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Selection of FACTs Devices for Better Reactive Power Compensation through Capacitor

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Abstract:

Flexible alternating current transmission systems (FACTs) technology opens up new opportunities for controlling power flow and enhancing the usable capacity of present, as well as new and upgraded lines. These FACTs device which enables independent control of active and reactive power besides improving reliability and quality of the supply. This paper describes the real and reactive power flow control through a short transmission line and then compensated short transmission line with different FACTs devices are used to selection of FACTs devices for better reactive power compensation with change in line capacitance/shunt capacitance to observe power flow. Computer simulation by MATLAB/SIMULINK has been used to determining better reactive power. TCSC, STATCOM, UPFC and SSSC FACTs controller with different capacitance are tested for controlling reactive power flow.

Keywords **— FACTS, TCSC, STATCOM, UPFC, SSSC, real and reactive power**

I .Introduction

Flexible AC transmission system is an evolving technology to help electric utilities. Its first concept was introduced by N.G Hingorani, in 1988 . The solutions to improve the quality of supply in the electrical networks with go through the applications of the developments in semiconductor power devices, that is to say, the utilization of static power converters in electrical energy networks. The technological advances in power semiconductors are permitting the development of devices that react more like an ideal switch, totally controllable, admitting high frequencies of commutation to major levels of tension and power. 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. By providing added flexibility, FACTs controllers allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines [1] .

The FACTs technology is essential to alleviate some but not all of these difficulties by enabling utilities to get the most service from there transmission facilities and enhance grid reliability. What is most interesting for transmission planners is that FACTs technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines the possibility that current through a line can be controlled at a reasonable cost enables a large potential of increasing the capacity of existing lines with larger conductors, and use of one of the FACTs controllers to enable corresponding power to flow through such lines under normal and contingency conditions [2].

These opportunities arise through the ability of FACTs controllers to control the interrelated parameters that govern the operation of transmission systems including series impedance, shunt impedance, current, voltage, phase angle, and the damping of oscillations at various frequencies below the rated frequency. The FACTs technology is not a single high-power controller, but rather a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters mentioned above. FACTs technology also tends itself to extending usable transmission limits in a step-by-step manner with incremental investment as and when required. However, the unique aspect of FACTs technology is that this umbrella concept revealed the large potential opportunity for power electronics technology to greatly enhance the value of power system and there by unleashed an array of new and advanced ideas to make it a reality. The well known FACTs devices are namely SVC, STATCOM, TCSC, SSSC and UPFC [3].

A - Thyristor Controlled Series Capacitor

Specific dynamical issues in transmission systems are addressed by Thyristor Controlled Capacitors (TCSC). In case of large interconnected electrical systems it increases damping. It also overcomes the problem of Sub- Synchronous Resonance (SSR). Sub-Synchronous Resonance is a phenomenon that involves an interaction between large thermal generating units and series compensated transmission systems. The high speed switching capability of TCSC provides a mechanism for controlling line power flow. This permits increased loading of existing transmission lines, and also allows for rapid readjustment of line power flow in response to various contingencies. Regulation of steady-state power flow within its rating limits can be done by the TCSC. The TCSC resembles the conventional series capacitor from a basic technology point of view. All the power equipment is located on an isolated steel platform, including the Thyristor valve which is used for controlling the behaviour of the main capacitor bank. Similarly the control and protection is located on ground potential along with other auxiliary systems [4].

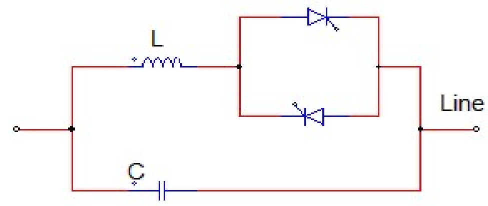

Fig. 1 Principle setup of TCSC

B - Static Synchronous Compensator

In transmission lines STATCOM is applied in shunt and it has the capability to dynamically adjust the required reactive power within the capability of the converter. The controlled current drawn by the converter has two components: active component and reactive component. The active component automatically meets the requirement of active power in DC link capacitor, whereas the reactive component of current is used for desired reference level. The control characteristic for the voltage is determined by the steepness of the static line between the current limitations. The STATCOM has the advantage that the reactive power provision is independent from the actual voltage on the connection point [5].

