High power applications now have motor control solution options - either low voltage or medium voltage drives. Find out how to analyze your options and determine the best solution for your specific application...

Historically, the task for low voltage users has been relatively straightforward; choose one supplier from many in the market, based on a number of criteria including price, reliability, functionality, and communications. However, for a drive control solution for larger industrial loads, the situation is not so clear-cut. Until quite recently, most engineers faced with a high-power application would choose a low voltage (LV) drive system working at very high levels of current.

The alternative of a medium voltage (MV) drive was not very attractive, due to perceived high purchase cost, physical size, requirement for custom engineering and high installation costs. Recently though, the MV drive, in particular Rockwell Automation's PowerFlex 7000 series, has shed this costly and unwieldy image and is offering a real alternative to LV drives in the higher power sector; especially where installations are judged across a wide range of criteria, rather than just initial drive cost.

The New Medium Voltage Drives
There are a number of reasons for heightened levels of interest in MV drives:
- **Increased selection** - most major manufacturers now have an MV product;
- **Advances in power semiconductor switches** - new devices such as SGCTs (symmetrical gate-commutated thyristors) improve packaging, increase reliability, and reduce overall drive cost; and
- **Standardisation** - in the past most MV drives were highly engineered products with lead times of six months or more. Today, greater levels of standardisation are substantially reducing delivery times for most 'standard' MV drives.

There are also several other major advantages. First, the transformerless design of Rockwell Automation's PowerFlex 7000 MV drive, reduces drive system size by 30% to 50%, and drive system weight by 50% to 70%. This design contributes to a lower total cost of ownership with improved system efficiency, by eliminating transformer heat losses, and air conditioning costs to cool the transformer. Second, the ease of use...
of the PowerFlex 7000 drive, provided by a user-friendly operator interface terminal with an interactive set-up wizard that facilitates fast start-ups, smooth operation and reduced downtime.

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Third, the patented Power Cage™ modules allow for quick replacement of power devices in less than five minutes.

Fourth, the ability of the MV drives to offer inherent, 4-quadrant regeneration capability, where LV drives are standard 1-quadrant.

Drive Comparison Analysis
The emergence of MV drives and their greater acceptance, generally, should not imply that the solution to every high-power application is an MV drive. No two applications are the same, and this means that, in applications where there is more than one possible solution, (i.e. LV or MV), then the most cost-effective strategy is to conduct an analysis of the benefits of the two potential systems. With different manufacturers’ products this can be difficult; however, with Rockwell Automation providing the PowerFlex series right across the power range, through LV up to 690V and 1500kW and MV up to 6,600V and 12 MW, an effective comparison is achievable.

Power
In some cases comparisons are unnecessary as the decision to go LV or MV is simply a question of the amount of power available in the distribution network at each voltage. If adequate power is available at more than one voltage rating, then the choice of selecting LV or MV has to be based on another factor.

Cost
The first area to be considered is cost. Even with recent developments, Medium Voltage AC Drives are not inexpensive; typically, the cost of a Low Voltage AC Drive and an Output (Step-Up) Isolation Transformer is only 50% to 75% of the initial cost of a Medium Voltage AC Drive. However, as the application current increases, the system fault current also increases. This may have safety repercussions and could affect the cost of the drive system. However, initial price is only part of the total solution, and, as we shall discuss later, when the costs for cabling and installation are added, the equation between the two drive options may be balanced out.

Drive topology
After initial cost considerations, the question becomes one of technical issues, such as: what drive architecture, or topology, is best suited to provide continuous, efficient and reliable operation at high power? This question is fundamental, because, at high power, the equipment investment is greater, as are the demands of the application. This means that VFD output power quality is an extremely important consideration for protecting the motor investment and ensuring its continued availability.

In terms of LV architectures, the most common is PWM (Pulse Width Modulation) VSI technology. This offers good levels of reliability, but does suffer losses in efficiency with each on/off switching
transition. In addition, the true levels of voltage and dv/dt rise produced by the pulse width modulation of voltage operation, may cause reflected waves, motor insulation stresses and ground fault currents. In contrast, the SGCTs in the PowerFlex 7000 MV drives are designed for high-voltage operation and ensure the lowest switching and conduction losses, while maintaining a high switching frequency. In addition, the SGCTs offer a simplified power structure, with the minimum of components to optimize reliability.

Harmonics Reduction
The simplified power structure of the PowerFlex 7000 also provides benefits in harmonics suppression. As more applications convert to VFD control, there is a greater emphasis by utilities to comply with harmonic standards such as IEEE 519, EN61000-2-4 and G5/4. Therefore, VFD manufacturers have incorporated methods to reduce harmonics in their VFD designs. With high-pulse number LV VFDs, and some MV drives, one common method of achieving harmonic reduction is through an isolation transformer with multiple phase-shifted secondary windings. These work on the principle of "the higher the pulse number, the greater the degree of harmonic reduction."

