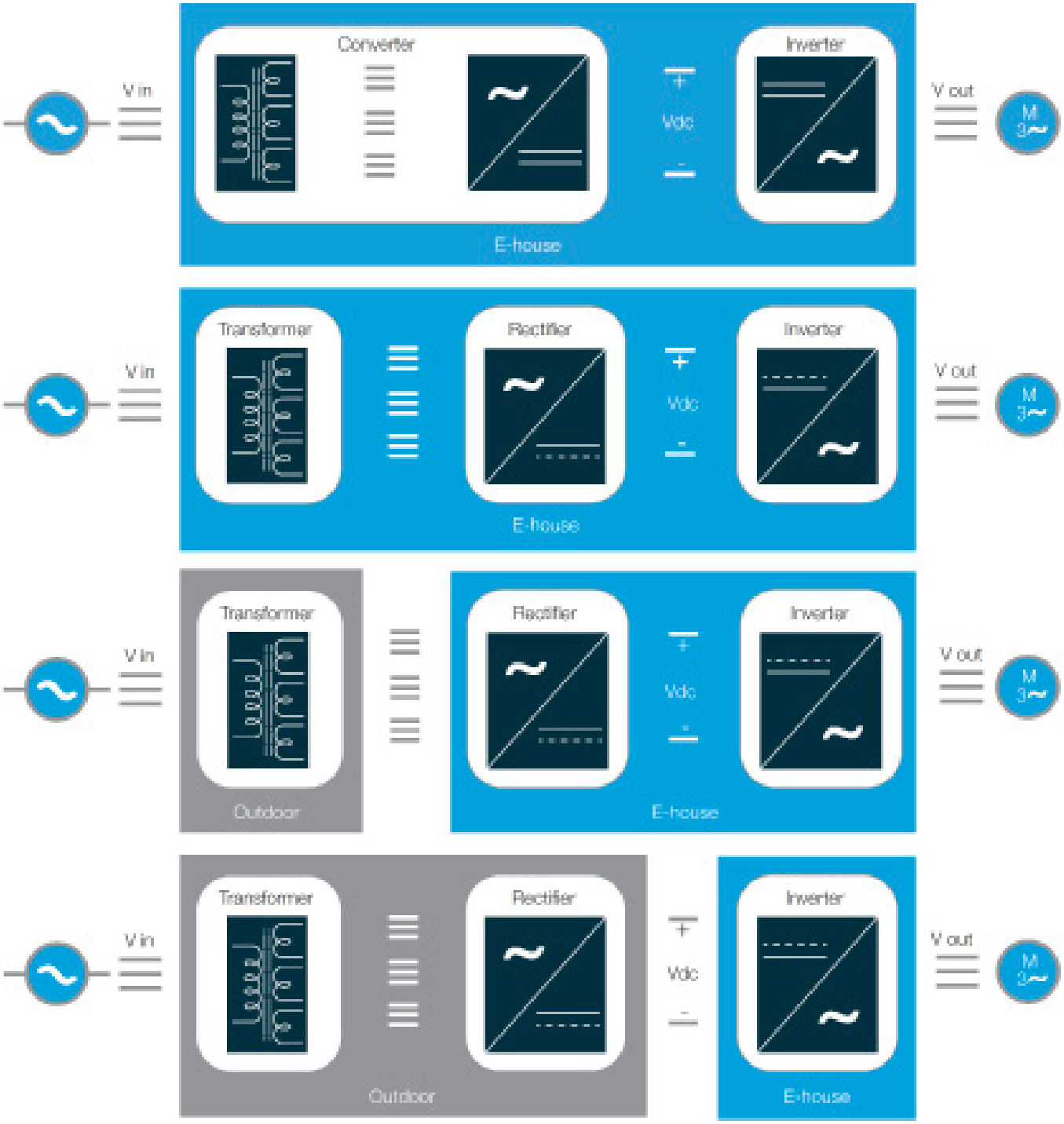
# INSTALLATION FLEXIBILITY

**Flexible packaging to accommodate project-specific requirements and limitations**




**Independent transformer, rectifier and inverter sections**

## INSTALLATION FLEXIBILITY, continued



## RELIABILITY

### *Reliability is More than a Calculated Number …*
### *It Starts with Superior Design and Reliable Components.*

| BENSHAW | Other Solutions on the Market … |
|---|---|
| Standard multi-pulse isolation transformer<br>• Limited number of secondary cables | Complex integrated multi-winding transformer<br>• Numerous secondary cables |
| Standard multi-pulse rectifier<br>• Lower component count | Complex power cell integrated rectifiers<br>• Unnecessarily high component count |
| Distributed DC link energy storage<br>• Low energy density | Concentrated energy storage<br>• High energy density |
| Film capacitors<br>• Proven reliable | Electrolytic capacitors<br>• Proven unreliable |
| Modular power cell based inverter<br>• Isolated faults | Non-modular integrated inverter<br>• Cascading failures |
| Reliable LV (1700 V) IGBTs<br>• Typical failure in time rate of 1001[1] | Less reliable HV (6500 V) IGBTs<br>• Typical failure in time rate of 4001[1] |

[1] Failure in time (FIT) rate of a device is the number of failures that can be expected in one billion device-hours of operation.

