# BASIC CONCEPT
# ON
# ELECTRIC POWER SAVING

**DIGITEK TECHNOLOGY CO. LTD.**

**1. What power to save?**

Saving electricity has become worldwide mainstream and has drawn major governmental and general public attention. However, so called saving on electricity energy is often misunderstood. There are three types of electric power. For single-phase power they are defined as follows:

Real power (KW) $P_1 = V \times I \times \cos\theta$

Reactive power (KVAR) $Q_1 = V \times I \times \sin\theta$

Apparent power (KVA) $S_1 = V \times I$

Cosθ is called Power Factor，while θ is the angle that the current lead the voltage.

Since

$$\cos\theta^2 + \sin\theta^2 = 1$$

hence

$$KVA^2 = KW^2 + KVAR^2.$$

Three-phase definitions are similar to single-phase definitions but with a factor of $\sqrt{3}$ :

Real Powe (KW)$P_3 = \sqrt{3}\ V \times I \times \cos\theta$

Reacitve Power (KVA)$Q_3 = \sqrt{3}\ V \times I \times \sin\theta$

Apparent Power (KVA) $S_3 = \sqrt{3}\ V \times I$

What the utility company supplies is KVAR, and what the consumer charged is KW times hours, i.e. KWH. KW is the real power transformed to different forms of energy used by the consumer. The production cost of electric power is based on the apparent power but the consumer is charged only on the real power. It is clear that for higher power factor one needs less apparent power for the same real power consumption. The utility company can therefore reduce power plan facility. Recently more attention has been paid to the reactive power consumption and higher power factor is strongly required.

At this point we have to emphasize that enhancement of power factor is to reduce the total power and in turn to reduce the power plan facility. It does not have anything to do with the real power consumed by the user. As far as the user is concerned, lowering of the real power consumption is the most important. For a motor it is better to consume less real power for the same work.

It is clear that:

a. In order to lower power production cost the utility company requires users to have higher power factor. On the other hand the users can avoid or lower the fine because of low power factor by having higher power factor for their equipments.
b. The users should lower the real power consumption for the same work in order to lower the utility charge.

**2. Simple way to raise the power factor and its effect on the real power**

Apart from raising the power factor of the equipment, use of capacitor is the simplest way to raise the power factor. Enhancement of power factor on an equipment is limited by the equipment itself. For a motor the power factor is lower at lower load and is higher at higher load.
Installation of capacitor is commonly used for enhancement of power factor. However, enhancement of power factor with capacitor can’t lower the real power.

As stated before,

KW = V x I x Cosθ〔Power Factor〕.

Enhancement of power factor with capacitor also lowers the current but the real power is not altered. In the market one often finds capacitors packed as energy savers. This kind of “energy saver” is claimed to be able to save energy by showing that with this “energy saver” the current is largely reduced. This is a misleading to the consumers. As stated before, a capacitor can reduce power factor and therefore lowers reactive power, but it can’t reduce real power.

Nevertheless, lowering current can indirectly reduce real power. This is simply due to the fact that lowering of the current can reduce line loss. Electric wire has resistance and current flowing through the wire can create heat. The amount of heat created is proportional to the resistance and squire of the current. Heat dissipation by the wire is a waste of the real power. The resistance is proportional to the length of the wire. Therefore the line loss is larger when the distance between the watt-hour meter and the equipment is longer, and on the other hand the smaller current the line loss is smaller. Clearly for larger current and longer distance between watt-hour meter and equipment installation of a capacitor can reduce the line loss and the real power is therefore reduced.

### 3. Saving on real power

As explained before, installation of capacitor next to equipment can reduce the line loss and lower the real power. The amount of the line loss reduced depends on the distance between the watt-hour meter and the equipment, the resistance characteristic of the wire, and the lowering of the current.

For a motor, enhancement of efficiency can effectively saving energy. Nola pointed out in 977 that a motor consumes more energy than what is needed at low load. This means that part of the energy is wasted. For lower load the percentage on wasted energy is larger. Lowering voltage by a variac or control the current flow can reduce the energy consumption of the motor.

