CONTROL OF DC CAPACITOR VOLTAGE IN A DSTATCOM USING FUZZY LOGIC CONTROLLER

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ABSTRACT

In this paper mainly presents about the DSTATCOM and control methodology of DC capacitor voltage, generally, the dc capacitor voltage is regulated using a 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 work, 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 change compared to a normal PI controller is obtained. The performance of the proposed strategy is proved using detailed simulation studies.

Keywords: *DC link voltage control, DSTATCOM, Fuzzy supervisor, Instantaneous symmetrical components, PI controller, power quality, transient response, voltage source inverter.*

I. INTRODUCTION

Now a day's the usage of power converters and other non-linear loads in industry and by consumers have increased extensively. This increases the sensitiveness of the loads and deterioration of power system (PS) voltage and current waveforms (such as magnitude, phase and harmonics). The presence of harmonics in the power lines results in greater power losses in distribution, interference problems in communication systems, in operation failures of electronics equipments, which are more and more sensitive. To cope with these difficulties, extensive research work is going on to improve power quality (PQ) for mitigating the harmonics. However, most of the methods use PI controller to improve transient state of the error signal. In this area some more controllers are also proposed such as, RST Controller and Fuzzy Logic. In this paper we discuss about The Distribution Static Compensator or the D-STATCOM is a shunt connected custom power device [2] which injects current at the point of common coupling (PCC) used to control the terminal voltage and improve the power factor. Various control algorithms have been proposed in literature [3]-[5] to extract the reference currents of the compensator. The theory of instantaneous symmetrical components [6] has been used because of its simplicity in formulation and ease of calculation. The source voltages are assumed to be balanced sinusoids and stiff. In a D-STATCOM, generally, the DC capacitor voltage is regulated using a 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 work, 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. An improvement in the performance of the controller is obtained because of appropriate variation of PI gains using expert knowledge of system behaviour and higher sampling during the transient period. The voltage waveform also has a faster settling time. The efficiency of the proposed strategy is proved using detailed MATLAB simulation studies.

II. PRINCIPLE OF DSTATCOM

Figure-1 shows the schematic diagram of DSTATCOM. The basic principle of a DSTATCOMs Installed in a PS is the generation of a controllable ac voltage source by a voltage source inverter

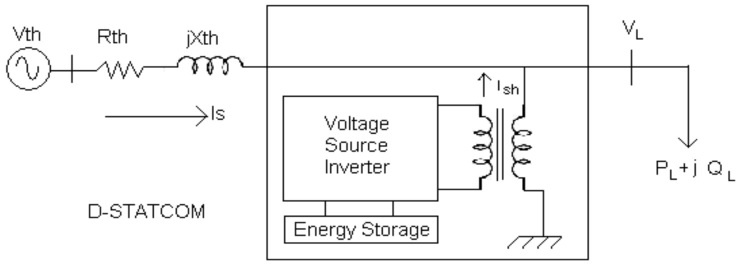

Figure1: Schematic diagram of DSTATCOM

(VSI) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the PS and the DSTATCOM is caused by the voltage difference across this reactance. The DSTATCOM is connected to the power networks at a PCC. The controller performs feedback control and outputs a set of switching signals to drive the main semiconductor switches IGBT's, which are used at the distribution level of the power converter. The ac voltage control is achieved by firing angle control. Ideally the output voltage of the VSI is in phase with the bus voltage (where the DSTATCOM is connected). In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses.

2.1. DSTATCOM VOLTAGE REGULATION TECHNIQUE

The DSTATCOM improves the voltage sags, swell conditions and the ac output voltage at the customer points, thus improving the PQ at the distribution side. In this the voltage controller technique (also called as decouple technique) is used as the control technique for DSTATCOM. This control strategy uses the dq0 rotating reference frame, because it offers higher accuracy than stationary frame-based techniques**.** In this V_{abc} are the three-phase terminal voltages, I_{abc} are the three-phase currents injected by the DSTATCOM into the network, V_{rms} is the rms terminal voltage, V_{dc} is the dc voltage measured in the capacitor, and the superscripts indicate reference values. Such a controller employs a phase-locked loop (PLL) to synchronize the three phase voltages at the converter output with the zero crossings of the fundamental component of the phase-A terminal voltage. The block diagram of a proposed control technique is shown in Figure 2. Therefore, the PLL provides the angle f to the abc-to-dq0 (and dq0-to-abc) transformation. There are also four proportional integral (PI) regulators. The first one is responsible for controlling the terminal voltage through the reactive power exchange with the ac network. This PI regulator provides the reactive current reference I_q*, which is limited between +1pu capacitive and -1pu inductive. Another PI regulator is responsible for keeping the dc voltage constant through a small active power exchange with the ac network, compensating the active power losses in the transformer and inverter. This PI regulator provides the active current reference I_d*. The other two PI regulators determine voltage reference V_d *, and V_q*, which are sent to the PWM signal generator of the converter, after a dq0-to-abc transformation. Finally, V_{ab}* are the three-phase voltages desired at the converter output.

2.2. PROBLEM OF DC LINK PI CONTROL

At steady state, the average power is updated at every half cycle during this time, the power to the load is supplied temporarily from the DSTATCOM. This leads to a decrease in dc link voltage, if load is increased or an increase in capacitor voltage, if the load is reduced. For good compensation, it is important that the capacitor voltage remains as close to the reference value as possible. After a load change has occurred, depending on the values of K_p and K_i the capacitor voltage takes 6-8 cycles to settle. However during transient operation, it is possible to improve the performance of the dc link by varying the gains of the PI controller using a set of heuristic rules based on expert knowledge. Also, improvements in technology such as faster Digital Signal Processing allow us to increase the sampling rate for better feedback as to how the system responds to changes. For nonlinear systems, fuzzy based control has been proved to work well .Fuzzy logic based supervision of the dc link PI controller gains improves the transient and settling performance of the dc link voltage control. Hence, the use of fuzzy logic for this application is justified.

