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
M2L Medium Voltage Drive

Technical Data

Input Line Specification
• Input voltage
  – 3Ø, 380 V–35 kV ±10%
• Input frequency
  – 50 or 60 Hz ±5%

Motor-Side Specification
• Output voltage
  – 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
• Output frequency
  – 0–90 Hz
• Output power
  – 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

Transformer/Rectifier

Inverter

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.
**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**

<table>
<thead>
<tr>
<th>Order</th>
<th>THD%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td></td>
</tr>
<tr>
<td>7th</td>
<td></td>
</tr>
<tr>
<td>11th</td>
<td></td>
</tr>
<tr>
<td>13th</td>
<td></td>
</tr>
<tr>
<td>17th</td>
<td></td>
</tr>
<tr>
<td>19th</td>
<td></td>
</tr>
<tr>
<td>23th</td>
<td></td>
</tr>
<tr>
<td>25th</td>
<td></td>
</tr>
</tbody>
</table>

- 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**

- PLC
- HMI
- Ethernet switch
- Benshaw Connect™
- PC
- Ethernet RS-485 Industrial
- Communication options
- Ethernet on fiber to cell control board
- Fiber optic fan out board 1
- Fiber optic fan out board 2
- Fiber optic fan out board 3
- LVDS backplane

**Cell Circuit Configuration**

- Cell control board (CCB)
- Power supply
- Isolation loop
- Send
- To FOB
- Receive
- To dc/cell

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

**Benefits**

- 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**

<table>
<thead>
<tr>
<th></th>
<th>Power Loss (kW)</th>
<th>Heat Load (BTU/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer</td>
<td>80</td>
<td>275,000</td>
</tr>
<tr>
<td>Rectifier</td>
<td>10</td>
<td>34,000</td>
</tr>
<tr>
<td>Inverter</td>
<td>25</td>
<td>85,000</td>
</tr>
<tr>
<td>Drive</td>
<td>115</td>
<td>394,000</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Indoor Transformer, Rectifier &amp; Inverter</th>
<th>Outdoor Transformer, Indoor Rectifier &amp; Inverter</th>
<th>Outdoor Transformer &amp; Rectifier, Indoor Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Yearly Operating Cost**

<table>
<thead>
<tr>
<th>Indoor Transformer, Rectifier &amp; Inverter</th>
<th>Outdoor Transformer, Indoor Rectifier &amp; Inverter</th>
<th>Outdoor Transformer &amp; Rectifier, Indoor Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td>$37,000</td>
<td>$11,000</td>
<td>$7,000</td>
</tr>
</tbody>
</table>

**20-Year Operating Cost**

<table>
<thead>
<tr>
<th>Indoor Transformer, Rectifier &amp; Inverter</th>
<th>Outdoor Transformer, Indoor Rectifier &amp; Inverter</th>
<th>Outdoor Transformer &amp; Rectifier, Indoor Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td>$788,000</td>
<td>$225,000</td>
<td>$158,0001</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel connected inverters</td>
<td>Extending air-cooled solution for HPs beyond traditional power limits</td>
</tr>
<tr>
<td>Single transformer and rectifier</td>
<td>Significant cost savings on equipment and real estate</td>
</tr>
<tr>
<td>Outdoor installation of transformer</td>
<td>Minimized indoor heat-load and air-conditioning requirements</td>
</tr>
<tr>
<td>and rectifier</td>
<td></td>
</tr>
<tr>
<td>Seamless control integration</td>
<td>Single operator interface (HMI) and process control</td>
</tr>
<tr>
<td>Option for redundant inverter</td>
<td>Highest reliability and availability on the market</td>
</tr>
</tbody>
</table>

**Parallel Inverters Running Multiple Motors**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel connected inverters</td>
<td>Optimized solution for applications with multiple motors</td>
</tr>
<tr>
<td>Single transformer and rectifier</td>
<td>Significant cost savings on equipment and real estate</td>
</tr>
<tr>
<td>Outdoor installation of transformer</td>
<td>Minimized indoor heat-load and air-conditioning requirements</td>
</tr>
<tr>
<td>and rectifier</td>
<td></td>
</tr>
<tr>
<td>Independent or integrated control</td>
<td>Optimized process control</td>
</tr>
<tr>
<td>Minimized component count</td>
<td>Increased reliability and availability</td>
</tr>
</tbody>
</table>
# M2L Medium Voltage Drive

