Voltage Sag Mtigatio in Fifty Bus System

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Abstract: The Distribution static synchronous compensator (D-STATCOM) is a power electronic based shunt connected Flexible AC transmission system device which exchange reactive power to the load for improving the voltage stability of the load busses. The Distribution static synchronous compensator is capable of reducing the losses and improving the voltage regulation in Multi Bus systems.

The Distribution static synchronous compensator injects a current into the system to reduce the losses. The Distribution static synchronous compensator is capable of enhancing the reliability and quality of power flow in low voltage distribution network. A Distribution static synchronous compensator is one of the new generation flexible AC transmission system devices with a promising feature of applications in power system. The Distribution static synchronous compensator is used to stabilize the system voltage by exchanging reactive power with the power system. Fifty Bus System with multiple STATCOMs is modeled and simulated. The improvement in voltage stability with Distribution static synchronous compensator is presented. Voltages at various buses with and without Distribution static synchronous compensator are also discussed.

***IndexTerms* – D-STATCOM, UPFC,SSSC,FACTS**

I. INTRODUCTION

The development and use of Flexible AC Transmission System (FACTS) controllers in power transmission systems had led to many applications of these controllers to improve the stability of power networks. Various flexible AC transmission system (FACTS) devices, such as static synchronous compensators (STATCOMs), static synchronous series compensators (SSSCs), and unified power flow controllers (UPFCs) are increasingly used in power systems because of their ability to stabilize power transmission systems and to improve power quality in power distribution systems. It has been reported that STATCOM can offer a number of performance advantages for reactive power control applications over the conventional SVC because of its greater reactive current output at depressed voltage, faster response, better control stability, lower harmonics and smaller size, etc Power quality is ultimately a consumer-driven issue, and the end user's point of reference takes precedence. Therefore, the following definition of power quality is established. The ultimate reason that we are interested in power quality is economic value. There are economic impacts on utilities, their customers, and suppliers of load equipment. The quality of power can have a direct economic impact on many industrial consumers.

II. FIFTY BUS SYSTEM

The Fifty bus system is considered for simulation studies. The Fifty bus system is simulated by using MATLAB SIMULINK. The Fifty bus system without STATCOM is shown in Figure 1.

