Enhancement of Power Transfer Capability of Interconnected Power System Using Unified Power Flow Controller (UPFC)

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***Abstract*—Unified Power Flow Controller (UPFC) is the most effective FACTS device. UPFC is able to control the real and reactive power along with voltage magnitude and phase angle. When we talk about the interconnected network, the main concern is maximum use of the transfer capacity of interconnected line. Within the line limits conditions, UPFC is capable to maximize the power transfer capacity between the two interconnected power systems. This paper proposes use of phasor model of UPFC to maximize the power transfer capacity of interconnected power systems. UPFC is installed at the interconnecting line. The modeling is done in Matlab/Simulink using test system consisting of 20 bus system incorporating UPFC. The simulation results clearly show that the model using UPFC has maximum value of power transfer as compared to the model without UPFC.**

***Index Terms*—UPFC, Matlab/Simulink, active power, reactive power**

I. INTRODUCTION

The power transfer between two or more power systems is a very useful concept in restructuring. A number of experiments have been done on power systems to maximize its power transfer capability. Unified Power Flow Controller (UPFC) is the most effective Flexible Alternating Current Transmission System (FACTS) device which is able to maximize the power transfer capability of interconnected power systems. The ability of UPFC to increase the capability of power transfer between two power systems was first shown in [1]. In this paper simulation results show the value of active power to be increased with use of UPFC. The concept of mid-point siting of UPFC in transmission line is defined in [2]. This concept of mid-point siting is very much efficient in controlling the reactive power and enhances the power transfer capacity to almost twice as compared to the uncompensated line.

The impact of UPFC on reliability of power system is examined in [3]. In this paper, two different parallel transmission lines are considered for natural power sharing. On these transmission lines UPFC is installed to utilize the maximum capacity of transmission line for power transfer.

Manuscript received October 7, 2014; revised August 17, 2015.

The application of UPFC for maximizing the real power transfer under three constraints: optimal location of UPFC, system topology and equipment constraints are given in [4]. Whereas a strategy proposing UPFC to enhance the power transfer capacity under voltage stability limits is done under [5]. This paper overcomes the problem associated with UPFC that it cannot regulate the bus voltage set point when operated at its rated capacity. A Newton-Raphson load flow algorithm is used for modeling and computation task. In [6] the use of stochastic based technique is done to find the optimal sizing of UPFC whereby the UPFC is employed to adjust the natural power sharing in the power system as well as for enhancement of steady-state voltage profile.

In this paper, a maximized power transfer capacity between interconnected power systems is achieved using UPFC. The test model consisting of 20 bus systems is studied over two stages: stage I and stage II. Stage I represents the test model without UPFC being installed whereas the stage II incorporates UPFC phasor model. The bus No. B10 is used as the interconnecting bus between the two power systems network. The values of real power on bus No. B10 in simulation results clearly shows an enhancement of real power from stage I to stage II.

II. MODEL DESCRIPTION

As the demand of power supply in world is going on increasing day by day, this makes the power system more and more complex. The transmission network is not only to be upgraded but also maximum utilization to be done of the existing transmission lines. In order to maximize the power flow of the interconnected power system, a simulation is carried out. The simulation diagram includes a Flexible Alternating Current Transmission System (FACTS) which is based on shunt-series compensator i.e. Unified Power Flow Controller (UPFC). The Unified power flow controller is a kind of flexible alternating current transmission system that can help not only to maximize the power flow but also control voltage magnitude, line impedance as well as the phase angle. The power system models used in this paper are tested in Matlab/Simulink. The model consists of a test system of 20 buses. The test system is based on interconnection of

doi: 10.18178/ijeee.4.3.199-202

power systems. The test system of 20 buses is divided into two subsystem. First subsystem includes 9 buses (B1-B9) and second subsystem includes 10 buses (B11-B20). The bus No. B10 is used for the interconnection of two systems having 9 buses and 10 buses as shown in Fig. 1 and Fig. 2. The bus No. B12 is connected with an R-L-C- series three phase load. This model can be extended for further increase in interconnection of power systems on bus No. B12 by removing the existing load. The test model consists of 6 three phase voltage sources (three voltages source are of 500KV and other three are of 25KV ratings), 6 two winding transformers and 7 R-L-C series three phase loads. For measurement purpose model includes a block known as VPQ measurement. This block is used for measurement of voltage magnitude, real power and reactive power of buses B1-B20. The simulation run time of model is 10 seconds. The UPFC is connected at bus No. B10 as shown in Fig. 2. The two subsystems consisting of 9 buses and 10 buses are interconnected with bus No. B10.