## PERFORMANCE

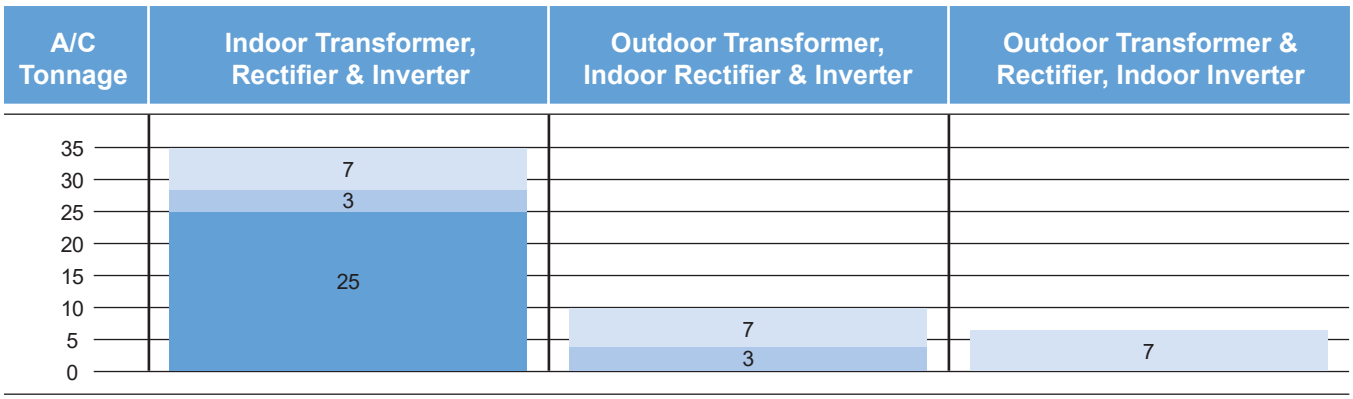
Significant savings on initial investment, operating costs and maintenance costs of air-conditioning systems can be realized by moving the majority of heat load outdoors.

### Heat Load Analysis

| | Power Loss (kW) | Heat Load (BTU/hr) |
|---|---|---|
| Transformer | 80 | 275,000 |
| Rectifier | 10 | 34,000 |
| Inverter | 25 | 85,000 |
| Drive | 115 | 394,000 |

## PERFORMANCE, continued

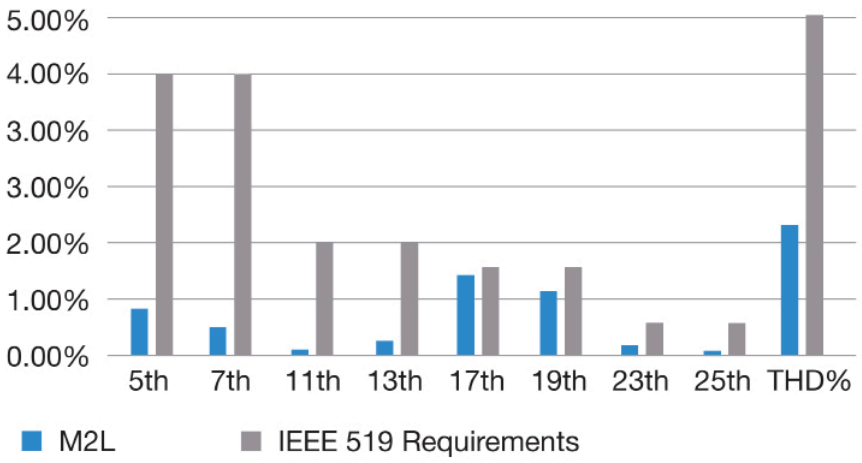
**Required air-conditioning tonnage to dissipate heat from e-house.**
**Example shown is for a typical 5000 HP MV drive with 97% overall efficiency.**




| | Indoor Transformer, Rectifier & Inverter | Outdoor Transformer, Indoor Rectifier & Inverter | Outdoor Transformer & Rectifier, Indoor Inverter |
|---|---|---|---|
| YEARLY OPERATING COST | $37,000 | $11,000 | $7,000 |
| 20-YEAR OPERATING COST | $788,000 | $225,000 | $158,000[1] |

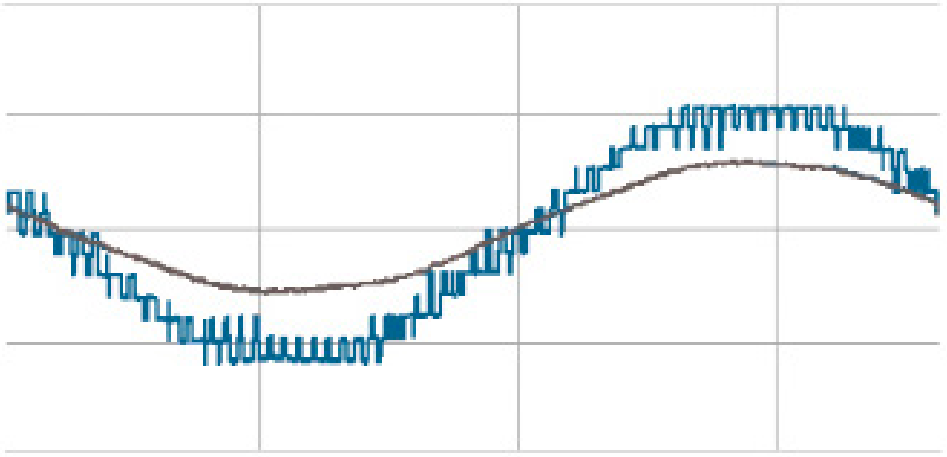
[1] Calculations above do not include redundant HVAC capacity or installation and maintenance cost of HVAC units.

