BENSHAW®
ADVANCED CONTROLS & DRIVES
A member of UNICO Technologies Group

M2L Series

Medium Voltage Variable Frequency Drive
2.3 kV Class – 7.2 KV Class

Patented technology enabling extended separation
of transformer, rectifier and inverter sections

Medium Voltage Drives

M2L Medium Voltage Drive

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

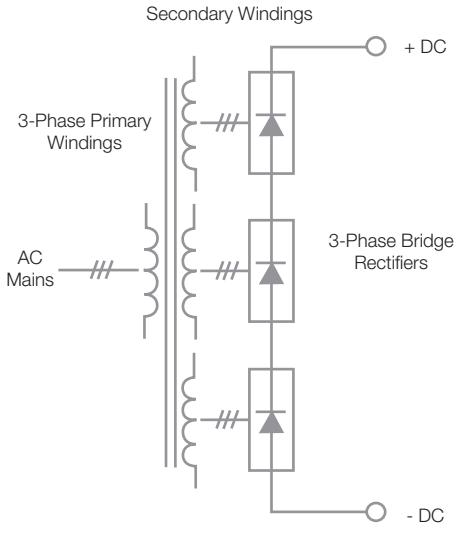
- Volts/hertz (V/Hz)
- Sensor-less vector control (SVC)

Advanced Control Features

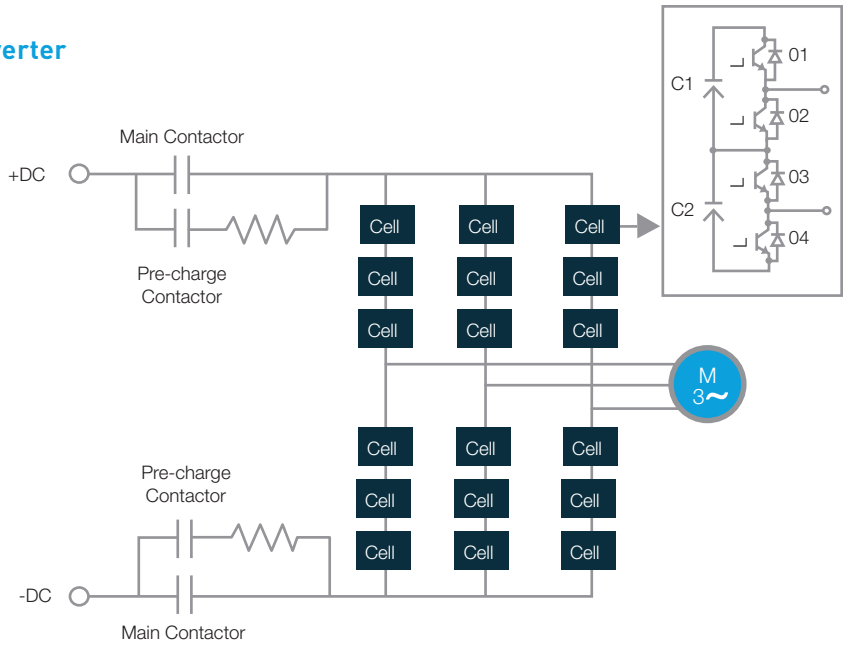
- Start/stop modes
- Speed control
- Motor control
- Metering and logging
- Motor protection
- Drive protection
- Power cell protection
- Parallel inverters — single motor
- Parallel inverters — multiple motors
- Synchronous transfer

[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.

Transformer/Rectifier



Inverter



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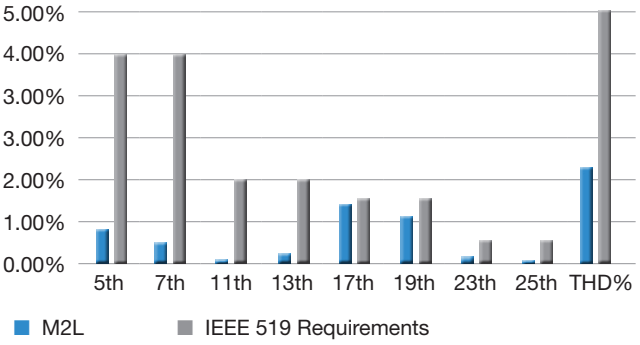
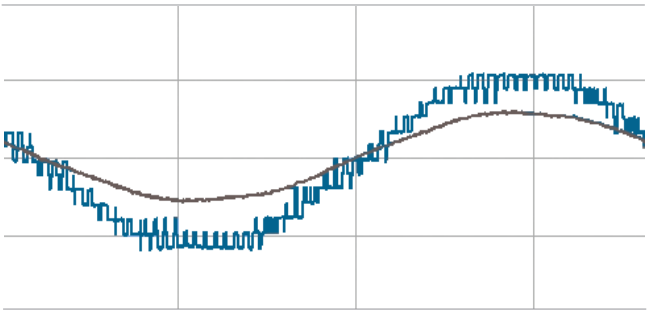
Benefits of Standard and Independent Rectifiers Combined with Multi-Level Power Cell Based Inverters in One New and Novel Topology Multi-level Modular Converter (M2LC)

