D-STATCOM with Fuzzy Logic Controller for Enhancing Steady-State and Quality Performances

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Abstract--Complex power systems are subjected to transient disturbances. In order to regulate voltage a device known as Static Synchronous Compensator (STATCOM) which is one kind of FACTS (Flexible AC Transmission System) devicesis used. This device can inject reactive power in order to correct the power factor. Therefore it is essential to exploit the device in order to improve quality of power supply. Many researchers were in this area to control voltage and handle transient disturbances in power systems. Recently Somsai et al. used D-STATCOM for power-factor correction and harmonic compensation. They also investigated a control schemeto get rid of power quality disturbances. In this paper we introduce Fuzzy logic controller to use with D-STATCOM which has many real world utilities to handle irregular data with respect to transient stability in power distribution systems. In this paper we study the problem of transient disturbances and build a prototype applicationto demonstrate the proof of concept. The empirical results reveal that the fuzzy controller achieves robustness in controlling DC-voltage.

Index Terms –STATCOM, power factor correction, fuzzy controller

I. INTRODUCTION

With the invent of new technologies in high-power electronics industry, FACTS, the devices used to get rid of problems in power systems. A compensator by name STATCOM is a kind of FACTS device that is widely used in power systems for transient stability, voltage regulation support, and reactive power provision. It has become an attractive alternative for enhancing transient stability in power systems. There were researchers who studied the compensator named STATCOM in the past [2], [1]. STATCOM is meant for controlling AV voltage source and ensure that the voltage differences are handled effectively. This device is used along with power network devices in order to enhance the transient stability of distributed power systems. It takes care of reactive power exchange between the transmission network and STATCOM [3]. For effective utilization of STATCOM, it is essential to have proper strategies to control objectives. PI controller [4] is the widely used controller used with STATCOM. The PI controllers can be built easily and they can add robustness to power systems. However, the performance of fuzzy controller decreases when the system encounters large disturbances. However, the fuzzy controllers can withstand imprecision and uncertainty in the power systems to a great extent. Under changing operating conditions, when compared with PI controllers, the fuzzy logic controllers perform well even though there are irregularities in system parameters [4]. Many successful applications were realized with respect to fuzzy logic controllers in the industry for last few decades. Many non-linear and complex processes successfully used fuzzy logic controllers [5]. It has been observed for many times that the fuzzy controllers are favoritemethod of designing controllers that can work in dynamic situations well when compared with traditionalmethods [6]. In this paper, we built fuzzy logic controller that works along with STATCOM DC capacitor voltage and tested its effectiveness under transient and steady conditions. We used it in Var compensation mode as we focused on the power-factor problem. We built a prototype application to demonstrate the proof of concept. The empirical results revealed that our approach is useful in enhancing the efficiency of voltage control in power systems. Our work is influenced by Somsai et al. [9]. The remainder of the paper is structured as follows. Section II provides literature pertaining to D-STATCOM and voltage controllers for power factor and harmonic compensation. Section III provides information about the proposed system. Section IV presents experimental results while section V concludes the paper.

II. STATCOM AND ITS CONFIGURATION

STATCOM is the compensator which is widely used in power systems in order to regulate or control voltage disturbances. Moreover this device is of FACTS family of devices. This device is made up of components like a DC capacitor, a control system, a voltage-sourced inverter, and a coupling transformer. In this paper, this device is used in for mainly reactive mode for steady-state power exchange between the ac system and device [7]. Regulating the amplitude of the device is essential for successful reactive power exchange in the power systems. In case if the amplitudes of ac system and output voltage of STATCOM are similar, zero is the reactive current. In this state the device will not be able to produce any reactive power. The functionality of STATCOM is described here. If amplitude of the output voltage of STATCOM gets increased beyond that of ac system voltage, then the STATCOM ensures that the current is flown via transformer to ac system. The power generated by the device is known as reactive power which is capacitive in nature. In the same fashion, when the amplitude of the output voltage of STATCOM is decreased than that of ac system, then the device takes steps to ensure that the current flows in reverse order in which the system absorbs reactive power which is inductive in nature. With respect to ac voltage system, the current obtained from STATCOM is shifted 90 degrees which may be either lagging which absorbs reactive power of it may be leading which generates reactive power.