### Example of Input Current Harmonic Spectrum



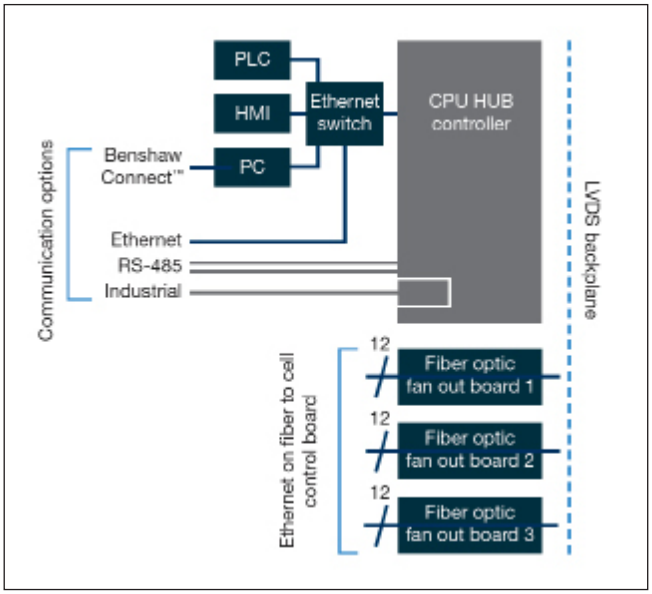

- Input current and voltages meet/exceed IEEE-519 requirements
- Input PF > 0.95
- Input filter not required

### Example of Output Line-to-Line Voltage and Current

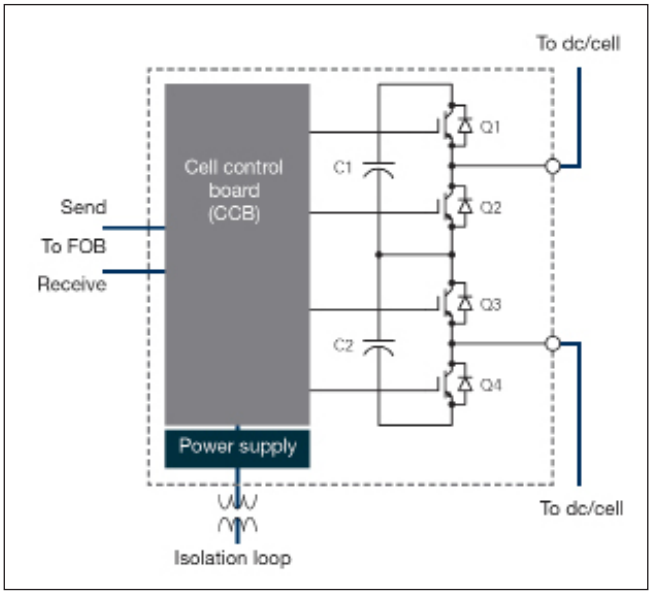


- Motor-friendly 13-level line-to-line output voltage
- Low harmonics and low dV/dt
- Output filter not required (cables up to 1000 ft.)

### Card Rack




### Cell Circuit Configuration

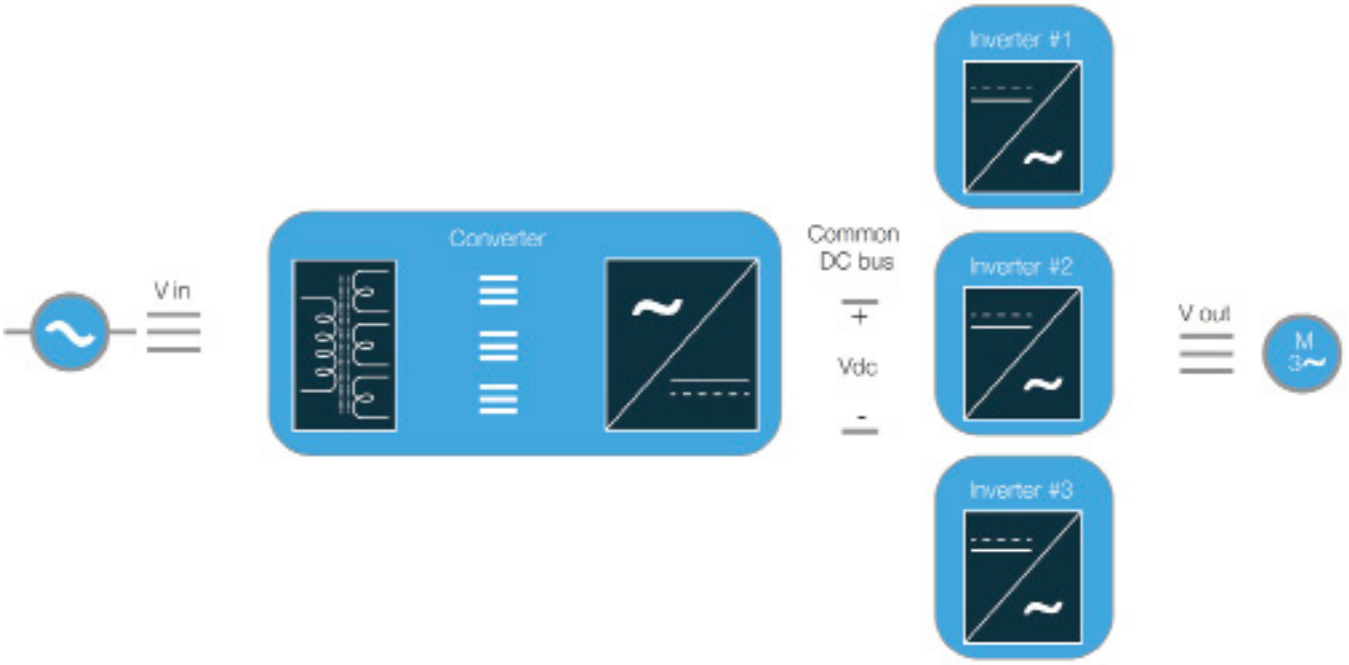



- Robust control architecture
- Distributed control with intelligent power cells
- Advanced control and protection features

