PowerFlex Medium Voltage Drives with Direct-to-Drive Technology — Eliminating the Isolation Transformer

Transformerless drives help industry reduce the cost of motor control while using standard motors.

Looking for ways to reduce the cost of motor control and condense valuable control room space?

Innovative medium voltage drive technology offers an alternative to large and costly transformers (previously the only option for mitigating harmonics and common mode voltage).

Advanced medium voltage drives no longer require a transformer to address these issues. Transformerless drives save floor space and reduce weight, as well as capital, installation and maintenance costs – all while using standard motor and cable insulation.

This paper looks at the technology of the Rockwell Automation PowerFlex 7000 transformerless drive and the cost savings associated with using Direct-to-Drive technology. Rockwell Automation was the first to introduce this technology and continues to lead with experience and further innovation.

Direct-to-Drive Technology

Historically, in a medium voltage motor AC drive (2.4 kV to 7.2 kV), the power converters generate common mode voltages. If not properly accounted for in the design, these voltages can add stress, which in turn can cause premature failure of the motor winding insulation. Transformers are typically used to absorb this common mode voltage, and can also be used to mitigate harmonics with multi-pulse configurations. However, transformers increase the size, cost, complexity and power losses of the drive system.

Advanced engineering in medium voltage drives has led to the use of Pulse Width Modulation (PWM) switching patterns and an integrated DC choke. This helps to accomplish the original goals of the transformer, but without sacrificing space, and achieving reductions in size, weight, cost and maintenance.
Harmonic Mitigation

Advances in semiconductor technology and CSI rectifier design have resulted in the introduction of Pulse Width Modulation switching patterns as an alternative method of harmonic reduction using PWM rectifiers (also known as Active Front End rectifiers or AFE) and Selective Harmonic Elimination (SHE).

An AFE rectifier is used as the input stage, without the need for a transformer. The higher switching frequency operation is achieved by using the Symmetric Gate Commutated Thyristor (SGCT) – an integration of the power semiconductor, its gate driver and reversing diode. Reduced gate inductance allows higher switching frequencies and current PWM patterns (SHE) that eliminate major harmonics right at the rectifier source, minimizing snubber requirements. The Total Harmonic Distortion (THD) of the input current is within IEEE-519 harmonic guidelines. Both input and output current and voltage waveforms are near sinusoidal, resulting in very low voltage stress on the motor winding, even when connected with long cables. With this technology, a transformer for the purpose of harmonic mitigation is not necessary.

Common Mode Voltage Mitigation

The usual method to mitigate common mode voltage (CMV) has been with the use of isolation transformers. This is accomplished by grounding the neutral point of the DC link (on VSI), or by grounding the neutral of the motor or wye point of the drive output through a grounding network. Although the motor is protected from common mode voltage by an input isolation transformer, the high level CMV stress that would have been imposed on the motor is now imposed on the transformer and line side cable insulation. Extra transformer and cable insulation is required to withstand the CMV stress, adding engineering and extra costs.

In Direct-to-Drive or D.T.D technology, an integrated DC choke adds impedance to the common mode circuit, eliminating CM current and voltage. The drive design integrates common mode impedance into existing components. The result is a drive capable of using standard motor and cable insulation designs without an isolation transformer. No additional insulation is required on the transformer or motor.

Reduced Size and Weight of Drive System

An isolation transformer can represent 30-50% of the drive system size and 50-70% of the weight. Drive system reduced size and weight are a strategic advantage for industries worldwide. Use of transformers and control room space is challenging and expensive. For example, on oil and gas platforms and in dense cities or applications with existing restrictions. Transformers can also be problematic at high altitudes due to the lower
cooling and insulating characteristics of lower density air. A transformerless MV drive is perfect for retrofit, process improvement or energy savings projects with existing motors, switches and control rooms, where space is often limited or at a premium.

A drive using Direct-to-Drive technology is typically smaller and lighter than drive technologies using isolation transformers. The typical volume of space required for a 750 kW (1000 Hp) drive with isolation transformer is 9.8 m$^3$ (346 ft$^3$), and typical weight is 4300 kg (9,460 lbs). The transformerless PowerFlex 7000 drive of the same voltage and power is 36% smaller at 6.3 m$^3$ (223 ft$^3$) and 32% lighter at 2955 kg (6500 lbs). A smaller and lighter drive system is easier to handle and install.

**Buckeye saves space and cost with Direct-to-Drive technology**

Buckeye Partners, L.P. has purchased four medium voltage drives with Direct-to-Drive technology from Rockwell Automation for the reduced space, weight benefits, and associated cost savings. Two 4000 Hp liquid-cooled medium voltage drives, commissioned in March 2005 for a capacity increase project on its Pennsylvania pipeline, were built into power control houses and then transported as a complete unit to the pipeline. A third transformerless drive, at 2000 Hp, was also commissioned in 2005 for the same project.

“Transformerless drives saved space in the control house,” said David Heine, Station and Terminal Engineer at Buckeye. “We would have either had to make the control house bigger or build a foundation and run cables to put a transformer outside. Either way, it would have added complexity and costs, as well as the cost of the transformer itself.”

