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Transient Stability Improvement of IEEE 14 Bus System with STATCOM

Bal Krishna Jadon,
Power System, SKIT, Jaipur,
302017 (INDIA)

Pooja Jain
Electrical Engineering,
SKIT, Jaipur, 302017 (INDIA)

Anjali Jain
Electrical Engineering,
SKIT, Jaipur, 302017 (INDIA)

Abstract: To maintaining power quality of the power system is always a difficult task, when the rapid expansion of the power system occurred. Conventional compensation techniques are not very much effective and reliable. The latest compensation techniques are based on power electronic device such as FACTS. This paper analyzed the transient behavior of standard IEEE bus system using PSCAD. To improve the transient performance of line, STATCOM (Shunt controller) is used. The RMS voltage for uncompensated and compensated system can be find out by simulation process at the end of line.

Keywords: Stability, Power Quality, Facts, Pscad, Statcom, IEEE 14 Bus Systems.

I. INTRODUCTION

In a power system, the power flow is a function of line impedance, the sending and receiving end voltages with phase angle between them. For controlling anyone of the power flow constraints the only possible way is control of the active as well as the reactive power flow.

A. Stability

Stability is one of the major criteria, deciding the power system operations.
"Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance with most of the system variables bounded so that the entire system remains intact" [1], [2].
The disturbances may be one of the following;

- Generator outages
- Line outages
- Faults
- Load changes
- Voltage collapse

Power system stability can be classified into rotor angle, voltage and frequency stability. Each of these three stabilities can be further classified into large disturbance or small disturbance, short term or long term.

B. Power Quality

Now-a-days, the main objective of the power systems is generating power quality improvement methods. Power Quality is defined [3] as "a set of electrical boundaries that allows equipment to function in its intended manner without significant loss of performance or life expectancy." As power electronic equipments are extensively used, the studies of power quality have been further emphasized [4].

Voltage sag is the major cause of the power quality problems. Voltage sag [5], [6] means a reduction in the supply voltage magnitude followed by a voltage recovery after a short period of time. The range of the voltage sag magnitude varies from 10% to 90% of nominal voltage [7]. The economic losses of an industry depend on voltage sag. Disturbance of the power in the power system is frequently occurred due to high voltage rating of the end-user equipment as the main power quality problems [8]. The major causes of voltage sag are faults in the system and high rating loads. High power quality is very important for smooth operation of the modern society and industries [9].

Control by FACTS devices is one of the of cost free type of improving power quality.

C. Facts controller

In 1980's the Electrical Power Research Institute (EPRI) introduced a concept regarding Improvement of Power Flow and System Stability of the power system. This technology is termed as "Flexible Alternating Current Transmission System" (FACTS). The FACTS technology provides the ability to increase the controllability of the power system and stability limits with advanced power electronics technology.
The main objectives of the FACTS devices [10] are:

- To increase the power transfer capability
- To provide the controlling of the direct flow
- To provide secure loading of a T-line
- To improve the damping of oscillations

Since 1980s, Number of different types of FACTS controllers is introduced to improve the stability and reliability regarding to a power system. FACTS can be used for reduce the oscillations in the network and improvement transient behavior of the power system. Although FACTS are quite expensive but it is expected that the price is less parameter as compare to utilization. STATCOM is one of the FACTS controllers to use for improving the performance of a power system.
According to types of compensation, FACTS controllers can be divided in to three categories:

- Series controllers
- Shunt controllers
- Combined series-shunt controllers

Table 1: Detail classification of the main FACTS devices

S.no.	CATEGORY	FACTS-Devices	
1	Series controllers	Thyristor Controlled Series Compensator(TCSC)	Static Synchronous Series Compensator (SSSC)
2	Shunt controllers	Static Var Compensator (SVC)	Static Synchronous Series Compensator (STATCOM)
3	Shunt-Series Controllers	Dynamic Flow Controller (DFC)	Unifies Power Flow Controller (UPFC)

Now a day, the system security can be increase by using different approaches. In a power system, shunt capacitors are used to support the system voltage at satisfactory level.

Shunt FACTS controllers used to inject current into the power system at the point, where the device is connected to maintain good voltage profile and reactive power. Series capacitors are used to compensate the transmission line reactance and thereby increase power transfer capability.

II. STATCOM

STATCOM is defined by IEEE as a self-commutated switching power converter supplied from an electrical energy source to produce a set of flexible multiphase voltage. It is a shunt connected compensation device that is capable of absorbing and/or generating reactive power. It may be coupled to an AC power system for exchanging real and reactive power. The shunt controller is a good way to control the voltage at the point of connection through injection of reactive current for voltage control and damping of voltage dynamics [11].