## SCALABILITY

### Parallel Inverters Running Single Motor

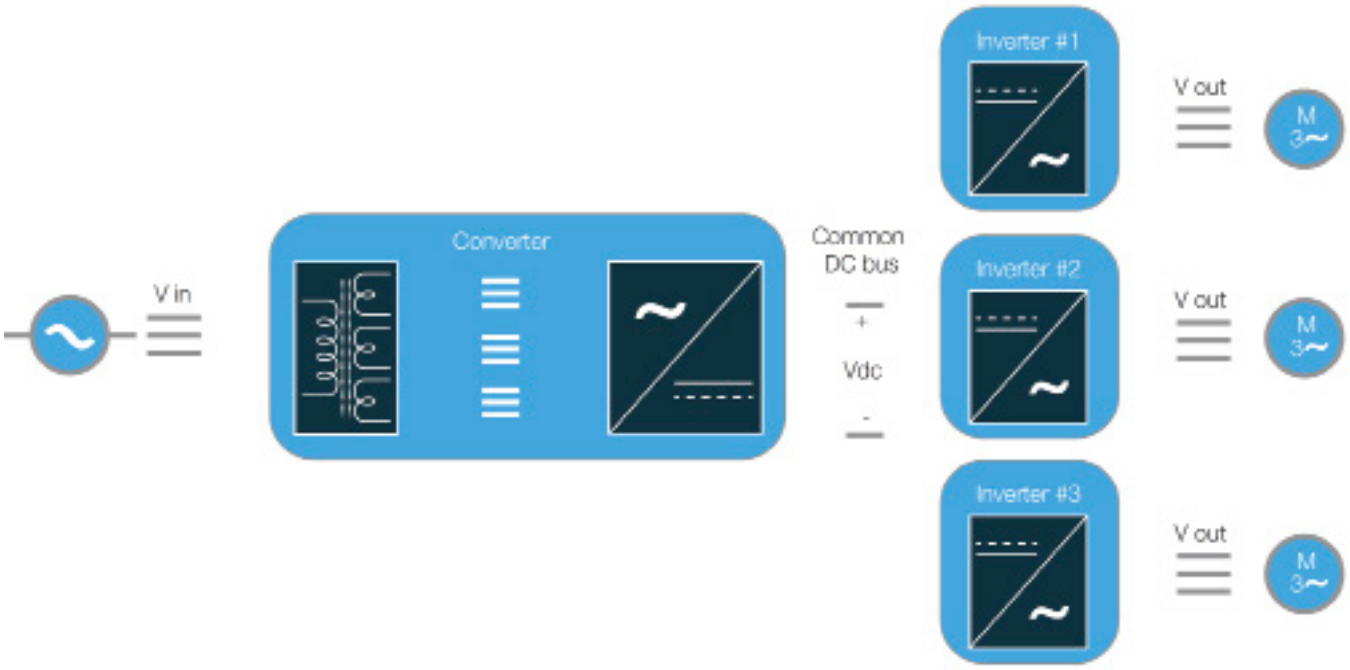
| FEATURE | BENEFIT |
|---|---|
| Parallel connected inverters | Extending air-cooled solution for HPs beyond traditional power limits |
| Single transformer and rectifier | Significant cost savings on equipment and real estate |
| Outdoor installation of transformer and rectifier | Minimized indoor heat-load and air-conditioning requirements |
| Seamless control integration | Single operator interface (HMI) and process control |
| Option for redundant inverter | Highest reliability and availability on the market |



## SCALABILITY, continued

### Parallel Inverters Running Multiple Motors

| FEATURE | BENEFIT |
|---|---|
| Parallel connected inverters | Optimized solution for applications with multiple motors |
| Single transformer and rectifier | Significant cost savings on equipment and real estate |
| Outdoor installation of transformer and rectifier | Minimized indoor heat-load and air-conditioning requirements |
| Independent or integrated control | Optimized process control |
| Minimized component count | Increased reliability and availability |



## SERVICEABILITY

***Simple, fast maintenance is ensured through the M2L's front access only design and advanced diagnostic tools such as Benshaw Connect™ and GMC® remote monitoring system.***

Benshaw Connect™ provides intuitive, user-friendly access to operational and conditional data, trends and events log as well as control and motor parameters.

GMC® remote monitoring system provides secure access to the drive and insights into its performance and condition. This system enables end users to rely on Benshaw's expertise and receive immediate support during unexpected situations.

**Preventative and corrective maintenance can be performed easier and faster than ever.**

| FEATURE | BENEFIT |
|---|---|
| Front access only | No rear access required |
| Modular power cell based inverter | Faults isolated to a power cell |
| Rack-out power cells | Easy and fast power cell replacement |
| Film capacitors | No capacitor reforming required |
| Modular fan cage design | Easy and fast fan replacement |
| Built-in self test (BIST) | Safe and fast system checks |
| 24/7/365 service and support | Ease of mind |

# SAFETY

### Safety by Design

- Inherently lower arc flash footprint
- Greatly reduced fault currents
- Distributed energy storage and isolated faults
- Arc flash detection in power cells

### Fast Arc Flash Detection

- Each power cell equipped with optical arc flash detection
- Instantaneous shut down of drive in case of arc detection
- Safe and fast communication to central control via fiber optics

### Built-in Self Test (BIST)

- Allows testing of inverter with 230 V connected only (no MV required)
- Reduces arc flash boundary to LV distances during testing, start-up and maintenance
- Allows for system, power cell and communication checks

### Safe and Reliable Components

- Use of dry-type film capacitors for energy storage
- Use of standard isolation transformer
- Use of LV IGBTs
- Use of high-speed fiber optic communication

