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Enhancement of Power Quality in Transmission Line Using Flexible Ac Transmission System

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***Abstract*— FACTS devices can be added to power transmission and distribution systems at appropriate locations to improve system performance. The real and reactive powers can be easily controlled in a power system with FACTS devices. Flexible AC Transmission System creates a tremendous quality impact on power system stability. This paper describes the basic principle of operation of UPFC, its advantages and to compare its performance with the various FACTS equipment available. The objective of this paper is to keep the power system to remain in voltage stable condition when it experiences a load change and contingency, also deals with the simulation of various FACTS controllers using simulation program with MATLAB/SIMULINK, simple circuit model of Thyristor Controlled Reactor (TCR), Fixed Capacitor Thyristor Controlled Reactor (FC-TCR) and Unified Power Flow Control (UPFC) systems were simulated.**

***Index Terms*— Flexible AC transmission systems (FACTS), FACTS Controllers, TCR, Real and reactive power, FCTCR, UPFC, Matlab Simulink**

I. Introduction

The promising concept of the Flexible AC Transmission System (FACTS) makes it possible to achieve fast and reliable power system control by means of power electronic devices. The emergence of the FACTS devices offers great opportunities to the operation and control of modern power systems. Better, faster, cheaper and more reliable utilization of electrical energy is an important subject that electric power companies are concerned about. Harmonics and reactive power flowing to the supply system, transients caused by less reliable electrical supply systems. In order to cope with these kinds of problems and increase usable power transmission capacity, FACTS (Flexible AC Transmission Systems) devices were developed and introduced to the market.

Traditionally, FACTS devices can only regulate either the active power flow or reactive power flow of a single transmission line. A breakthrough is made by the availability of the UPFC, which is one of the most versatile FACTS devices and is capable to control the active and reactive power flows in the transmission line at the same time.

Power Flow is one of the major problems in a transmission system. When a fault occurs in a transmission system there is said to be a drop in the voltage. The UPFC is capable of improving transient stability in a power system. It is the most complex power electronic system for controlling the power flow in an electrical power system.

The UPFC in its general form can provide simultaneous, real-time control of all basic power system parameters (transmission voltage, impedance and phase angle) and dynamic compensation of ac system [1]. The Unified Power Flow Controller (UPFC) is a relatively new and more versatile device in the FACTS family, because of its simultaneous control ability of active and reactive power, and its effective damping capability for transient swings.

Now, more than ever, advanced technologies are paramount for the reliable and secure operation of power systems. Many studies were made before in order to achieve the suitable and optimal representation of the UPFC model with the Newton-Raphson load-flow algorithm. The drawback of these represented models is mainly for its difficulty and heavy computation burden. In this paper, control of both real and reactive power flow of transmission line is achieved through a suggested UPFC model.

Within this paper, which is on the trace of our previous works [2], the impact of the Unified Power Flow Controller (UPFC) on power flow regulation is analyzed. The proposed models accurately represent behavior of the controllers, and are adequate for transient and steady state analysis of power systems [3].

In recent years, MATLAB has become more and more popular in all engineering fields for its flexibility and the well support from its toolboxes. The real power and reactive power in the load is measured using the Active & Reactive Power measurement block.

II. OPERATING PRINCIPLE OF UPFC

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers [4]. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other

