Role of STATCOM in Voltage Stability Margin Enhancement

S.Padhee, T. Prakash, S. Behera, M. Tripathy

***Abstract*— In this paper, voltage profile, change in voltage(dv) ,power loss analysis with appropriate utilization of STATCOM is depicted and the comparison is made considering the IEEE 57-bus test system with and without STATCOM. STATCOM used here is treated as voltage controlled bus providing shunt compensation to the system. Voltage profile and the loading margin gives optimistic results with the introduction of STATCOM into the system, thus, making it, a good shunt compensating device. Also active and reactive power losses of the system with STATCOM reduces than compared to the system without any shunt compensation.**

***Index Terms*—voltage stability, shunt compensation, STATCOM**

I. INTRODUCTION

Modern day power systems are vast and complex consisting of interconnected systems having large number of generators and buses. [1]. There is continuous growth in load demand which led to the newer installations and expansion of transmission network.. This process is expensive and takes considerable amount of time for completion. In this scenario, in order to meet the increasing load demand, electric utilities are relying on the power exchange through the existing transmission lines. This, in turn, has deteriorated voltage profile and system stability. Thus, increased possibility of transient, oscillatory and voltage instability are now considered as one of the main concerns of electric utilities during planning and operation [2],[3],[4] .

Voltage instability depends on the load side and caused by the reactive power deficit at the load end. It is the main cause of the system voltage collapse, which makes the system voltage decay to such a level from where it is impossible to recover resulting in partial or full interruption of power supply. To overcome this situation, the only way is to reduce reactive power consumption or to supply additional reactive power to the system. Sources of reactive power like shunt capacitors and/or FACTS devices located at appropriate places are useful in tackling the problem of voltage instability.

The recent development and use of FACTS devices added flexibility to the transmission system by not only reducing the voltage instability of the system but also improving safe and secure operation of the system. Commonly used FACTS devices are Stati Var Compensator (SVC), Static Compensator (STATCOM), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Capacitor (SSSC), and Unified Power Flow Controller (UPFC) [5],[6]. Each one of them has their own characteristics [9],[10],[11] and limitations and are chosen by the electric utilities which is more beneficial to them for achieving voltage stability criterion.

In this paper, voltage profile assessment of the system with reactive shunt compensation provided by STATCOM is studied and compared with the system without it in the IEEE 30-bus test system. For easy and simple use, STATCOM is treated as voltage controlled bus and power flow solution is obtained.

Rest of the paper is organized as follows: Section II shows a brief introduction and representation of STATCOM. A test system and analysis tools are briefly explained in Section III. Section IV consists of results and discussions of simulated system. Section V investigates the role of STATCOM on voltage stability when there is a line outage in the system. Finally, conclusions are summarized in Section VI.

II. STATCOM

STATCOM is the Voltage-Source Inverter (VSI), which converts a DC input voltage into an AC output voltage in order to compensate the active and reactive power needed by the system [5],[6]. Fig. 1 shows the schematic diagram of STATCOM which is a shunt-connected device that controls the voltage at the connected bus to the reference value by adjusting voltage and angle of internal voltage source. From Fig. 2, the terminal characteristic of STATCOM is shown which depicts the status of STATCOM either inductive or capacitive dependent on the converter voltage adjustment. STATCOM injects or absorbs reactive to the bus to which

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it is connected accordingly when required, thus, controlling reactive power flow of the system and improving voltage stability of the whole system [8].