### Remote Control and Monitoring

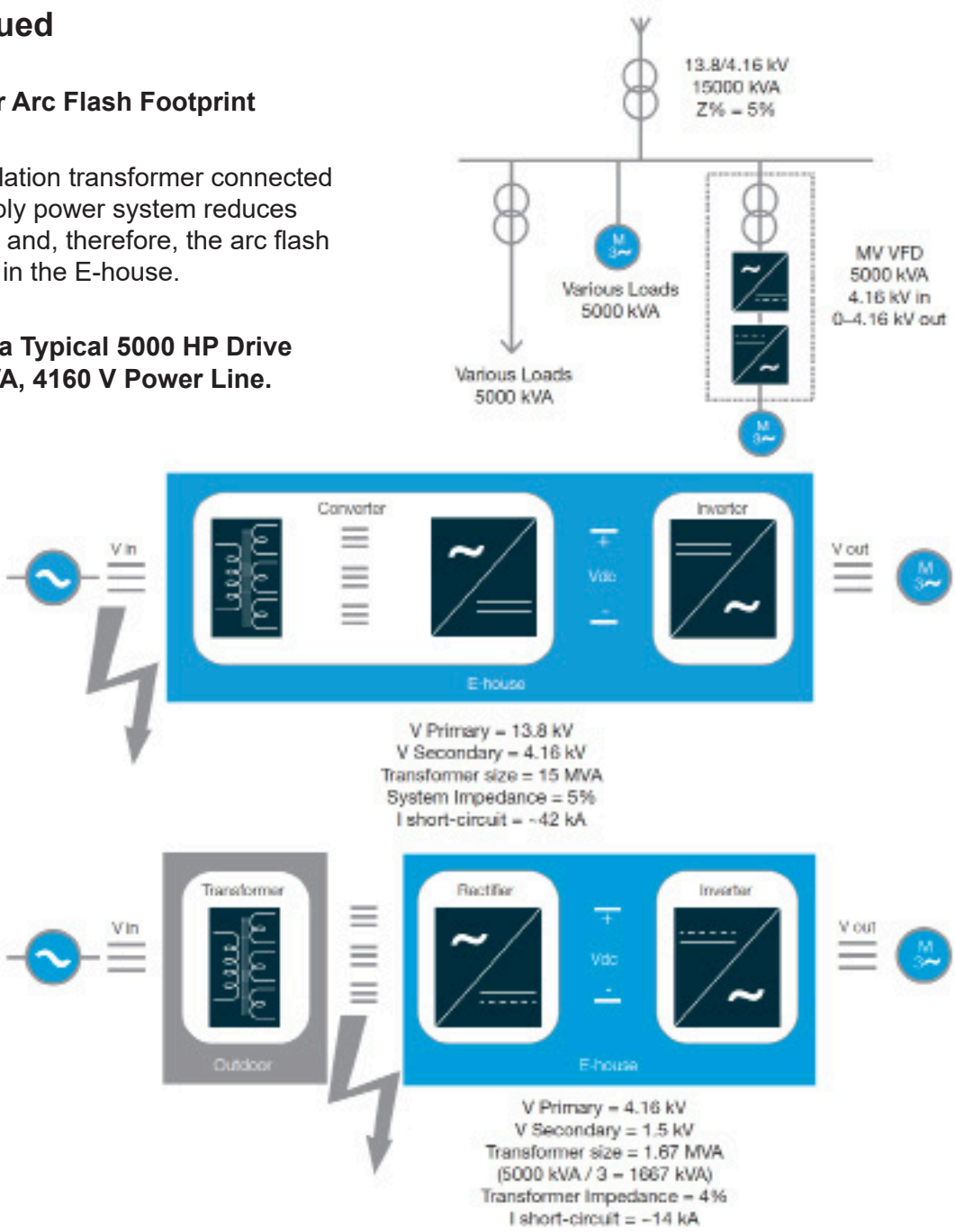
- Remotely mounted HMI
- Remotely connected PC
- Secured gateway ready
- Remote control and monitoring via Bluetooth®
- Remote control and monitoring via internet

## SAFETY, continued

### Significantly Smaller Arc Flash Footprint

The impedance of isolation transformer connected in series with the supply power system reduces the short-circuit rating and, therefore, the arc flash energy and boundary in the E-house.

**Example Shown for a Typical 5000 HP Drive Supplied by a 15 MVA, 4160 V Power Line.**




Note: Calculations above are simplified to show the impact of isolation transformer on reducing the short circuit currents available in the E-house. These calculations do not consider impact of protection equipment such as circuit breakers and fuses, cables and motor contributions to the short circuit currents. Short-circuit analysis must be performed for each specific power system.

# Technical Data

### Input Line Specification

- Input voltage[1]
  - 3Ø, 380 V–35 kV ±10%
- Input frequency
  - 50 or 60 Hz ±5%

### Motor-Side Specification

- Output voltage[1]
  - 3Ø, 0–2.3 kV
  - 3Ø, 0–4.16 kV
  - 3Ø, 0–7.2 kV
- Output current
  - 0–770 A single inverter
  - >770 A parallel inverters[2]
- Output frequency[3]
  - 0–90 Hz
- Output power[4]
  - Up to 12,000 HP

### Efficiency

- Inverter
  - >99.5%
- Drive system
  - >97%

### Input Transformer

- 6–36-pulse
- Air-cooled or oil-filled
- Indoor or outdoor installation

### Rectifier

- 6–36-pulse
- Diode front end
- Indoor or outdoor installation

### Motor-Side Inverter

- Multi-level PWM
- LV IGBT power cells
- Indoor installation

### Control Methods

- Volts/hertz (V/Hz)
- Sensor-less vector control (SVC)

### Advanced Control Features

- Start/stop modes
- Speed control
- Motor control
- Metering and logging
- Motor protection
- Drive protection
- Power cell protection
- Parallel inverters
  - single motor
- Parallel inverters
  - multiple motors
- Synchronous transfer

1 Consult factory for voltages other than specified ranges.

2 Consult factory for parallel inverters.

3 Consult factory for higher output frequency requirements.

4 Consult factory for higher power requirements.

# ADVANCED CONTROL FEATURES

## START, STOP AND SPEED FUNCTIONS[1]

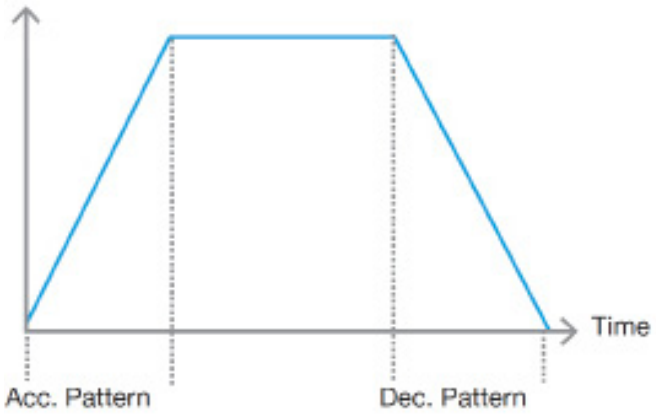
| FEATURE | DESCRIPTION |
|---|---|
| Multiple start functions | Accelerate from zero, flying start, DC brake then start |
| Multiple stop functions | Decelerate to zero, coast to stop, decelerate or coast then DC brake |
| Multiple acceleration and deceleration profiles | Linear, U-curve, S-curve |
| Advanced speed functions | Skip frequencies, dwell frequency, optimal deceleration |

