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ANALYSIS OF REAL AND REACTIVE POWER CO-ORDINATION FOR UPFC USING FLC

Mr.Saleem Pasha[1], Dr. G. Tulasi Ram Das[2]

[1]Associate Professor, EEE Dept, BVRIT,Narsapur,Telangana, (India)

[2]Professor & Vice Chancellor, JNTU, Kakinada, (India)

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. 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 (the bus to which the shunt converter is connected) excursions occur during reactive power transfers. A new reactive power coordination controller has been designed to limit excessive voltage excursions during reactive power transfers. MATLAB-SIMULINK simulation results have been presented to show the improvement in the performance of the UPFC control by fuzzy logic controller with the proposed real power and reactive power coordination controller.

Index Terms: **FACTS, Unified Power Flow Controller (UPFC), Coordination Controller, FLC Controller.**

I. INTRODUCTION OF UPFC

In a competitive electricity market, installation of the Unified Power Flow Controller (UPFC) can improve power transfer capability and help market participants keep their schedules very close to preferred ones and at the same time may retain the competitive behavior of participants. Putting the UPFC in service may assist system to operate within its physical limits and reduce total generation cost associated with out-of-merit order caused by constrained transmission. However, a competitive electricity market necessitates a reliable method to allocate congestion charges, transmission usage, and transmission pricing in an unbiased, open-accessed, basis. Therefore, it is usually necessary to trace contribution of each participant to line usage and congestion charges, and then to calculate charges based on these contributions. It has been a common practice to use distribution factors to calculate these contributions [5].

The present Paper derives relationships to model impact of UPFC on line flows and transmission usage where we present modified admittances and distribution factors that model impact of utilizing UPFC on line flows and system usage. The relationships derived show how bus voltage angles are attributed to each of changes in generation, injections of UPFC, and changes in admittance matrix caused by inserting UPFC in transmission lines. The relationships derived can be adopted for the purpose of allocating usage and payments to users of transmission network and owners of control devices used in the network. The relationships derived are applied to test systems, where the results illustrate how transmission usage is affected when UPFC is utilized [4].

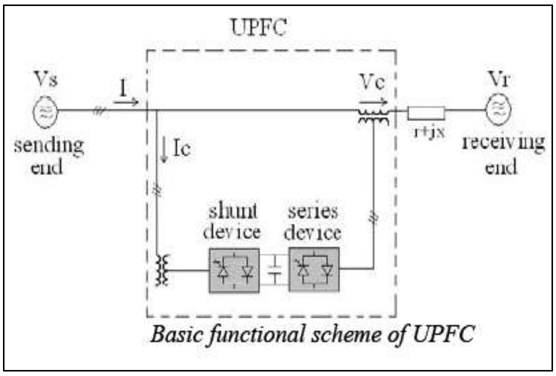


Figure 1: Basic Functional Scheme of UPFC

The series power converter works to obtain a constant balanced sinusoidal load voltage. The shunt converter regulates the DC link voltage and compensates for the reactive current of the source within the rated current of the converter. To design the required capacity for the series-shunt power converter, the relation between the converter capacity and the load power factor at constant compensation voltage is introduced. The required capacity of the series-shunt power converter is reduced by more than 50% compared with that of a conventional series power converter. The effectiveness of the proposed load voltage compensation technique using the series-shunt power converter [6].

The IEEE 39 bus system which contain total 10 generator bus and remaining load bus , a load flow analysis is carried out and found bus no 26 & 39 are weak, voltage less tan one per unit at these bus.

A UPFC is connected between 26 & 39 bus with two different controller PI and fuzzy and are presented.

II. TUNING OF PI CONTROLLER

A PI controller responds to an error signal in a closed control loop and attempts to adjust the controlled quantity to achieve the desired system response. The controlled parameter can be any measurable system quantity such as speed, torque, or flux. The benefit of the PI controller is that it can be adjusted empirically by adjusting one or more gain values and observing the change in system response.

Tuning of PI Controllers

Proportional-integral (PI) controllers have been introduced in process control industries. Hence various techniques using PI controllers to achieve certain performance index for system response are presented. The technique to be adapted for determining the proportional integral constants of the controller, called *Tuning*, depends upon the dynamic response of the plant.

This error is manipulated by the controller (PI) to produce a command signal for the plant according to the relationship.

$$U(s) = K_p (1+1/ \tau_i s)$$

Or in time domain $U(t) = K_p [e(t) + (1/\tau_i) \int edt]$

Where K_p = proportional gain

τ_i = integral time constant

II. FUZZY LOGIC CONTROLLER

The FIS (Fuzzy inference system) structure in the MATLAB is designed, that contains all the fuzzy inference system information. This structure is stored inside each GUI tool. Access functions such as getfis and setfis make it easy to examine this structure[3].

