REACTIVE POWER COMPENSATION AND PERFORMANCE ANALYSIS OF FACTS DEVICES EMPLOYING FUZZY LOGIC

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***Abstract**-Generally a STATCOM is installed to sustain electricity networks that have a reduced power factor and frequently poor voltage regulation. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The active power ability can be improved if a appropriate energy storage device is coupled across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. The reply time of a STATCOM is shorter than that of an SVC, mainly due to the rapid switching times provided by the switches of the voltage source converter. The STATCOM also provides better reactive power carry at low AC voltages than an SVC. But these devices can do shunt compensation only. To overcome this crisis we proposed the paper on line loss minimum conditions in loop distribution systems, and experimentally achieved these conditions by using the Unified Power Flow Controller (UPFC). It can do both series and shunt compensation. It can control both li2e voltage and current. In this paper a STATCOM and UPFC using fuzzy logic controller to compensate reactive power in distribution networks is developed.*

Keywords: STATCOM, UPFC, FUZZY logic controller, FACTS, SVC

I. Introduction

FACTS technology consists of high power electronic based equipment with its real time operating control. There are two groups of FACTS controllers based on different technical approaches, both resulting in controllers able to solve transmission problems. The first group employs reactive impedances or tap-changing transformers with thyristor switches as controlled elements, second group employs self-commutated voltage source switching converter. The static var compensators (SVC), Thyristor Controlled Series capacitor, (TCSC) and Phase Shifter, belong to the first group of controllers. STATCOM, Static Synchronous Series Compensator (SSSC), UPFC and Interline Power Flow Controllers (IPFC) belong to second group.[2]

Static synchronous compensator (STATCOM) and Unified power flow controller (UPFC) systems are the most frequently used FACTS device for reactive power compensation. STATCOM which is capable of generating or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. The UPFC is a member of the family of compensators and power flow controllers Arup Ratan Bhowmik and Champa Nandi (2011) [3]. The latter use the synchronous voltage source (SVS) concept to offer a unique comprehensive ability of transmission system control. The UPFC is capable to control simultaneously or selectively all the parameters disturbing power flow patterns in a transmission network, as well as voltage magnitudes and phases, and real and reactive powers [4]. These basic capabilities build the UPFC the most powerful device in the current day transmission and control systems.

In this work Static synchronous compensator (STATCOM) is injected in fourteen bus system and shows the real power, reactive power and voltage. Then it is compared by Unified power flow control (UPFC) injected in fourteen bus system AlirezaSelfi et al. (2010) [1]. This work proposes the appraisal of Static synchronous compensator (STATCOM) and Unified power flow controller (UPFC) for the power quality enhancement in fourteen bus system.

The chance of improving the power quality using UPFC and STATCOM are explored. Low voltage at the receiving end affects the performance of the loads. To improve the receiving end voltage, comparison of static synchronous compensator (STATCOM) and Unified power flow controller (UPFC) in fourteen bus system are suggested for improving the power quality. Static synchronous compensator is a Shunt compensation device and Unified power flow controller is a combination of Shunt and Series compensation device.

II.Reactive power c ompensation

The need for reactive power compensation in a system is to increase voltage regulation, to increase system stability, better utilization of machines connected to the system, to reduce losses associated with the system and to prevent voltage collapse as well as voltage sag.

Thus it can be inferred 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 [6]. 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.

III.UPFC

In the FACTS family, UPFC is one of the most powerful and versatile FACTS devices available so far. Being able to almost instantaneously insert a synchronous voltage of arbitrary magnitude (within a pre-specific range) and phase angle (with respect to the sending-end voltage) into the transmission line, UPFC can be used to adjust the real electrical power output of an electric power system in real time [5]. Thus, UPFC is regarded by many researches as an ideal candidate for improving the transient and dynamic performance of an electric power system.

