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Reactive power and power factor correction of the electrical power system network of Kuwait

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I. Introduction

In recent years, when fuel inflation increases, so did the cost of creating electrical power. As a result, there is a need to optimize the design and usage of electrical power at all levels of generation, transmission, and distribution. the most common methods used to achieve the power optimization are; reactive power compensation and power factor correction (**PFC**). Most of electrical power systems, instruments, and devices operate with active and reactive power.

Active power which referred as **P** is measured in **kW** and it consumed and transferred to another kind of energy such as; mechanical power, heat, light and others depending of the proposed load. The active power always positive, has one way direction and flows from source (Generation/Transformer) to load.

On the other hand, there is **reactive power** which referred as **Q** and measured in **kVar**. The reactive power cannot be consumed or transferred to any type of energy but it can be help in building and keeping up the magnetic field in the electrical network loads which is important to this kind of loads so as to operate fully functional. The reactive power has some features such as; it can change the direction and it's positive or negative depending the direction of the flow.

In addition**, apparent power (S)** is the sum of the two previous power and it can be measured in **kVA or** multiplying the voltage and the current. The power triangle in Fig. 1 illustrates the relation between active, reactive and apparent power.

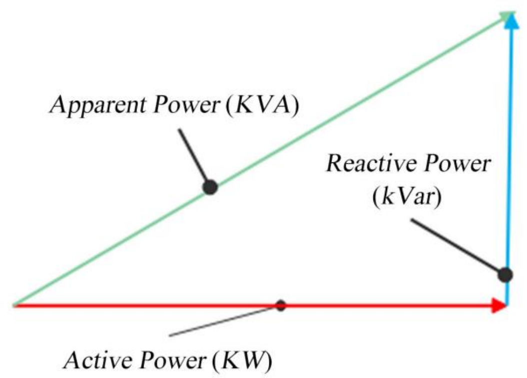

Figure 1 – Power triangle.

Reactive Power and Power Factor Analysis

After discussing and showing the basic definitions of the three powers (**P, Q** and **S**), the power factor term will be illustrated.

As shown in Fig. 1, the angle between **P** and **S** is defined as **Power Angle (φ)** and its cosine is called **Power Factor** (**PF**) and it equals the ratio of **P and Q** in ideal case without considering harmonics. Our goal here is to minimize the reactive power **Q** and that will cause in large **PF (close to Unity)** and higher **P**, on the other hand, as **Q** increases, the power angle will increases and **PF** will decrease and this means a small portion of **P.** Therefore, it's deduced that the power factor **PF** is a measure of the performance of the power system efficiency.

Regarding electrical loads, there are three types; resistive, capacitive and inductive. For resistive loads, current and voltage are in phase (power angle = 0) and **PF** becomes **unity**. On the other hand, for capacitive and inductive loads, current and voltage are phase-shifted by **90º (as shown in Fig. 2)** which produce very low **PF** and **P = 0.**

For further explanation, the **P** in capacitors during the first-quarter of the period is Positive and becomes Negative in the other quarter. The opposite in inductors, the **P** becomes Negative in the first-quarter and Positive in the other quarter. This means that capacitors and inductors are storing and returning back the energy to the source.

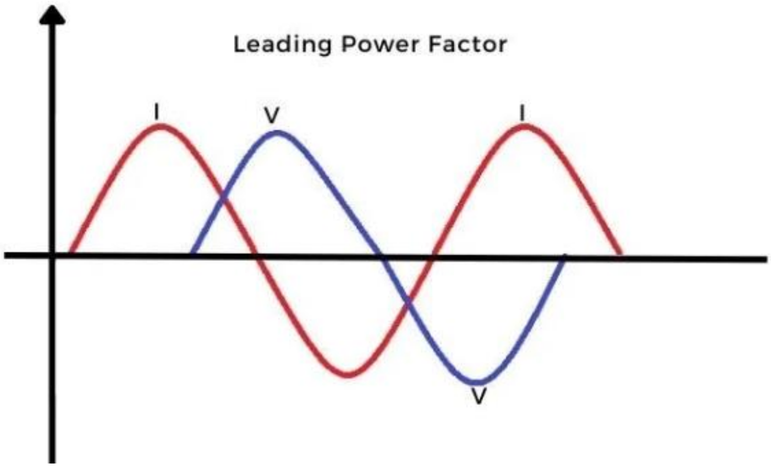

Figure 2 – current and voltage are phase-shifted.

The next table shows typical power factor values for different industrial loads.

Industry	Percent uncorrected PF
Chemical	65-75
Coal Mine	65-80
Clothing	35-60
Hospital	75-80
Forge	70-80
Machine Manufacturing	60-65
Metal Working	65-70
Plastic	75-80
Textile	65-75

Table 1 – Power factor values.