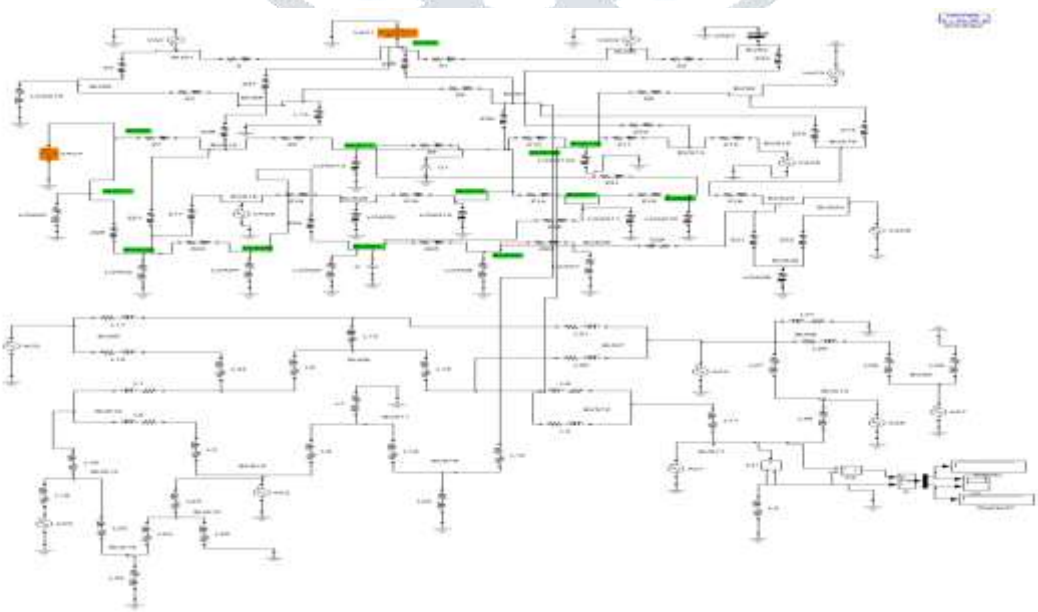

Figure 1 IEEE Fifty bus system without STATCOM

The circuit model of the fifty bus system is considered, each line represents the series impedance model and the shunt capacitance of the line is neglected because the electrical distribution system lines are the short lines. The Fifty bus system consisting of fourteen generating buses and eight load buses. The loads are connected to the respective buses. When the breaker is closed the loads are connected, the voltages at bus 4, &12 are measured.

III PRINCIPLE OF OPERATION

The devices of the power electronic based equipments having capability to maintain power flow pattern and increase the fundamental capability of the existing lines. The devices are changes the parameters like voltage, impedance and phase angle. The Flexible AC transmission devices having the capability to modify or vary the parameters rapidly and continuously which leads the system operation control. In order to use the Flexible AC transmission devices, it can improve the power transfer capability in electrical distribution system, it improve the system efficiency, improve power factor and minimizing harmonic content. The voltage of the system can be controlled by exchange the reactive power to the system. Among all the FACTS devices, Static synchronous compensators having fast response at lower current.

The Flexible AC transmission system devices are used for shunt compensation, series compensation and both series and shunt compensation. The STATCOM is a static synchronous compensator, which is used to compensate the reactive power for regulating the voltage in the supply line.

The static synchronous compensator is used for high power applications. Most of the power quality problems have been occurred in the power system due to reactive power. In order to test the power system it requires both static and dynamic system analysis. In order to consider the practical applications the dynamic analysis has to be considered to evaluate the system.

The Flexible AC transmission system devices are provided fast controllability by using power electronics technology. The conventional devises are having great feature i.e. differentiation factors. The static devices are nothing but there are no moving parts like mechanical switches for controlling dynamic performance. So we can conclude the FACTS devices are both static and dynamic. Various types of conventional and FACTS devices are shown in Table 2.1. The conventional or switched devices are containing resistance, inductance and capacitance together with transformers. The Flexible AC transmission devices are not only having above elements but also having additional power electronic valves or converters. For considering the power electronics based shunt connected devices are the conventional devises, which are having resistance, inductance, and capacitance together with transformer.

IV RESULTS

The circuit model of fifty bus system with Distribution static synchronous compensator is shown in Figure 6.6. The Distribution static synchronous compensator is connected between the Bus-13 &17. The fifty bus system consisting of fourteen generating buses and fifty load buses. The loads are connected in series with respective buses. When the breaker is closed the loads are connected, the voltages at buses 11, 13, 19,25,30,35 &45 are measured. The voltage across Bus-11 is shown in Figure 6.7. It can be seen that the voltage is resumed to rated voltage after 0.05 seconds by adding the Distribution static synchronous compensator in the circuit.