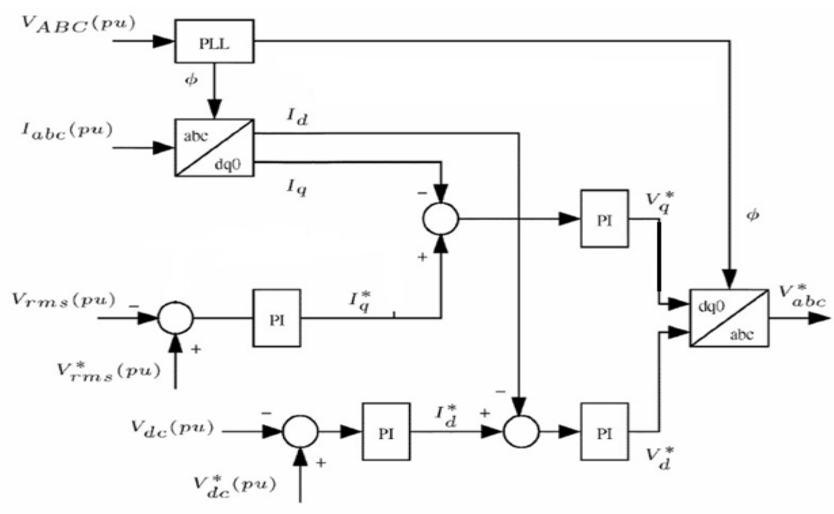

Figure 2: Proposed control technique of DSTATCOM.

III. DC LINK PI CONTROL AND FUZZY CONTROL

The source voltages are assumed to be balanced sinusoids and stiff. The reference currents based on this theory are given in (1) below.

$$\begin{aligned} i^*_{fa} &= i_{la} - i_{sa} = i_{la} - \frac{V_{sa} - \gamma(V_{sb} - V_{sc})}{\Delta}(P_{lavg} + P_{loss}) \\ i^*_{fb} &= i_{lb} - i_{ba} = i_{la} - \frac{V_{sb} - \gamma(V_{sc} - V_{sa})}{\Delta}(P_{lavg} + P_{loss}) \\ i^*_{fc} &= i_{lc} - i_{bc} = i_{lc} - \frac{V_{sc} + \gamma(V_{sa} - V_{sb})}{\Delta}(P_{lavg} + P_{loss}) \end{aligned} \quad (1)$$

where $\Delta = \sum_{j=a,b,c} V_{sj}^2$ and $\gamma = \tan\phi / \sqrt{3}$

For obtaining unity power factor at the source, φ = 0 and thus γ = 0. The term P_{lavg} is the average value of load power which would be a constant value if there is no load change. This is computed using a moving average filter for half cycle. P_{loss} is the amount of power that is required to be drawn from the source to compensate for the losses which occur in the inverter. If this term is not included, then these losses will be supplied by the dc capacitor and dc link voltage will fall. It is however extremely difficult to compute the exact losses that occur in the inverter. Thus, P_{loss} is obtained using a PI controller. At steady state, the P_{loss} value is updated every half cycle or every 180^0. The sum of P_{loss} and P_{lavg} terms determines the amount of power drawn from the source. The moving average filter used to calculate P_{lavg} takes half a cycle to settle to the new value of average power. During this time, the power to the load is supplied temporarily from the DSTATCOM. This leads to a decrease in dc link voltage if the load is increased or an increase in capacitor voltage if the load is reduced. For good compensation, it is important that the capacitor voltage remains as close to the reference value as possible. After a load change has occurred, depending on the values of K_p and K_i, the capacitor voltage takes 6-8 cycles to settle. Most of the times, the gains are chosen by trial and error. A method to obtain good K_p and K_i values for the DSTATCOM application is given in [7]. This has been used as

the base values during steady operation. However, during transient operation, it is possible to improve the performance of the dc link by varying the gains of the PI controller using a set of heuristic rules based on expert knowledge. Also, improvements in technology such as faster DSPs allow us to increase the sampling rate for better feedback as to how the system responds to changes. For nonlinear systems, like the DSTATCOM, fuzzy based control has been proved to work well [8]. In this paper, it has been shown that fuzzy logic based supervision of the dc link PI controller gains improves the transient and settling performance of dc link voltage control. Hence, the use of fuzzy logic for this application is justified. This paper has been organized in the following manner. First an explanation of the VSI topology for the DSTATCOM used is given and then the state space modelling used to simulate the working of the DSTATCOM is explained. The design of the fuzzy supervisor for this system is elucidated. The methodology and results of the simulation are shown in the final section, proving improved dc link performance. During load changes, there is some active power exchange between the DSTATCOM and the load. This leads to a reduction or an increase in the dc capacitor voltage. Using a PI controller, the P_{loss} term in (1) is controlled to ensure that the dc capacitor voltage does not deviate from the reference
The control output of a PI controller is given by (2)

$$P_{loss} = K_p(v_{dc}^{ref} - v_{dc}) + K_i(\int (v_{dc}^{ref} - v_{dc})dt \quad (2)$$

The input to the PI controller is the error in the dc link voltage and the output is the value of P_{loss}. The value of P_{loss} depends on the value of K_p, K_i and the error in dc link voltage. Thus, it is important to tune K_p and K_i properly. Because of the inherent non-linearity and complexity of the system, it is difficult to tune the gains of the controller. It is usually done by trial and error. The base values of K_p and K_i have been designed using the energy concept proposed in [7]. Also, it has been shown in literature that fuzzy supervision can improve the performance of PID controllers in nonlinear systems [10]-[12].However, these mostly deal with set-point changes in control applications. The derivative control term is not used because improvement in stability may or may not be obtained when used only with proportional control and if it is used with integral control as well, tuning for good performance is difficult [13]. The design of a fuzzy system is highly system specific and requires in-depth knowledge of the system and the various parameters that can be controlled for good performance. The design of a fuzzy supervisor for dc link PI control in a DSTATCOM is given in the next section.

IV. DESIGN OF THE FUZZY LOGIC SUPERVISOR FOR PI CONTROLLER

PID controllers are extensively used in industry for a wide range of control processes and provide satisfactory performance once tuned when the process parameters are well known and there is not much variation. However, if operating conditions vary; further tuning may be necessary for good performance. Since many processes are complicated and nonlinear, fuzzy control seems to be a good choice. Literature shows many approaches where the PI controller has been replaced by a fuzzy controller [14]-[15]. However, instead of completely modifying the control action, it is sufficient to use an additional level of control by supervising the gains using fuzzy techniques to improve the performance of the system [16].A PI controller is preferred to regulate the dc link voltage as the presence of the integral term ensures zero steady state error. The dc link capacitor voltage waveform contains a ripple because according to the instantaneous symmetrical component theory, which is used in this work, the compensator supplies the oscillating part of the active power also. Thus there is always a zero average oscillating power exchange between the compensator and the load. This ripple can be seen in the simulation results in Fig. 9. The fuzzy controller scaling has been designed to give a good output irrespective of the presence of the ripple during the transient period. Some of the main aspects of fuzzy controller design are choosing the right inputs and outputs and designing each of the four components of the fuzzy logic controller shown in Fig. 2. Each of these will be discussed in the subsections below: Also, the fuzzy controller is activated only during the transient period and once the value of the dc link voltage settles down, the controller gains are kept constant at the steady state value. A detailed description of the design of a fuzzy logic controller has been given in [17].