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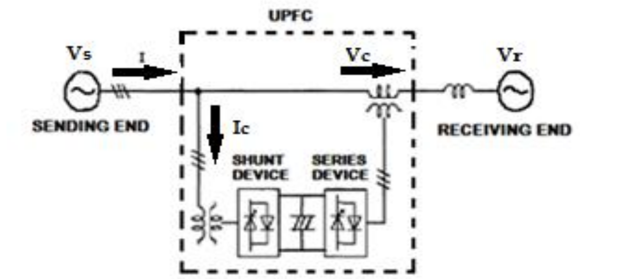
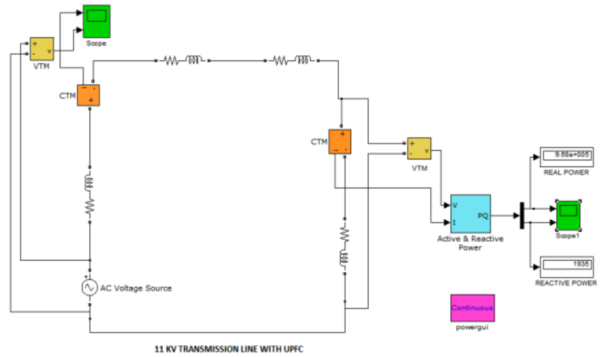


one is connected in series through a series transformer. A basic UPFC functional scheme is shown in fig.1.

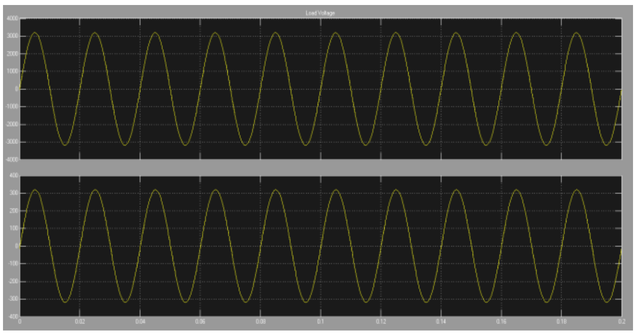
Fig.1 Basic functional scheme of UPFC

A. Basic Transmission Line

The voltage measurement block is used to measure the source voltage. The current measurement block is used to measure the instantaneous current flowing in the transmission line. Fig.2 represents the source impedance and the line impedance of (6+j0.023) Ω, and the load impedance of (2+j0.02) Ω respectively. Scope displays the signals



generated during a simulation. In, scope is used to view both



the line current and source voltage.

