Stabilization of Voltage in Power System by Using STATCOM

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Abstract-Voltage stability problems usually occur in heavily loaded systems. Modern power systems are prone to widespread failures. With the increase in power demand, operation and planning of large interconnected power system are becoming more and more complex, so power system will become less secure Nowadays the power demand increases enormously. When the load increases suddenly, voltage magnitude also varies beyond the permissible voltage stability limit. But the voltage magnitude must be maintained within the limit for proper operation of the system. Hence, voltage stability must be improved. This paper deals with performance, analysis and operating principle of a power Electronics based device called STATCOM, which is used for voltage stability and compensation of reactive power and make the system stable. Power system stability is defined as the ability of a power system that enables it to remain in stable operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. In this paper STATCOM is use for stabilization of voltage in power system. The role of STATCOM will be to mitigate the voltage problems like voltage sag voltage swell which are generally occurs in power system during high voltage and low voltage condition.

Keywords- *voltage stability, voltage source converter. Continuation power flow, STATCOM, Voltage sag, voltage swells.*

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I. INTRODUCTION

Voltage stability of a system is affected by reactive power limit of the system. FACTs devices improve the reactive power flow in system thereby improving voltage stability. Voltage stability has become an increasingly important phenomenon in the operation and planning of the present day power systems. Voltage collapse is a process in which the appearance of sequential events together with the voltage instability in a large area of system can lead to the case of unacceptable low voltage condition in the network [1]. Load increasing can lead to excessive demand of reactive power, system will show voltage instability. If there are not sufficient reactive power resources and the excessive demand of reactive power can lead to voltage collapse. This paper addresses the static modeling of Static Synchronous Compensator (STATCOM). The best location of the (STATCOM) can be obtained using load flow study, which can also be used to determine the optimal value of the reactive power needed at different load conditions. Voltage sags and momentary power interruptions are probably the most important power quality problems affecting industrial and large commercial customers. These events are usually associated with a fault somewhere on the supplying power system. Actual interruptions occur when the fault is on the circuit supplying the customer. Voltage sags are much more common since they can be associated with faults remote from the customer. Even voltage sags lasting only 4-5 cycles can cause a wide range of sensitive customer equipment to drop out.By using STATCOM tis power quality problems can be minimized.

II STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is a Static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage. STATCOM is one of the key FACTS Controllers. A STATCOM is a controlled reactive power source. It provides voltage support by generating or absorbing capacitors banks. It regulates the voltage at its terminals by compensating the amount of reactive power in or out from the power system [3]. When the system voltage is low the

STATCOM injects the reactive power to and when the voltage is high it absorbs the reactive power [4]. The reactive power is fed from the Voltage Source Converter (VSC) which is connecting on the secondary side of a coupling transformer as shown in the Fig 1. By varying the magnitude of the output voltage the reactive power exchange can be regulated between the convertor and AC system. STATCOM is such a device in which the modern power electronic converters have been employed. These converters are capable of generating reactive power with no/very little need for large reactive energy storage elements.

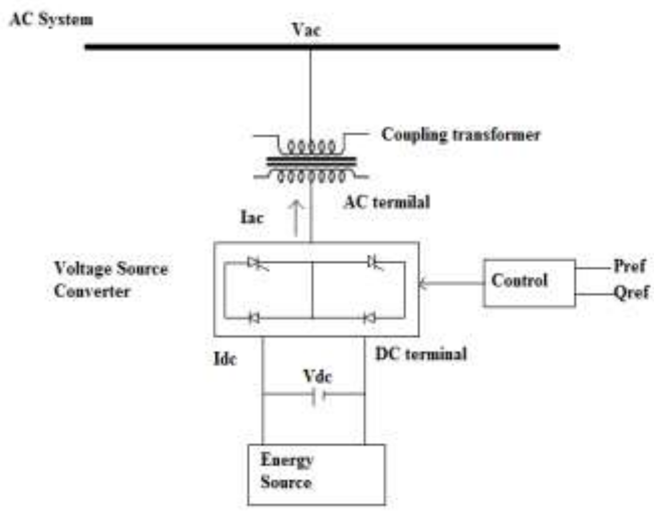

Figure 1: Functional block diagram of STATCOM

A.OPERATING PRINCIPLE

The STATCOM generates a balanced 3-phase voltage whose magnitude and phase can be adjusted rapidly by using