The real power (P) and reactive power (Q) are given by equation 1 and 2:

$$P = \frac{EV}{X}\sin\partial \qquad ...(1)$$

$$Q = \frac{E^2}{X} - \frac{EV}{X}\cos\partial \qquad ...(2)$$

E is the line voltage of T-line. V is the generated voltage of VSC. X is the equivalent reactance and δ is the angle between E and V.

A. *Transient Stability Characteristics of STATCOM*

A STATCOM or static Synchronous Compensator is a regulating Devices used on alternating current. It is used as a source or sink of reactive AC power and working as voltage source converter based on power electronics.

In the given figure 1 the STATCOM can be used for controlling an increased transient behavior in both inductive and capacitive operating regions. [12]

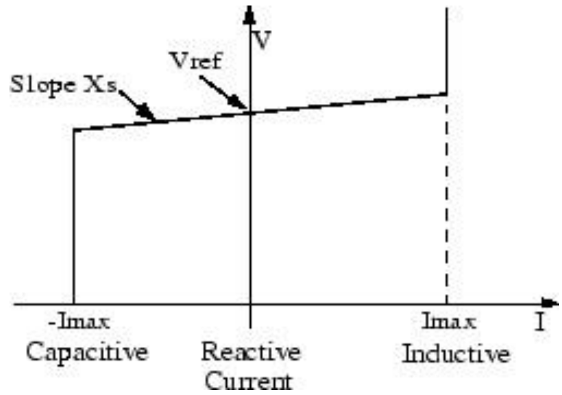

Figure1: Characteristics of STATCOM

III. IEEE 14 BUS

The IEEE 14 BUS system is taken for simulation of optimal power flow. The system consists of 14 buses, 5 generators buses, 11 loads, 3 Transformers, 22 branches.

Table 2: The System Parameter

S. No.	System Parameters	Ratings
1.	Bus Voltage	138 kV
2.	Frequency	60 HZ
3.	Generator	100 MVA

Out of five generators two generators supply real power while three generators are the reactive sources i.e. synchronous condensers to provide the reactive power supply. The system consists of total real load of 244.1 MW and reactive load of 72.4 MVAr. Three transformers data include the tap setting with the transmission data i.e. resistance, reactance and susceptance. The system branch data include resistances, reactance and IEEE-14 BUS SYSTEM The IEEE-14 bus System is running under NF & OPF. The system used for the simulation is shown in figure 2.

