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Application of Fuzzy Logic Controller in UPFC to Mitigate THD in Power System

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Abstract:- This paper mitigate the harmonics, current balancing and investigate THD in distribution system. When the fuzzy logic controller with UPFC in power system is connected to distribution system to maintain the stability of a system in power quality issues like variation of voltage, current and harmonics at source side and load side will be penetrated into the distribution system. The simulation is carried out in MATLAB SIMULINK and the results shows the results confirm the feasibility of proposed system.

Keywords:- Unified power flow controller (UPFC), Total harmonics distortion (THD),

I. INTRODUCTION

A Power quality problem is an occurrence manifested as a non standard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. With the restructuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions [6].

At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Among these, the UPFC and the dynamic voltage restorer are most effective devices, both of them based on the VSC principle. UPFC injects a current and voltage into the system to correct the power quality issues. Comprehensive results are presented to assess the performance of each device as a potential custom power solution [3].

The FACTS (Flexible AC Transmission Systems) technology is a new research area in power engineering. It introduces the modern power electronic technology into traditional ac power systems and significantly enhances power system controllability and transfer limit. In this paper, the unified power flow controller (UPFC) with fuzzy logic control will be used to improve power system dynamic behavior after a system disturbance [1].

II. BASIC CONFIGURATION AND OPERATION OF UPFC:

a. Basic Configuration:

UPFC is a combination of a shunt compensator and series compensation. It acts as a shunt compensating and a phase shifting device simultaneously under proper control can manage the capacitor i.e., the dc voltage source, to be charged (or discharged) to the required voltage level [2]. In this way, or by PWM controller, the amplitude of the output voltage of the inverter can be controlled for the purpose of reactive power generation or absorption.

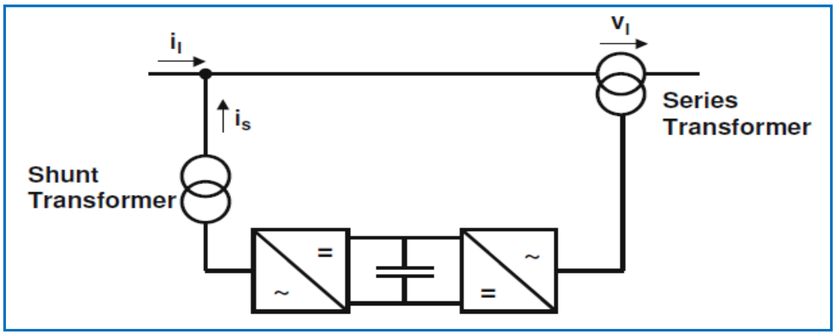


Fig. 1 Principle configuration of an UPFC

The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. This setup, as shown in Figure1,provides the full controllability for voltage and power flow. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously [3]

2.2 Operating Principle Of Upfc

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer. A basic UPFC functional scheme is shown in **fig.2.**

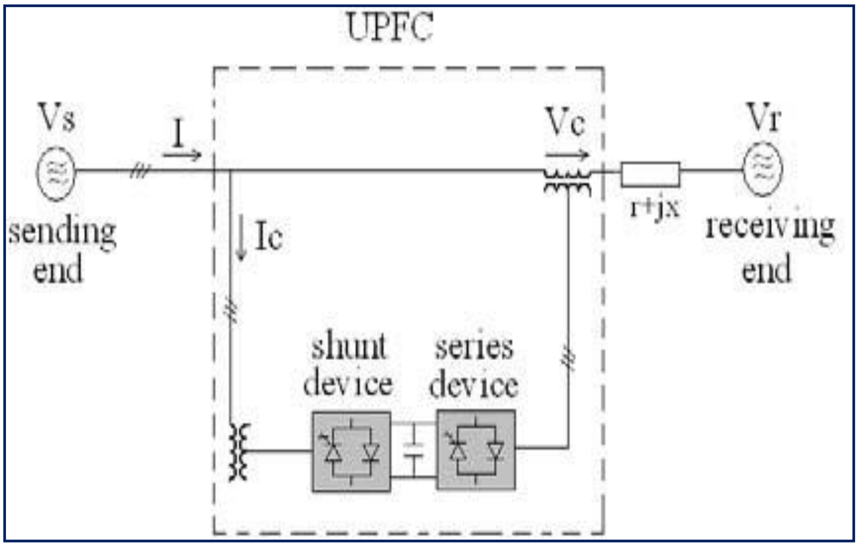


Fig.2 UPFC functional operation

The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point [3].

The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power low on the line.

The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, I_{sh} into the transmission line. The shunt inverter can be controlled in different modes [3].

VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, V_{dc}, is also required.

Automatic Voltage Control Mode: The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways.

Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phase angle of the series voltage.

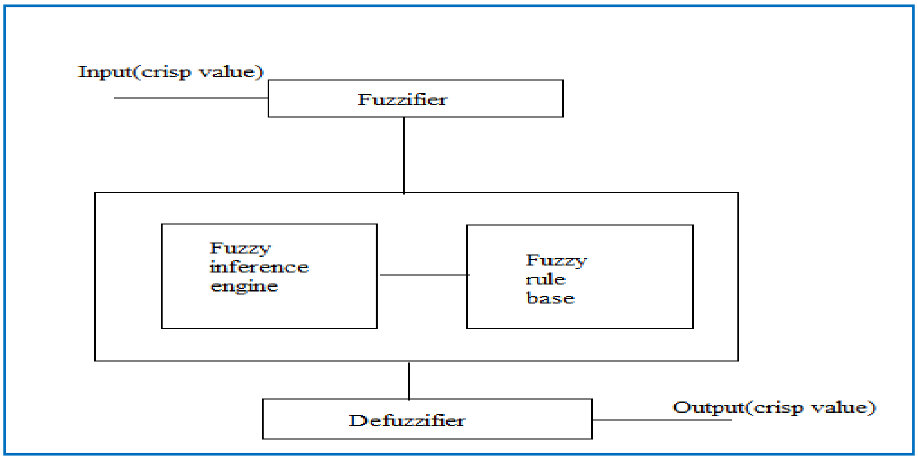
Phase Angle Shifter Emulation mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage. Line Impedance Emulation mode: The reference input is an impedance value to insert in series with the line impedance

Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

III. FUZZY LOGIC CONTROLLER

3.1. Fuzzy Logic:

In a fuzzy logic controller (FLC), the dynamic behavior of a fuzzy system is characterized by a set of linguistic description rules based on expert knowledge. The expert knowledge is usually of the form IF (a set of conditions are satisfied) THEN (a set of consequences can be inferred). Since the antecedents and the consequents of these IF-THEN rules are associated with fuzzy concepts (Linguistic terms), there are often called fuzzy conditional statements [4]. A fuzzy control rule is a fuzzy conditional statement in which the antecedent is a condition in its application domain and the consequent is a control action for the system under control. Basically, fuzzy control rules provide a convenient way for expressing control policy and domain knowledge. Furthermore several linguistic variables might be involved in the antecedents and the conclusion of these rules. When this is the case the system will be referred as multiple input multiple output fuzzy systems **[5].**



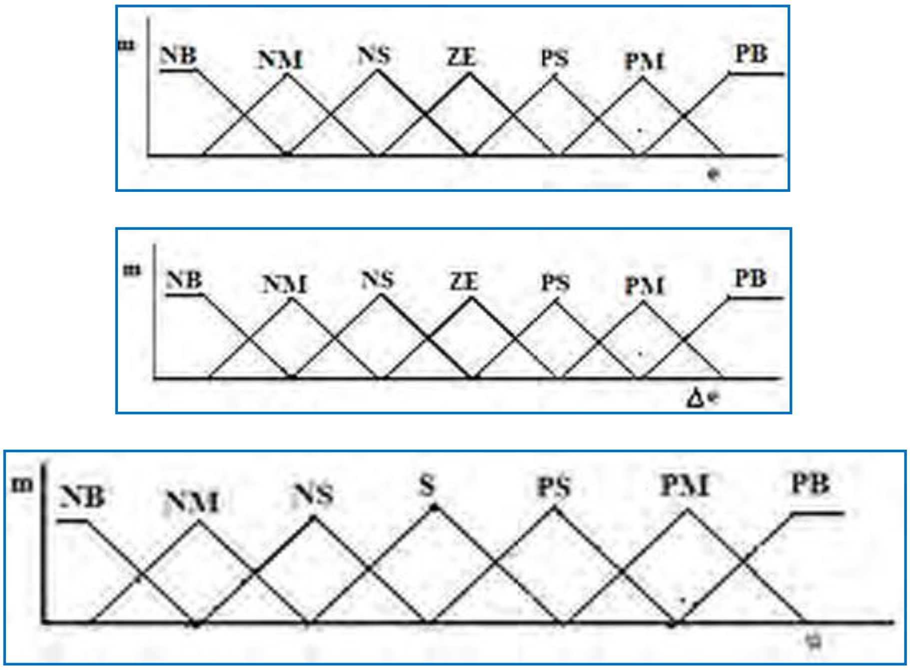


Fig.3. Membership Functions

The table shows the rule base. The rule is represented such as
If e is NM and Δe and PS then u is NS.

