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Implementation for Controller to Unified Single Phase Power Flow Using Digital Signal Processor (DSP)-TMS320C31

Abdul Aziz Mohammed Al Buaijan, Yasser Hassan Al Haddad
Department of electrical power, Higher Institute of power, The Public Authority for Applied Education and Training (PAAET), Kuwait
Department of electrical power, Higher Institute of power, The Public Authority for Applied Education and Training (PAAET), Kuwait

ABSTRACT
Presenting in his paper, Digital signal processor (DSP)-based implementation of a single phase unified power flow controller (UPFC). For shunt side and series side An efficient UPFC control algorithm is achieved. Discussing the laboratory experimental results using DC source are taken as an UPFC linked by two ll-bridge PWM voltage source converters.
Keywords: algorithm, power flow, controller, experiment

I. INTRODUCTION

In order to fully utilize the existing transmission facilities and hence, minimizing the gap between the stability and thermal limit. Flexible AC Transmission Systems (FACTS) is used. It provides the corrections needed of the transmission functionality, the Unified Power Flow Controller (UPFC), is capable of selectively controlling transmission line impedance, phase angles and voltage magnitudes in a power system. The major benefits of UPFC brings can be realized in power systems steady state operation as well as in the emergency situations [1]. Supporting voltage and control power flow is the main function of the UPFC [2,3,4].

To complement the research process A hardware setup of UPFC and control system is needed. Digital control hardware is simplified by using Digital signal processor (DSP)-based control of power conversion circuits and systems, this improved reliability and reduced environmental effects such as temperature, components aging and supply voltage fluctuations. Comparing to other methods DSP-based control has greater flexibility, because of software implementing control algorithms [5]. other DSP used in FACTS is implemented in References [5,6,7]. Reference [5], describing power factor correction converter system active-switch using a DSP-control. References [6,7], covering the STATCOM DSP-based multifunctional capabilities. In this paper, implementing UPFC and verifying its function and its practical problems in laboratory. instantaneous adaptive control algorithm and a new closed loop of a single phase UPFC presented in this paper. Basing on the active power filter (AF). in [8,9,10] references current calculations found . Single phase transmission line mid-point used as an experimental point to connect UPFC. The proposed control method results that derived from experiment, verify the efficiency of the DSP-based control system.

II. BASICS of UPFC

[1,3] describing unified power flow controller basic operation. As shown in Fig. 1 the UPFC circuit a DC link supply connected to two switching converter. Converter 1 which is connected in shunt and known as (shunt converter) main function is supplying or absorbing the demanded active power by Converter 2 (series converter) at the dc common link. It is represented by the 1a current. The line can be controlled by Converter 1 which absorb or generate controllable reactive power that achieves independent line shunt reactive compensation. That is represented by 1_q current. The main function of the UPFC is performed by the second Converter 2 (series converter). Converter 2 injects a controllable magnitude AC voltage and controllable phase angle in series with the transmission line.

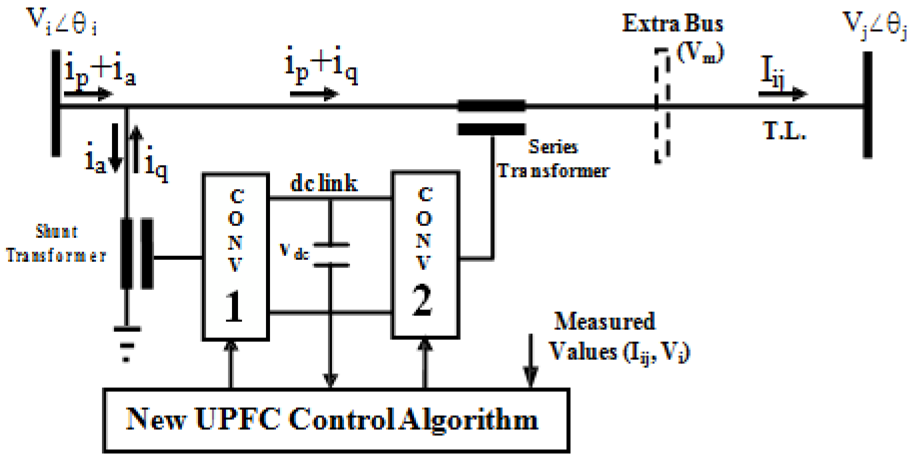

Fig.1. New UPFC Control Algorithm

III. UPFC with new control algorithm open loop

Instantaneous adaptive control algorithm and a new closed loop of a single phase UPFC presented in this paper. Basing on the active power filter (AF). in [8,9,10] references current calculations found

By neglecting the dc and harmonic components, the line current consists of active and reactive components, these terms represented in the following equations:

$$I(t)= i_p(t) + i_q(t)= i_p \sin(\omega\ t) + i_q \cos(\omega\ t) \quad (1)$$

Where:

equations represented without UPFC shunt compensation

$I_p(t)$ represents in phase line active current of the T.L

$I_q(t)$ represents reactive current of the T.L

The active current component is the only component needed to be supplied to the bus connected to the UPFC shunt converter for voltage regulating aim. Equation (1), shows that if reactive component supplied by the shunt converter of the UPFC , only the active component needs to be supplied from that sending bus as shown in Fig.1.Subtracting the active current component from the measured line current derivates the equation (2).

$$I_q\ (t) = i(t) - 1_p \sin(\omega\ t) \quad (2)$$

Where:

1p : the in-phase current magnitude (to be estimated)
sin(ω t) : a sinusoidal in phase with the line voltage.
This operation can be represented in the next shown figure in Fig.2.
To explaining the 1_p estimation we have to consider the product of a sinusoid in phase with the line voltage and the line current of eqn. (1).

