Fluid Couplings vs VFDs for High Inertia Rotating Driven Loads

A Selection Guide Reviewing the Merits of Both Options

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As the old adage goes, "There is more than one way to skin a cat." In the early stages of any project, system designers are faced with choices; whether they are designing a new application or retrofitting an old one, they need to determine what is the most efficient, economical and practical way of completing the task at hand. Though there are usually at least two viable means to accomplish the task, the first step is always to review and weigh the merits of each option. Fully understanding these options, as well as the benefits and drawbacks of each, will invariably lead to a better, more robust design. Not weighing these possibilities can lead to project delays and budget overruns.

When it comes to high inertia, rotating driven loads, several factors should be addressed. Startup and slowdown behaviors are typically the primary concerns but attention must also be given to the behavior of the equipment while running. Applications can vary from large conveyor systems, crushers, pumps, fans or any number of equipment types. Each application will have its own operating nuances, and these will need to be considered during the design process.

For handling the startup/slowdown and operational running dynamics of a high inertia, rotating driven load, two options are commonly reviewed: fluid couplings and variable frequency drives (VFDs). Starting and stopping any high inertia load and dealing with the massive potential energies of such a system is always a challenge. If you then add the potential shock loads, resonance issues or any number of other concerns that typically accompany this style of system, you can see that particular attention must be paid to mitigating these factors. Ramp up, ramp down and dampening become of paramount importance, and controlling/protecting the prime mover is a critical design concern.

Both fluid couplings and VFDs have inherent benefits and drawbacks. Understanding these benefits/drawbacks as well as the application at hand will allow for choosing the most appropriate solution for a particular application. The following discussion of technical intuition may assist those facing these design challenges at the project's onset.

Variable Frequency Drives (VFDs)

Before discussing the merits of a VFD, let's first discuss its operation and the applications for which they are used. A VFD is an electronic device often used in place of a magnetic motor starter. Its purpose is to start/stop a motor as well as to control its speed, speed ramps, current draw and a wealth of other control features. (For the purpose of this article, when we discuss a motor it will be assumed it is in reference to an induction squirrel cage motor.)

VFDs accomplish this motor control by utilizing solid state switching to first rectify incoming power into Direct Current (DC) and then invert that to outputted power as Alternating Current (AC) at a variable frequency. With reference to speed control of a motor the equation is as follows:

$$N = \frac{120f}{p}$$

Where:
N = Synchronous Speed
f = Frequency in Hz
P = # of Poles in the Stator

When looking for variables to modify speed over a broad range in this equation, frequency immediately stands out as the best opportunity. This is where the core value of a VFD lies. By changing the frequency of the outputted current we are able to control a motor's acceleration, deceleration and velocity while also controlling current draw and overload dynamics. This ability to control current is often thought of as a secondary benefit but it should not be overlooked. The algorithms and user interfaces offered today make this a feature almost as important as the speed control depending on the application.

As applied to high inertia rotating driven loads, a VFD would be used to control the motor (prime mover) used to drive the load. When looking to mitigate the issues associated with startup, slowdown and dynamic speed control of a high inertia rotating driven load, being able to control velocity, acceleration and deceleration by varying frequency is pretty self-evident. VFDs typically utilize an observer control system that offers excellent results given the algorithms currently in use. This control can also be upgraded through the implementation of a motor speed encoder. This additional feature allows for a very robust control and has the added benefit of system monitoring for operators. As utilizing a speed feedback sensor for a high inertia rotating load application is fairly commonplace, the additional cost for implementation is often negligible.

The ability to slowly ramp up a high inertia rotating load allows for the use of a smaller prime mover and can lower the overall cost of other mechanical components within the system. Dynamic speed control of such a load is also a very useful feature and can help add to the overall versatility of a system. A good example would be the ability to control the speed of a boiler in-feed pump at a power generating station. These days it is critical for power plants to be able to dynamically react to renewable energy sources that are feeding the grid at unpredictable rates, system features like the aforementioned are needed to accomplish this. Deceleration control is another critical feature for a high inertia rotating load. If the potential energy of the system is not properly dispelled in a controlled manner, it can have grave consequences for both the system and those that operate it.

Deceleration in particular is a large concern during system design. Luckily, most VFDs now offer a feature for dynamic braking/regeneration that will allow for a motor to act as a generator during deceleration/braking period. The energy that is generated during this cycle can then either be reintroduced to the grid (offering an energy savings) or dissipated over a set of braking resistors. This feature although sometimes overlooked, can offer excellent control and the breaking power available is only limited by the physical constraints of the prime mover (i.e., the power generated by the motor during deceleration). This can be a very effective means of breaking for such applications.