Δe \ e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

Fig.4. Fuzzy rule

Similarly membership function for gain updating factor is obtained

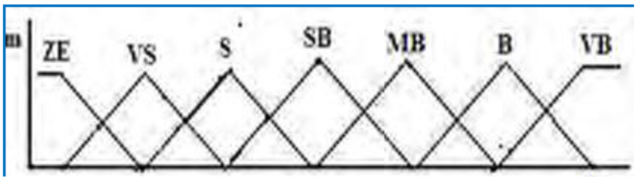


Fig.5. Membership function for Beta

The rule for gain updating factor is represented as
If e is E and Δe is ΔE then β is β.

The output scaling factor is modified by self tuning mechanism. The normalized values of error, change in error and output is given by

$e_N = N_e\ e$, $\Delta e_N = N_{\Delta e}\ \Delta e$, and $\Delta u = (\beta\ N_u)\Delta u_N$

Δe \ e	NB	NM	NS	ZE	PS	PM	PB
NB	VB	VB	VB	VB	B	MB	SB
NM	VB	VB	VB	B	MB	SB	S
NS	VB	VB	B	MB	SB	S	VS
ZE	VB	B	MB	SB	S	VS	ZE
PS	B	MB	SB	S	VS	ZE	ZE
PM	MB	SB	S	VS	ZE	ZE	ZE
PB	SB	S	VS	ZE	ZE	ZE	ZE

Fig. 6. Fuzzy rule

where Ne and NΔe are the input scaling factor of error and change of error respectively and Nu is the output scaling factor. The rule base is shown in fig 6

