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MODELLING, SIMULATION AND COMPARISON ANALYSIS OF VARIOUS FACTS DEVICES FOR POWER STABILITY

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ABSTRACT

This paper compares in a load flow calculation, line losses, reactive power and active power and power factor comparison without any device, Static Synchronous Series Compensator (SSSC), static synchronous compensator (STATCOM) and Unified Power Flow Controller (UPFC). The power systems of today large are mechanically controlled. There is a widespread use of microelectronics, computers and high-speed communications for control and protection of present transmission systems by using these fact devices. Role of ttransient stability control plays a significant role in ensuring the stable operation of power systems in the event of large disturbances and faults. In effect, from the point of view of both dynamic and steady-state operation, the system is really uncontrolled[1]. Because all FACTS Controllers represent applications of the same basic technology, their production can eventually take advantage of technologies of scale. Just as the transistor is the basic element for a whole variety of microelectronic chips and circuits, the thyristor or high-power transistor is the basic element for a variety of high-power electronic Controllers. FACTS devices are capable of controlling the active and reactive power flows in a transmission line by controlling its series and shunt parameters[1,2].

KEYWORDS: SSSC, STATCOM, FACTS, UPFC, VAR.

INTRODUCTION

With the rapid development of power electronics technology and computer control technology, a variety of new type of automatic, fast reactive power compensation device have appeared. Early in time, mechanical switching capacitor device is used in power grid, it was switched on group though circuit breaker or contactor. When the circuit breaker is used in the power grid to put into capacitor or filter, a great change and development have taken place. On the one hand, it may produce the stretching discharge phenomena and so on, this phenomenon will reduce action times of circuit breakers, therefore it should not to be switched frequently; On the other hand, due to the action time of mechanical circuit breaker contact is dispersion. So it is lack of synchronicity, and will inevitably produce transition process. This result may cause system shock, especially frequent switching the circuit breaker will make the system unstable [3].

Static Var Compensator is the shunt compensation equipment of thyristor switched for reactive compensation in power system as a reactive source. It is on the basis of parallel capacitor and inductor of machinery investment and cut-style. Static Var Compensator is development with large-capacity thyristor instead of circuit breaker, that is a widely used in distribution system. The thyristor is adopted as switch to connect capacitors, reactors and other equipment to connect to the power grid, which actualizes the equipment's speediness, no arc, no impact switching, and has superior performance. Operational difficulties and the impact of inrush current is greatly reduced when the switching time. The dynamic response time of about 0.01 to 0.02s.The same time, the Thyristor Switched Capacitor can fast-track and response to the mutation of shock loading, at any time the power factor is maintained at the optimum value. Thus realize the dynamic reactive power compensation, and to reduce the voltage fluctuations and to improve power quality. Recent development of power electronics introduces the use of FACTS controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. The well known FACTS devices are namely SVC, SSSC, STATCOM and UPFC [1,2,3].

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) DEVICES

The FACTS are controllers based on solid states technologies, whose two main objectives are: the increase of the transmission capacity and the control of the power flow over designated transmission routes. On this way, as we see in fig. 1 the Controllers FACTS can be classified into four categories: Series Controllers, Shunt Controllers, and Combined series-series Controllers, Combined series-shunt Controllers. Variable impedance controllers include [3]:-

- Static Var Compensator (SVC), (shunt connected)
- The VSC based FACTS controllers are:
- Static synchronous Compensator (STATCOM) (shunt connected)
- Static Synchronous Series Compensator (SSSC) (series connected)
- HVDC Voltage Source Converter (HVDC- VSC
- Unified Power Flow Controller (UPFC) (Combined shunt-series).

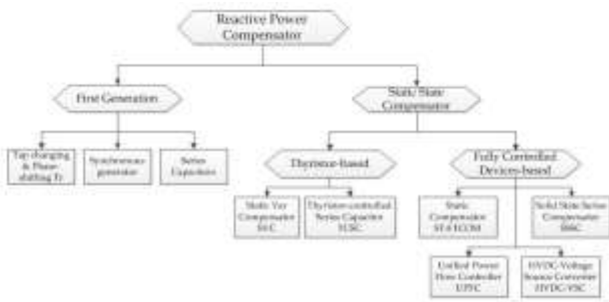

Figure 1 Various Category of Fact devices

STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

A STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. Figure 2 Basic structure of STATCOM A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage)[3].