*Designed for Reliability*

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

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

\(^1\) 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.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front access only</td>
<td>No rear access required</td>
</tr>
<tr>
<td>Modular power cell based inverter</td>
<td>Faults isolated to a power cell</td>
</tr>
<tr>
<td>Rack-out power cells</td>
<td>Easy and fast power cell replacement</td>
</tr>
<tr>
<td>Film capacitors</td>
<td>No capacitor reforming required</td>
</tr>
<tr>
<td>Modular fan cage design</td>
<td>Easy and fast fan replacement</td>
</tr>
<tr>
<td>Built-in self test (BIST)</td>
<td>Safe and fast system checks</td>
</tr>
<tr>
<td>24/7/365 service and support</td>
<td>Ease of mind</td>
</tr>
</tbody>
</table>
M2L Medium Voltage Drive

Advanced Control Features

Start, Stop and Speed Functions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple start functions</td>
<td>Accelerate from zero, flying start, DC brake then start</td>
</tr>
<tr>
<td>Multiple stop functions</td>
<td>Decelerate to zero, coast to stop, decelerate or coast then DC brake</td>
</tr>
<tr>
<td>Multiple acceleration and deceleration profiles</td>
<td>Linear, U-curve, S-curve</td>
</tr>
<tr>
<td>Advanced speed functions</td>
<td>Skip frequencies, dwell frequency, optimal deceleration</td>
</tr>
</tbody>
</table>

Protective Functions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc flash detection</td>
<td>Fast and reliable arc flash detection system in each power cell</td>
</tr>
<tr>
<td>Motor protections</td>
<td>Ground fault, thermal overload, overcurrent and undercurrent, speed control</td>
</tr>
<tr>
<td>Drive protections</td>
<td>DC link overvoltage and undervoltage, DC link ripple, output and input phase loss, overcurrent and undercurrent, pre-charge failure, control failure</td>
</tr>
<tr>
<td>Power cell protections</td>
<td>Arc flash detection, communication failure, overvoltage, overcurrent, overtemperature</td>
</tr>
</tbody>
</table>

1 Not all functions are shown.

Output Frequency

- Configurable linear acceleration and deceleration
- Configurable U-curve acceleration and deceleration

Time to Trip

- Adjustable motor thermal overload trip
- Advanced skip frequency function
User-Friendly Operator Interface

User Interface Features

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMI functions</td>
<td>Touchscreen, local or remote operation, advanced value/trend monitoring, easy configuration and diagnostics</td>
</tr>
<tr>
<td>Benshaw Connect™</td>
<td>Seamless wired or wireless connectivity, advanced value/trend monitoring, easy configuration and diagnostics</td>
</tr>
<tr>
<td>Communication protocols</td>
<td>Modbus TCP/IP, PROFIBUS DP, Modbus RTU (consult factory for other communication protocols)</td>
</tr>
<tr>
<td>PLC I/O</td>
<td>Fully customizable user I/O modules for every application possibility</td>
</tr>
</tbody>
</table>

Benshaw Connect™

- Touchscreen HMI
  - OUTPUT (Hz): 60.00
  - Real-time operational status indicator
  - DC Pole Voltage: 6070
  - DC Bus Current: 130
  - Peak Temp (°C): 50
  - Motor Voltage LL: 4160
  - Phase Currents: A: 120, B: 120, C: 120
  - Motor kW: 746

- Real-time operational values screen
- Type and value of PLC I/Os
- Power cell voltages and temperatures

Easy access to parameters and meters

Easy access to I/Os

Customizable trend monitoring

*Not all screens are shown.*
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 reducing the 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
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

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

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

M2L Series

Electrical Solutions to Mechanical Problems.

Benshaw.com
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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