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Control of Real and Reactive Power Flow Using Unified Power Flow Controller (UPFC) in Integrated Power System (Electrical Grid and Wind Power Generation)

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Abstract
Unified power flow controller (UPFC), as the name suggests is used to control the power flow in transmission systems. UPFC is a kind of flexible alternating transmission system (FACTS device) which is able to control both active and reactive power along with voltage magnitude as well as phase angle. This paper proposes the use of phasor model of UPFC to control the real and reactive power flow in integrated power system (consist electric grid and wind power generator). The DFIG technology felicitates us to get maximum energy from the wind for wind speeds of low value by optimizing the turbine speed, while minimizing mechanical stresses on the turbine. The modeling is done in Matlab/Simulink using IEEE 5-bus and 10-bus system incorporating UPFC. The models are simulated to find the value of real and reactive power flow and waveforms for each of the model. The simulation results show clearly that the model using UPFC have enhanced value of real power compared to the model without UPFC. The numerical result of real power made very clear that the UPFC can be used in integrated power system for the maximum use of the transmission lines.

Keywords: *Wind power generation, DFIG, unified power flow controller*

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INTRODUCTION

The concept of UPFC was first defined by L. Gyugyi in 1991. The Unified Power Flow Controller (UPFC) is able to control almost every parameter of the power system like real power and reactive power, phase angle, impedance and voltage magnitude. Initially a series power flow controller (SPFC) was used which was joined with transmission line by a series transformer. This device can absorb and generate reactive power. If SPFC is provided with some means by which it can interchange real power in both directions i.e. from the system to device and vice versa, then it is termed as unified power flow controller [1]. Unified power flow controller (UPFC) is known as the most flexible FACTS device. UPFC is able in improving the transmission capability. This is clearly verified by the Kansai electric power corporation using analog power system simulator (APSP) [2].

A better profile of real and reactive power is achieved using UPFC [3]. In this paper, two models consisting of IEEE 5-bus system and 10-bus systems are studied over two stages: one is in which UPFC is not installed and other in which UPFC is installed. The simulation results show clearly that the value of real and reactive power of 5-bus and 10-bus that are enhanced/controlled in comparison to the model simulated without UPFC.

Matlab/Simulink software is used to design power system model incorporating UPFC [4–7]. A paper based on coordination between real and reactive power is presented using MATLAB by Kannan *et al.* [4]. In this paper, a model is designed using two sources, three transformers, one series inverter, and one shunt inverter incorporated with UPFC. The behavior of real and reactive power is examined. A paper analyzing the real and reactive power with UPFC is presented by Liming *et al.* [5]. In this paper the UPFC is connected in the middle of the line. Results of the simulation show two successfully analyzed different cases: 1) effect of UPFC in changing real power, 2) effect of UPFC in changing reactive power. A matrix converter based

UPFC effectively controlling real and reactive power is shown by Monteiro *et al.* [6]. A direct power control technique based UPFC is used for controlling the power flow through the transmission line is exhibited by Verveckken *et al.* [7]. Simulation results under balanced and unbalanced condition for real and reactive power show the effectiveness of this technique.

In this paper, an integrated power system model is used consisting of electric grid and wind power generation. The wind power generation is done using the doubly-fed induction generator. The DFIG technology facilitates us to get maximum energy from the wind for wind speeds of low value by optimizing the speed of turbine while minimizing mechanical stresses. The modeling is done in Matlab/Simulink using IEEE 5-bus and 10-bus system incorporating UPFC. The models are simulated to find the value of real and reactive power flow and waveforms for each of the model. The simulation results show clearly that the model using UPFC have enhanced value of real power compared to the model without UPFC.