STATCOM generate control reactive power which may be of type inductive or capacitive. The power supply reactively generated by the STATCOM is computed as follows where Q represents reactive power, the magnitude of STATCOM is represented by Vstat, system voltage magnitude is represented by Vs, and x is the impedance between system and STATCOM.

$$Q = \frac{V_{stat} - V_s}{x} V_s$$

STATCOM generates reactive power when the Q value is positive or else it simply absorbs reactive power. The D-STATCOM which is an improved form of STATCOM is as shown in figure 1.

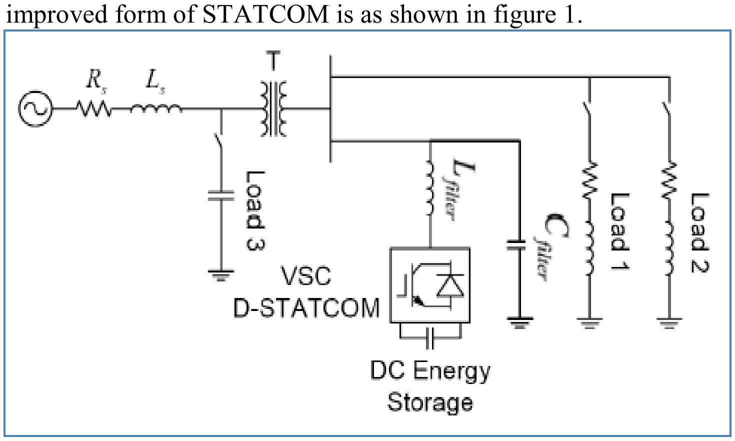

Fig. 1 –D-STATCOM enabled power system

DC/AV voltage source converter generates output voltage of D-STATCOM. The converter can produce a set of controllable voltages whose frequency resembles AC power system. Through coupling reactance output voltage is associated with AC voltage. The reactive power exchange between the AC system and D-STATCOM can be controlled by changing the quantity of output voltage. When amplitude output voltage is decreased or increased beyond AC system voltage, the converter either generates of absorbs reactive power. In this context the DSTATCOM plays an important role. In fact it acts as a shunt compensator.

III. CONTROL STRATEGY FOR DSTATCOM

The main aim of DSTATCOM is power compensation. This device can eliminate harmonic current, power oscillation, and improve power factor. The overview of the control scheme using DSTATCOM is as shown in figure 2.

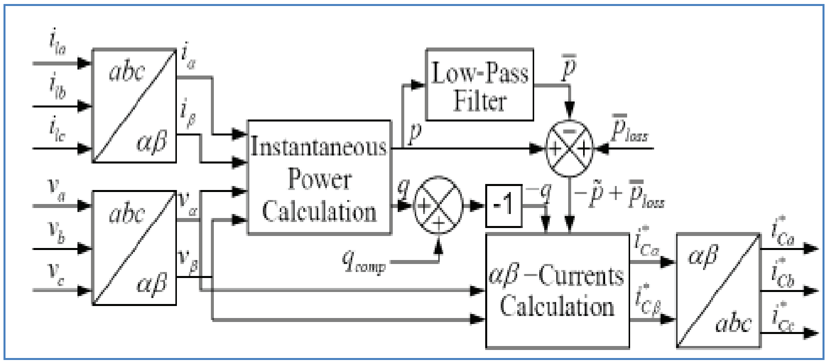

Fig. 2 – Control Scheme

As can be seen in figure 2, it is evident that there is instantaneous power calculation component that takes care of power factor correction andharmonic compensation. The shunt's instantaneous compensation is as given in figure 3.