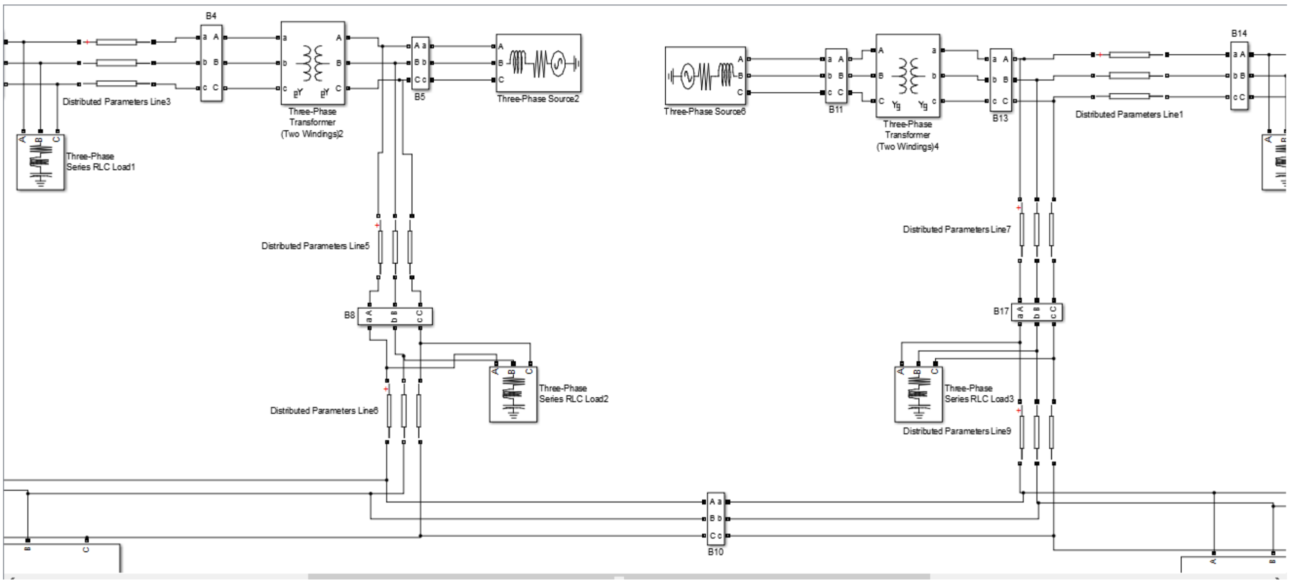

Figure 1. Portion of the Matlab simulation diagram of test system having 20 bus showing B10 bus without UPFC (stage I).

