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Design and Simulation of Fuzzy Logic Controller for DSTATCOM in Power System

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Abstract: This paper mainly presents the Distribution Static Compensator (DSTATCOM) and control methodology of Direct Current (DC) capacitor voltage. Generally, the DC capacitor voltage is regulated using a Proportional Integral (PI) controller when various control algorithms are used for load compensation. However, during load changes, there is considerable variation in dc capacitor voltage which might affect compensation. In this study, a fuzzy logic based supervisory method is proposed to improve transient performance of the dc link. The fuzzy logic based supervisor varies the proportional and integral gains of the PI controller during the transient period immediately after a load change. A considerable reduction in the error in DC link capacitor voltage during load changes compared to a normal PI controller is obtained. The performance of the proposed strategy is proved using detailed simulation studies.

Keywords: *DSTATCOM; FACTS; FIS; Power Quality (PQ).*

1. INTRODUCTION

Capacitor banks were used for reactive power compensation and voltage regulation, but they have great problems such as stress and sudden changes in capacitors. Also their response to transient errors is very slow, so they were replaced by Static Var Compensators (SVC) which will reduce the time of response and improve the voltage stability [1] .But the SVC transient stability is low, so DSTATCOM is proposed to be used instead of these devices because it has fast response in compensation and voltage profile correction [2].

2. DISTRIBUTION STATIC COMPENSATOR

DSTATCOM is a shunt connected device designed to regulate the voltage either by generating or absorbing the reactive power. The schematic diagram of a DSTATCOM as shown in **Fig. 1** shows DC capacitor, Voltage Source Inverter (VSI), coupling transformer and reactor. It uses Pulse Width Modulation (PWM) switching technique for this purpose. This voltage is delivered to the system through the reactance of the coupling transformer. The voltage difference across the reactor is used to produce the active and reactive power exchange between the STATCOM and the transmission network [3]. This exchange is done much more rapidly than a synchronous condenser and improves the performance of the system.

3. CONTROL OF DSTATCOM

Fig. 2 shows synchronously rotating d-q frame (SRF) algorithm. The average values of ild and ilq are obtained from the low pass filters as ild_{dc} and ilq_{dc} and i_d and i_q are the output of the DC voltage PI controller and AC voltage PI controller. The desired reference source currents in d-q frame are obtained as:

$$I_{sd} = ild_{dc} + i_d \quad (1)$$

$$I_{sq} = ilq_{dc} + i_q \quad (2)$$

where, I_{sd} and I_{sq} are the estimated DC components of active and reactive currents of reference source currents ind-q frame [4].

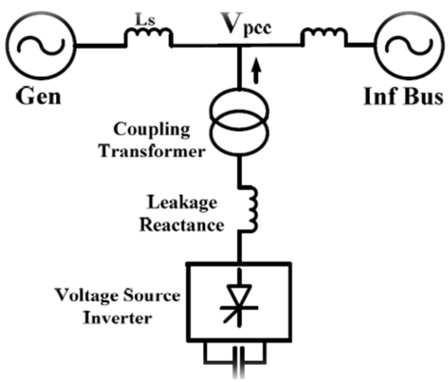

Fig. 1. Schematic diagram of DSTATCOM

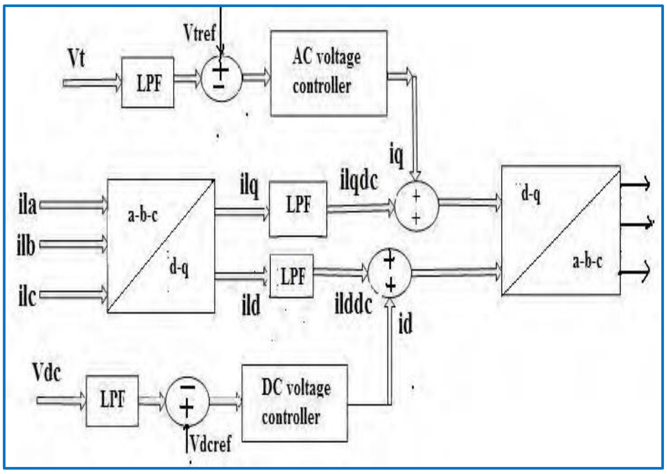

Fig. 2. Block diagram of SRF algorithm

3.1 Design of Fuzzy Logic Based Supervision of DC Link PI Control

A fuzzy logic based supervisor control is designed to manipulate the gains of PI controller employed for DC link voltage control [5]. The fuzzy supervisor is designed in such a way that the gains generated by the fuzzy supervisor which are added to the reference proportional and integral gains are able to maintain the DC Link voltage fairly constant so that voltage regulation is done satisfactorily [6]. **Fig. 3** shows the fuzzy supervisor implemented for DC link PI control.

