SIMULATION OF UPFC AND IPFC USING MATLAB/ SIMULINK

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Abstract: *This paper proposes a new real and reactive power coordination controller for a unified power flow controller (UPFC). The basic control for the UPFC is such that the series converter of the UPFC controls the transmission line real/reactive power flow and the shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the DC link capacitor voltage. In steady state, the real power demand of the series converter is supplied by the shunt converter of the UPFC. A new reactive power coordination controller has been designed to limit excessive voltage excursions during reactive power transfers. The shunt converter of the UPFC +controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. Recent advances in high voltage IGCT technology allow for higher switching frequencies with lower losses. This allows for practical implementation of PWM control. The switching frequency for the converters has been chosen to be nine times the fundamental. Here we use matlab/simulink for the simulation purpose and outputs are verified in the scope.*

Index Terms: UPFC control, IPFC controller, Real power, Reactive power, Series converter, and Shunt converter.

1. INTRODUCTION

UPFC is the most comprehensive multivariable flexible ac transmission system (FACTS) controller. Simultaneous control of multiple power system variables with UPFC posses enormous difficulties. In addition, the complexity of the UPFC control increases due to the fact that the controlled and the control variables interact with each other. UPFC which consists of a series and a shunt converter connected by a common dc link capacitor can simultaneously perform the function of transmission line real/reactive power flow control in addition to UPFC bus voltage/shunt reactive power control [1]. The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter of the UPFC controls the transmission line real/reactive power flows by injecting a series voltage of adjustable magnitude and phase angle.

The interaction between the series injected voltage and the transmission line current leads to real and reactive power exchange between the series converter and the power system. Under steady state conditions, the real power demand of the series converter is supplied by the shunt converter. But during transient conditions, the series converter real power demand is supplied by the dc link capacitor. If the information regarding the series converter real demand is not conveyed to the shunt converter control system, it could lead to collapse of the dc link capacitor voltage and subsequent removal of UPFC from operation [1]. Very little or no attention has been given to the important aspect of coordination control between the series and the shunt converter control systems. The real power coordination discussed is based on the known fact that the shunt converter should provide the real power demand of the series converter.

In this case, the series converter provides the shunt converter control system an equivalent shunt converter real power reference that includes the error due to change in dc link capacitor voltage and the series converter real power demand. The control system designed for the shunt converter in causes excessive delay in relaying the series converter real power demand information to the shunt converter.

This could lead to improper coordination of the overall UPFC control system and subsequent collapse of dc link capacitor voltage under transient conditions. In this paper, a new real power coordination controller has been developed to avoid instability/excessive loss of dc link capacitor voltage during transient conditions. In contrast to real power coordination between the series and shunt converter control system, the control of transmission line reactive power flow leads to excessive voltage excursions of the UPFC bus voltage during reactive power transfers. This is due to the fact that any change in transmission line reactive power flow achieved by adjusting the magnitude/phase angle of the series injected voltage of the UPFC is actually supplied by the shunt converter.

2. UNIFIED POWER FLOW CONTROLLER (UPFC)

Gyugyi proposed the Unified Power Flow Controller (UPFC**)** concept in 1991. The UPFC was devised for the real time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the delivery industry. Within the framework of traditional power transmission concepts, the UPFC is able to control, simultaneously or selectively, all the parameters affecting power flow in the transmission line (i.e., voltage, impedance and phase angle), and this unique capability is signed by the adjective “unified” in its name. Alternatively, it can independently control both the real and reactive power flows in the line.

Circuit Arrangement:

In the presently used practical implementation, The UPFC consists of two switching converters, which in the implementations considered are voltage source inverters using gate turn-off (GTO) thyristor valves, as illustrated in the Fig 2.1. These back to back converters labeled "Inverter 1 and "Inverter 2" in the figure, are operated from a common dc link provided by a dc storage capacitor. This arrangement functions as an ac to ac power converter in which the real power can freely flow in either direction between the ac terminals of the two inverters and each inverter can independently generate (or absorb) reactive power at its own ac output terminal.