Equipments controlled by motors, such as machines, air conditioners and refrigerators, are not the only power consuming facilities. Lightings, electronic equipments and equipments controlled by motors all consume power.

a. Lightings:

Design of a lighting system is based on the rated voltage and is allowed the voltage to be 10% higher or lower. This means that the brightness is acceptable even the voltage is 10% higher or lower than the rated voltage. In general, a lighting device consumes more energy and is brighter at higher voltage. For a 40 W fluorescent light with 110 V rated voltage, its energy consumption at different voltage is as follows:

| V | W | AMP |
|---|---|---|
| 105 | 35.5 | 0.626 |
| 110 | 40.8 | 0.728 |
| 115 | 45.3 | 0.801 |
| 120 | 50.2 | 0.895 |

We see that an increase of 15V the energy consumption is increased by 41%. Therefore lowering of voltage can reduce the energy consumption noticeably.

b. Electronic equipments:

Electronic equipments require stable voltage with small tolerance. If we lower the voltage too much, the electronic equipments may not operate properly.

c. Equipments controlled by motors:

A motor at lower load wastes more energy in percentage and has more possibility to save more energy. At heavy load if we lower the voltage it might increase the current and the energy consumption might also be increased. When the voltage is lowered too much the torque might not be enough and the motor might be stopped.

Let us discuss the different ways to save energy for different types of equipments.

a. Lightings:

As explained before, lightings consume more energy at higher voltage with higher brightness. Therefore the most efficient way to save energy on lightings is to lower the voltage. On the other hand, lowering the voltage also lowers the brightness. Lucky enough the design of a lighting system allows the voltage 10% lower than the rated voltage with brightness still acceptable. Therefore if one can maintain the voltage close to the lower limit of the acceptable voltage, one can save energy noticeably. This is the basic idea for energy saving on lightings.

A good energy saver for lightings should be able to save energy at the same time should be able to maintain brightness as required. This energy saver can also prolong the lifespan of the lightings. For fluorescent light, increase of 1 V can increase the temperature of the ballast 0.6 ℃，and increase of 10 ℃ can shorten the lifespan of the ballast to half. Therefore lower the voltage can also prolong the lifespan of the lightings.

Not all lightings can save energy by lowering the voltage. For example, lightings with electronic ballast can’t save energy by lowering voltage.

b. Electronic equipments:

There is a lowest voltage requirement on electronic equipments and the power consumed by electronic equipments is comparatively minor, therefore it is not really significant to save energy on electronic equipments.

c. Equipments controlled by motors:

One may save energy on motors with the following methods:

i. Lower voltage with variac:

In the past there was a time that lowering voltage with variac for saving energy purpose became very popular. It is well known that torque is proportional to squire of the voltage. Therefore at low load one may lower the voltage to save energy on motor. Use of variac is the easiest way to lower voltage. However, the load of a motor is often not constant. How much lowering on voltage is best for a motor is extremely difficult for a variac design. For example, at load close to full load, the power factor is close to the rated power factor of the motor and there is no room for energy saving. If one lowers the voltage by brut force with a variac, the voltage might be too low and the current might increase. As a result it might increase energy consumption instead. It might also happen that the motor is stooped because the voltage is too low and the torque is not enough. The biggest problem with variac for energy saving purpose is that it can't efficiently detect the load of a motor and lower the voltage properly.