 ISSN: 2321-8169
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semiconductor switches. The STATCOM is composed of a voltage-source inverter with a dc capacitor, coupling transformer, and signal generation and control circuit [5]. Let V_1 be the voltage of power system and V_2 be the voltage produced by the voltage source (VSC). During steady state working condition, the voltage V_2 produced by VSC is in phase with V_1 (i.e. =0) in this case only reactive power is flowing. If the magnitude of the voltage V_2 produced by the VSC is less than the magnitude of V_1, the reactive power is flowing from power system to VSC (the STATCOM is absorbing the reactive power). If V_2 is greater than V_1 the reactive power is flowing from VSC to power system (the STATCOM is producing reactive power) and if the V_2 is equal to V_1 the reactive power exchange is zero. The amount of reactive power can be given as:

$Q = V_1 (V_1-V_2) / X$

B V-I CHARACTERISTICS OF STATCOM

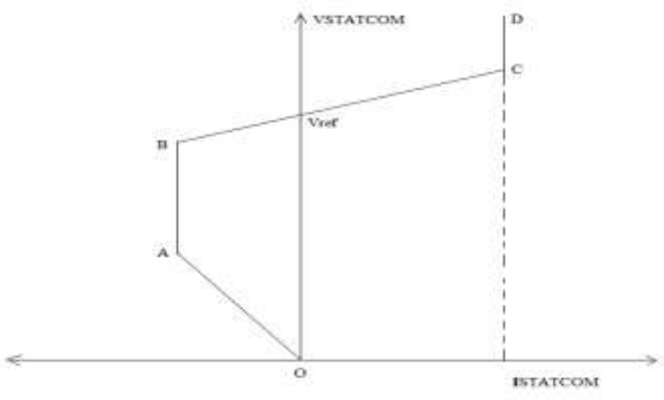

Fig 2: V-I Characteristics of STATCOM

From Fig 2, STATCOM exhibits constant current characteristics when the voltage is low/high under/over the limit. This allows STATCOM to delivers constant reactive power at the limits compared to SVC. Since SVC is based on nominal passive components, its maximum reactive current is proportional to the network voltage. While for STATCOM, its reactive current is determined by the voltage difference between the network and the converter voltages and therefore, its maximum reactive current is only limited by the converter capability and is independent of network variation.

As an important member of the FACTS controllers' family, Static Synchronous Compensator (STATCOM) has been at the center of attention and the subject of active research for many years. Through regulation of the line voltage at the point of connection, STATCOM can enhance the power transmission Capability and thus extend the steady-state stability limit. STATCOM can also be used to introduce damping during power system transients and thus extend the transient stability margin. Theoretically, FACTS controllers can be realized by either a voltage-source converter (VSC) or a current-source converter (CSC) [2]; however, except for the work reported in [11] more than 10 years ago, the focus of all the published work on STATCOM has been on using VSC topology [12]–[13]. The reasons behind the choice of VSC over CSC are as follows:

1) A CSC is more complex than a VSC in both powers and control circuits. Filter capacitors are used at the ac terminals of a CSC to improve the quality of the output ac current waveforms. This adds to the overall cost of the converter. Furthermore, filter capacitors resonate with the ac-side inductances. As a result, some of the harmonic components present in the output current might be amplified, causing high harmonic distortion in the ac-side current. Besides, conventional bi-level switching scheme cannot be used in CSC.
2) Unless a switch of sufficient reverse voltage withstanding capability such as Gate-Turn-Off Thyristor (GTO) is used; a diode has to be placed in series with each of the switches in CSC. This almost doubles the Conduction losses compared with the case of VSC.
3) The dc-side energy-storage element in CSC topology is an inductor, whereas that in VSC topology is a capacitor. The power loss of an inductor is expected to be larger than that of a capacitor. Thus, the efficiency of a CSC is expected to be lower than that of a VSC.