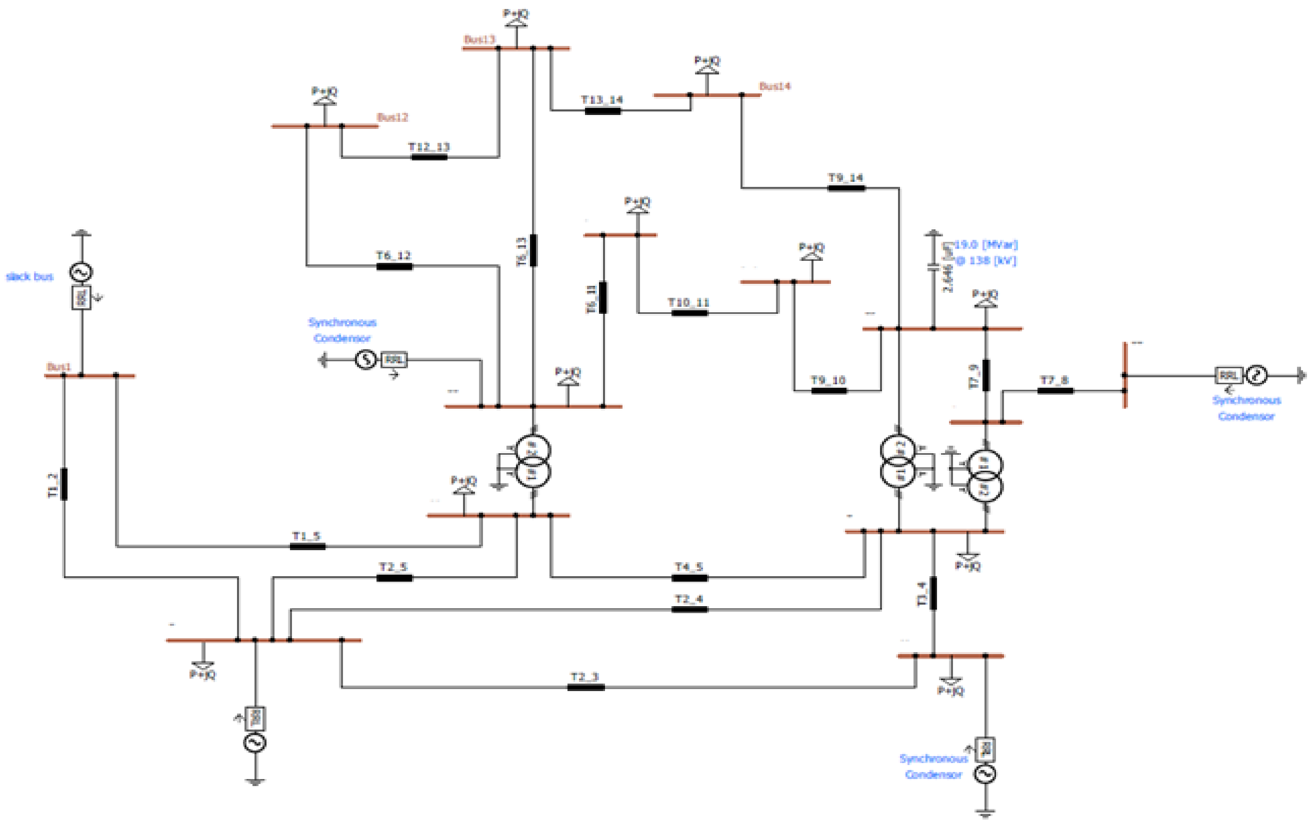

Figure 2: IEEE 14 bus system

A. *Methodology For Deciding The Weak Bus*

As our test system is the IEEE 14 BUS system which has 16 lines and 14 buses. Bus 1 is Slack Bus and Buses 2,3,6,8 are the generator buses. All the buses except bus 1,7 and 8 contains loads also. So it is important to decide that which bus is the most critical bus or weak bus. Voltage of the bus changes when any fault is occurred no matter what type of fault it is. The bus which is always affected by the faults in the system, is called as most critical bus. The technique is used in PSCAD which gives the bus number [13] is as following:

B. *Steps*

- At first we created the 3 phase fault at the mid-point of each line for a short period, as the 3 phase fault is the most severe one.
- Then we measured the voltages of all the buses except the generator and slack bus.
- Then we selected the 2 most critical lines. They are called critical because when we created the fault on these lines, the effect of 3 phase fault was most severe and they are affecting the most number of buses in the system.
- After preparing the table for these results we selected the line 7-9, line 9-10 and line 9-14 as the most critical lines.
- Now we do the same work for the single line to ground fault.

Table 3: Analysis from above steps

Transmission Line No		7-9	9-10	9-14
3 Phase to Ground Fault	Buses With Sag	4,7,9,10,11,14	4,7,9,10,11,14	7,9,10,13,14
	Most Critical	7,9,10,14	7,9,11	7,9,10,14
Single Line to Ground Fault	Buses With Sag	4,7,9,10,11,14	7,9,10,11,14	9,10,11,14
	Most Critical	4,7,9,10,14	7,9,10,14	9,10,14

We created both the faults at different locations and finally, we concluded that bus 9 is the most critical when the fault is at mid of the line. As we can see the figure when three phase fault creates between the lines 7-9.