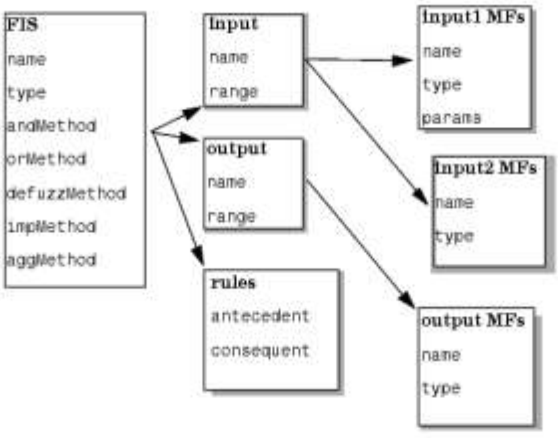


Figure 2: Fuzzy Interface System

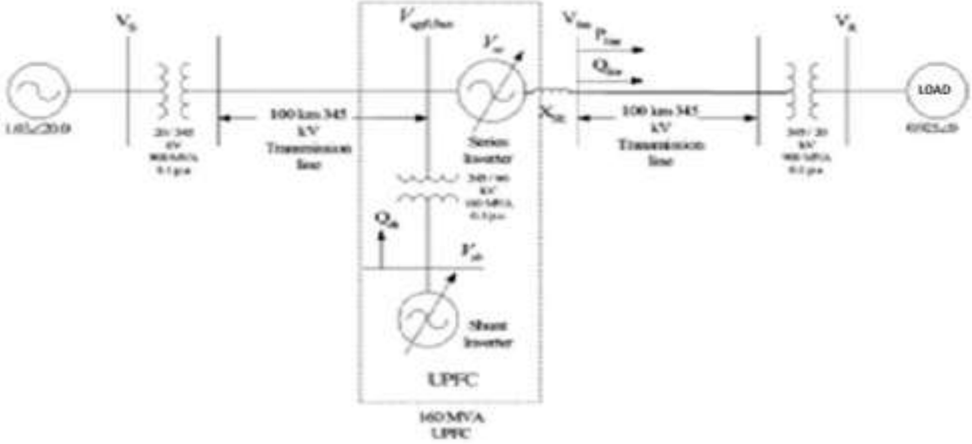
Advantages of the Sugeno Method

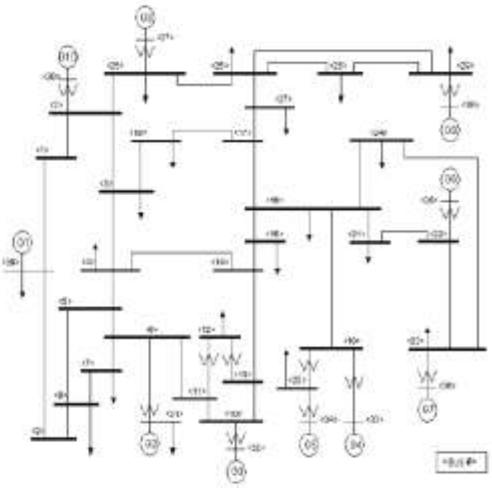
- It is computationally efficient.
- It works well with linear techniques (e.g., PID control).
- It works well with optimization and adaptive techniques.
- It has guaranteed continuity of the output surface.
- It is well-suited to mathematical analysis [2].

Advantages of the Mamdani Method

- It is intuitive.
- It has widespread acceptance.
- It is well suited to human input.

