STUDY ON EFFECT OF UPFC DEVICE IN ELECTRICAL TRANSMISSION SYSTEM: POWER FLOW ASSESSMENT

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Abstract - The power transfer capability of electric transmission lines are usually limited by large signals ability. Economic factors such as the high cost of long lines and revenue from the delivery of additional power gives strong intensive to explore all economically and technically feasible means of raising the stability limit. On the other hand, the development of effective ways to use transmission systems at their maximum thermal capability. Fast progression in the field of power electronics has already started to influence the power industry. This is one direct out come of the concept of FACTS aspects, which has become feasible due to the improvement realized in power electronic devices in principle the FACTS devices should provide fast control of active and reactive power through a transmission line. The UPFC is a member of the FACTS family with very attractive features. This device can independently control many parameters. This device offers an alternative mean to mitigate transmission system oscillations. It is an important question is the selection of the input signals and the adopted control strategy for this device in order to damp power oscillations in an effective and robust manner. The UPFC parameters can be controlled in order to achieve the maximal desire effect in solving first swing stability problem. This problem appears for bulky power transmission systems with long transmission lines. In this paper a MATLAB Simulink Model is considered with UPFC device to evaluate the performance of Electrical Transmission System of 22 kV and 33kV lines. In the simulation study, the UPFC facilitates the real time control and dynamic compensation of AC transmission system. The dynamic simulation is carried out in conjunction with the N-R power flow solution sequence. The updated voltages at each N-R iterative step are interpreted as dynamic variables. The relevant variables are input to the UPFC controllers.

Key words: UPFC model, Power Flow Analysis (N-R load flow method), MATLAB / SIMULINK.

I. INTRODUCTION

In competitive electricity markets the most important component is Transmission system/ network and it serves as the key mechanism for generators to compete in the supply to reach large users. With the restructuring in power supply industry and open access the importance of controllers for achieving Flexible AC Transmission systems (FACTS) is increasing. Comprehensive FACTS Controller referred to as the Unified Power Flow Controller (UPFC). It utilizes the synchronous voltage sources to provide comprehensive control of power flow in transmission systems [1]. Installing the UPFC can improve power transfer capability. The UPFC is an advanced power system device capable of providing simultaneous control of Instantaneous speed of response voltage magnitude, active and reactive power flows in an adaptive fashion. It has

- Extended functionality
- Capability to control voltage, line impedance and phase angle in the power system network
- Enhanced power transfer capability
- Ability to decrease generation cost
- Ability to improve security and stability
- Applicability for power flow control, loop flow control, load sharing among parallel corridors [2-3].

In this paper, the development of a comprehensive method for steady state power flow

analysis of a transmission system with UPFC Simulink Model to evaluate the performance of a single electrical transmission line system has been focused. This device offers an alternative mean to mitigate transmission system oscillations. It is an important question is the selection of the input signals and the adopted control strategy for this device in order to damp power oscillations in an effective and robust manner. The UPFC parameters can be controlled in order to achieve the maximal desire effect in solving first swing stability problem. This problem appears for bulky power transmission systems with long transmission lines.

Dynamic simulation of the UPFC controllers will remove the assumption that the specified UPFC control objectives have been achieved in the steady state UPFC model. The new UPFC model for power flow analysis is based on the explicit dynamic simulation of both the shunt converter and series converter controllers. The dynamic simulation is carried out in conjunction with the N-R power flow solution sequence. The updated voltages at each N-R iterative step are interpreted as dynamic variables. The relevant variables are input to the UPFC controllers. The response of the controllers to the inputs, subject to the limits and priority specified in the controllers, are the voltage sources associated with shunt and series converters. The voltage sources are input to power network at UPFC locations for the subsequent N-R iteration. The constraint solution problem encountered in previous UPFC steady state

model in which there are interactions among the UPFC equations representing the control objectives and inequality constraints representing the operating limits is avoided completely. The relative priority in UPFC control is inherently taken in to account in the new formulation via the direct simulation in a dynamical form of the UPFC controllers. The overall simulation can be considered to be a hybrid one in which dynamic simulation based model of the UPFC is combined with the N-R power flow method for power network. The applications of the simulation technique are those in power systems planning and design where UPFCs are proposed. This device offers an alternative means to mitigate power system oscillations. Thus an important question is the selection of the input signal and the adopted control strategy for these devices in order to damp power oscillations in an effective and robust manner. This paper work shows that UPFC is an effective device to improve the power flow in transmission system by incorporating UPFC in transmission line. Since it is a solid state controller which can be used to control active and reactive power flow in a transmission line.