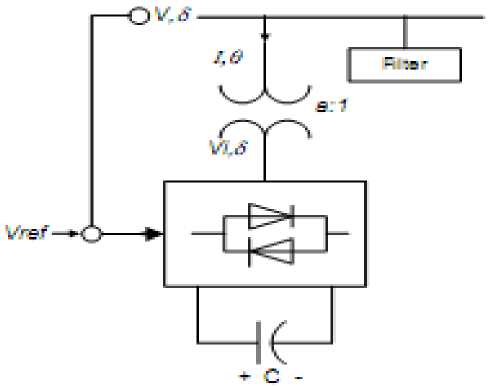

Fig. 1. Schematic diagram of STATCOM

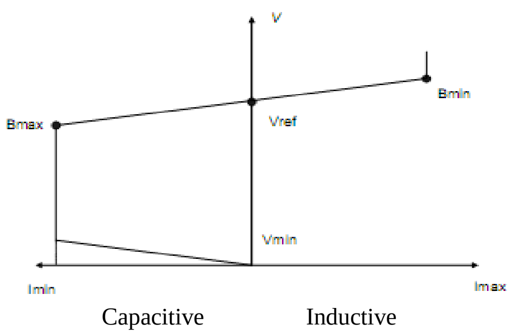

Fig. 2. Terminal characteristic of STATCOM

III. Test System And Analysis Tools

IEEE 30-bus test system is used throughout the study which consists of five generators located at buses 2, 5, 8, 11, and 13. There are forty one branches and thirty buses in this test system. Single line diagram of IEEE 30-bus test system is shown in Fig. 3.

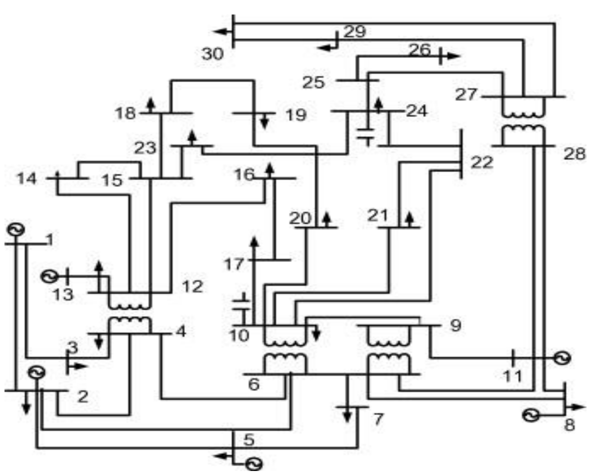

Fig. 3. Single Line Diagram of IEEE 30-bus Test System

STATCOM used in the study is treated as voltage controlled bus and is connected to the weakest bus 26 and 30 after studying the voltage profile of the test system. STATCOM are placed to maintain the voltage magnitude of the buses to which it is connected at 1 p.u.

Newton Raphson (NR) method of power flow is used in power flow calculation in MATLAB environment. The loading of the test system at bus 20 is increased from 0 to 200 % and thus, the results obtained with and without STATCOM are then compared.

IV. Results And Discussions

A. Voltage Profile

As the loading at one of the bus is increased, the voltage magnitude of that bus decreases. When STATCOM, as a shunt compensating device, is added to the system the voltage margin of that bus increases. In Fig. 4, it has been illustrated that the voltage margin of the system with STATCOM is more than that of the system without any shunt compensation. Shunt compensation device like STATCOM injects the reactive power at the connected bus. The test system requires reactive power support at the weakest bus. Introduction of shunt compensating devices at that bus or near its surrounding can improve voltage stability margin.

Voltage profile of the test system with STATCOM and without STATCOM is shown in Fig. 5. From Fig. 5, it is clearly observed that STATCOM provides at better voltage profile to the system compared to the system without it. In the test system, STATCOM has been installed at bus 26 and 30. STATCOM introduces reactive power support at both the buses, which in turn improves voltage profile around its surrounding.

B. Power Losses in the System

Active and reactive power losses of the test system at various loading factors, with and without STATCOM, are shown in Fig. 6 and Fig. 7 respectively. Table I shows the numerical values of the voltage magnitude at bus 20 and active and reactive power losses of the system with and without STATCOM when loading is increased at bus 20 from 0-200 %. From the figures, it is clearly been observed that both active and reactive power losses follow the same pattern in this test system. As the loading factor increases both active and reactive power losses increases. But with the introduction of STATCOM into the test system, the active and reactive power losses are less for the same loading factor when compared to the system without STATCOM.