Example of Input Current Harmonic Spectrum



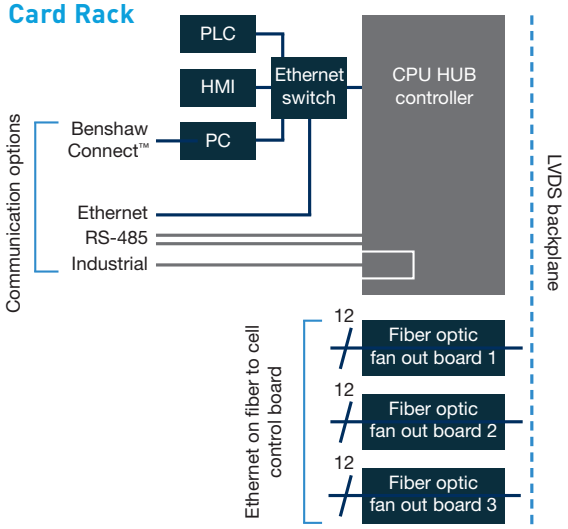
- Input current and voltages meet/exceed IEEE-519 requirements
- Input PF > 0.95
- Input filter not required

Example of Output Line-to-Line Voltage and Current

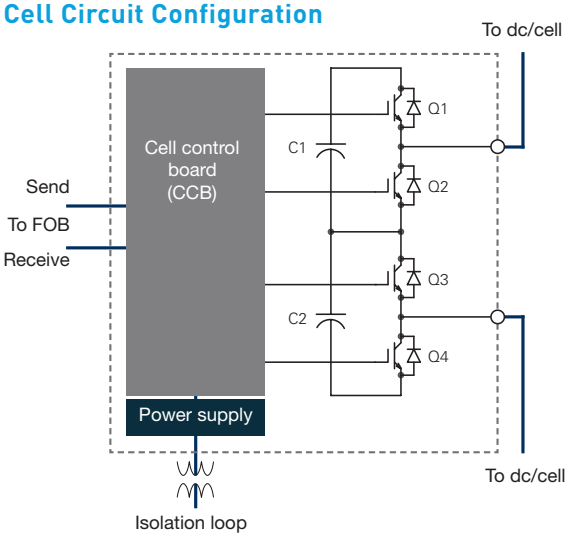


- Motor-friendly 13-level line-to-line output voltage
- Low harmonics and low dV/dt
- Output filter not required (cables up to 1000 ft.)

Card Rack



Cell Circuit Configuration



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

- Unique in installation flexibility
- Lowest in arc flash footprint
- Unmatched in scalability
- Highest in efficiency
- Improved reliability and serviceability

M2L Medium Voltage Drive

Designed for Flexibility

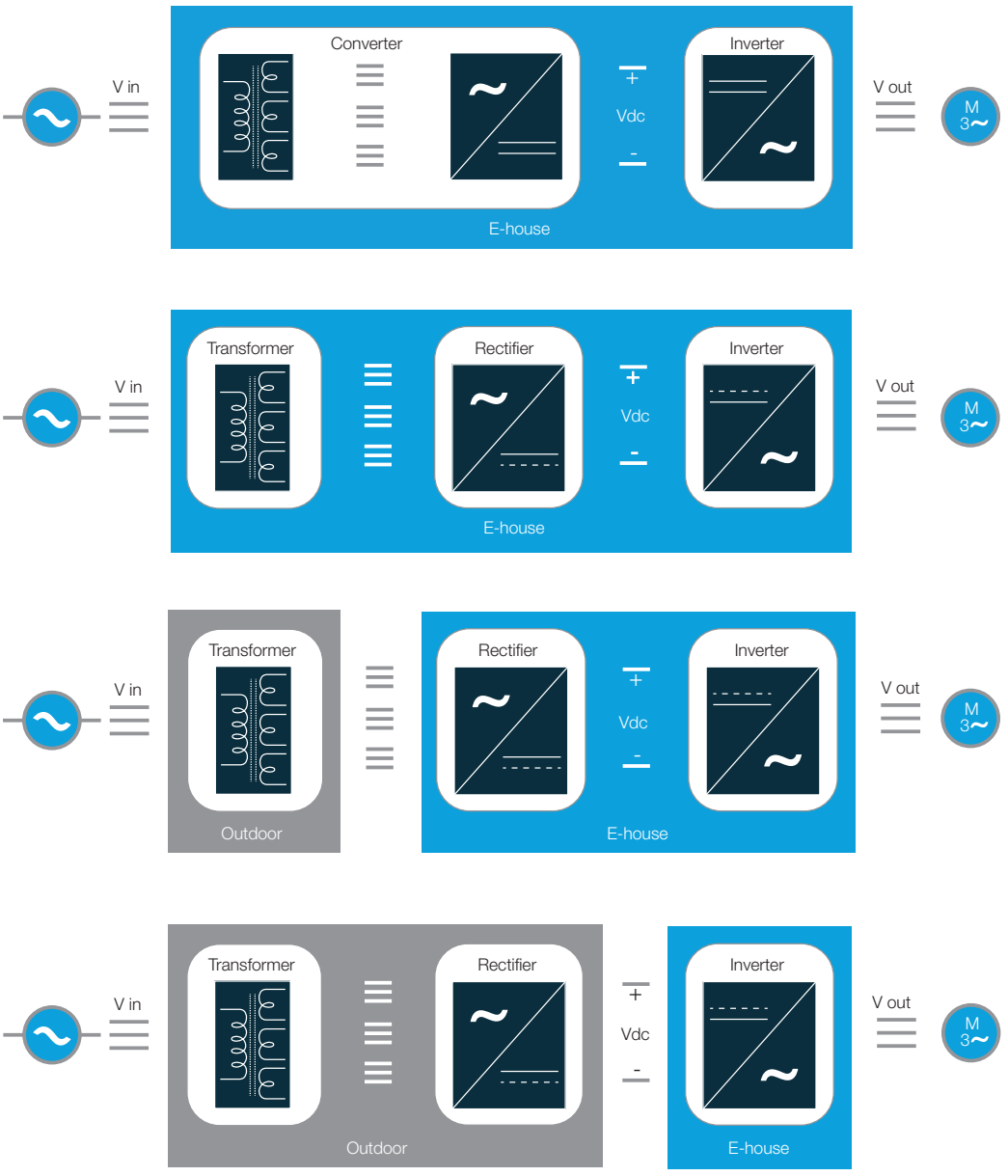
Flexible Packaging to Accommodate Project-Specific Requirements and Limitations
Independent Transformer, Rectifier and Inverter Sections

