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Performance Enhancement Of Power Balance Theory Based DSTATCOM Using Fuzzy Logic Controller

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Abstract

In this paper performance enhancement of Power Balance Theory (PBT) based DSTATCOM (Distribution Static Compensator) using Fuzzy logic controller for power factor improvement is investigated. Distribution system has poor power quality due to insufficient reactive power during steady and dynamic state. DSTATCOM is promising shunt connected custom power device for solving power quality issues. DC Bus Capacitor voltage is regulated by fuzzy logic controller and investigated the performance over PI controller for UPF mode of operation.

Simulation is also done for implementation of PBT based DSTATCOM (Distribution Static Compensator) using Fuzzy logic controller for Reactive power management and performance over PI based DSTATCOM is observed. The simulation results show that fuzzy logic control provides better system response and improvement in THD (Total Harmonic Distortion) of source current over PI controller.

Keywords: *Power Balance Theory, DSTATCOM, Fuzzy Logic Control, PI control, Power quality.*

1. Introduction

Most common problems encountered in Power distribution system are poor Power Quality due to non linear and dynamic loads. With the advancement in technology, power electronic converters are widely used for control of appliances, which hampers the power quality both at source as well as load end. Reactive power requirements of load, results in poor voltage regulation and increases losses in the system which necessities the entire power system to operative at higher MVA than as per load requirements. At the outset, Reactive power management at load end supports the system for power factor improvement and voltage regulation of the system, which improves the regulation and minimizes the losses in system. Reactive power control at the load end is managed by a promising shunt connected custom power compensating device, DSTATCOM [1]. DSTATCOM (Distribution static compensator) consists of VSC. It is used in the distribution system and is more efficient in generating reactive power at load side It mitigates the current based power quality problems in a distribution system such as reactive power, harmonics and unbalance neutral current [2] .DSTATCOM uses PI controller for stabilising DC bus voltage across capacitor [3] However PI controller works satisfactorily and give best results, but for dynamic and highly non linear loads the stability of the system hampers. A Fuzzy controller gives better performance under dynamic as well as for non linear loads [4]-[6]. In this Paper the Performance Enhancement of Power balance theory (PBT) for control of DSTATCOM using Fuzzy controller is proposed over PI controller. The comparative results are analyzed and found that Fuzzy logic controller gives better response compared to PI controller. The PBT control algorithm for DSTATCOM implemented using PI and fuzzy logic controls are discussed.

2. System configuration and control Algorithm

Fig.1 shows the power module for implementation of PBT based DSTATCOM for reactive power management in Distribution system [7]. Carrier based Pulse width modulation technique is implemented for generation of pulses for operating 2-Level Voltage source converter [8]. A three phase linear load is connected to the source for validation of algorithm in Matlab environment by using Sim power system Block sets for reactive power management in two modes of control strategies i.e., PI controller and Fuzzy Logic controller. Fig.2 shows schematic diagram for extraction of reference currents using PBT based algorithm [1].

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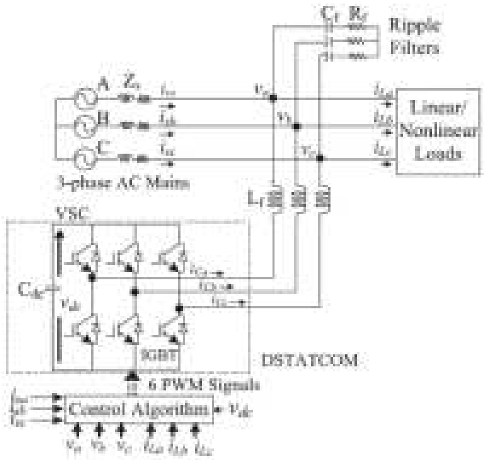

Fig. 1 Schematic diagram of VSC based three phase DSTATCOM.