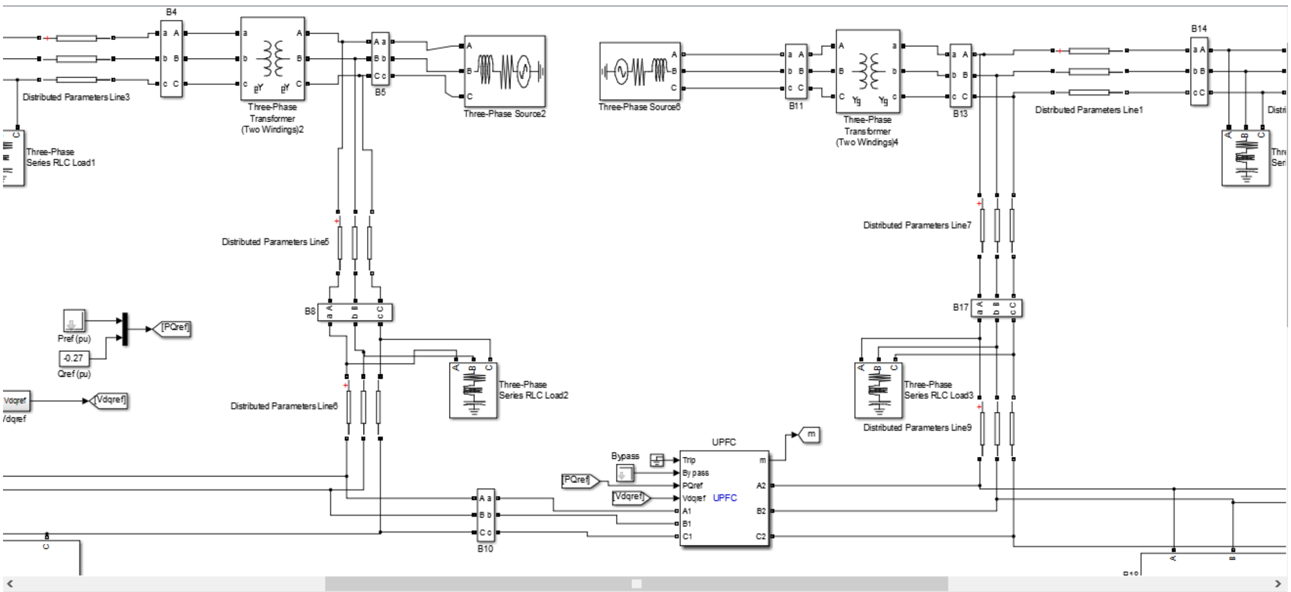

Figure 2. Portion of the Matlab simulation diagram of test system having 20 bus showing B10 with UPFC phasor model (stage II).

III. Simulation Results

The simulation results of stage I and stage II are complied in Table I and eight waveforms are shown from Fig. 3 to Fig. 10. The simulation results clearly show the enhanced value of real power at bus No. B10. The values of real power at bus no. B10 are 328.7MW and 591.5MW for stage I and stage II respectively. The simulation result is this section show in two different forms one is numeric data form and second is in the form of waveforms which made the result more clear to understand to the observer. By giving a close watch on the waveform, it is observed that there is an enhancement in the real power at bus No. 10 when the UPFC is installed as compared to model in which UPFC is not installed.

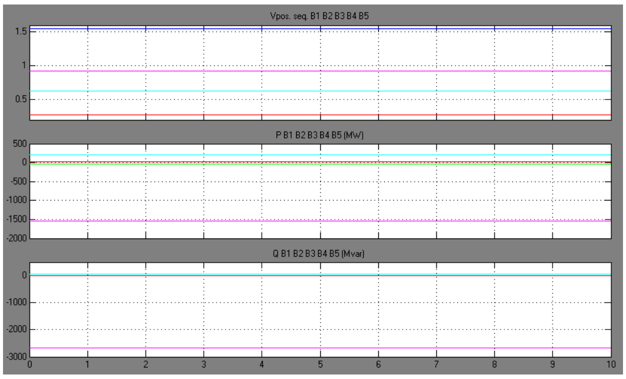

Figure 3. Voltage magnitude, real power and reactive power waveforms of bus (B1-B5) for stage I.

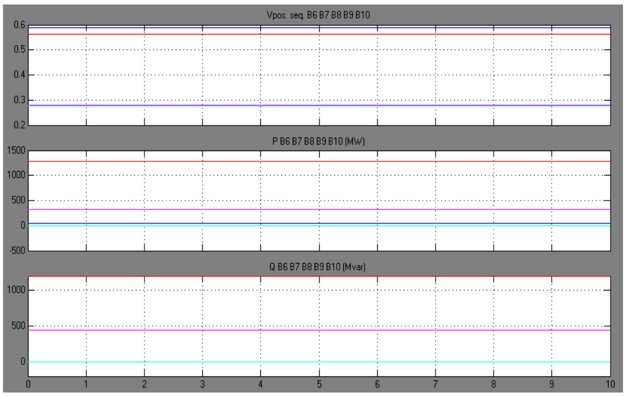

Figure 4. Voltage magnitude, real power and reactive power waveforms of bus (B6-B10) for stage I.