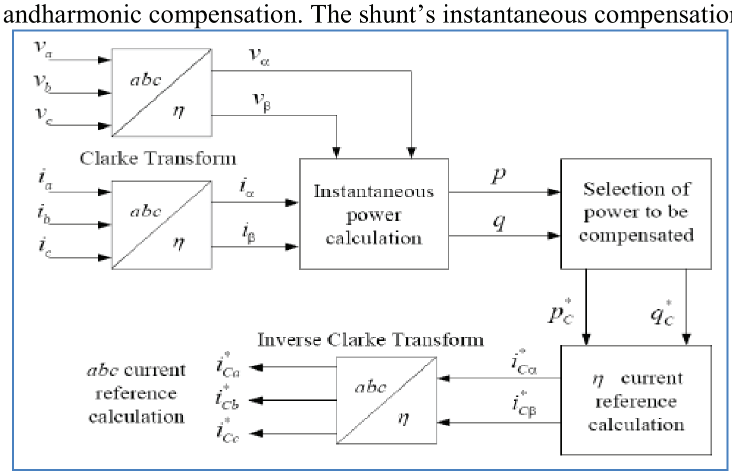

Fig. 3 –Control block of instantaneous power theory based shunt

As can be seen in figure 3, it gives general idea about the present compensation of shunt which is based on the instantaneous power theory. As the traditional PI controller has several drawbacks it is replaced with fuzzy logic controller. By changing the controller we can bring about flexibility in the usage of D-STATCOM for controlling power quality problems.

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic controller is widely used in controlling disturbances in power systems. The other controller known as PI controller is not efficient for many reasons. They include its inability to withstand abrupt changes in error signal, and it is not dynamic in determining the present error signal. In this paper we proposed the usage of fuzzy logic controller in order to improve the performance of STATCOM for Dc-bus voltage control. Through experimentation we have built a rule base which is used by the fuzzy logic controller for robustness in controlling voltage. We defined fuzzy subsets for inputs error signal and changes in the error signal. The representation of fuzzy logic controller is as shown in figure 4.

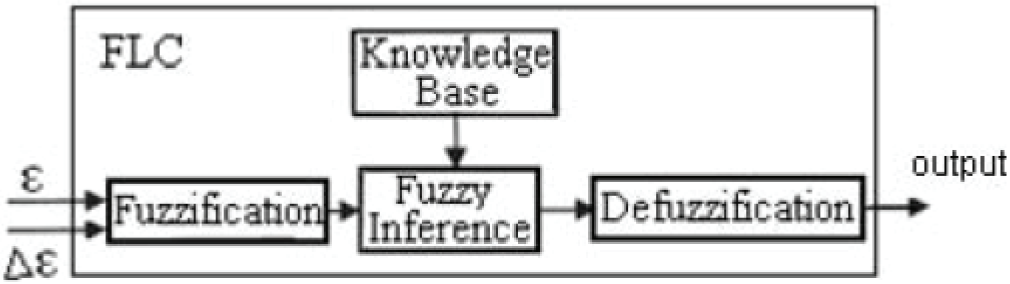

Fig. 4 – Overview of fuzzy logic controller

As shown in figure 4, the fuzzy logic controller has certain components known as fuzzification, knowledge base, fuzzy inference and defuzzification. Fuzzification takes input and then fuzzy inference makes use of knowledge base and processes its logic accordingly while defuzzification produces required output.

V. EXPERIMENTAL RESULTS

The proposed control scheme is examined to know its efficiency to compensate harmonic current and correcting power factor using a 22-KV power distribution feeder. Figure 3 shows the visualization of 22-KV power distribution feeder.