Reactive power (Var) control mode:-

An inductive or capacitive reactive power request is taken to be the reference input in reactive power control mode. The Var reference is transferred into a corresponding current request by the converter control and the gating of the converter is adjusted to establish the desired current.

Automatic voltage control mode

The voltage control mode is normally used in practical applications. In voltage control mode to maintain the transmission line voltage to a reference value at the point of connection the converter reactive current is automatically regulated.

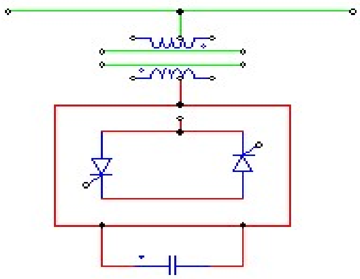

Fig. 2 Principle setup of STATCOM

C - Unified Power Flow Control

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously. The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously [6].

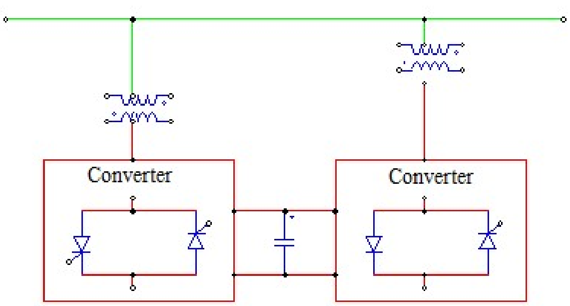

Fig. 3 Principle setup of UPFC

D - Static Synchronous Series Compensator

The SSSC is connected in transmission line in series and it injects a voltage with controlled magnitude and angle into it. The flowing power on the line is controlled by the injected voltage. The injected voltage is however dependent on the operating mode selected for the SSSC to control power flow [7].

There are two operating modes which are as follows

Line impedance compensation mode:- When the injected voltage is kept in quadrature with respect to the line current, so that the series insertion emulates impedance when viewed from the line, to emulate purely reactive (inductive or capacitive) compensation. This mode can select to match existing series capacitive line compensation in the system.

Automatic power flow control mode:- The magnitude and angle of the injected voltage is controlled so as to force such a line current that results in the desired real and reactive power flow in the line. In automatic power flow control mode, the series injected voltage is determined automatically and continuously by a closed-loop control system to ensure that the desired real and reactive power flow are maintained despite power system changes.

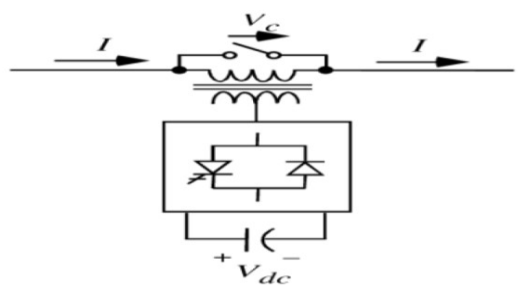

Fig. 4 Principle setup for SSSC

II Power Flow Problem

Power flow calculation determine the complex voltages at the nodes and the power flows on the lines for a specified power system at steady state with the generation and load schedule at each bus given. The steady state time frame includes common power system devices such as transmission line, transformers, generators and loads.

