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Efficient energy management: is variable frequency drives the solution

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Abstract

Over the last few years the cost of power electricity has increased significantly. Researchers and manufacturers of electrical goods have been trying to find ways to minimize the use of power electricity while maintaining the efficiency of electrical equipments. To provide efficient energy management for today's market, manufacturers are now turning to a technology known as variable frequency drives (VFDs). VFDs are being used for various equipments ranging from small electrical appliances to the largest of mine mill drives and compressors. Household air conditioning compressors, for example, are not short of running on VFD technology. This concept paper will discuss the alternative use of this energy.

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Keywords: Variable Frequency Drives; Adjustable Speed Drives; Ac Motor; Ac Drives

1. Introduction

The cost of power electricity has increased significantly over the last few years. Many researcher and manufacturer of electrical goods have sought to minimize the use of electrical consumptions while maintaining the efficiency of electrical equipments. One such approach is through the use of a single minded technology for one time solution by replacing lighting or cooling equipment with more an efficient system. However, by employing strategic energy management, the savings can be increased by roughly by 20% of total energy consumption (U.S. Department of Energy Data Book, 2011). As can been in Fig. 1 below, The United States and China have a

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combined consumption of about 39% of the total world energy consumption. In the United States, about 41% of total energy consumed is by the building sectors compared to the 30% consumed by the industrial sector.

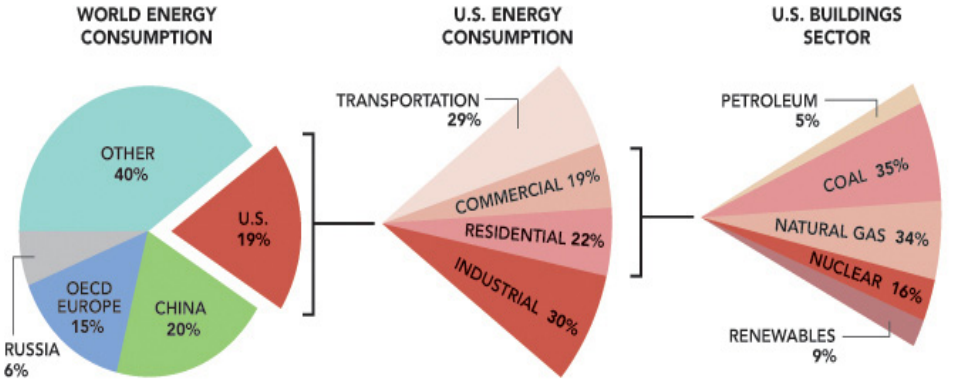

Fig. 1. Source: US Department of Energy (2011)

Many a building sector does not have a strategic energy management plan in place. Those that do are often unaware of its effectiveness and other perhaps better energy management alternatives that could provide better savings. Without a strategic energy management plan in place, it is easy to fall victim to a wide range of energy management costs, thus making it very difficult to successfully manage a budget.

This said, what, exactly, is efficient energy management? According to VDI guideline 4602, energy management is defined as the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives. To manage energy efficiently, there are two opposing common market technological trends. One is the renewal energy technology versus the non-renewal energy technology. Renewable energy is generally defined as energy that comes from resources which are naturally replenished such as sunlight, wind, rain, tides, waves and geothermal heat. Examples of renewal energy technologies are energy-generating windmills and solar energy. A non-renewable energy source on the other hand is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time-frames. An example of this is carbon-based, organically-derived fossil fuel such as electrical motor of air conditioning units, compressors and pumps. The object of this paper is to not only review the efficiency of the renewal and the non-renewal energy technologies but also to discuss the pros and cons of each of them.

1.1 Windmill energy

Over the years, consumers have learned to expect electricity on demand from power plants that run on coal, natural gas or oil. But these fossil fuels, which provide reliable, around-the-clock energy, also emit harmful toxic gasses and megatons of chemicals that contribute to global warming.

Windmills provide emission-free energy, but only generate electricity when wind blows. Surplus energy can be stored for later use, but today's electrical grid has little storage capacity, so other measures are used to balance electricity supply and demand. Wind energy is a promising form of renewable energy and is the fastest growing source of energy in the world (US Department of Energy, 2012). An increasing number of people are using windmills for electricity in their homes (Mchale, 2009). In Europe, since 2000, about one third of all installed electricity has been wind energy and for country like Denmark, more than 20% of the total electricity production has been using wind power (European Commission, 2013). This not only saves energy but saves a lot of money too. Another advantage is that windmills can be homemade as well (Anonymous, 2013). There are many other advantages to harnessing energy from windmills (Anonymous, 2014), but with these advantages come

disadvantages that have put many an interested renewable-energy consumer off. For one thing, a windmill has to be light so it is made thin and tall. Due to this, even the most minor of storms is capable of tearing a windmill apart. Also, installing large windmills next to residential buildings are deemed both impractical and undesirable in appearance.

