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Review on Reactive Power Compensation in Transmission Line Using FACTS Technology

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Abstract: **A Comprehensive revises on reactive power compensation in transmission line to balanced voltage profile management for safe and economic operation. As we know that voltage instability or voltage sag condition is very much common in today's fast growing world. In this we study FACTS technology for stable the power system. Mainly we focus on compensation techniques given by the different papers and give a brief review on that which is quite useful in maintaining voltage stability.**

Keywords: **FACTS, SVC, SATCOM, VAR, D-Var, D-SMES.**

1. INTRODUCTION

An optimal reactive power compensation can significantly improve the performance of a radial distribution network by reducing its power loss and improving its voltage profile, and line loadability. There are several reactive power compensation strategies reported time-to-time in the literature, for example capacitor placement [1] [2], combined operation of on-load tap changer and capacitor banks [3], and integration of distributed generation (DG) [4][5]. The latest addition is the distribution (FACTS) device allocation. FACTS devices are brilliantly used in power quality improvement they can be used in optimal reactive power compensation as well. FACTS controllers are used which provides the best ,continuous capacitive ,inductive reactive power supply to power system as we all know that electrical power system has three components real power(P), reactive power(Q), apparent power (S) [6][7]. Real power is that power that is work producing power in watts(W) or kilo watts(KW) and reactive is not a power to do some useful work or certain work but it is that which is needed to start a equipment or system and is measured in volt ampere reactive(VAR).

There are so many causes for low power factor such as follows:

1. It started increasing heating losses in transformers and distribution systems.

2. It reduces system growth.

3. Increased cost.

4. Decrease efficiency of power system.

5. It also increase the electricity cost and which in total increase the overall cost of installation [3].

2. NEED FOR REACTIVE POWER COMPENSATION

The main reason for reactive power compensation in a system is:

1. The voltage regulation.

2. Increased system stability.

3. Overheating of generator and motor.

4. Reducing losses and to maintain the ability of the system to withstand disturbances.

5. Prevent voltage collapse as well as voltage sag.

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The impedance of transmission lines and the need for lagging VAR by most machines in a generating system results in the consumption of reactive power, thus affecting the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to increased losses which needs to be supplied by the source and in turn leading to outages in the line due to increased stress on the system to carry this imaginary power. Thus we can infer that the compensation of reactive power not only mitigates all these effects but also helps in better transient response to faults and disturbances. In recent times there has been an increased focus on the techniques used for the compensation and with better devices included in the technology, the compensation is made more effective. It is very much required that the lines be relieved of the obligation to carry the reactive power, which is better provided near the generators or the loads. Shunt compensation can be installed near the load, in a distribution substation or transmission substation.

3. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

FACTS are technologies that increase flexibility of transmission systems by allowing control of power flows and increasing stability limits of transmission lines. FACTS devices can be installed in a substation, requiring less space and permitting than additional transmission lines. There are several varieties of FACTS devices. Some of the FACTS devices for reactive power management are static var compensators (SVC), static synchronous compensators (STATCOM), dynamic var (D-var) and distributed superconducting magnetic energy storage (D-SMES).

Technological Principles of the Reactive Power Compensation Equipment Static Var Compensators (SVC):

SVC is a reactive power compensation device, which has the major forms of Thyristor Controlled Reactor (TCR), Thyristor Switch Capacitor (TSC), the mixing device of TCR and TSC, etc. Its operation mechanism is power electronics technology. SVC is a widely used dynamic reactive power compensation technology device at the moment, which is due to the ability to solve the problem of three imbalances, low power factor, high harmonic content, the voltage fluctuation and flicker [2]. SVC has occupied a dominant position among the type of stationary reactive power compensation device in some economically developed areas [3]. Its principle is shown in in Figure 1.