4.1. 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.

$$\text{err}(i) = V_{dc}^{ref} - V_{dc}(i) \qquad (3)$$

$$\text{derr}(i) = \text{err}(i) - \text{err}(i-1) \qquad (4)$$

In (3) and (4) above, e (i) is the error and $\dot{e}(i)$ is the change in error in the i^{th} iteration. V_{dc}^{ref} is the reference dc link voltage and $V_{dc}(i)$ is the dc link voltage in the i^{th} iteration. The outputs of the fuzzy supervisor are chosen as the change in K_p value and the change in K_i value.

$$K_P = K_{pref} + \Delta K_p \qquad (5)$$

$$K_i = K_{iref} + \Delta K_i \qquad (6)$$

K_{pref} and K_{iref} are the steady state values determined by the method specified in [7] and ΔK_p and ΔK_i are the outputs of the fuzzy logic supervisor.

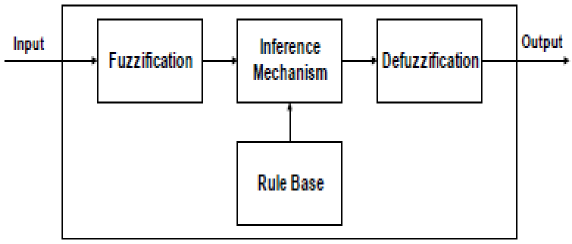

Figure 3. Fuzzy controller architecture.

4.2. FUZZIFICATION

The fuzzification interface modifies the inputs to a form in which they can be used by the inference mechanism. It takes in the crisp input signals and assigns a membership value to the membership function under whose range the input signal falls. Typical input membership functions are triangular trapezoidal or exponential. Seven triangular membership functions have been chosen: *NL* (Negative Large), *NM* (Negative Medium), *NS* (Negative Small), *Z* (Zero), *PS* (Positive Small), *PM* (Positive Medium) and *PL* (Positive Large) for both error (*err*) and change in error (*derr*) . The input membership functions are shown in Fig-4. The tuning of the input membership function is done based on the requirement of the process. Each membership function has a membership value belonging to [0 1]. It can be observed that for any value of error or change in error, either one or two membership functions will be active for each.

4.3 INFERENCE MECHANISM

The two main functions of the inference mechanism are: a) Based on the active membership functions in error and the change in error inputs, the rules which apply for the current situation are determined. b) Once the rules which are on are determined, the certainty of the control action is ascertained from the membership values.

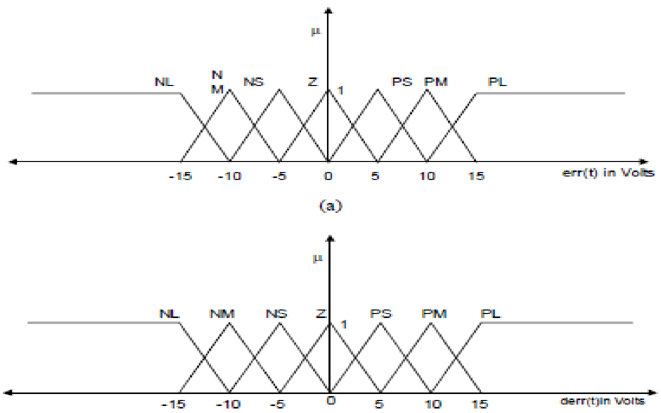

Figure. 4(a) Membership functions for error input. and (b) Membership functions for change in error input

This is known as premise quantification. Thus at the end of this process, we shall have a set of rules each with a certain certainty of being valid. The database containing these rules is present in the rule base from which the control action is obtained. The rule base will be discussed in the next section. An example of a rule is given in (7). The terms *PL* and *PM* are the membership functions for error and for change in error respectively.
IF "error" is PL (positive large) "change in error" is PM (positive medium) THEN "ΔK_p"is L (Large K_p) "ΔK_i" is SK_i (Small K_i) The minimum operation is used to determine the certainty called $\mu_{premise}$ of the rule formed by their combination.

4.4. THE RULE BASE

Designing the rule base is a vital part in designing the controller. It is important to understand how the rule base has been designed. Fig. 4 shows a typical dc link voltage waveform after an increase in the load without the inherent ripple due to compensation. The waveform has been split into various parts depending on the sign of error and change in error. The rules in the rule base are designed based on which part of the graph the waveform is in. The important points involved in the design of the rule base are the following: a) If the error is large and the change in error shows the dc link waveform deviating away from the reference, then increases Kp. b) If the waveform is approaching the reference value, then increase the K_i value to reduce overshoot and improve settling time. Keeping these aspects in mind, two rule base matrices have been developed for K_p and K_i. table. 5(a) gives the rule base matrix for K_p and table. 5(b) gives the rule base matrix for K_i. The output membership functions for the proportional gain are LK_i, SK_i and *Z* and the output membership functions for integral gain are *L*, *M*, *S* and *Z*. These matrices provide rules such as the example seen in (7) for all possible combinations of the membership functions for error and change in error. Thus, using information from the rule base, the rule and its certainty is determined by the inference mechanism. The method to convert the fuzzy result to crisp control action is called defuzzification. This is explained in the next section.

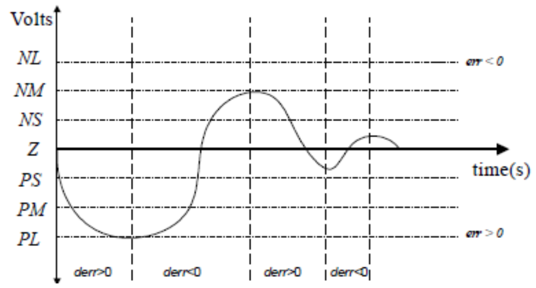

Figure 5. Typical dc link voltage waveform after a load change

Table 5(a) Rule base matrix for change in K_p.

err v/s 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 5 (b) Rule base matrix for change in K_p

err v/s derr	NL	NM	NS	Z	PS	PM	PL
NL	SK_i	SK_i	SK_i	Z	Z	Z	Z
NM	SK_i	SK_i	SK_i	Z	Z	Z	Z
NS	LK_i	LK_i	LK_i	Z	Z	Z	Z
Z	LK_i	LK_i	LK_i	Z	LK_i	LK_i	LK_i
PS	Z	Z	Z	Z	LK_i	LK_i	LK_i
PM	Z	Z	Z	Z	SK_i	SK_i	SK_i
PL	Z	Z	Z	Z	SK_i	SK_i	SK_i

4.5. DEFUZZIFICATION

The inference mechanism provides us with a set of rules each with a $\mu_{premise}$. The defuzzification mechanism considers these rules and their respective $\mu_{premise}$ values, combines their effect and comes up with a crisp, numerical output. Thus, the fuzzy control action is transformed to a non fuzzy control action. The 'center of gravity' method has been used in this work for this. If we use this method, the resultant crisp output is sensitive to all of the active fuzzy outputs of the inference mechanism. Fig. 6(a) and Fig. 6(b) show the output membership functions chosen for K_p and K_i. According to this method the weighted mean of the center values of the active output membership functions is taken as the output, the weights being the area under the line representing the. *μpremise*.