Various Power Quality Problems are as follows:

a) Poor transmission efficiency Losses in all power system elements from the power station generator to the utilization devices increase due to reactive power drawn by the loads, thereby reducing transmission efficiency.

b) Poor voltage regulation Due to the reactive power flow in the lines, the voltage drop in the lines increases due to which low voltage exists at the bus near the load and makes voltage regulation poor.

c) Low power factor the operating power factor reduces due to reactive power flow in transmission lines.

e) Need of largesized conductor the low power factor due to reactive power flow in line conductors necessitates largesized conductor to transmit same power when compared to the conductor operating at high power factor.

f) Increase in KVA rating of the system equipment the reactive power in the lines directly affects KVA rating of the system equipment carrying the reactive power and hence affects the size and cost of the equipment directly

g) Reduction in the handling capacity of all system elements Reactive component of the current prevents the full utilization of the installed capacity of all system elements and hence reduces their power transfer [8].

III Block Diagram of Proposed Solution

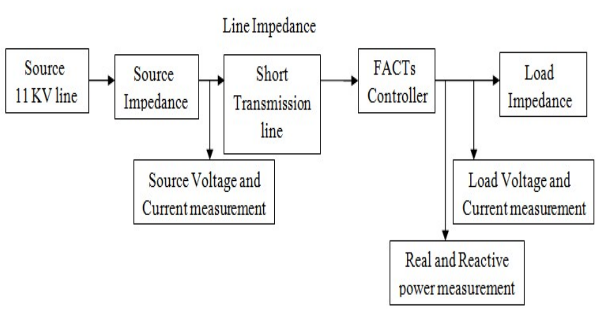

Fig. 5 Block diagram for propose solution

\IV Simulink of Transmission Line

A Simulink of Uncompensated Transmission Lines