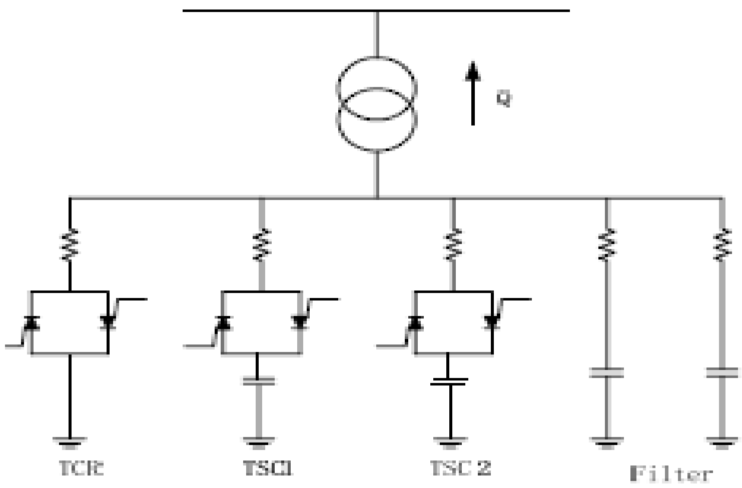

Figure 1. Schematic diagram of working principle of SVC

Firstly, SVC can be used as system compensation device to maintain the transmission line capacity, to improve transient stability of the power grid, to improve the transmission capacity of active power and static stability of the grid, to increase the system damping and restrain the power oscillation. Secondly, it is also can be used as a load compensation device to suppress voltage fluctuation and flicker caused by load changes, to improve the power factor and optimize energy flow within the network, to compensate for active and reactive power load imbalance.

However, there are some shortcomings in the application of SVC. It belongs to impedance compensators. With the voltage dropping, the reactive power output drops by the relation of square to the voltage [4]. When the voltage is low, that process will get into a vicious cycle. And as its main element, IGBT converter itself has certain uncontrollable nature, which is accompanied by the harmonic.

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Static Synchronous Compensators (STATCOM):

With the application of high-power and full-controlled power electronic devices, such as GTO, IGBT and other various controlled techniques (PWM, phase control technology, four-quadrant converter technology), the development of the inverter technology accelerates. On this basis, a new stationary reactive power compensation technology (ASVG) – STATCOM becomes a hot point in the field of reactive power control research [5]. STATCOM, as a member of the FACTS family, is important shunt compensation equipment. It can be divided into two types by its circuit, one is voltage-bridge circuit (shown in Figure 2), the other is current type bridge circuit (shown in Figure 3).

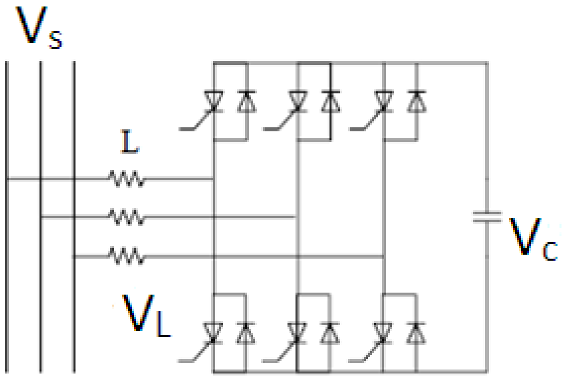

Figure 2. Voltage type bridge circuit

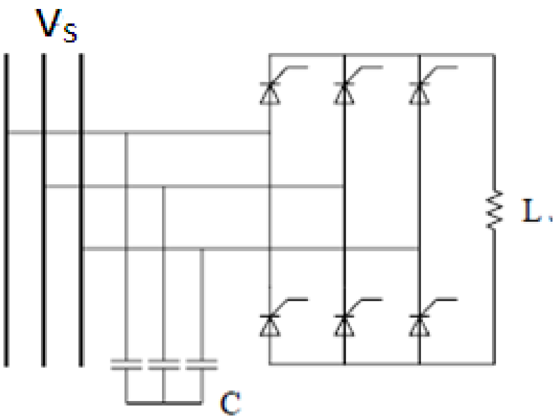

Figure 3. Current type bridge circuit

In the following, the voltage-bridge circuit is taken as an example to illustrate the basic operating principle of STATCOM. Capacitor is connected to the power line in parallel with the bridge circuit, which can adjust the output voltage by adjusting the commutation angle of the shutting down device. Thus, the reactive power can be provided in a real-time and dynamic way. There are two main directions for STATCOM to better the power quality: one is improving the power factor, the other is improve the power grid voltage [6].

Power Factor Improvement:

The simplified wiring diagram of STATCOM system is shown in Figure 4. E_s stands for the equivalent potential of the infinite system. $R_s + jX_s$ is the equivalent Thevenin impedance from the load side. $R_{eq} + jX_{eq}$ stands for the equivalent impedance of STATCOM. U is the voltage at the point of junction between the STATCOM and system, which is namely the voltage of the common connection point. When the STATCOM is in the standby state, the system undertakes all the reactive component (L_{QI}) of the load current (L_I), and S_{QI} is equal to L_{QI} . If the L_{QI} is larger, the load power factor will be reduced and the line loss will be increased. When the STATCOM is put into operation, the capacitive current C_{QI} will moderately compensate reactive component L_{QI} of the load current, which will reduce the reactive power demand. In the ideal case, C_{QI} is equal to L_{QI}, load reactive current will be neutralized completely by the STATCOM, Which will achieve the best condition with the power factor of 1.

