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Power Quality Profile Improvement Using Hybrid Fuzzy Controlled based Improved DSTATCOM

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Abstract- Power quality is a growing concern for a wide range of customers. Usually the term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. However there are many devices that mis-shape or distort the waveform. Modern active harmonic filters are outstanding in filtering performance of harmonics. The Improved DSTSTCOM employs a simple control scheme for the estimation of the reference compensation current based on hybrid fuzzy technique. This improved power quality conditioner is able to operate in different load conditions (balanced, unbalanced, variable). Conventional filters may not have good performance in dynamic conditions. The auto tuned filters give good results for harmonic elimination, reactive power compensation and load balancing. The proposed control scheme gives the THD well within IEEE-519 standards. The proposed control scheme is tested for wide range of different types of Loads with Improved dynamic behavior of Improved DSTATCOM using hybrid fuzzy logic controller.

Keywords – Power factor, fuzzy controller, Improved DSTATCOM, harmonic elimination.

I. INTRODUCTION

With increasing applications of nonlinear and electronically switched devices in distribution systems and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. In order to meet PQ standard limits, it may be necessary to include some sort of compensation [4]. Modern solutions can be found in the form of active rectification or active filtering.

Multilevel inverters are being investigated and recently used for active filter topologies. Three-level inverters are becoming very popular today for most inverter applications, such as machine drives and power factor compensators. The advantage of multilevel converters is that they can reduce the harmonic content generated by the active filter because they can produce more levels of voltage than conventional converters (more than two levels). This feature helps to reduce the harmonics generated by the filter itself. Another advantage is that they can reduce the voltage or current ratings of the semiconductors and the switching frequency requirements [5]. The more levels the multilevel inverter has, the better the quality of voltage generated because more steps of voltage can be created.

An Improved DSTATCOM is suitable for the suppression of negative load influence on the supply network, but if there are supply voltage imperfections, a series active power filter may be needed to provide full compensation [1]. And also we have compensation techniques such as tapping transformers, shunt condensers etc. In recent years, solutions based on flexible ac transmission systems (FACTS) have appeared. The application of FACTS concepts in distribution systems has resulted in a new generation of compensating devices. It is similar to Unified Power Flow Controller (UPFC).

The UPFC is the combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC), which are coupled via a common dc link, to allow bidirectional flow of active power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM [2]. The unified power quality conditioner (UPQC) compensator seems to be a particularly promising power conditioner device.

A solution that has similar performances and advantages, but also makes cost reduction possible, is the proposed MC-DPFC. Advance of UPFC is DPFC. The DPFC is able to control all system parameters. The DPFC eliminates the common dc link between the shunt and series converters. The active power exchange between the shunt and the series converter is through the transmission line at the third-harmonic frequency [3].

During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. Fuzzy control is based on fuzzy logic-a logical system that is much closer in spirit to human thinking and natural language than traditional logical systems [6]-[9]. The fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy. Recently, fuzzy logic controllers (FLC's) have generated a good deal of interest in certain applications.

II. IMPROVED DSTATCOM PROPOSED SYSTEM

The Improved DSTATCOM, with a self-controlled dc bus, has a topology similar to that of a static compensator (DSTATCOM) used for reactive power compensation in power transmission systems. Improved DSTATCOM compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the Improved DSTATCOM operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°. A three-phase diode rectifier with input impedance and R-L load is considered as a nonlinear load as shown in fig. 1. Due to the presence of source inductance, six overlapping and six non-overlapping conduction intervals occur in a cycle. During a non-overlapping interval only two devices will conduct while during an overlapping interval three devices of the bridge will conduct simultaneously.

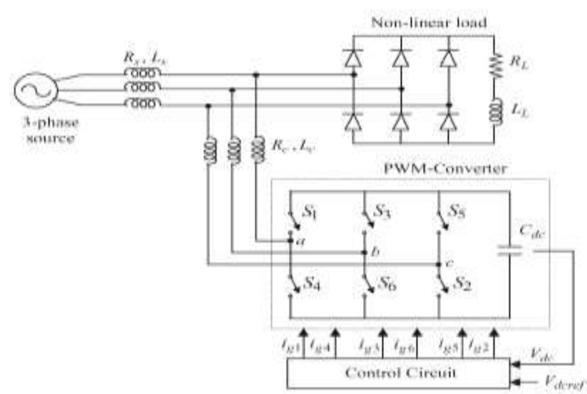

Fig1. schematic diagram of Improved DSTATCOM.