Features

- Inverter power supplied using only two cables
- Practically no limit on distances (remote transformer and rectifier)
- Use of existing transformer
- Use of existing DC supply
- Direct supply (transformerless) from generator

Benefits

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



- Extended separation of main components
- Multiple indoor and outdoor installation options

Significant Saving on Your Air-Conditioning Cost

Significant Savings on Initial Investment, Operating Cost and Maintenance Costs of Air-Conditioning System by Moving Majority of Heat Load Outdoors

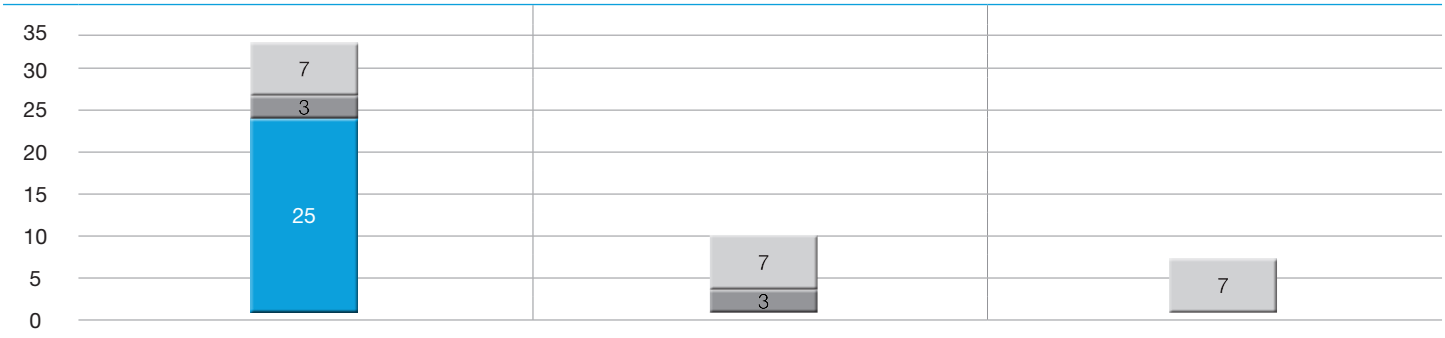
Heat Load Analysis

Example Shown for a Typical 5000 HP MV Drive with 97% Overall Efficiency

