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IMPROVING VOLTAGE STABILITY BY CONTROLLING DC VOLTAGE OF A STATCOM BASED ON HYBRID MULTILEVEL H BRIDGE CONVERTER USING FUZZY TECHNIQUES

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***Abstract*- In this paper, the control strategy for the static synchronous compensator (STATCOM) is investigated, and a novel fuzzy based DC voltage control strategy is presented. This new STATCOM in each phase consist of series connection of a high-voltage H-bridge converter operating at fundamental frequency and a low-voltage H-bridge converter operating at 5 kHz . Clustered balancing control is realized by injecting a zero-sequence current to the delta-loop, while individual voltage control is achieved by adjusting the fundamental content of ac quasi-square-waveform voltage of high-voltage converter The hybrid multilevel STATCOM which can be used at the point of common coupling (PCC), for improving power quality is modelled and simulated using proposed control strategy.**

Index Terms –**Cascade Multilevel Inverter, Static Synchronous Compensator (STATCOM), Hybrid Multilevel Converter, Power Quality, Reactive Power Compensation, Harmonics, THD.**

I. INTRODUCTION

RECENTLY, with the growth of nonlinear loads in industrial manufactures, the electric power quality has become more and more important. As one of the most common issues about the electric power quality, voltage fluctuations influence domestic lighting and sensitive apparatus in transmission and distribution systems [1]. CASCADED H-bridge converter with equal dc voltage has been widely used for static synchronous compensator (STATCOM) application because of high-quality output spectrum [2]–[4].

A cascaded two level inverter based STATCOM is designed for harmonic reduction [3]. Hybrid multilevel technology provides a good tradeoff between waveform quality and switching loss. A single dc source (such as battery or fuel cell) as the first dc source with the remaining $n - 1$ dc sources being capacitors in the cascaded H-bridges multilevel inverter, which is referred to as the hybrid cascaded H-bridge multilevel inverter (HCMLI) [6]-[8].

In recent years most of the papers have suggested methods or designing STATCOM PI controllers using linear control techniques, in which the system equations are linearized at a specific operating point and the PI controllers are tuned at that point based on the linearized model, in order to have the best possible performance [9]-[11]. The drawback of such PI controllers is that their parameters are mostly tuned based on a trial and error approach.Moreover, their performance degrades as the system operating conditions change. Nonlinear adaptive controllers on the other hand can give good control capability over a wide range of operating conditions, but they have a more sophisticated structure and are more difficult to implement compared to linear controllers. In addition, they need a mathematical model of the system to be controlled [12]-[14]. Fuzzy logic controllers offer solutions to this problem. They are nonlinear controllers that are usually independent of a mathematical model for the plant to be controlled. Moreover, they can provide efficient control over a wide range of systemoperating conditions. Conventional fuzzy logic controllers have been widely applied in power systems [15]-[18].

In proposed system, STATCOM application using Hybrid multilevel converters are introduced. Here a delta-type hybrid single-phase H-bridge topology is preferred because of modularity and simplicity This paper designs an adaptive Mamdani based fuzzy- logic controller for a DC voltage control of Hybrid Multilevel STATCOM.

II WORKING PRINCIPLE OF STATCOM

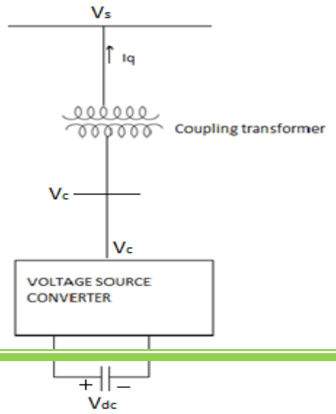
The Static Synchronous Compensator (STATCOM) is based on a shunt connected solid state reactive compensation device, implemented with voltage source converter. It is connected to the power system through coupling at the point of common coupling without the need of large external reactors and capacitor banks. The operating principle of STATCOM is explained in fig.1.