3.2 Inputs and Outputs

The inputs of the fuzzy supervisor have been chosen as the error in DC link voltage and the change in error in DC link voltage [7]. The outputs of the fuzzy supervisor are chosen as the change in $k_p$value and the change in k_i value. The two inputs to the fuzzy controller are error and change in error, and the two outputs Dk_p and Dk_i are shown in the **Fig. 4**.

3.3 System Fuzzification

Seven triangular membership functions have been chosen: Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Large (PL) for both error (err) and change in error (derr). The input membership functions are shown in **Figs 5 and 6**. The membership functions for Dk_p and Dk_i are as shown in **Fig. 7 and 8**, respectively.

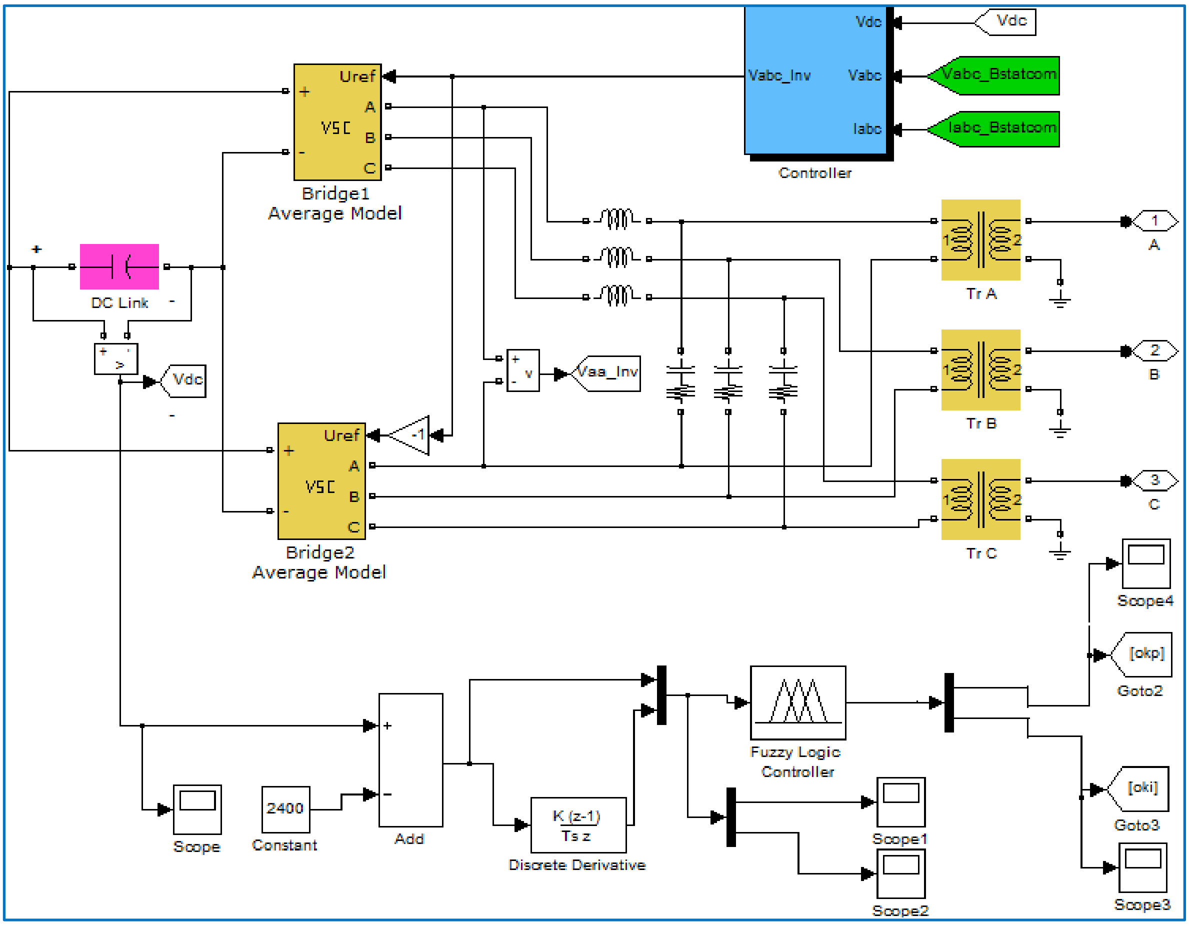

Fig. 3. Fuzzy controller for DC link

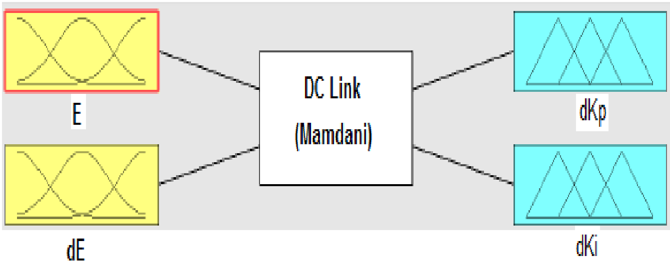

Fig. 4. Fuzzy logic controller

