



Introduction

The efficiency of power generation, transmission or conversion is improved when operated at near unity power-factor. The least expensive way is to install power factor correction capacitors. Power factor correction capacitors must be able to withstand high voltage transients and power line variations without breakdown.

The use of Capacitors has long been accepted as the most practical solution to the low power factor problem in power systems. The modern Capacitor is a reliable, maintenance free, cheap source of VARs needed in inductive circuits to synchronize the voltage and current wave forms. In the past the application of Capacitors was straight forward; all that was required was a knowledge of KW (or KVA), existing power factor and target power factor. In recent years, however this practice has been complicated by the proliferation of non-linear loads, that is, loads that draw non-sinusoidal currents.

Role of Power Capacitors

Reactive Power

Reactive power is one of the most misunderstood concepts in electricity. By definition, real power is the electrical energy that does real work such as providing light in bulbs and turning motor shafts to provide horsepower. Reactive power is a component of electricity unique to an alternating current (AC) system. Volt amperes reactive (VAR) is the measure of amount of current that makes up the reactive component. The VAR component of an AC electric system flows out of phase with the real

component and typically lags the real power flow. The VAR component of an AC electrical system is commonly referred to as the useless part of a power circuit. Fewer VARs means more useful energy and better performance.

The concern for kVAR, or useless, portion of the electrical system is growing. Utilities want the flow of kVARs kept to a minimum to ensure maximum flow of real power (kW) through transmission and distribution circuits. Surges of reactive power can result in power quality disturbances in the utility system.

Need for reactive compensation

Reactive power is the product of voltage times current where the voltage and current are 90° out of phase with one another. The current associated with reactive power does flow through the conductor and creates extra losses. Most loads draw lagging reactive power, which causes electric power system voltage to sag. On the other hand, under light loads, the capacitance of high-voltage lines can create excessive leading reactive power, causing the voltage at some locations to rise above the nominal value.

Utilities and others commonly compensate for VARs in electrical power circuits throughout the entire system, from the utility transmission grid down to motor control centers in a typical industrial plant. In most cases, fixed capacitors are arranged in banks of varying sizes to provide VAR compensation. Generally these are switched on or off remotely in response to changing load conditions. Switching in more capacitors allows a path for reactive power to circulate without having to flow in the complete



electrical system. Reducing kVAR current flow in the system causes the utility voltage to rise. Adding more power factor correction increases the utility voltage. Thus, utilities employ transformer tap-changing devices in substations along with capacitor banks to manage the nominal voltage value of the power system.

In an industrial plant, capacitor banks are used for the same purpose but on a much smaller scale. The capacitor banks are referred to as power factor correction capacitors. Most are fixed value banks; some are mechanically switched in steps using contactors. As the plant load changes over the course of a day, some switching of these capacitor banks may occur.

Switching a capacitor bank causes large current surges and voltage transients to occur as the capacitors are connected to a circuit. Large transients can shutdown sensitive devices connected to the power system. This problem can be much worse, and cover a wide area, when a utility switches a very large capacitor bank on the medium or high voltage system. Different schemes and devices are employed in some cases to limit this phenomenon, but it remains a problem for sensitive loads. Loads that generate large amounts of VARs with rapid variation require special solutions. The devices that can mitigate these issues are referred to as dynamic or “fast VAR” systems.

The fluctuations in VAR demand create a new problem called flicker for electrical devices that have rapidly changing load characteristics. Flicker is defined as a perceptible change in the intensity of an electric light source due to fluctuation of the input voltage. Simple examples of flicker are seen in homes every time a large load, such as the air conditioning compressor turns on. However, people living near a rock quarry or sawmill could experience this several times a minute. With growing concern for overall

power quality, flicker standards and enforcement are getting much greater attention.

In the past, very large dynamic loads such as arc furnaces in steel mills applied large rotating machines, called synchronous condensers as a VAR compensator. These devices are large synchronous motors running with no mechanical load. During the last 20 years greater use of electronic devices has made dynamic VAR compensation more cost effective. Thyristor-switched capacitors on power electronic inverters are the solid-state equivalent of a synchronous condenser.