In the simulation study, the UPFC facilitates the real time control and dynamic compensation of AC transmission system [4-5]. It provides the necessary functional flexibility required for solving the problems faced by the utility industry. The UPFC could be considered as comprehensive real and reactive power compensation capable of independently controlling voltage profile as well as the real and reactive powers in the line.

II. METHODOLOGY

The concept of the control system, in a transmission line is taken to implement the use of UPFC. The two modes that is the power flow control mode and voltage injection mode is simulated in simulink model to see the effect of UPFC [6-7-8] on a transmission line. It is carried out to verify the utility of UPFC device. The UPFC could be considered as comprehensive real and reactive power compensation capable of independently controlling voltage profile as well as the real and reactive powers in the line. The corresponding simulation models with and without UPFC are developed in MATLAB / SIMULINK [9-10] environment for the following cases.

III. TESTING OF 22KV AND 33KV TRANSMISSION LINE SYSTEM WITHOUT UPFC DEVICE.

The basic function of the electric power system is to supply electrical energy to consumers as economical as possible with an acceptable level of reliability. An efficient transmission system is expected to have the optimum capability to provide the transfer of electrical energy between the point of supply and the point of delivery. Transmission line

performance assessment depends on data collection capabilities and performance metrics to ensure continued grid adequacy and security. The testing of single line transmission system without UPFC device in MATLAB / SIMULINK model has been discussed in the following sections.

A. Simulink model of 22kVTransmission line

The simulation model of Single line transmission system of 22kV Line is shown in Fig.1. The model is simulated and corresponding results of voltage magnitude, real and reactive power flows in the line are shown in Figs.2and 3 respectively.
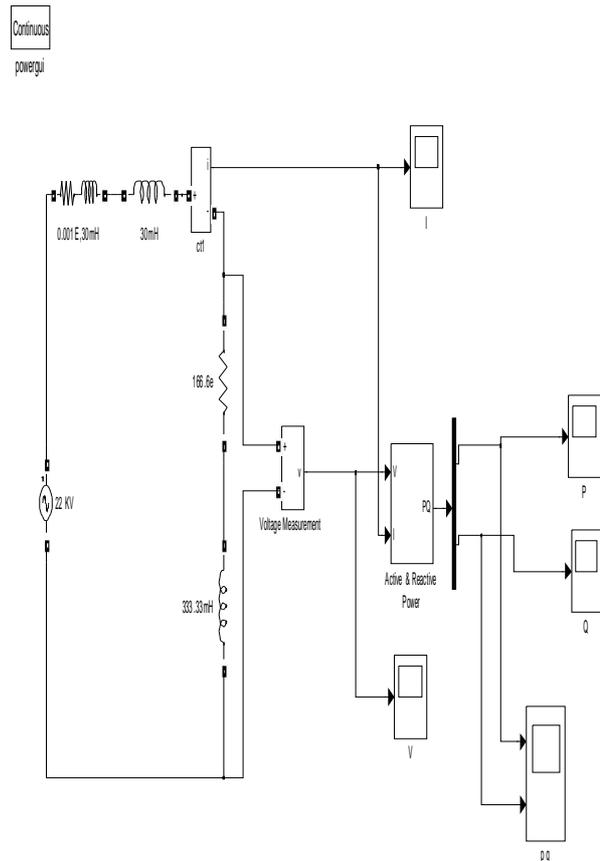

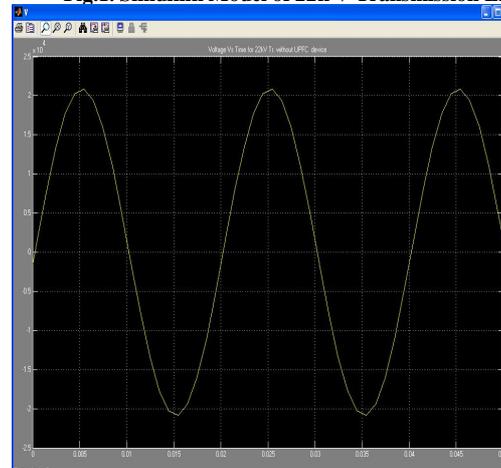**Fig.1. Simulink Model of 22k V Transmission Line.**