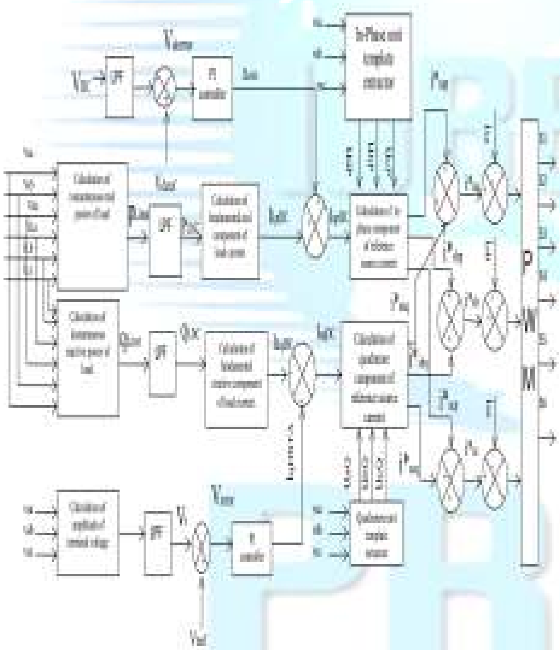

Fig. 2 Schematic diagram of PBT based control Algorithm for extracting reference source currents

This PBT control algorithm is based on extraction of fundamental components of load currents from instantaneous power consumed by the loads. This algorithm needs the sensing of PCC voltages, supply currents, load currents, and DC bus voltage of the VSC of the DSTATCOM. The fundamental active power component of load current is added to the output of the DC link PI voltage controller in order to generate the fundamental active power component of reference supply currents. The fundamental reactive power component of load currents is subtracted from the output of the AC terminal voltage PI controller to estimate the fundamental reactive power component of reference supply currents. These active and reactive power reference supply currents are DC quantities corresponding to fundamental currents. The instantaneous active power components of reference supply currents are estimated by multiplying the amplitude of active power component of reference supply currents by in-phase unit templates and the reactive power components of reference supply currents are obtained by multiplying the amplitude of reactive reference supply currents by quadrature unit templates. Finally, reference supply currents of each phase are generated by adding in-phase and quadrature reference supply currents of the corresponding phases.

The instantaneous active and reactive power of the load are calculated as

$$pL = vsaiLa + vsbiLb + vsciLc$$

$$pL = PLDC + PLAC \tag{1}$$

$$qL = \left(\frac{1}{\sqrt{3}}\right)(vsa - vsb)iLc + (vsb - vsc)iLa + (vsc - vsa)iLb$$

$$qL = QLDC + QLAC \tag{2}$$

From the instantaneous active power (pL) and reactive power (qL) of the loads, the fundamental components of active power (PLDC) and reactive power (QLDC) of the loads are extracted using LPFs (low-pass filters).

The amplitude of the fundamental reactive power component of load currents is obtained from average load power (PLDC) as

$$ILpDC = (2/3)(PLDC/Vsp) \tag{3}$$

Similarly, the amplitude of the fundamental reactive power component of load currents is obtained from the DC component of reactive power (QLDC) as

$$ILqDC = (2/3)(QLDC/Vsp). \tag{4}$$

The amplitude of the active power component of reference supply currents is estimated by adding the output of the DC voltage PI controller of the DSTATCOM to the fundamental active power of the load currents. The output of the DC voltage PI controller (I_{loss}) is considered as the loss component of the DSTATCOM is estimated. Therefore, the instantaneous value of the amplitude of the fundamental active power component of reference supply currents is

$$IspDC = Iloss + ILpDC \tag{5}$$

The instantaneous value of the fundamental active power component of reference three-phase supply currents are estimated by multiplying in-phase unit templates and the amplitude of the active power component of reference supply currents. Three phase instantaneous in-phase reference supply currents are