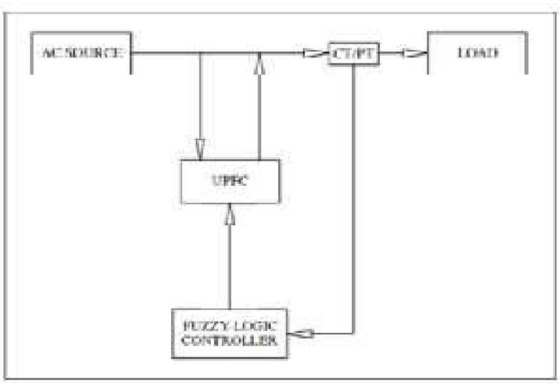

Fig. 3.1 Proposed block diagram of UPFC

The UPFC is a member of the family of compensators and power flow controllers. The latter utilize the synchronous voltage source (SVS) concept to provide a unique comprehensive capability of transmission system control. The UPFC is able to control simultaneously or selectively all the parameters affecting power flow patterns in a transmission network, including voltage magnitudes and phases, and real and reactive powers. With this device, the real and reactive power flows in a transmission line can rapidly and precisely be controlled.

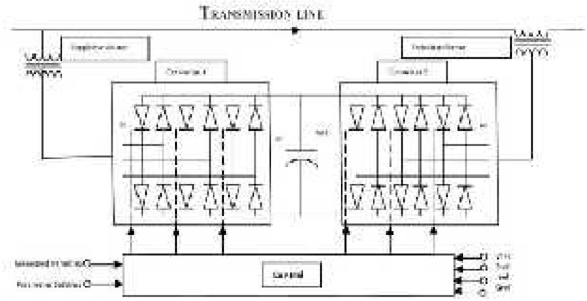

Fig. 3.2 UPFC circuit diagram

The function of the parallel converter is to supply or absorb the active power demanded by the series branch. This converter is connected to the ac-terminal through a parallel-connected transformer. If required, it may also inject leading or lagging reactive power directly into the connection bus bar. The second (series connected) converter provides the main function of the UPFC by injecting an AC-voltage with controllable magnitude and phase angle. The transmission line current flows through this voltage source, resulting in an active and reactive power exchange with the ac-system.

The UPFC is the most versatile FACTS controller developed so far, with all-encompassing capabilities of voltage regulation, series compensation and phase shifting. It can independently and very rapidly control both real and reactive power flows in a transmission line. It is configured as shown in the above diagram (Fig 3.2) and comprises two VSCs coupled through a common dc terminal. One VSC convertor is connected in shunt with the link through a coupling transformer, the other VSC convertor is inserted in series with the transmission line through an interface transformer.

The DC voltage for both convertors is provided by a common capacitor bank. The series convertor is controlled to inject a voltage phasor, in series with the line, which can be verified from 0 to 180. Moreover, the phase angle can be independently varied from 0° to 360°. In this process, the series convertor exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by series convertor, the real-power generation/absorption is made feasible by the DC energy storage device that is capacitor.

The shunt convertor maintains constant voltage of the DC bus. Thus the net real power drawn from the AC system is equal to the losses of the two convertors and their coupling transformers. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/absorbing a requisite amount of reactive power. The Unified Power Flow Controller (UPFC) operates with constraints on the following variables:

1. The series-injected voltage magnitude.
2. The line current through series convertor.
3. The shunt-convertor current.
4. The minimum line-side voltage of the UPFC.
5. The maximum line-side voltage of the UPFC
6. The real-power transfer between the series convertor and the shunt convertor.

To know the design of a real power co-ordination controller for a UPFC, consider a UPFC connected to a transmission line as shown in Fig. 3.2. The interaction between the series injected voltage (Vse) and the transmission line current (Ise) leads to exchange of real power between the series converter and the transmission line [7,8]. The real power (Pse) demand of the series converter (Pse) causes the dc link capacitor voltage (Vdc) to either increase or decrease depending on the direction of the real power flow from the series converter. This decrease/increase in dc link capacitor voltage (Vdc) is sensed by the shunt converter controller that controls the dc link capacitor voltage (Vdc).

