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PowerFlex Medium Voltage Drives
Direct-to-Drive technology
eliminates isolation transformer

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

ALLEN-BRADLEY • ROCKWELL SOFTWARE **Rockwell Automation**

For industry 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 the large and costly transformers that were once 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 using standard motor and cable insulation.

This paper looks at the technology of a transformerless drive and the cost savings associated with using a transformerless drive.

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PowerFlex 7000 medium voltage drives with Direct-to-Drive technology combine three innovations:

- *Pulse Width Modulation converters (or Active Front End rectifiers)*
- *SGCT (Symmetric Gate Commutated Thyristor)*
- *Integrated dc choke (or common mode impedence)*

Direct-to-Drive Technology

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

Advances made in medium voltage drives now use Pulse Width Modulation (PWM) switching patterns and an integrated dc choke to accomplish the original goals of the transformer, but without sacrificing space, and achieving reductions in size, weight, costs and maintenance.

Harmonic mitigation

In the past decade, advances in semiconductor technology resulted in the introduction of Pulse Width Modulation switching patterns as an alternative method of harmonic reduction using PWM converters (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 high switching frequency operation is achieved by using the Symmetric Gate Commutated Thyristor (SGCT) - an integration of the power semiconductor and its gate driver. The gate driver and power semiconductor in close proximity gives it a superior switching pattern that prevents the drive from producing high levels of line current harmonics and minimizes snubber requirements. The Total Harmonic Distortion (THD) of the input current is within IEEE-519 harmonic guidelines. Both current and voltage waveforms are near sinusoidal, resulting in no voltage stress on the motor winding, even if connected through long cables. With this technology, a transformer for the purpose of harmonic mitigation is redundant.

Common Mode Voltage Mitigation

The common method to mitigate common mode voltage (CMV) has been the use of isolation transformers, either by grounding the neutral point of the DC link, or by grounding the neutral of the motor or wye point of the output filter capacitors through a grounding network. Although the motor is protected from common mode voltage using transformers, the high level CMV stress that would have been imposed on the motor is now imposed on the transformer and cable insulation. This requires extra transformer insulation and cable insulation to withstand the CMV stress, adding extra engineering requirements and extra costs.

The integrated dc choke is used to block the common mode voltage and mitigate motor neutral to ground voltage. The drive utilizes existing components by integrating common mode impedance. The result – a drive capable of using standard motor and cable insulation designs, without an isolation transformer.

Combining the innovations of the common mode impedance, active front end rectifier and SGCT, resulted in the patented Direct-to-Drive technology from Rockwell Automation. The company collaborated with The Ryerson Power Research Team, of Ryerson University in Toronto, to develop a transformerless option for its medium voltage drive. Direct-to-Drive technology connects the power supply directly to the medium voltage drive without an isolation transformer. Both the inverter and the rectifier use SGCTs, and both operate at optimal switching frequency to minimize the switching losses. Industries can use standard motors and will not require any extra motor or cable insulation.

Reduced Size and Weight of Drive System

An isolation transformer can represent 30-50% of a drive system's size and 50-70% of the system's weight. Reduced drive system size and weight are a strategic advantage for industries world-wide, where use of transformers and control room space is challenging and expensive, such as on oil and gas platforms and in dense cities. Transformers can be also problematic at high altitudes due to thinner air cooling and insulating characteristics. 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.

Space and Weight comparison of a 1250hp (950kW) drive:

1. *With isolation transformer:*

   459 cubic feet (13 m3)
   9,259 lbs (4200 kg)

2. *PowerFlex 7000 MV drive with Direct-to-Drive technology:*

   60% smaller at
   190 cubic feet (5.4m3)

   65% lighter at
   2976 lbs (1350 kg)

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 1250 hp (950 kW) drive with isolation transformer is 459 cubic feet (13 m3), and typical weight is 9,259 lbs (4200 kg). The transformerless PowerFlex 7000 drive of the same voltage and power is 60% smaller at 190 cubic feet (5.4 m3) and 65% lighter at 2976 lbs (1350 kg). 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 and 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 biggest benefit to using a transformerless drive comes down to dollars. The reduced capital cost of not having to buy a transformer (ranging from $15,000 to $150,000), 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 medium voltage drive's high efficiency and inherent regenerative capability that converts the variable frequency power generated to a signal that can be pushed back to the utility. The drive can provide 100% continuous full current regenerative braking capability without putting thermal stress on the motor.

Drive Technology Comparison

Cost Comparison	Direct-to Drive Technology	#-Pulse Drive with Isolation Transformer	Drive with Line Reactor and Special Motor
Drive Cost	$	$	$
Isolation Transformer Cost		$	
Motor with Extra Insulation			$
Increased Input Cable Insulation Cost		$	
Increased Output Cable Insulation Cost			$
Transformer Protection Relay		$	
Transformer Crating Cost		$	
Transformer Shipping Cost		$	
	$	$$$$$$	$$$
Efficiency Comparison			
Typical Transformer Efficiency	N/A	98%	N/A
Typical Drive Efficiency	97-98%	97-98%	97-98%
Total System Efficiency	**97-98%**	**95-96%**	**97-98%**

Shell uses existing motor and cable with PowerFlex 7000 Direct-to-drive technology for substantial savings

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 by6 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.”

Conclusions

Customers world-wide now have the ability to specify a smaller, lighter, more efficient and highly reliable medium voltage drive that 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.

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
- Wind Tunnel
- Marine

The rising and hidden costs of transformers

The cost of power and distribution transformers is ever-increasing as the cost of raw material rises. Grain-oriented steel used in producing transformers is in tight supply as there are a limited number of steel mills that produce this high grade of electrical steel, and global demand has increased. Pricing of grain-oriented steel in early 2006 was approximately 258% higher than it was in 2004 according to pricing indexes at National Material Company.

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 overall installation. 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 the customer 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.

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