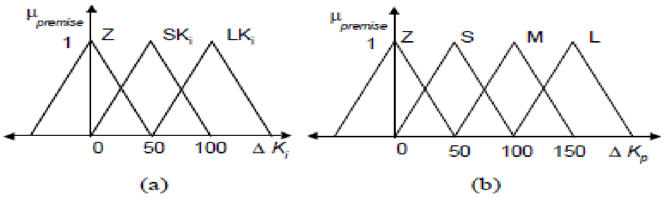

Figure . 6(a) Output membership function for *Kp* and (b) Output membership function *Ki.*

V. SYSTEM INVESTIGATED FOR DSTATCOM AND ITS RESULTS

The test system shown in figure7.1 comprises of 25KV, 100 MVA, 50Hz system feeding a distribution network of 600V through a 25KV transmission network. The transmission network comprises of 3 buses. Between B_1 and B_2 a 21KM feeder of R=0.1153 Ohm/KM and L=1.048e-3 H/KM is connected. Between B_2 and B_3 a 2Km feeder and a RC load of 3MW and 0.2MVAR are connected. At Bus-3, 25KV/600V, 6MVA transformer is connected to which a variable load of 3000A, 0.9pf and a nonlinear load comprising of a 3-Phase full wave rectifier with a power load of 10KW and 10KVAR are connected.

In this paper the above test system was implemented in MATLAB /Simulink. This section is divided into three cases. Case (1) Without DSTATCOM; Case (2) DSTATCOM Voltage controller; Case (3) DSTATCOM voltage controller with Fuzzy logic based supervision of DC Link PI control. Then the simulation results for voltage regulation of all the cases are compared. The DC link voltage for case (2) without Fuzzy supervision and case (3) with fuzzy supervision are compared.

