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Simulation and Implementation of UPFC System

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ABSTRACT: The UPFC is a versatile FACTS controller, which can be used to control the active and reactive power in the line independently. 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 shunt converter of the UPFC supplies the real power demand of the series converter. To avoid instability/loss of DC link capacitor voltage during transient conditions, a new real power coordination controller has been designed. The need for reactive power coordination controller for UPFC arises from the fact that excessive bus voltage excursions occur during reactive power transfers.

KEYWORDS: FACTS, unified power flow controller (UPFC), Coordination controller

I. INTRODUCTION

In the evolving utility environment, financial and market forces are continue to, demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution. Now, more than ever, advanced technologies are paramount for the reliable and secure operation of power systems. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilization and control of the existing transmission system infrastructure is required. Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment, or Flexible AC Transmission Systems (FACTS), provide proven technical solutions. The need for reactive power coordination controller for UPFC arises from the fact that excessive bus voltage excursions occur during reactive power transfers. This project proposes a new real and reactive power coordination controller for a unified power flow controller (UPFC). [2]-[5] 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 [1].

FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines. Traditional solutions to upgrading the electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, as experiences have proven over the past decade or more, the process to permit, site, and construct new transmission lines has become extremely difficult, expensive, time-consuming, and controversial. FACTS technologies provide advanced solutions as cost-effective alternatives to new transmission line construction.

II. CONTROL STRATEGY FOR UPFC PERFORMANCE

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 bus voltage and the dc link capacitor voltage. [4], [5]

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.

III. REAL AND REACTIVE POWER COORDINATION CONTROLLER

Real Power Coordination Controller

To understand the design of a real power coordination controller for a UPFC, consider a UPFC connected to a transmission line as shown in Fig1. The interaction between the series injected voltage (Vse) and the transmission line current (Ise) leads to exchange of real power between the series converter and the transmission line. The real power (Pse) demand of the series converter (Pse) causes the dc link capacitor voltage (Vdc) to either increase or decrease depending on the direction of the real power flow from the series converter. This decrease/increase in dc link capacitor voltage (Vdc) is sensed by the shunt converter controller that controls the dc link capacitor voltage (Vdc) and acts to increase/decrease the shunt converter real power flow to bring the dc link capacitor voltage (Vdc) back to its scheduled value.

To provide for proper coordination between the shunt and the series converter control system, a feedback from the series converter is provided to the shunt converter control system. The feedback signal used is the real power demand of the series converter (Pse). The real power demand of the series converter (Pse) is converted into an equivalent D-axis current for the shunt converter (idse). By doing so, the shunt converter responds immediately to a change in its D-axis current and supplies the necessary series converter real power demand. The equivalent D-axis current (idse) is an additional input to the D-axis shunt converter control system. Equation (1) shows the relationship between the series converter real power demand (Pse) and the shunt converter D-axis current (idse)

$$\text{idse} = \text{Pse} \,/\, \left| V_{upfc}\ bus \right| \qquad \text{--- [1]}$$

Reactive Power Coordination Controller

The in-phase component (Vsed) of the series injected voltage which has the same phase as that of the UPFC bus voltage, has considerable effect on the transmission line reactive power (Qline) and the shunt converter reactive power (Qsh). Any increase/decrease in the transmission line reactive power (Qline) due to in-phase component (Vsed) of the series injected voltage causes an equal increase/decrease in the shunt converter reactive power (Qsh) [6]. Increase/decrease in the transmission line reactive power also has considerable effect on the UPFC bus voltage. Increase in transmission line reactive power reference causes a decrease in UPFC bus voltage. Decrease in UPFC bus voltage is sensed by the shunt converter UPFC bus voltage controller which causes the shunt converter to increase its reactive power output to boost the voltage to its reference value.