MODEL DESCRIPTION

The models of power system stated in this paper are designed in Matlab/Simulink using IEEE 5-bus system and 10-bus system. First, 5-bus systems consist of integrated power system: one three phase source of 828 kV and wind power generator, one three phase R-L-C load, and two transformers: one is of two winding whereas other is 12 terminal series transformer and three circuit breakers. Wind turbines comprise of a doubly-fed induction generator which is consists of a wound rotor induction generator with a power electronic devices known as an AC/DC/AC IGBT-based PWM converter. The stator winding is coupled directly to the 60 Hz grid while the rotor is supplying at variable frequency through the AC/DC/AC converter. The operating time of circuit breaker is 4/60 to 10/60 sec. The model run time is 5.0 sec. This model incorporates UPFC phasor model. This model is simulated in two stages. Stage-1 incorporates a model without UPFC, whereas stage-2 incorporates a model with UPFC and both are shown in Figures 1 and 2 respectively. A parallel 200 km line is built with main line, whereas circuit breakers are used to isolate the area under faulty condition if it occurs. In Figure 2, UPFC is installed at bus no. B3. In this model, there is an additional scope known as UPFC measurement which measures the active power, reactive power, and voltage magnitude and phase angle. The second model which incorporates 10-bus system, is an interconnection of two models. Both models have identical 5-bus systems as explained above. The UPFC is connected at bus no. 5.

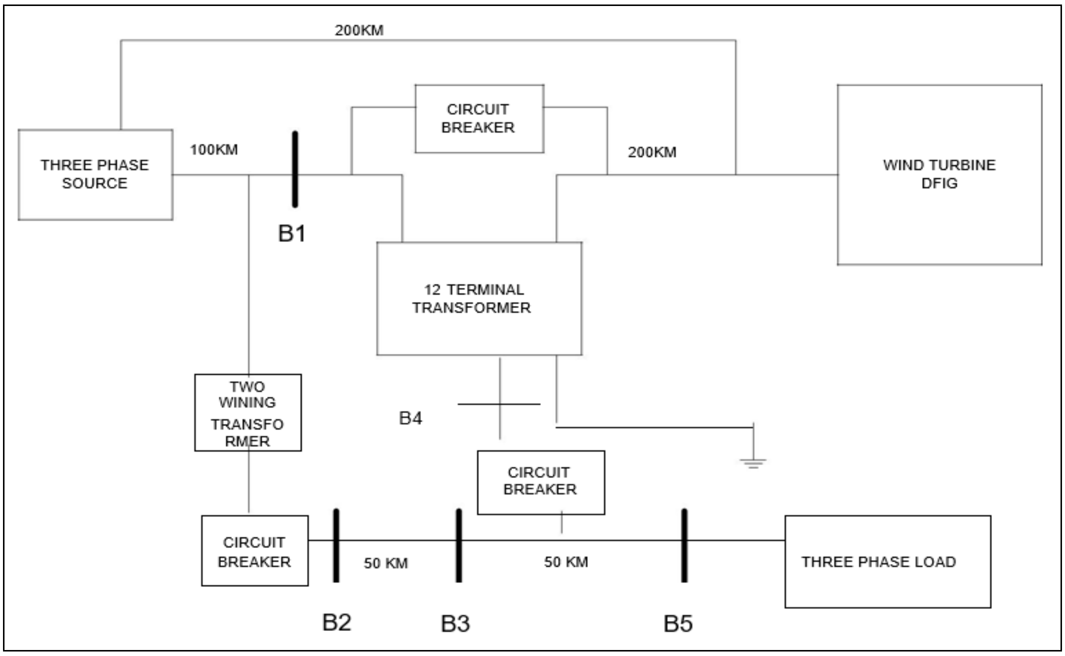

Fig. 1: *Single Line Diagram of Integrated Power System of 5-Bus System without UPFC.*