$$i*sap = usaIspDc,$$
$$i*sbp = usbIspDC,$$
$$i*scp = uscIspDc. \quad (6)$$

The amplitude of the reactive power component of reference supply currents is estimated by subtracting the fundamental reactive power component of the load currents from the fundamental reactive power component of the DSTATCOM current. The reactive power component of the DSTATCOM current is estimated by using a terminal voltage PI controller and it is considered as IqDSTAT. Therefore, the instantaneous value of the amplitude of the fundamental reactive component of reference supply currents is

$$IsqDC = IqDSTAT - ILqDC. \quad (7)$$

The instantaneous values of the fundamental reactive power component of reference three phase supply currents are estimated by multiplying quadrature unit templates by the amplitude of the reactive component of reference supply currents given in above equation. Three Phase instantaneous quadrature reference supply currents are estimated as

$$i*saq = usaqIsqDC$$
$$i*sbq = usbqIsqDC,$$
$$i*scq = uscqIsqDC. \quad (8)$$

Instantaneous fundamental reference supply currents are estimated by adding in-phase and quadrature reference supply currents:

$$i*sa = i*sap + i*saq,$$
$$i*sb = i*sbp + i*sbq,$$
$$i*sc = i*scp + i*scq. \quad (9)$$

These reference three-phase supply currents (i*sa, i*sb, i*sc) are compared with respective sensed three phase supply currents (isa,isb,isc) to estimate current errors. These current errors are amplified and amplified current errors are compared with the triangular carrier wave to generate the switching pulses of the VSC of the DSTATCOM.

3. Fuzzy Logic Control of DSTATCOM.

A fuzzy logic controller (FLC) consists of four elements, which are a fuzzification interface, a rule base, an inference mechanism, and a defuzzification interface. A FLC is designed for voltage regulation of DC bus, The design of the FLC for DC voltage regulator is described in detail [9]-[10]. The design of the fuzzy controllers for the AC and current regulators follows similar procedure. FLC designed for DC voltage regulator has two inputs and one output. The error $e(t)$($e = Vdcref - Vdc$) and the rate of change of error $\dot{e}(t)$ the inputs and the output of the FLC is ΔId. In fact, ΔId is integrated to produce $Idref$. Fig.3 shows schematic diagram for implementation of FLC for DC voltage regulation across DC Link capacitor [3] .where GE, GCE, and GCU are the scaling factors for the inputs and output respectively. The linguistic variables for error $e(t)$, the rate of change of error $\dot{e}(t)$ and the controller output ΔId will take on the following linguistic values:

NL = Negative Large
NM = Negative Medium
NS = Negative Small
ZO = Zero
PS = Positive Small
PM= Positive Medium
PL = Positive Large.

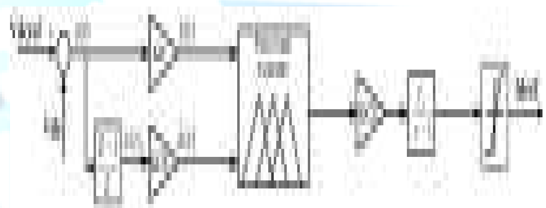

Fig. 3 schematic diagram for implementation of FLC diagram.

The above linguistic quantification has been used in this paper to specify a set of rules or a rule-base. The rules are formulated from practical experience. For the FLC with two inputs and seven linguistic values for each input, there are $7^2 = 49$ possible rules with all combination for the inputs. The tabular representation of the FLC rule base (with 49 rules) of the fuzzy control based DC voltage regulator is shown in Table I [3].

TABLE I. 7 × 7 FLC RULE-BASE IN TABULAR FORM

$e(t)$ \ $\dot{e}(t)$	NL	NM	NS	ZO	PS	PM	PL
PL	ZO	PS	PM	PL	PL	PL	PL
PM	NS	ZO	PS	PM	PL	PL	PL
PS	NM	NS	ZO	PS	PM	PL	PL
ZO	NL	NM	NS	ZO	PS	PM	PL
NS	NL	NL	NM	NS	ZO	PS	PM
NM	NL	NL	NL	NM	NS	ZO	PS
NL	NL	NL	NL	NL	NM	NS	ZO

The membership functions to be employed for the inputs/output are of the triangular type. The membership functions for the inputs and the output of the fuzzy controller for the DC voltage regulator are shown in following 4,5and 6 respectively.