Power Loss and Heat Load

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

Required Air-Conditioning Tonnage to Dissipate Heat from E-house



	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	$158,0001

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

M2L Medium Voltage Drive

Designed for 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

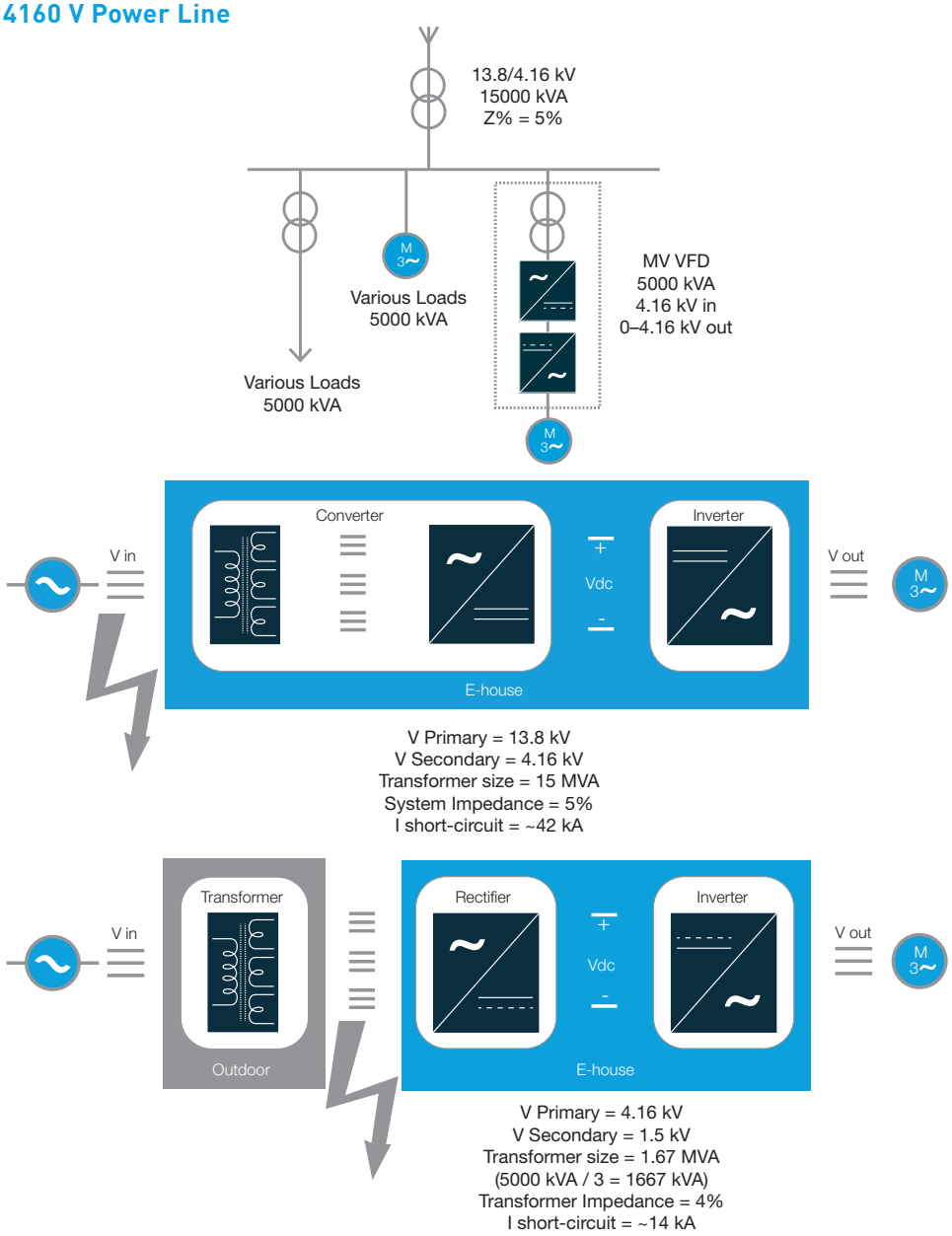
Remote Control and Monitoring

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

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.

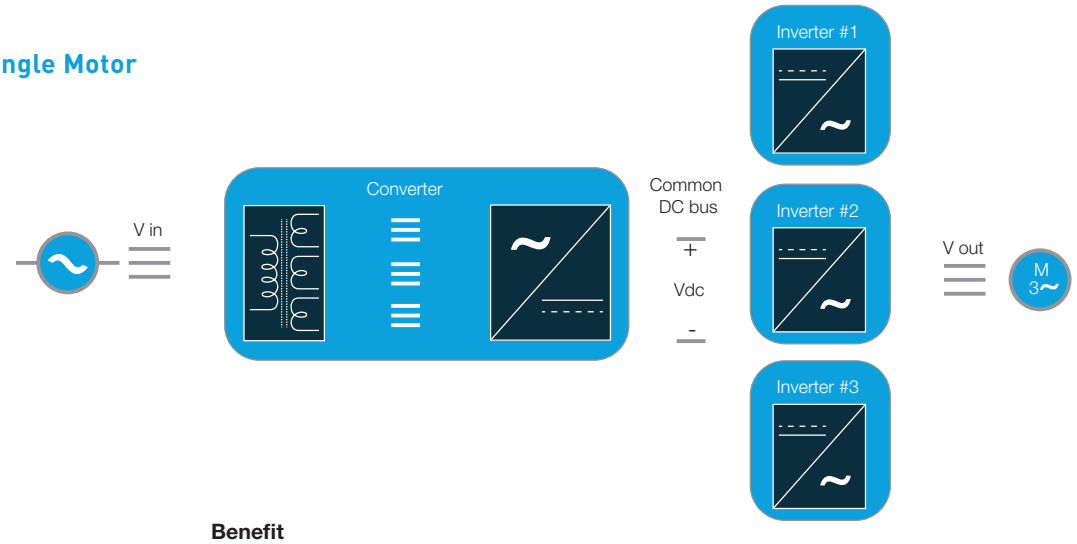
Example Shown for a Typical 5000 HP Drive Supplied by a 15 MVA, 4160 V Power Line



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.