III. SIMULATION MODEL AND ITS SUBSYSTEMS





IEEE 39 BUS SYSTEM UPFC IS CONNECTED BETWEEN 26 & 39 BUS

Figure 3: UPFC connected in power system

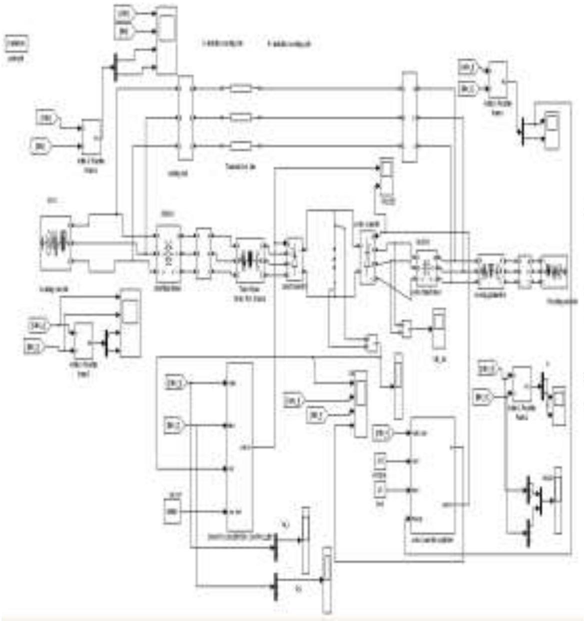


Figure 4: Simulation of PI controller

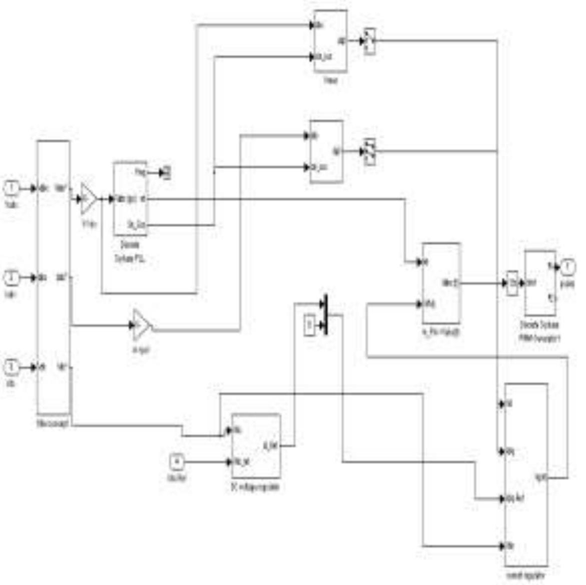


Figure 5: Shunt converter controller using PI

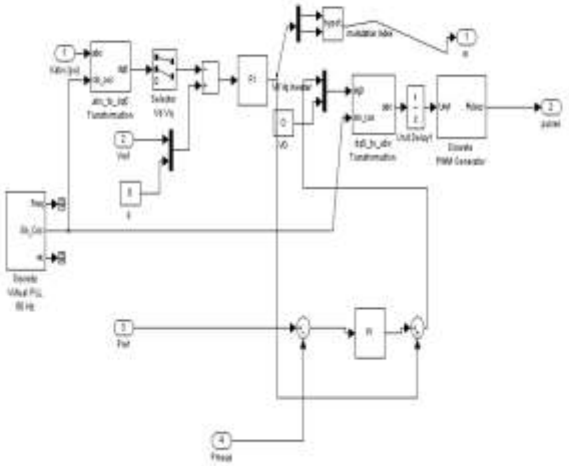


Figure 6: Series converter controller using PI