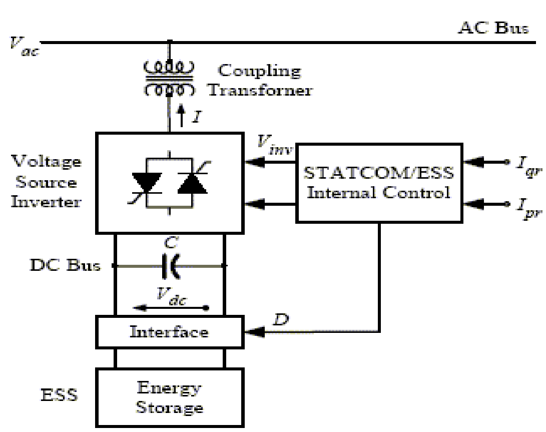

Figure 2 Basic structure of STATCOM

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Static Synchronous Series Compensator (SSSC)

SSSC is connected in series with a power system. Figure 3 Simplified diagram of a SSSC. It has a voltage source converter serially connected to a transmission line through a transformer. It can be considered as asynchronous voltage source as it can inject an almost sinusoidal voltage of variable and controllable amplitude and phase angle, in series with a transmission line. The injected voltage is almost in quadrature with the line current. A small part of the injected voltage that is in phase with the line current provides the losses in the inverter. Most of the injected voltage, which is in quadrature with the line current, provides the effect of inserting an inductive or capacitive reactance in series with the transmission line. The variable reactance influences the electric power flow in the transmission line[3].

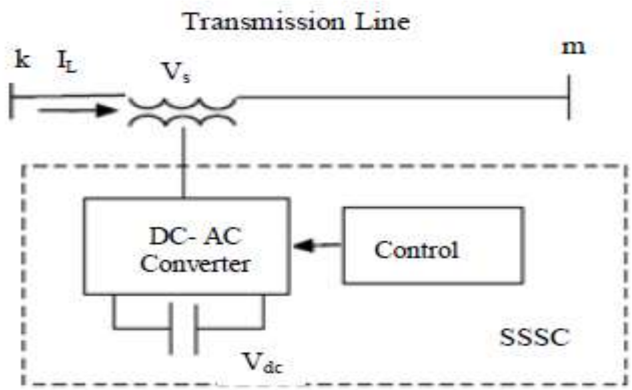

Figure 3 Simplified diagram of a SSSC

Unified Power Flow Controller (UPFC)

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile device that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 4. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real

Power absorbed from or injected into the power system by the series converter plus the losses by regulating the dc bus voltage at a desired value[3].

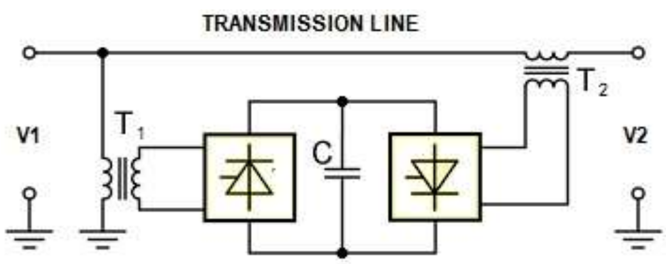

Figure 4 Basic structure of UPFC

COMPARISON BETWEEN UPFC, , STATCOM, AND SSSC FOR POWER SYSTEM STABILITY

Description of a single line diagram

1. Figure 5 is the single line diagram of a 500kv/230 kv transmission system. The system is connected in a loop configuration consists of 5 buses (b1 to b5), interconnected to 3 transmission line (L1, L2, L3) and two 500kv/230kv transformer bank tr1, tr2[2].

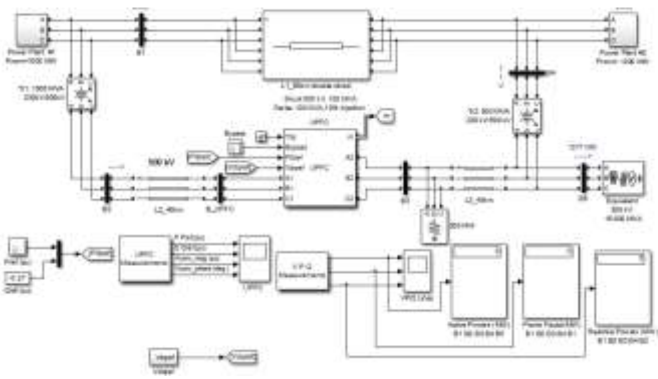

Figure 5 MATLAB Simulink model of single line diagram of above transmission line without using UPFC.