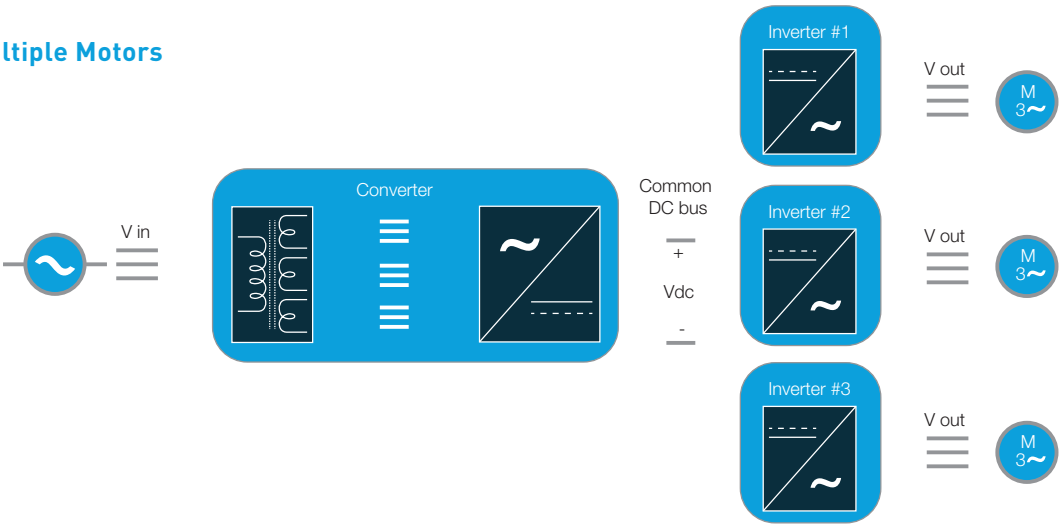
Designed for Scalability

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

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

M2L Medium Voltage Drive

Designed for Reliability

Reliability is More than a Calculated Number. Reliability Starts with Reliable Components.

Benshaw Benefit	vs. Other Solutions on the Market
Standard multi-pulse isolation transformer	Complex integrated multi-winding transformer
• Limited number of secondary cables	• Numerous secondary cables
Standard multi-pulse rectifier	Complex power cell integrated rectifiers
• Lower component count	• Unnecessarily high component count
Distributed DC link energy storage	Concentrated energy storage
• Low energy density	• High energy density
Film capacitors	Electrolytic capacitors
• Proven reliable	• Proven unreliable
Modular power cell based inverter	Non-modular integrated inverter
• Isolated faults	• Cascading failures
Reliable LV (1700 V) IGBTs	Less reliable HV (6500 V) IGBTs
• Typical failure in time rate of 100[1]	• Typical failure in time rate of 400[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.

Designed for Serviceability

Serviceability

Simple and fast maintenance is ensured through 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

M2L Medium Voltage Drive

Advanced Control Features

Start, Stop and Speed Functions[1]

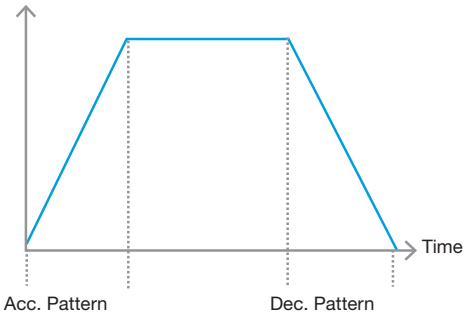
Feature	Description
Multiple start functions	Accelerate from zero, flying start, DC brake then start
Multiple stop functions	Decelerate to zero, coast to stop, decelerate or coast then DC brake
Multiple acceleration and deceleration profiles	Linear, U-curve, S-curve
Advanced speed functions	Skip frequencies, 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

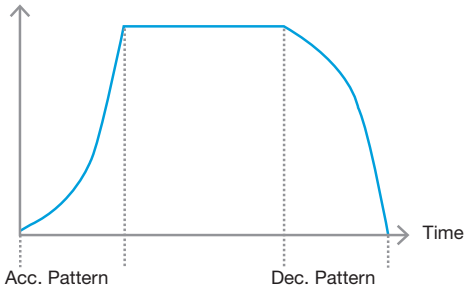
[1] Not all functions are shown.

Output Frequency



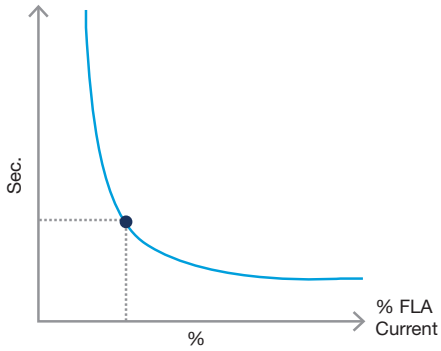
Configurable linear acceleration and deceleration

Output Frequency



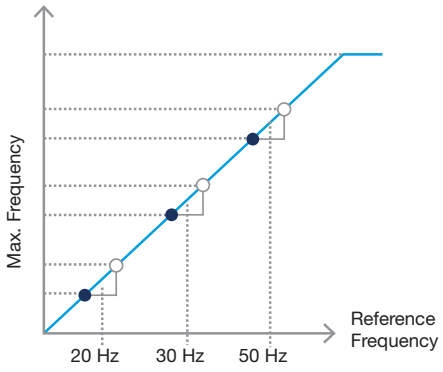
Configurable U-curve acceleration and deceleration