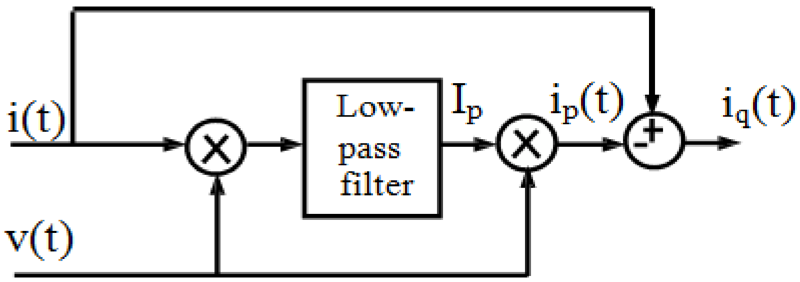

Fig.2. calculating the UPFC shunt injected current by using Open-loop system.

These will derivates the equation (3)

$$I(t).\sin(\omega\ t) = 1_p/2\ [1-\cos(2\ \omega\ t)]+1_q/2\sin(2\ \omega\ t) \quad (3)$$

In equation (3) only the dc term is proportional to 1_p. While a low-pass filter permits to obtain 1_p after the multiplication, a low-pass filter cutoff frequency is below ω, this gives $i_p(t)$ magnitude estimation. Obtaining an estimation of the instantaneous active current $i_p(t)$ done by multiply that dc value by the same in-phase sinusoid. Finally, obtaining the reactive current $i_q(t)$ injected to the power system, by subtracting $i_p(t)$ value from the measured line current. Many problems found by using this open-loop system method these problems covered by using the closed-loop system as shown in Fig. 3.

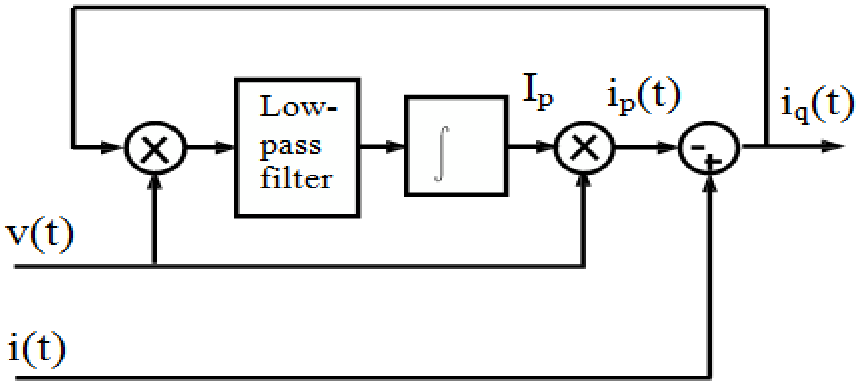

Fig. 3.UPFC shunt injected current Closed-loop system

IV. CONFIGURATION AND SYSTEM CONTROL

Single phase UPFC configuration and its control system shown in figure (4). A 50 Hz Single phase AC supply 220 volt feeds the single phase transmission line model. the mid-point of the transmission line gives the scaled current LA (divided by 1.0) and scaled voltage signals LV (divided by 73.0).

Fig. 5, shows the input signals of the control system through DSP analogue to digital input channels. The input signals divided by 10.0 by the DSP input channels. opt coupler circuit isolates the PWM four signals . These four signals are the eight MOSFETs gate signals, constructing series (H-bridge 1) and shunt converters (H-bridge 2). Two MOSFETs switched on in the same time by one signal. The input of shunt transformer is the output of shunt converter which injects reactive current to the system mid-point.