5.1 WITHOUT DSTATCOM

Case (1) Without DSTATCOM

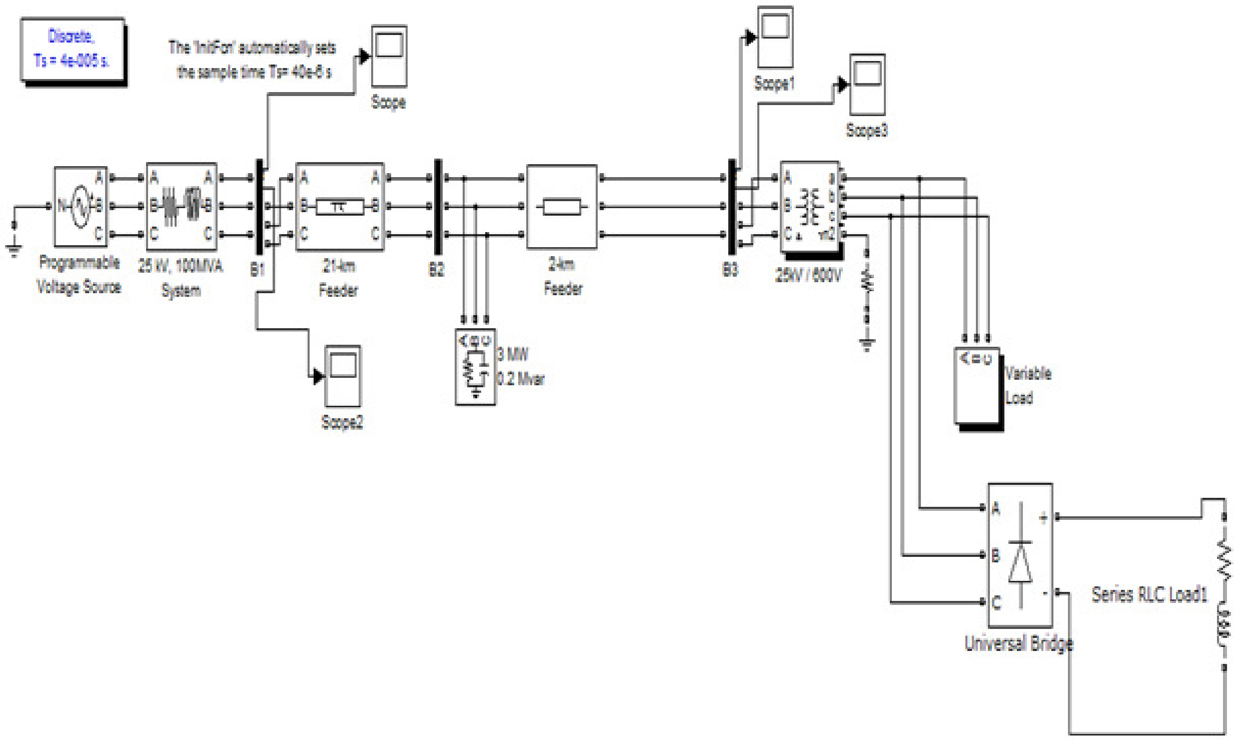

Figure 7.1 MATLAB Simulink model without DSTATCOM

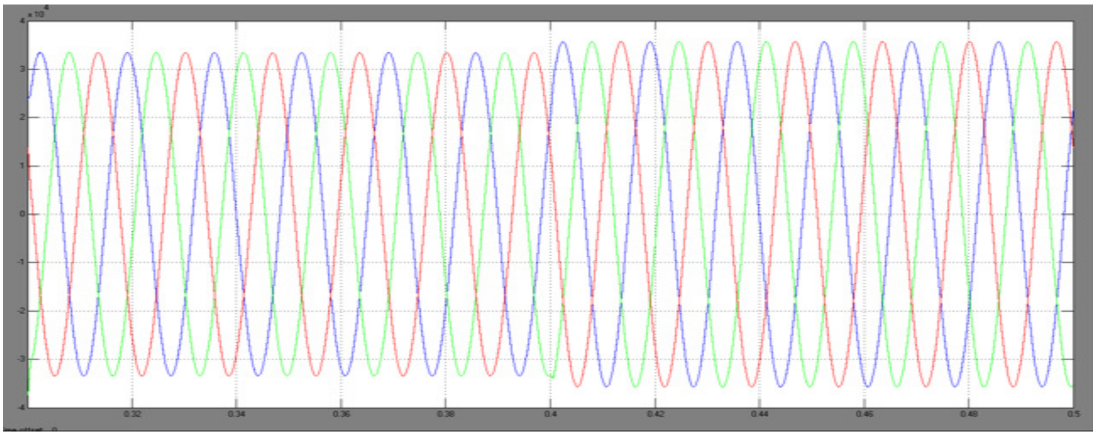

Figure 7.2 Three phase Voltage in Pu at Bus-3 without DSTATCOM

Using programmable voltage source a voltage swell of 1.077 Pu is created at 0.4 seconds as shown in the above figure.

5.2 DSTATCOM VOLTAGE CONTROLLER

Case (2) DSTATCOM Voltage controller

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.

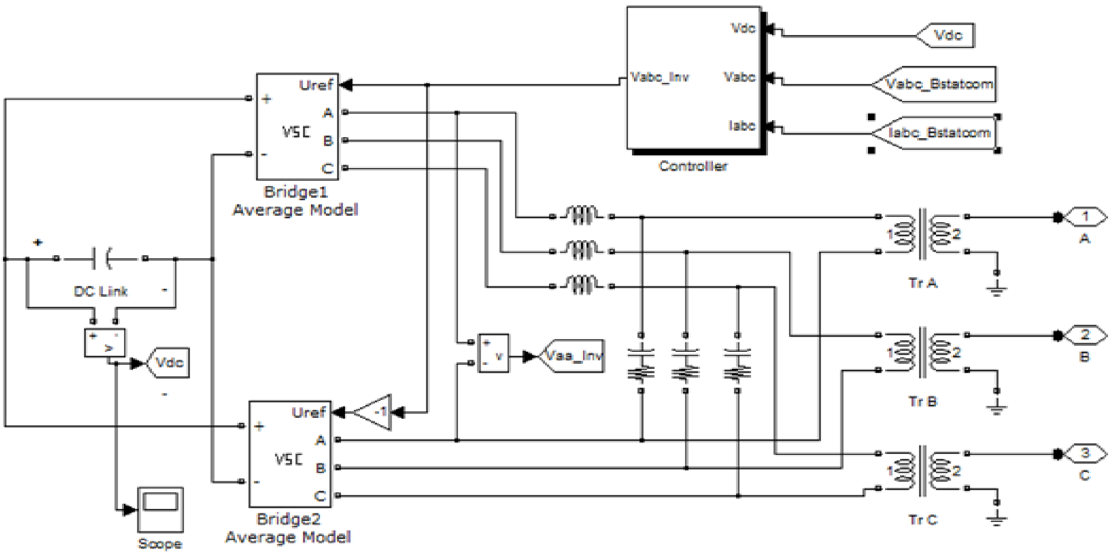

Figure 7.3 shows the Simulink model of DSTATCOM implemented.

In this case DSTACOM voltage controller with its detail model is used to improve the PCC voltage at Bus-3 which is shown in Figure 7.3.If there is any voltage disturbance occurs at PCC, the voltage controller of DSTATCOM will generate the reference signals V_d and V_q which are sent to the converter, after a dqo-abc transformation .This signal will generate the pulses such that the converter will produce the output similar to that of the reference voltages. The improved PCC voltage simulation results with the DSTATCOM for Case (1) is as shown in figure 7.1 During the process of voltage regulation, the voltage controller tries to keep the capacitor voltage constant to produce the reference voltages. Because the output voltage of the converter depends on the capacitor DC link voltage. The figure 7.6 shows the voltage across the capacitor. In the above figure Simulink model of DSTATCOM is shown which consists of two Voltage Source Converters connected in cascaded form by a DC link which acts as a voltage source for the two inverters. The V_{ref} input given to the VSC is generated by the voltage controller .Based on the V_{ref} generated the average model of VSC will generate its output voltage