The active and reactive power flow in the line in terms of converter voltage(Vc) and supply voltage(Vs), the transformer impedance(X) and the angle difference between both bus bars (δ) can be

$$P_c = \frac{Vs.Vc}{X} \sin\delta \qquad (1)$$

$$Q_c = \frac{Vc(Vc - Vs.COS\ \delta)}{X} \qquad (2)$$

The angle between the Vs and Vc in the system is δ. When the STATCOM operates with δ=0 ,the active power send to the system is zero , while the reactive power will mainly depend on the voltage.



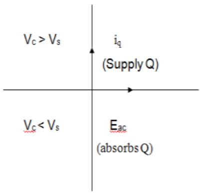


Fig.1 Schematic Configuration of STATCOM

III HYBRID MULTILEVEL STATCOM

The configuration of Hybrid Multilevel Converter based STATCOM is connected on a transmission line as shown in Fig.2. In this system, each phase cluster consist of one single-phase H-bridge cell acts as a high voltage converter, and the other single-phase H-bridge cell acts as a low-voltage converter. This high voltage and low voltage converter helps to maintain an unequal voltage across each cluster.

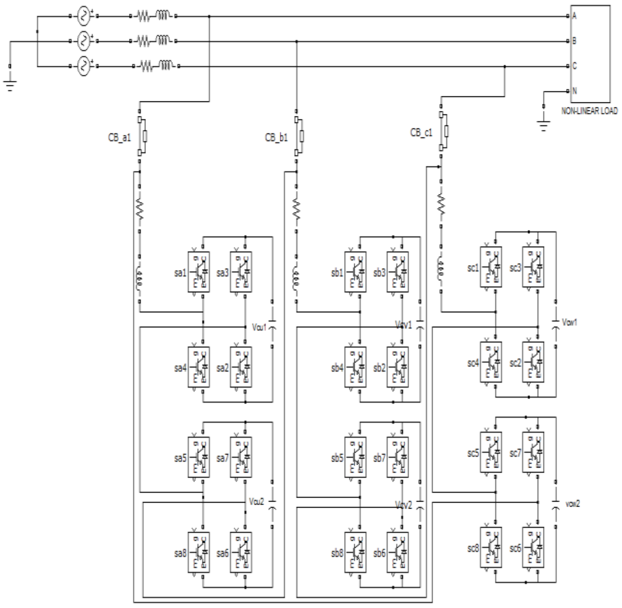


Fig.2 Configuration of Hybrid Multilevel STATCOM

Each cell is equipped with an isolating electrolytic capacitor with a capacitance value of 9800 μF. No auxiliary circuit is connected to the six split dc capacitors except for six voltage sensors. A starting resistor (R_s) of value 100Ω can be used to prevent the inrush current. An ac inductor is also required for each cluster to support the difference between the sinusoidal source voltage and the ac pulse width modulation (PWM) voltage of each cluster, and it also makes contribution in filtering out switch ripples caused by high-frequency modulation. Here the switching frequencies of 50 Hz and 5kHz are assigned to high-voltage converter and low-voltage converter, respectively. The constant dc voltages are achieved purely by the control algorithm. This design is reasonable to verify the improvement of input voltage waveform, when non-linear load is connected.

IV.CONTROL SYSTEM STRATEGY

In this section, the fuzzy control fundamentals will be outlined first.