In a study done by a Stanford team, windmills are found to generate far more energy than they consume. The study showed that windmill actually produces enough surplus electricity to support up to 72 hours of either battery or geologic storage. Although the results were very encouraging for the wind industry, the wind intensity that is available may not always be sufficient. And the turbine has to be placed after considering the geographical locations and their weather conditions. So a windmill is almost useless in most urban areas.

1.2 Solar energy

In recent years, researchers have become increasingly aware of the fact that many of our energy sources are non-renewable. Thus they are looking for new, renewable and cleaner energy sources. For the solar industry, the advantages are plenty. Unlike windmill energy, solar energy uses solar panels that can easily be installed on rooftops, thus eliminating the problem of finding extra land to build a solar generation plant in order to produce electricity for personal home use.

Although the initial cost of solar panels may be high, but once they are installed, they provide a free source of electricity, which will pay off over the coming years (Anonymous, 2014). Solar generation allows users to become less dependent on the worlds fossil fuel supplies (Bratley, 2007). This also means that consumers no longer have to rely on the electricity supplied by power companies.

This said high initial installation cost is the biggest disadvantage of solar energy (Bratley, 2007). In addition, some households may need more than a few panels to generate power; making the initial installation of solar panels even more costly than it already is. Another disadvantage of solar energy is that it can only be used to generate electricity during daylight hours. This means that solar panels will not produce energy for homes for one half of the day. Besides this, one other point to take into consideration when deliberating the use of solar panels is the surrounding environment. Weather and pollution can affect the productivity and efficiency of solar panels thus.

These disadvantages are reason why businesses and large industry players cannot afford to adopt solar energy. Most factories and office buildings being situated in polluted areas such as major cities, the fact that mere air pollutants can affect the productivity of solar panels is a liability rather than a desirable option to those looking for alternative electrical power supplies.

Besides this, it should be noted that one advantage windmill energy has over solar energy is that it has an enormous energy return on investment. Deshmukh (2013) argued that wind energy is one of the cheapest forms of energy available today and therefore it can be used by everyone and wind turbines are capable of generating enough electricity for the entire house while not releasing any harmful pollutants

1.3 Variable Frequency Drives (VFD)

Earlier, it was mentioned that based on available data from the United States, about 41% of total electrical energy generated is consumed by building services. It is worth noting here that in building services; energy consumptions are mainly used in the heating and cooling of the building which almost always involves rotating equipment. According to current estimates, about 65% of this total figure is consumed by centrifugal or flow related applications such as fans, blowers, compressors, and pumps (U.S. Department of Energy Data Book, 2011). Variable speed drive technology offers a cost-effective method to match driver speed to load demands and represents an opportunity to reduce operating costs and improve overall productivity (Bose, 2011).

A variable-frequency drive (VFD) (also termed *adjustable-frequency drive*, *variable-speed drive*, *AC drive*, *micro drive* or *inverter drive*) is defined as a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage(Bose, 2000; Dubey, 2001). Usage of this VFD is now common in our everyday lives. VFDs are made available in electrical appliances as small table fans and room air conditioning units to heavy industries that use AC and DC motors. Toyota manufacturers have incorporated this VFD technology for their green technological automobiles such as Toyota Hybrid Prius.

Moreover, in Japan, since the cost of energy is at a very high level, most homes use variable speed air-conditioners to save energy (Bose, 2009).

Without going into technical detail of how VFD works, it is perhaps worth mentioning here the drawbacks of this highly efficient device. For one thing, a VFD manufacturer must first address the problem of heat. Manufacturers of VFD are unable to produce an ideal set of components to counter the heat in the drive. In most cases, VFD has an efficiency rating between 95% and 98%. This means that the amount of air that must be moved will produce heat. This heat then can cause significant additional cooling costs to be added into the design. If the drive must be placed in a classified location, then the airflow going to the drive will need to be purged and pressurized which again will incur additional costs.

Heating is not the only problems with VFD. The other significant problem lies in system harmonics. In an ideal power electronics state, these harmonics should not exist at all. These harmonics cause problems to the electrical components. In general, harmonic is a larger issue than overheating. For example, when a radio is slightly out of tune, static noise is unbearable to listen to although it is possible to hear the music. In telecommunication circuits, this crosstalk is not only annoying thing but will cause overheating. Fortunately now there are a number of ways to mitigate harmonics by placing a filter on either side of the VFD. The last problem related to this technology is that it can create load issues as well. This power loss is generally attributed to the nature of sinusoidal waves which comes from unchecked harmonics.

Despite the fact that VFDs generate heat, power losses and harmonics, they would not be as widely used and popular today if they did not have significant economic benefits. In countries like Japan, motor drives have been used for the past fifty years in engineering fields such as industrial fields and elevators (Konishi, Kamiyama and Ohmae ,1980; Munaka et al., 2002; Tominaga et al., 2002).

The underlying technical concept behind VFD is to controlling motor speed (Bose, 1980). If the speed of a motor can be controlled to match the process requirement, then system efficiency can be improved. For example, in order to save the energy used in a household air conditioning unit, one can choose to either increase the temperature or reduce the speed of the fan. However, the energy saved is marginal because the motor in the compressors is working at normal speed. In VFD, both the speed and the torque of the motor are technically adjustable.