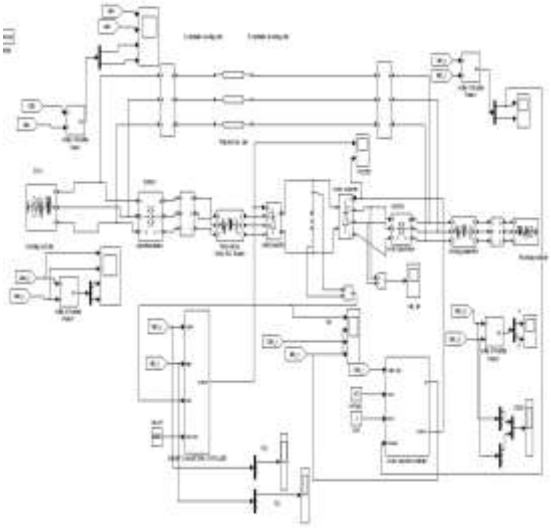


Figure 7: Simulation of Fuzzy Model

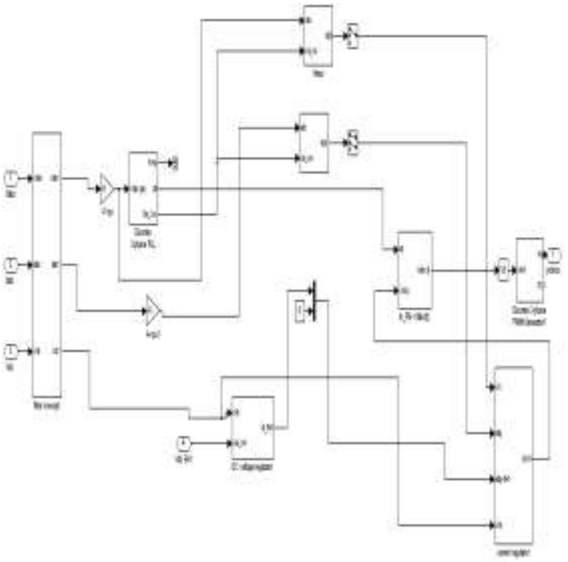


Figure 8: Shunt Converter Controller for Fuzzy

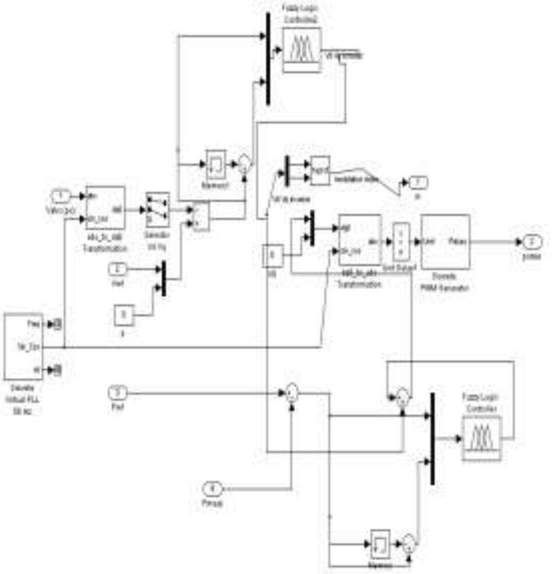


Figure 9: Series Converter Controller for Fuzzy

IV. SIMULATION RESULTS

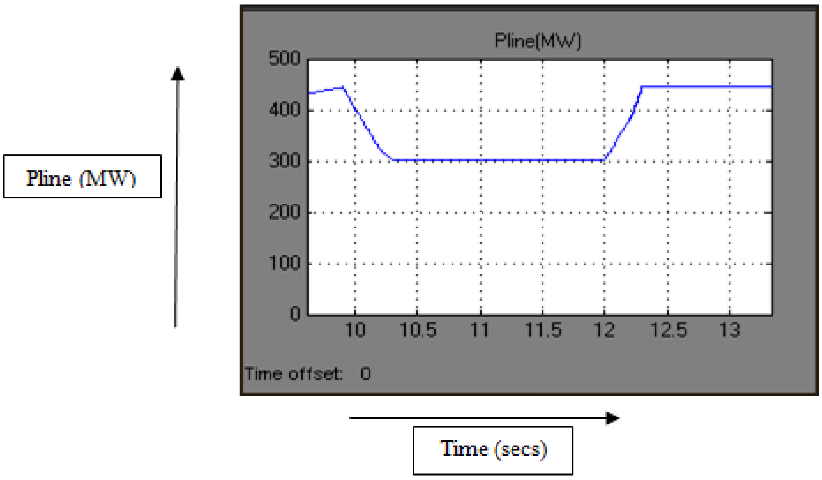


Figure 10: Response of power system to step changes in transmission line real power reference.