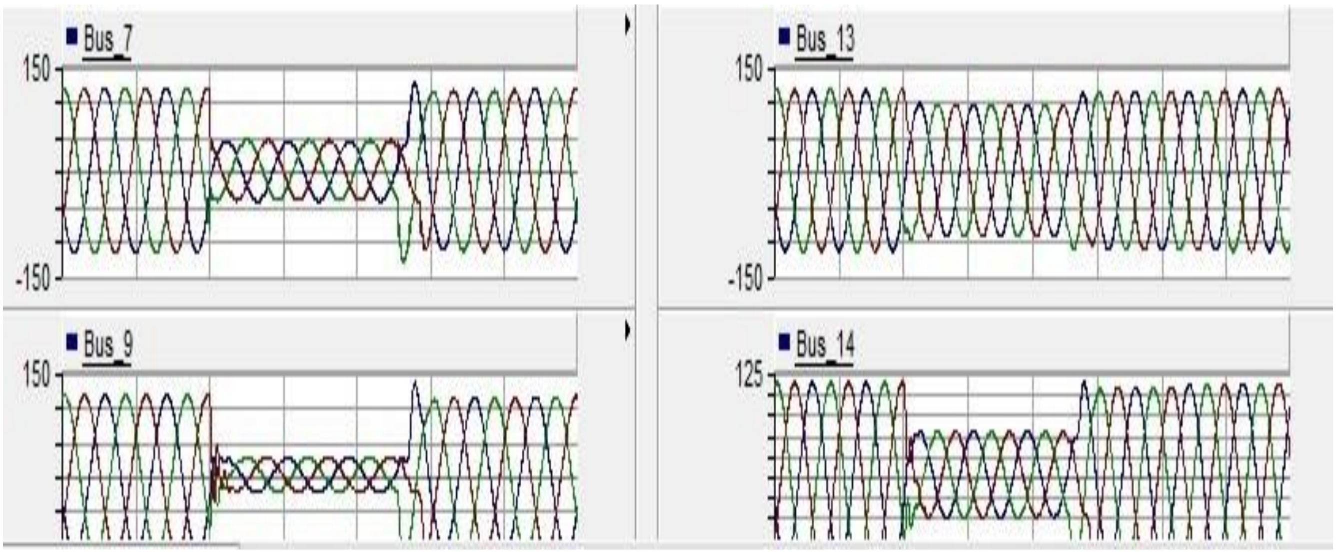

Figure 3: Three Phase Fault At Mid of the Line 7-9

IV. RESULT

In this research paper, we try to find out the impact of load increment at the bus 9.

Case I: Pre-Load Increment:

The real power and reactive power at the bus 9 are 9.833 MW and 5.533 MVAR respectively. The voltage waveform of the bus 9 is as shown in the figure 4:

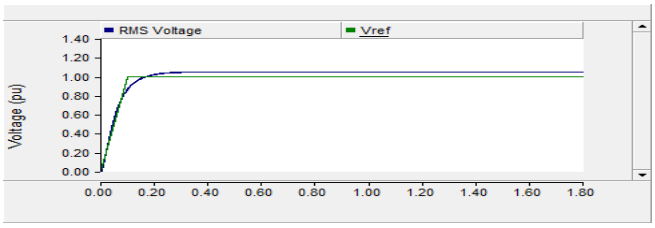

Figure 4: Pre load increment voltage variation

Case II: During Load Increment:

In this case we add new load of real power and reactive power at the bus 9 are 29.499 MW and 16.599 MVAR respectively in parallel with case I load at 1 sec through the circuit breaker. The waveform is as shown in figure 5:

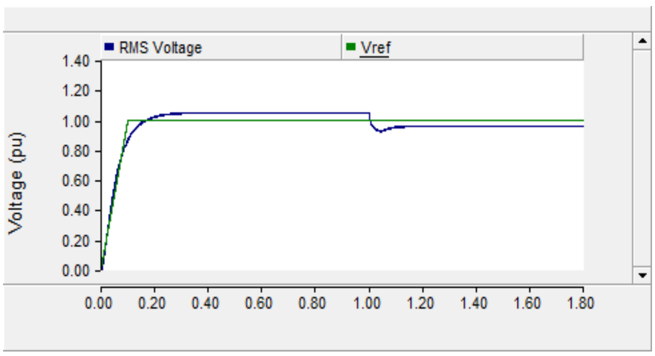

Figure 5: During load increment voltage variation

Case III: Post Load Compensation:

Our main work regarding to this paper is implementation of such device which is very effective for improvement the voltage profile so we choose STATCOM as a FACTS device here. In this case we use STATCOM as a compensator to improve the voltage level at the bus 9 as shown in the figure 6:

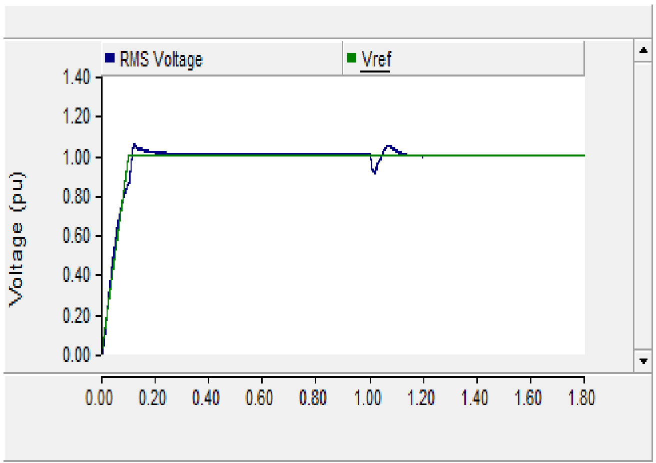

Figure 6: Post fault compensation voltage variation

The figure 5 shows that when the load increases at the bus 9, the voltage reduces as per case II. When the STATCOM is connected at this bus, the voltage reduction is compensated as shown in the figure 6.

V. CONCLUSION

STATCOM improves system voltage and system stability for heavy load conditions and light load conditions. For the result analysis, we study pre-load increment, during load increment and post load compensation using PSCAD. The optimum system founded by connecting STATCOM at weak bus. The

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final result can see the figure 4 where the voltage at bus 9 is automatically regulated with load increment. The technique for deciding the weak bus by PSCAD is better than others for small bus system.

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