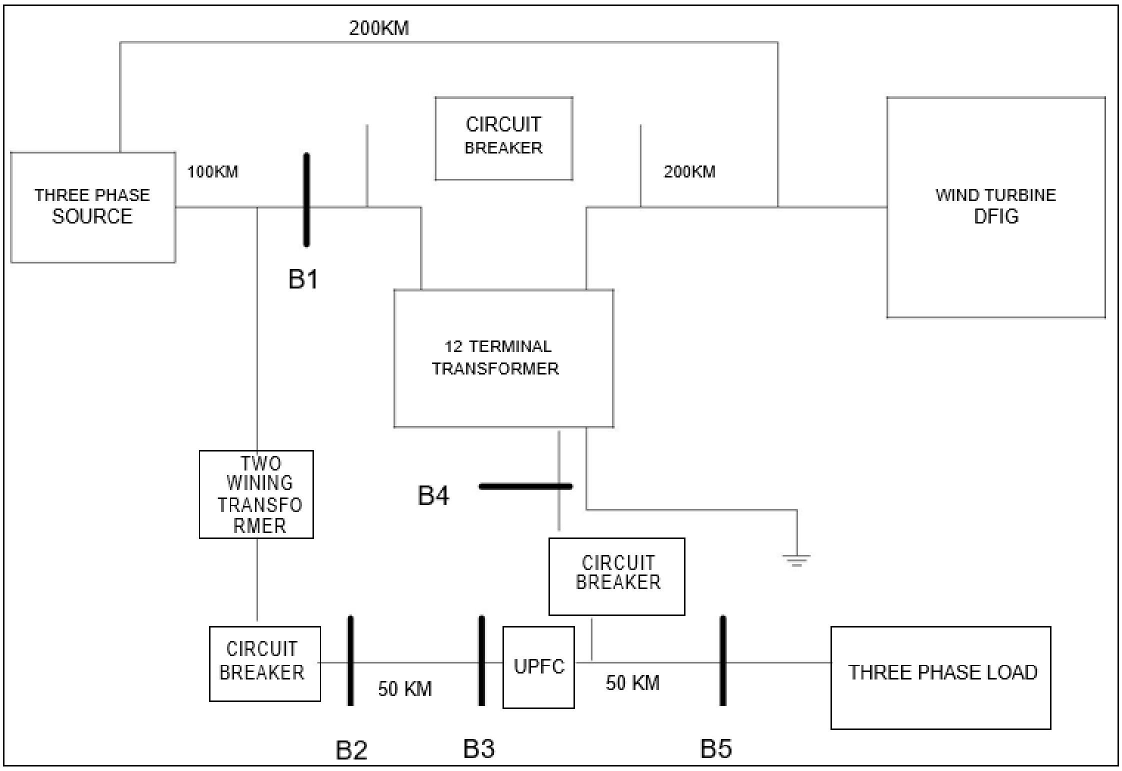

Fig. 2: *Single Line Diagram of Integrated Power System of 5-Bus System with UPFC.*