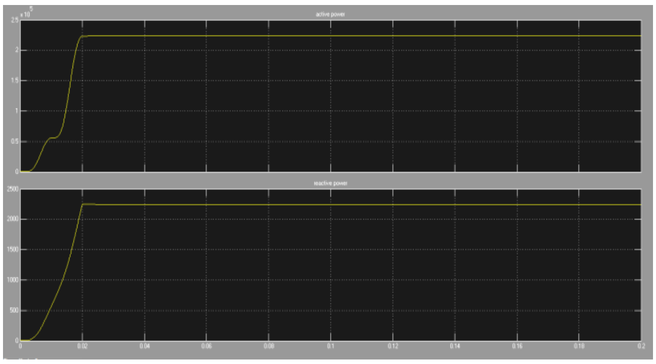


Fig. 2 Basic 11 KV transmission line without compensation

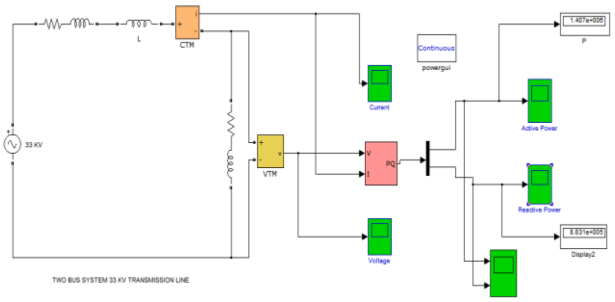


Fig.3 Load Voltage & current Waveforms

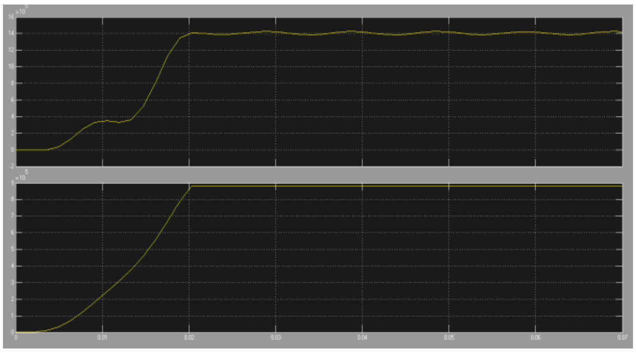


Fig. 4 Active Power & reactive Powers

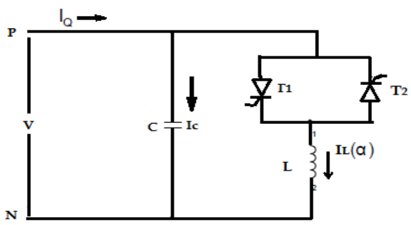
Fig. 5 Basic 33 KV transmission line without compensation

Fig .6 Active Power & reactive Powers

III. SIMULATION RESULTS

A. Fixed Capacitor Thyristor-Controlled Reactor

The Fixed Capacitor Thyristor-Controlled Reactor (FC-TCR) is a var generator arrangement using a fixed (permanently connected) capacitance with a thyristor controlled reactor as shown in Fig.7. The model of FC-TCR with the line voltage of 11KV is shown in Fig.8. The current through the TCR is measured



using the current measurement block. The line impedance of (5+j0.023) Ω is represented by resistance and inductance of source side.

Fig. 7 Fixed Capacitor Thyristor Controlled Reactor

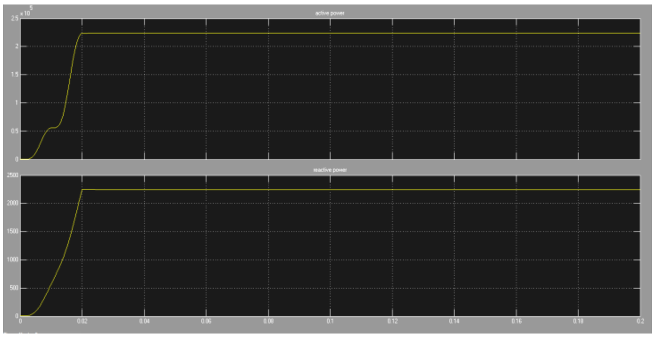
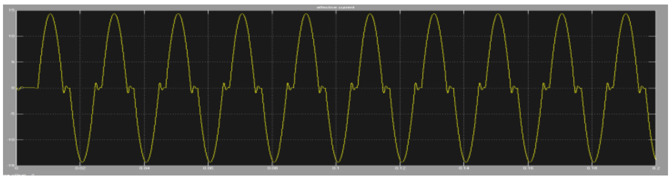


Fig. 8 Simulation Circuit of FC-TCR

Fig. 9 Active Power & reactive Powers

The value of FCTCR reactor is 100mh and capacitor C is the fixed capacitor of 200 µF. The current through FCTCR is shown in Fig.10 and behavior of Real and Reactive Power is



shown in Fig. 11 also the load voltage and the load current respectively.

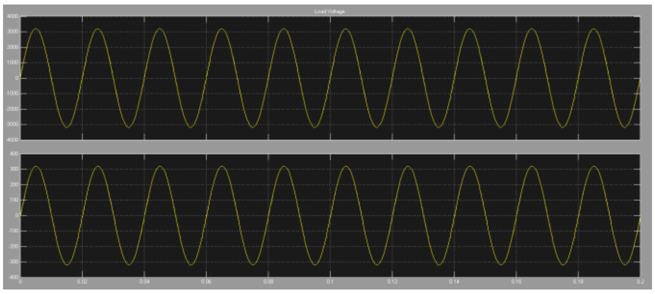
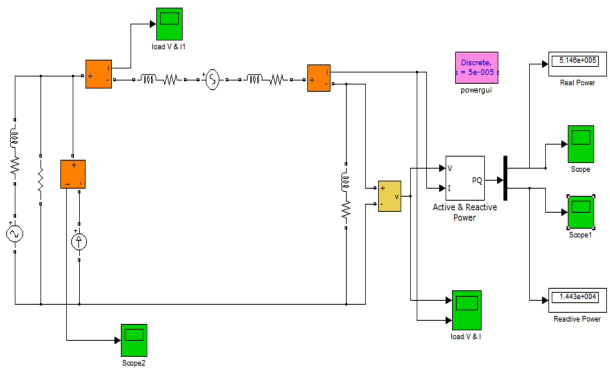