IV. SIMULATION RESULTS

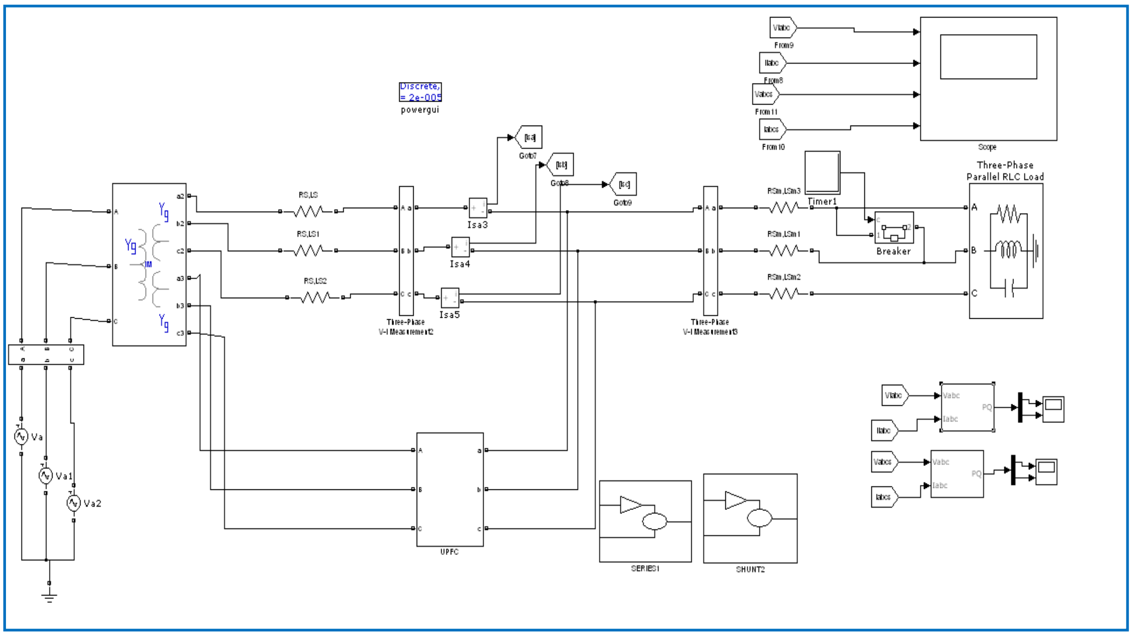


Fig.7 Simulink model of proposed system connected to linear load

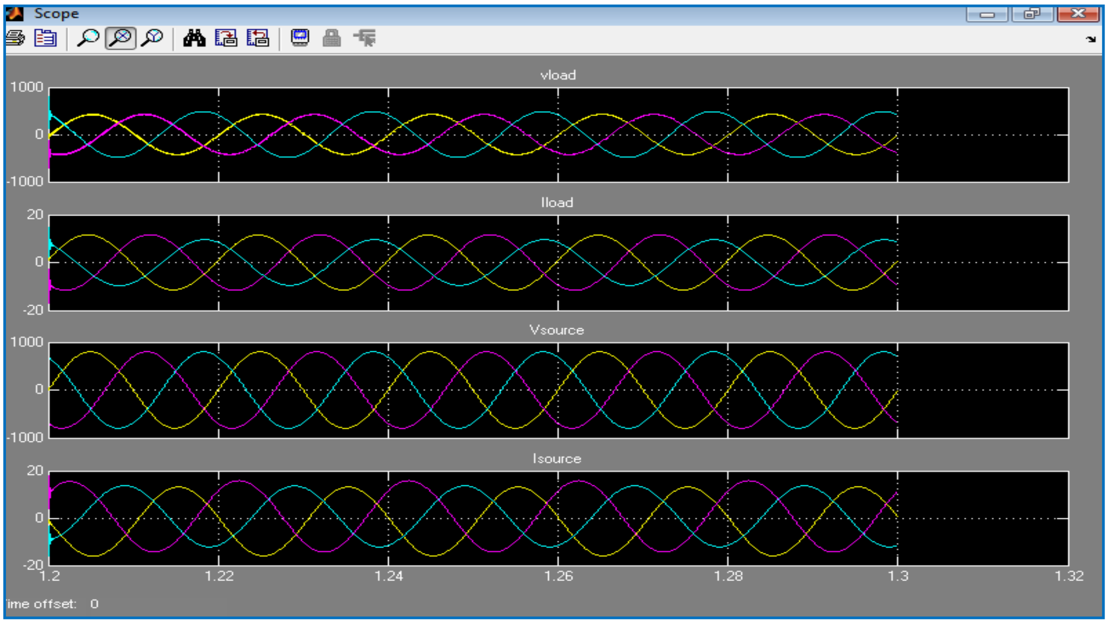
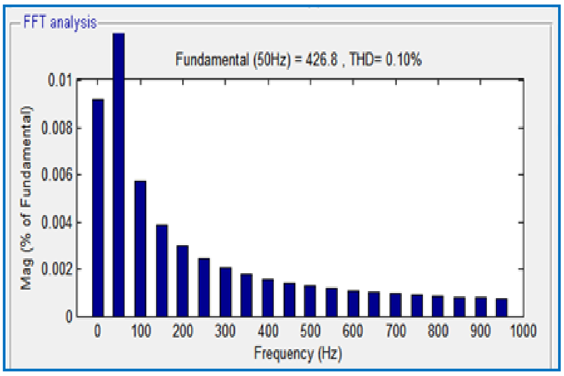
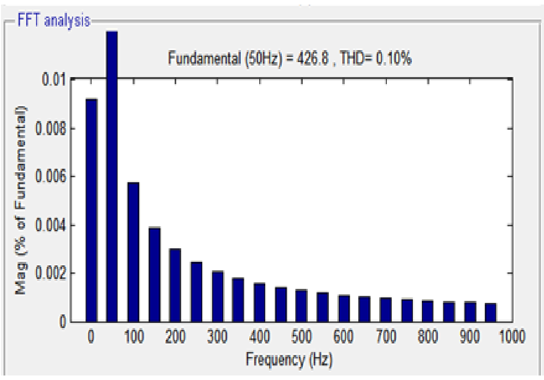


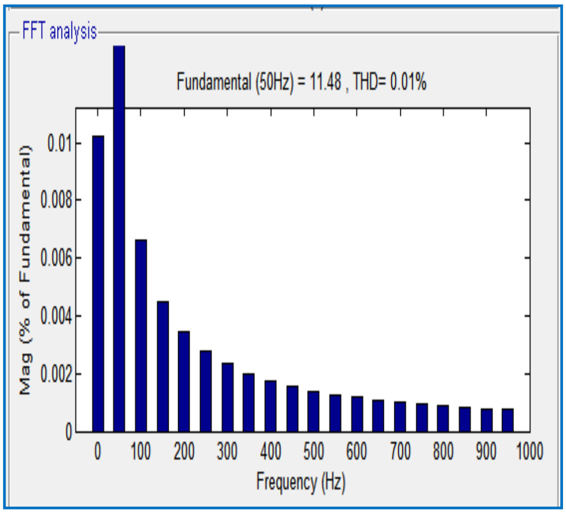
Fig. 8 Waveforms of Load Voltage, unbalanced load current, balanced source current, source voltage with unbalanced linear load



