Capacitor Banks - The Glue Holding the Electric Transmission and Distribution System Together

An Online Continuing Education Course for Engineers

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The Glue Holding the Electric Transmission & Distribution System Together

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Introduction

Capacitors provide/generate reactive power; what is reactive power?

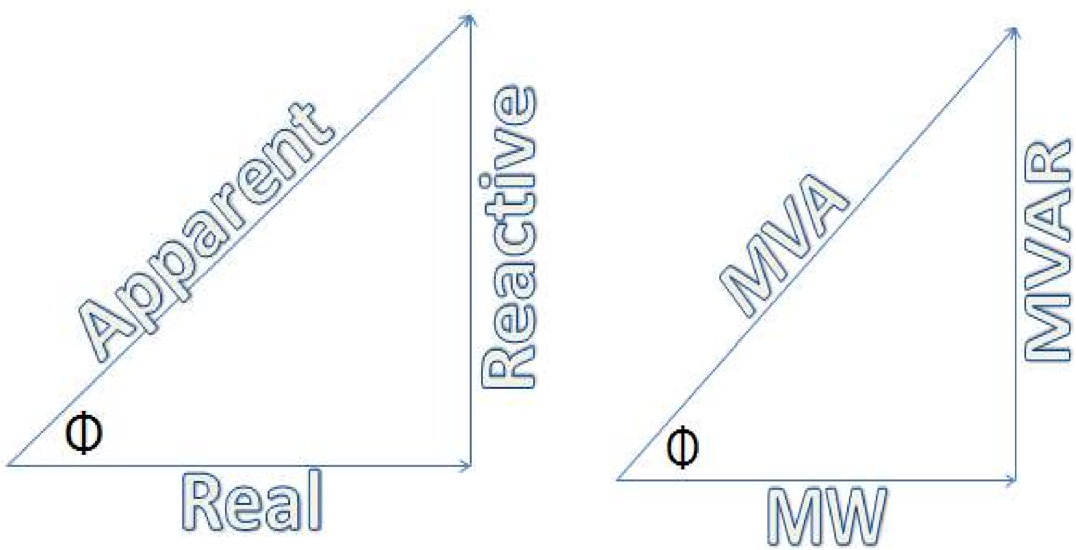
A capacitor bank, also known as cap bank or simply cap, provides/generate reactive power; what is reactive power?

After purchasing a 16Gb iPhone and taking a few pictures, you will soon realize that you ran out of storage space; at that moment, you realize that you only have 11GB or so of storage to use for your pictures/videos and apps, etc. The 4-5 GB (25-30% of the overall storage space) is usually used by the operating system.

Reactive power is like the ***glue*** that keeps the electric grid intact; the voltage is the potential/pressure difference; reactive power is the tool needed to maintain proper pressure. Adequate reactive power is extremely crucial during emergency events when a large generator, a transmission line, etc., is not available. The reactive power usage is the highest during the summer peak as a result of the heavy usage of air conditioners that require reactive power to operate as designed. Capacitors are fundamental for maintaining a reliable operation of the electric system during peak conditions and other times. There are numerous advantages to the entire system.

The Power Triangle

The power triangle describes the relationship between real, reactive, and apparent power; power factor, cos(Φ) = Real/Apparent or MW/MVA.



Real/Reactive Power

- Real Power provides useful power, the power that spins the customer's electric meter. Real power is measured in watts; kW (kilowatts, 1 kW = 1,000 watts) or MW (megawatts, 1 MW = 1,000 kW) will be utilized as this paper covers utility-scale power load demand.

- Reactive Power – some books identify reactive power as useless power and compare it to beer foam; the author prefers the cappuccino analogy, where the foam represents reactive power (cappuccino won't be a cappuccino without the foam). The unit of measuring reactive power is VAR (voltage VAR reactive).

- Apparent Power (measured in VA [volt ampere]) is the square root of real and reactive power squared:

$$\sqrt{(Real\ Power^2 + Reactive\ Power^2}$$

- Real Power – P = V*I*Cos(Φ)

- Reactive Power – Q = V*I*Sin(Φ)

- Apparent Power – S = V*I

Most customer equipment and motors are inductive in nature, i.e., require reactive power to operate. The larger the motor size, the larger the reactive demand. Substation equipment such as transformers are inductive in nature, i.e., require reactive current to operate. Supplying reactive power results in increased system losses and voltage drop. The reactive power sources are:

- Generators – large power plants (due to the climate change efforts, widespread renewables, cheaper natural gas prices, coal power plants are forced to shut down; thus, they will not generate real or reactive power).
- Capacitors – connected to the distribution (on distribution poles) and transmission systems (at transmission substations).
- Charging – underground cables (mainly transmission) generate reactive power by virtue of their design since they act as capacitors due to the insulation and proximity to the earth.

Capacitors add leading current (capacitive current) and reactive power (VARs) to the system to improve the power factor close to unity and boost the voltage.
Capacitors are connected to all primary and transmission voltages (not secondary); they are installed at the substations and attached to distribution poles. They are not installed in the underground system, mainly due to the difficulty of connecting such equipment to cables.

Capacitors are installed for multiple purposes; the main reasons are:

- Reduce system losses
- Reduce circuit/substation reactive loading – capacity release
- Improve power factor
- Voltage support
- Load relief

The critical path for installing distribution capacitors is finding the ideal location along the
circuit. There are many existing rules of thumb ide the installat stribution
capacitors; you may have heard of the 2/3 acitor bank at the
load center i were the power
plants; thus, nand will be
coming from ifferent country or
even continent ver plant may
supply 9 VARs .

A large num onsumption.
Recently, some u drops below a
certain level, i.e., d if the power
factor drops below er improve
the power factor, i.