Although VFD has been in the global market for more than 10 years, the situation in Malaysia is somewhat nonexistent. To this aim, a preliminary research was done to compare the traditional usage of electricity versus the usage of VFD in a library at a local public university.

2. Research Method

2.1 Research setting

Any building running on central air conditioning systems should also have a chilling system, chilled water pumps and condensed water pumps, Air Handling units (AHU) and a cooling tower. AHU is a device used to condition and circulate air as part of the heating, ventilating, and air-conditioning (HVAC) system. An air handler is usually a large metal box panel containing a blower, heating or cooling elements filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to a ductwork ventilation system that distributes the conditioned air through the building and returns it to the AHU. Sometimes AHUs discharge (*supply*) and admit (*return*) air directly to and from the space served without ductwork. The building that was conveniently chosen is the main library of a public university. The library has four floors running on two AHUs on each floor. It operates 24 hours a day for 7 days a week.

2.2 Sample size

Although the university has many buildings with central air conditioning systems, only the main library is open 24 hours a day for 7 days a week. The main Library has four floors with each floor having two separate AHUs. One VFD panel was installed at one AHU at the second floor of the main library and the other one panel at the other AHU on the third floor of the main library. The AHUs at the second and third floor are used as to compare the electrical consumption usage of VFD panel.

2.3 Data collection method

Data was recorded by data logger every hour for the period of two weeks during university semester session. Two weeks in a semester session was deemed enough to obtain the required data as during this period, the library was optimized to its full capacity being that the university had been running at the peak of a semester.

2.4 Results analysis

It was found that using the VFD panels, the electrical consumptions were reduced by twenty to thirty percent. Although the savings were not much difference during the peak hours, it was nonetheless greatly so during non peak hours such as during the night. The problems relating to heat and harmonics were easily solved by the use of filters and these results prove that energy can be managed efficiently by the use of VFD panels.

Table 1. Reduced operating frequency

FREQUENCY (Hz)	% REDUCTION	ENERGY CONSUMPTION (%)	ENERGY CONSUMPTION SAVING (%)
25	50%	13%	88%
30	40%	22%	78%
35	30%	34%	66%
40	20%	51%	49%
45	10%	73%	27%
50	0%	100%	0%

In Table 1 above it can be seen that when the frequencies were reduced, the energy consumptions were also reduced while there is no change in the efficiency of the air conditioning. For example, if we reduce the 30KW motor running from 50Hz to 45Hz, the energy of the motor will be running at30kW x (45Hz/50Hz)3 = 21.87kW or 72%. This concur with *Affinity law* that states

$$\frac{HP_1}{HP_2} = \frac{N_1{}^3}{N_2{}^3} \quad \text{or} \quad \frac{HP_1}{HP_2} = \frac{F_1{}^3}{F_2{}^3} \quad \text{or} \quad \frac{kW_1}{kW_2} = \frac{F_1{}^3}{F_2{}^3} \qquad (1)$$

Where HP is Horse Power, N is Speed, F is Frequency, and kW: Power (KW)

Another advantage of using VFD is that since a motor's speed can be controlled, it can be gradually increased during the start, thus reducing wear and tear of the motor. There is no in-rush current that is common with STAR-DELTA starting circuit. For water pumps, it can reduce the water hammer effect on water pipes during starting of pumps.

3. Discussion

From the results of preliminary study, it can be worth mentioning here that in terms of economic strategy in efficient energy management the VFD is the technology of the future for countries like Malaysia. This concurred with Bose (2009) who have said "Air conditioners can use load proportional variable-speed control, instead of

traditional thermostatic control that can save up to 30% energy". Solar energy is not economic because of its high initial investments while windmill energy is not suitable in the mountainous regions and places where there are no constant winds such as Malaysia. Thus it is strategic energy efficient in Malaysia to install VFD is buildings where there are high demands of air conditioners such as library, offices, shopping centers and hospitals (American Hospitals Association, 2014).

Malaysia is a tropical country that is hot and humid almost every day throughout the year. Most buildings in Malaysia uses central air conditioning systems that have a chilling system, chilled water pumps and condensed water pumps, Air Handling units (AHU) and a cooling tower. This central air conditioning system have a rotating motor and since VFD is a system that controls the motor speed, then the air conditioning system efficiency can be further improved which in turn saves up to 30% energy consumption.

The preliminary study has found that it is a very strategic energy management to install a VFD for buildings such as a main library because it not only saves energy by about thirty percent but it also does not incur heavy initial investment. In fact this strategic energy management system can also be incorporated to other commercial buildings to any type weather environment not only in Malaysia.

4. Conclusion

For renewal as well non-renewal energy, the technological advances of today is directed to the usage of VFD for its cost effectiveness. Although there are few problems with VFD, the technological issues can be easily handled and further research can be done to develop this VFD to become more efficient, cheaper and readily available in household electronic homes appliances.

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