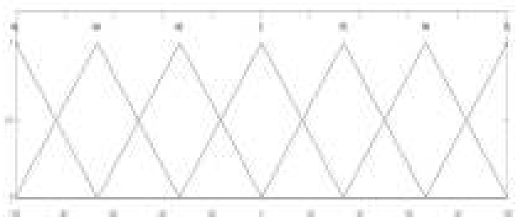

Fig. 4 Membership functions considered for scaling input error *e*(*t*).

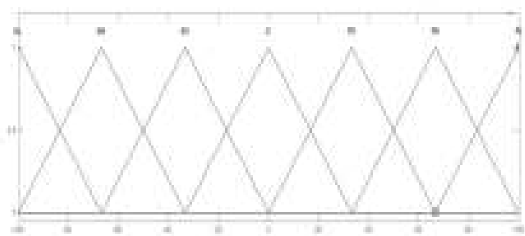

Fig. 5 Membership functions considered for scaling the rate of change of error *e*(*t*)

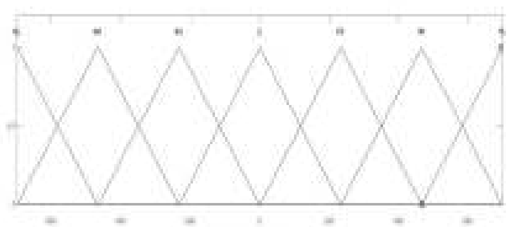

Fig. 6 Membership functions considered for scaling the output.

4. Results

In this section Simulation results related to PBT based DSTATCOM are observed for the following cases i) Without DSTATCOM, ii)DSTATCOM with PI controller, iii) DSTATCOM with fuzzy logic controller. Fig. 7 shows Reactive Power Compensation without DSTATCOM and it is clear that the required reactive power is supplied form the source. Fig.8 shows Reactive Power Compensation with DSTATCOM using PI controller and it is observed from the figure that the required reactive power is supplied by DSTATCOM. Fig.9 shows Reactive Power compensation with DSTATCOM using fuzzy logic controller where it is observed the reactive power supplied from the source in comparison with PI controller found to be less

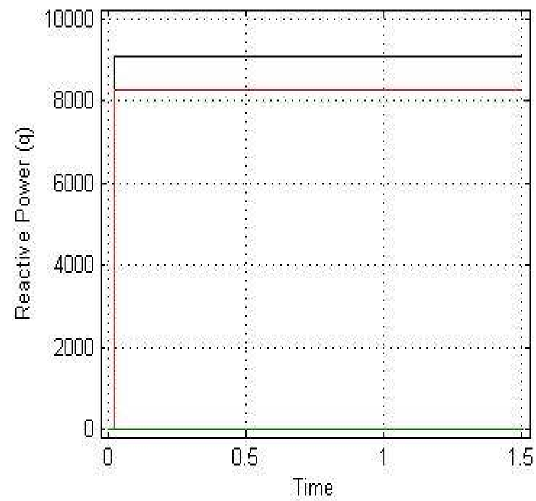

Fig. 7 Reactive power flow in the system without DSTATCOM

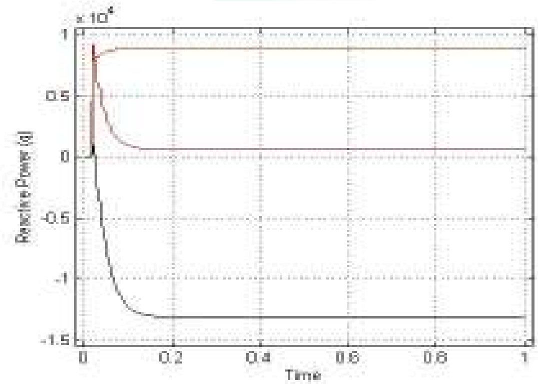

Fig.8 Reactive Power flow in the system with DSTATCOM using PI controller.