## PROTECTIVE FUNCTIONS[1]

| FEATURE | DESCRIPTION |
|---|---|
| Arc flash detection | Fast and reliable arc flash detection system in each power cell |
| Motor protections | Ground fault, thermal overload, overcurrent and undercurrent, speed control |
| Drive protections | DC link overvoltage and undervoltage, DC link ripple, output and input phase loss, overcurrent and undercurrent, pre-charge failure, control failure |
| Power cell protections | Arc flash detection, communication failure, overvoltage, overcurrent, overtemperature |

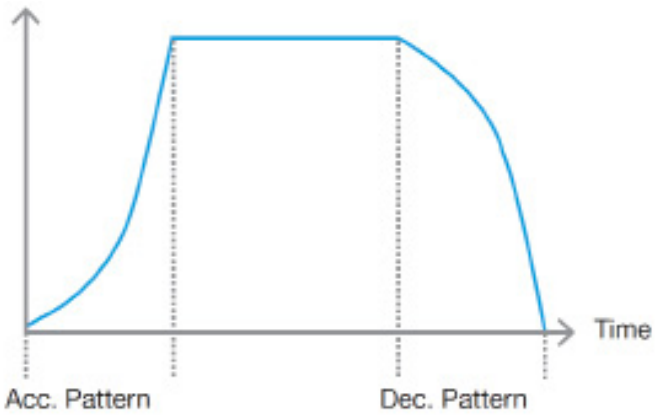
[1] Not all functions are shown.

**Output Frequency**



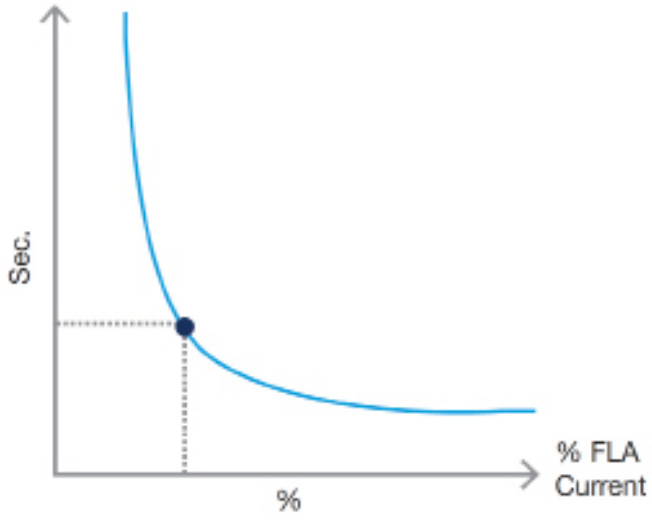

Configurable linear acceleration and deceleration

**Output Frequency**



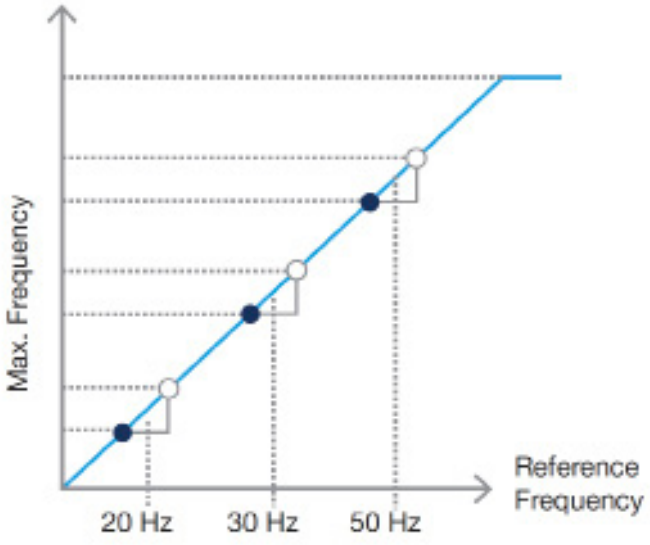

Configurable U-curve acceleration and deceleration

**Time to Trip**




Adjustable motor thermal overload trip

**Output Frequency**

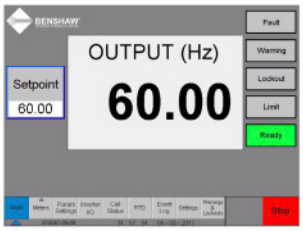



Advanced skip frequency function

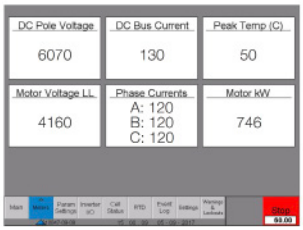
## USER-FRIENDLY OPERATOR INTERFACE

| PRODUCT | DESCRIPTION |
|---|---|
| HMI functions | Touchscreen, local or remote operation, advanced value/trend monitoring, easy configuration and diagnostics |
| Benshaw Connect™ | Seamless wired or wireless connectivity, advanced value/trend monitoring, easy configuration and diagnostics |
| Communication protocols | Modbus TCP/IP, PROFIBUS DP, Modbus RTU (consult factory for other communication protocols) |
| PLC I/O | Fully customizable user I/O modules for every application possibility |