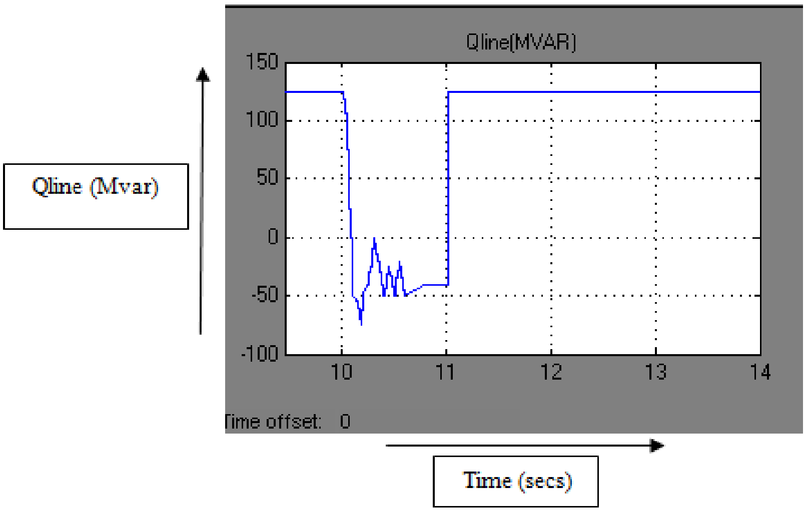


Figure 11: Response of step change in reactive power reference

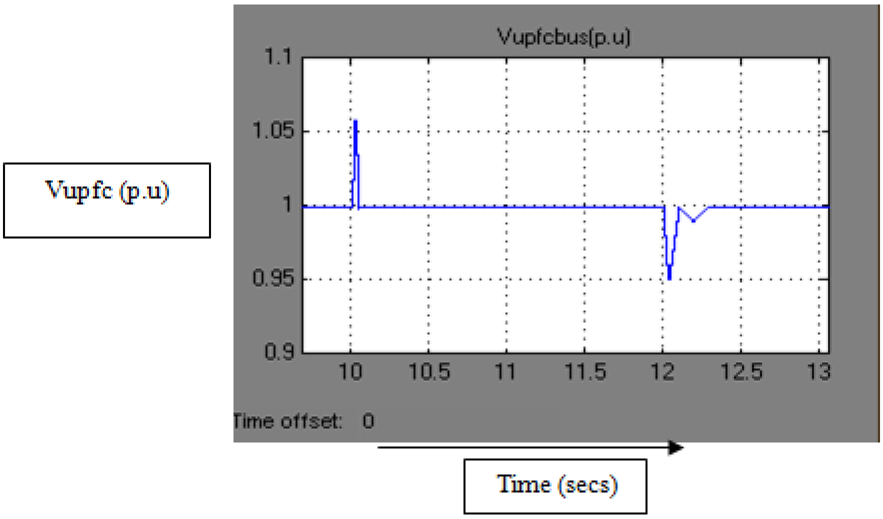


Figure 12: Response of UPFC bus voltage WITHOUT COORDINATION

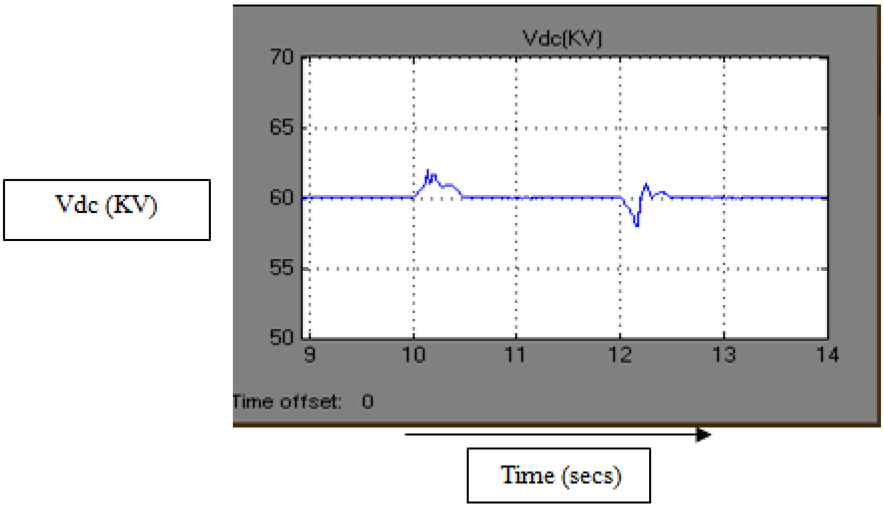


Figure 13: Response of dc link voltage WITH OUT COORDINATION

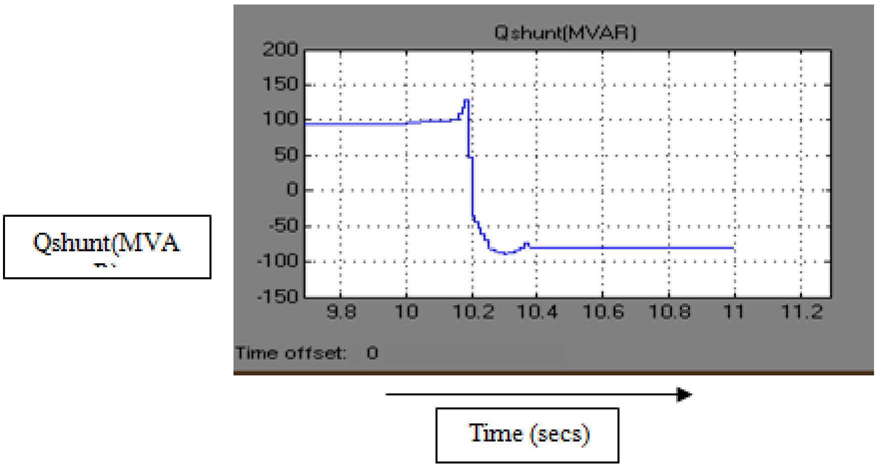


Figure 14: Response of Shunt Reactive Power

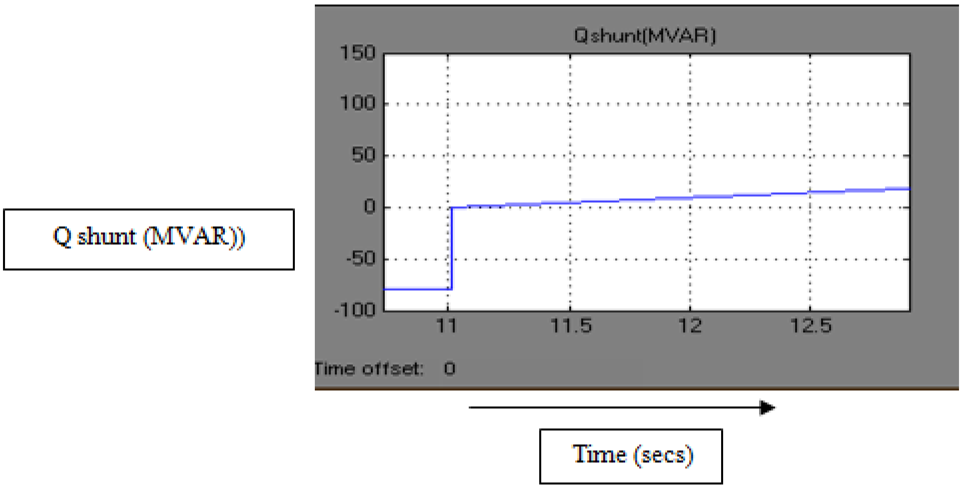