Space, weight and related cost savings of the transformerless drive motivated Buckeye to purchase a fourth drive, at 1250 Hp, for an additional capacity increase along the pipeline, scheduled for installation in late 2006.

**Lower Total Cost of Drive Ownership**

The most significant benefit to using a transformerless drive comes down to dollars. The reduced capital cost of not having to buy a transformer (ranging from $40,000 to $200,000), reduced operating and service costs, lower transportation and installation expenses, cabling costs, and increased operating efficiency all contribute to a lower total cost of ownership.

The Direct-to-Drive design reduces initial capital investment, because it not only eliminates the need to purchase an isolation transformer, it also eliminates the need for an isolation transformer protection relay, a DV/DT filter, sine filter or motor terminator, and special cables.

Overall operating costs are also reduced due to the transformerless CSI medium voltage drive's higher efficiency and inherent regenerative capability that delivers any power generated back to the utility. Incorporating CM impedance in to the DC Link reactor creates some additional losses, but far less than is gained by the removal of a transformer. The drive can provide 100% continuous full current in motoring or regenerative modes.
## Drive Technology Comparison – Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Direct-to-Drive Technology</th>
<th>Pulse Drive with Isolation Transformer</th>
<th>Drive with Line Reactor and Special Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Cost</td>
<td>$</td>
<td></td>
<td></td>
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<tr>
<td>Isolation Transformer Cost</td>
<td>$</td>
<td></td>
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<tr>
<td>Motor with Extra Insulation</td>
<td>$</td>
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<tr>
<td>Increased Input Cable Insulation Cost</td>
<td>$</td>
<td></td>
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<tr>
<td>Increased Output Cable Insulation Cost</td>
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<tr>
<td>Transformer Protection Relay</td>
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<td>Transformer Shipping and Handling</td>
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<td>Transformer Installation Cost</td>
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<tr>
<td><strong>Total</strong></td>
<td>$</td>
<td>$$$$$</td>
<td>$$</td>
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## Drive Technology Comparison – Efficiency

<table>
<thead>
<tr>
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<th>Drive with Line Reactor and Special Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Transformer Efficiency</td>
<td>N/A</td>
<td>98%</td>
<td>N/A</td>
</tr>
<tr>
<td>Typical Drive Efficiency</td>
<td>97-98%</td>
<td>97.5-98.5%</td>
<td>97-98%</td>
</tr>
<tr>
<td>Total System Efficiency</td>
<td>97-98%</td>
<td>96.5-97.5%</td>
<td>97-98%</td>
</tr>
</tbody>
</table>

Shell Canada purchased a medium voltage drive with Direct-to-Drive technology in 2004 to control a vacuum bottoms pump at its Fort Saskatchewan, Alberta, oil upgrader facility. Colt Engineering, an Edmonton engineering consulting firm, oversaw the specification, design and implementation of the system. Colt Engineering determined that the transformerless drive was the best solution based on the ease of installation, space savings, and the resultant cost savings due to the elimination of the transformer and the re-use of existing cables.

"By utilizing the PowerFlex 7000 drive with transformerless Direct-to-Drive technology, we were able to reduce the capital cost of the project by using the existing motor and cables," said Monte Zobell of Colt Engineering. "Other technologies would have required us to upgrade both the motor and the cable or install an isolation transformer. The resultant savings to the project were estimated to be in the order of $50,000 dollars when the cost of the cable and its installation were considered, which was a substantial savings."
Applications

Applications for PowerFlex 7000 Medium Voltage Drives with Direct-to-Drive technology include pumps, fans, and conveyors in these industries:

• Petrochemical
• Water/Wastewater
• Mining, Aggregate & Cement
• Pulp & Paper
• Marine propulsion
• Metals
• Rubber
• Utilities

Conclusion

Customers worldwide have the ability to specify a smaller, lighter, more efficient and highly reliable medium voltage drive. That same drive will use less control room space, save initial costs and continue to save money in the long term. The ability to use existing motors and cables also adds significant savings.

The rising and hidden costs of transformers

The cost of power and distribution transformers is ever-increasing as the cost of raw material rises. Price for copper has increased more than 250% in the past 4 years.

An isolation transformer adds to total project costs with extra cabling, air conditioning to cool the transformer, civil engineering, concrete pad construction for outdoor transformers and oil containment systems. A transformerless drive reduces costs through greater efficiency because there are no transformer losses.

Costs for isolation transformer crating, handling and transportation are also eliminated. Shipping large transformers can add extra costs you don’t see a return on. International shipments of transformers too large for container storage have to be specially crated and shipped on the deck, which can cost extra thousands of dollars. An isolation transformer shipment to Argentina from the U.S. added costs of $18,700 US when no vessels were available to take break-bulk cargo. The transformers had to be sent to a New York port to be shipped, for a total of 25 days transit time.

In a typical situation, shipping the transformer overseas will add more than $4000 and three to four weeks transport time. If a transformer fails, this transportation time for the replacement equipment represents significant downtime and potential lost revenue.