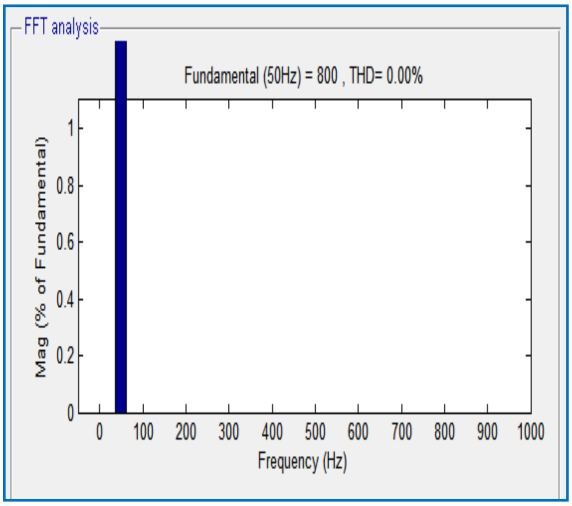
(a)



(b)



(c)



(d)

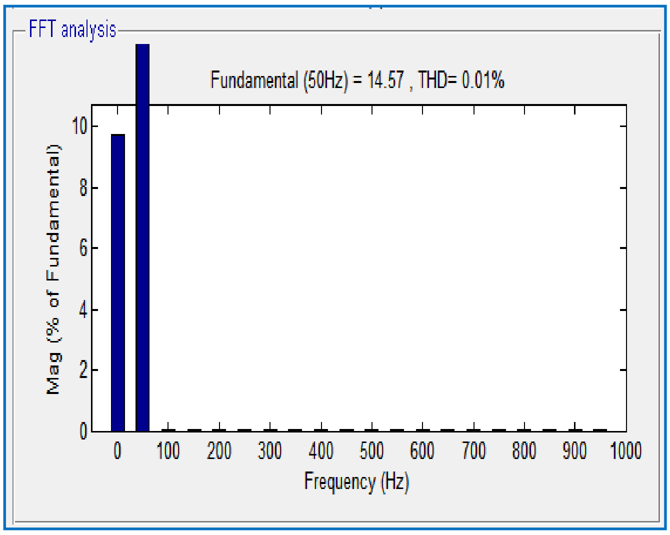
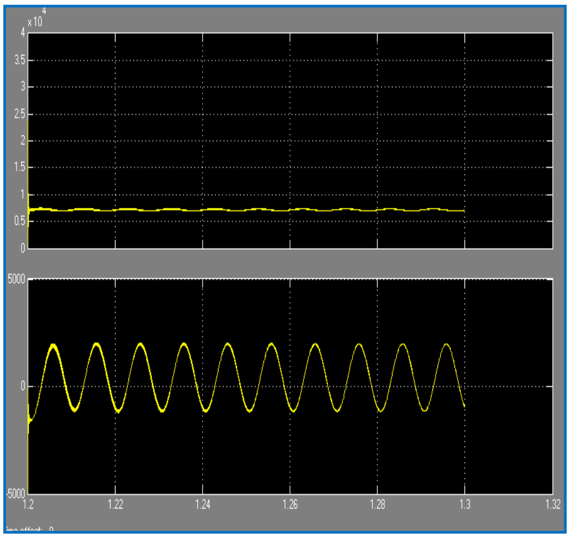
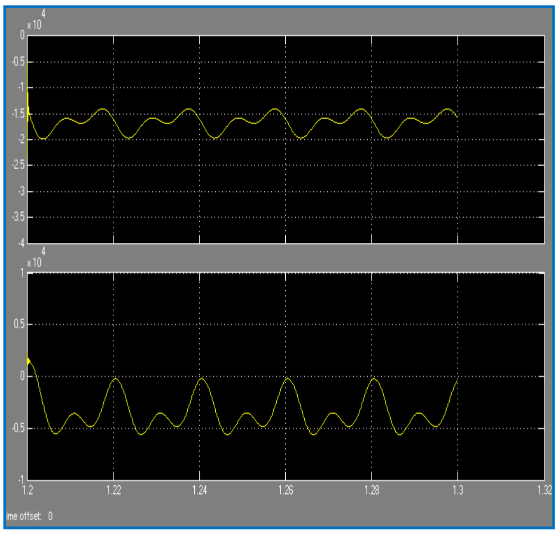


Fig.9 THD of (a) Load Voltage, (b) unbalanced load current, (c) balanced source current, (d) source voltage with unbalanced linear load



(a)



(b)

Fig. 10 waveform of active and reactive power (a) load side, (b) source side with linear load