As a result of the recent developments in the control of CSC and the technology of semiconductor switches, the above situation is likely to change for the following reasons:
1) Due to the presence of the ac-side capacitors, both Voltage and current waveforms at the output terminals Of a CSC are good sinusoids. The capacitors are the Inherent filter for the CSC. Although a 48-pulse VSC STATCOM does not require a filter [8], the cost of the filter is transferred to the cost of multi-converters and multi-winding transformer. Additional filter has to be used in a VSC STATCOM if operating at a lower frequency. It is possible to operate a CSC STATCOM under 900 Hz of switching frequency with a single converter. This reduces the filtering requirements compared with the case of a VSC. The problem of the resonance between the capacitances and inductances on the ac-side can be overcome by careful design of the filter capacitors and introduction of sufficient damping using proper control methods. Furthermore, all the switching problems faced in the early stages of CSC development can be overcome by employing trilevel switching scheme, which has become a standard technique in the control of CSC.
2) Featuring high ratings, high reverse voltage blocking capability, low snubber requirements, lower gate-drive power requirements than GTO, and higher switching speed than GTO, Integrated Gate Commutated Thyristor (IGCT) is the optimum combination of the characteristics demanded in high-power applications. Using the state-of-the-art technology of the semiconductor switches, there will be no need for the series diode in the CSC topology anymore.
3) The dc-side losses are expected to be minimized using superconductive materials in the construction of the dc-side reactor.

III *BASIC PRINCIPAL OF POWER COMPENSATION IN TRANSMISSION SYSTEM.*

Figure 3 shows the simplified model of a power transmission system. Two power grids are connected by a transmission line which is assumed lossless and represented by the reactance X_L. $11\delta\angle V$ and $22\delta\angle V$ represent the voltage phasors of the two

ISSN: 2321-8169
018– 021

power grid buses with angle $\delta = \delta_1 - \delta_2$ between the two. The corresponding phasors diagram is shown in Figure 3

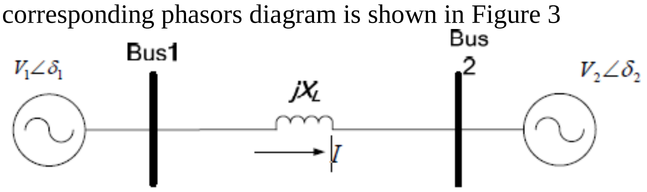

Figure 3 Power transmission system

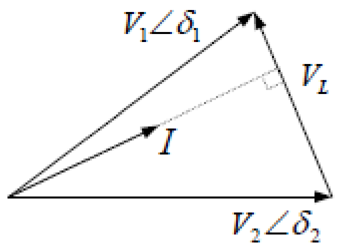

Figure 4 phase diagram

The magnitude of the current in the transmission line is given by:

$$I = \frac{V_L}{X_L} = \frac{\left|V_1\angle\delta_1 - V_2\angle\delta_2\right|}{X_L}$$

Equation 1.

The active and reactive components of the current flow at bus 1 are given by:

$$P_1 = \frac{V_1 V_2 \sin\delta}{X_L}, \qquad Q_1 = \frac{V_1(V_1 - V_2\cos\delta)}{X_L}$$

Equation 2.

Similarly, the active and reactive components of the current flow at bus 2 can be given by:

$$I_{d2} = \frac{V_1 \sin\delta}{X_L}, \qquad I_{q2} = \frac{V_2 - V_1\cos\delta}{X_L}$$

Equation 3.

The active power and reactive power at bus 2 are given by:

$$P_2 = \frac{V_1 V_2 \sin\delta}{X_L}, \qquad Q_2 = \frac{V_2(V_2 - V_1\cos\delta)}{X_L}$$

Equation 4.

Equations (1- through (4) indicate that the active and reactive power/current flow can be regulated by controlling the voltages, phase angles and line impedance of the transmission system. From the power angle curve shown in Figure 4, the active power flow will reach the maximum when the phase angle δ is 90°. In practice, a small angle is used to keep the system stable from the transient and dynamic oscillations.