The real power demand of the series converter (Pse) is the real part of product of the series converter injected voltage (Vse) and the transmission line current (Ise). Vupfc bus, iDse represent the voltage of the bus to which the shunt converter is connected and the equivalent additional D-axis current that should flow through the shunt converter to supply the real power demand of the series converter. The equivalent D-axis additional current signal (iDse) is fed to the inner control system, thereby increasing the effectiveness of the coordination controller**.**

In transmission line, the power factor is controlled by means of injecting a voltage across it. The transmission line consists of lumped R and L parameters. Without an injecting of voltage, the power factor is lagging in RL circuit. By injecting additional voltage across it, the angle between V and I is reduced and the power factor is improved. By aptly selecting the value of injecting voltage, the power factor can be made to unity.

IV.STATCOM

The STATCOM is a shunt connected reactive compensation equipment, which is able of generating or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. A STATCOM is normally used to control transmission bus voltage by reactive power shunt compensation as shown in Figure:4.1. The power circuit diagram for STATCOM is shown in Figure 4.2. It is a controlled reactive power source. It provides the reactive power generation and absorption by means of electronic process of the voltage and current waveforms in a voltage source.

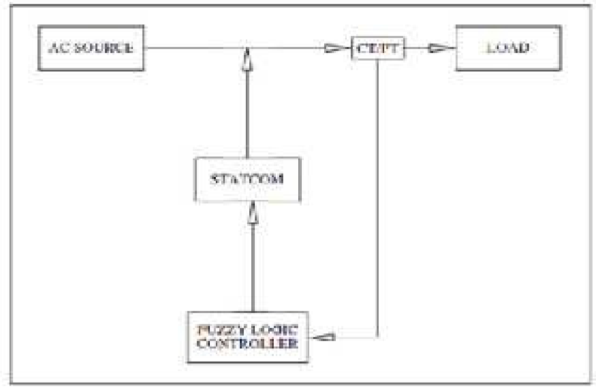

Figure: 4.1 Proposed block diagram of STATCOM

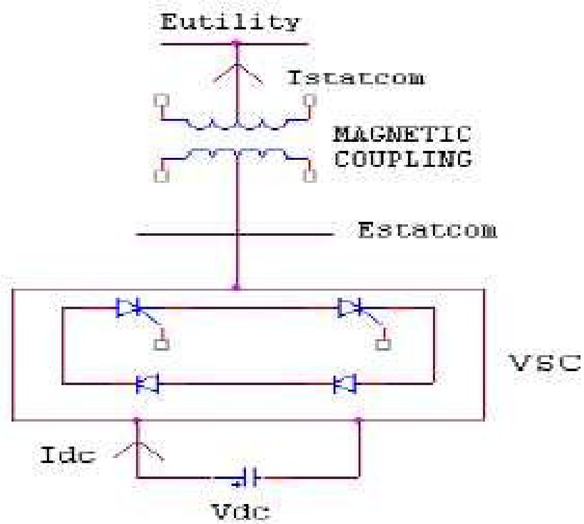

Fig. 4.2. Power circuit diagram of STATCOM

A single line diagram of STATCOM is shown in Figure 4.3. where Vsc is connected to the utility bus through the magnetic coupling transformer. It is a compact design, small foot print, low noise and low magnetic impact. The exchange of reactive power between the converter and AC system can be controlled by varying the three phase output voltage, Estatcom of the converter. If the amplitude of the output voltage is increased above the utility bus voltage, then the current flows through the reactance from the converter to the AC system and the converter acts as a capacitance and generates reactive power for the AC system [9]. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows through the reactance from the AC system to the converter and the converter act as inductance and it absorbs the reactive power from the AC system.