As concern for power quality continues to increase, more applications for VAR support and compensation appear. The latest is wind farms connected to utility grids. The unpredictable nature of wind power causes fluctuation in the amount of power produced. The large wind turbine generators must produce and absorb VAR current. This variation in the VAR current demand is a real issue for utility companies that accept the power from these farms.

Shunt & Series Compensation

Shunt and series reactive compensation using capacitors has been a widely recognized and powerful method to combat the problems of voltage drops, power losses and voltage flicker in power distribution networks. The importance of compensation schemes has gone up in recent years due to the increased awareness on energy conservation and quality of supply on the part of the Power Utility as well as power consumers.

Compensating a lagging load by using shunt capacitors will result in

- Lesser power loss everywhere upto the location of capacitor and hence a more efficient system.
- Releasing of tied-up capacity in all the system equipments thereby enabling a postponement of the capital intensive capacity enhancement programmes to a later date.
- Increased life of equipments due to optimum loading on them.
- Lesser voltage drops in the system and better regulation.
- Less strain on the excitation system of generators and lesser excitation losses.
- Increase in the ability of the generators to meet the system peak demand thanks to the released capacity and lesser power losses.

Shunt capacitive compensation delivers maximum benefit when employed right across the load, and

employing compensation in HT & LT distribution network is the closest one can get to the load in a power network. Power utilities in most countries employ about 60% capacitors on feeders, 30% capacitors on the substation buses and the remaining 10% on the transmission system.

Just as a lagging system power factor is detrimental to the system, a leading system PF is also undesirable. It tends to result in over-voltages, higher losses, lesser capacity utilisation, and reduced stability margin in the generators. The reduced stability margin makes a leading PF operation of the system much more undesirable than the lagging PF operation.

Shunt compensation is successful in reducing voltage drop and power loss problems in the network under steady load conditions. But the voltage dips produced by DOL starting of large motors, motors driving sharply fluctuating or periodically varying loads, arc furnaces, welding units etc can not be improved by Fixed shunt capacitors since it would require a rapidly varying compensation level (Dynamic Compensation).

Dynamic Compensation (SVC) is considered ideal for handling voltage dip problem brought about by motor starting, arc furnaces, welders etc.

Mechanical versus static compensation

Utilities frequently install capacitors connected from line to ground to compensate for lagging reactive power and reactors connected from line to ground to compensate for leading reactive power. These reactors and capacitors are switched in and out with mechanical switches based on the level of line loading as it varies throughout the day. However, frequent operation of these mechanical switches may reduce their reliability.

It is desirable to have a controllable source of reactive power (leading or lagging); and the static VAR compensator, controlled with static switches, called thyristors, for higher reliability, fulfills this function. It is more expensive than mechanically switched capacitors and reactors and hence its use is based on an economic trade-off of benefits versus cost.

Economic justification for use of Capacitors

High voltage capacitor banks are mainly installed in following type of applications:

- Cement factories.
- Electric arc furnace installations.
- Chemical and petro-chemical plants.

- Water pumping stations.
- H.V motor centers.
- Water purification plant.
- Desalination plants.
- Wind farms.
- Airports.
- Power generating stations and mini power generating stations.
- Transmission centers / sub-stations.
- Paper manufacturing units.
- Electric power distribution companies.
- Large industries in general.

The incremental benefits of 1 kVAR of additional compensation diminishes as the system power factor approaches unity. However some customers segments have an incentive to go to unity power factor. This fact prompts an economic analysis to arrive at the optimum compensation level. Different economic criteria can be used for this purpose. The annual financial benefit obtained by using capacitors can be compared against the annual equivalent of the total cost involved in the capacitor installation. A more sophisticated method would be able to calculate the present value of future benefits and compare it against the present cost of capacitor installation.