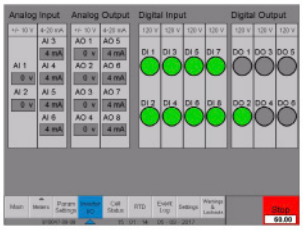
### TouchScreen HMI[1]



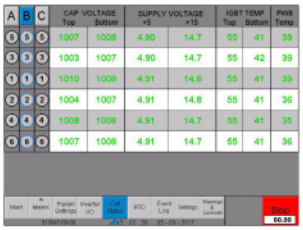

Real-time operational status indicator




Real-time operational values screen



Type and value of PLC I/Os



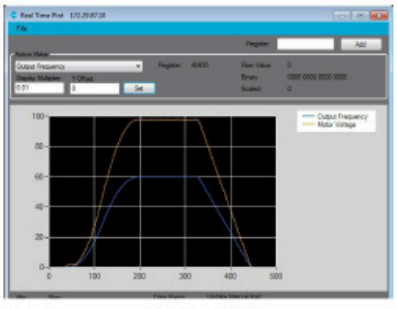
Powercell voltages and temperatures

[1] Not all screens are shown

### Benshaw Connect™[1]


Easy access to parameters and meters


Easy access to I/Os



Customizable trend monitoring

# Applications

***Benshaw's M2L Series Drive is highly versatile, with a number of installation configurations available to suit environmental conditions. The result? Significant cost savings and reduced total cost of ownership.***

**Synchronous Transfer**

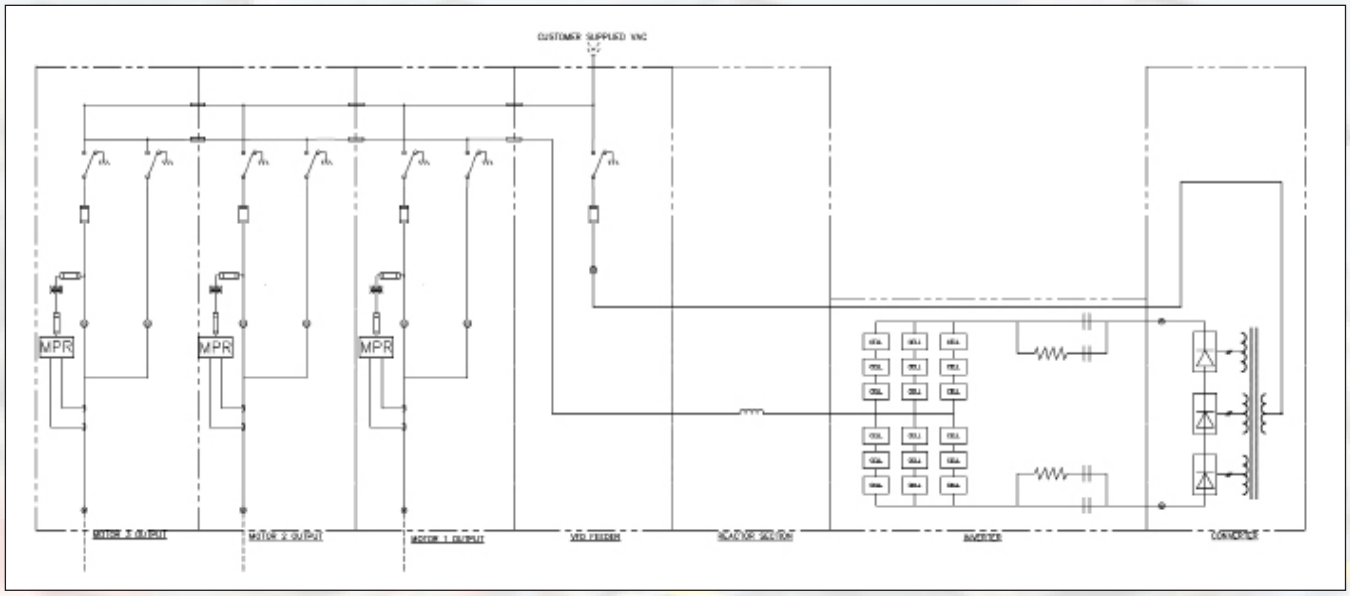
Advanced synchronous transfer setup allows the motor to be transferred to the supply line after the motor voltage magnitude and phase angles at the motor terminals are synchronized and matched with the ones at the supply line terminals. Advanced synchronous transfer controller provides "bump-less" transfer of the motor, which ensures minimized stress on the motor and driven system.

Benshaw offers all the isolation disconnects, contactors, sync reactor and synchronous controller as well as the M2L MV drives, providing an easy, fast and smooth one- stop shop experience.

**Single VFD with Single Motor** — Single motor setup provides the ability to soft start a motor and eliminate any inrush current, thus reducing the impact on the power system. The motor may be operated at variable speeds using the M2L MV drive or transferred across the line to operate at full speed.

**Single VFD with Multiple Motors** — Multiple motors setup provides the ability to soft start any of the motors and eliminate any inrush current, thus the reducing impact on the power system. Some or all the motors may be synchronized with the utility supply and be operated at full speed. One motor may be operated at variable speeds using the M2L MV drive for load trimming purposes.