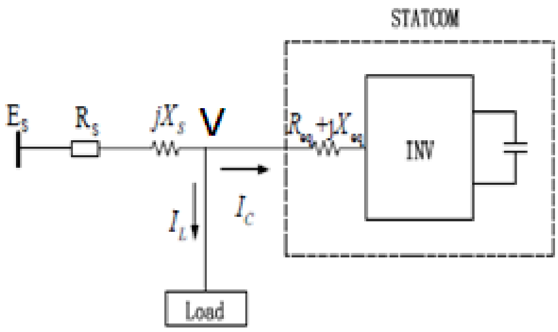

Figure 4. System wiring diagram of STATCOM

Power grid voltage Improvement:

The voltage of the amplitude nodes in the network is determined by the reactive power demand. Once reactive power demand of the system exceeds the maximum reactive power, it will produce large amounts of reactive power flowing in the network, which is bound to worsen voltage and increase the net loss. Assuming that the active component and reactive component providing by the system in Figure 4 are P_S and QS, the active and reactive power demand needing by the load are P_L and Q_L, the reactive power providing by the STATCOM is QC. Then when STATCOM is not put into operation, the system will supply for the reactive power load demand, and Q_S is equal to Q_L. The voltage loss system can be expressed as follows:

$$\Delta V = \frac{R_S R_S + Q_S X_S}{V} = \frac{R_L R_S + Q_L X_S}{V} \qquad \ldots\ldots\ldots 1$$

$$Q_s = Q_L - Q_C \qquad \ldots\ldots\ldots\ldots\ldots 2$$

$$\Delta V = \frac{R_S R_S + Q_S X_S}{V} = \frac{R_L R_S + (Q_L - Q_C)\, X_L}{V} \qquad \ldots\ldots\ldots 3$$

By the formula (1) and (3) showing that, as long as there is proper control of the STATCOM reactive power output Q_C , the system voltage loss will be reduced, in turn, the voltage level of the whole system will be adjusted and the voltage quality, voltage passing rates and other indicators will be improved[4].

D-var (Dynamic Var):

D-var voltage regulation systems dynamically regulate voltage levels on power transmission grids and in industrial facilities; D-var is a type of STATCOM. D-var dynamic voltage regulation systems detect and instantaneously compensate for voltage disturbances by injecting leading or lagging reactive power to the part of the grid to which the D-var is connected [6][7]. D-var systems provide dynamic var support for transmission grids that experience voltage sags, which are typically caused by high concentrations of inductive loads, usually in industrial manufacturing centers, or from weaker portions of the transmission grid, typically in remote areas or at the end of radial transmission lines. D-var systems also are suited to address the need for dynamic var support at wind farms [8]. Because of the remote locations of most large wind farms, the power they generate must often be delivered a long distance to the ultimate customer on a relatively weak utility transmission grid. A D-var system is ideally suited to mitigating voltage irregularities at the point of interconnection between the wind farm and the grid. D-var systems can be integrated with low cost capacitor banks to provide an extremely cost-effective solution for large wind farms.

Distributed SMES or D-SMES:

Superconducting magnetic energy storage (SMES) system is a device for storing and instantaneously discharging large quantities of power. These systems have been in use for several years to solve voltage stability and power quality problems for large industrial customers. A distributed-SMES (D-SMES) system is a new application of proven SMES

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technology that enables utilities to improve system reliability and transfer capacity [10]. D-SMES is a shunt-connected Flexible AC Transmission (FACTS) device designed to increase grid stability, improve power transfer and increase reliability. Unlike other FACTS devices, D-SMES injects real power as well as dynamic reactive power to more quickly compensate for disturbances on the utility grid [11]. Fast response time prevents motor stalling, the principal cause of voltage collapse.

4. CONCLUSIONS

Reactive power compensation devices, SVC, STATCOM and D-Var, is widely used in transmission and distribution network, large industrial mining, electric railways, wind farms and other occasions, which plays a significantly role in suppressing flicker, reducing losses, voltage supporting and so on. With the implement of the energy saving policy thoroughly and the improvement of the transmission line reliability requirements, the dynamic reactive compensation technology will be more promoted and applied. Its compensation way will vary with the system changes and ultimately boost further reactive compensation technology integration and development.

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