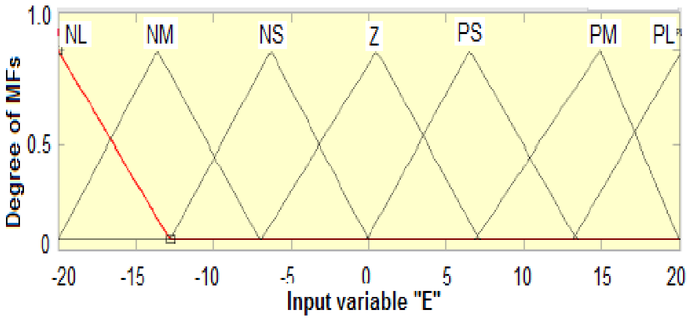

Fig. 5. Membership functions for error input

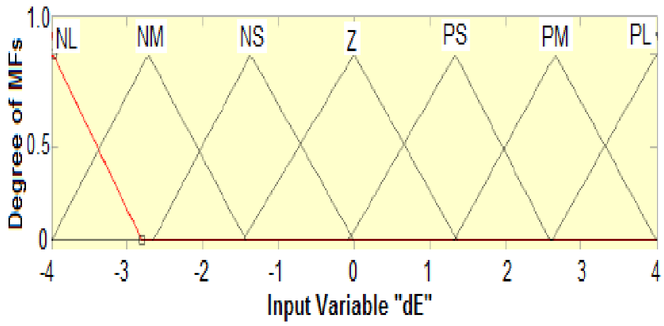

Fig. 6. Membership functions for change in error

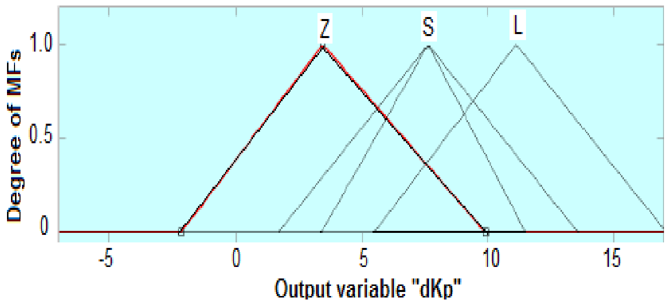

Fig. 7. Output membership functions for Dk_p

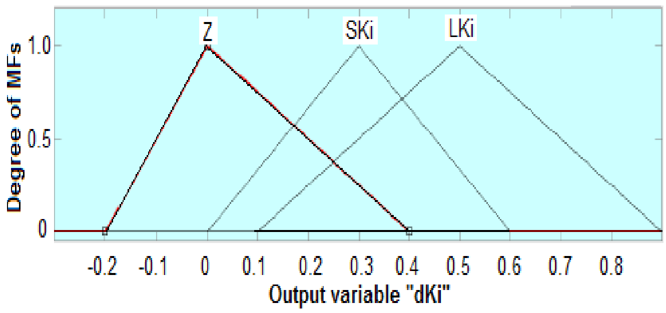

Fig 8. Output membership functions for Dk_i

3.4 The Rule Bases

In this study there are forty-nine rules for change in k_p and forty-nine rules for change in k_i.
Some rules for change in k_P are:
If error is NL and derr is NL then Dk_P is L
If error is NL and derr is NM then Dk_P is L
If error is NL and derr is NS then $Dk_P$is L
If error is NL and derr is Z then Dk_P is M
. . . . . .
. . . . . .
. . . . . .
If error is PL and derr is PM then $Dk_P$is L
If error is PL and derr is PL then Dk_P is L
The whole control rules for change in k_p are shown in **Table 1.**