Fig.2. Voltage magnitude of 33 kV Transmission Line

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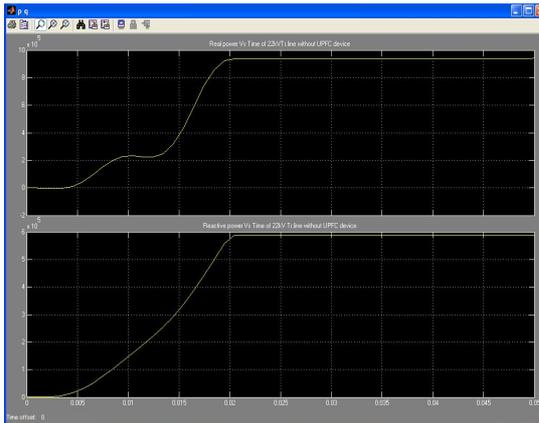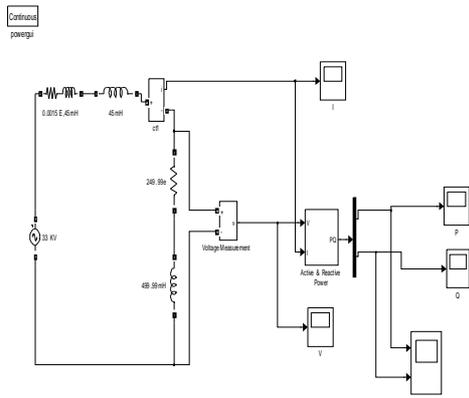
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Fig.3 Real and Reactive power flows of 22 kV Line.

By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is 20.04 kV, the real power is 93.69MW and the reactive power is 57.53MVAr.

B. Simulink model of 33kV Transmission line

The simulation model of Single line transmission system of 33kV, Line is shown in Fig.4. The model is simulated and corresponding results of voltage magnitude, real and reactive power flows in line are shown in Figs.5 and 6 respectively.
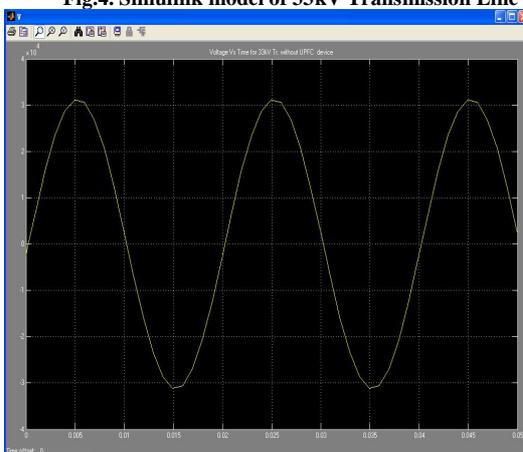

Fig.4. Simulink model of 33kV Transmission Line
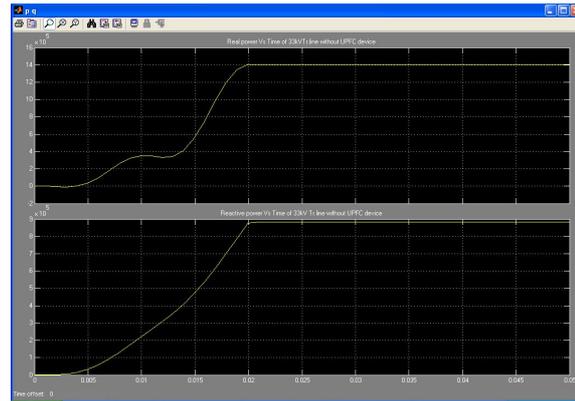

Fig.5. Voltage magnitude of 33 kV Transmission Line.

Fig.6. Real and Reactive power flows of 33 kV Line.

By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is 31.08 kV, the real power is 1.40MW and the reactive power is 88.501MVAr.

IV. TESTING OF 22KV AND 33 KV TRANSMISSION LINE SYSTEM WITH UPFC DEVICE.

With the development of power systems especially the opening of electric energy markets, it becomes more and more important to control the power flow along the transmission line, thus to meet the need of power transfer. On the other hand the fast development of power electronic technology has made UPFC a promising part for future power system needs. This device is an advance power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows in an adaptive fashion [10]. The following section is discussing the testing of transmission line with UPFC device with MATLAB / SIMULINK model environment [11-12].