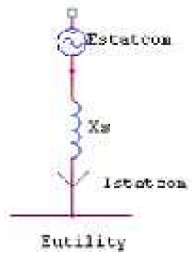

Fig. 4.3. Line diagram of STATCOM

If the output voltage equals the AC system, then the reactive power exchange becomes zero. In that condition, STATCOM is said to be in a floating state [10]. STATCOM controller provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks.

V.RESULTS AND DISCUSSION

The simulation is done by using MATLAB Simulink and the results are presented. Each line is modeled by its series impedance. The load at the load buses are represented by the combination of R and L. The shunt capacitances of the line are neglected. The circuit model of fourteen bus system with STATCOM closed loop controller is shown Fig 5.1. The circuit model of fourteen bus system with UPFC fuzzy logic controller is shown fig 5.4. The voltage waveform across bus 4 with STATCOM controller is shown in fig.5.2 .The real and reactive power waveform at bus 4 with STATCOM is shown in fig.5.3. The technical specifications are as follows.

V1 = 11 KV   R = 30 Ohms   L= 0.1mh.

The voltage waveform across bus 4 with UPFC controller is shown in figure.5.5. The real and reactive power waveform at bus 4 with UPFC is shown in fig.5.6.

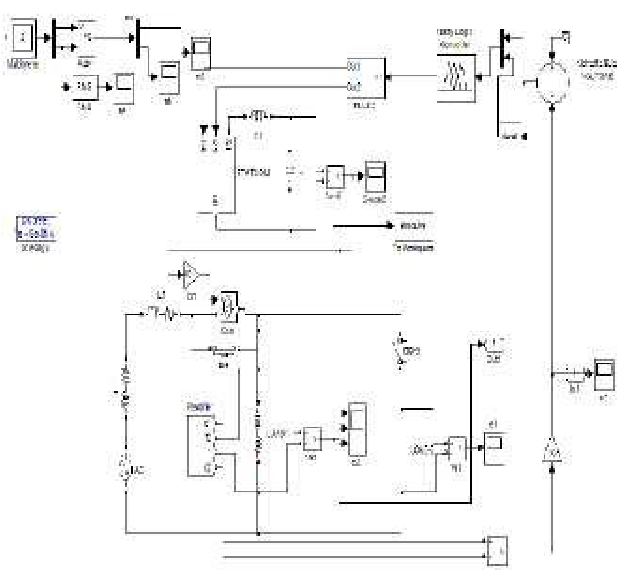

Fig. 5.1 Circuit diagram of fourteen Bus System with STATCOM fuzzy logic Controller

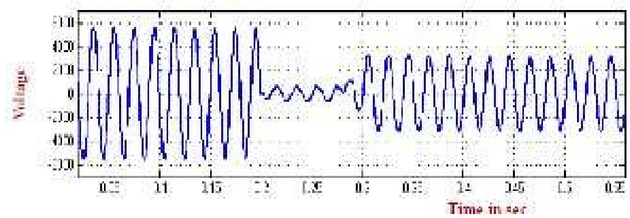

Figure 5.2. Voltage waveform at bus 4 with STATCOM

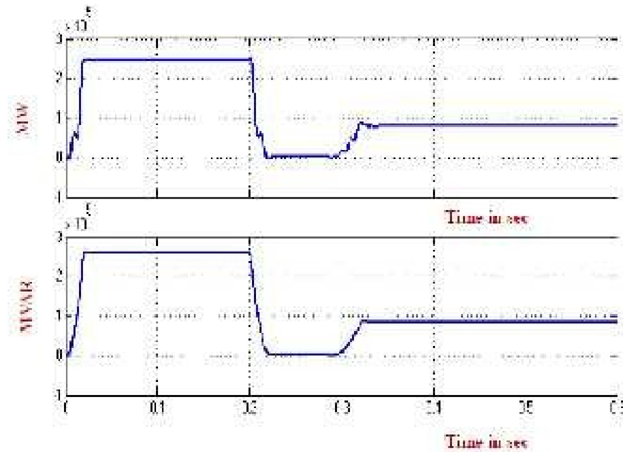

Fig. 5.3. Real and Reactive power at bus 4 with STATCOM

The simulation of UPFC is also done by using MATLAB Simulink and the results are presented. The variation of reactive power is possible with variation of firing angle**.** Simulation results closely agree with the theoretical results**.** The use of UPFC helps in increasing the power and voltage which is connected at bus 4 respectively**.**