V. NONLINEAR UPFC

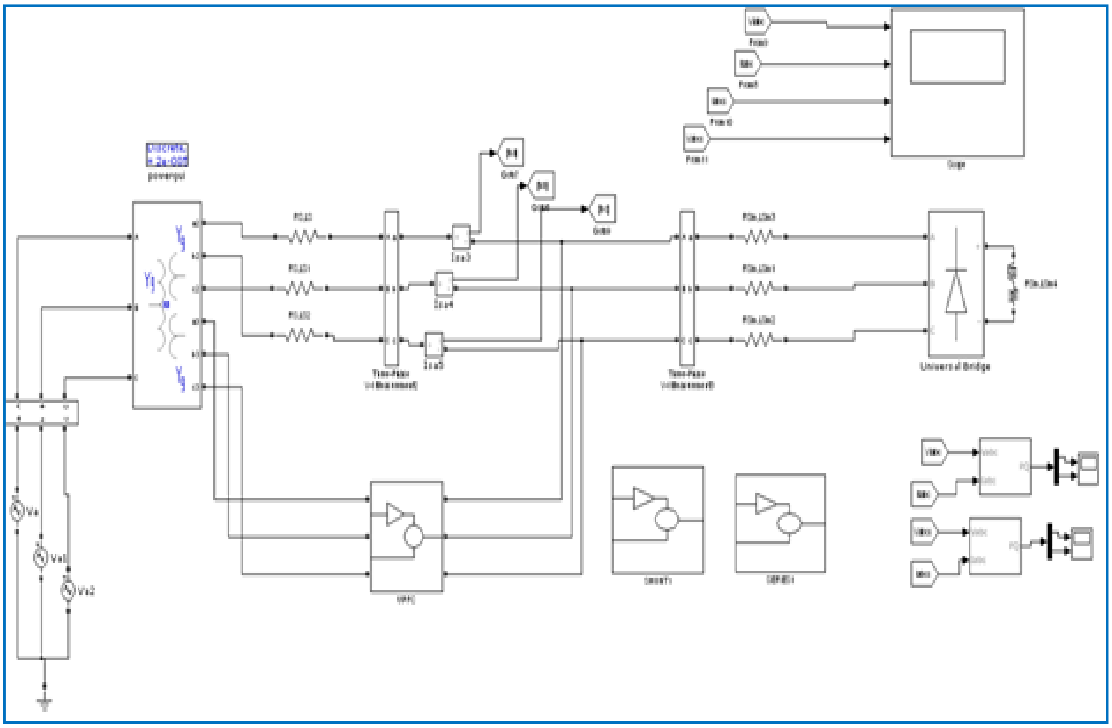


Fig.11 Simulink model of proposed system connected