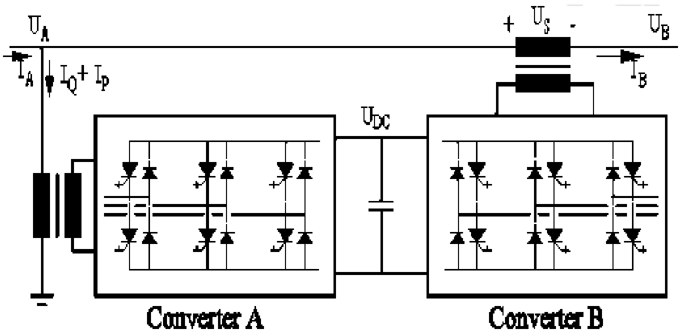


Fig.2.1. Basic circuit arrangement of unified power flow controller

3. Operation of UPFC

Inverter 2 provides the main function of the UPFC by injecting an ac voltage Vpq with controllable magnitude V_{pq} ($0 \leq V_{pq} \leq V_{pqmax}$) and phase angle $\rho(0 \leq \rho \leq 360)$, at the power frequency, in series with the line via an insertion transformer. The injected voltage is considered essentially as a synchronous voltage source. The transmission line current flows through this voltage source resulting in real and reactive power exchange between it and the ac system. The real power exchanged at the ac terminal [2] (i.e., at the terminal of insertion transformer) is converted by the inverter into dc power that appears at the dc link as positive or negative real power demanded. The reactive power exchanged at the ac terminal is generated internally by the inverter. The basic function of inverter 1 is to supply or absorb the real power demanded by Inverter 2 at the common dc link. This dc link power is converted back to ac and coupled to the transmission line via a shunt-connected transformer. Inverter 1 can also generate or absorb controllable reactive power, if it is desired, and there by it can provide independent shunt reactive compensation for the line. It is important to note that where as there is a closed "direct" path for the real power negotiated by the action of series voltage injection through Inverters 1 and 2 back to the line[2], the corresponding reactive power exchanged is supplied or absorbed locally by inverter 2 and therefore it does not flow through the line.

Thus, Inverter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by the Inverter 2. This means there is no continuous reactive power flow through UPFC.

Basic Control Functions

Operation of the UPFC from the standpoint of conventional power transmission based on reactive shunt compensation, series compensation, and phase shifting, the UPFC can fulfill these functions and thereby meet multiple control objectives by adding the injected voltage V_{pq}, with appropriate amplitude.

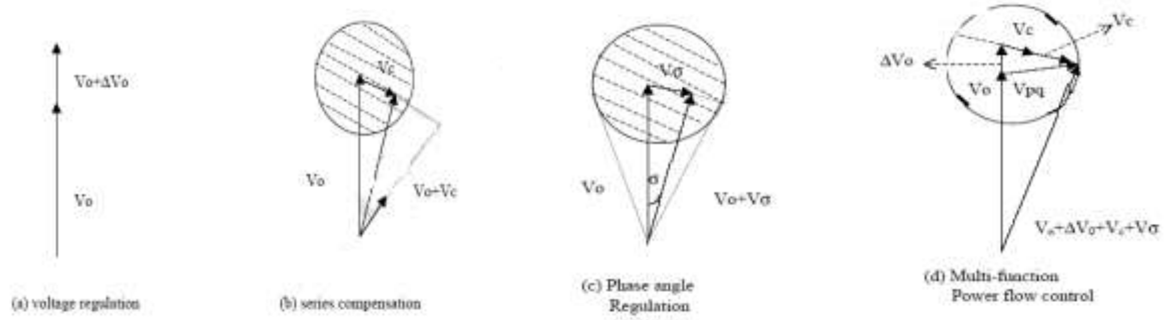


Fig. 2.2. Basic UPFC control functions : (a) Voltage regulation, Fig. 2.3.- (b) series compensation , Fig. 2.4.- (c) Angle regulation, Fig. 2.5.- (d) multifunction power

Terminal Voltage Regulation, similar to that obtainable with a transformer tap-changer having infinitely small steps, as shown at (a) where $V_{pq}=\Delta V$ (boldface letters represent phasors) is injected in-phase (or anti-phase) with V_o.