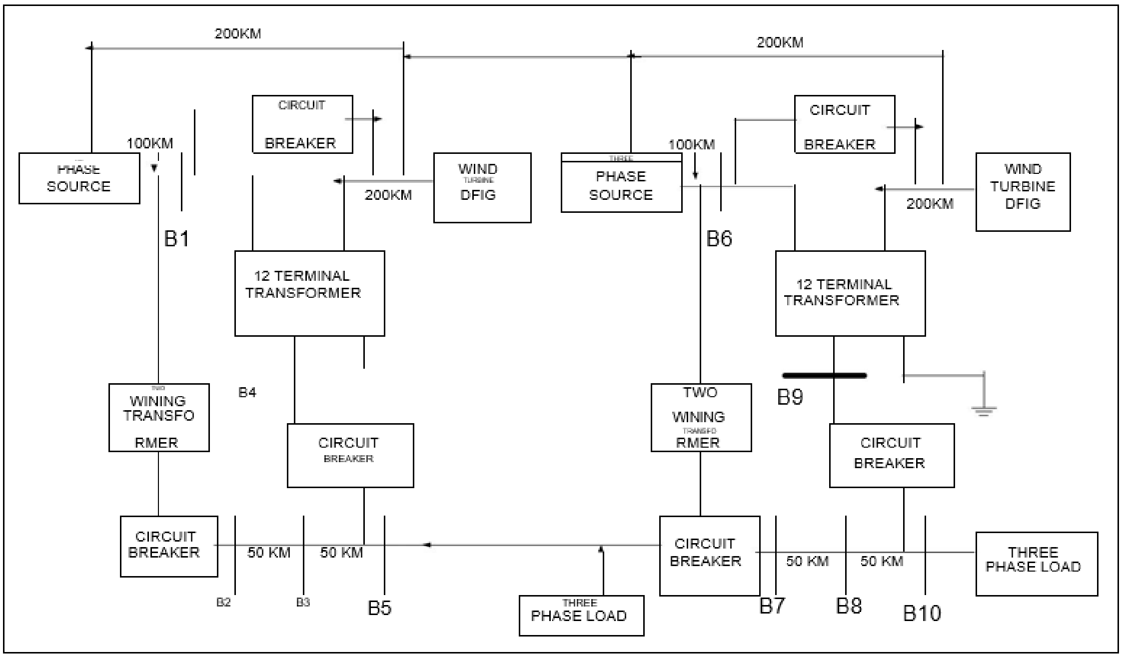

Fig. 3: *Single Line Diagram of Integrated Power System of 10-Bus System without UPFC.*

Table 1: *Real Power Values at Different Buses of Model-1 for Stages-I and II.*

Bus Sr. No.	Real Power of Model-1 (With UPFC) (MW)	Real Power of Model-2 (Without UPFC) (MW)
B1	31.82	11.74
B2	111.3	18.75
B3	64.59	10.14
B4	–4.747	–0.8216
B5	3.553	0.6149