Fig. 10 Effective current through FCTCR

Fig.11 Load Voltage & current Waveforms

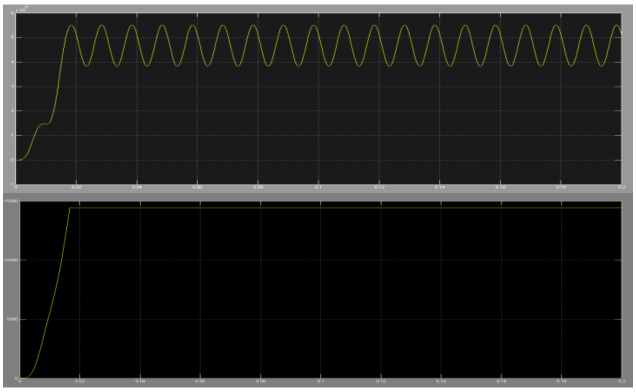
Simulation model of two bus system with UPFC shown in Fig. 12 The series convertor is represented as Voltage source (Vseries), and shunt convertor is represented as Voltage



source (Vshunt). Power measurement block is connected at the load side to measure Real Power and Reactive Power.

Fig. 12 Simulation Circuit of UPFC

The Variation of Real power with the variation of injected angle is given in Table1. The real power is increase with the increase in the angle of injection [5]. The corresponding graph is shown in fig. 14 The Variation of Reactive power with the variation of injected angle is given in Table2. The



bus voltage increases with the increase in the injected voltage. The corresponding graph is shown in fig. 16

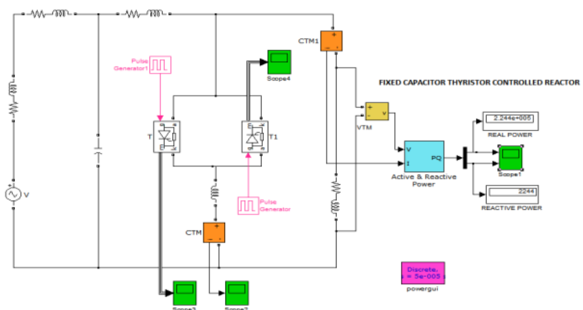
Fig. 13 Active Power & Reactive Powers

The Real power and the Reactive Powers measured in the load are 0.23MW and 1.12MVAR as shown in Fig.13. By introducing FACTS Controllers in the transmission line, the power flow can be increased [6] [7].

Table.1 Variation of Real Power & Angle of injected Voltage

S. No.	Angle of injected Voltage in series (deg)	Real Power (MW)
1	0	0.274
2	30	0.338
3	60	0.471
4	90	0.644
5	120	0.807

The reactive power can be further increased by increasing



the magnitude of injected voltage. The corresponding graph is shown in fig. 16. It can be seen that the reactive power further increases with the increase in the injected voltage.

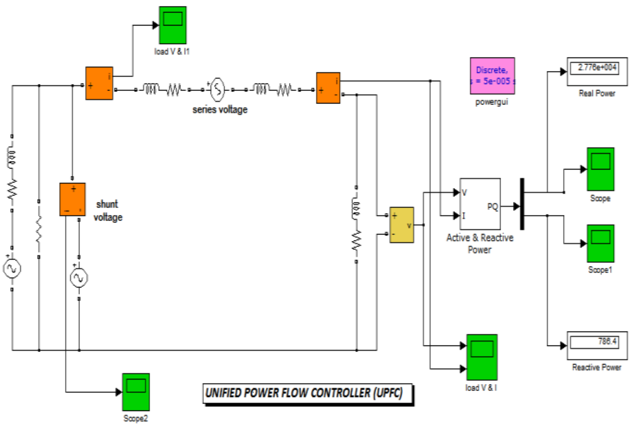


Fig. 14 Angle Vs Real Power

Table.3 shows the variation of Real and Reactive powers by injecting a series voltage of fixed magnitude 3kV at different angles of injection from 0° to 360°[8] Table.2 shows the variation of Reactive Powers.