III. DESIGN OF CONTROL SCHEME

A. PI CONTROLLER

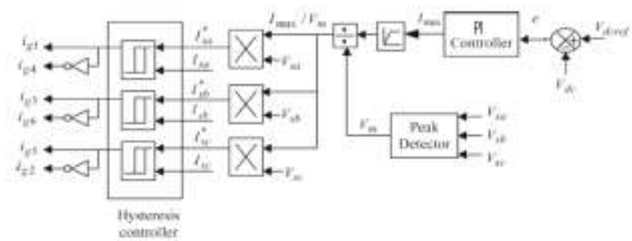

Fig 2. Improved DSTSTCOM control scheme with PI controller.

The error signal is fed to PI controller. The output of PI controller has been considered as peak value of the reference current. It is further multiplied by the unit sine vectors (u_{sa}, u_{sb}, and u_{sc}) in phase with the source voltages to obtain the reference currents (i_{sa}^*, i_{sb}^*, and i_{sc}^*). These reference currents and actual currents are given to a hysteresis based, carrier less PWM current controller to generate switching signals of the PWM converter. The difference of reference current template and actual current decides the operation of switches [10]. To increase current of particular phase, the lower switch of the PWM converter of that particular phase is switched on, while to decrease the current the upper switch of the particular phase is switched on. These switching signals after proper isolation and amplification are given to the switching devices as in fig 2. Due to these switching actions current flows through the Improved DSTATCOM inductor L_c, to compensate the harmonic current and reactive power of the load, so that only active power drawn from the source.

A proportional-integral-derivative controller (PID controller) is control loop feed back mechanism used in industrial control systems. In an industrial process a PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly. The PID controller calculation (algorithm) involves three separate modes; the Proportional mode, the Integral mode and Derivative mode. The proportional mode determines the reaction to the current error, the integral mode determines the reaction based on recent errors and the derivative mode determines the reaction based on the rate by which the error has been changing. The weighted sum of the three modes is outputted as a corrective action to a control element such as a control valve or heating element. By adjusting constants in the PID controller algorithm the PID can provide individualized control specific to process requirements including error responsiveness, overshoot of set point and system oscillation. Some applications may require only using one or two modes to provide the appropriate system control. A PID controller will be called a PI, PD, P or I controller in the absence of respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise.

Proportional mode responds to a change in the process variable proportional to the current measured error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain or proportional sensitivity. With integral mode, the controller output is proportional to the amount and duration of the error signal. The integral mode algorithm calculates the accumulated proportional offset over time that should have been corrected previously (finding the offset's integral). While this will force the controller to approach the set point quicker than a proportional controller alone and eliminate steady state error, it also contributes to system instability as the controller will always be responding to past values. This instability causes the process to overshoot the set point since the integral value will continue to be added to the output value, even after the process variable has reached the desired set point. The

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characteristic equation of the voltage control loop is used to obtain the constants of PI controller in this case, can be written as

$$1+(K_p+\frac{K_i}{s})\frac{3[V_s-L_cI_{co}s-2I_{co}R_c]}{C_{dc}V_{dco}s}=0$$

B. Fuzzy control scheme

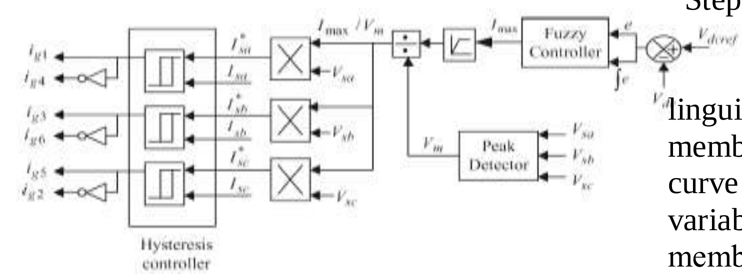

Fig 3. Improved DSTSTCOM control scheme with Fuzzy controller.

In a fuzzy logic controller, the control action is determined from the evaluation of a set of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The internal structure of the fuzzy controller is shown in Fig. 3.

Fig 4. fuzzy controller

A fuzzy inference system (or fuzzy system) basically consists of a formulation of the mapping from a given input set to an output set using fuzzy logic as shown in fig 4. This mapping process provides the basis from which the inference or conclusion can be made.