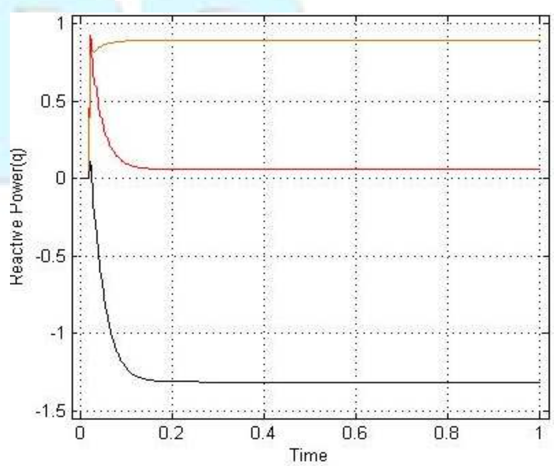

Fig. 9 Reactive power flow in the System with DSTATCOM using Fuzzy Logic Controller.

From the Fig 10.a it is observed that source Phase voltage and current are out of phase in the absence of DSTATCOM From the Fig 10.b it is observed that source Phase voltage and current are in phase with PI controlled DSTATCOM . From the Fig 10.c it is observed that source Phase voltage and current are in phase even with Fuzzy controlled DSTATCOM. It can also observed that with fuzzy controlled DSTATCOM the current supplied form the source is less in comparison with PI and also stability of the system in terms of DC voltage regulation across DC bus capacitor is improved .

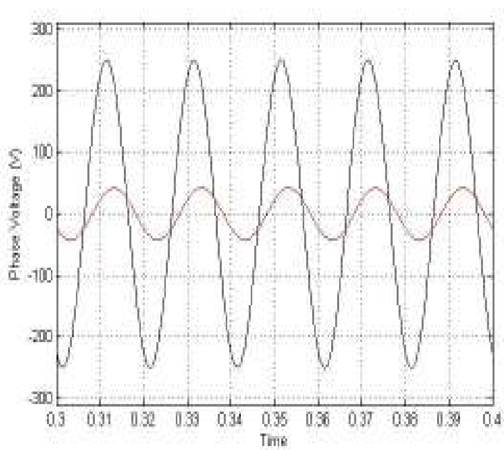

Fig. 10 (a) Source Phase Voltage and Current Relation Without DSTATCOM

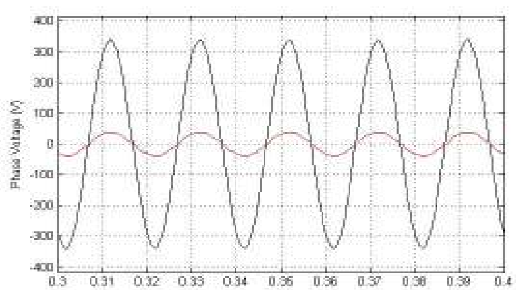

Fig. 10(b) Source Phase Voltage and Current Relation with PI controlled DSTATCOM

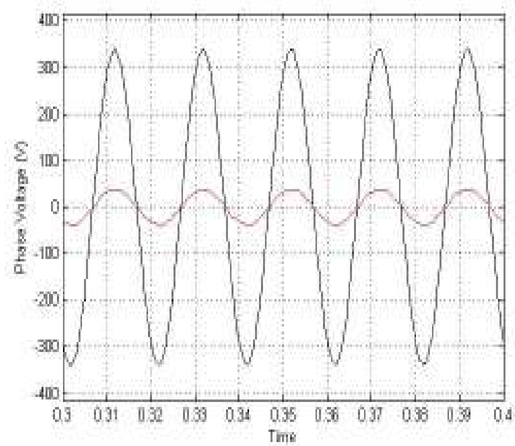

Fig. 10(c) Source Phase Voltage and Current Relation with Fuzzy Logic Controller controlled DSTATCOM