Reactive Power (Var) Compensation

The management and operation of reactive power to enhance the performance of the electrical network is called Reactive Power Compensation. In general, there are two problems regarding reactive power compensation: load compensation and voltage regulation. For load compensation, the target is to increase the power factor value to balance the active power **P** drawn from the supply**.**

The most common methods used in Var compensation are; Series, shunt Var Compensation and Traditional Var Generators. They mainly used to improve the electrical characteristics of the network. **Series Compensation** improves the transmission and distribution stages. The main idea about using series compensation is to decrease the equivalent impedance of the power lines using series capacitors. **Shunt Compensation** changes the equivalent impedance of the loads. Fig. 3 illustrates the effect of using shunt var compensation in a regular AC power system. The proposed system has a voltage source V1, a power transmission line and an inductive load. As shown, the load is considered to be inductive, so, it requires reactive power for normal operation, and, hence, the source must supply it. So, to reduce the required reactive power, this can be done using; capacitors, current source and voltage source near the load to compensate the reactive power (**IQ**).

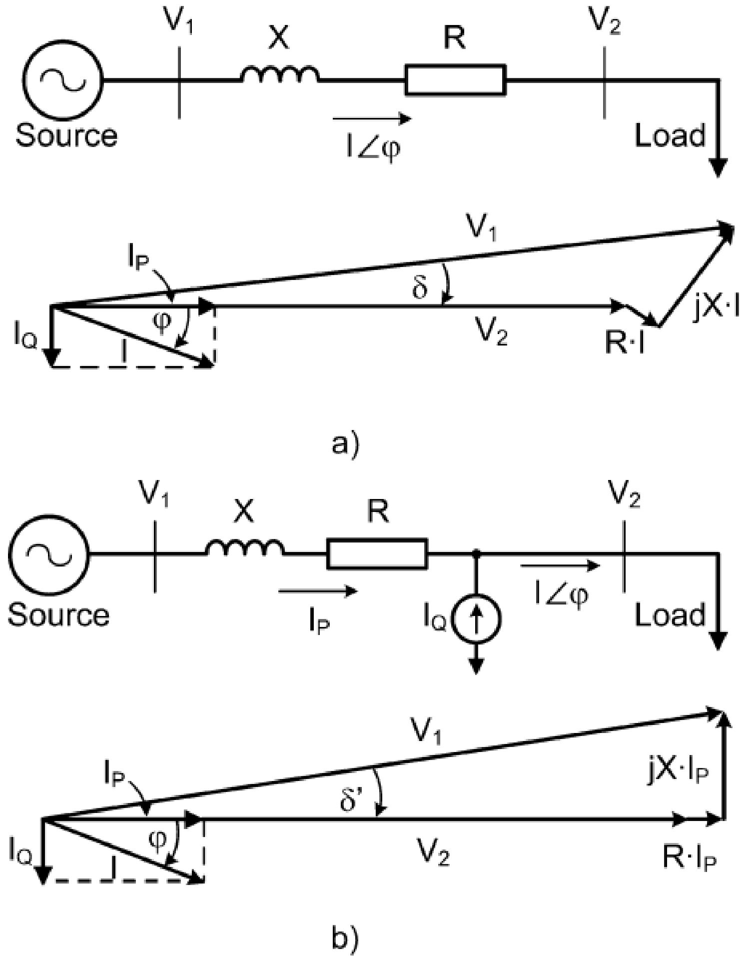

Figure 3 – Shunt compensation operation.

Traditional Var Generators are categorized based on the technology used in their operation and how they connected to the network. There are; Synchronous Condenser and Fixed or Mechanically Switched Capacitors.

- Synchronous Condenser

Synchronous condenser is considered to be a synchronous machine that can control the reactive power of the system using the exciting-field. It can provide or absorb the reactive power as needed (automatically) as shown in the following figure.

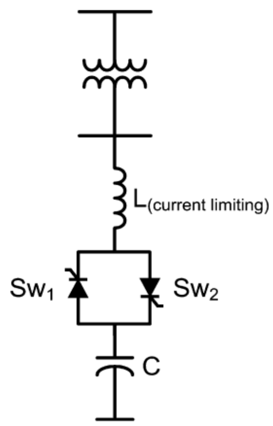

Figure 4 – Synchronous-condenser exciter field control scheme.

- Fixed or Mechanically Switched Capacitors

Case Study

As referred to Attachment (1), WAFRA Substation in Kuwait (11/33/132) kV and it consists of three main transformers, each has a power of 45MVA, and it's used to supply a 67MW load (Active power) and 50MVAR load (Reactive power) and the estimated power factor is 0.801. The following tables shows the results after using power factor corrections methods.

Objective	Before Correction	After Correction
PF	0.801	0.950
P	67	67
Q	50	22
S	83.6	70.52

Table 2 – Results before/after using power factor correction.

It's necessary that all subscribers must use power factor correction methods to enhance the network performance.

II. Conclusion

Many electrical loads require reactive power to operate normally. As a result, there will be losses in generation and transmission lines and there will be voltage unbalance at the load-end. To avoid this serious problem, strategies has been taken like; reactive power compensation as mentioned in the previous sections and power factor correction. Hence, the reactive power required is handled using these strategies and there will be significant improvement in the power system performance.

References

[1]. Reactive Power Compensation Technologies: State-of-the-Art Review – JUAN DIXON.
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[3]. www.mew.gov.kw

Attachment(s)