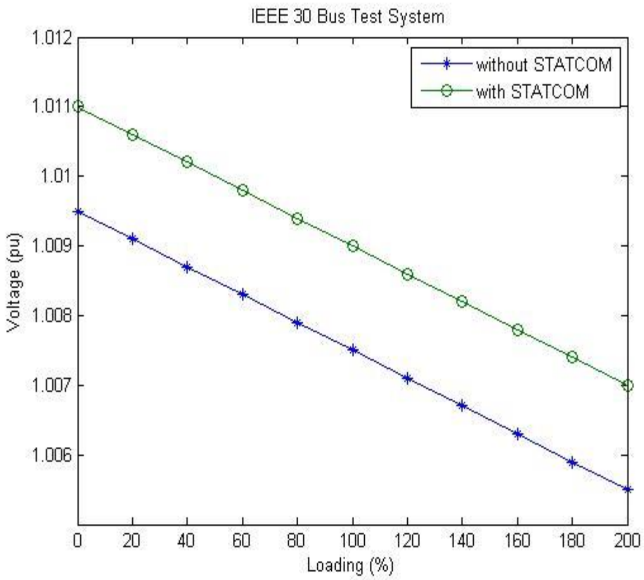

Fig. 4. Loading vs. Voltage magnitude of the test system with and without STATCOM at bus 20

TABLE I

Load ing (%)	P Load (pu)	Without STATCOM			With STATCOM		
		V (pu)	P Loss (pu)	Q Loss (pu)	V (pu)	P Loss (pu)	Q Loss (pu)
0	2.20	1.0095	0.1776	0.2284	1.0110	0.1769	0.2241
20	2.64	1.0091	0.1782	0.2313	1.0106	0.1775	0.2270
40	3.08	1.0087	0.1789	0.2342	1.0102	0.1782	0.2299
60	3.52	1.0083	0.1796	0.2371	1.0098	0.1788	0.2328
80	3.96	1.0079	0.1802	0.2400	1.0094	0.1795	0.2357
100	4.40	1.0075	0.1809	0.2430	1.0090	0.1802	0.2387
120	4.84	1.0071	0.1816	0.2460	1.0086	0.1808	0.2416
140	5.28	1.0067	0.1823	0.2490	1.0082	0.1815	0.2446
160	5.72	1.0063	0.1830	0.2520	1.0078	0.1822	0.2476
180	6.16	1.0059	0.1836	0.2550	1.0074	0.1829	0.2506
200	6.60	1.0054	0.1843	0.2580	1.0070	0.1836	0.2536