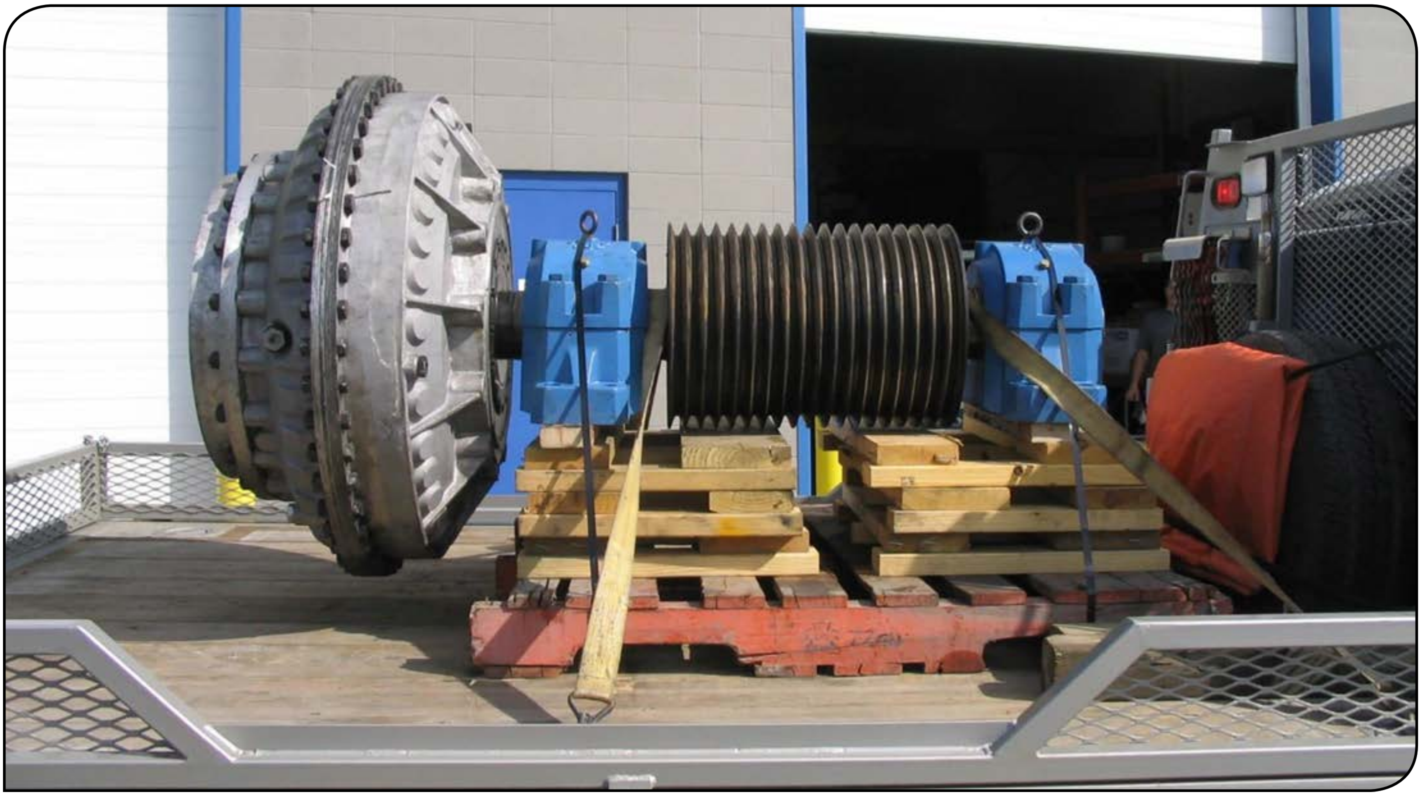
The control systems included in most VFDs today make them much more than a simple means of controlling motor speeds. Often manufacturers incorporate user programmable control systems with inputs/outputs (both digital and analog) and a wide range of communication protocols. This means that for some systems, the VFD can also be used as a standalone control platform, further reducing integration costs. The ever-growing options for communication protocols also make integration into existing control systems evermore seamless.

The evolving control platforms now offered on most VFDs make programming current control/overload dynamics much easier. This allows for advanced means of ensuring that both the equipment and power grid to which it is attached is protected. This current control will not eliminate torsional vibration or shocks transmitted from the load to the motor but it does allow for the control of how the motor reacts by means of controlling the current available. This feature can also be used to trigger alarms, limit current draw/dynamics or trip the system if the current draw of the motor exceeds a predetermined value, value over time, or even value acceleration as defined by the programmer. Such features can help prevent/reduce the instance of catastrophic failures and provide operators and maintenance staff with a better understanding of the condition of the equipment. Current draw can also be trended and used to provide operating baselines under different operating conditions, another tool that can be used to determine/evaluate equipment life/condition.

