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Saving Energy with VFDs

Retrofitting your chiller plant with the right VFD solution will result in quick payback due to energy savings, reduced maintenance and improved operation.

The price of power continues to rise, sparking greater need for facilities to further optimize chiller plants to lower energy consumption and increase the speed to positive ROI, positioning themselves as competitors in the global economy. Chiller plants are commonly used for large-scale cooling applications, such as air conditioning spaces over 20,000 square feet (200 square meters) with cooling requirements that exceed 250 tons of refrigeration. For example, manufacturing plants in the chemical, petrochemical, mining and other process industries often install customized chiller plants to provide process cooling. Their attractive returns, as well as decreasing implementation costs, have encouraged manufacturers to identify smaller-scale applications for chiller plants where they were formerly cost-prohibitive (*table 1*).

The case for chiller plants in manufacturing

Chiller plants have long been accepted as the most efficient technology for reducing air temperature in large facilities because they provide greater efficiency in terms of tons of refrigeration per units of electrical input. Although they present a significant capital investment, the payback for chiller plants is often measured in months (depending on the application), making it an attractive investment for manufacturers. But a chiller plant alone won't deliver the returns needed to succeed in today's environment.

Chiller plants consist of multiple components, but the greatest opportunity for improvement lies in the optimization of the compressor motor operation. Because the main chiller motor is large, ranging from 750 Hp to 8,000 Hp, it typically runs on medium-voltage power ranging from 2.3 kv to 13.8 kv. Yet even with this broad range, an estimated 80 percent of existing chiller plants run the compressor motor at full speed without a variable frequency

Common applications for chillers
Educational institutions
Hospitals and medical offices
Department / big-box stores
Shopping centers
Food manufacturing
Grocery stores
Commercial food preparation
Arenas, theater and convention centers
Hotels / motels, resorts and casinos
Pharmaceutical manufacturing
Aerospace
Electronics manufacturing
Data centers

Table 1

drive (VFD) and mechanically throttle the output in order to meet the varying load. The other 20 percent of existing chiller plants use a VFD or a reduced-voltage soft-starter (RVSS) supplied by the chiller manufacturer. Manufacturers that purchase chillers largely base their VFD selections on cost rather than performance; and while this minimizes the initial cost, it increases long-term operating costs compared to other high-performance VFDs.

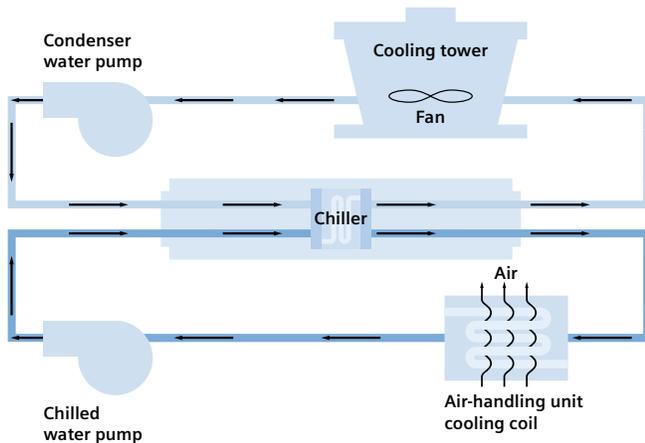


Figure 1: Chiller plant diagram

In retrofit cases, when upgrading a chiller plant with a VFD or replacing an existing VFD, the choice of both partner and product will determine how quickly payback is obtained and how great the payback is.

In this white paper, we will identify the importance of upgrading to a VFD, as well as provide recommendations to manufacturers on selecting the right VFD. Additionally, you will see a real-world example of chiller plant optimization that focuses on the VFD and compressor motor. This optimization enables more precise temperature control and reduced maintenance—delivering substantial savings and payback in as little as 12 months.

Chiller plant operation

As illustrated in *figure 1*, a chiller plant consists of multiple pieces of equipment operating in conjunction with one another, including the chiller compressor, chilled water pump, air-handling unit cooling coil, cooling tower and condenser water pump.

Air (for air conditioning) is cooled in the air-handling unit cooling coil through which chilled water is circulated. Water is chilled by the cooling effect of evaporation in the chiller compressor. The cooling tower is used to remove heat from the chiller compressor condenser via the condenser water loop. Chiller plants utilize multiple pieces of rotating equipment including chiller compressors, chilled water pumps, condenser water pumps and cooling tower fans.

Most chiller plants are required to operate over a wide range of conditions. For example, air-cooling demand during a summer day can be extremely high due to increased occupancy, high ambient temperatures and direct sunlight. Conversely, air-cooling demand can be extremely low during a winter night due to low occupancy, low ambient temperatures and the cooling effects of wind.

As a result, chiller plants are sized for maximum demand load, but often operate at low demand loads during much of the year. Chillers in manufacturing plants can exhibit similar operating characteristics varying with time of day, seasons and plant operations that can start, stop and vary in terms of demand. Operating over this wide range of demand loads efficiently is a challenge for many chiller plants.