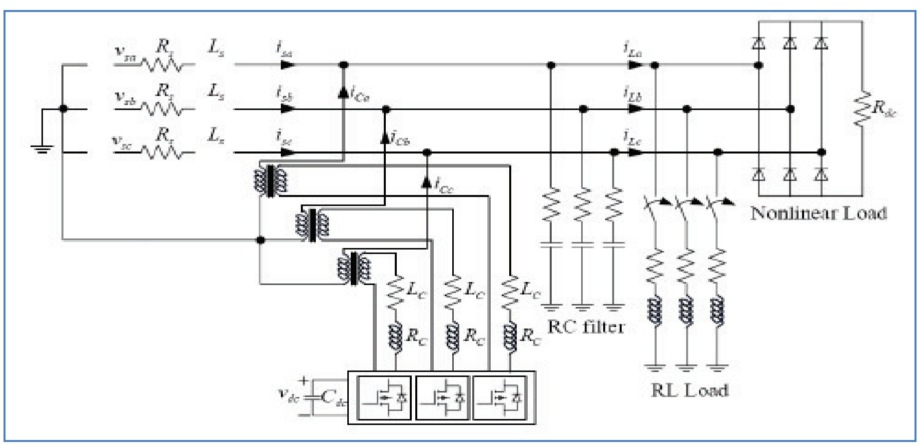

Fig. 5 –22 KV power distribution feeder used for experiments

We built simulations in MATLAB to demonstrate the proof of concept. The environment used to build the simulations is a PC with 4 GB RAM, core 2 dual processor running Windows operating system. The empirical results are presented below.
The evaluation of fuzzy controller is made below. Fuzzy controller replaces traditional PI controller in this paper.

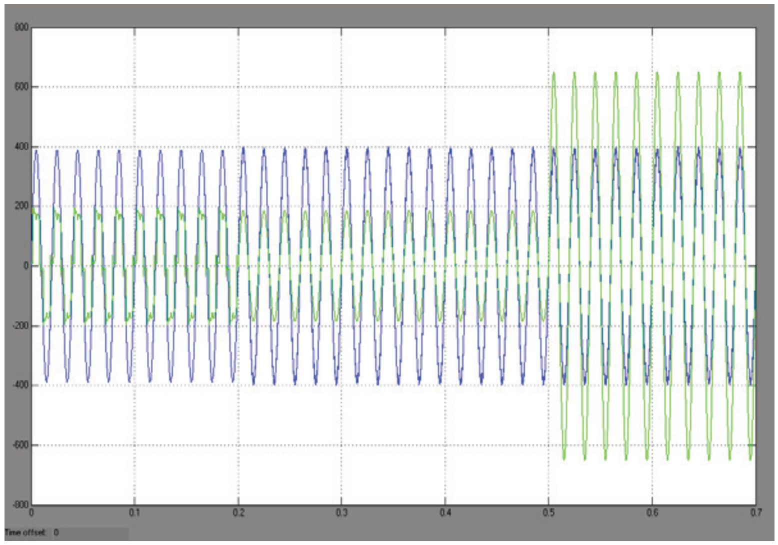

Fig. 6- Source voltage and source current (Response during t=0~1)

As can be viewed in figure 6, it is evident the result of source voltage and source currentoveraperiodoftime.After0.5 seconds of simulation time there is Uniformly increase in the reading.

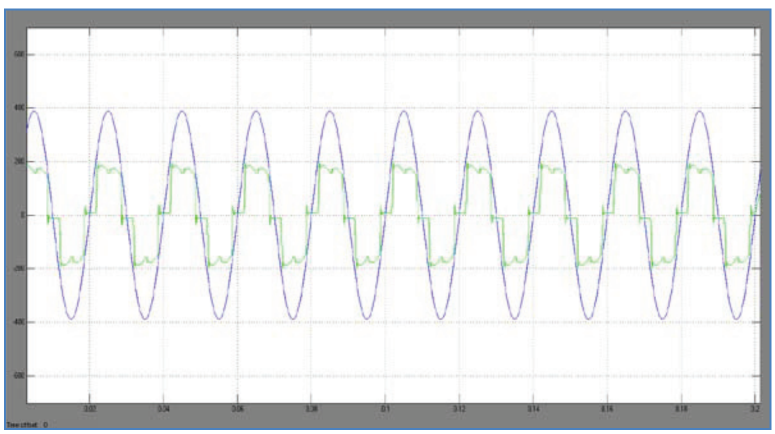

Fig. 7 - Source current and source voltage (Response during t=0-0.2s)

As can be viewed in figure 7, it is evident the result of source voltage and source current over a period of time. Interestingly there is steady reading of both is witnessed.