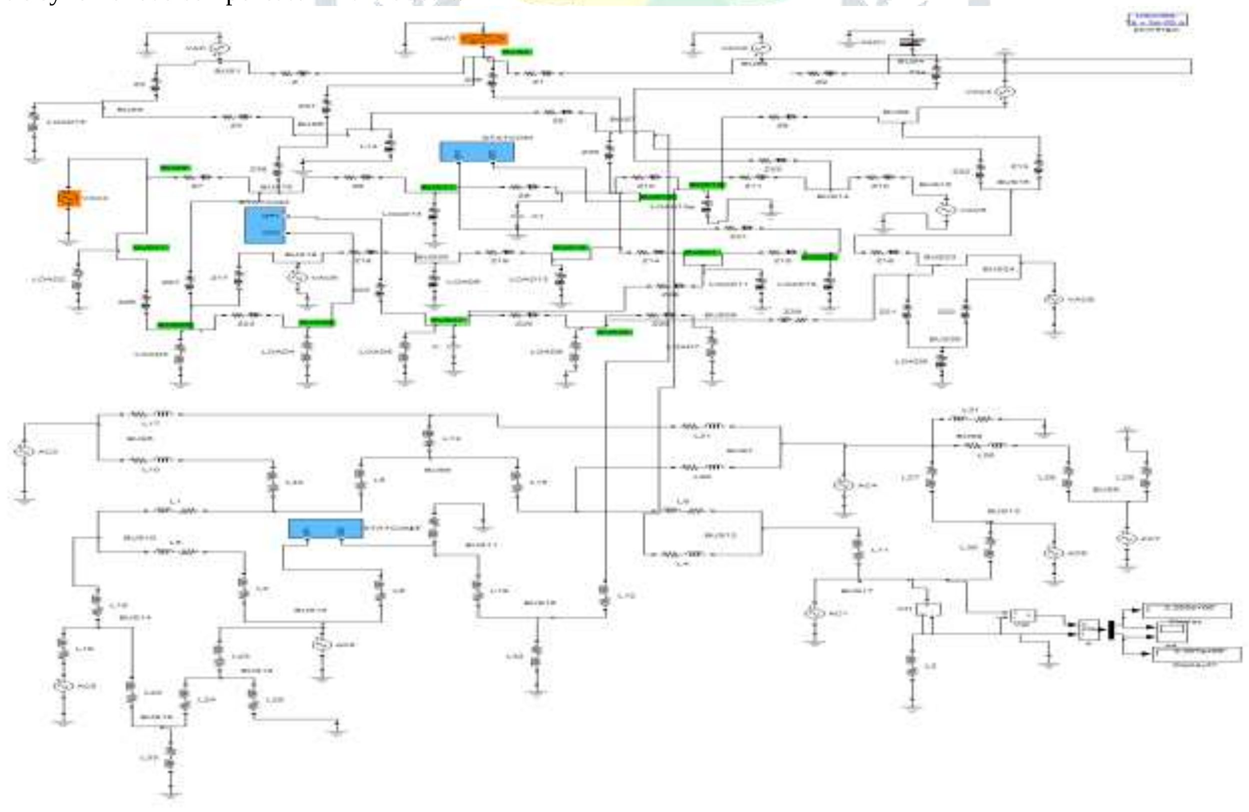

Figure 2 IEEE Fifty bus system with STATCOM

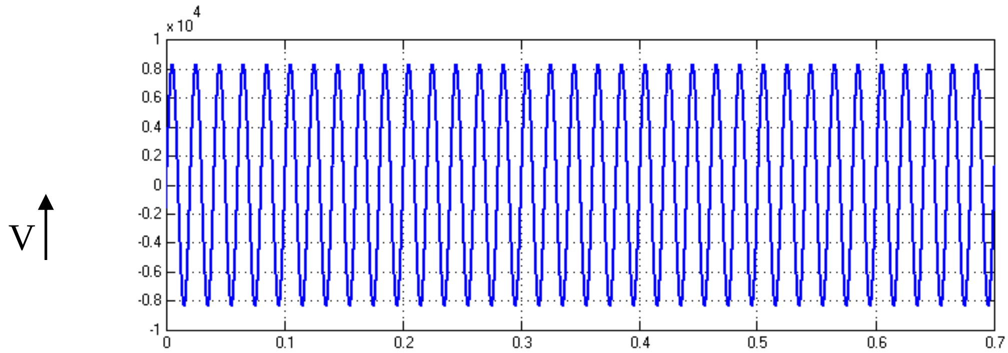

Figure 3 Voltage at bus-11

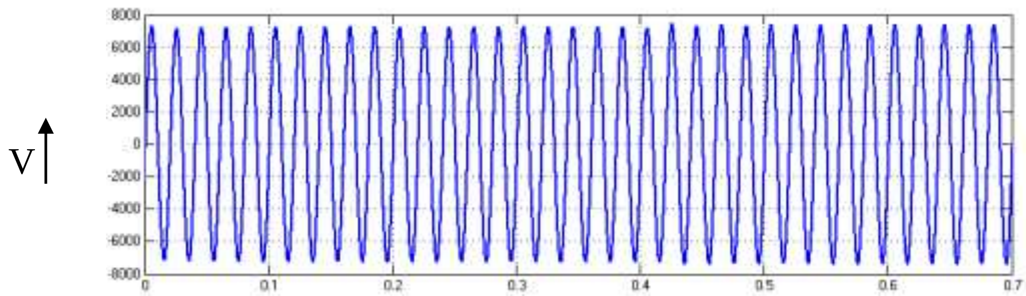

Figure 4 Voltage at bus-13

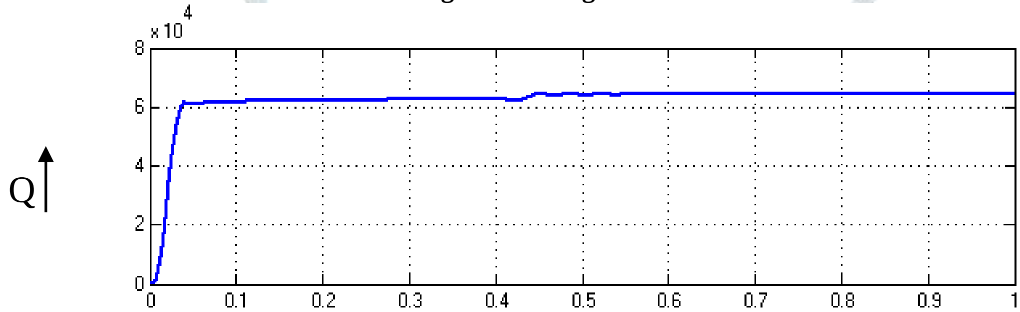

Figure 5 Reactive Power at bus 13

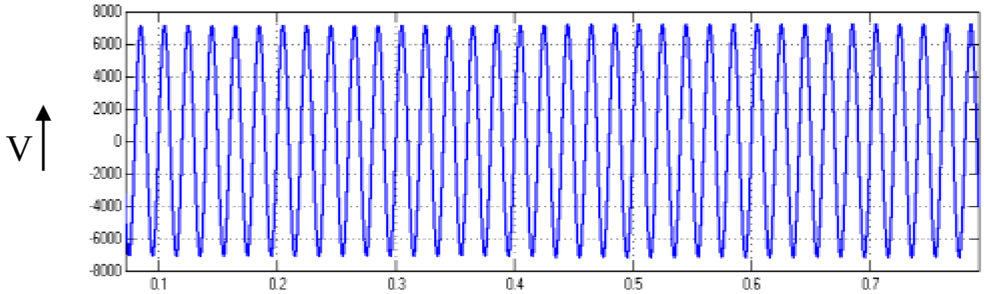

Figure 6 Voltage at bus-19

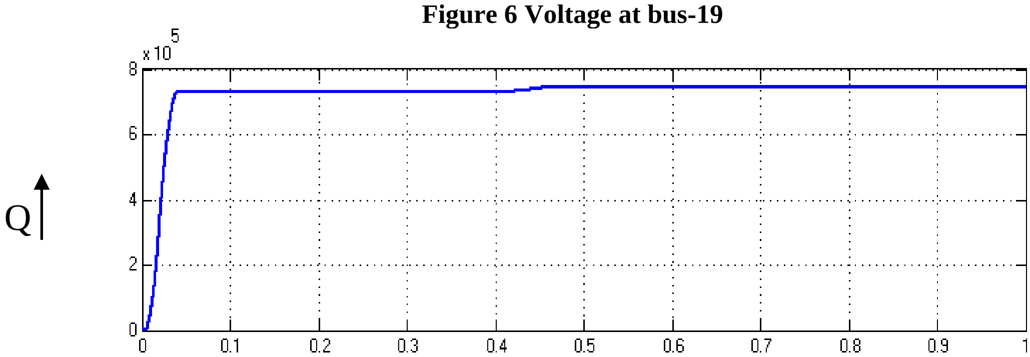

Figure 7 Reactive Power at bus 19

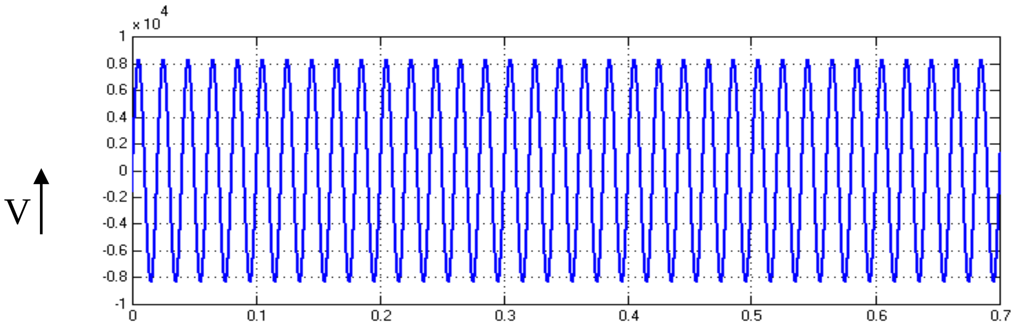

Figure 8 Voltage at bus-25

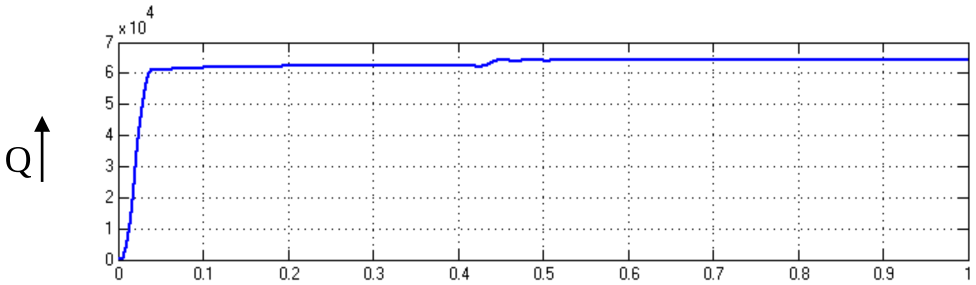

Figure 9 Reactive Power at bus-25

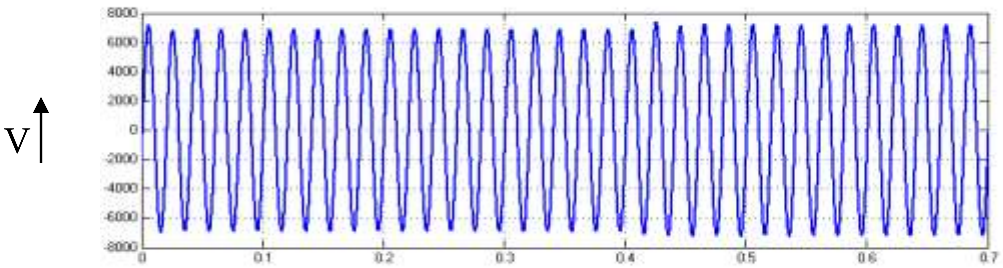

Figure 10 Voltage at bus-30

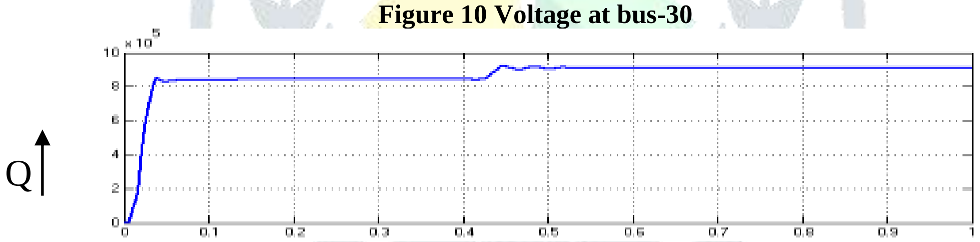

Figure 11 Reactive power at bus-30

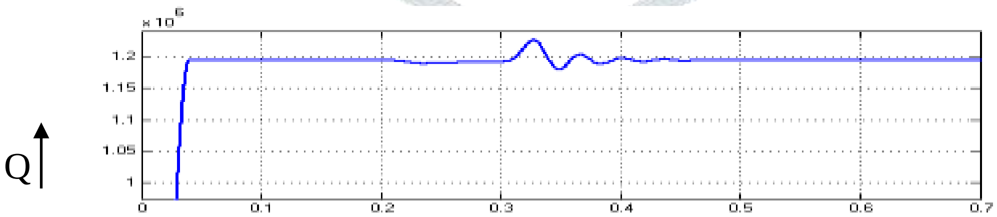

Figure 12 Reactive power at bus 35

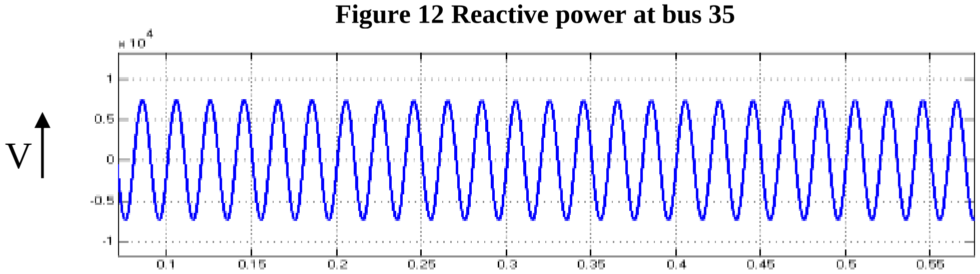

Figure 13 Voltage at bus-45

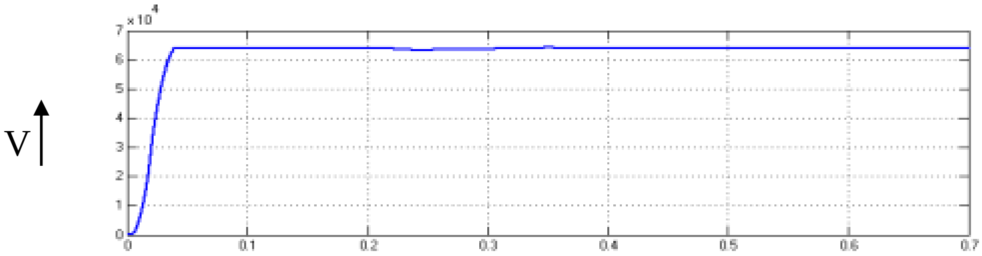

Figure 14 Reactive Power at bus 45

Table:1Reactive Power at different buses with and without STATCOM

BUS NO.	REACTIVE POWER WITHOUT STATCOM (MVAR)	REACTIVE POWER WITH STATCOM (MVAR)
BUS-1	0.304	0.352
BUS-2	0.301	0.348
BUS-3	1.32	1.801
BUS-4	2.210	2.788
BUS-5	2.23	2.791
BUS-6	2.27	2.810
BUS-7	2.26	2.842
BUS-8	2.241	2.846