The chiller compressor motors are usually the largest motors in chiller plants with sizes typically ranging from 750 Hp to 8,000 Hp, and operating at a medium voltage between 2.3 kV and 13.8 kV. Due to their large relative size, the chiller compressor motors consume most of the electricity used to operate the chiller plant. They also represent the greatest opportunity for reducing electrical energy consumption in the chiller plant.



Figure 2: image of a VFD.

In 80 percent of existing chiller plants, the chiller compressor motor runs at full speed because there is no variable speed drive. The compressor output is mechanically throttled to meet varying load demands, so the compressor produces more hydraulic energy than required.

A superior approach is to optimize the motor operation with a VFD. This precisely controls the speed of the chiller compressor motor so the compressor produces only the amount of hydraulic energy required to meet the load demand. Operating the compressor motor at the speed dictated by the load increases overall efficiency, reduces energy consumption and reduces maintenance.

Reasons to use a VFD

The chiller compressor motor is often run at full speed, with the corresponding output of the chiller plant throttled with vanes, valves or other mechanical devices. A VFD (*figure 2*) can be effectively used to electronically vary the speed of the compressor motor, matching its speed to the load. This is a much more energy-efficient approach than running the compressor motor at full speed and mechanically throttling its output.

The inherent soft-start capability of a VFD greatly reduces the power draw of the compressor motor at startup. This eliminates excessive motor heat and can reduce electrical demand charges. Many utilities employ demand charges

that increase rates based on highest instantaneous power demand. Therefore, one large spike in power use—such as starting a large motor across the line without a VFD or a RVSS to reduce instantaneous power consumption—can increase rates for an entire billing period.

Utilizing a VFD to vary the motor speed also allows better matching of the hydraulic energy generated by the chiller to the demand load, increasing the overall efficiency of the chiller system. This not only reduces electrical energy consumption, but can also provide more precise control of chilled water temperature.

Operating the compressor at a lower speed reduces maintenance by creating less wear and tear on both the motor and the compressor. In addition, the VFD will allow motor speed to be varied in real time, making it easy to quickly follow the demand load.

The electronic nature of VFDs eliminates the need for throttling mechanical components that can wear, break and stick. These components require frequent maintenance and are often the source of operational issues that can cause downtime, inefficiency and inaccurate control of air and water temperature.

Advantages of using VFDs are summarized in *table 2*.

Choosing the right VFD

Using a VFD to control the speed of the chiller compressor motor is a good idea in nearly all cases, but choosing a generic or OEM VFD can be short-sighted. Though they may cost less up front, they can eliminate your ability to achieve significant additional long-term electrical energy cost savings, performance gains and reduced maintenance.

Generic and OEM VFDs typically control the suction pressure by adjusting the motor compressor speed. The suction pressure is representative of the refrigerant temperature entering the compressor. Therefore, controlling the suction pressure stabilizes only one process variable in a relatively complicated chiller plant system with many process variables. This has some benefits, but you'll see even more significant operational improvements when you carefully take into account the additional process variables before adjusting the compressor speed.

SIEMENS SINAMICS PERFECT HARMONY GH180 air- and liquid-cooled VFDs have partnered with Evolutionary Energy Solutions to develop a multivariable control strategy that

Reasons for VFD retrofit on existing chiller plants

Increased efficiency
Lower energy use
Soft start
More precise temperature control
Lower maintenance
Less wear and tear on motor and the chiller
Eliminates mechanical components that can wear, break or stick
Siemens solution can produce chiller turndowns as low as 50%

Table 2



Figure 3: The Mirage Hotel and Casino, Las Vegas Photo credit: Alan Copson/Photodisc/Getty Images

optimizes efficiency by considering not only the chiller compressor suction pressure, but additional process variables as well. In some installations of high-performance VFDs, electrical energy consumption can be reduced by an additional 50 percent of the reduction generated by installing a generic or OEM VFD that is controlled solely by compressor suction pressure.

High-performance VFDs optimize the operation of a chiller plant further by analyzing a number of variables in addition to suction pressure. Using all relevant variables, a controller computes and sends a signal to the VFD, typically 0–10 V DC, to precisely control the motor speed.

In addition to looking at a greater number of variables, the chiller's control system analyzes these variables with patented algorithms. This ensures the signal from the chiller interface to the VFD controls precisely how the motor speed and vane are positioned to optimize operation of the entire chiller plant, maximizing efficiency and delivering precise temperature control.

With this in mind, consider purchasing and installing a high-performance VFD that utilizes chiller plant optimization algorithms in lieu of a less-expensive generic or OEM VFD.

The cost associated with the purchase and installation of generic or OEM VFDs versus similar costs for purchasing and

installing high-performance VFDs should be analyzed in conjunction with the electrical energy cost savings attributable to the optimization algorithms. In many cases, the additional electrical energy cost savings will pay back the incremental VFD cost in only a few months. Although the time to positive ROI is longer, replacing an existing variable speed drives with a high-performance, optimized VFD will also deliver significant savings.