Time to Trip



Adjustable motor thermal overload trip

Output Frequency



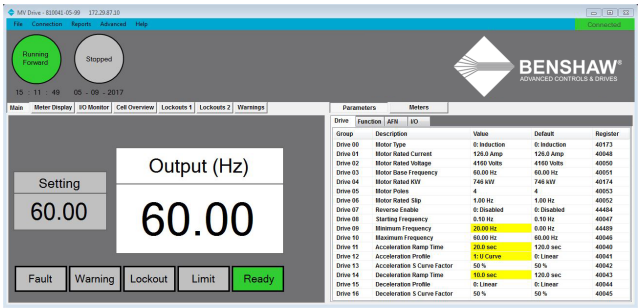
Advanced skip frequency function

User-Friendly Operator Interface

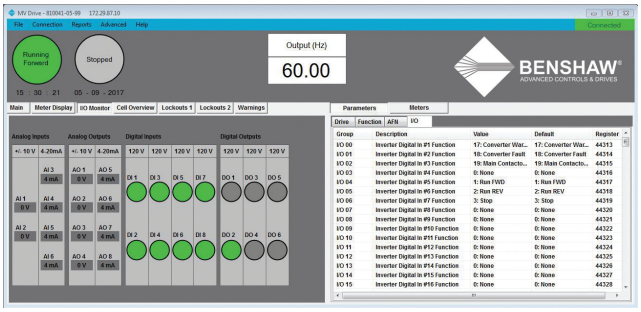
User Interface Features

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

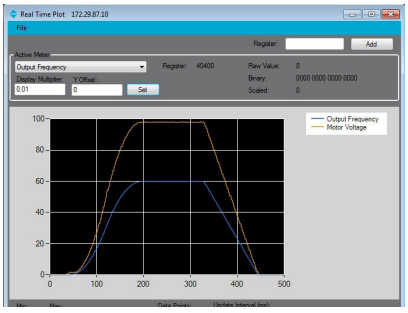
Benshaw Connect[1]



Easy access to parameters and meters



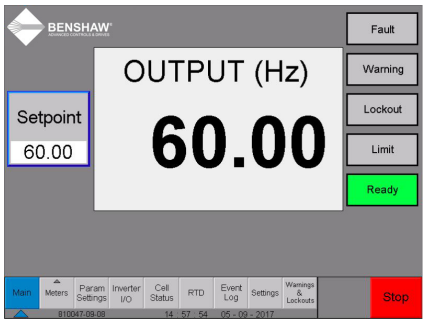
Easy access to I/Os



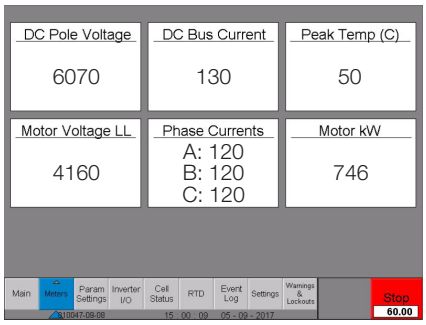
Customizable trend monitoring

[1] Not all screens are shown.

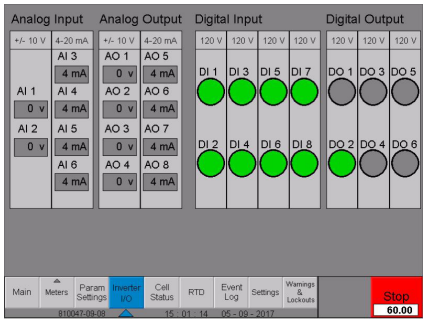
Touchscreen HMI[1]



Real-time operational status indicator



Real-time operational values screen



Type and value of PLC I/Os

Power cell voltages and temperatures

M2L Medium Voltage Drive

Special Applications

Synchronous Transfer

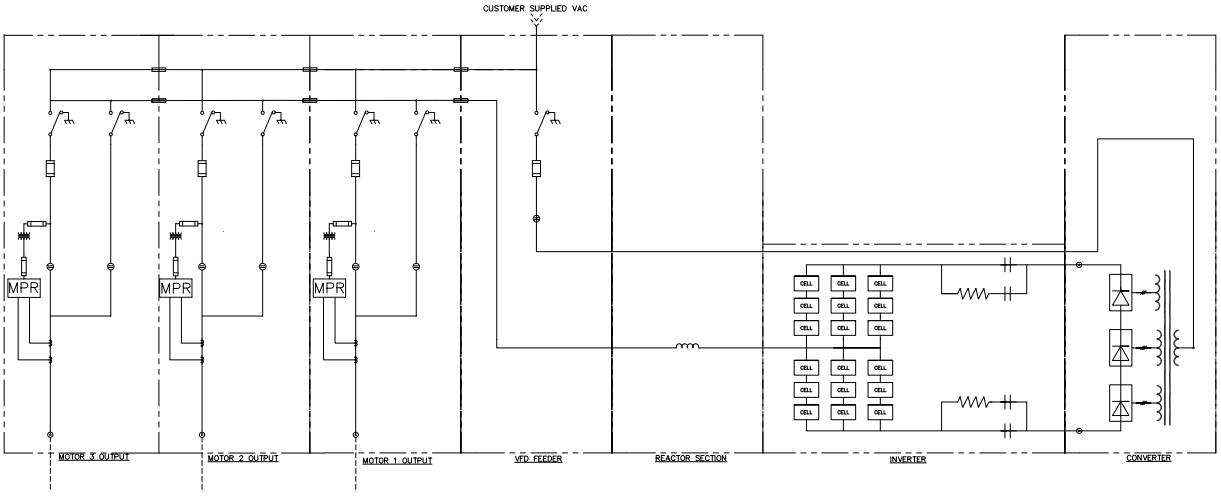
Advanced synchronous transfer setup allows the motor to be transferred to the supply line after the motor voltage magnitude and phase angles at the motor terminals are synchronized and matched with the ones at the supply line terminals. Advanced synchronous transfer controller provides “bump-less” transfer 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.