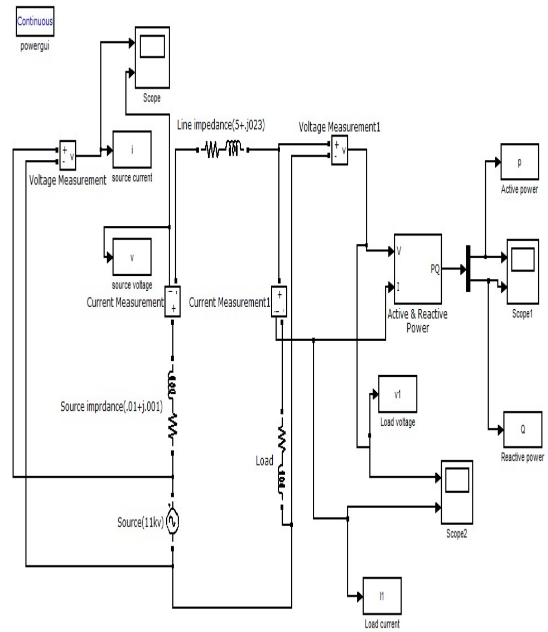

Fig. 6 Transmission line model for 11kv

B Simulink of Transmission line with TCSC

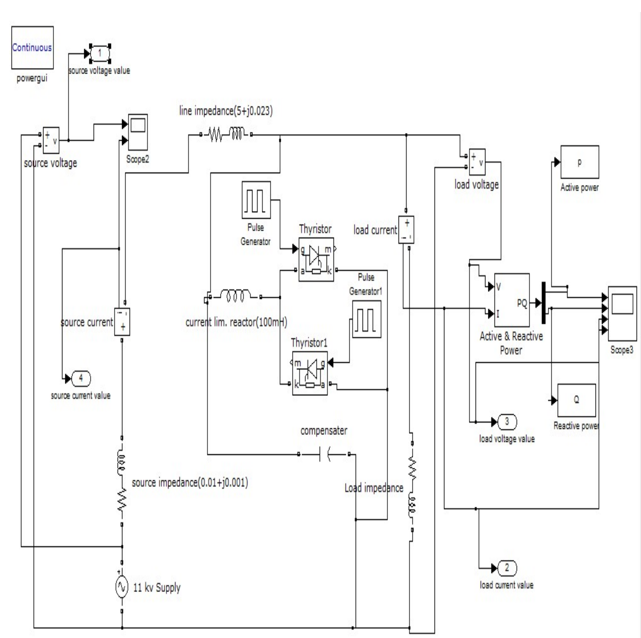

Fig. 7 Simulink of TCSC

C Simulink of Transmission line with STATCOM

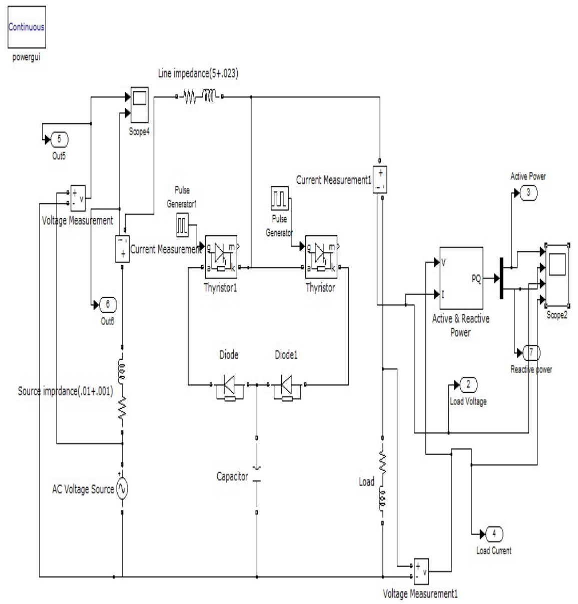

Fig. 8 Simulink of STATCOM

D Simulink of Transmission line with UPFC

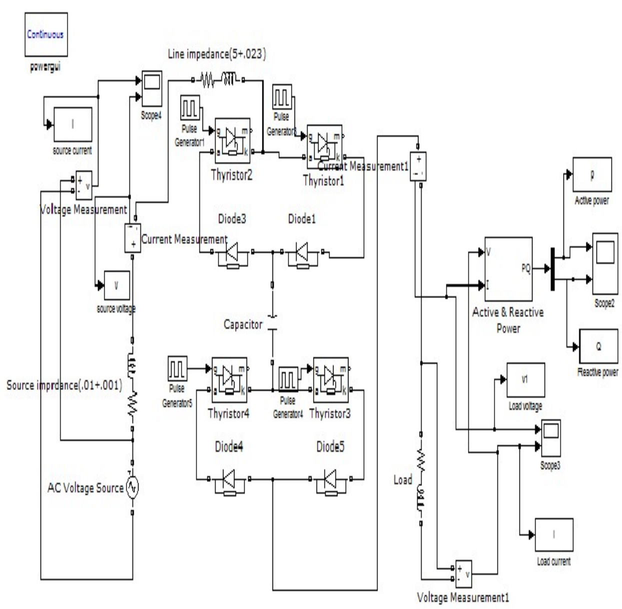

Fig. 9 Simulink of UPFC

E Simulink of Transmission line with SSSC

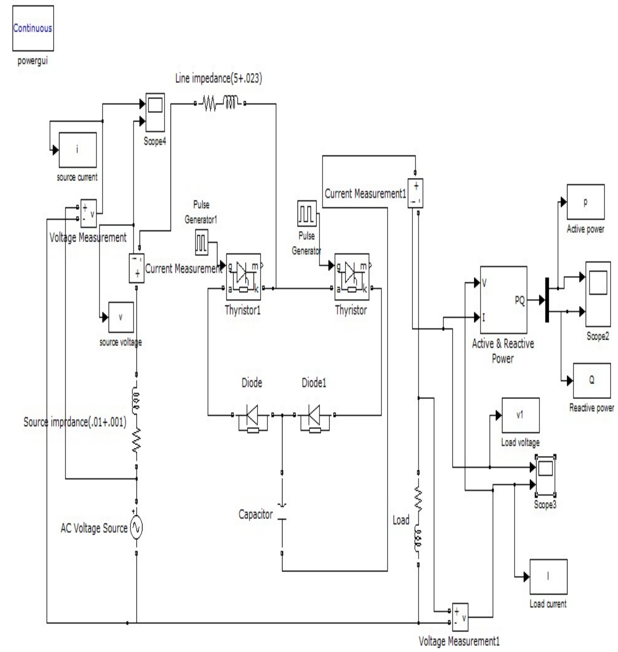

Fig. 10 Simulink of SSSC

V Results

A Result of Uncompensated Transmission Lines

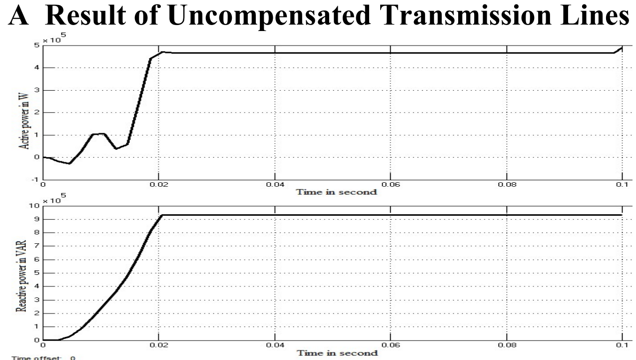

Fig. 11 Simulink result of uncompensated transmission line

B Result of Compensated Transmission Lines with TCSC

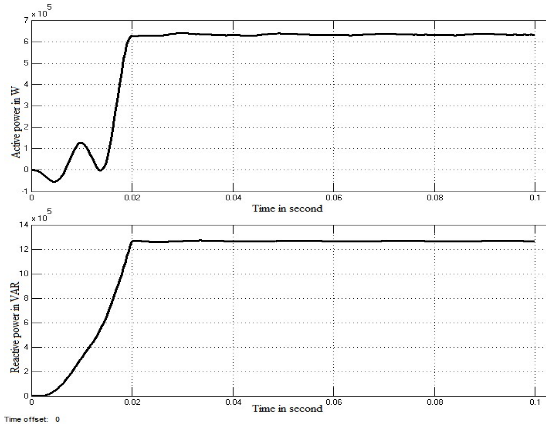

Fig. 12 Simulink result of TCSC

C Result of Compensated Transmission Lines with STATCOM

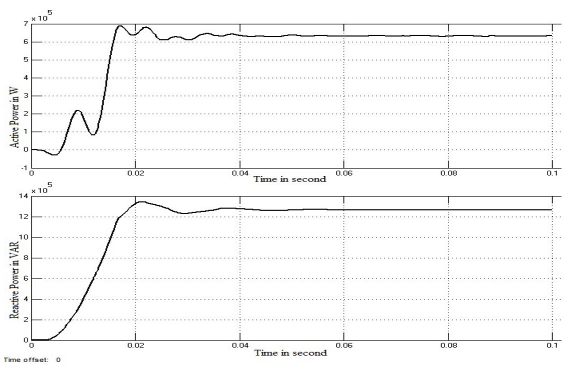

Fig. 13 Simulink result of STATCOM

D Result of Compensated Transmission Lines with UPFC

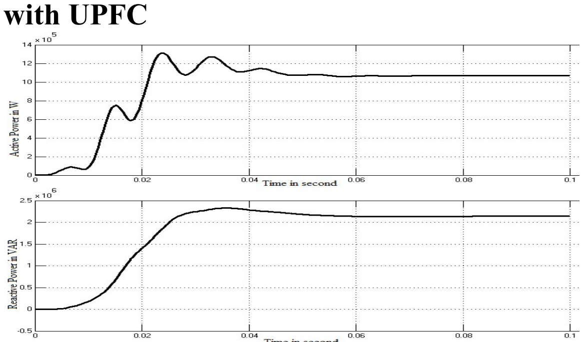

Fig. 14 Simulink result of UPFC

E Result of Compensated Transmission Lines with SSSC

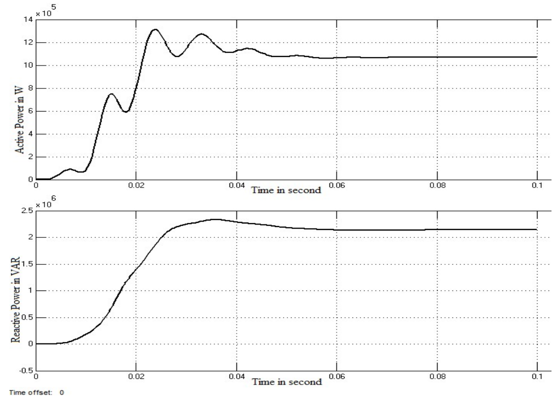

Fig. 15 Simulink result of SSSC

VI Result Analysis