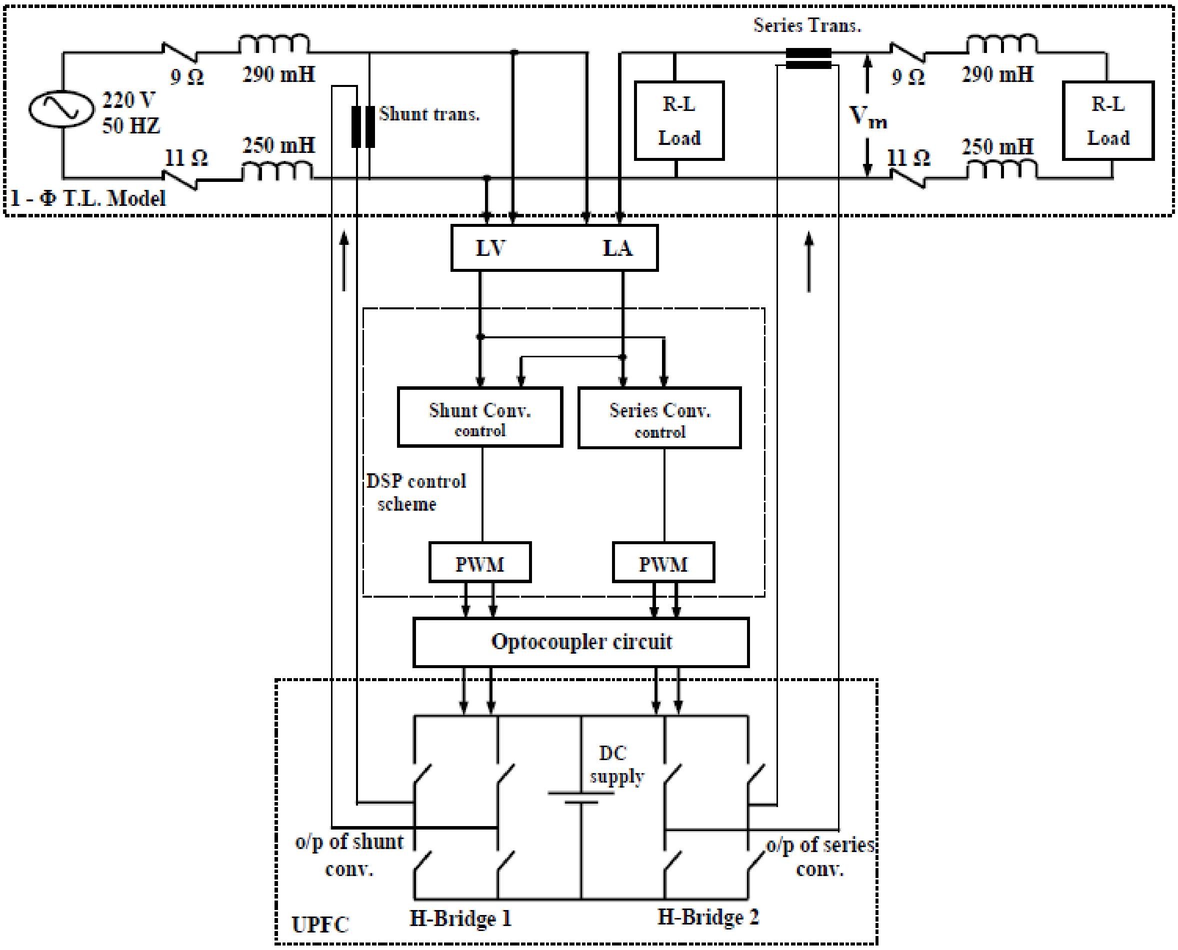

Fig.4. Configuration of Single phase UPFC system

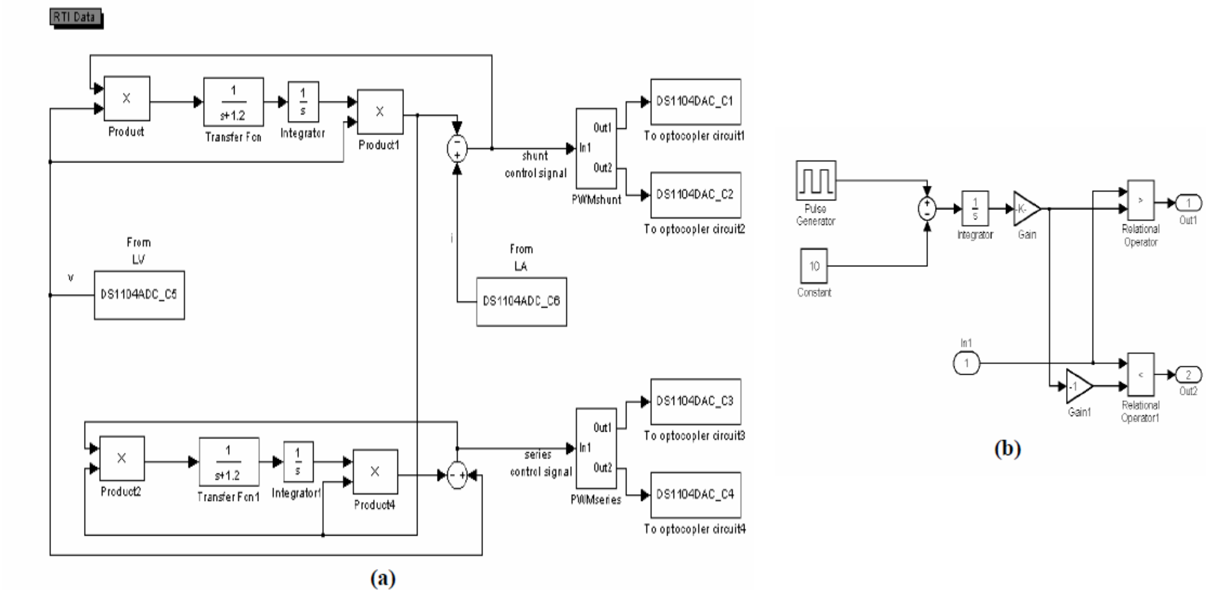

Fig.5. (a) Single phase UPFC Control algorithm

(b) PWM subsystem

Series converter output is the input of series (boosting transformer) transformer. The boosting transformer adds a series injected voltage to the voltage of the mid-point. Appendix shows All System elements.

V. PERFORMANCE OF UPFC

Two cases tested in laboratory and the values appears in figures 6 to 15 the test made for light loads as a first case and for a heavy load as a second cases the UPFC test made for series and shunt converters.