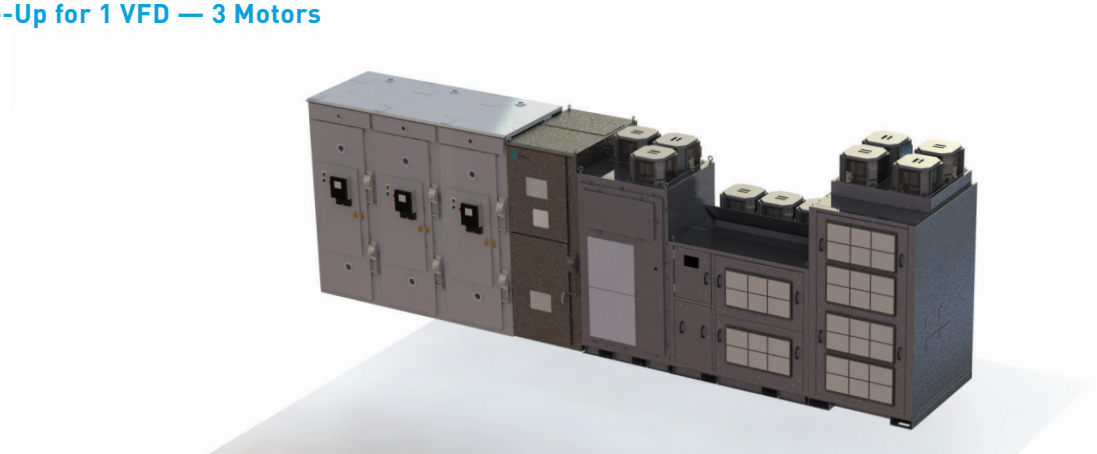
Single VFD with Single Motor — Single motor setup provides the ability to soft start a motor and eliminate any inrush current, thus reducing the impact on the power system. The motor may be operated at variable speeds using the M2L MV drive or transferred across the line to operate at full speed.

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.

One-Line Diagram with 1 VFD — 3 Motors



Line-Up for 1 VFD — 3 Motors



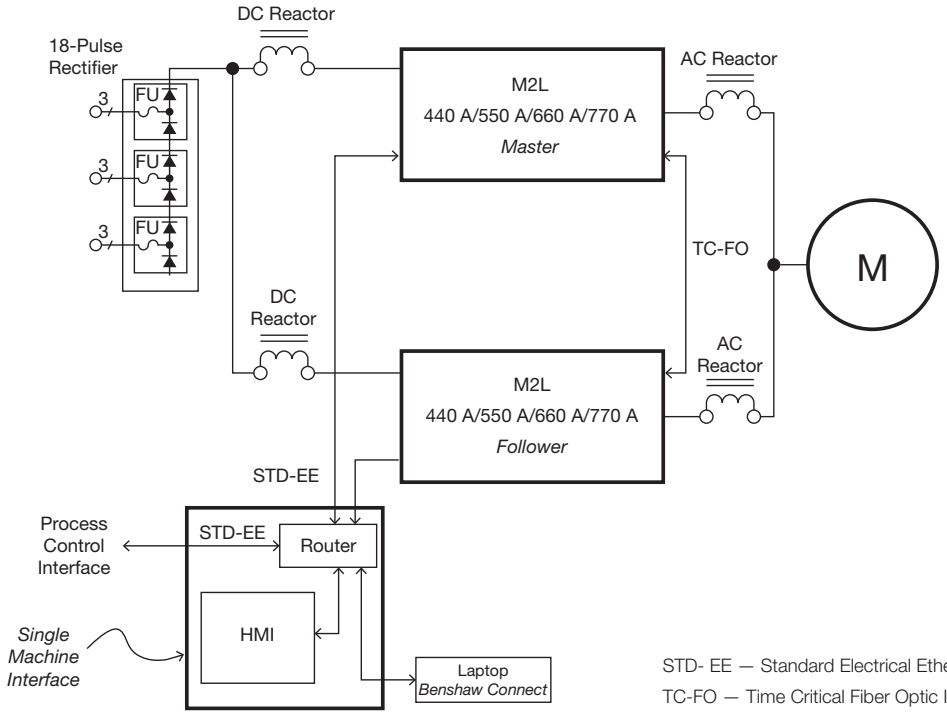
Special Applications

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.

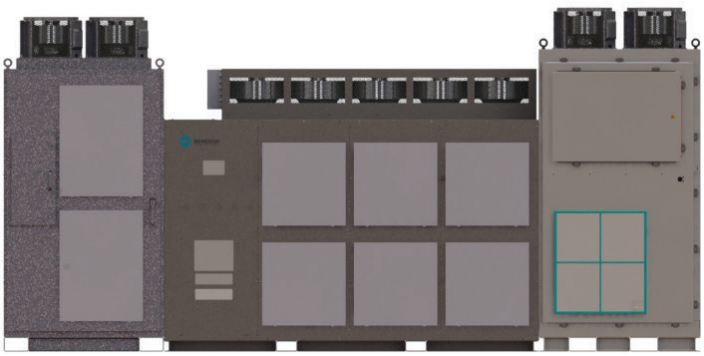
The 2ML design utilizes modular building blocks; therefore, the same components are used to achieve higher horsepower ratings. Using modular building blocks allows the customer to standardize on lower-cost spare parts, minimizing downtime and maintenance costs.