to non linear load

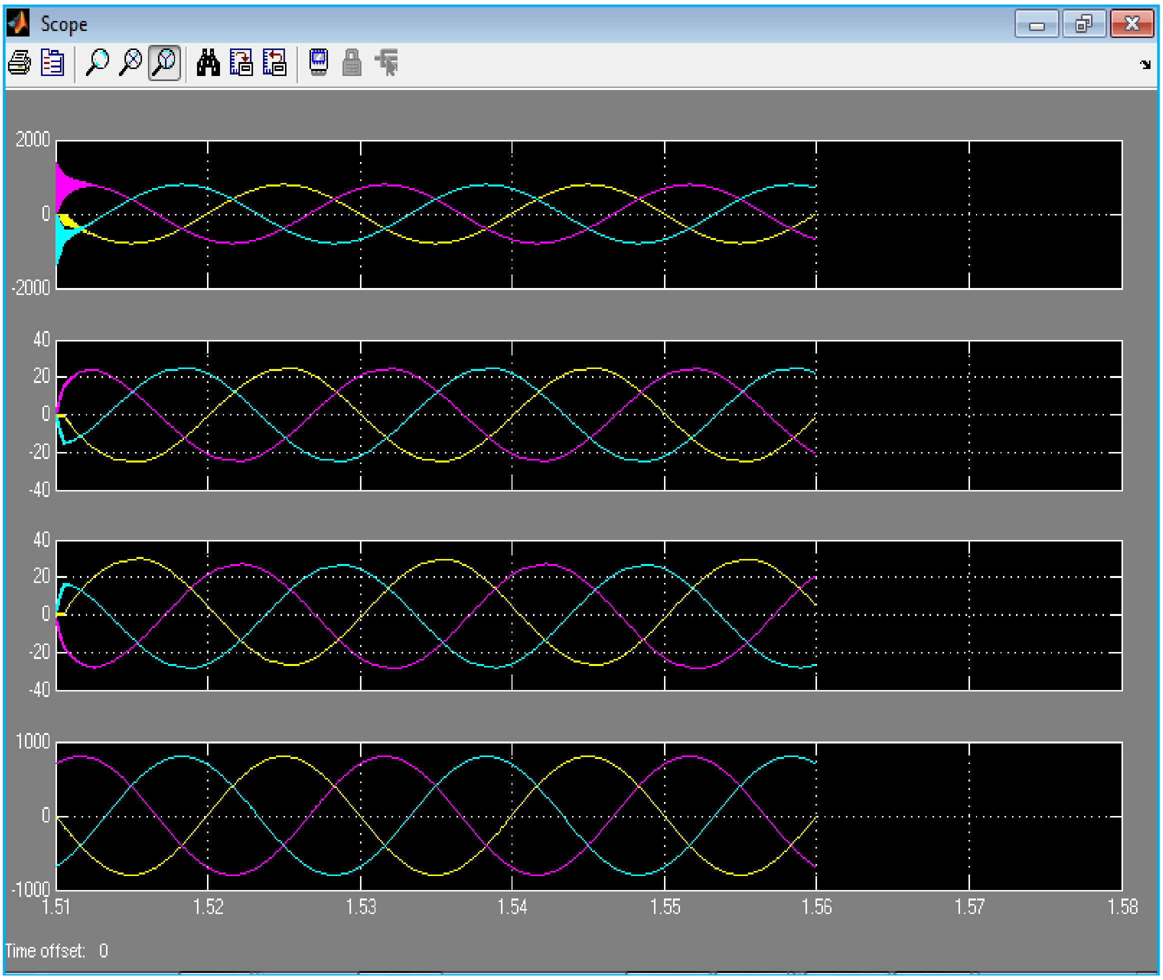
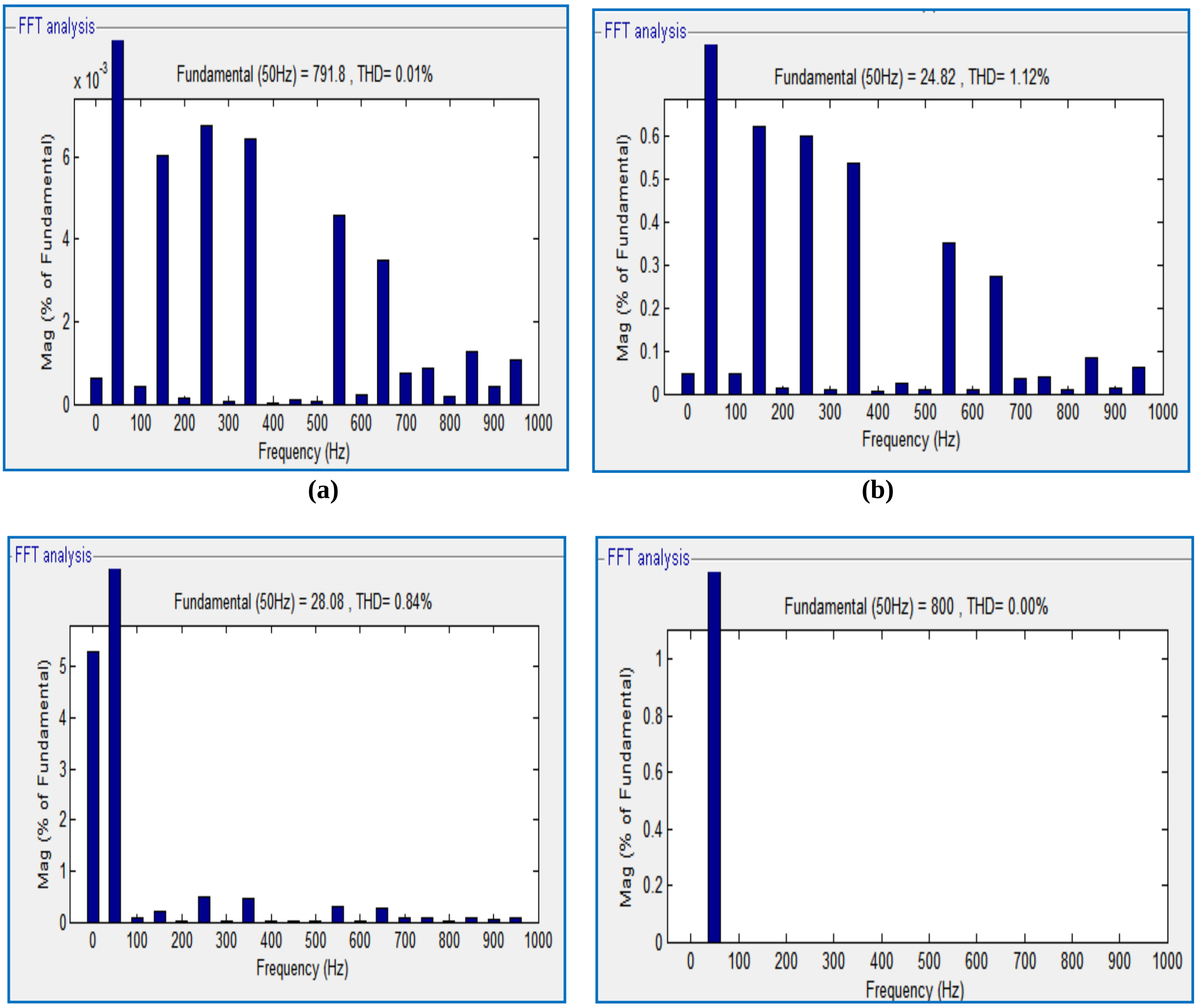