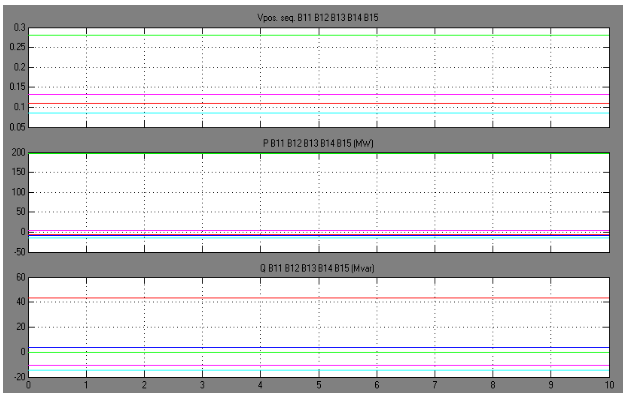

Figure 5. Voltage magnitude, real power and reactive power waveforms of bus (B11-B15) for stage I.

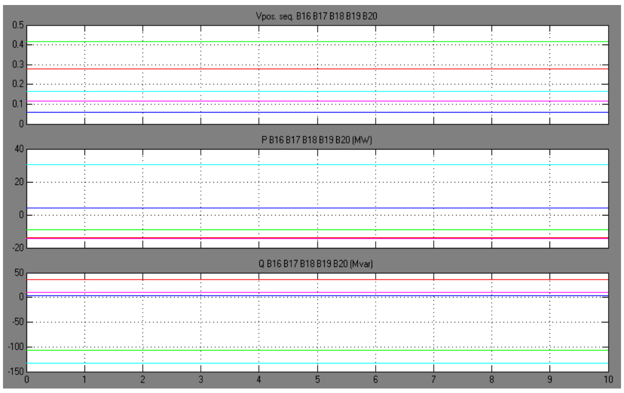

Figure 6. Voltage magnitude, real power and reactive power waveforms of bus (B16-B20) for stage I.

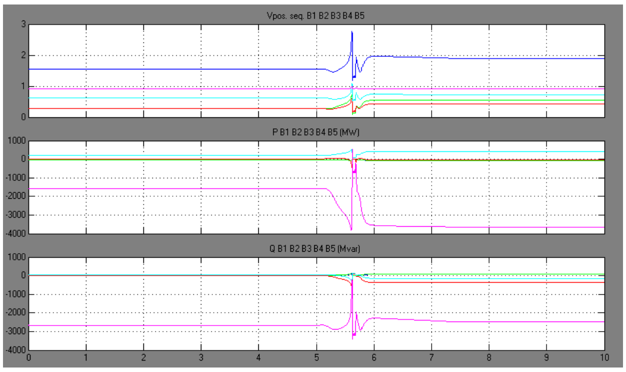

Figure 7. Voltage magnitude, real power and reactive power waveforms of bus (B1-B5) for stage II.

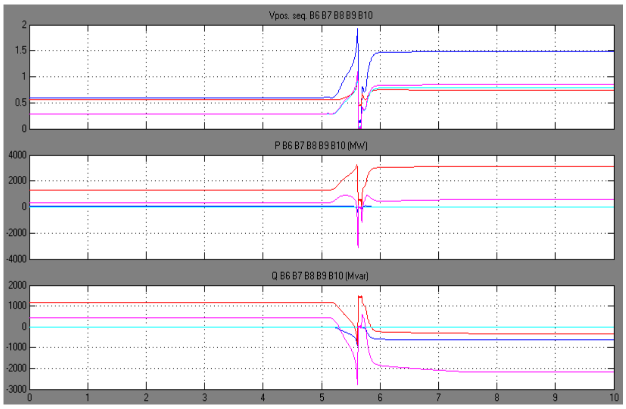

Figure 8. Voltage magnitude, real power and reactive power waveforms of bus (B6-B10) for stage II.