Energy savings aren't a mirage

The Mirage Hotel and Casino in Las Vegas was built by developer Steve Wynn and designed by Joel Bergman (*figure 3*). When it opened in 1989, it was the most expensive hotel-casino in history, with a construction cost of U.S. \$630 million. With The Mirage, Wynn upped the ante for Vegas hotels and was instrumental in transforming Las Vegas from a down-market destination to a world-class luxury resort destination.

The Mirage uses a multi-compressor chiller plant (*figure 4*) of significant size and complexity—an example representative



Figure 4: Chiller plant at The Mirage



Figure 5: Siemens SINAMICS Perfect Harmony VFD installed at Mirage chiller plant

or better than most other chiller plants. In addition, The Mirage chiller plant is highly automated and heavily instrumented, making it an ideal location to obtain accurate measurements of chiller plant performance.

As such, it was the perfect location in which to verify the savings projected from the use of the Siemens and Evolutionary Energy Solutions VFD solution. Siemens SINAMICS Perfect Harmony GH180 medium voltage VFDs (figure 5) were installed to control the speed of existing chiller compressor motors running at fixed full speed at The Mirage chiller plant.

The Mirage has 9,600 tons of air-conditioning capacity. Its central plant serves 3,044 hotel rooms, casinos and a 40,000-square-foot ballroom, while an auxiliary plant cools its 90,000-square-foot event center. The former contains six 1,350-ton chillers operating at 4,160 V AC, while the latter has three 500-ton chillers operating at 480 V AC.

To reduce energy consumption and improve operation, the solution was to install VFDs to control the existing chiller motors, but there were three main challenges:

1. The chiller manufacturers said it couldn't be done without using a proprietary OEM drive. Even then, they didn't recommend doing so, because of potential motor damage.
2. The requirements demanded a zero-harmonic VFD to ensure no impact on a motor's life span—a critical condition because each motor can cost up to \$80,000 to replace.
3. A control solution must be developed to optimize operation between the chillers and the VFDs.

The recommendation was to deploy a Siemens SINAMICS Perfect Harmony GH180 4,160-V, zero-harmonic VFD to three of the six 1,350-ton chillers in the central plant. In the auxiliary plant, a Siemens SINAMICS Perfect Harmony G150 VFD was recommended for two of the three 500-ton chillers.

In both plants, the remaining chillers without the VFDs would remain operating at full power, while the VFD-equipped chillers would become the buffers providing the variable capacity needed to accommodate varying demands determined by the time of day and season.

To precisely control the VFDs and the chiller plant, 11 sensors were installed on each chiller and connected to the VFD control system, which was in turn managed by the prototype Plant Pro software created by Airmasters Australia, John Leslie and Conserveit (Plant Efficiency Solutions). In early 2007, the new Siemens-based solution was ready to go.

The results of the Siemens-based solution were as expected. To start, the VFD-equipped chillers in the central plant were saving over 200,000 kWh in electricity. Together with power savings from the auxiliary plant, The Mirage was saving an average of \$20,000 a month in operating costs. The power savings also qualified The Mirage for significant rebates of approximately \$70,000 from Nevada Power, going a long way to offset the costs of the Siemens VFD solution. As for emissions, the Siemens VFD-equipped chillers save about 400,000 pounds of CO₂ each month, adding up to 4.8 million pounds of CO₂ each year.

Following the commissioning of the Siemens VFD solution, annual savings were estimated at about \$1 million in total operating costs. As a result, the Siemens VFD solution was deployed at other MGM Resorts properties, including MGM Macau, a property that features the world's largest gaming floor.

Retrofit applications such as these can generate cost savings resulting in paybacks as short as 12 months, and paybacks for new applications can be even shorter. It is clear that specifying the right VFD up front is more efficient than retrofitting.

The Siemens solution applied at The Mirage, which has since been refined and improved to deliver additional benefits, is now offered to customers worldwide through a partnership with Siemens and Evolutionary Energy Solutions.

Conclusion

Immediate consideration should be given to installing VFDs on all existing chiller compressor motors currently operating at constant speed. These retrofits will considerably reduce electrical energy consumption, reduce maintenance and improve operations—all of which will economically justify installation.

For significant additional energy savings and operational improvements—especially when the chiller compressor motors are currently controlled by generic or OEM VFDs—consider installing the Siemens and Evolutionary Energy Solutions VFD solution.

While this white paper focuses on improving the operation of existing chiller plants by installing a VFD to control the compressor motor, the Siemens and Evolutionary Energy Solutions VFD solution should also be seriously considered for new chiller compressor purchases.

Installing a VFD will save energy, but installing the Siemens and Evolutionary Energy Solutions VFD solution will save much more, it will and more than justify the incremental cost.

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