Some rules for change in K_i are:
If error is NL and derr is NL then Dk_i is Sk_i
If error is NL and derr is NM then Dk_i is Sk_i
If error is NL and derr is NS then Dk_i is Sk_i
If error is NL and derr is Z then Dk_i is Z
. . . . . .
. . . . . .
If error is PL and derr is PM then Dk_i is Sk_i
If error is PL and derr is PL then Dk_i is Sk_iThe whole control rules for change in K_i are shown in **Table 2**.

3.6 Defuzzification

There are several methods for defuzzification, the center of gravity method has been used in this work, because in this method, the resultant crisp output is sensitive to all of the active fuzzy outputs of the inference mechanism.Figure9 shows the PI controller with inputs from DC link voltage with fuzzy logic supervisor.

Table 1. Rule base for change in k_p

error / derr	NL	NM	NS	Z	PS	PM	PL
NL	L	L	L	M	S	S	Z
NM	L	L	M	S	S	Z	S
NS	L	M	S	S	Z	Z	Z
Z	M	Z	Z	Z	Z	Z	M
PS	Z	Z	Z	S	S	M	L
PM	S	Z	S	S	M	L	L
PL	Z	S	S	M	L	L	L

Table 2. Rule base for change in ki

error / derr	NL	NM	NS	Z	PS	PM	PL
NL	Ski	Ski	Ski	Z	Z	Z	Z
NM	Ski	Ski	Ski	Z	Z	Z	Z
NS	Lki	Lki	Lki	Z	Z	Z	Z
Z	Lki	Lki	Lki	Z	Lki	Lki	Lki
PS	Z	Z	Z	Z	Lki	Lki	Lki
PM	Z	Z	Z	Z	Ski	Ski	Ski
PL	Z	Z	Z	Z	Ski	Ski	Ski