A fuzzy inference process consists of the following steps:

Step 1:Fuzzification of input variables.
Step 2: Application of fuzzy operator (AND,OR,NOT) in the IF(antecedent) part of the rule.
Step 3: Implication from the antecedent to the consequent (THEN part of the rules).
Step 4: Aggregation of the consequents across the rules.
Step 5: Defuzzification

The crisp inputs are converted to linguistic variables in fuzzification based on membership function (MF). An MF is a curve that defines how the values of a fuzzy variable in a certain domain are mapped to a membership value μ (or degree of membership) between 0 and 1. A membership function can have different shapes. The simplest and most commonly used MF is the triangular-type, which can be symmetrical or asymmetrical in shape. A trapezoidal MF has the shape of a truncated triangle. Two MFs are built on the Gaussian distribution curve: a simple Gaussian curve and a two-sided composite of two different Gaussian distribution curves. The bell MF with a flat top is somewhat different from a Gaussian function. Both Gaussian and bell MFs are smooth and non-zero at all points and fuzzy rules are tabulated in table 1.

Table.1 fuzzy rules

Change in error(ce) \ error(e)	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	Ps
NB	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

IV. RESULTS AND DISCUSSIONS

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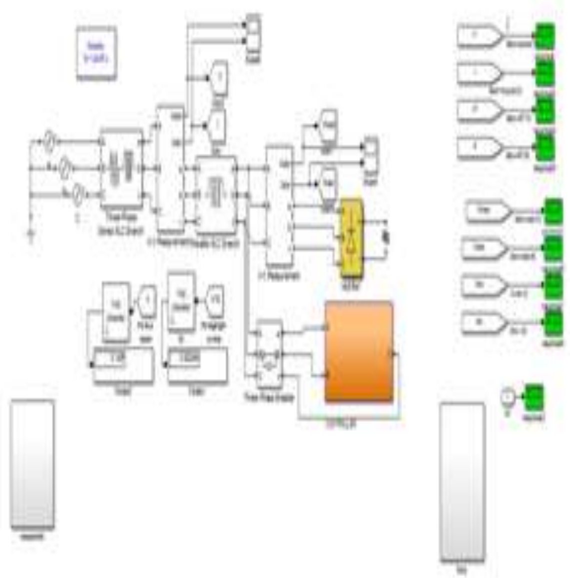

Fig 5. Simulink diagram

Case 1: Non linear load without Improved DSTATCOM:

Fig.6 represents the three phase source voltages, three phase source currents and load currents respectively without Improved DSTATCOM of hybrid fuzzy control scheme as shown in fig.5. Here evaluates the without Improved DSTATCOM load current and source currents are same.

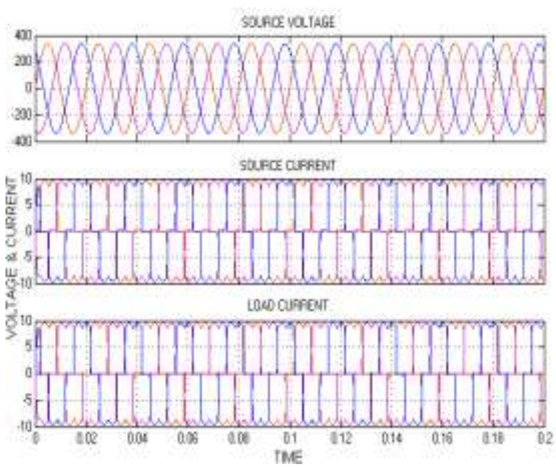

Fig 6. source voltage,source current&load current without Improved DSTATCOM

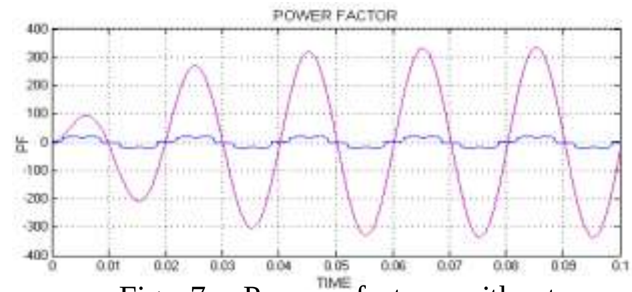

Fig 7. Power factor without Improved DSTATCOM

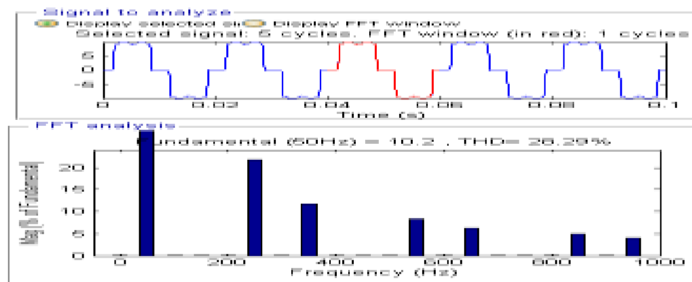

Fig:8 FFT Analysis of Phase-A Source Current without Active power Improved DSTATCOM

The simulations results of the proposed Improved DSTATCOM controlled by fuzzy logic and a conventional PI controller with MATLAB program. The three phase source voltages are assumed to be balanced and sinusoidal.