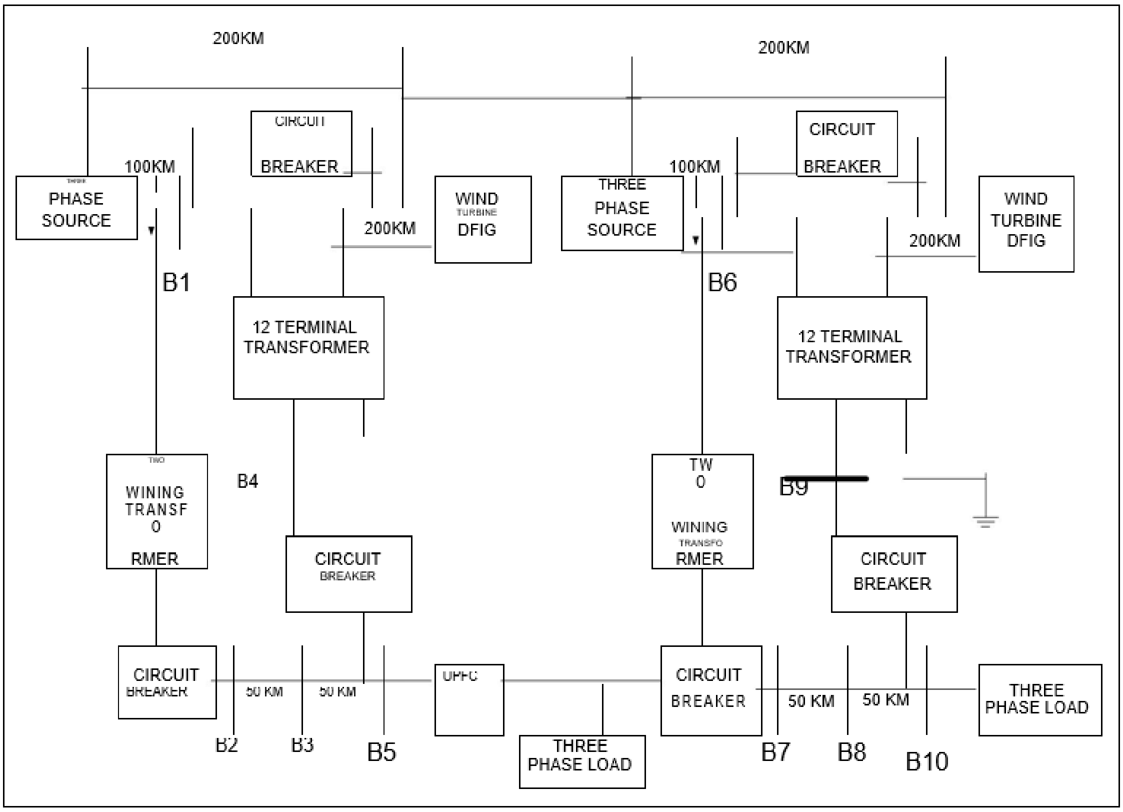

Fig. 4: *Single Line Diagram of Integrated Power System of 10-Bus System with UPFC.*

Table 2: *Real Power Values at Different Buses of Model-2 for Stages-I and II.*

Bus Sr. No.	Real Power of Model -2 (with UPFC) (MW)	Real Power of Model-2(without UPFC) (MW)
B1	114.7	121.3
B2	191.8	158.9
B3	115.4	92.37
B4	–39.91	–29.32
B5	–2.131	–4.55
B6	107.7	61.87
B7	5.613	4.123
B8	3.035	2.229
B9	–0.2449	–0.1791
B10	0.1841	0.1353

RESULTS AND DISCUSSION

Simulation results are compiled in two tables (Tables 1 and 2) and twelve waveforms (Figures 5–10). The results show clear evidence of enhancement/control of real and reactive power for the said power system models.

The waveform pattern is as shown in Figures 3 and 4. In this pattern, the run time of model is 5 sec. The active and reactive power dips from 0.066 to 0.166 sec. This dip occurs because in this particular time, the circuit breakers operate.

From Table 1 it can be observed that the highest value of real power is at bus no. 2 of model-1. From Table 2 it made very clear that highest value of real power is at bus no. 2 for model-2. So it is clear from the result of simulation that there is an enhanced value of active and reactive power in the scope for the model in which UPFC is installed as compared to the value of active and reactive power of the scope of the model in which UPFC is not installed.