BUS-9	2.238	2.832
BUS-10	2.861	2.989
BUS-11	2.85	3.36
BUS-12	3.23	3.25
BUS-13	2.29	2.28
BUS-14	1.971	1.998
BUS-15	1.38	1.57
BUS-18	2.798	2.861
BUS-19	2.388	2.458
BUS-20	2.386	2.451
BUS-21	2.210	2.788
BUS-22	3.612	3.629
BUS-25	3.121	3.221
BUS-26	2.843	2.856
BUS-27	1.32	1.801
BUS-29	3.35	3.36
BUS-34	2.241	2.846
BUS-35	1.971	1.998
BUS-36	1.32	1.801
BUS-37	2.27	2.810
BUS-38	2.26	2.842
BUS-42	3.35	3.36
BUS-43	3.23	3.25
BUS-44	2.29	2.28
BUS-45	1.971	1.998
BUS-46	1.38	1.57
BUS-47	1.86	1.89
BUS-48	2.879	2.978
BUS-49	2.98	2.97

BUS-50	2.89	2.987

The Table 1 explains how the reactive power is decreased after adding the additional load in parallel with the load-1 after 0.2 seconds and again it resumes the rated value because of Distribution static synchronous compensator presents in the circuit. The reactive power is constant from 0 to 0.3 seconds under normal operating condition. The reactive power is decreased at 0.3 seconds due to reduction in voltage. After 0.1 seconds, the reactive power is resumed to rated value due to addition of Distribution static synchronous compensator between buses 13 & 17.