Fig. 15 Simulation Circuit of Shunt injected UPFC

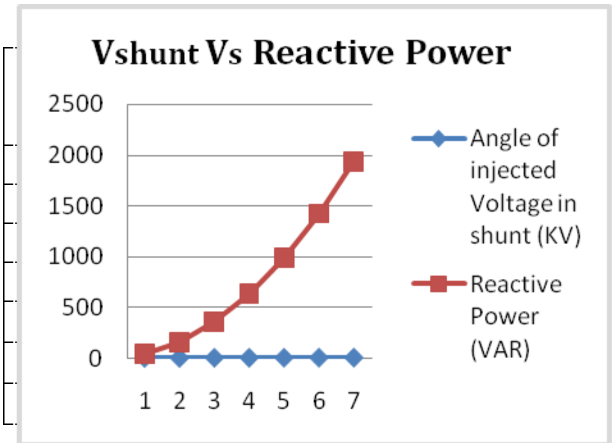


Table.2 Variation of Reactive Powers

Fig. 16 Reactive Power Vs Shunt Voltage

IV. Results

The real and reactive powers increase with the increase in angle of injection. Simulation results show the effectiveness of UPFC to control the real and reactive powers [10] It is found that there is an improvement in the real and reactive powers through the transmission line when UPFC is introduced. The simulation results are similar to the predicted results.

S. No.	Angle of injected Voltage (Deg)	Source Current (A)	Effective Current (A)	Real Power in (MW)	Reactive Power in (MVAR)
1	0	220	232	0.274	0.007
2	30	255	253	0.338	0.009
3	60	260	296	0.471	0.012
4	90	266	347	0.644	0.017
5	120	262	390	0.807	0.021
6	150	250	347	0.644	0.017
7	180	224	426	0.920	0.026
8	240	174	384	0.697	0.021
9	270	164	340	0.532	0.016
10	300	171	290	0.387	0.019
11	360	218	232	0.274	0.007

Table.3 Variation of Real and Reactive Powers with variation in the angle of injected voltage

V. Conclusion

Improvements in simulation environment with the incorporation of FACTS devices, schemes with in MATLAB/SIMULINK have been presented. UPFC is capable of improving the power quality by injecting the voltage. The intention of the simulation study is to prove that the UPFC is capable of improving the voltage stability. This paper presents the control and performance of the UPFC for power quality improvement. The voltage compensation using UPFC system is also studied. In the simulation study, MATLAB/ environment is used to simulate the model of UPFC. The simulation results are similar to the predicted results. Studying the results has given an indication that UPFC are very useful when it comes to organize and maintain power system. Following conclusions are made-

1. Power flow control is achieved and congestion is less.
2. Transient stability is improved.
3. Faster Steady State achievement.
4. Improved Voltage Profile

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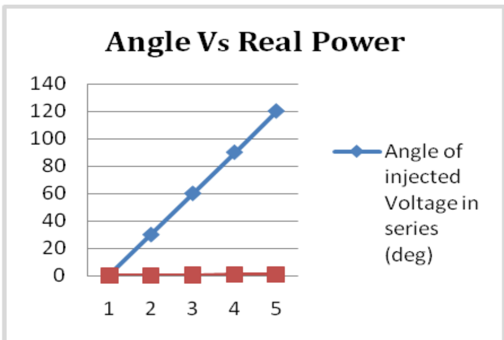

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