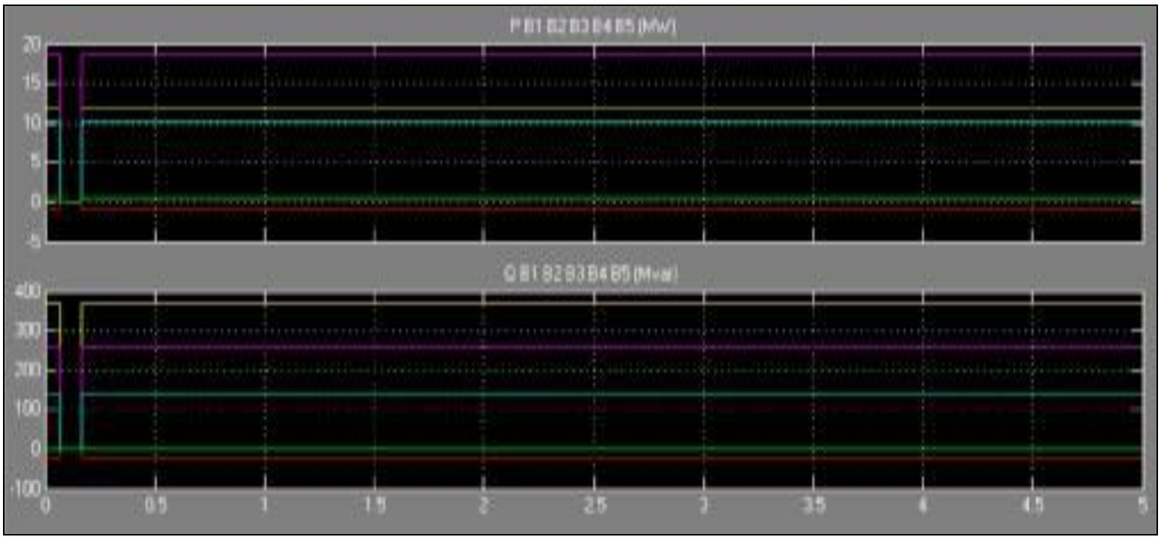

Fig. 5: *Real Power and Reactive Power Waveform without UPFC for Model-1.*

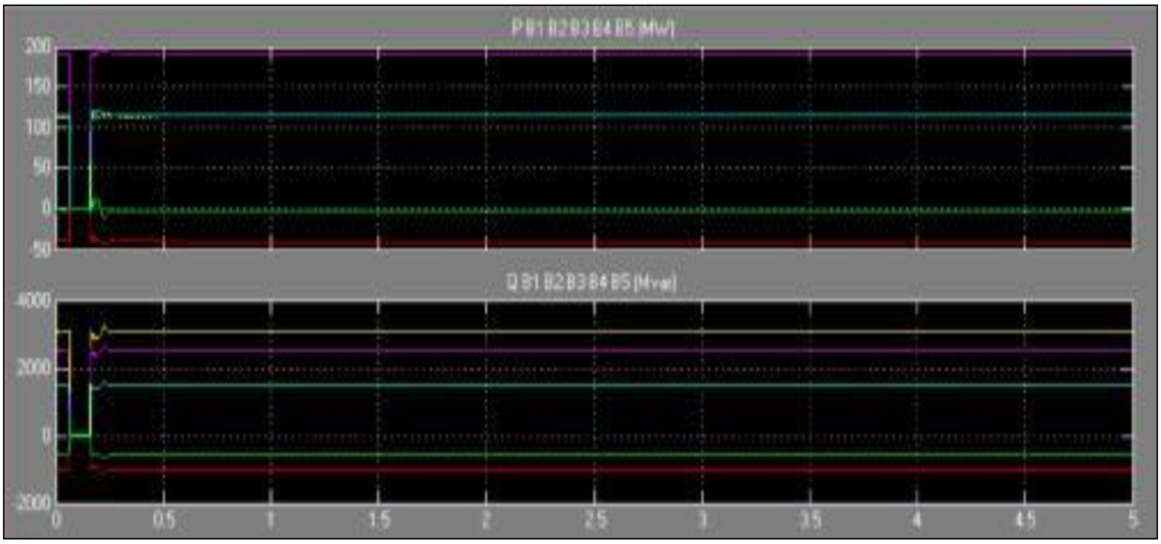

Fig. 6: *Real Power and Reactive Power Waveform with UPFC for Model-1.*