Case1 and case2 were tested and showed in

Figures 6 and 7 show the phase relation between the series converter control waveforms and the measured input current, and the phase relationships between the shunt converter control waveforms and measured input voltage.

The phase shift between voltage and currents shown in fig.6,The important issue here is the output of the converters. For light load in case1 the output current is 244 mA, and lagging the voltage by 72 degree, the measured input voltage is 204.4 V. As shown in figure 8 the input voltage lagging output voltage by 90, the shunt converter output voltage has a 70 V (fixed) peak value. For the future work the study should focus on controlling the peak voltage value of shunt converter according to the injected reactive current required.

In Fig. 9, the series converter output voltage leading the measured voltage by 144 which means leading the line current by 216 degree.

Fig. 10 representing heavy load of 1.4 A as case 2, the waveforms of show that the shunt converter measured voltage still lagging the output voltage by 90, while decreasing in the measured input voltage to 153.3 V. Fig.11 shows that controlling the DC supply (link) can adjust the magnitude of the series injected voltage, and the series converter line current lagging the output voltage by 36 degree.

Each converter output is injected throughout voltage transformer to the mid-point of the simple power system. Both figures 12 and 13 show cases 1 and 2 the voltage of point connecting the UPFC respectively. For case 1 the voltage is increased up to 219 volt and for case 2 it reached 201 volt. The mid-point voltage after adding the series injected voltage for both cases can be seen in figures 14 and 15.

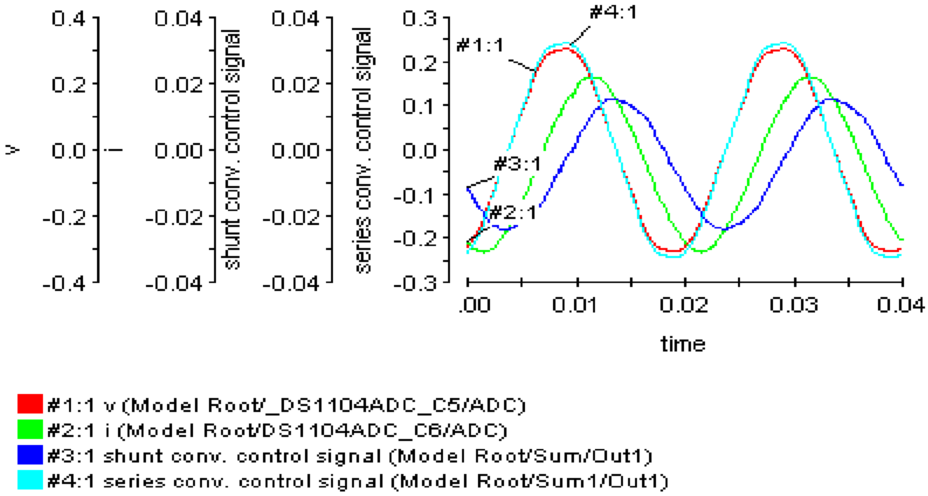

Fig.6. control series and shunt converter control waveforms for case (1), input current (i), input voltage (v).

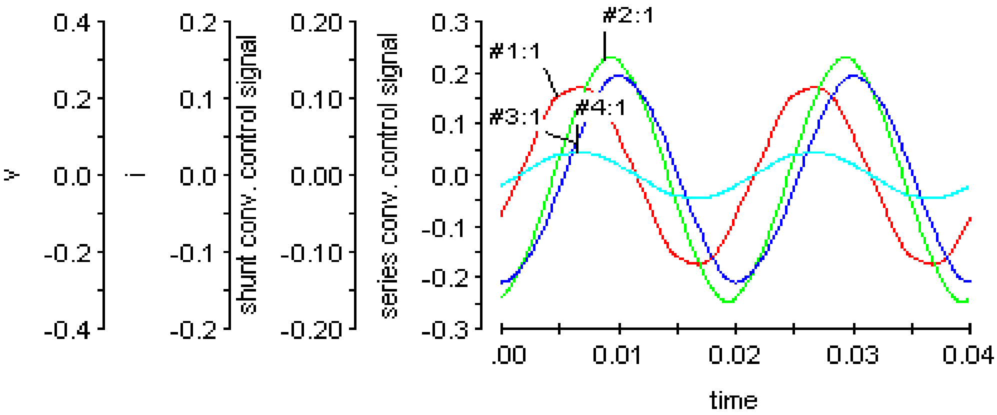

Fig. 7. shunt converter control and series converter control waveforms for case (2), input voltage (v), input current (i).