The summary of the reactive power with and without Distribution static synchronous compensator is shown in Table 6.1. This table explains how the reactive power is being varied with addition of the load in parallel with the load-1 at various buses with and without Distribution static synchronous compensator in the fifty bus system. The reactive power at bus-1 is measured as 0.304 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 0.352 MVAR. By comparing with and without Distribution static synchronous compensator reactive power values at bus-1, it is shown that 0.048 MVAR is been increased. The reactive powers without and with Distribution static synchronous compensator at bus-2 are 0.301MVAR and 0.348 MVAR, it is shown that MVAR is increased by 0.047. The reactive power at bus-3 is measured as 1.32 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.801 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-3 it is shown that MVAR is increased by 0.481. The reactive power at bus-4 is measured as 2.21 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.788 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-4, it is shown that MVAR is been increased by 0.578.

The reactive power at bus-5 is measured as 2.23 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.791 MVAR. By comparing with and without Distribution static synchronous compensator reactive power values at bus-5, it is shown that 0.561 MVAR is been increased. The reactive power at bus-6 is measured as 2.27 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.81 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-6, it is shown that 0.54 MVAR is been increased. The reactive power at bus-7 is measured as 2.26 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.842 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-7, it is shown that MVAR is increased by 0.582.

The reactive power at bus-8 is measured as 2.241 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.846 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-8, it is shown that MVAR is increased by 0.605. The reactive power at bus-9 is measured as 2.238 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.832 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-9, it is shown that MVAR is increased by 0.594. The reactive power at bus-10 is measured as 2.861 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.989 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-10, it is shown that MVAR is increased by 0.128.

The reactive power at bus-11 is measured as 2.85 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 3.36 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-11, it is shown that MVAR is increased by 0.51. The reactive power at bus-12 is measured as 3.23 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 3.25 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-12, it is shown that MVAR is increased by 0.02.

The reactive power at bus-13 is measured as 2.29 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.28 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-13, it is shown that MVAR is increased by 0.01. The reactive power at bus-14 is measured as 1.971 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.998 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-14, MVAR is increased by 0.027.

The reactive power at bus-15 is measured as 1.38 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.57 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-15, it is shown that MVAR is increased by 0.19. The reactive power at bus-16 is measured as 1.86 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.89 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-16, it is shown that MVAR is increased by 0.03.

The reactive power at bus-17 is measured as 2.879 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.978 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-17, it is shown that MVAR is been increased by 0.099.