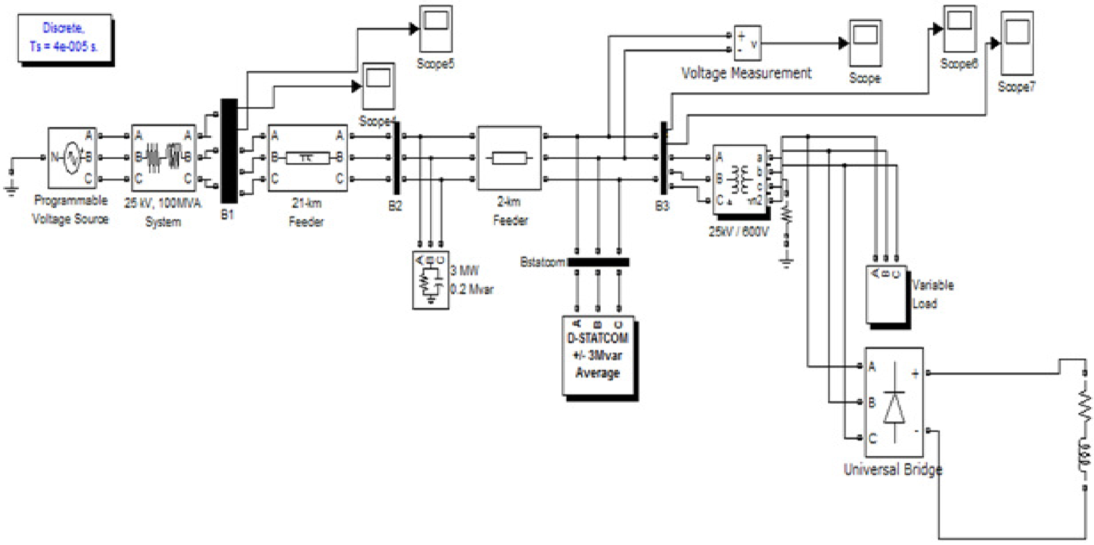

Figure 7.4 Simulink model with DSTATCOM

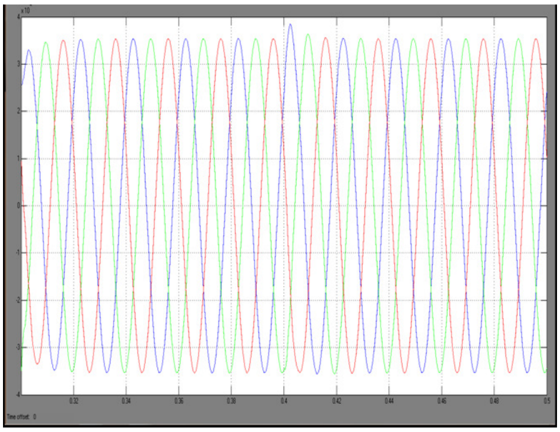

Figure 7.5 Load Voltage (PCC voltage) waveforms with DSTATCOM

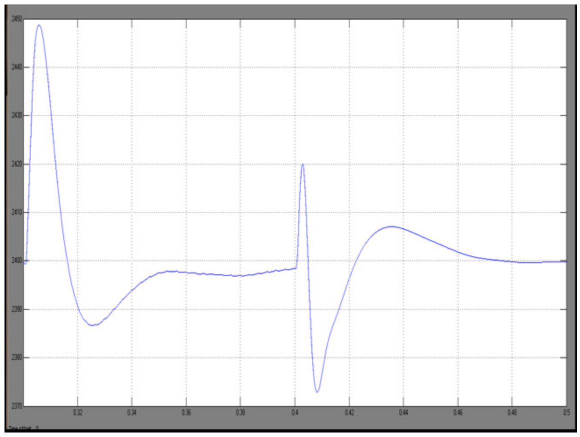

Figure 7.6 DC Link voltage of DSTATCOM

There is a considerable variation in the DC link voltage due to sudden voltage swell created at 0.4sec as shown in Fig. 7.5.For good compensation , it is important that capacitor voltage remains as close to the reference value as possible. This is done by using Fuzzy logic supervision of DC link PI control which will be discussed in next case.

5.3 FUZZY LOGIC BASED SUPERVISION OF DC LINK PI CONTROL

Case (3): D-STATCOM voltage controller with Fuzzy logic based supervision of DC link PI control
In this case a fuzzy logic based supervisor control is designed to manipulate the gains of PI controller employed for DC link voltage control. 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. The figure 7.7 shows the fuzzy supervisor implemented for DC link PI control. The two inputs to the fuzzy error and change in error and the two outputs ΔK_p and ΔK_i are shown in the figure 7.8 The membership functions for error and change in error of DC link voltage are as shown in Fig.7.9 (a) and Fig.7.9 (b). The membership functions for ΔK_p and ΔK_i are as shown in Fig.7.9(c) and Fig.7.9 (d). The defuzzified outputs of fuzzy logic supervisor i.e. ΔK_p and ΔK_i values at each and every instant of time are as shown in Fig.7.10 (a) and Fig.7.10 (b). Figure 7.11 shows the addition of Fuzzy supervisor outputs i.e. defuzzified outputs shown in Fig.7.10 to the proportional and integral gains of PI controller employed for DC link voltage control. With the implementation of Fuzzy logic supervision the improved load voltage i.e. PCC voltage is shown in Fig.7.13.