Figure 15: Response of Shunt reactive power

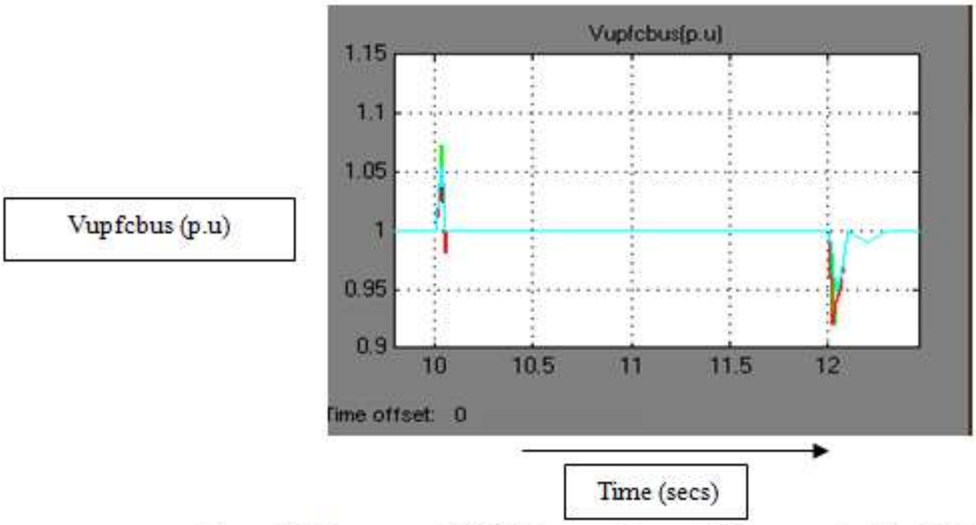


Figure 16: Response of UPFC bus voltage with fuzzy controller & PI Controller

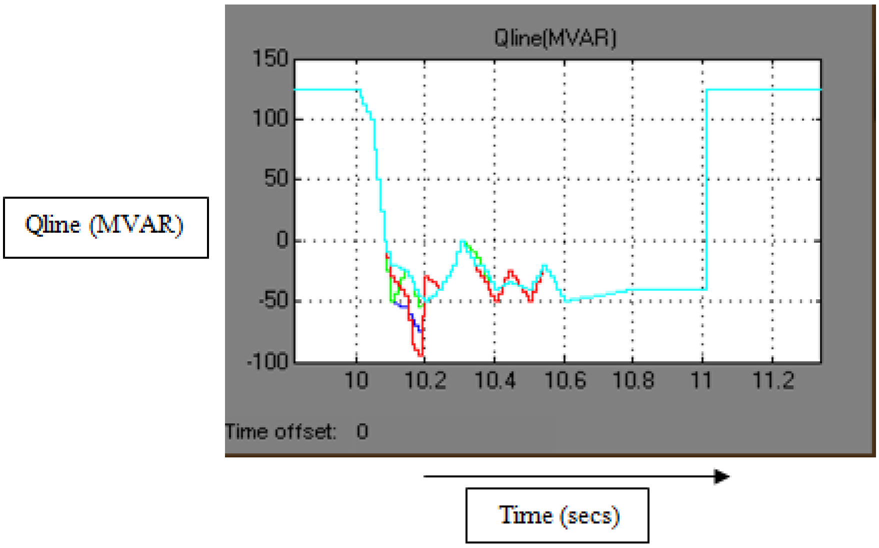


Figure 17: Impact of reactive power coordinate controller with fuzzy (BLUE) &PI (RED)

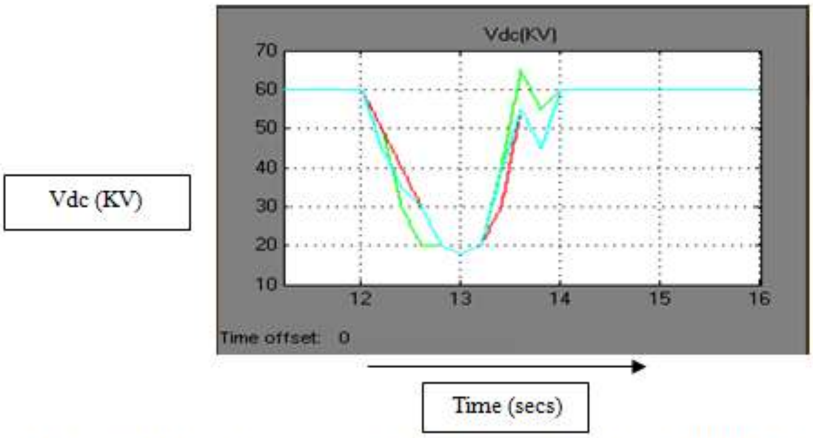


Figure 18: Response of dc link voltage with real power coordinate Fuzzy (BLUE) controller& PI (RED), Without Coorddinate controller (GREEN)