From the figure 11.a it is observed that Total Harmonic distortion of source current with PI controller based DSTATCOM is 4.07%. From the figure 11.b it is observed that Total Harmonic distortion of source current with Fuzzy controller based DSTATCOM is 3.55%.From the results it is clear that Fuzzy logic controller works efficiently as compared to PI controller.

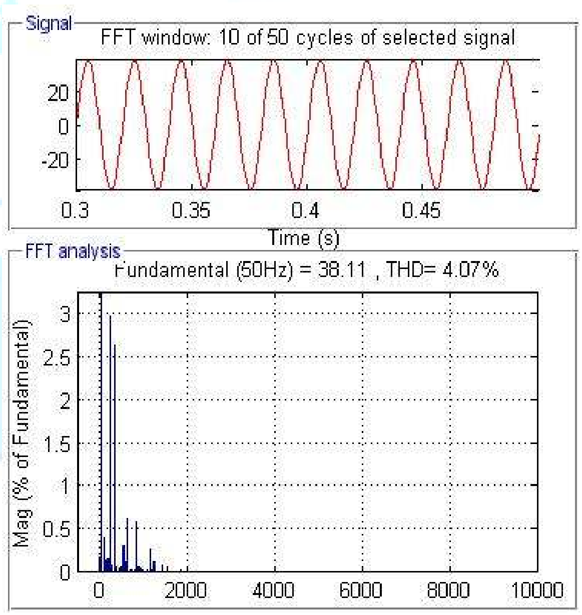

Fig. 11(a) Waveform and harmonic analysis of source phase current with PI controller.

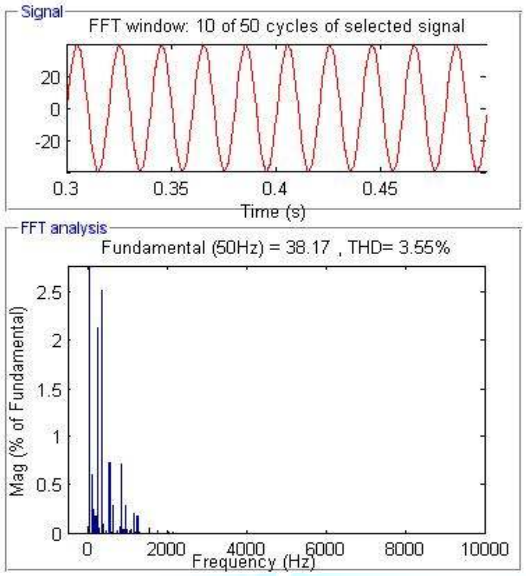

Fig. 11(b) Waveform and harmonic analysis of source line current with Fuzzy controller.

5. Summary and Conclusions

In this paper performance enhancement of PBT based DSTATCOM with PI and Fuzzy controllers are simulated using Matlab/Simulink for reactive power control. The performance of this algorithm for UPF mode of operation of DSTATCOM with PI and Fuzzy controllers is investigated and found that with Fuzzy controller the operation of DSTATCOM is more satisfactory with respective to improvement in Total Harmonic Distortion of source current and reactive power supplied by the source has been decreased in comparison with PI controlled DSTATCOM.

APPENDIX

Data for simulation

AC line to line voltage 415V, Frequency 50 HZ; Source Impedance: Rs=2Ω, Ls = 1mH;
Voltage source converter: Reference DC link voltage 700V, DC link Capacitor 128 μF, interfacing inductor 22mH, Switching frequency 10 kHz.
Load: Active Power 25KW, Reactive Power 15KVAR.

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