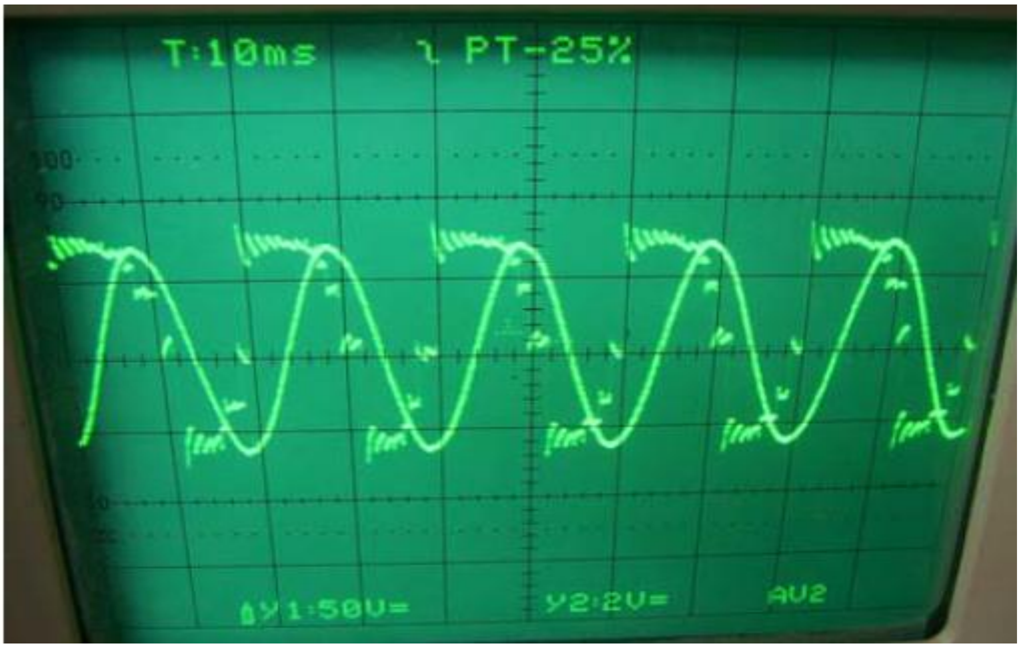

Fig.8. Case (1) shunt converter Output voltage and measured input voltage waveforms

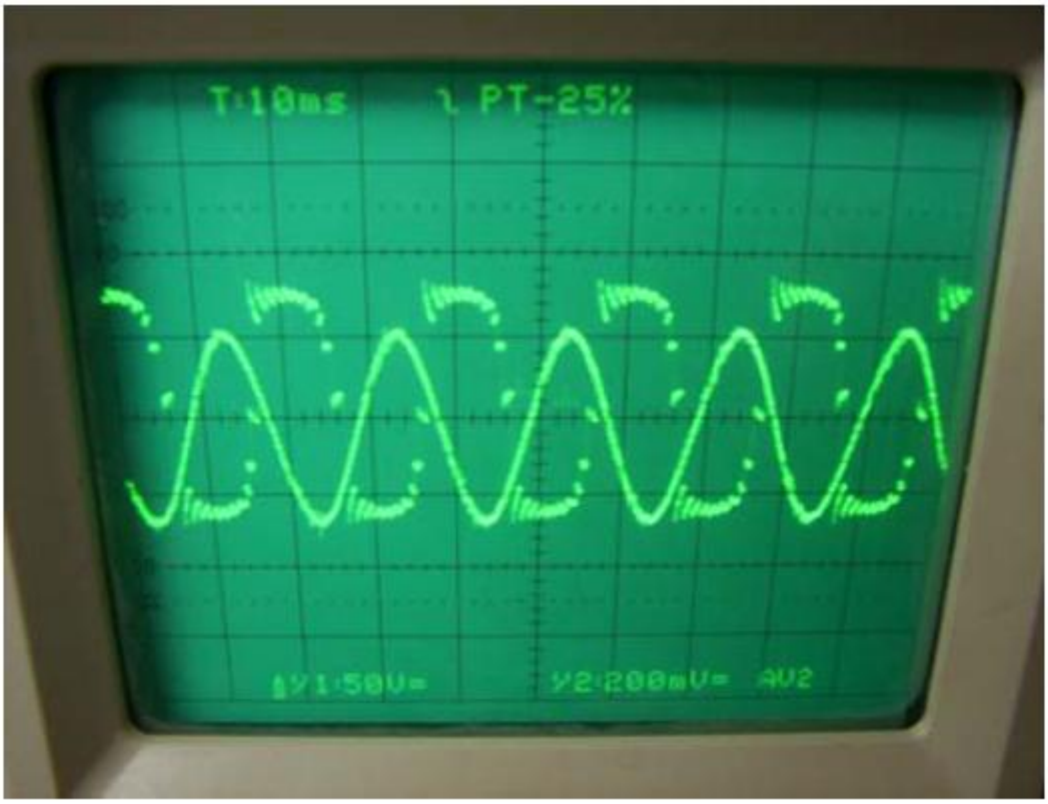

Fig. 9. case (1) series converter Output voltage and measured input current waveforms