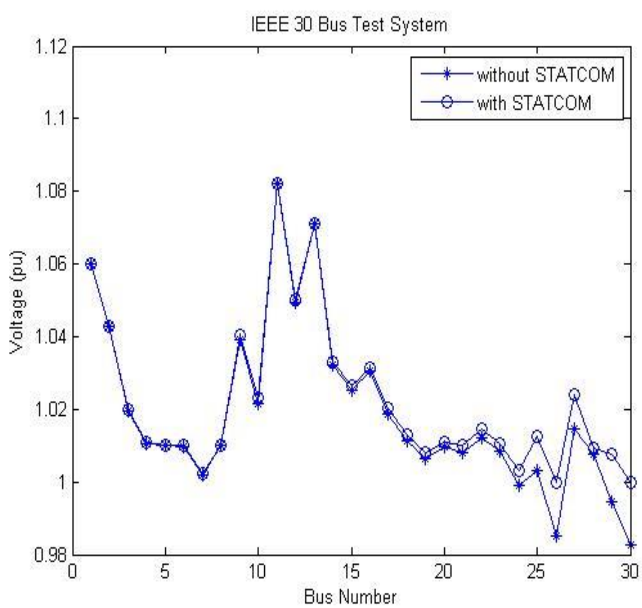

Fig. 5. Voltage profile of the system with and without STATCOM

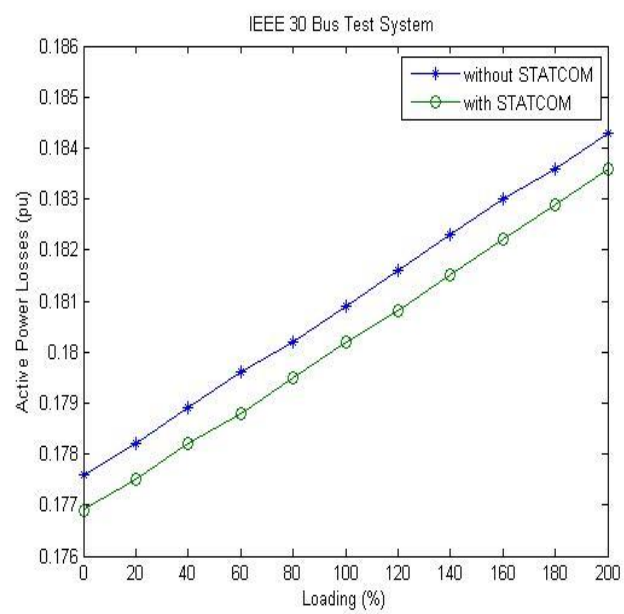

Fig. 6. Active power losses of the system with and without STATCOM

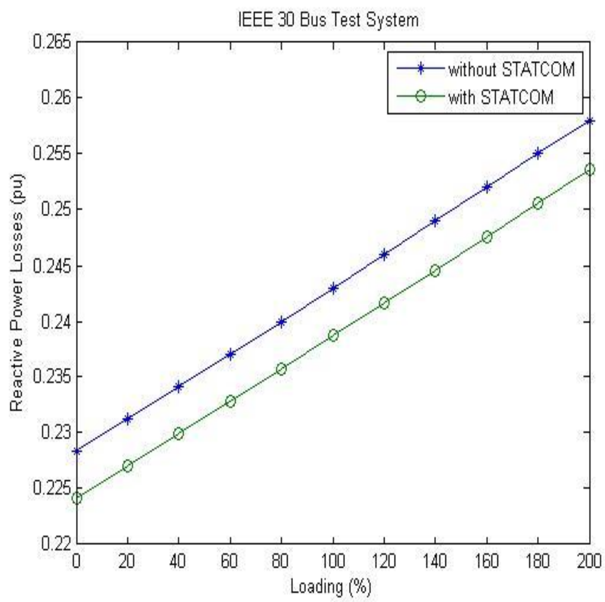

Fig. 7. Reactive power losses of the system with and without STATCOM

V. A CASE STUDY OF A LINE OUTAGE

A case study of line outage has been studied in this paper. In IEEE 30-bus test system, outage of the line 12-15 is made and its effect on voltage profile and power losses has been studied.

Fig. 8 shows the voltage magnitude of the bus 20 when the loading of the bus is increased from 0 to 200% in case of a line outage. It shows that voltage magnitude decreases with the increasing loading and is less as compared to the system when there is no any line outage.

Fig. 9 shows the voltage profile of the test system in case of line outage. Careful study of the figure reveals that voltage profile deteriorates in case of a line outage as compared to the healthy system. With STATCOM placed at proper position can enhance the voltage stability margin in case of line outage which is easily seen in the figure.

Fig. 10 and Fig. 11 show the active and reactive power losses in case of a line outage respectively. Clear observation of the figure points out that when there is a line outage, then, active and reactive power losses increases with respect to the healthy system. Addition of STATCOM to the system in case of line outage decreases the losses to a certain level.

VI. CONCLUSION

In this paper, voltage stability assessment of the IEEE 30-bus test system is studied with STATCOM. STATCOM, as a shunt compensating device, provides voltage stability margin to the system than the system without any shunt compensating devices. The test system requires reactive power support at the weakest bus located in the distribution level. Introduction of reactive power support at this bus using STATCOM can improve the loading margin and reduces active and reactive power losses. In case of a line outage, voltage profile deteriorates and power losses increases. Addition of STATCOM to the system having line outage improves the voltage profile and reduces active and reactive losses.