A. Simulink model of 22 kV Transmission Line

The simulation model of Single line transmission system of 22kV Line is shown in Fig .7. The model is simulated and corresponding results of voltage magnitude, real and reactive power flows in line are shown in Fig's 8 and 9espectively.
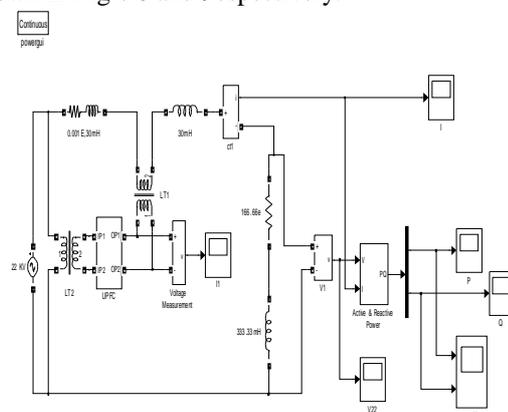

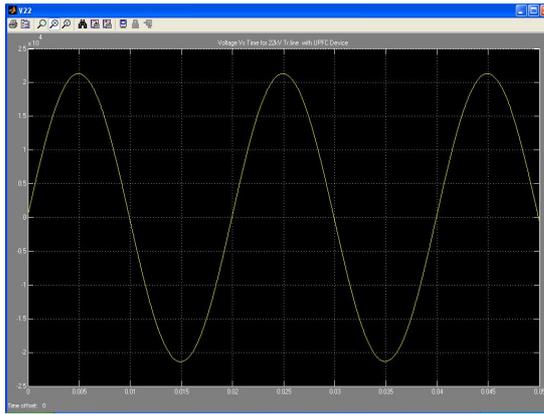**Fig.7. Simulink Model of 22k V Transmission Line.**
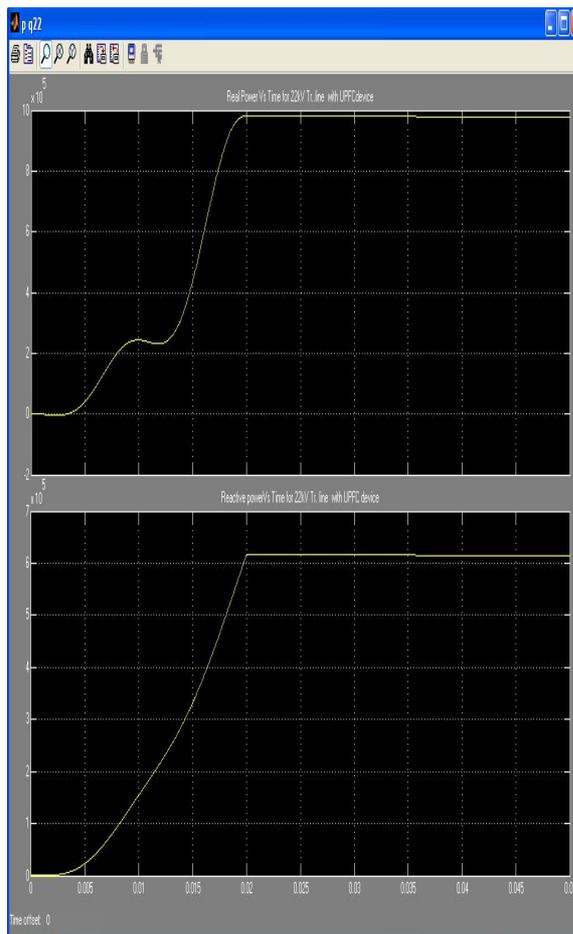
Fig.8. Voltage magnitude of 22 kV Transmission Line.

Fig.10. Simulink Model of 33 k V Transmission Line.

Fig.9. Real and Reactive power flows of 22 kV Line.

Fig.11 Voltage magnitude of 33 kV Transmission Line.

Fig.12 Real and Reactive power flows of 33 kV Line.

By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is 21.23kV, the real power is 98.15MW and the reactive power is 61.64 MVAr