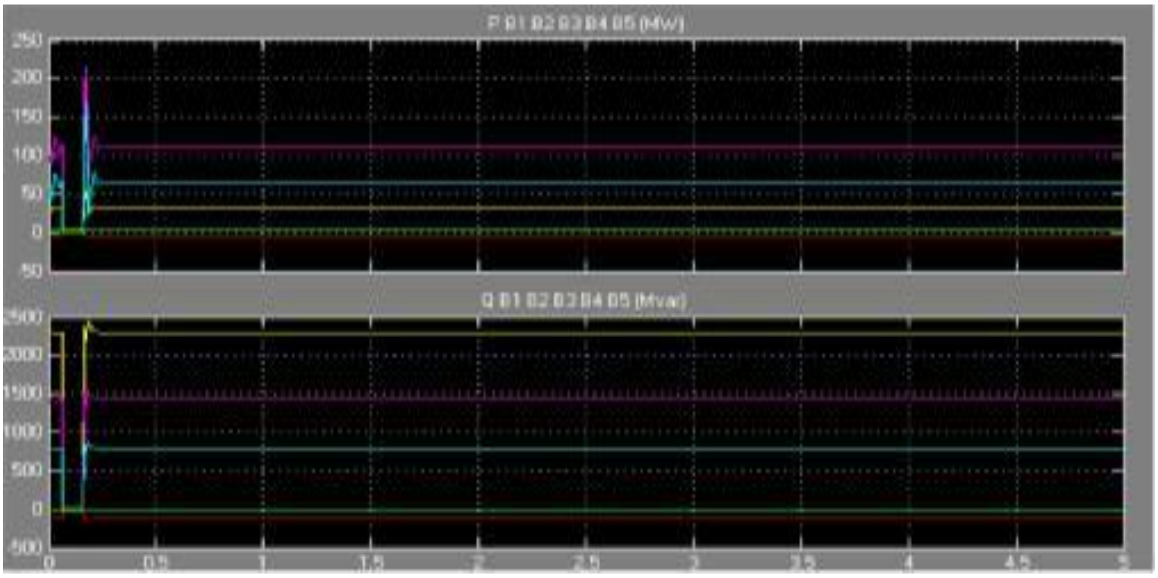

Fig. 7: *Real Power and Reactive Power Waveform for Buses (B1-B5) without UPFC of Model-2.*

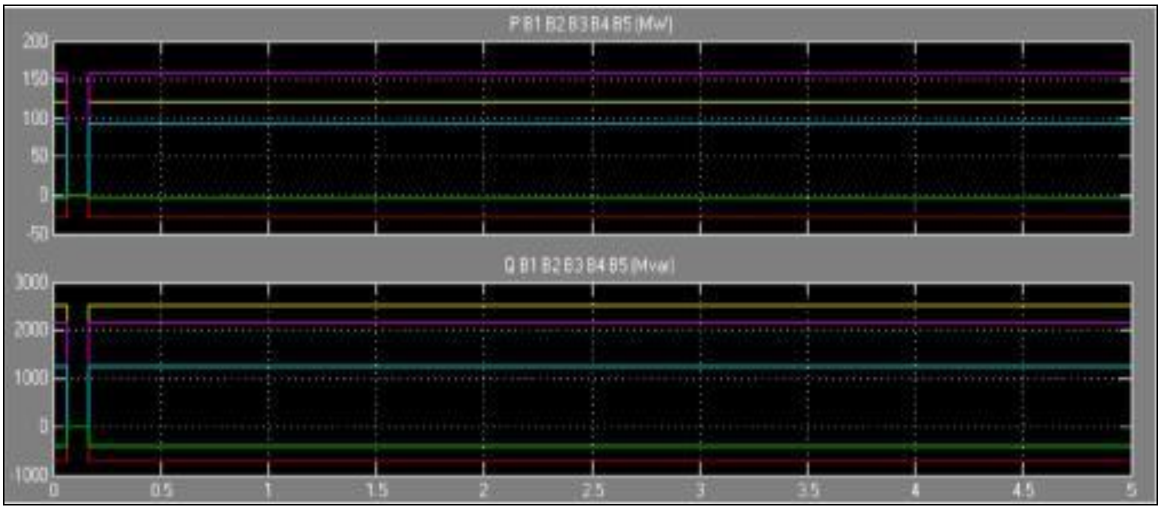

Fig. 8: *Real Power and Reactive Power Waveform for Buses (B6-B10) without UPFC of Model-2.*