2. Two power plants located on 230 kv system, generate a total of 1500 MW power, which is transmitted to a 500kv, 15000 MVA and to a 200 MW RLC load connected at bus B3.
3. UPFC or any other device is connected at the right end line L2is used to control the active or reactive power at bus UPFC is connected at the right end of line L2 is used to control the active and reactive power at the 500 kv bus b3 .Each plant model includes a speed regulator, an excitation system as well as power system stabilizer. The 1200 MW generating capacity power plant p1 is exported to the 500 KV equivalents through two 400MVA transformer connected between (B4, B5) BUS.
4. The UPFC is joined at the right end of line L2 is used to control the active and reactive power at the 500kv bus B3 the UPFC used here include two 100 MVA, both the converter are interconnected through a DC bus two voltage source inverter connected by a capacitor charged to a DC voltage realize the UPFC the converter number one which is a shunt converter draws real power from the source and exchange it (minus the losses) to the series converter the power balance between the shunt and series converter is maintained to keep the voltage across the DC link capacitor constant[2].

MODELLING OF VARIOUS FACT DEVICES

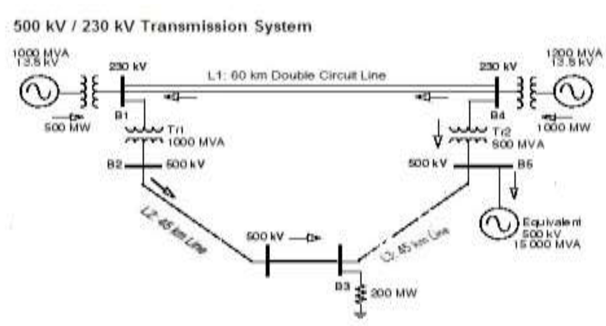

Figure 7 single line diagrams without any device of 500/230Kv transmission system

Now as we see in the fig. 7 we have taken the length of double transmission line L1 of 60km and the other transmission line as L2 of 45km and L3 also of 45km in the MATLAB SIMULINK of this circuit. This circuit doesn't have any device connected to it. The system is connected in a loop configuration consists of 5 buses (b1 to b5), interconnected to 3 transmission line (L1, L2, L3) and two 500kv/230kv transformer bank tr1, tr2. Two power plants located on the 230 kV system generate a total of 1500 MW (illustrated in figure 2) which is transmitted to a 500 kV, 15000 MVA

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equivalent and to a 200 MW load connected at bus B3. As we run the model we get the result values of active power, reactive power loss and power factor.

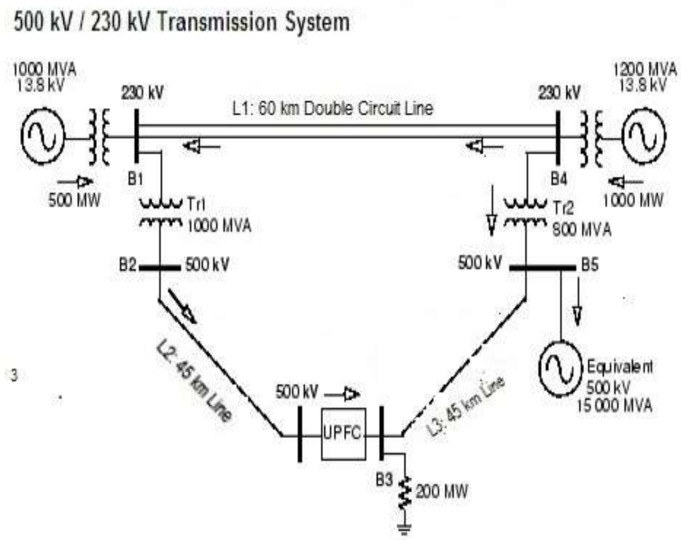

Figure 8 single line diagram with UPFC of 500/230Kv transmission system

Now as we see in the fig.8 we have taken the length of double transmission line L1 of 60km and the other transmission line as L2 of 45km and L3 also of 45km in the MATLAB SIMULINK of this circuit. This circuit have the UPFC connected to it. As we run the model we get the result values of active power, reactive power loss and power factor.