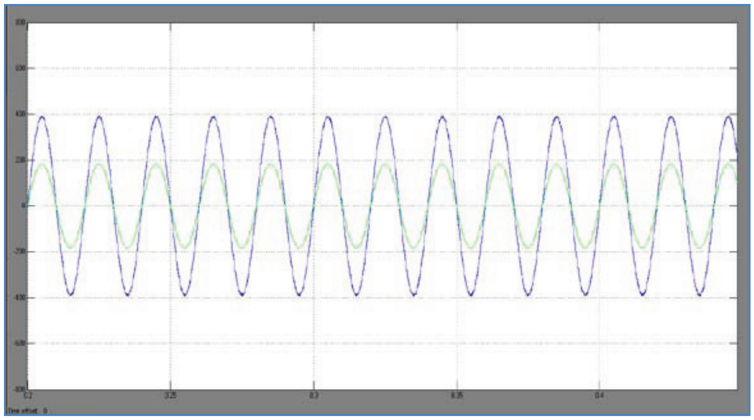

Fig. 8 - Source voltage and source current(Response during t=0.2-0.5s)

As can be viewed in figure 8, it is evident the result of source voltage and source current over a period of time. Interestingly there is steady reading of both is witnessed

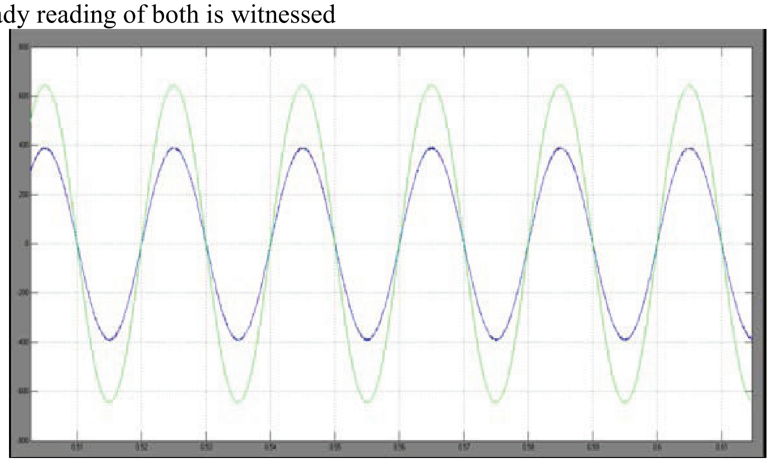

Fig. 9 - Source voltage and source current (Response during t>0.5s)

As can be viewed in figure 9, it is evident the result of source voltage and source current over a period of time. Interestingly there is steady reading of both is witnessed

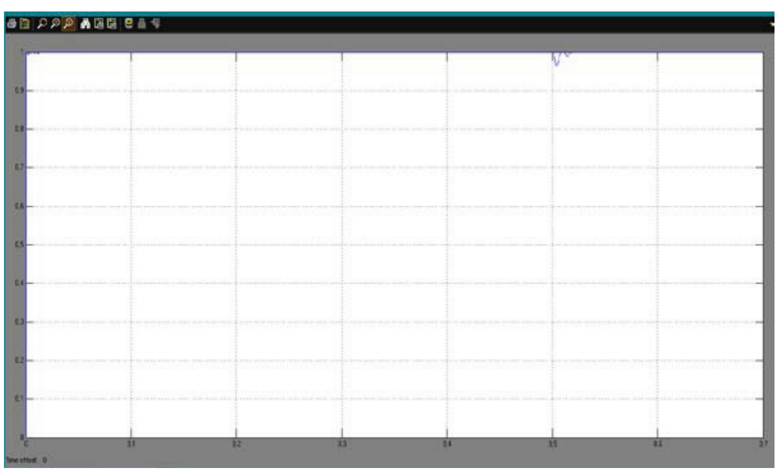

Fig. 10 - Instantaneous Power factor of fuzzy logic controller

As can be seen in figure 10, the instantaneous power factor of fuzzy logic controller is presented.