Generally, the compensation of transmission systems can be divided into two main groups: shunt and series compensation.

IV POWER QUALITY ISSUES

Power quality problems have many names and descriptions. Surges, spikes, transients, blackouts, noise, voltage sag, voltage swell, interruption, dc offset are some common descriptions .In order to increase the reliability of a power distribution system, many methods of power quality problems have been following:

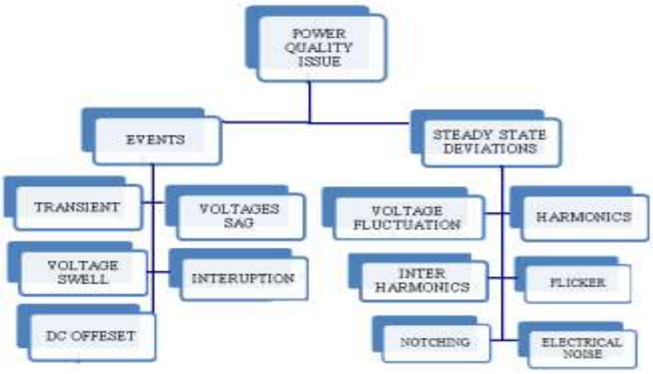

Figure 5 Power quality issues

A. VOLTAGE SAG

Voltage sag is described as a drop of 10-90% of the rated system voltage lasting for half a cycle to one minute. The causes of voltage sag are:

- Voltage sags are caused by system faults.
- It can also be caused by energisation of heavy loads.
  Voltage sags which can cause equipment impacts are usually caused by faults on the power system. Motor starting also results in voltage sags but the magnitudes are usually not severe enough to cause equipment misoperation.

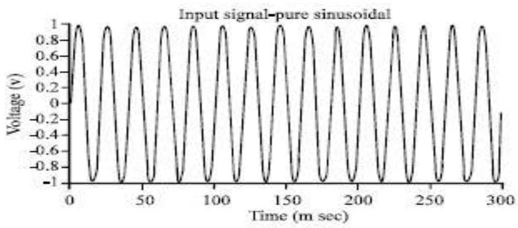

Figure.6 Input Signal

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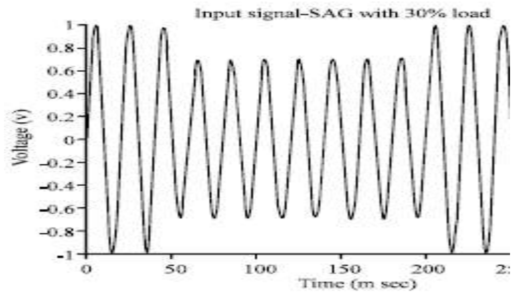

Figure. 7 Input signalwi sag effect

The 10, 20 and 30% sag disturbances lasting for 15 cycles are shown in fig.5 they are generated with the simulation diagram as shown in fig 5.In the sag wave form obtained by adaptive decomposition, can be observed that there is a decrease in value of R.M.S voltage during sag. The error signal will show spikes during sag period and finally the adoption error will be reduced to zero.

B. VOLTAGE SWELL

Voltage Swell is defined by IEEE 1159 as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycle to one (1) minute. It is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems mentioned in the second post of the power quality basics series of this site. Voltage swell is basically the opposite of voltage sag or dip.

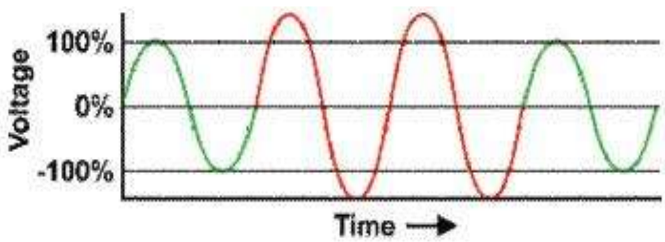

Figure. 8 Voltage Swell Effect

The disturbance is also described by IEEE C62.41-1991 as "A momentary increase in the power-frequency voltage delivered by the mains, outside of the normal tolerances, with duration of more than one cycle and less than a few seconds". However, this definition is not preferred by the power quality community.