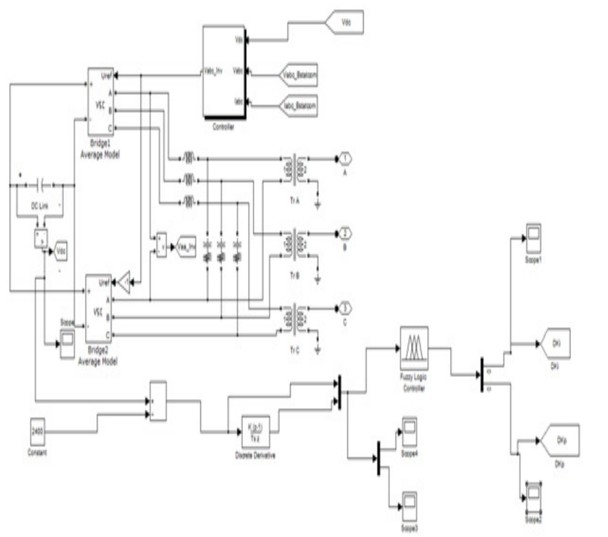

Figure 7.7 Fuzzy logic control implemented for DC link

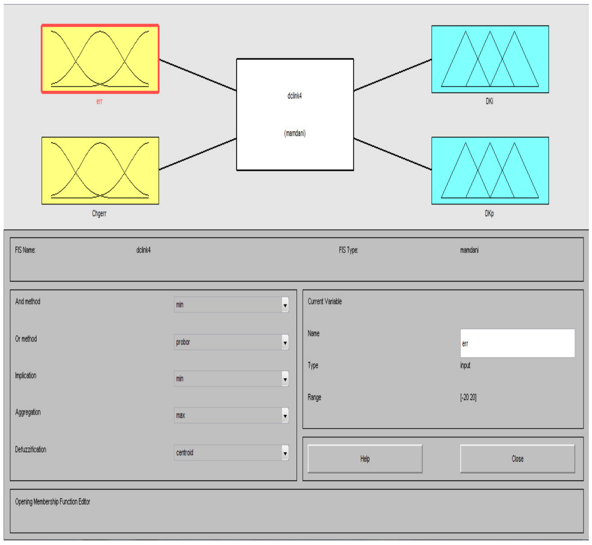

Figure. 7.8 MATLAB Fuzzy logic controller design

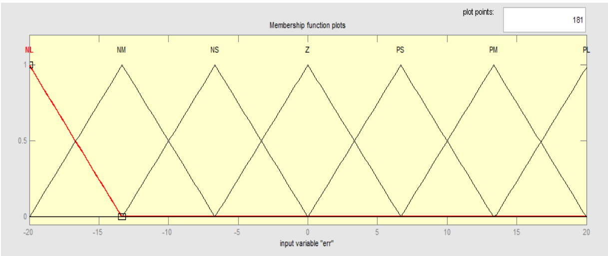

Figure 7.9(a) Membership functions for error input

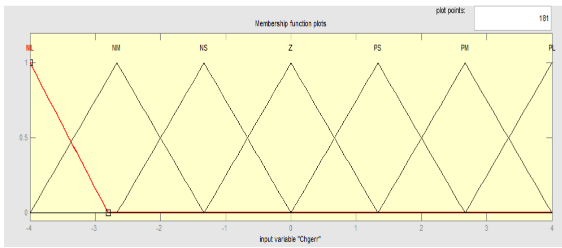

Figure. 7.9 (b) Membership functions for change in error

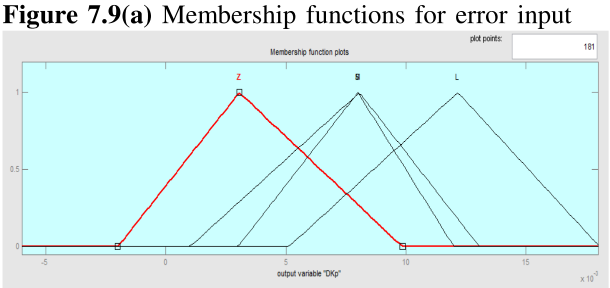

Figure 7.9 (c) Output membership functions for ΔKp

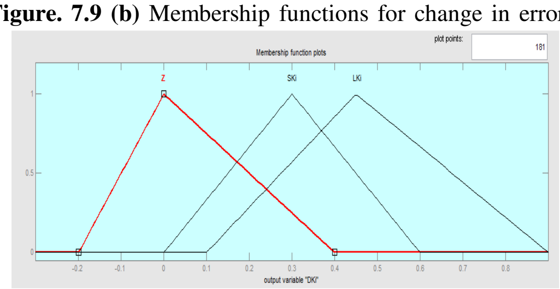

Figure 7.9(d) Output membership functions for ΔKi

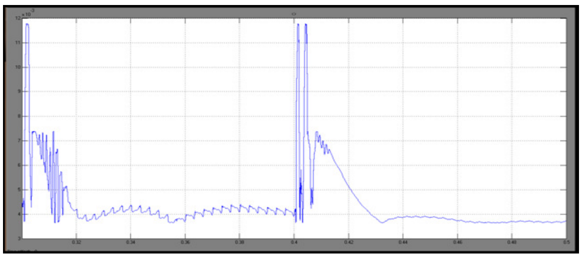

Figure 7.10(a) Defuzzified outputs of ΔKp

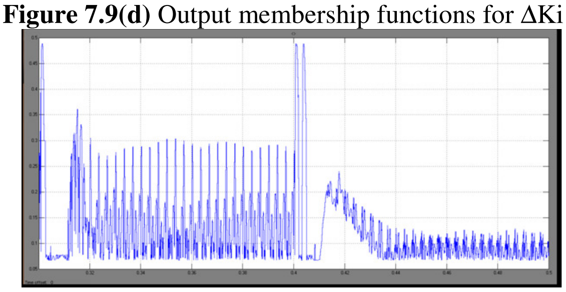

Figure 7.10 (b) Defuzzified outputs of ΔKi

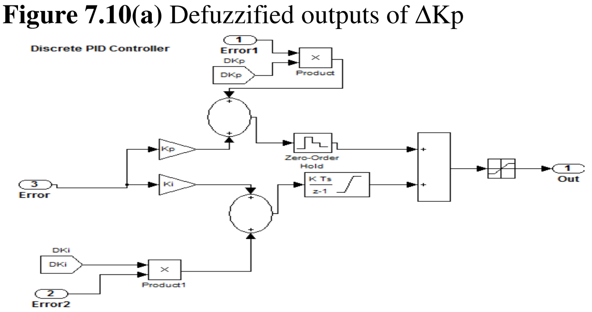

Figure 7.11 PI controller with inputs from Fuzzy logic supervisor

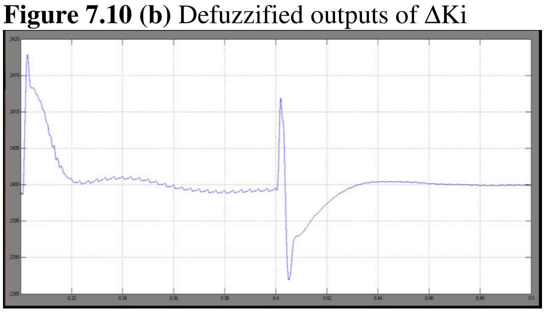

Figure 7.12 DC link Voltage with Fuzzy design

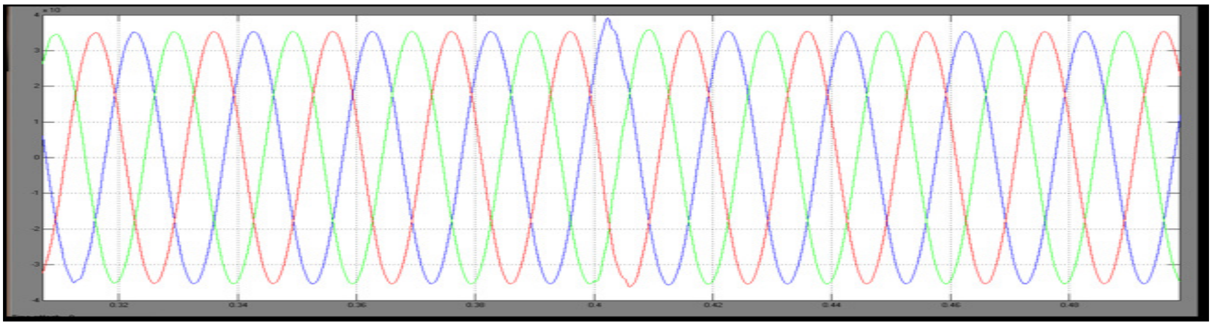

Figure 7.13 Load voltage at PCC with Fuzzy supervision of DC Link PI control.

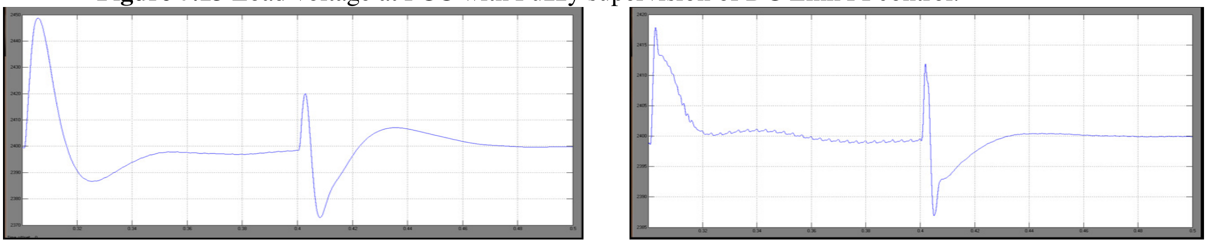

Figure 7.14 Comparison of DC link voltage of DSTATCOM without and with Fuzzy supervisor

By comparing the DC link voltages without Fuzzy supervision and with Fuzzy supervision from Fig. 7.14 the following conclusions are drawn.

(a) A 50-60% 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.