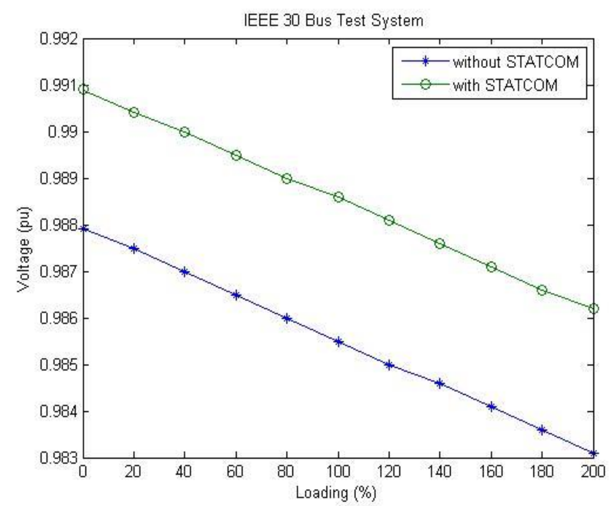

Fig. 8. Load vs. Voltage magnitude of the system at bus 20 with and without STATCOM in case of line outage.

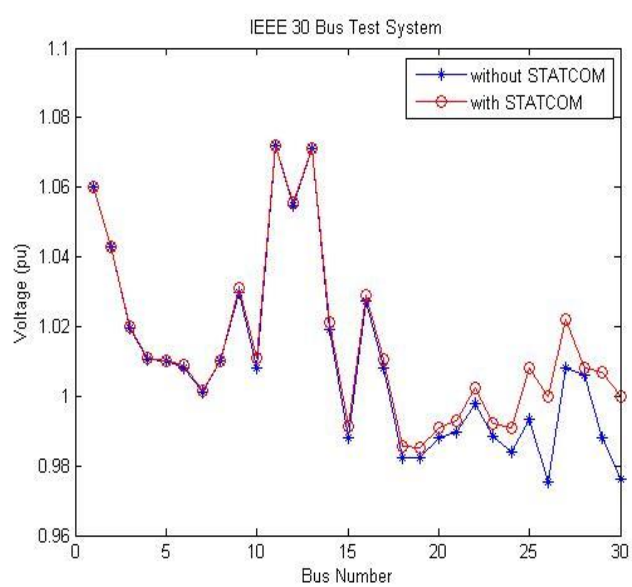

Fig. 9. Voltage profile of the system with and without STATCOM in case of a line outage.

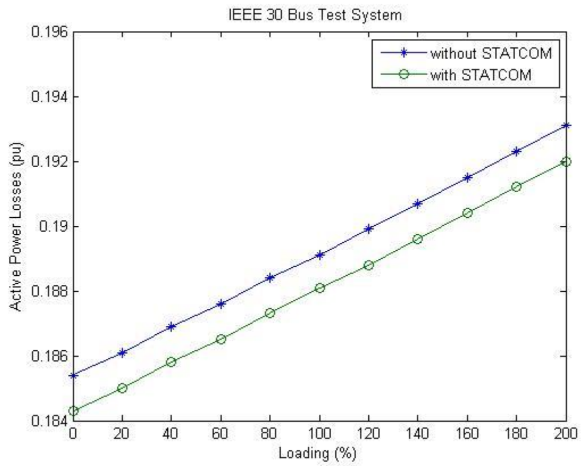

Fig. 10. Active power losses of the system with and without STATCOM in case of a line outage

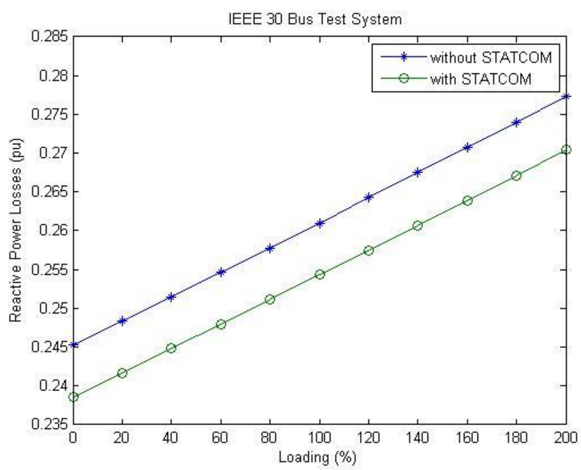

Fig. 11. Reactive power losses of the system with and without STATCOM in case of a line outage

VII. REFERENCES

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