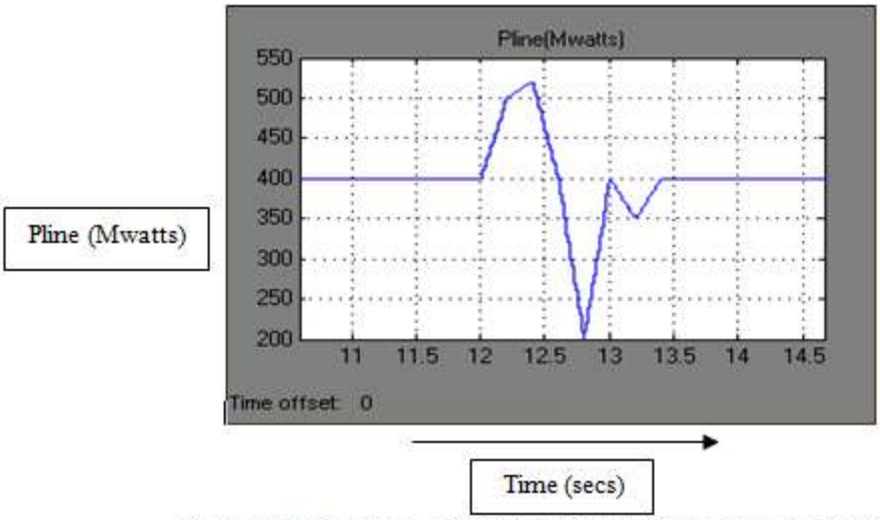


Figure 19: Response of power system to three phase fault with UPFC

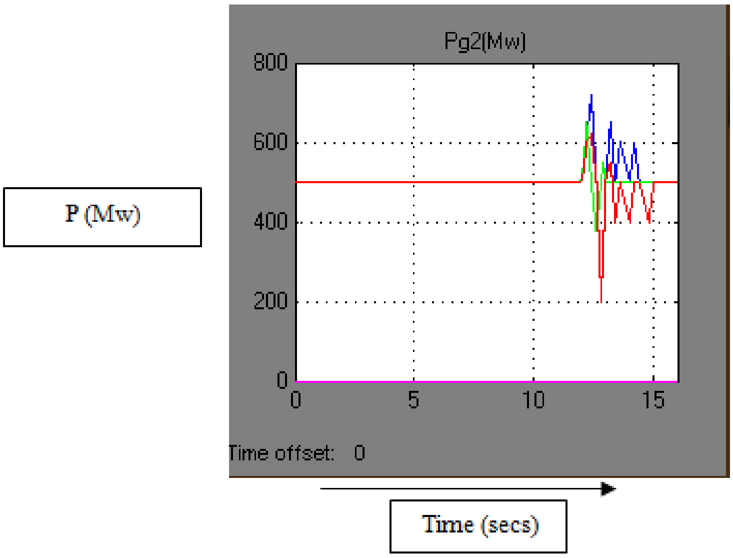


Figure 20: Electrical power without UPFC (BLUE), with UPFC PI (GREEN) and FLC controller (RED)

V. RESULTS AND DISCUSSION

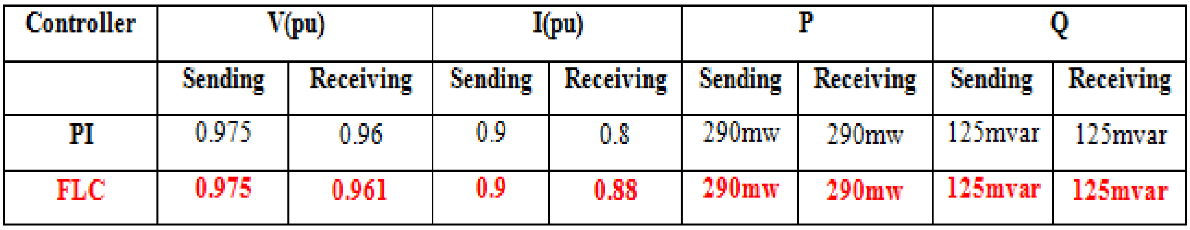
5.1 Performance of Reactive Power Coordination Fuzzy Controller

UPFC is connected between 26 and 39 bus of IEEE 39 bus system in a 200km 345 transmission line and specification (Appendix). Initial real power and reactive power (line) in the transmission line is 290MW &125MVAR respectively & shunt reactive power is 80MVAR. When a step change in transmission line reactive power reference Decreases/Increases at 10sec there is a equal amount of Decreases/Increases of shunt reactive power is observed as shown in figure 12, 15, 16. With out reactive power coordination.

With reactive power coordination fuzzy controller, the UPFC bus voltage Rise is reduced from 1.06 pu to 1.05pu as shown in fig 17 and also the line reactive power settling time is reduced as shown in fig 18.

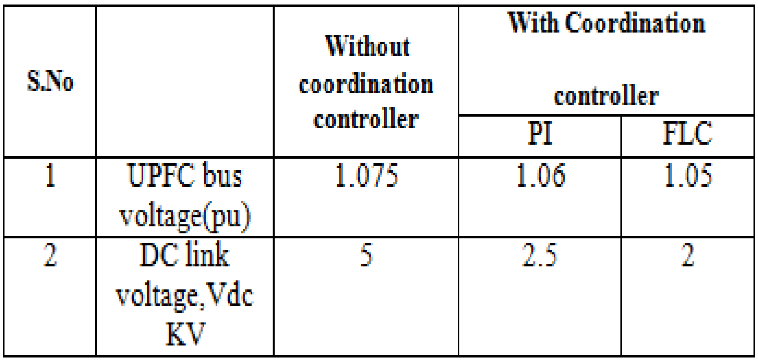
5.2 Performance of Real Power Coordination Fuzzy Controller

At 12 sec three phase fault is applied with real power fuzzy coordination controller the excessive dc link voltage is reduced from 2.5 to 2 kv as sown in fig 18. and recovery time is improved as shown in figure 19, and also the electrical power is very much stable as shown in fig 20.



Controller	V(pu)		I(pu)		P		Q	
	Sending	Receiving	Sending	Receiving	Sending	Receiving	Sending	Receiving
PI	0.975	0.96	0.9	0.8	290mw	290mw	125mvar	125mvar
FLC	0.975	0.961	0.9	0.88	290mw	290mw	125mvar	125mvar

Table 1: REAL AND REACTIVE POWER COORDINATION CONTROLLER

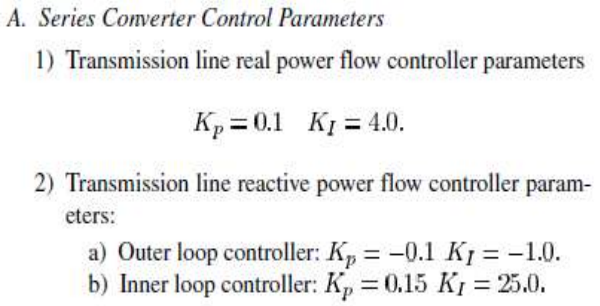


S.No		Without coordination controller	With Coordination controller	
			PI	FLC
1	UPFC bus voltage(pu)	1.075	1.06	1.05
2	DC link voltage,Vdc KV	5	2.5	2

VI. CONCLUSIONS

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. Two important coordination problems have been addressed in this paper related to UPFC control with Fuzzy logic controller. One, the problem of real power coordination between the series and the shunt converter control system. Second, the problem of excessive UPFC bus voltage excursions during reactive power transfers requiring reactive power coordination. 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.