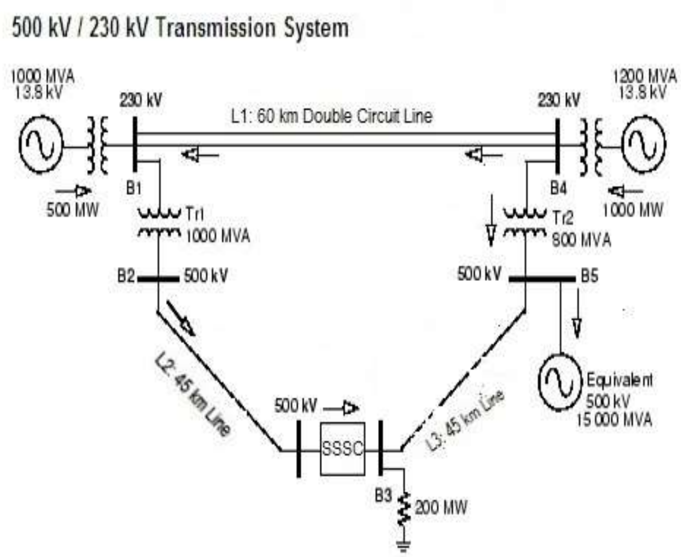

Figure 9 single line diagrams with SSSC of 500/230Kv transmission system

Now as we see in the fig. 9 we have taken the length of double transmission line L1 of 60km and the other transmission line as L2 of 45km and L3 also of 45km in the MATLAB SIMULINK of this circuit. It works as a controllable voltage source. Series inductance exists in AC transmission lines. On long lines, when a large current flows, this causes a large voltage drop. To compensate, series capacitors are connected, decreasing the effect of the inductance. In this circuit we have the SSSC connected to it. As we run the model we get the result values of active power, reactive power loss and power factor.

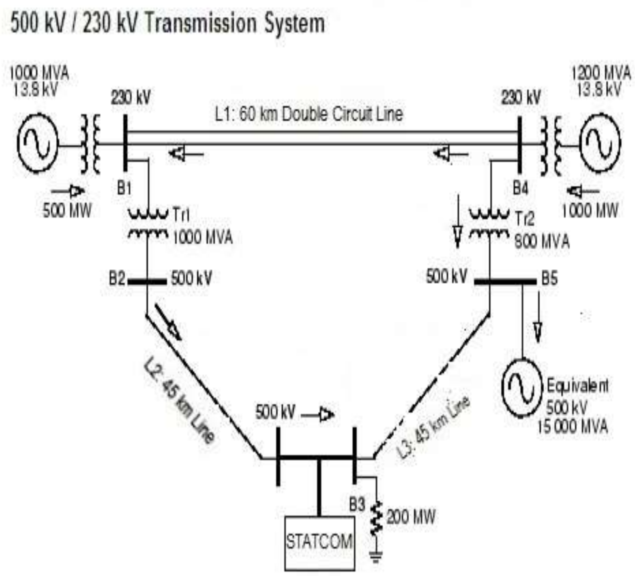

Figure 10 single line diagram with STATCOM of 500/230Kv transmission system

Now as we see in the fig. 10 we had taken the length of double transmission line L1 of 60km and the other transmission line as L2 of 45km and L3 also of 45km in the MATLAB Simulink of this circuit. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability.This circuit we have the STATCOM connected to it. As we run the model we get the result values of active power, reactive power loss and power factor.

RESULTS

In the single line diagram the (UPFC) is connected to bus B3 and the SIMULINK results thus we obtain shows that how the (UPFC) reduces the reactive power in the line, without using (UPFC) the reactive power. Similarly we get required readings as in the table 1. Table 1 shows the comparison of various fact devices in a circuit. In table 1 we have included the results of the active power, reactive power and power factor. And we investigated that the various values of length of transmission line we have drawn the various graph.

As we see in the above fig.11 we see that the comparison of active power for various fact devices. We analyse from the bar graph that various values of active power when we have the UPFC, SSSC and STATCOM connected and also the reading when there is no fact device connected to circuit.

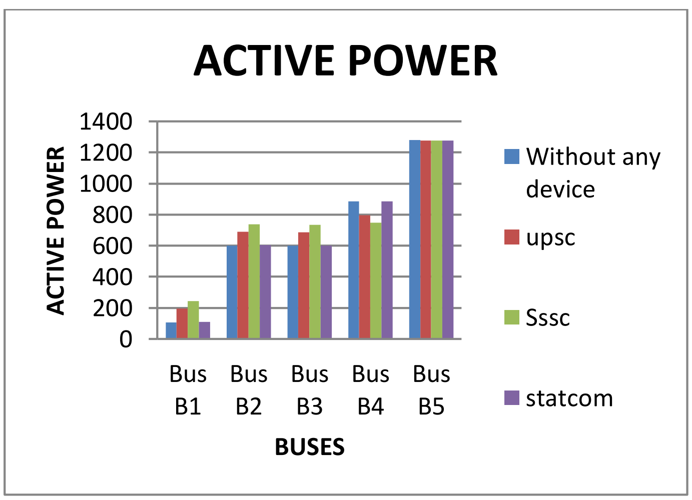

Figure 11 Active powers Comparison Plot for various buses and for different lengths

We analyse from the graph that UPFC have more active power as compared to that of various other fact devices. But at various buses STATCOM and SSSC are better as they are the series and shunt fact device. But when we analyse for overall performance from the table and the graph we have the UPFC found to be better as it has the advantage of both series and the shunt device. So on the basis of the given readings we have the UPFC a better device as compared to various other devices.