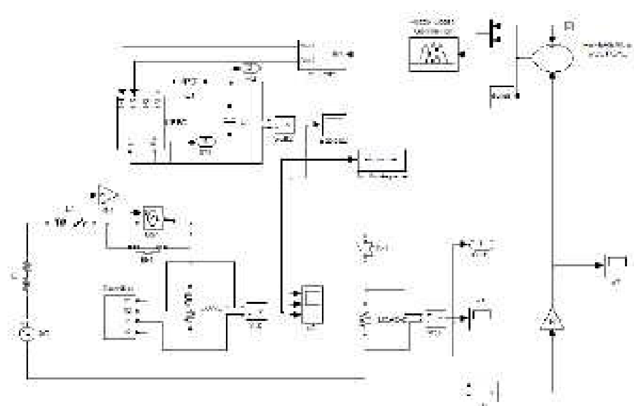

Fig. 5.4. Circuit diagram of fourteen Bus System with UPFC fuzzy logic Controller

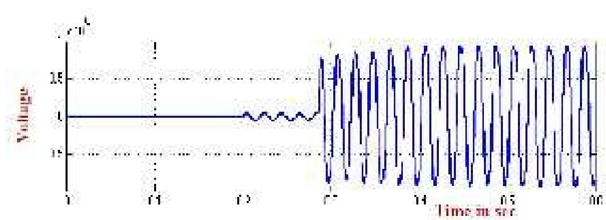

Fig: 5.5. Voltage waveform at bus 4 with UPFC

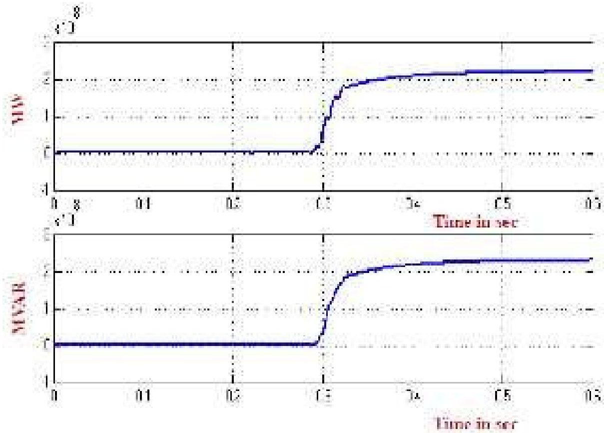

Fig. 5.6. Real and Reactive power at bus 4 with UPFC

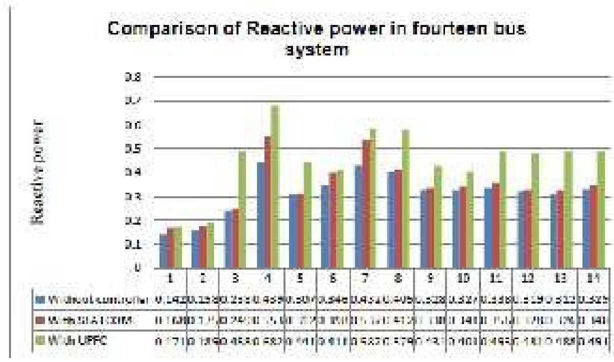

Fig: 6.3. Comparison of Reactive Power in Fourteen Bus System with and without Controller

VI.COMPARISON TABLE

The summary of real & reactive power for fourteen bus systems with and without controller is given in table 6.1 .The voltages for fourteen bus system with and without controller is given in table 6.2.