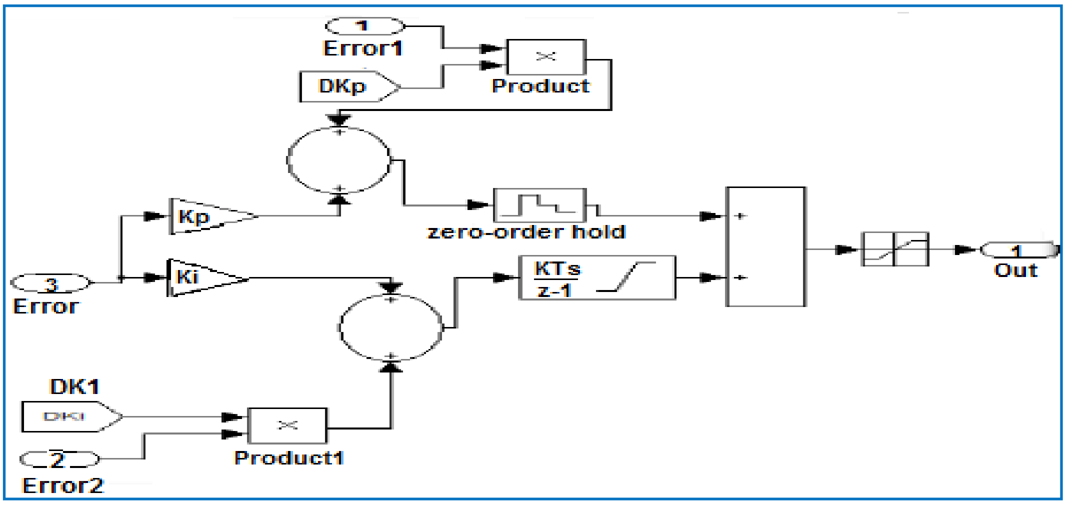

Fig. 9. PI controller with fuzzy supervisor

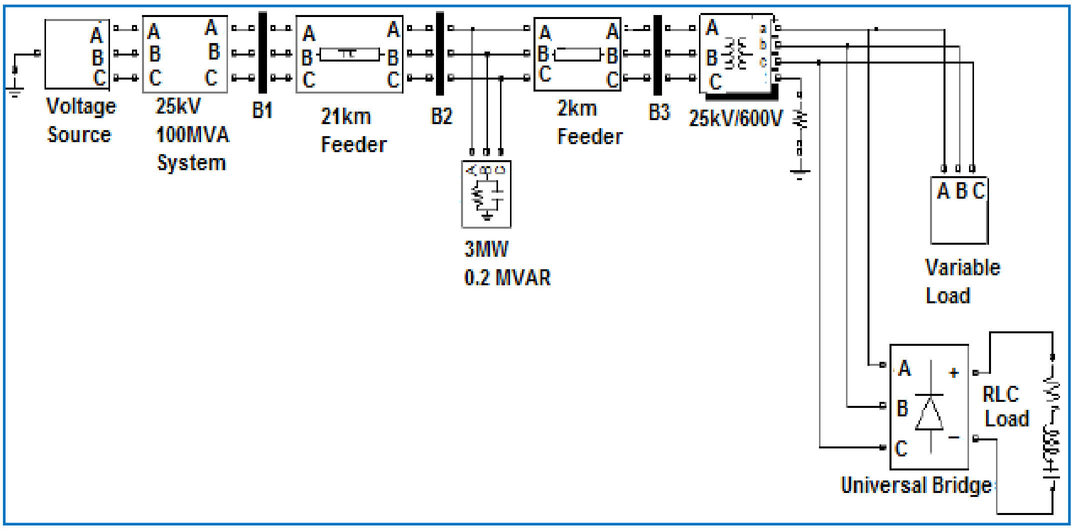

Fig. 10. MATLAB/Simulink model without DSTATCOM

4. SIMULATION RESULTS

Fig. 10 shows the MATLAB model for the system without DSTATCOM while **Fig. 11** shows three phase voltage in pu at Bus-3 without DSTATCOM using programmable voltage source.

4.1 System with DSTATCOM Voltage Controller

As shown in **Fig. 12**, DSTATCOM is connected to Bus-3 through 1.25/25 kV Linear transformers. The compensation capacity of DSTATCOM is +/- 3 MVAR and the voltage level of DC link is 2400V. The capacitance of DC link is 10000μF. **Fig. 13** shows the load voltage wave forms in case of connecting DSTATCOM. There is a considerable variation in the DC link voltage due to sudden voltage swell created at .4 seconds as shown in **Fig. 14**.

4.2 Fuzzy Logic Based Supervision of DC Link PI Control

Fig. 15 shows the DC link voltage after adding the fuzzy controller. The improved load voltage with implementation of fuzzy supervision is shown in **Fig. 16**. By comparing the DC link voltages without Fuzzy and with Fuzzy it found that reduction in the error in DC link capacitor voltage compared to a normal PI controller is obtained and also voltage waveform has a faster settling time

5. CONCLUSIONS

A fuzzy logic supervisory control of DC link PI controller in a DSTATCOM has been proposed. The supervisor varies the gain of the PI controller during the transient period in a way that improves the system performance. The system has been modeled and simulated in the MATLAB technical environment with a case study.