Now from the table 1 we check the various values of reactive power when we have the UPFC, SSSC and STATCOM connected and also the reading when there is no fact device connected to circuit. We analyse from the table 1 that UPFC have more absorption of reactive power as compared to that of various other fact devices. UPFC found to be better device as compared to other fact devices.

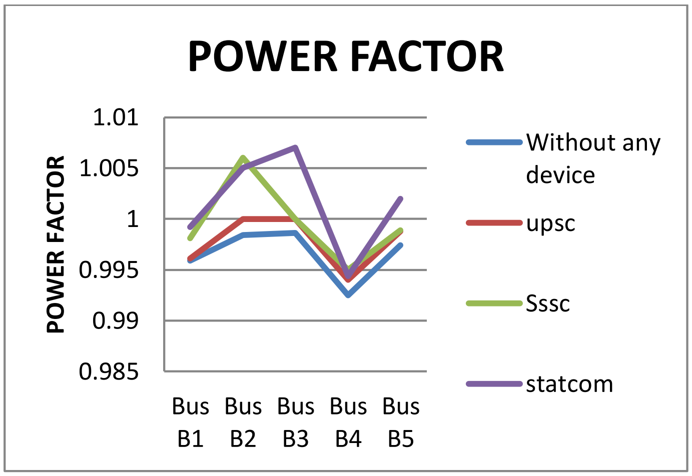

Figure 12 Power Factor Comparison Plot for various buses and for different lengths

As we see in the above fig. 12 we see that the comparison of active power for various fact devices. We analyse from the bar graph that various values of power factor when we have the UPFC, SSSC and STATCOM connected and also the reading when there is no fact device connected to circuit. We analyse from the graph that UPFC have more power factor near to one as compared to that of various other fact devices. We should always have power factor near to one for the minimum loss in transmission line and various other equipment's.

Table 1: Comparison between FACTS Devices for Power System Stability

	WITHOUT ANY DEVICE			UPFC			SSSC			STATCOM		
BUSES	REAL POWER	REACTIVE POWER LOSS	POWER FACTOR	REAL POWER	REACTIVE POWER LOSS	POWER FACTOR	REAL POWER	REACTIVE POWER LOSS	POWER FACTOR	REAL POWER	REACTIVE POWER LOSS	POWER FACTOR
B1	107.5	-18.24	0.9959	196.3	-29.47	0.9961	244.7	-42.87	0.9981	109	-23.31	0.9992
B2	601.1	-62.26	0.9984	689.4	-88.3	1	737.5	-125.9	1.006	602.5	-93.29	1.005
B3	599.4	-31.41	0.9986	687	-27	1	734.7	-32.07	1	600	42.2	1.007
B4	886.2	26.82	0.9925	796.4	16.07	0.994	747.2	13.85	0.995	884.8	13.9	0.9944
B5	1280	-111.6	0.9974	1277	-93.42	0.9988	1276	-89.18	0.9989	1276	-49.02	1.002

CONCLUSON

In this paper the response of the various facts devices has studied on the bases of load flow comparison and cost par var. UPFC has the attributes of Superior dynamic response & fast fault recovery as compared to that of conventional facts devices. FACTS are powerful devices to improve the voltage profile and power system enhancement. In this

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paper, comparison of different FACTS devices with respect System Stability Enhancement is carried out and gives an idea about the FACT devices. It is found that the performance of the UPFC is higher for power system stability improvement is compared with the other FACTS devices such as SVC, STATCOM, and SSSC respectively. The UPFC has settling time in post fault period is found to be around 0.6 second and maximum loss can be reduced compared to other FACTS device.

FUTURE SCOPE

The UPFC model can be reduce the harmonics and ability to control real and reactive powers. The heating in the transformers is reducing by using multilevel response. This is due to the reduction in the harmonics. So That the simulation results are in line with the predictions .They are used for power quality too.

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