Series capacitor compensation is shown at (b) where $V_{pq}=V_c$ is in quadrature with the line current I.

Transmission angle Regulation (phase shifting) is shown at (c) where $V_{pq}=V_o$ is injected with angular relationship with respect to V_o that achieves the desired s phase shift (advance or retard) without any change in magnitude.

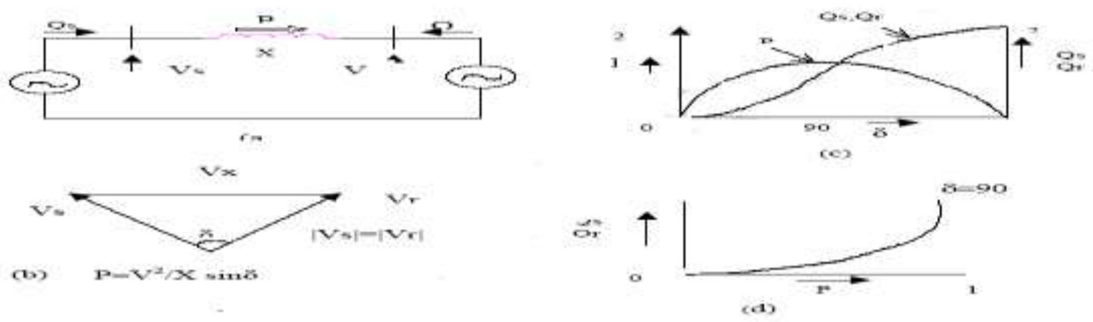


Fig. 2.6.- simple two machine system (a), Fig. 2.7.- related voltage phasors (b), Fig. 2.8.- real and reactive power verses transmission angle (c), Fig. 2.9.- series sending-end/ receving-end reactive power verses transmitted real power(d).

Basic power system of fig with the well known transmission characteristics is introduced for the purpose of providing a vehicle to establish the capability of the UPFC to control the transmitted real power P and the reactive power demands, Q_s and Q_r, at the sending end, respectively, the receiving end of the line.

4. MODELLING OF CASE STUDY

4.1 CONTROL STRATEGY FOR UPFC

Shunt Converter Control Strategy

The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. In this case, the shunt converter voltage is decomposed into two components. One component is in-phase and the other in quadrature with the UPFC bus voltage. De-coupled control system has been employed to achieve simultaneous control of the UPFC [3] bus voltage and the dc link capacitor voltage.

Series Converter Control Strategy

The series converter of the UPFC provides simultaneous control of real and reactive power flow in the transmission line. To do so, the series converter injected voltage is decomposed into two components. One component of the series injected voltage is in quadrature and the other in-phase with the UPFC bus voltage. The quadrature injected component controls the transmission line real power flow. This strategy is similar to that of a phase shifter. The in-phase component controls the transmission line reactive power flow. This strategy is similar to that of a tap changer.

5. BASIC CONTROL SYSTEM

5.1 Shunt Converter Control System

Fig.1 shows the de-coupled control system for the shunt converter. The D-axis control system controls the dc link capacitor voltage and the Q-axis control system controls the UPFC bus [4] voltage /shunt reactive power. The details of the de-coupled control system design can be found .The de-coupled control system has been designed based on linear control system techniques and it consists of an outer loop control system that sets the reference for the inner control system loop. The inner control system loop tracks the reference.