The increase in shunt converter reactive power output is exactly equal to the increase requested by the transmission line reactive power flow controller (neglecting the series transformer reactive power loss). Similarly, for a decrease in transmission line reactive power, the UPFC bus voltage increases momentarily. The increase in UPFC bus voltage causes the shunt converter to consume reactive power and bring the UPFC bus voltage back to its reference value. The decrease in the shunt converter reactive power is exactly equal to the decrease in transmission line reactive power flow (neglecting the reactive power absorbed by the series transformer). In this process, the UPFC bus voltage experiences excessive voltage excursions. To reduce the UPFC bus voltage excursions, a reactive power flow coordination controller has been designed. The input to the reactive power coordination controller is the transmission line reactive power reference. [6]

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IV. BASIC CONTROL SYSTEM

UPFC which consists of series and shunt converter connected by a common dc link capacitor. 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. No attention has been given to the important aspect of coordination control between the series and the shunt converter control systems.

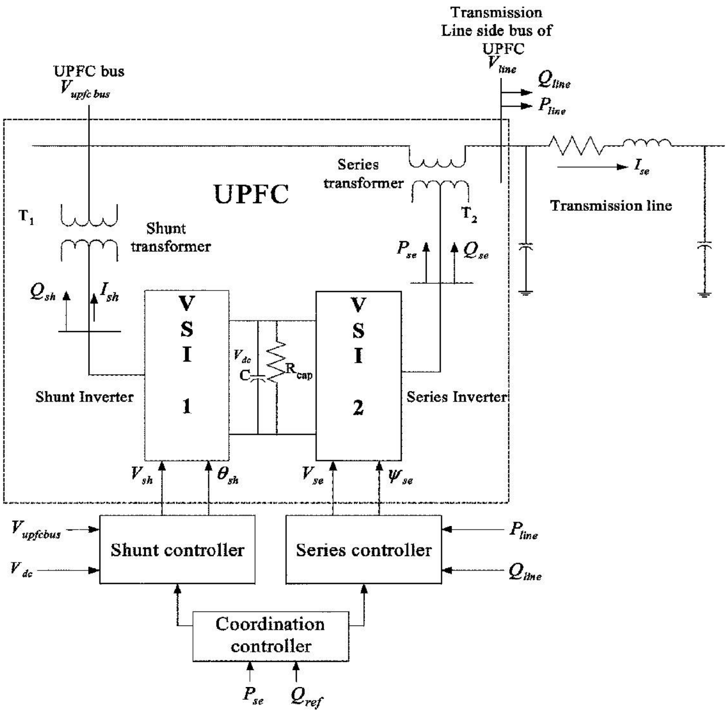

Fig.1 UPFC connected to a transmission line.

The real power coordination discussed in this project 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 it cause an excessive delay in relaying the series converter real power demand information to the shunt converter. [3]

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 project, 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. A new reactive power coordination controller between the series and the shunt converter control system has been designed to reduce UPFC bus voltage excursions during reactive power transfers. [2]- [5]

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V. SIMULATION RESULTS

The simulation is done using MATLAB. The results of the MATLAB simulation with real and reactive power coordination controllers are found. Also the performances are evaluated using six bus system. By varying the rectifier angle the real and reactive power of the transmission line are controlled and their performance are described using MATLAB simulation. The variations in the real and reactive power by varying the rectifier angle are also tabulated and are as follows.