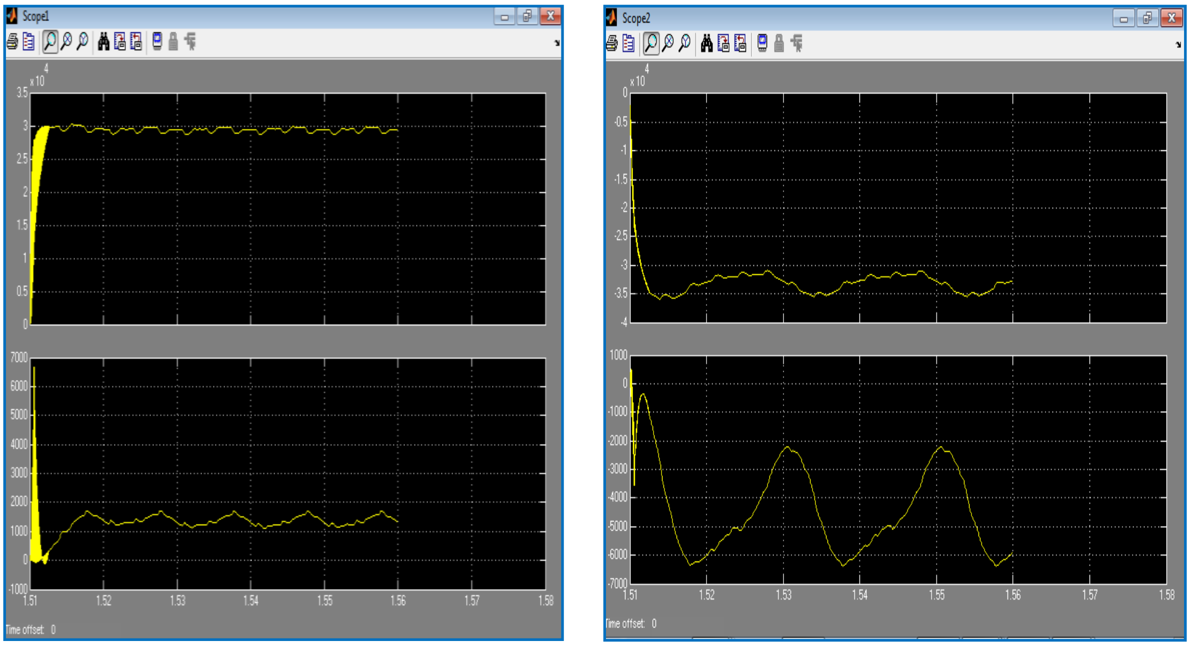
Fig. 12. Waveforms of Load Voltage, load current, source current, source voltage with non linear load



(a) (b)

(c) (d)

Fig.13 THD of (a) Load Voltage, (b)load current,(c) source current,(d) source voltage with non linear load



(a) (b)

Fig. 14 waveform of active and reactive power (a) load side, (b) source side with non linear load

VI. CONCLUSION

This paper presents the of fuzzy logic based UPFC to mitigate the harmonics, current balancing and investigate THD in distribution system. The simulation is carried out for both linear and non-linear loads. The fuzzy controller is different from conventional controller as it attempts to implement the operator's knowledge rather than mathematical equations of plant. The control engineer can design the fuzzy rule base for fuzzy controller and as well as fuzzy rule base for gain updating factor according to our knowledge. The proposed fuzzy based controller is proven to improve the performance of conventional controller.
Matlab based simulation results have verified the effectiveness of the design methodology. It significantly enhances the power system stability.

APPENDIX

Source Parameters

Line Voltage	415V Source Frequency	50Hz
Ripple filter	Rr=4 Ω, Cr= 35μF	
UPFC PARAMETERS		
DC Bus voltage	800V Switching Frequency	10kHz DC
Bus Capacitor	11000 μF	

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