Swells are subdivided into three categories:

Voltage Swell	Magnitude	Duration
Instantaneous	1.1 to 1.8 pu	0.5 to 30 cycles
Momentary	1.1 to 1.4 pu	30 cycles to 3 sec
Temporary	1.1 to 1.2 pu	3 sec to 1 min

Table I Types of Swell

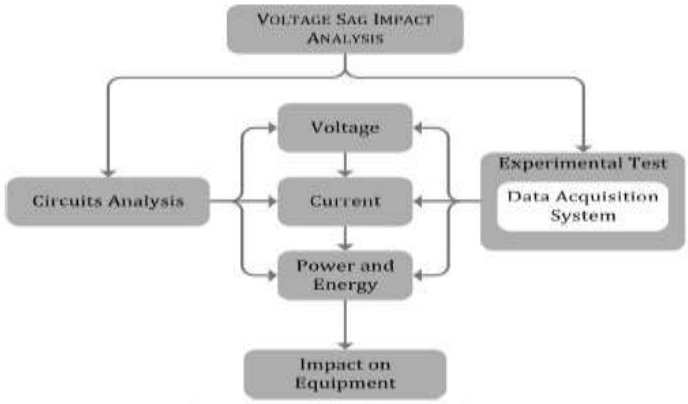

Fig ure 9.Praposed Voltage sag impact analysis

C .INTERRUPTIONS

An interruption is defined as a reduction in the supply Voltages or load current to a level less than 0.1 p.u. for a time not more than 1 minute.

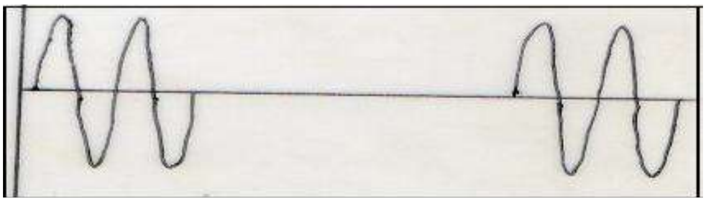

Figure 10 Interruption

D. TRANSIENTS

Transients, commonly called "surges" are sub-cycle Disturbances of very short duration that vary greatly in Magnitude

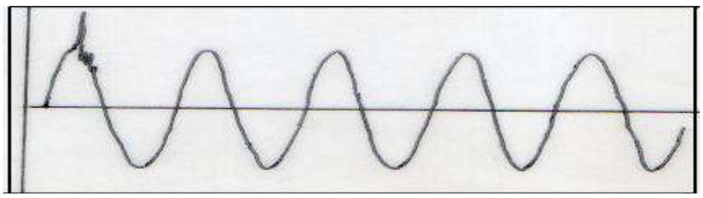

Figure 11 Transient event

V. Simulation Result Requirement

The requirement of the simulation result is that when the STATCOM is connected in generation side at a particular location it has to solve the power quality problems. Such that when there is a sudden increase in the voltage level then on it has rectify the problem of Voltage swell. And if there is a drop in voltage then Voltage sag problem should be clear by using STATCOM.In this way STATCOM work as a Custom device for solving Power quality problems.

VI. CONCLUSION

From the review of different paper it is seen that the STATCOM with the proposed controller can improve the Voltage profile of the power system during different kinds of disturbances. A STATCOM model will developed with all the

ISSN: 2321-8169
018– 021

necessary components and controllers in order to demonstrate its effectiveness in maintaining a fast voltage regulation at any bus bar. Then the simulation results will be compared with that of the system without compensation. With that comparison Simulation results should have prove the ability of the STATCOM to respond to the system demand for inductive or capacitive requirements with satisfactory performance. Finally, it has to be be concluded that the STATCOM used in this study can contribute significantly to the improvement of power quality in unbalanced systems.

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