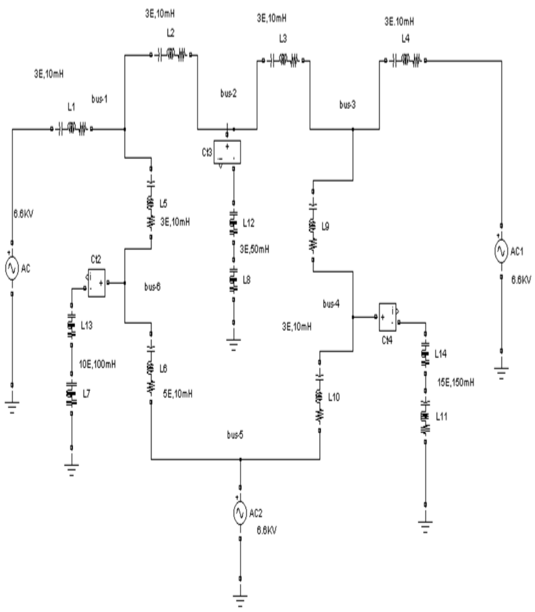

Fig.2 Six bus system without compensator

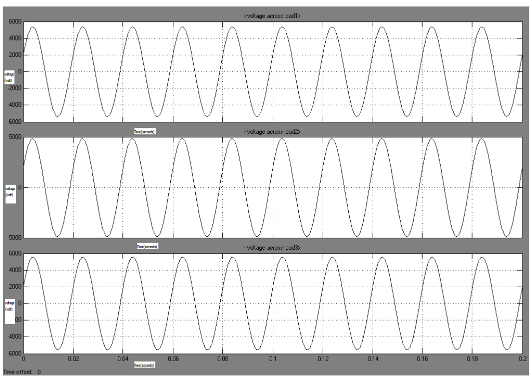

Fig.3 VOLTAGE ACROSS LOAD1, LOAD2, LOAD3.

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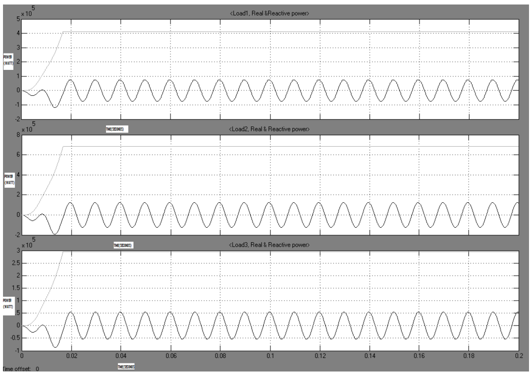

Fig.4 REAL AND REACTIVE POWER AT ALPHA=0 DEG.

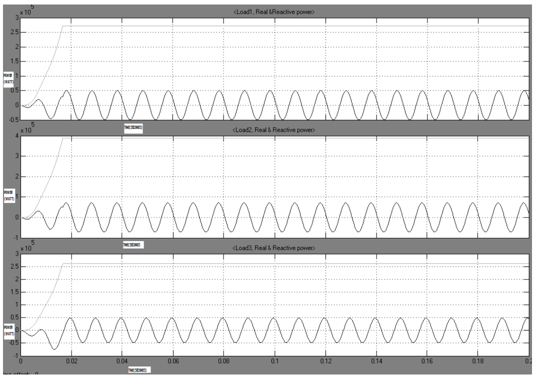

Fig.5REAL AND REACTIVE POWER AT ALPHA=90 DEG**.**

TABLE.1 VOLTAGE AND POWER ACROSS VARIOUS LOADS.

Loads	Firing angle (Degrees)	Voltage (volts)	Real power (KW)	Reactive power (KVAR)
Load 1	0	2000	73.63	412.2
	90	3262	20.2	272.7
Load 2	0	1933	120.2	681.9
	90	2910	20.01	389.2
Load 3	0	1886	53.46	295.1
	90	2063	46.02	260.8

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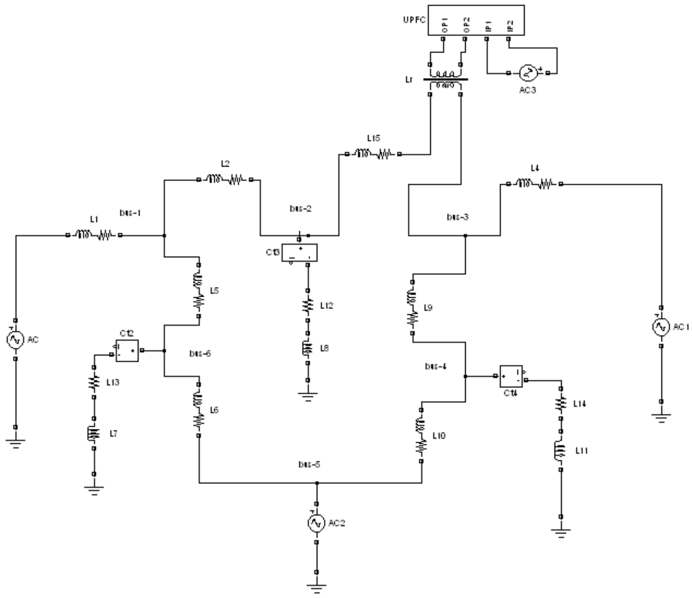