B. Simulink model of 33kV Transmission Line

The simulation model of Single line Transmission system of 33kV, Line is shown in Fig 10. The model is simulated and corresponding results of voltage magnitude, real and reactive power flows in line are shown in Fig's 11 and 12 respectively.
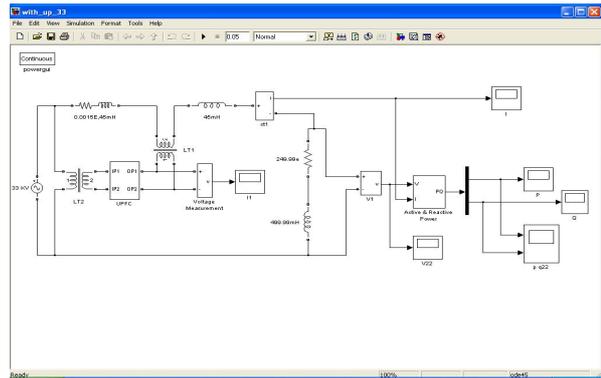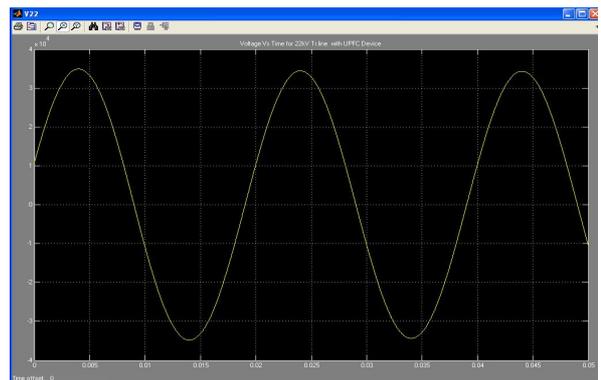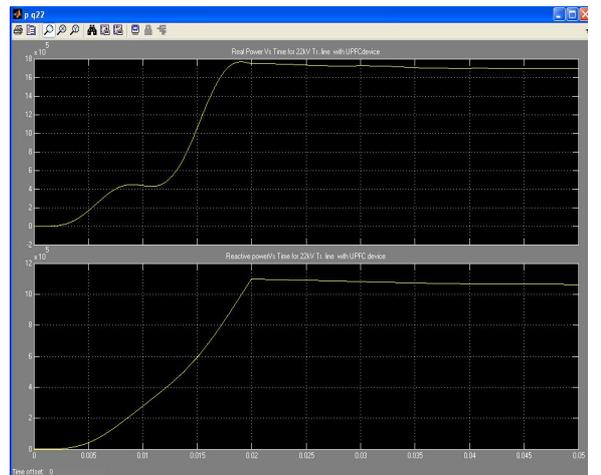
By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is32.5 kV, the real power is 1.77MW and the reactive power is 99.5 MVAr respectively.

Here, comparing Fig .2 with that of Fig. 8, we can observe that at the same steady state time the magnitude of peak voltage is improved from 20.04 kV to 21.23 kV and by comparing Fig.3 with that of Fig.9, we can observe that at the same steady state time the magnitude of real power is improved from 93.69MW to 98.15MW and the reactive power is improved from 57.53MVAr to 61.64MVAr for 22kV transmission line.

Similarly comparing Fig .5 with that of Fig. 11, we can observe that with the same steady state time the magnitude of peak voltage is improved from 31.04kV to 32.50kVand by comparing Fig.6 with that of Fig12, we can observe that with the same steady state time the magnitude of real power is improved from 1.77MW to 99.50MVAr. The Voltages, real power and the reactive powers with compensation have been improved when compared to normal circuit. The UPFC scheme provides a way to transfer real power between sensitive loads in individual line through the common dc link this compensates by improving the real power from the dc link.

Therefore when a fault occurs in the line, the UPFC in the line acts to compensate is by taking the real power from the common dc link. The initial drop is due to the sudden power change in line 22kV, and initially this power is supplied by 33kV line. It takes certain time to react to the power change. The real power needed by the 22kV feeder to compensate the voltage collapse is exactly equal to the real power delivered by the 33kV feeder. From the output waveforms, of all the voltage magnitudes and power flows are clearly observed that the magnitude of the maximum real power of 22 kV feeder is improved by controlling circuit by supplying the real power from 33kV feeder vice versa, which is practically possible, so the power flows and voltage profile has been improved. The summary of the results are tabulated in Table.1.

Table.1 Summary of 6.6kV and 22 kV lines with and Without UPFC as shown in table 4.1

Parameters	22kV Line		33kV Line	
	Without UPFC	With UPFC	Without UPFC	With UPFC
Voltage magnitude(kV)	20.04	21.23	31.08	32.25
Real Power (MW)	93.69	98.15	1.40	1.77
Reactive Power (MVAr)	57.53	61.64	88.50	99.50

V. CONCLUSIONS

In the simulation study, MATLAB/ SIMULINK model is used to simulate the model of rectifier and inverter based UPFC connected with transmission lines i.e. 22kV and 33kV. This work gives control and performance of the UPFC used for power quality improvement and to obtain the steady state time, objectives are achievable by control settings of the UPFC controllers. Simulation results show the effectiveness of UPFC to control the real and reactive powers as well as voltage magnitude. It is found that there is an improvement in the real power and reactive power and voltage magnitude through the transmission line when UPFC is introduced. The UPFC concept provides a powerful tool for the cost effective utilization of individual transmission lines by facilitating the independent control of both the real and reactive power flow. There is an improvement in both voltage and power profiles, through the transmission line when UPFC is incorporated in the system.

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 inline with the predictions.

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