(b) From Fig. 7.6 and Fig. 7.12 it can also be concluded that a good voltage control is also achieved by implementing Fuzzy logic supervisor for DC link PI control.

VI. CONCLUSIONS

A fuzzy logic supervisory control to the DC link PI controller in a D-STATCOM has been proposed. The supervisor varies the gain of the PI controller during the transient period in a way that improves performance. The system has been modelled and simulated in the MATLAB technical environment with a case study. The performance of the DC link voltage and its performance compensation were observed with and without the fuzzy supervisor. Simulation result show a 50-60% reduction in voltage deviation of the DC link voltage 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 a D-STATCOM for load compensation has been demonstrated. Instantaneous symmetrical component theory has been used for load compensation. Good compensation has been observed as source current THDs for each phase is 1.63%, 1.77% and 1.58% while the load THDs are 12.37%, 10.5% and 14.54% respectively. Thus, through simulation studies, the implementation of a fuzzy supervisor for DC link voltage control in a DSTATCOM using instantaneous symmetrical component theory for load compensation has been demonstrated.

VII. FUTURE SCOPE OF STUDY

To propose a control strategy, where the optimum values of the PI controller parameters are tuned by Particle Swarm Optimization and Hybrid control algorithm.

REFERENCES

[1] Harish Suryanarayana and Mahesh k. Mishra, "Fuzzy logic based supervision of DC link PI control in a DSTATCOM ", IEEE India conference 2008,volume-2,pages 453-458

[2] J.L.Aguero,F.Issouribehere,P.E.Battaiotto," *STATCOM Modelling for mitigation of voltage fluctuations caused by Electric Arc Furnaces*", IEEE Argentina conference 2006, pp: 1-6.

[3] N. Hingorani ,Lasjlo Gyugyi, "*Understanding FACTS ," 1st edition ,IEEE pres , Standard publishers,2001,pp: 135-205.*

[4] R. Mohan Mathur ,Rajiv K. Varma, "*Thyristor-Based FACTS Controllers For Electrical Transmission Systems*", IEEE press series on power engineering, John Wiley & sons publishers,2002, pp: 413-457

[5]A. Ghosh and G. Ledwich; "*Power Quality enhancement using custompower devices*," Kluwer Academic Publishers, Boston, 2002

[6] H. Akagi, Y. Kanazawa, and A. Nabae, "Instantaneous reactive power compensators comprising switching devices without energy storage components," IEEE Trans. on Ind. Appl. Vol. 20, no. 3, 625-630, 1984.
[7] F. Z. Peng and J. S. Lai, "Generalized instantaneous reactive powertheory for three-phase power systems," *IEEE Trans. on Instrumentation and Measurement*. Vol. 45, no. 1, 293-297, 1996
[8] H. Kim, F. Blaabjerg, B. B. Jemsen and J. Choi, "Instantaneous powercompensation in three-phase systems by using p-q-r theory," *IEEE Trans. on Power Electronics*, Vol. 17, no 5, 701-709, 2002.
[9] A. Ghosh and A. Joshi, "A new approach to load balancing and power factor correction in power distribution system," *IEEE TranS.onPowerDelivery*,Vol.15,no 1 pp. 417-422, 2000.
[10] S. Tzafestas and N. P. Papanikolopoulos, "Incremental fuzzy expert PID control," *IEEE Transactions on Industrial Electronics*, Vol. 37, pp. 365-371, 1990.
[11] Zhen-Yu Zhao, M. Tomizuka and S. Isaka, "Fuzzy gain scheduling of PID controllers", *IEEE Tran. on Systems, Man and Cybernetics*, Vol. 23, pp. 1392-1398, 1993.
[12] K. H. Ang, G. Chong and Y. Li, "PID control system analysis, designand technology," IEEE Trans. on Control Systems Technology, Vol. 13,no. 4, 559-576, 2005
[13] B. N. Singh, A. Chandra and K. Al-Haddad, "DSP-based indirectcurrent-controlled STATCOM. I. Evaluation of current control techniques," *IEE Proc. on Electric Power Applications*, Vol. 147, pp.107-112, 2000
[14] A. Ajami and H.S. Hosseini, "Application of a Fuzzy Controller for Transient Stability Enhancement of AC Transmission System by STATCOM," *International Joint Conference SICE-ICASE*, pp. 6059-6063, 2006
[15] H.R. Van Lauta Nemke and Wang De-zhao, "Fuzzy PID Supervisor,"*24th IEEE Conf. on Decision and Control*, Vol. 24, pp 602-608, 1985
[16] K. M. Passino and S. Yurkovich; "*Fuzzy Control*" Addison-Wesley,, 1998
[17] P. Venkata Kishore et. al. " Voltage sag mitigation in eight bus system using D-STATCOM for power quality improvement" International Journal of Engineering Science and Technology Vol. 2(4), 2010, pp.529-537
[18] P. Venkata Kishore, Dr. S. Rama Reddy, "modeling and simulation of thirty bus system with D-STATCOM for power quality improvement" International Journal of Engineering Science and Technology Vol. 2(9), 2010, pp. 4560-4569.
[19] Bhim Singh, *Senior Member, IEEE*, and Jitendra Solanki "A Comparison of Control Algorithms for DSTATCOM" *IEEE Transactions on Industrial Electronics*, VOL. 56, NO. 7, JULY 2009, pp. 2738-2745
[20] Mahesh K. Mishra*, Member, IEEE*, and K. Karthikeyan "A Fast-Acting DC-Link Voltage Controller for Three-Phase DSTATCOM to Compensate AC and DC Loads "*IEEE Transactions On Power Delivery,* VOL. 24, NO. 4, OCTOBER 2009, pp. 2291-2299.
[21] Wei-Neng Chang and Kuan-Dih Yeh "Design And Implementation Of Dstatcom For Fast Load Compensation Of Unbalanced Loads"*Journal of Marine Science and Technology, Vol. 17, No. 4, pp. 257-263,2009.*
[22] Saeid Esmaeili Jafarabadi,Dept. of EEE, Shahid Bahonar University of Kerman*,* Iran "A New Modulation Approach To Decrease Total Harmonic Distortion In Vsc Based D-Facts Devices*"*European Journal of Scientific Research ,ISSN 1450-216X Vol.25 No.2 (2009), pp.325-338
[23] Rahmat-Allah HOOSHMAND, Mahdi BANEJAD, Mostafa AZIMI "Voltage Sag Mitigation Using A New Direct Control In D-Statcom For Distribution Systems "U.P.B. Sci. Bull., Series C, Vol. 71, Iss.4, 2009, ISSN 1454-234 pp.49-62

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