When reactive power is provided only by generators, each system component (generators, transformers, transmission and distribution lines, switch gear and protective equipment etc) has to be increased in size accordingly. Capacitors reduce losses and loading in all these equipments, thereby effecting savings through power loss reduction and increase in generator, line and substation capacity for additional load. Depending on the initial power factor, capacitor installations can release at least 30% additional capacity in generators, lines and transformers. Also they can increase the distribution feeder load capability by about 30% in the case of feeders which were limited by voltage drop considerations earlier. Improvement in system voltage profile will usually result in increased power consumption thereby enhancing the revenue from energy sales.

Thus, the benefits to be considered in an economic analysis of compensation requirements are released generation capacity, released transmission capacity, released distribution substation capacity, reduced energy loss, reduced voltage drop and released feeder capacity.

Capacitors in distribution system will release generation and transmission capacities. But when individual distribution feeder compensation is in question, the value of released capacities in generation and transmission system are likely to be too small to warrant inclusion in economic analysis.

State of Industry

In India, there are about 10 large manufacturers in the HT power capacitor sector whereas in the LT power Capacitor sector the actual number of manufacturers may be more than 50. The estimated turn over of the total power capacitor industry is Rs. 350 crores. This represents a very small share of the global market. Industry can improve the presence in the global market by broad basing its activities suitably.

Majority of the supplies in India are being made to state electricity boards, DISCOMS and utilities. The purchasing policies of buying at the lowest price have resulted in distortions of this business segment. Some newly formed DISCOMS have changed the procurement procedures.

Due to various initiatives of Power Ministry, the demand for HT /LT power sector improved substantially. In 2008-09 production of HT Power Capacitors increased by about 7% where as production of LT Capacitors registered a modest 1% increase. The market for LT Capacitor is estimated around 15300 MVAR and for HT Capacitors in the region of 13600 MVAR. Electricity Boards and utilities are encouraging installation of capacitors by industrial & commercial consumers through a combination of stiff penalties and significant incentives in the electricity tariff structure.

Export of Power Capacitors has almost tripled while import has increased by about 22%. With the existing large installed base within the country and additional competition from foreign suppliers, price realization for LT power capacitors leaves much to be desired.

MFD Capacitors are at almost the same level as last year. The overall market consists of two broad segments i.e., the OEM segment & the Open market segment. OEM segment has introduced "E-Sourcing" in procurement practices due to which local industry is exposed to very stiff competition from global sources. The Open market segment being highly price conscious, presence of inferior quality capacitors creates intense pressure on the industry. Insignificant by value though, there is a significant jump in demand for special Capacitors for Pulse Power, Energy Storage etc. Industrial business is picking up in Govt. Sector such as Bokaro Steel.

Private projects are yet to take off; one of the reasons could be that they can't reconcile to price increase, on account of appreciation of \$, at a time when other product prices are coming down. There is not much movement on the State Utilities' front. In EHV and HVDC, orders are flowing thanks to PGCIL.

Overall, Capacitor industry is witnessing an upward trend. It seems to be better placed than other Power Products. Globally there has been an exponential growth in Capacitors in the last 3-4 years. It is likely to continue for the next few years since MVAR is lagging MW by a wide margin.

There is concern about frequent increase in raw material prices. The challenge is in quoting prices against tenders with validity of few months. Industry has practically exhausted all avenues for cost saving such as design optimization, productivity etc. while the input cost increases cannot be passed through fully. Shunt Compensation segment is ripe for commoditisation thanks to the high volume and low margins. However, Series Compensation is a high value proposition. Transmission segment is not likely to be commoditised in the foreseeable future. Manufacturers are moving towards providing total solutions instead of just supplying products.

Conclusion

In reactive power compensation, reliability and good return has been a traditional trigger for investment. Today, environmental benefits often drive investments in the form of reduced energy losses, low noise emissions and efficient use of existing overhead lines. Apart from financial gains, a positive environmental impact is an added value for customers.

The blackouts that occurred in several countries in 2003 reflect a reality, in which investments in transmission infrastructure have failed to follow the growth of electricity consumption and the advancing age of assets is a problem in many countries.

Energy market liberalization further emphasises a need to focus on efficiency and transparency.

Today the market outlook seems positive for energy saving solutions regardless of the turbulences of world economy, politics and other factors affecting the short-term market demand.



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