However, at high pulse numbers, of 24-pulse and greater, it is difficult to balance the electrical symmetry of the transformer secondary windings. In addition, some manufacturers have limitations on the distance between the VFD and transformer to prevent overheating problems.

Transformerless Direct-to-Drive Technology
The problems of cost, complexity and added weight, size and heat that transformers bring to LV and most MV systems, have motivated Rockwell Automation to design a series of MV drives that do not require them.

The technology is known as Direct-to-Drive: it allows utility power to be connected directly to the PowerFlex 7000 drive without an isolation transformer; and new or existing motors to be connected directly to the drive, eliminating unnecessary motor filtering. Instead of a transformer, Direct-to-Drive enables the PowerFlex 7000 with a highly-compact active front-end rectifier that reduces harmonics by active switching and selective harmonic elimination. Direct-to-Drive technology also reduces common mode voltage to levels suitable for existing motors, but with no transformer or transformer protection relays required, offers users the substantial benefits of reduced equipment and cabling costs, reduced installation, and also savings in floor space.

Reduced Size and Weight
The ability of Direct-to-Drive technology to save space also impacts two other areas where a direct comparison between LV and MV drives is essential: their relative size and weight. When analyzing these factors it is important to include all components that make up the drive solution: the VFD; the input impedance; output impedance; input disconnect device; and input and output filters. This is not a problem with MV systems as they are traditionally supplied as totally integrated and cabled solutions. Normally this would mean that they are bulkier and heavier; however, by using the Direct-to-Drive transformerless technology in the Powerflex 7000 MV drive, the MV drive
package becomes competitive in terms of both size: with reductions of between 30% and 50% compared to conventional systems, and weight: reductions being anywhere between 50% and 70%.

The size and weight calculation is not always straightforward with LV systems. Manufacturers often provide the system components separately because of a number of advantages: the ability to distribute components of the system throughout areas such as control rooms; easier movement of components through areas of restricted space during installation; components being lighter to move individually; and, finally, cooling of the drive. In general terms, though, a packaged LV system would definitely be smaller and lighter than an MV system based upon conventional architecture, but the margin between the systems would be much closer using the Direct-to-Drive technology of PowerFlex 7000.

**Cabling Costs**

Cable cost must be determined as part of the VFD solution because of its impact on total cost of ownership. Cable size and cost vary with the level of current they conduct: the higher the current, the larger the cable, and the greater its cost. This means that for LV drives at high power, cable and installation costs are high. In addition, LV installations require expensive shielded EMC (Electro-Mechanical Compatibility) cable. The contrasting expense for MV systems is much less, due largely to the lower current their cables carry, and the fact that they do not need to employ EMC shielded cables. In addition, by using a transformerless PowerFlex 7000 MV drive, cabling and wiring costs are cut further still.

The example below shows that the cable cost difference between the 480V and the 4160V VFD solutions grows disproportionately as the motor current increases. Moreover, the distance between the source, the VFD and the motor have a big impact on cable cost, especially at high powers.

**Cooling Costs**

In addition to cabling, another cost that must be included when comparing VFD solutions is cooling. All equipment that
uses or handles power generates a certain amount of heat. With high-power drive systems in enclosures, this heat can be a particular problem. Consider LV drives; most are air cooled, and at high power, heat losses can become significant: for example: a 3% loss at 2MW is 60kW, a figure which would well justify the use of air conditioning to cool the drive and its associated components.

The alternative of liquid cooling effectively removes about 90% of the heat generated by the VFD losses out of a control enclosure, but involves additional costs for pumping cabinets and heat exchangers if not already available on site.

The decision between air conditioning or liquid cooling is usually application-based, and best made after assessing the availability of either option at the site. For example, in the water industry the availability of liquids and pumping equipment may offer distinct benefits when selecting liquid cooling solutions.

Communications
An important consideration in the LV versus MV debate is communications. For users, the question is: if I choose an MV drive will it give me the same capability for integration into factory-wide automation networks as LV drives? LV drives are more commonly associated with the communication interfaces that facilitate factory networks. However, Rockwell Automation has taken a lead with its PowerFlex range of LV and MV drives, by ensuring that they all offer the same communication options, and, in addition, employ the same programming and software tools.

Maintenance
Finally, there has to be the question of service and maintenance. Many plant maintenance engineers are comfortable with LV AC drive applications, but have concerns regarding medium voltage applications, which they may see as very complex solutions that are almost always installed, commissioned and maintained by the drive supplier. The concerns are expense and dependence on the manufacturer.

How relevant these concerns are today is debatable: certainly custom engineered products of the past were unwieldy and required highly specialized attention, usually above and beyond that available from internal plant personnel. However, the move to more modular MV systems, as epitomized by the PowerFlex 7000 family is simplifying MV structures, making their acceptance more widespread and their application more understood in the same way as LV types.

The decision to re-evaluate pre-conceived perceptions when looking at both solutions and taking into account the discussed points may result in a change in solution or may re-affirm your choice in the solution you currently adopt. The informed choice is now yours.