Fig.6 SIX BUS SYSTEMS WITH UPFC COMPENSATION MODEL:

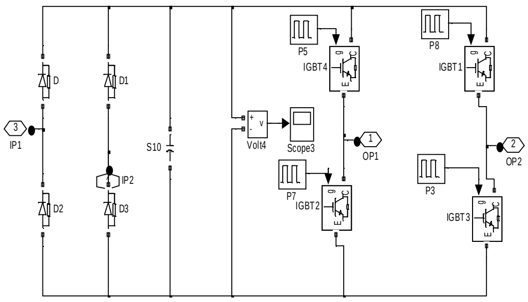

Fig.7 CIRCUIT MODEL WITH UPFC

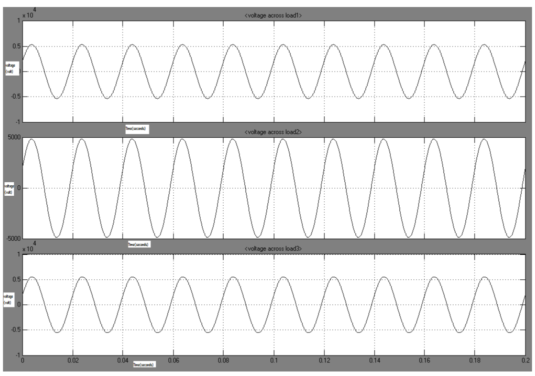

Fig.8 VOLTAGE ACROSS LOAD1, LOAD2, LOAD3.

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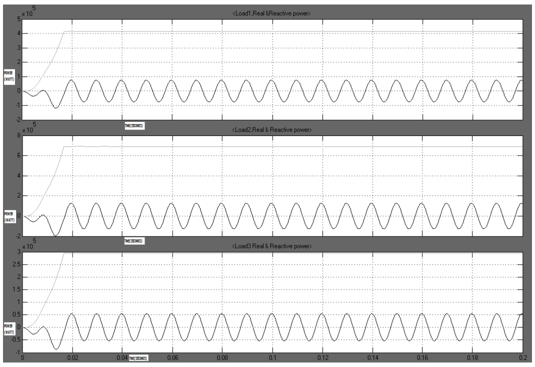

Fig.9 REAL & REACTIVE POWER AT ALPHA=0 DEGREES

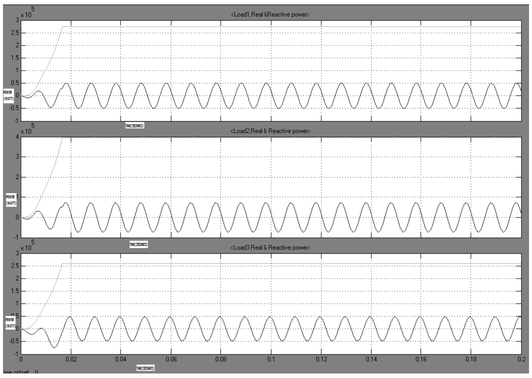

Fig.10 REAL & REACTIVE POWER AT ALPHA =90 DEG

TABLE.2 VOLTAGE AND POWER ACROSS VARIOUS LOADS.

Loads	Firing angle (Degrees)	Voltage (volts)	Real power (KW)	Reactive power (KVAR)
Load 1	0	1998	73.86	413
	90	3259	20.33	273.4
Load 2	0	1923	122.1	690
	90	2900	20.92	394.5
Load 3	0	1890	53.26	294.3
	90	2067	45.84	260

VI. CONCLUSION

In this paper, the performance of UPFC connected to a transmission line has been designed and evaluated. This paper also describes the control strategy for real and reactive power of the transmission line using UPFC. For the study of controllers, simulation using MATLAB and the hardware implementation of the controller were performed. The results of the simulation clearly indicate that Unified Power Flow Controllers are effective to enhance the security, capacity and flexibility of power transmission systems.

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