The reactive power at bus-18 is measured as 2.798 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.861 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-18, it is shown that MVAR is increased by 0.063. The reactive power at bus-19 is measured as 2.388 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.458 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-19, it is shown that MVAR is increased by 0.07.

The reactive power at bus-24 is measured as 1.971 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.998 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-24, it is shown that MVAR is increased by 0.027. The reactive power at bus-25 is measured as 3.121 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 3.221 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-25, it is shown that MVAR is increased by 0.01.

The reactive power at bus-26 is measured as 2.843 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.856 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-26, it is shown that MVAR is increased by 0.013. The reactive power at bus-27 is measured as 1.32 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.801 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-27, it is shown that MVAR is increased by 0.481. The reactive power at bus-29 is measured as 3.35 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 3.36 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-29, it is shown that MVAR is increased by 0.01.

The reactive power at bus-34 is measured as 2.241 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.846 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-34, it is shown that MVAR is increased by 0.605. The reactive power at bus-35 is measured as 1.971 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.998 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-35, it is shown that MVAR is increased by 0.027. The reactive power at bus-36 is measured as 1.32 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.801 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-36, it is shown that MVAR is increased by 0.481.

The reactive power at bus-37 is measured as 2.27 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.810 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-37, it is shown that MVAR is increased by 0.54. The reactive power at bus-38 is measured as 2.26 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.842 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-38, it is shown that MVAR is increased by 0.582.

The reactive power at bus-43 is measured as 3.23 MVAR without Distribution static synchronous compensator and reactive power at the same bus with D-STATCOM is 3.25 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-43, it is shown that MVAR is increased by 0.02. The reactive power at bus-44 is measured as 2.29 MVAR without Distribution static synchronous compensator and reactive power at the same bus with D-STATCOM is 2.28 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-44, it is shown that MVAR is =increased by 0.01.

The reactive power at bus-45 is measured as 1.971 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.998 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-45, it is shown that MVAR is increased by 0.027. The reactive power at bus-46 is measured as 1.38 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.57 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-46, it is shown that MVAR is increased by 0.19.

The reactive power at bus-47 is measured as 1.86 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.89 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-47, it is shown that MVAR is increased by 0.03. The reactive power at bus-48 is measured as 2.879 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.978 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-48, it is shown that MVAR is increased by 0.099.

The reactive power at bus-49 is measured as 2.98 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.97 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-49, it is shown that MVAR is increased by 0.01. The reactive power at bus-50 is measured as 2.89 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.987 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-50, it is shown that MVAR is increased by 0.097.

Table 6.2Voltage & Reactive Power at different busses with and without STATCOM

Bus No.	Reactive Power without STATCOM (MVAR)	Reactive Power with STATCOM (MVAR)	Line Voltage (volt)	STATCOM Voltage (volt)
BUS-4	2.210	2.788	3154	4260
BUS-11	2.85	3.36	3124	4503
BUS-36	1.32	1.801	3126	4551

Table 6.2 represents the reactive power at various buses with and without Distribution static synchronous compensator, line voltages at various buses and STATCOM voltage at various buses. The reactive power at bus-4 is measured as 2.210 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 2.788 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-4, it is shown that MVAR is increased by 0.578.

The reactive power at bus-11 is measured as 2.85 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 3.36 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-4, it is shown that MVAR is increased by 0.51. The reactive power at bus-36 is measured as 1.32 MVAR without Distribution static synchronous compensator and reactive power at the same bus with Distribution static synchronous compensator is 1.801 MVAR. By comparing the results with and without Distribution static synchronous compensator reactive power values at bus-4, it is shown that MVAR is increased by 0.481.

V CONCLUSIONS

Fifty bus system is modeled and simulated using MATLAB SIMULINK and the results are presented. The simulation results of Fiifty bus system with and without Distribution static synchronous compensator are presented. This system has improved reliability and power quality. The simulation results are in line with the predictions.

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