A load with highly nonlinear characteristics is considered for the load compensation. The THD in the load current is 28.29%. The phase-a load current is shown in figure 8. The source current is equal to the load current when the compensator is not connected

Case 2: Non-linear load with dc link controlled based shunt active power Improved DSTATCOM:

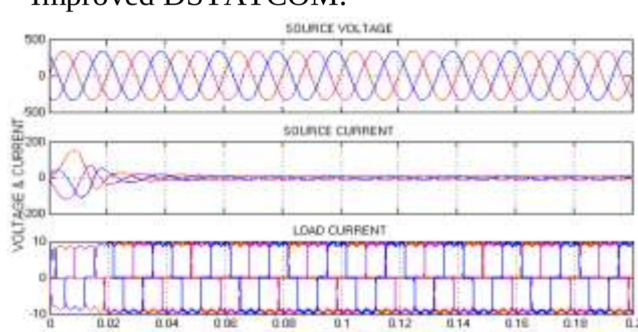

Fig:9 Source Voltage, Source Current, Load Current – with dc link controller

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Fig 9 represents the three phase source voltages, three phase source currents and load currents respectively with dc link controlled based Improved DSTATCOM. Here evaluates the with Improved DSTATCOM load current are distorted and source currents are harmonic free response.

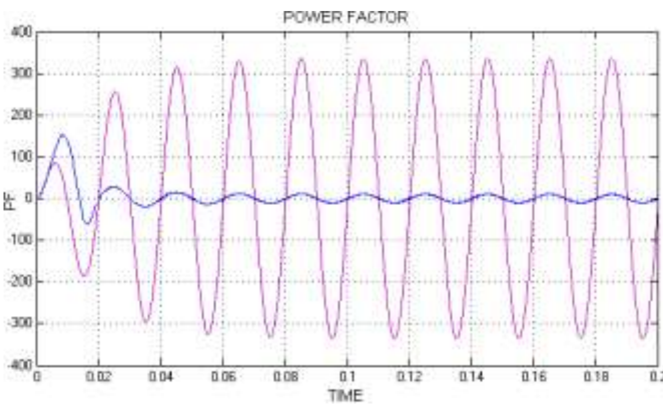

Fig.10 Power Factor with dc link controller

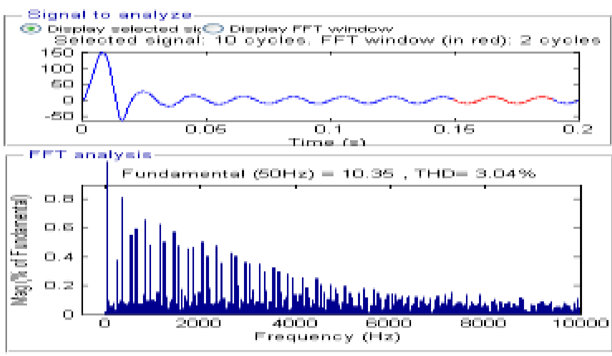

Fig.11 FFT Analysis of Phase-A Source current with dc link controller

Case 3:Non-linear load with hybrid fuzzy controlled based Improved DSTATCOM:

From the wave forms it is clear that harmonic distortion is reduced after connecting compensator. Compared to PI controller fuzzy controller fuzzy controller gives better harmonic compensation.

The system studied has also been modeled using simulink and performance of PI and Fuzzy controllers is analyzed. Figures 12-14 shows the simulation results of the implemented system with PI controller and fuzzy controllers. The source voltage waveform of the reference phase only (phase-a, in this case) is shown in fig.8. An induction motor load is taken as non-linear load. The THD of the load current is 28.29%. The optimum values (K_p and K_i) are found to be 0.2 and 9.32 respectively.