From the table it shows that voltage is increased due to the presence of UPFC when compared to STATCOM.

Bus.No	Real Power (MW)			Reactive Power (MVAR)		
	Without controller	With STATCOM	With UPFC	Without controller	With STATCOM	With UPFC
1	0.125	0.157	0.167	0.142	0.168	0.171
2	0.146	0.160	0.177	0.150	0.175	0.189
3	0.201	0.225	0.471	0.238	0.249	0.488
4	0.364	0.395	0.427	0.439	0.553	0.682
5	0.284	0.303	0.432	0.307	0.312	0.441
6	0.352	0.369	0.397	0.346	0.398	0.411
7	0.463	0.400	0.500	0.432	0.537	0.587
8	0.391	0.406	0.661	0.405	0.412	0.579
9	0.306	0.323	0.423	0.328	0.338	0.431
10	0.319	0.325	0.492	0.327	0.341	0.401
11	0.319	0.338	0.489	0.338	0.356	0.493
12	0.292	0.315	0.468	0.319	0.328	0.481
13	0.305	0.317	0.467	0.312	0.326	0.488
14	0.319	0.324	0.471	0.329	0.348	0.491

Table: 6.1. Summary of Real and Reactive Powers for fourteen Bus System with & without Controllers

BUS NO	VOLTAGE (V) WITHOUT CONTROLLER	VOLTAGE (V) WITH STATCOM	VOLTAGE (V) WITH UPFC
1	784	954	1048
2	989	1052	1153
3	847	910	1073
4	721	927	1164
5	868	954	1034
6	821	917	1024
7	764	928	1063
8	836	985	1089
9	852	973	1062
10	876	982	1030
11	917	994	1097
12	875	963	1032
13	939	1026	1087
14	884	961	1042

Table: 6. 2. Summary of voltage for fourteen bus system with and without controller

The behavior of UPFC and STATCOM was analyzed in closed loop control for fourteen bus system. STATCOM and UPFC are connected in bus no 4. After injecting STATCOM in bus no 4, the reactive power increased from 0.439 to 0.553 and after injecting UPFC in the same bus no 4, the reactive power increased from 0.439 to 0.682.

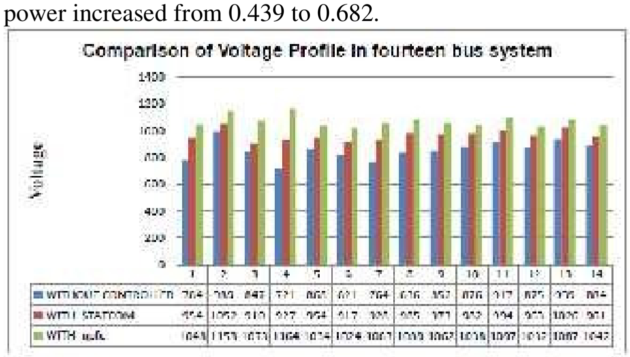

Fig. 6.2 Comparison of voltage in Fourteen Bus System with and without Controller

CONCLUSION

In this proposed work, the performance of UPFC and STATCOM are connected to a transmission line has been designed and evaluated. This project also describes the comparison for real and reactive power of the transmission line using UPFC and STATCOM. For the study of controllers, simulation using MATLAB and the hardware implementation of the controller were performedFrom the above table 6.1 it concludes UPFC shows 82.3% improvement than the STATCOM for the improvement of reactive power. The results of the simulation clearly indicate that UPFC and STATCOM are effective to enhance the security, capacity and flexibility of power transmission systems. From the above results we can observe that the voltage increases in UPFC compare to STATCOM .So finally we can conclude that by using FACTS devices such as UPFC and STATCOM voltage can be raised. The future work of this project is that, we can implement it by making use of the two methods they are: Neural networks and Genetic algorithm.

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