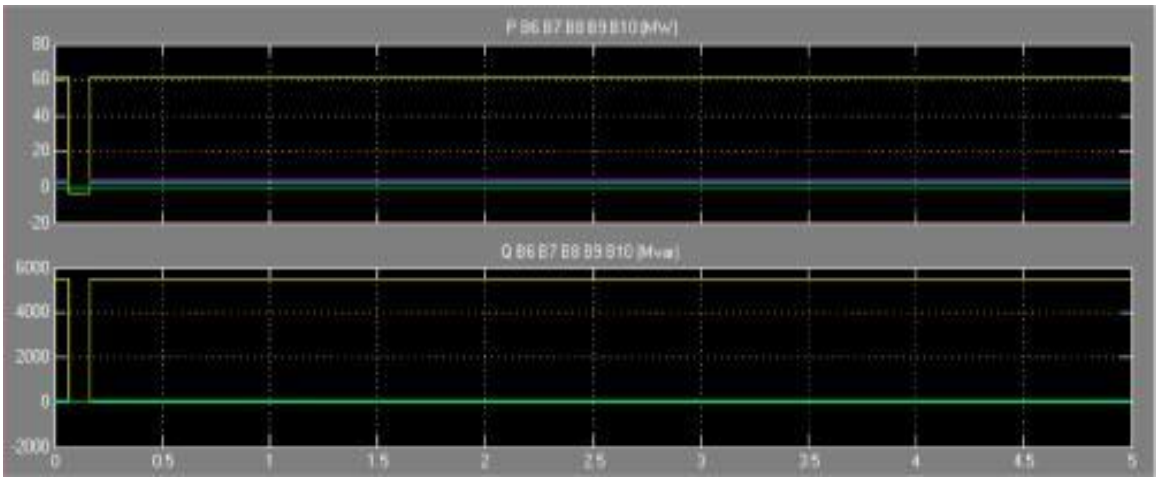

Fig. 9: *Real Power and Reactive Power Waveform for Buses (B1-B5) with UPFC of Model-2.*

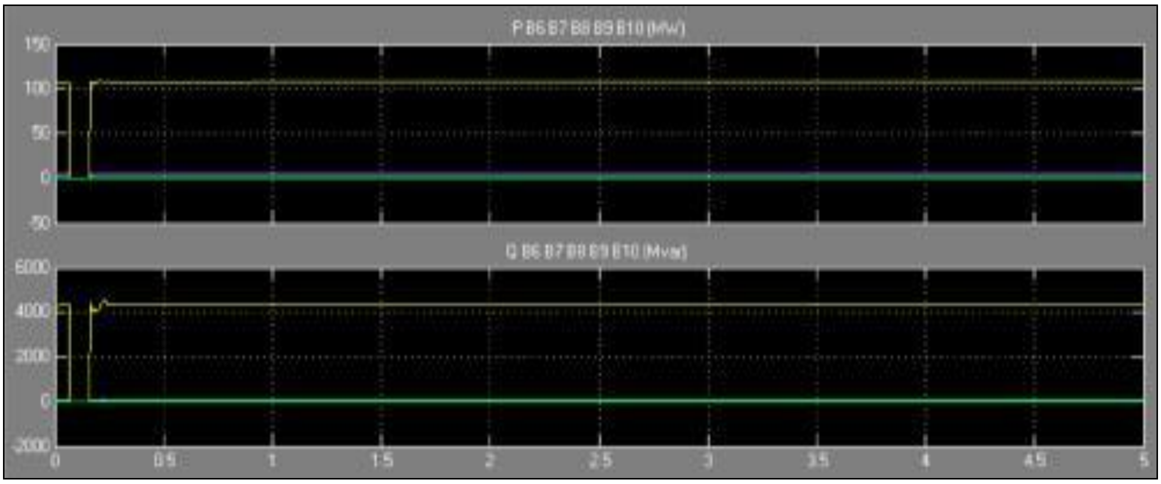

Fig. 10: *Real Power and Reactive Power Waveform for Buses (B6-B10) with UPFC of Model-2.*

CONCLUSION

Unified power flow controller is used to control the value of active and reactive power. A phasor model of UPFC is used to enhance/control the real power for IEEE 5-bus and 10-bus system. This paper validates the successful implementation of phasor model of UPFC for real and reactive power enhancement and control for integrated power system.

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