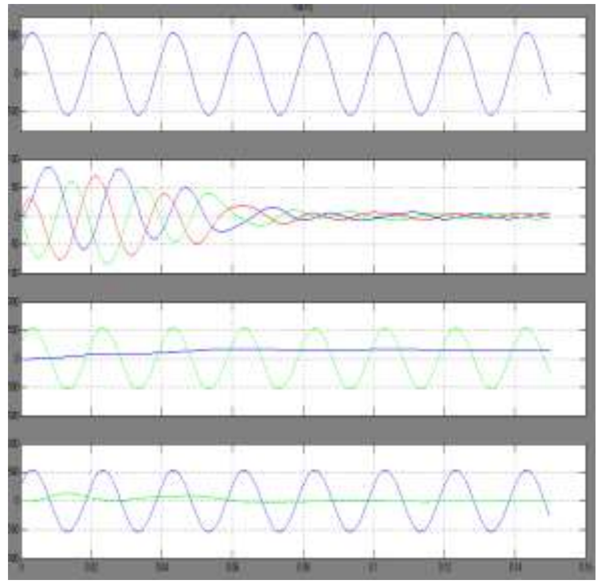

Fig.12 source voltage, source current with Improved DSTATCOM, Power factor with & without Improved DSTATCOM

From the responses it is depicted that the settling time required by the PI controller is approximately 8 cycles whereas incase of fuzzy controller is about 6 cycles. The source current THD is reduced form 27.88% to 2% incase of PI controller and 2.89% incase of fuzzy controller which is below IEEE standard with both the controllers.

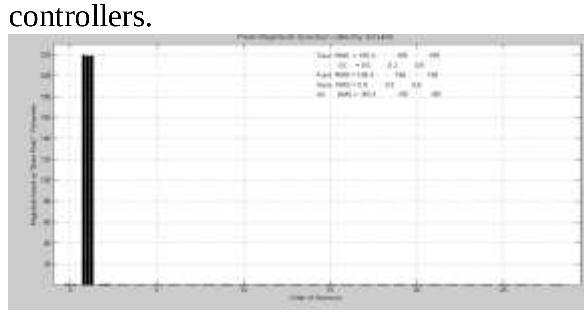

Fig.13 FFT analysis with Improved DSTATCOM

Figures 12-15 shows the simulation results of the implemented system with PI controller and fuzzy controllers. The source voltage waveform of the reference phase only (phase-a, in this case) is shown in fig.12. An induction motor load is taken as non-linear load. The THD of the load current is 28.29%.

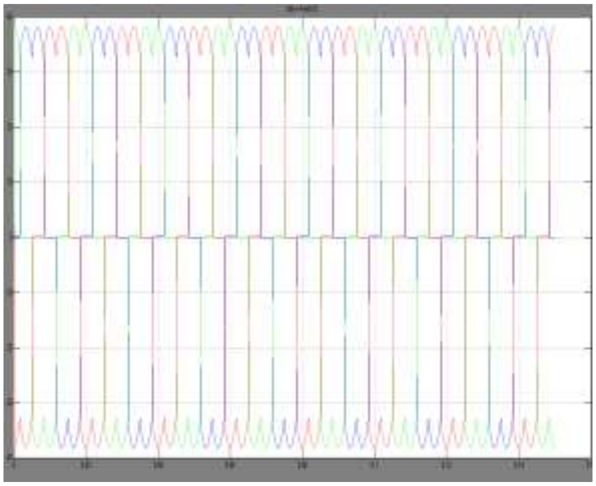

Fig:14 load current

From the responses it is depicted that the settling time required by the PI controller is approximately 10 cycles whereas in case of fuzzy controller is about 7.5 cycles. The peak overshoot voltage incase of PI controller is 220 Volts (approx) whereas in case of fuzzy controller is 210 volts (approx). The source current THD is reduced from 28.29% to 3.04% which is below IEEE standard with both the controllers. After compensation both source voltage and current are in phase with each other means that the harmonics are eliminated and reactive power is compensated to make power factor close to unity. As the source current is becoming sinusoidal after compensation power quality is improved.

V. CONCLUSION

An Improved DSTATCOM has been incorporated for power quality improvement i.e., to reduce harmonics in source currents. Various simulations are carried out to analyze the performance of the system consisting of non linear loads. Both PI controller and fuzzy logic controller based Improved DSTATCOM is implemented for harmonic and reactive power compensation of the non-linear load. A program has been developed to simulate the fuzzy logic based and PI controller based Improved DSTATCOM in MATLAB.

It is observed from simulation results that Improved DSTATCOM improves power quality of the power system by eliminating harmonics and reactive current of the load current, which makes the load current sinusoidal and in phase with the source voltage. The performance of both the controllers has been studied and compared. A simulation model has been developed in MATLAB Version. The fuzzy controller based Improved DSTATCOM has better performance compared to PI controller in steady state except that settling time is very less in case of fuzzy controller. The THD of the source current is below 5%, the harmonics limit imposed by IEEE standard.

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