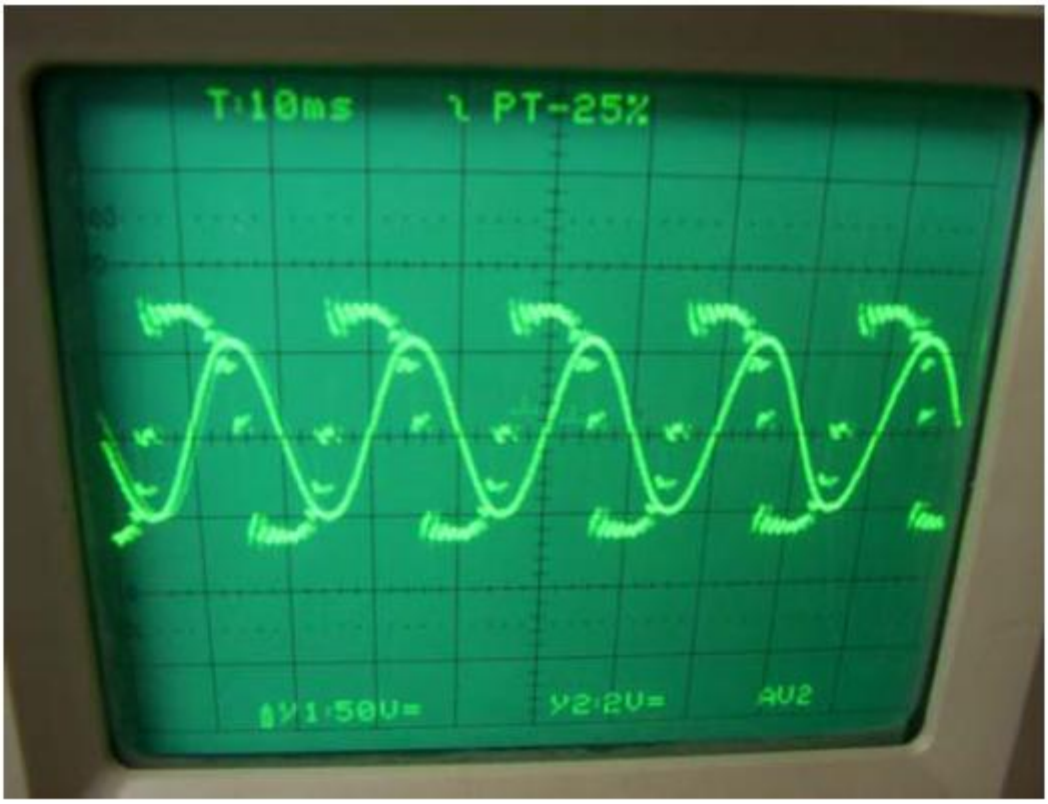

Fig.10. Case (2) shunt converter Output voltage and measured input voltage waveforms

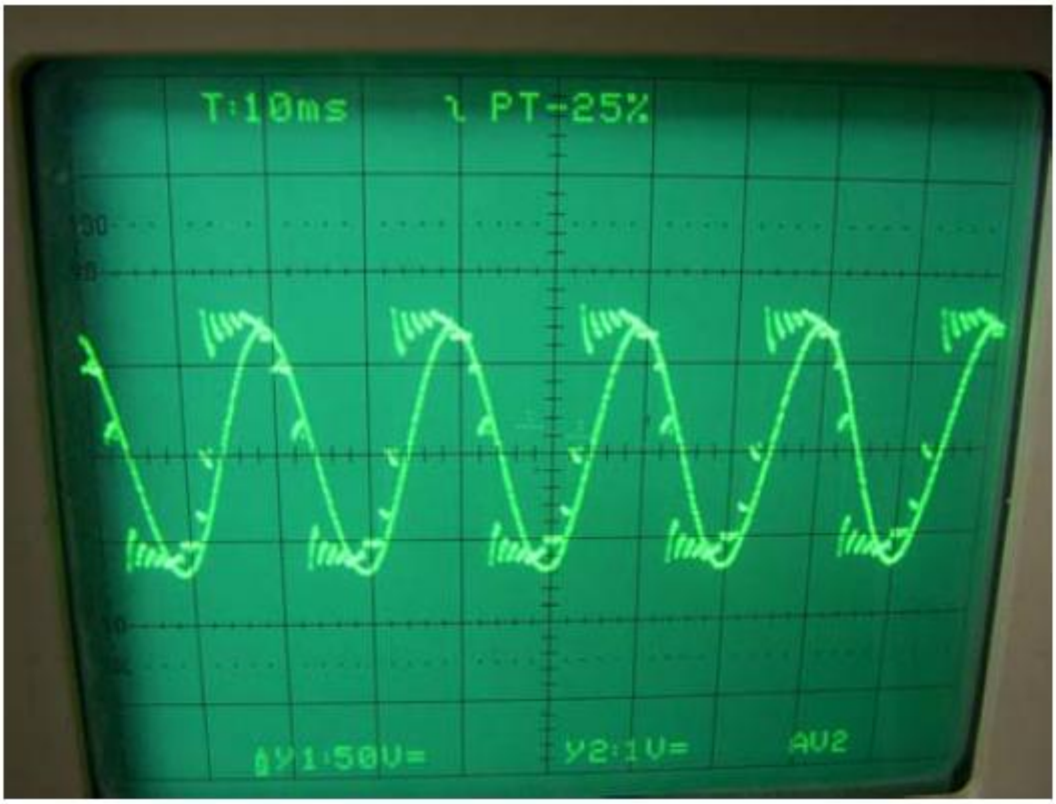

Fig.11. Case (2) **series converter Output voltage and measured input current waveforms**