Fluid Couplings

Fluid couplings are mechanical couplings that are filled with a fluid, typically oil. A common example and one that most people would recognize is a torque converter in any vehicle with an automatic transmission. The fluid coupling (or torque converter as it is commonly known) is used to couple the prime mover (the engine, typically gas or diesel driven) to the transmission of the vehicle. The fluid coupling is what enables an automatic transmission vehicle to be at rest while the engine is running and also controls the dynamics of starting and stopping the drivetrain of the vehicle. As anyone who has ever stopped at a red light while driving such a vehicle knows, this is a very convenient feature. When stopped at the light, the engine is still turning at idle speed but the coupling is allowing for 100% slip, thus keeping the engine from stalling and the vehicle from moving.

A fluid coupling is able to accomplish this feat by way of



Refurbished crusher drive assembly for a coal fired power plant. Photo courtesy of Motion Industries (Canada) Inc. service center in Edmonton, AB.

both a simple and eloquent design and construction. In its most basic form, it can be thought of as two coupling halves or bladed wheels enclosed by a housing. These two halves are not mechanically linked but are submerged inside the same body of fluid. As the drive side begins to turn, it is free to move independent of the driven side. As the speed increases, gradually energy is transmitted via hydro dynamic forces from the drive side to the driven side.

The amount of energy that is transmitted (i.e., the level of slip) is highly dependent on the level of fluid within the coupling and the speed at which the drive side is turning. Starting, stopping and running dynamics of a system can be modified/customized by varying the level within the coupling housing. Furthermore, level control is a feature that can be dynamically controlled through the addition of an external hydraulic circuit. This can allow for on-the-fly adjustments by a control system or operator. When referencing these two types of couplings, they are typically defined as either "fixed level" or "variable level" couplings.

As applied to high inertia rotating driven loads, fluid couplings are typically mounted between the prime mover and the driven load. Unlike a VFD, whose use is limited to electrical motors, a fluid coupling can be used in a far broader fashion. But like a VFD, a fluid coupling is typically implemented when looking to mitigate the issues associated with startup, slowdown and dynamic speed control of a high inertia rotating driven load.

For applications where dynamically varying the operating speed is less important than controlling start up, slow down, drive train isolation or load sharing dynamics of a given system a fluid coupling is a good fit. The bulk of applications utilize a fixed level but variable level couplings do exist and are not that uncommon. The cost associated with the design and manufacturing of this style of coupling can be cost prohibitive. When selecting a variable level coupling a lot of time is needed to work collaboratively with the manufacture to ensure that the right design is selected prior to manufacturing.

For applications utilizing the fixed displacement style of coupling, attention must be paid during the design and commissioning stages to ensure that the appropriate fluid volume is determined to match the application. This is a critical step in the design process as it will have the greatest effect on system operation. This level will also determine the speed at which the driven load will operate.

One of the greatest benefits of a fluid coupling is its ability to dampen torsional vibration and shocks transmitted from the load to the prime mover, thus extending equipment life. Slip within the coupling can reach one hundred percent during extreme events, often preventing catastrophic failure. Load balancing for multiple drive applications is also possible by adjusting individual fluid levels and can help to greatly reduce project costs by driving a load from multiple smaller prime movers.

Summary

The advent and advancement in recent years of both fluid coupling and VFD design have made system design of high inertia rotating driven loads much easier. These advancements have allowed designers to tackle application challenges and to build more robust equipment for industry. As these products continue to advance, particular care needs to be given to fully understanding all of their features and how they can be applied to tackle design challenges. Determining what is the most efficient, economical, and practical product for your given application is the key to good system design.

When it comes to determining if you will select a VFD or fluid coupling for your particular application there are many things to consider. Both options have similar advantages but also offer some unique features. Facilitating speed ramps/running dynamics and load sharing are shared features.

The unique feature for a VFD is its ability to control current to the prime mover. It has the ability to fully control current, thus enabling the system to eliminating current spikes, control and react to overloads and also reroute power from the motor enabling for a form of dynamic breaking. Past that, a VFD offers great system/control flexibility. Features such as over speeding a motor by raising the frequency past 60 Hz and its ability to be used as a control platform for small standalone applications can greatly reduce capital costs and provide system flexibility during start-up and commissioning.

A fluid coupling's differentiating features mostly have to do with its ability to dampen torsional vibration and shocks transmitted from the load to the prime mover. This is ideal for applications like crushers, where issues of erratic loading and unloading of the system exists as does the possibility of jamming.

Never before has there been a time where so many products of such advanced design have been available for implantation. Continued diligence by system designers to stay current with these technologies is needed to ensure that full advantage can be taken on the behalf of end users of these great advancements. **PTE**

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