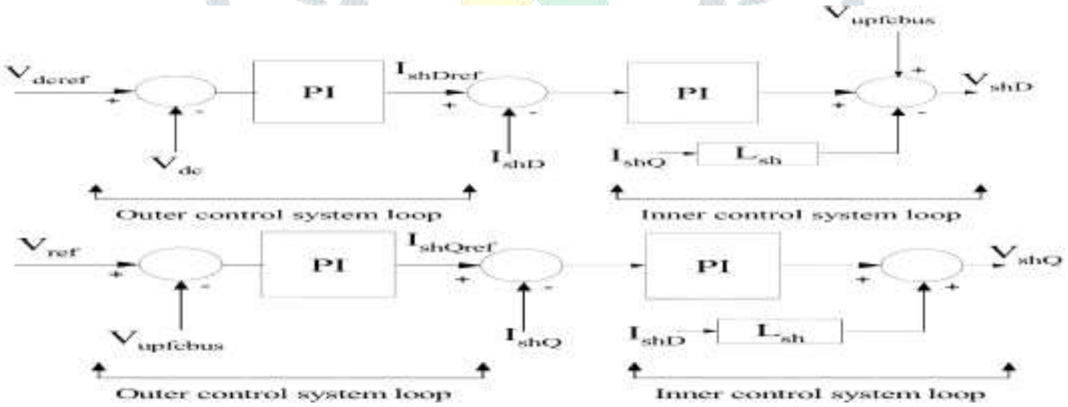


Fig. 5.1.- De-coupled D-Q axis shunt converter control system.

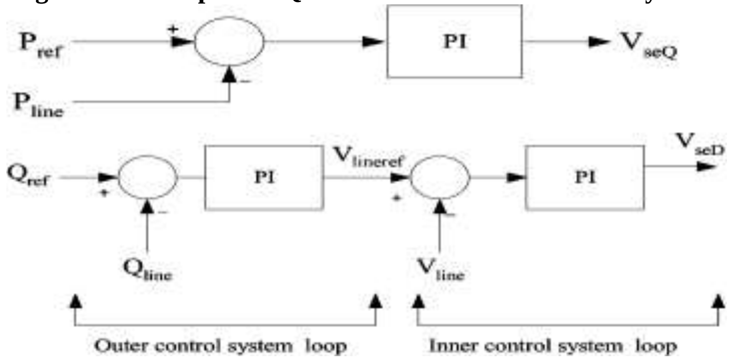


Fig. 5.2.- Series converter real and reactive power flow control system.