Simulation results conclude that both active and reactive power increases in compensated transmission line using different FACTs device as compare to uncompensated transmission line. Active power and Reactive power increases in compensated transmission line in sequence SSSC > UPFC > STATCOM > TCSC respectively. As per configuration reactive power compensation is obtained at UPFC and SSSC type FACTs will use.

Table 1

Active and Reactive power of Various FACTs

Sr. No.	Configuration	Active Power (MW)	Reactive power (MVAR)
1	Uncompensated Transmission line	0.49	0.93
2	Compensated Transmission line with TCSC	0.63	1.26
3	Compensated Transmission line with STATCOM	0.63	1.26
4	Compensated Transmission line with UPFC	1.07	2.13
5	Compensated Transmission line with SSSC	1.07	2.14

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VII Experimental Analysis of Capacitor

If the values of the capacitors are changed then corresponding values for real and reactive power shown in table for different FACTs device.

Table 2

Variation of power flow with change in capacitance of TCSC

Sr. No.	Capacitance value (µF)	Real Power (MW)	Reactive power(MVAR)
1	200	0.51	1.02
2	400	0.63	1.26
3	600	0.78	1.57
4	800	0.99	1.98
5	1000	1.25	2.51
6	1200	1.56	3.13
7	1400	1.87	3.76
8	1600	2.09	4.18
9	1800	2.09	4.21
10	2000	1.90	3.81

From table 2 and simulation results conclude that both active and reactive power increases with increase in capacitance value up to 1800µF.

Table 3

Variation of power flow with change in capacitance of STATCOM

Sr. No.	Capacitance value (µF)	Real Power (MW)	Reactive power(MVAR)
1	200	0.48	0.96
2	400	0.63	1.26