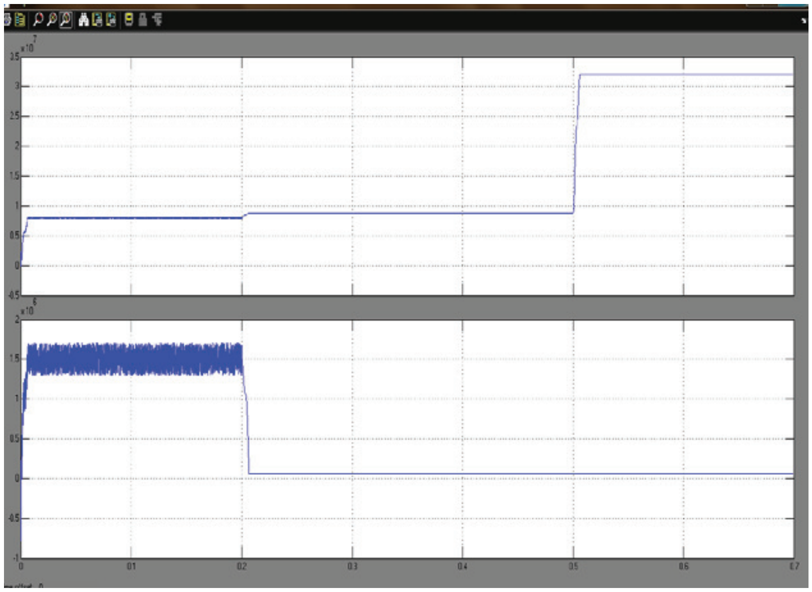

Fig. 11- Instantaneous real power and reactive power regulation

As can be viewed in figure 11, the instantaneous real and reactive power regulation of fuzzy logic controller presented. Real powers, reactive powers and DC link voltages of each case were observed and then compared. Figs 11-12 present the comparison of which for real power, reactive power and DC link voltage, respectively. The response of the observed reactive powers clearly confirmed that during the overall operation, the proposed control scheme can well perform the function of power factor correction. This can be seen with the zero reactive power in Fig. 12

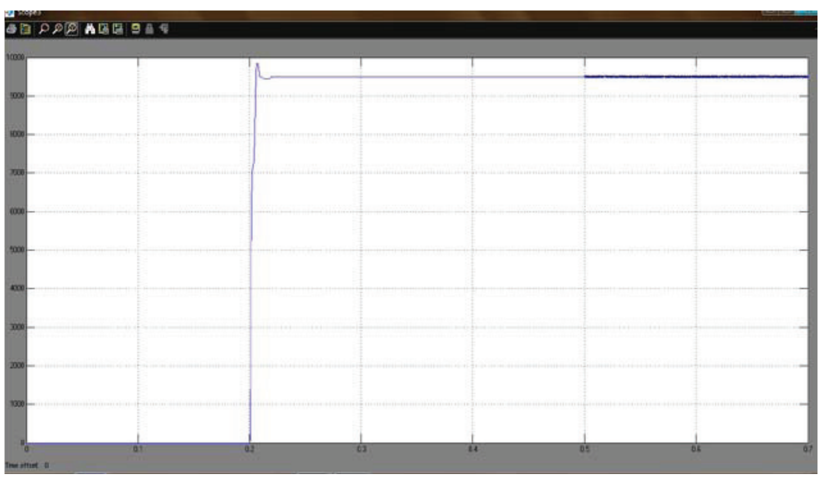

Fig 12-: Instantaneous DC-link voltage regulation

As can be seen in figure 12,the instantaneous DC- link voltage regulation of fuzzy logic controller is presented.

VI. CONCLUSION

In this paper we study the problem of transient disturbances in power systems. We implement fuzzy logic controller with D-STATCOM, a compensator of FACTS devices. As we focused on the power – factor we used the device in Var compensation mode which is aimed at reactive power control. The device monitors the load current for finding quadrature component and then injects compensating current in order to ensure that the power transmission line maintains unity power factor. We also used direct component of current in order to regulate DC-bus voltage. The proposed system is less sensitive to the parameters change in the system. We built a prototype application to simulate the proof of concept. The experimental results are encouraging as the fuzzy logic controller is flexible and can yield robust controllingof voltage.

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