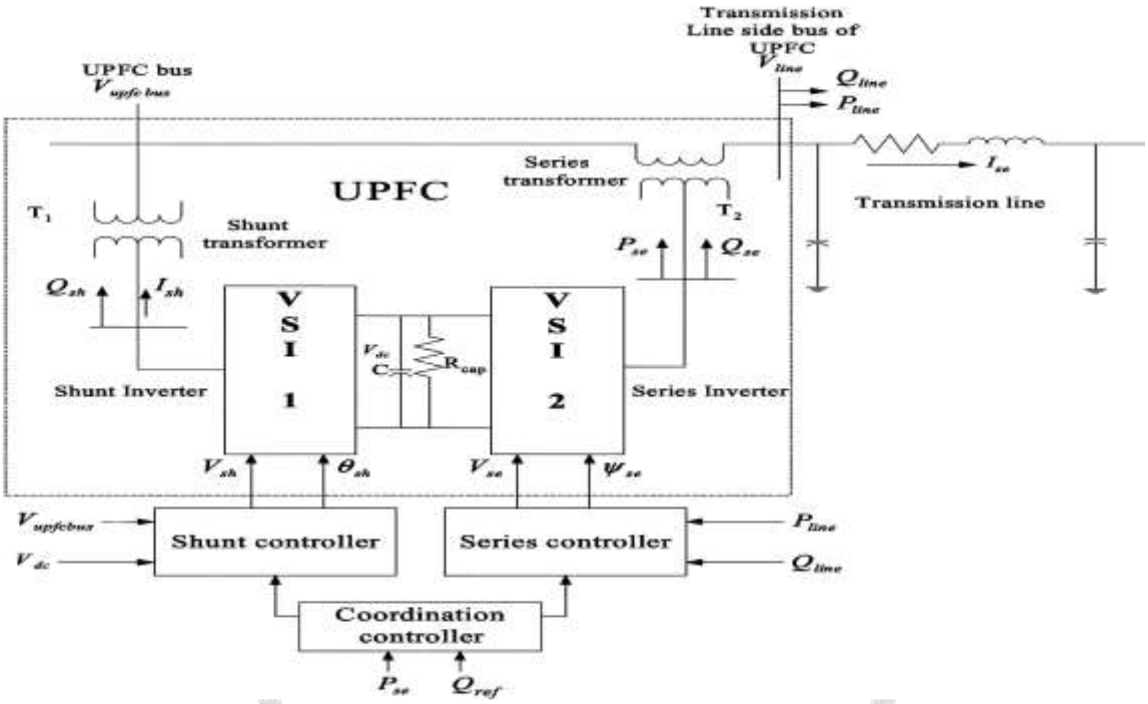


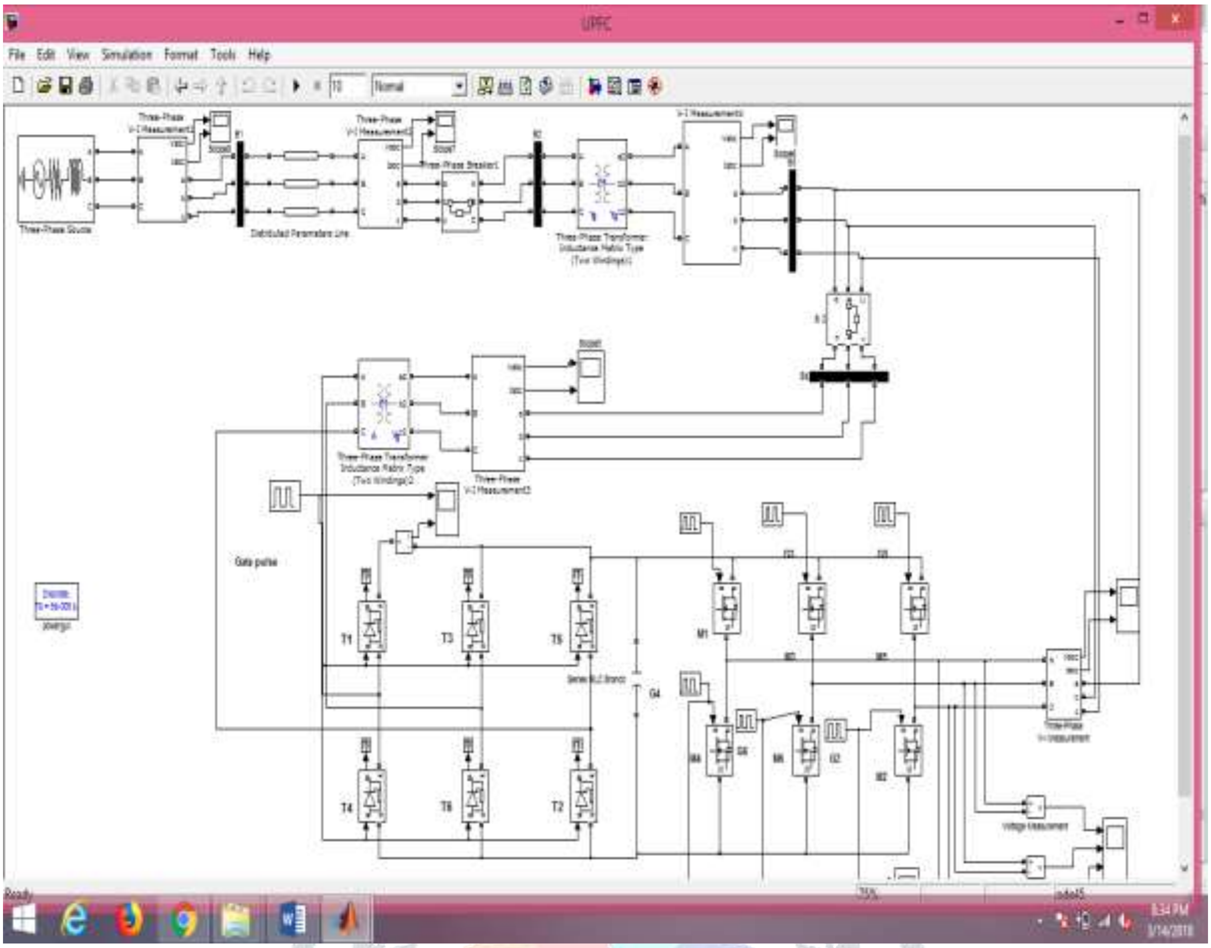
Fig. 5.3.- UPFC connected to a transmission line.