3	600	0.84	1.69
4	800	1.13	2.27
5	1000	1.48	2.95
6	1200	1.75	3.50
7	1400	1.78	3.56
8	1600	1.54	3.08
9	1800	1.19	2.39
10	2000	0.89	1.78

From table 3 and simulation results conclude that both active and reactive power increases with increase in capacitance value up to 1400µF.

Table 4

Variation of power flow with change in capacitance of UPFC

Sr. No.	Capacitance value (µF)	Real Power (MW)	Reactive power(MVAR)
1	100	0.21	0.42
2	200	1.42	2.85
3	300	1.44	2.89
4	400	1.07	2.13
5	500	0.86	1.72

From table 4 and simulation results conclude that both active and reactive power increases with increase in capacitance value up to 300µF.

Table 5

Variation of power flow with change in capacitance of SSSC

Sr. No.	Capacitance value (µF)	Real Power (MW)	Reactive power(MVAR)
1	100	0.21	0.42
2	200	1.42	2.85
3	300	1.44	2.90
4	400	1.07	2.14
5	500	0.86	1.72

From table 5 and simulation results conclude that both active and reactive power increases with increase in capacitance value up to 300µF.

VII Conclusion

The real power without FACTs devices was obtained as 0.49 MW and after FACTs devices was 0.63 MW (TCSC), 0.90 MW (STATCOM), 1.35 MW (UPFC), 1.36 MW (SSSC). The reactive power without FACTs devices was obtained as 0.93 MVAR and after FACTs devices was 1.26 MVAR (TCSC), 1.27 MVAR (STATCOM), 2.77 MVAR (UPFC), 2.78 MVAR (SSSC). Maximum power flow achieved with SSSC and UPFC FACTs device.

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