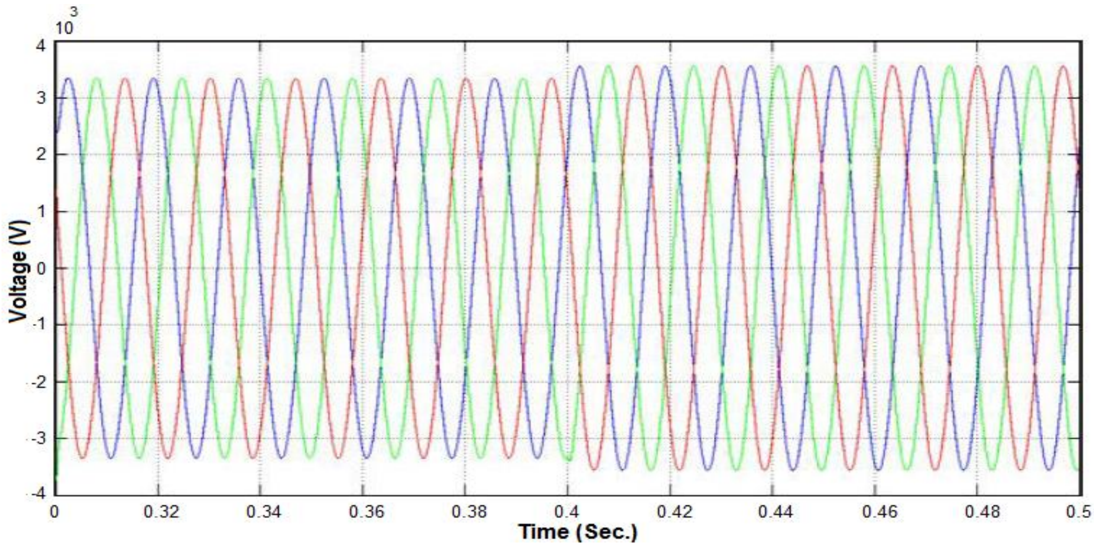

Fig. 11. Three phase Voltage in Pu at Bus-3 without DSTATCOM

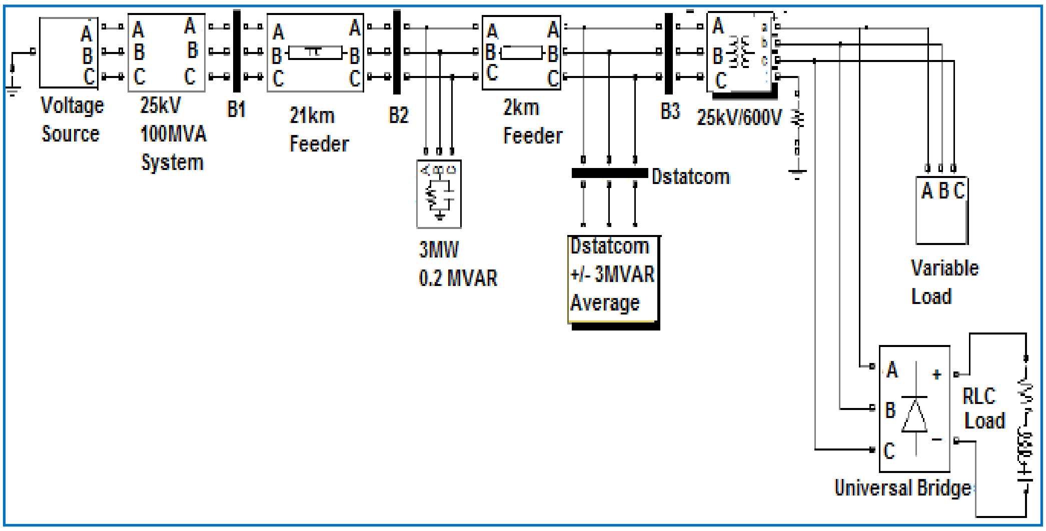

Fig. 12. Simulink model with DSTATCOM

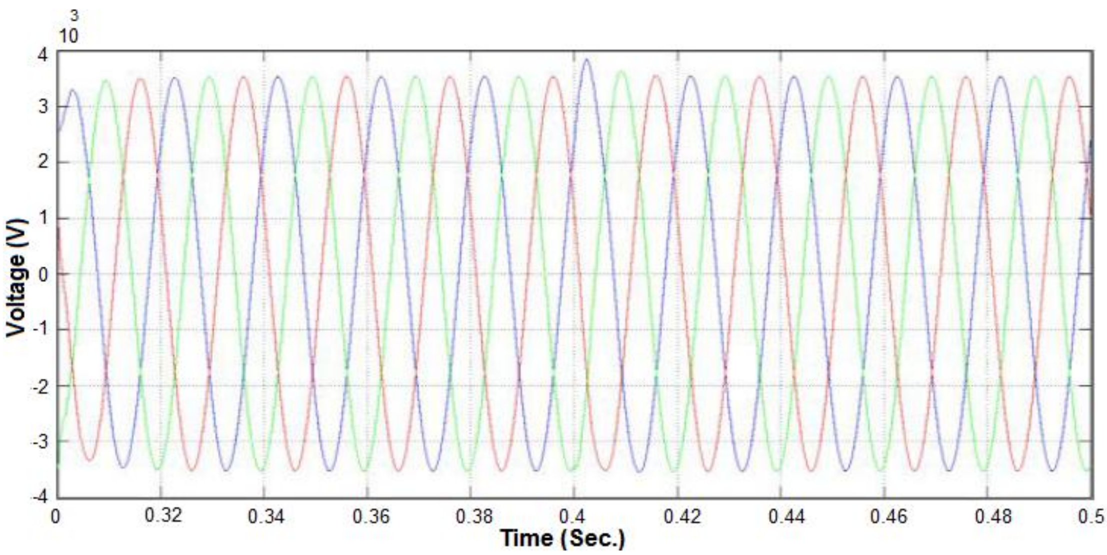

Fig. 13. Load Voltage waveforms with DSTATCOM

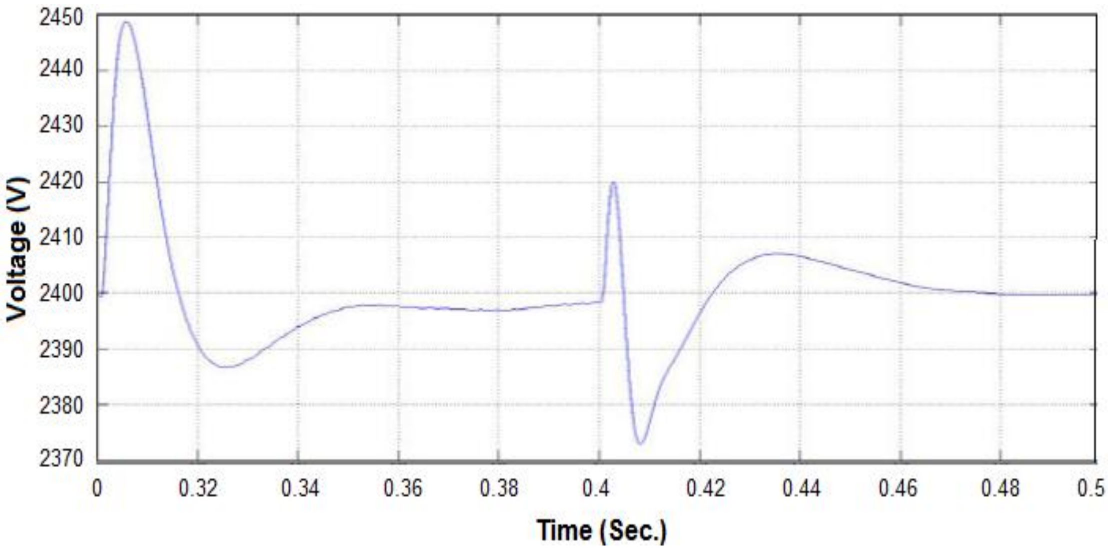

Fig. 14. DC Link voltage of DSTATCOM

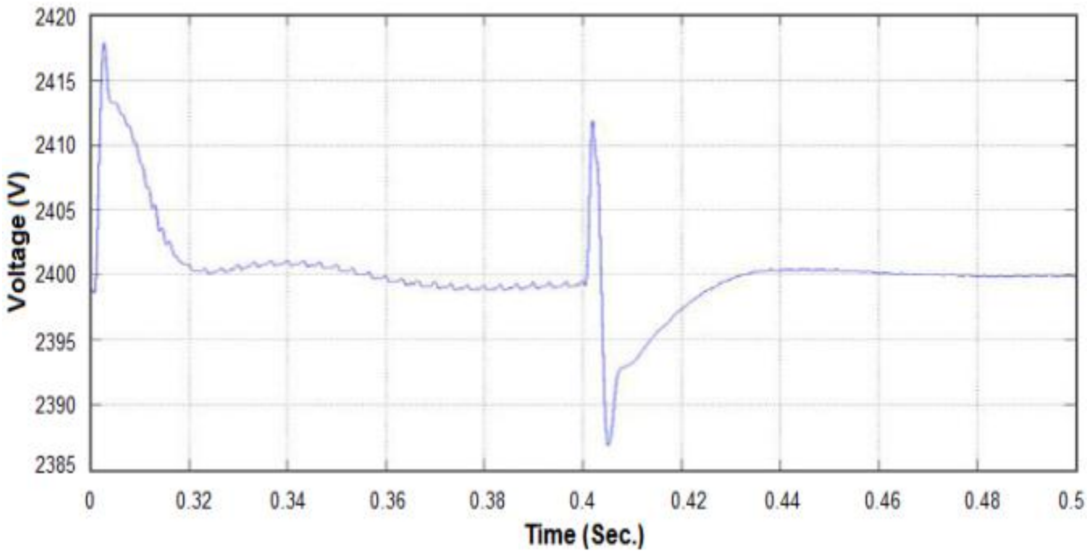

Fig. 15. DC link voltage with fuzzy design

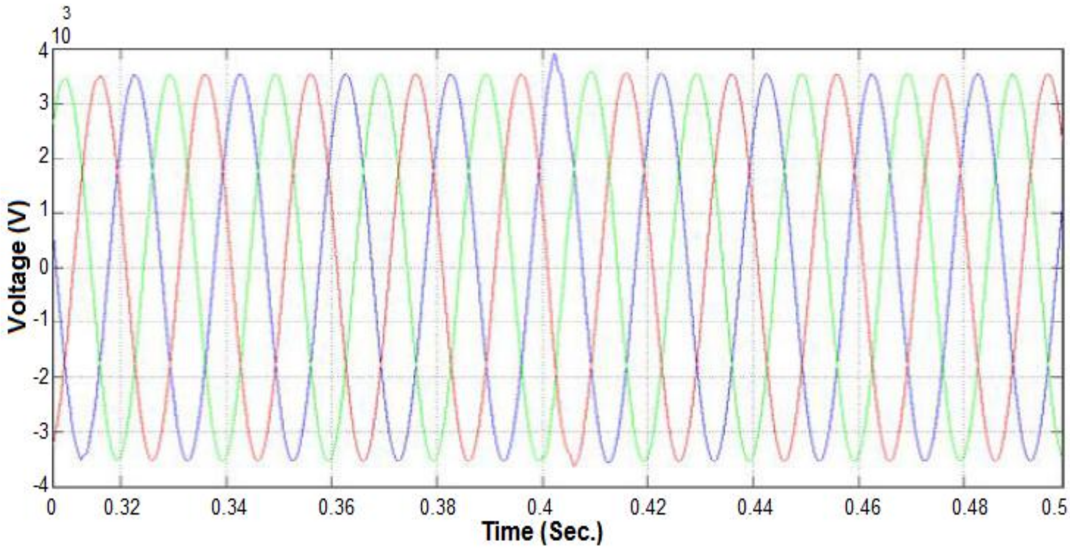

Fig. 16. Load voltages at PCC with fuzzy supervision of DC Link PI control

The performance of the DC link voltage and its compensation were observed with and without fuzzy supervisor.