Series Converter Control System

Fig.5.3 shows the overall series converter control system. The transmission line real power flow is controlled by injecting a component of the series voltage in quadrature with the UPFC bus voltage. The transmission line reactive power is controlled by modulating the transmission line side bus voltage reference . The transmission line side bus voltage is controlled by injecting a component of the series voltage in-phase with the UPFC bus voltage.

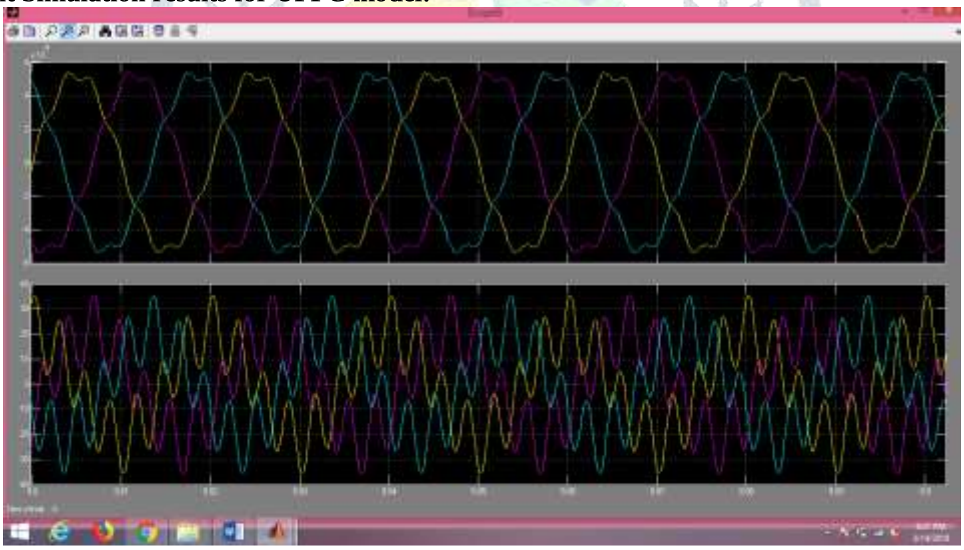
6. MATLAB DESIGN OF CASE STUDY AND RESULTS

UPFC MODEL:



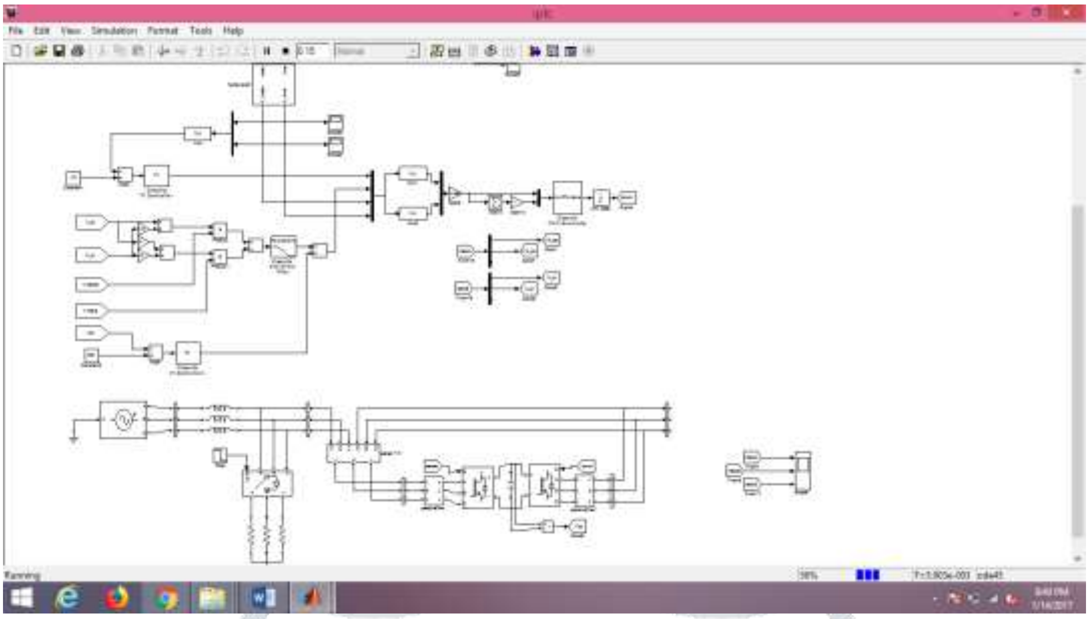
Designing Modeling of UPFC

Voltage and current Simulation results for UPFC model:



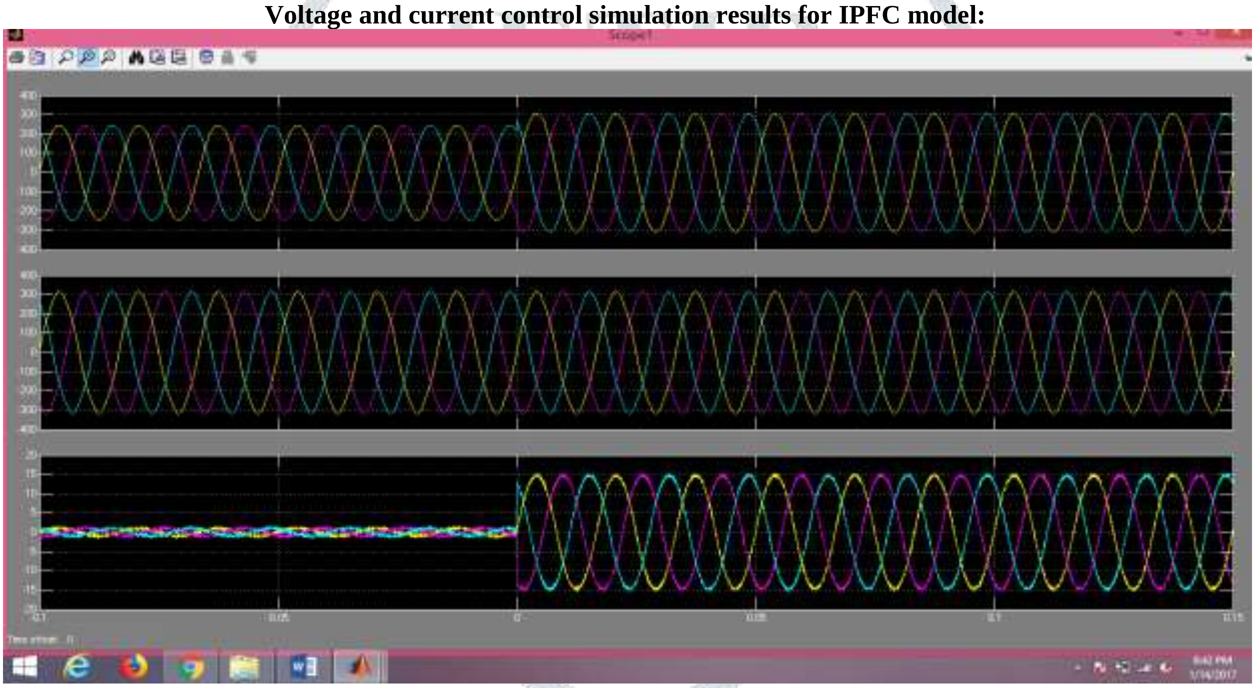
Simulation Results of UPFC

IPFC MODEL :



Designing Modeling of IPFC

Voltage and current control simulation results for IPFC model:



Simulation Results of IPFC

7. CONCLUSION

This paper has presented a new real and reactive power coordination controller for a UPFC. The basic control strategy is such that the shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter controls the transmission line real and reactive power flow. The contributions of this work can be summarized as follows.

Inclusion of the real power coordination controller in the UPFC control system avoids excessive dc link capacitor voltage excursions and improves its recovery during transient conditions. MATLAB simulations have been conducted to verify the improvement in dc link voltage excursions during transient conditions.

Significantly reducing UPFC bus voltage excursions during reactive power transfers. The effect on transmission line reactive power flow is minimal. MATLAB simulations have shown the improvement in power oscillation damping with UPFC.

8. REFERENCES

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