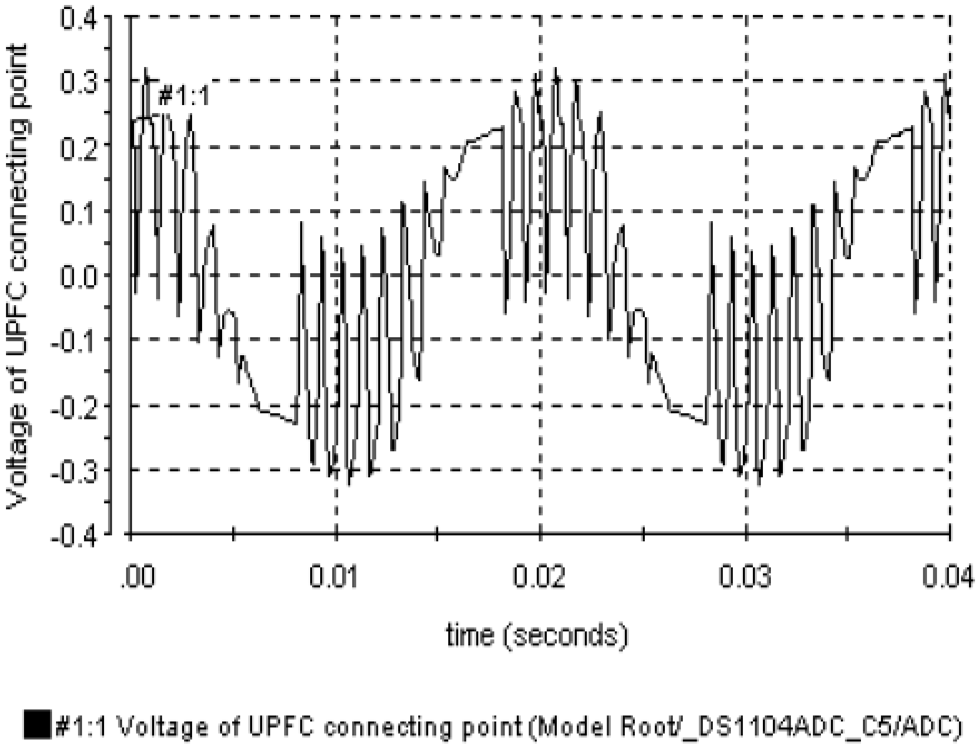

Fig. 12. Case (1),UPFC connecting point voltage waveform

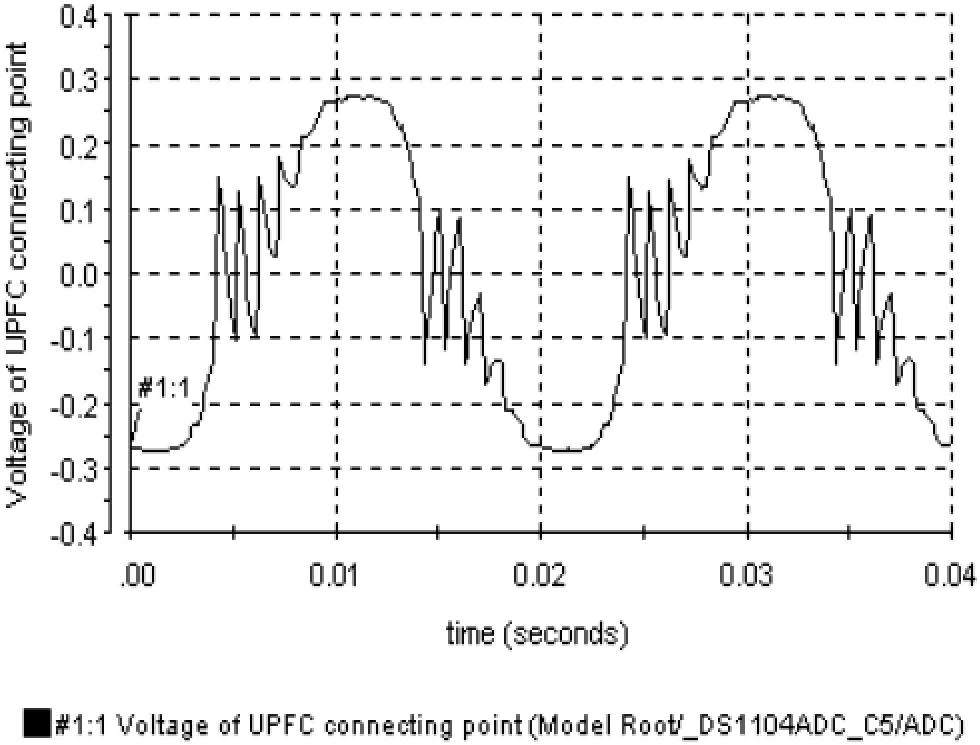

Fig.13. Case (2), UPFC connecting point voltage waveform

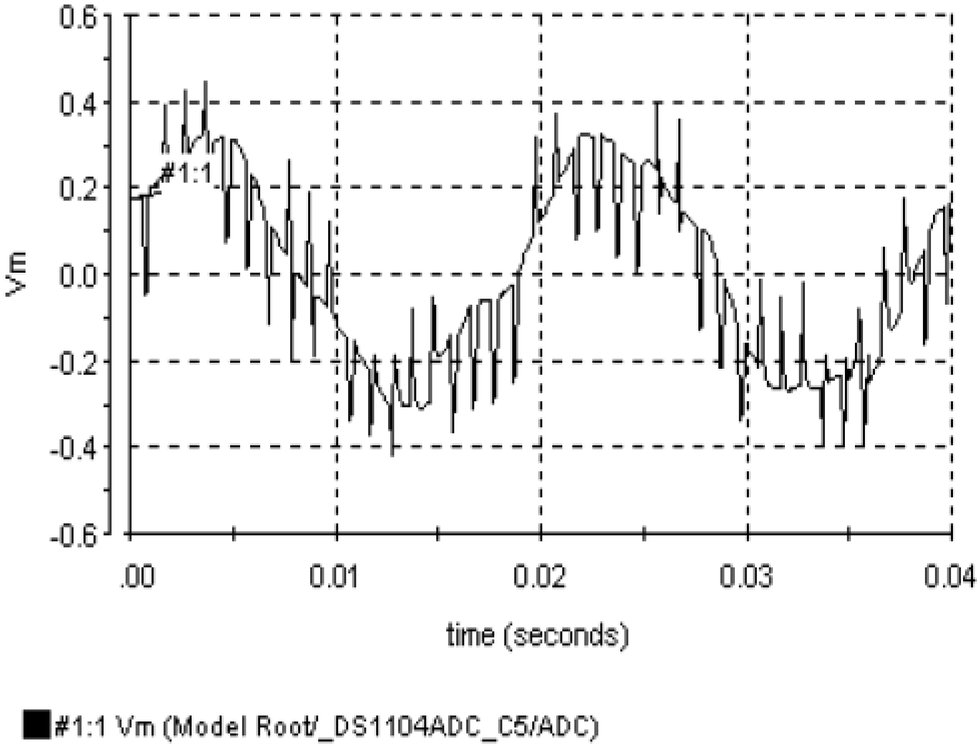

Fig.14. Case (1),mid-point Boosted voltage waveform

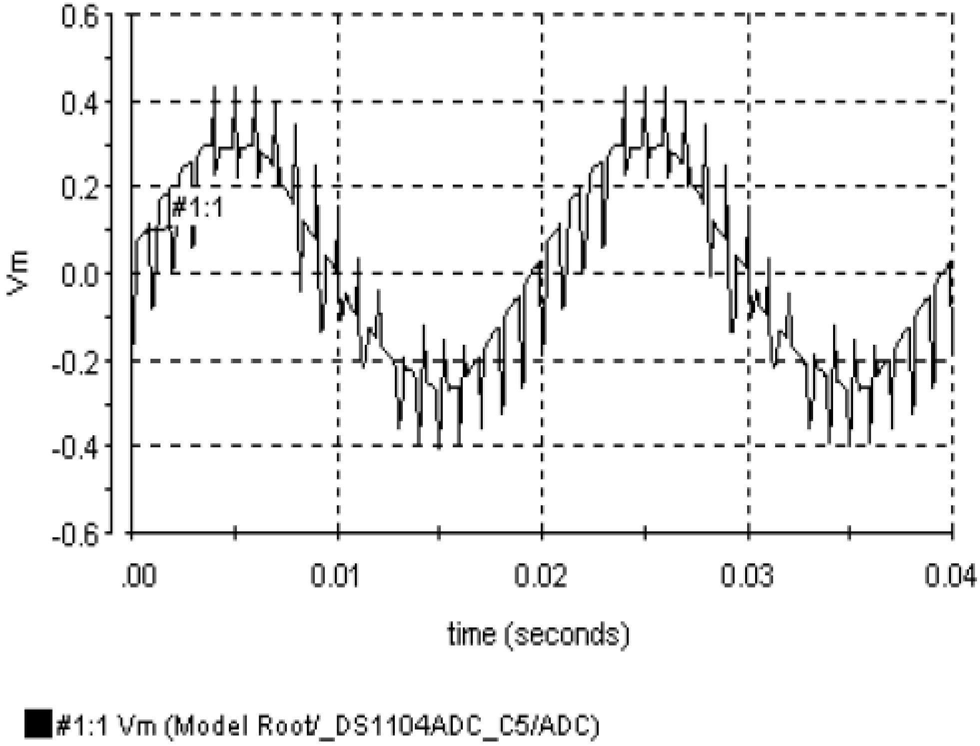

Fig.15. case (2)mid-point Boosted voltage waveform

VI. CONCLUSION

Implemented a Digital signal processor (DSP) – based single phase unified power flow controller (UPFC). For both series side and shunt side achieved an efficient and simple UPFC control algorithm. The active powers filter current reference calculation method used as base to the algorithm. UPFC build by using the PWM voltage source linked by DC source converters. The line current is lagging output voltage of the series converter by an angle dependent on the required power flow in the transmission line and the UPFC. In large scale power systems the effect of series converter control is obvious while the need to control the direction and amount of power flow between many different busses required. Output voltages of the shunt converter are found in quadrature with the bus voltage connecting UPFC and achieves voltage support. We can practically avoid the problem of the harmonics waveforms which produced and injected by voltage transformer with using suitable series and shunt transformers. The experimental results have been analyzed

VII. APPENDIX

Laboratory elements used are:

Two H-bridges each consists of 4- power MOSFETs (IRFP460), Fixed 70 volt DC supply and single phase voltage transformer 220/57.7 volt. Windows 98, PC, Matlab6.1(R12.1)/ Simulink, DSP-TMS320C31 Hardware, DSpaceR4.3 Software, 2 Single-Phase 250 Km T.L. model, Single-Phase source (220 volt, 50 Hz), 2 Single-Phase 400 Watt / 300 Var variable (R-L) load, 1 LV25-P (400 V), 1 LA25-NP (25 A), Optoisolator circuit (4N35). Two H-bridges each consists of 4- power MOSFETs (IRFP460), Fixed 70 volt DC supply and single phase voltage transformer 220/57.7 volt.

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