In addition to the fact that a variac can't efficiently detect the load of a motor and lower the voltage properly, the production cost of a variac is too high and the payback is too long. It is not cost effective. In order to save the installation cost, a variac is often installed at the power supply of the whole factory, office or house. By doing so it is very difficult to control the voltage properly for electronic equipments that require stable voltage. Furthermore, there is no way to control proper voltage for individual motors with different loads. For lighting system it will also have difficulty to control the voltage properly to maintain the brightness needed. Over all, the application of variac for energy saving purpose is quite limited.

ii. Make use of thrysters to lower current and voltage:

As stated before, voltage, current and power factor are related as follows:

$$KW = V \times I \times \cos\theta$$

If the voltage and current can be lowered without effecting proper operation of the motor and at the same time the change of the power factor is small, then KW can be lowered and the energy can be saved. This idea was pointed out in 1977 by Nola and he had proposed an analog circuit with SCR for energy saving purpose. First of all, detect the power factor as a reference of the load of a motor. Based on the load information decide the fire angle of the SCR for lowering the current and voltage. For lower load one may lower voltage and current more. Of course, when the voltage drop is too big the motor might not be able to operate properly or even be stopped.

How to detect the load of a motor and automatically adjust the firing angle promptly as suggested by Nola is the key technology in this approach. DIGITEK has made a break through in this approach.

This approach not only lowers the real power but also lowers the reactive power. From the reactive power definition,

$$KVAR = V \times I \times \sin\theta$$

one sees that lowering of voltage, current, or power factor will lower the reactive power too. Lowering of Sinθ means increase on power factor (Cosθ). Closing part of sign wave can lower voltage and current. As a result the power factor might be increased slightly. An increase of power factor will increase real power and lower reactive power. Therefore the change of real power and reactive power all depend on the over all change on voltage, current and power factor.

By making use of thryster, one can also have soft start, soft stop, over load protection, over high voltage and over low voltage protection, and phase loss protection. Therefore, with thrysters one can design a motor controller with multiple purposes.

A motor controller for multiple purposes can have different specific design for different specific purpose. For a large air compressor the motor can't be stopped during the idle period due to the large inrush current at start. However, with soft start, one may stop the motor during the idle period. DIGITEK-IIIAC can detect the pressure of the air tank. When the pressure reaches the high limit, the unit stops the motor and pumping of air into the air tank is stopped. When the pressure reaches the low limit, the unit starts the motor again with soft start and pumping of air into the tank is resumed. With soft start the large inrush current can be avoided. High inrush current can affect the surrounding power network and the motor should not be started often without soft start.

A lot of conveyers operate under low load a lot of time. Therefore conveyers are good candidates for energy savings. Others like plastic injection machines have heavy and light load working cycles. An injection machine with proper operation condition can save energy 10~15% or more. For oil pump jacks DIGITEK-IIIGS can save energy 5~15% depending on the well condition. For an oil pump jack the energy saving percentage might not be high, but it works 24 hours a day and the total saving is noticeable.

By making use of thrysters, one not only can design a good motor controller for multiple purposes, one can also design a energy saver for lightings. As Stated before, a fluorescent light with rated voltage 110 V consumes energy at 120 V 41 % higher than at 105 V. If one can maintain the voltage to the lightings at the lower acceptable voltage, then one can save energy at the area with voltage higher than rated voltage a lot. The lowering of voltage not only saves energy, it can also prolong lifespan of the ballast and bulbs and therefore save maintenance cost.

iii. Making use of inverter to lower the speed of motor for energy saving purpose

The main purpose of an inverter is to control the speed of a motor in order to control the speed of a machine. For example, an elevator should start and stop slowly in order to avoid uncomfortable feeling with sudden start and sudden stop. Inverter was originally designed for control of motor speed. After energy saving has become important issue, application of inverter for energy saving purpose has also become popular.

Speed of a motor is proportional to frequency of the power supply. An inverter changes the frequency of the power supply and therefore changes the speed of the motor. At lower speed a motor consumes less energy, therefore a converter can be used as energy saver. For example, at a large hotel, during the evening it needs more water supply to the rooms and during the day it needs less water. When more water is needed the motor can run faster to pump water faster and when less water is needed the motor can run slower to pump water slower from the basement to the water tower. By doing so the water tower can be smaller to save the construction cost of the water tower and at the same time energy can be saved. For a chemical factory, an inverter also can be used for flow control and energy saving purpose.