Simulation results show that a 50-60% reduction in voltage deviation of the DC link voltage is obtained with faster settling time. Good compensation has been observed. Thus, through simulation studies, the implementation of a fuzzy supervisor for DC link voltage control in DSTATCOM for load compensation has been demonstrated

REFERENCES

[1] Gupta A., Sharma P.R. “Design and Simulation of Fuzzy Logic Controller for DSTATCOM In Power System,” International Journal of Engineering Science and Technology. Vol.3. No.10, pp.7815-7822, 2011.
[2] K. R. Padiyar,” Facts Controllers In Power Transmission And Distribution”, Pubulished By New Age International.
[3] Janak B. P., Amitkumar S. “Modeling Analysis and Solution of Power Quality Problems Using DVR & DSTATCOM,” IJSRD -International Journal for Scientific Research & Development. Vol. 1, Issue 5, 2013.
[4] Gupta A., Sharma P.R. “Design and Simulation of Fuzzy Logic Controller for DSTATCOM In Power System,” International Journal of Engineering Science and Technology. Vol.3. No.10, pp.7815-7822, 2011.
[5] K.M. Passino and S. Yurkovich,“Fuzzy Control” Addison-Wesley, 1998.
[6] ShaikKhaja Nawaz, Shaik Hameed “Mitigation of Power Quality Problems by Using D-statcom,”International Journal of Recent Advances Engineering and Technology. Vol.1. pp. 2347-2812, 2013.
[7] Kumar K.S.,Venu N. “Improvement of DC link voltage in D-Statcom based on Fuzzy Logic,” International Journal Of Engineering And Science (IJES). Vol.2, pp.77-84, 2013.