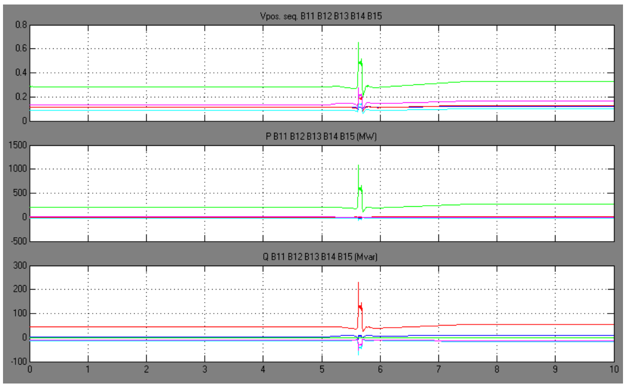

Figure 9. Voltage magnitude, real power and reactive power waveforms of bus (B11-B15) for stage II.

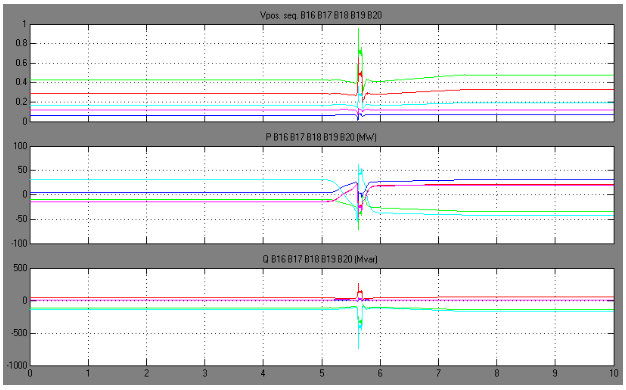

Figure 10. Voltage magnitude, real power and reactive power waveforms of bus (B16-B20) for stage II.

Fig. 3 to Fig. 6 show the simulation result of the stage I in which UPFC is not installed. The simulation result includes the waveforms of the voltage magnitude, real and reactive power. Fig. 4 shows clear value of the real power at bus No. 10 is 328.7MW. Fig. 7 to Fig. 10 show the simulation result of the stage II in which UPFC is installed. Fig. 8 shows clear value of the real power at bus No. 10 is 591.5MW. Result shows a clear enhancement of the real power transfer from 328.7MW to 591.5MW.

TABLE I. REAL POWER VALUES OF BUSES FOR STAGE I AND STAGE II

Bus Sr. No.	Real Power (MW) (stage I)	Real Power (MW) (stage II)
B1	-28.71	-60.93
B2	-28.51	-60.91
B3	22.22	-40.48
B4	207.9	412.2
B5	-1542	-3643
B6	50.32	10.17
B7	-4.627	-16.87
B8	1282	3126
B9	-4.66	-17.06
B10	**328.7**	**591.5**
Bus Sr. No.	Real Power (MW) (stage I)	Real Power (MW) (stage II)
B11	-7.87	4.808
B12	196.6	267.5
B13	-6.872	5.968
B14	-14.03	-25.21
B15	4.152	-0.01768
B16	4.093	30.46
B17	-9.101	-33.93
B18	-13.78	21.16
B19	30.31	-41.64
B20	-14.47	20.08

These simulation results gives us a clear idea about the uses of UPFC on the interconnection of two different power system in order to maximize the real power flow between them. As the capability of UPFC are to control the real and reactive power as well as the line impedance, phase angle and voltage magnitude. So it is very clear that UPFC able to control the flow of real power, which is one of the aspects of UPFC.

IV. CONCLUSION

Unified power flow controller is used to enhance the power transfer capacity of power system. Our power system is an interconnection of different electric power grids and different electric loads centers. In such situation it become necessary to maximum utilizes the power transfer capability of the interconnecting lines within the line limit conditions. In this paper, a phasor model of UPFC is used to maximize the real power transfer from one power system to other power system through interconnection for a test system of 20 bus system. This paper validates the successful implementation of phasor model of UPFC for enhancement of real power transfer capacity of interconnected power systems.

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