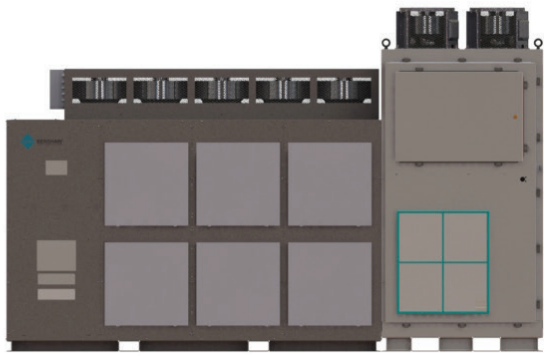
One-Line Diagram with Parallel Drive and Outdoor Transformer



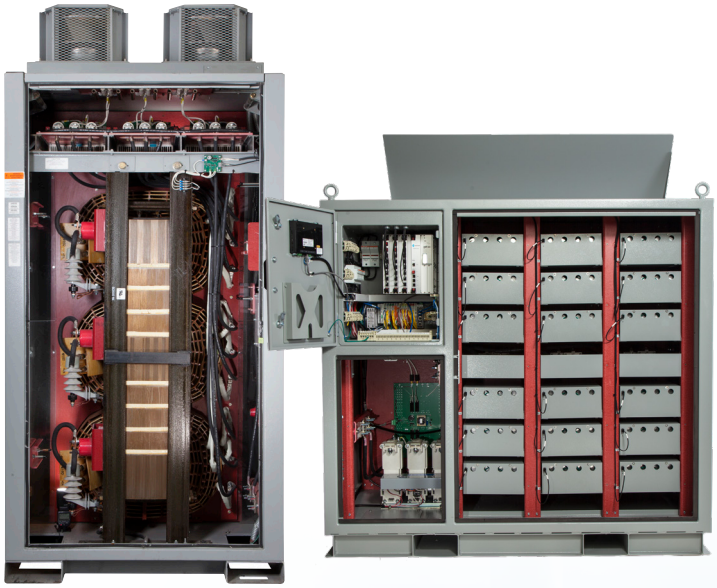
STD- EE — Standard Electrical Ethernet (100 MB)
TC-FO — Time Critical Fiber Optic Inter-Inverter Communication

Line-Up for 8000 HP 4160 V Parallel Drive with Outdoor Transformer





Medium Voltage Drives



M2L Series

- Full Voltage Controls
- Variable Frequency Drives
- Low Voltage Solid State Starters
- Medium Voltage Drives
- Medium Voltage Controls
- Medium Voltage Switchgear

Medium Voltage Drives

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

BENSHAW®
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Electrical Solutions to Mechanical Problems.

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Advanced Controls and Drives

- Full Voltage Controls
- Variable Frequency Drives
- Low Voltage Solid State Starters
- Medium Voltage Drives
- Medium Voltage Controls
- Medium Voltage Switchgear

UNICO Technologies Group

Power and Precision in Motion

Taking care of our customers' power needs has been our single focus for 88 years. Our two leading brands bring innovative control and electrical solutions to solve your challenges. Through thousands of systems in a broad array of applications, we've learned what it takes to make your system live up to its potential.

At a glance: With facilities in 12 countries, we combine the convenience of local service with the economies-of-scale and efficiency of a large global organization.

Innovative solutions via technology: We bring you mission-critical motor control and protection products, designed and built with expertise and precision to maximize your output and minimize downtime.

Engaged and knowledgeable: We like to think of ourselves as "Application Smart," which always includes critical dependencies such as standards, compliance and regulatory issues.

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Power and Precision in Motion

Visit us online at unicotg.com, or contact:

UNICO Technologies Group

3725 Nicholson Road
PO Box 0505
Franksville, WI 53126-0505

After Hours Tech Support

Phone: 800.203.2416

BENSHAW®
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24/7 Technical Support

- 24/7 hotline support from Pittsburgh (USA) and Listowel (Canada)
- Overnight parts shipment
- Coordination of all service capabilities — repair, spare parts, field engineering, retrofit and training

Repairs

- Trained, experienced, field personnel
- Equipped with the latest diagnostic and test equipment
- Start-up commissioning, field repairs, field analysis/data collection and preventative maintenance

Benshaw Product Line

- Solid state starters fractional to 30,000 HP at 15 kV
- LV AC drives to 700 HP
- MV AC drives to 12,000 HP
- Electromechanical controls to 800 A

Benshaw Express

- 24/7 online inventory and order system for authorized Benshaw distributors
- 24/7 shipment
- Air or truck delivery

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BENSHAW, Inc.

615 Alpha Drive
Pittsburgh, PA 15238

Phone: 412.968.0100
Fax: 412.968.5415

BENSHAW Canada

550 Bright Street East
Listowel, Ontario N4W 3W3

Phone: 519.291.5112
Fax: 519.291.2595
1-877-291-5112