## APPLICATIONS, continued

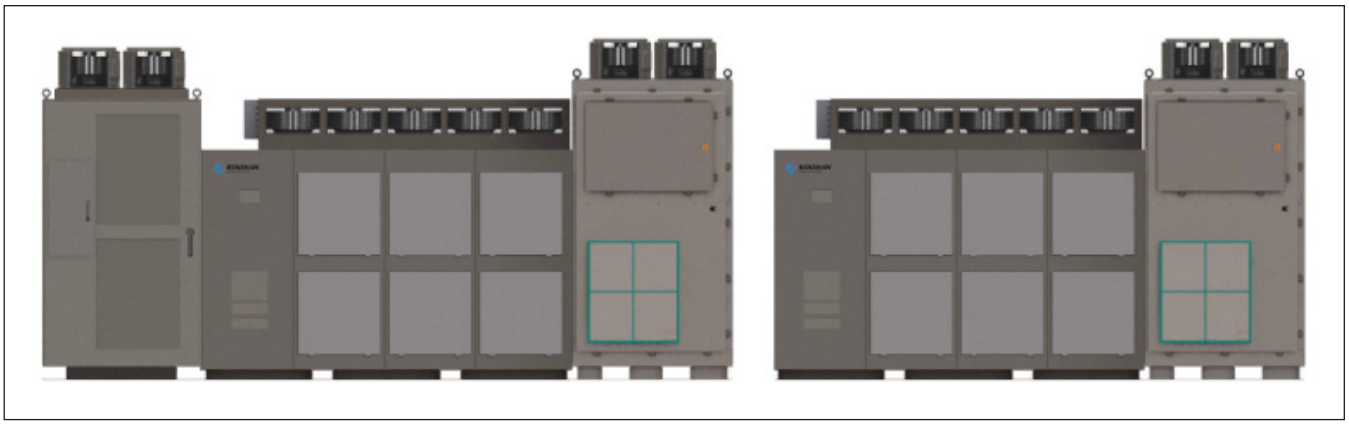



One-line diagram with 1 VFD — 3 motors

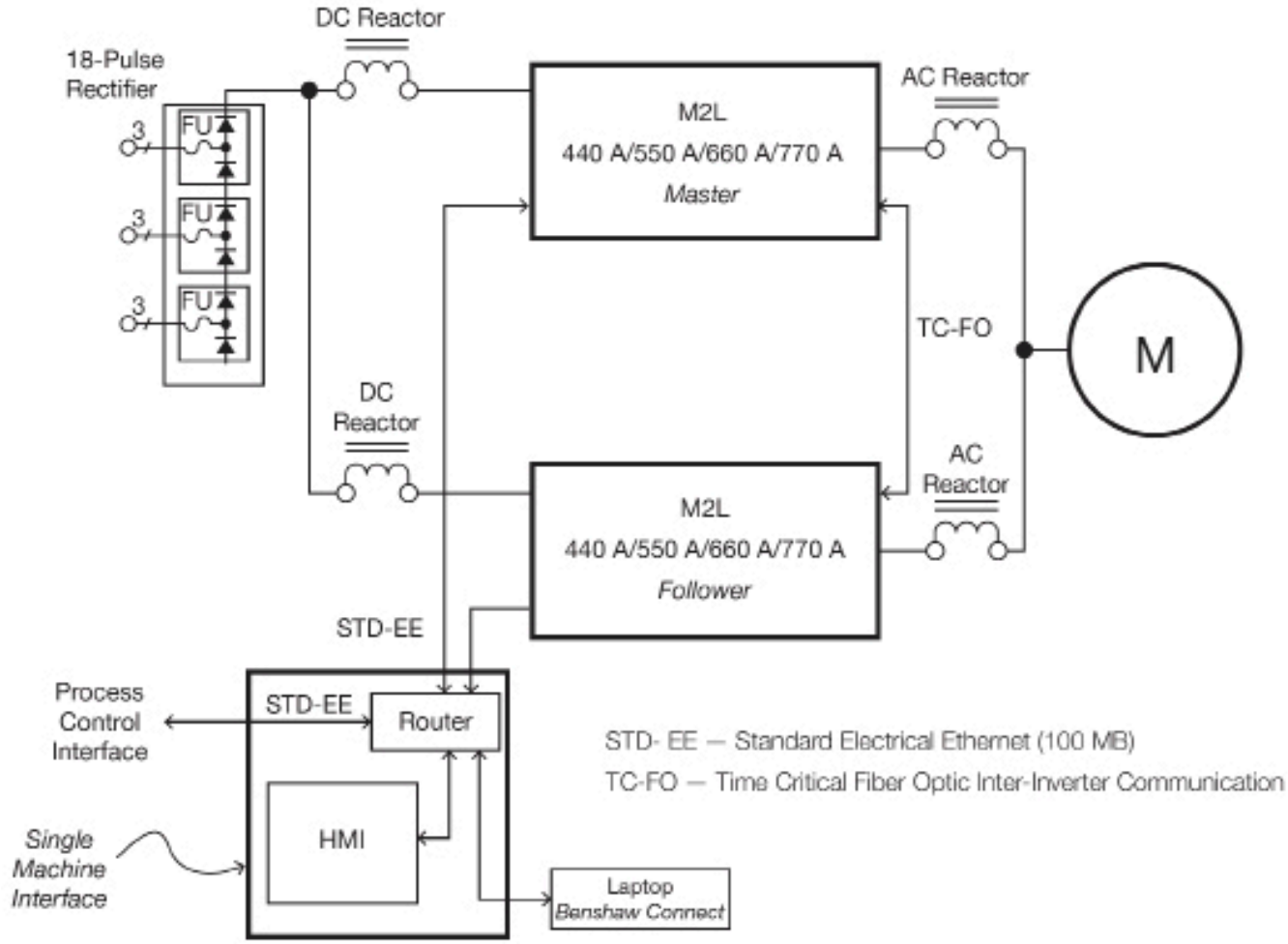
### Parallel Drive

The modular and flexible design of the M2L MV drive provides the ability to utilize two inverters in parallel and expand the HP rating of a fully air-cooled solution to beyond 10,000 HP range. An air-cooled solution at this HP range eliminates cumbersome piping and complex and unreliable liquid-cooling systems, thus offering significant cost savings during initial investment, installation and operation of the drive.

The 2ML design utilizes modular building blocks; therefore, the same components are used to achieve higher horsepower ratings. Using modular building blocks allows the customer to standardize on lower-cost spare parts, minimizing downtime and maintenance costs.



Line-up for 8000 HP 4160 V parallel drive with outdoor transformer




One-line diagram with parallel drive and outdoor transformer


PEMEX