6.1 Appendix ‘A’ [1]

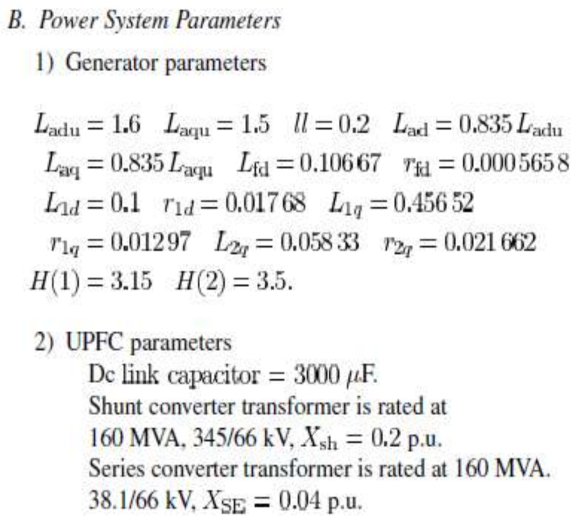


A. Series Converter Control Parameters

1) Transmission line real power flow controller parameters

$$K_p = 0.1 \quad K_I = 4.0.$$

2) Transmission line reactive power flow controller parameters:
   a) Outer loop controller: $K_p = -0.1$ $K_I = -1.0$.
   b) Inner loop controller: $K_p = 0.15$ $K_I = 25.0$.

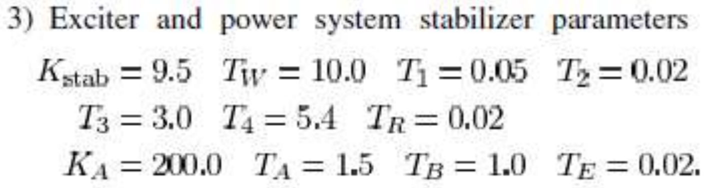


B. Power System Parameters

1) Generator parameters

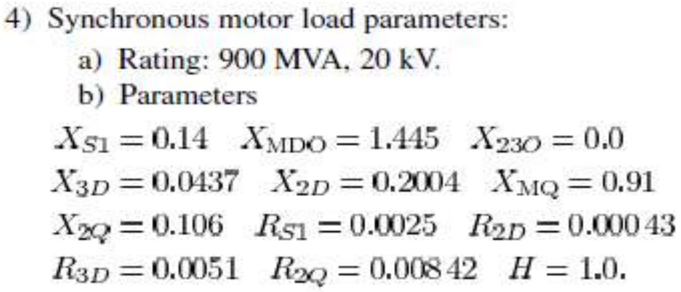
$$L_{\text{adu}} = 1.6 \quad L_{\text{aqu}} = 1.5 \quad ll = 0.2 \quad L_{\text{ad}} = 0.835\,L_{\text{adu}}$$
$$L_{\text{aq}} = 0.835\,L_{\text{aqu}} \quad L_{\text{fd}} = 0.106\,67 \quad r_{\text{fd}} = 0.000\,565\,8$$
$$L_{1d} = 0.1 \quad r_{1d} = 0.017\,68 \quad L_{1q} = 0.456\,52$$
$$r_{1q} = 0.012\,97 \quad L_{2q} = 0.058\,33 \quad r_{2q} = 0.021\,662$$
$$H(1) = 3.15 \quad H(2) = 3.5.$$

2) UPFC parameters
   Dc link capacitor = 3000 μF.
   Shunt converter transformer is rated at
   160 MVA, 345/66 kV, $X_{\text{sh}} = 0.2$ p.u.
   Series converter transformer is rated at 160 MVA.
   38.1/66 kV, $X_{\text{SE}} = 0.04$ p.u.



3) Exciter and power system stabilizer parameters

$$K_{\text{stab}} = 9.5 \quad T_W = 10.0 \quad T_1 = 0.05 \quad T_2 = 0.02$$
$$T_3 = 3.0 \quad T_4 = 5.4 \quad T_R = 0.02$$
$$K_A = 200.0 \quad T_A = 1.5 \quad T_B = 1.0 \quad T_E = 0.02.$$



4) Synchronous motor load parameters:
   a) Rating: 900 MVA, 20 kV.
   b) Parameters

$$X_{S1} = 0.14 \quad X_{\text{MDO}} = 1.445 \quad X_{23O} = 0.0$$
$$X_{3D} = 0.0437 \quad X_{2D} = 0.2004 \quad X_{\text{MQ}} = 0.91$$
$$X_{2Q} = 0.106 \quad R_{S1} = 0.0025 \quad R_{2D} = 0.000\,43$$
$$R_{3D} = 0.0051 \quad R_{2Q} = 0.008\,42 \quad H = 1.0.$$

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