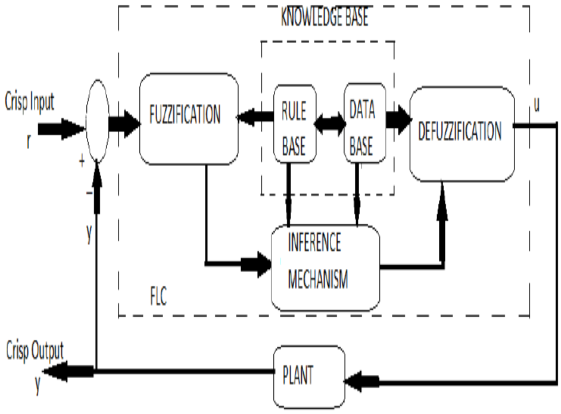


Fig.3 Basic structure of fuzzy logic system

A. Fuzzy Control Philosophy

A basic FLC system structure, which consists of the knowledge base, the inference mechanism, the fuzzification interface, and the defuzzification interface, is shown in Fig. 3. Essentially, the fuzzy controller can be viewed as an artificial decision maker that operates in a closed-loop system in real time. It grabs plant output $y(t)$, compares it to the desired input $r(t)$, and then decides what the plant input (or controller output) $u(t)$ should be to assure the requested performance.The inputs and outputs are “crisp.” The fuzzification block converts the crisp inputs to fuzzy sets, and the defuzzification block returns these fuzzy conclusions back into the crisp outputs.

B. Overview of Fuzzy Logic DC Voltage Control System

As is known to everyone, the traditional PI controller is widely used in industrial applications for its simplicity and reliability. However, in practice, a traditional PI controller with constant parameters may not be robust enough due to the variations of design parameters.

A fuzzy adjustor is used to adjust the parameters of proportional gain K_P and integral gain K_I based on the error e and the change of error Δe

$$K_P = K^*_P + \Delta K_P \quad (3)$$
$$K_I = K^*_I + \Delta K_I \quad (4)$$

where K^*_P and K^*_I are the reference values of fuzzy-PI-basedcontrollers. In this paper, K^*_P and K^*_I are calculated offlinebased on the Ziegler–Nichols method [20].The error e and the change of error Δe are used as numerical variables from the real system. To convert these numerical variables into linguistic variables, the following seven fuzzy sets are chosen: negative big (NB), negative medium (NM),negative small (NS), zero (ZE), positive small (PS), positive medium (PM), and positive big (PB).

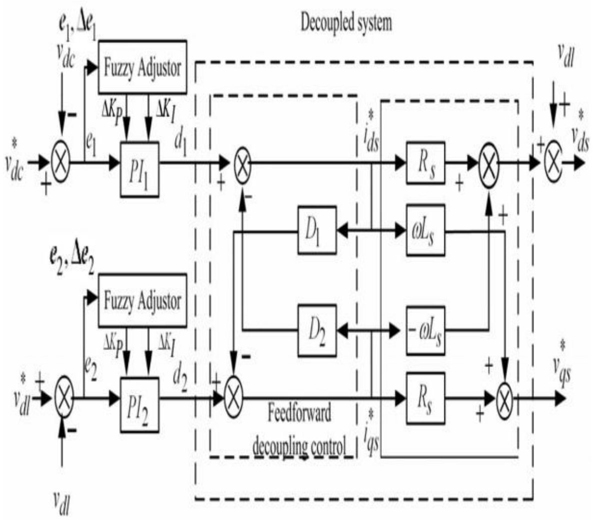


Fig.4 Schematic configuration of the improved fuzzy based controller

To ensure the sensitivity and robustness of controllers, the membership function is shown in Fig. 5.

The controller core is the fuzzy control rules which are mainly obtained from intuitive feeling and experience. The design process of fuzzy control rules involves defining the rulesthat relate the input variables to the output model properties [19]–[21].

For designing the control rule bases to tune ΔKP and ΔKI , the following important factors have been taken into account.

1) For large value of $|e|$, a large ΔKP is required, and vice versa.

2) For $e * \Delta e > 0$, a large ΔKP is required, and vice versa.

3) For the large values of $|e|$ and $|\Delta e|$, ΔKI is set to zero,which can avoid control saturation.

4) For small value of $|e|$, ΔKI is effective, and ΔKI is larger when $|e|$ is smaller, which is better to decrease steady-state error.

Therefore, the tuning rules of ΔKP and ΔKI can be obtained as Tables I and II.

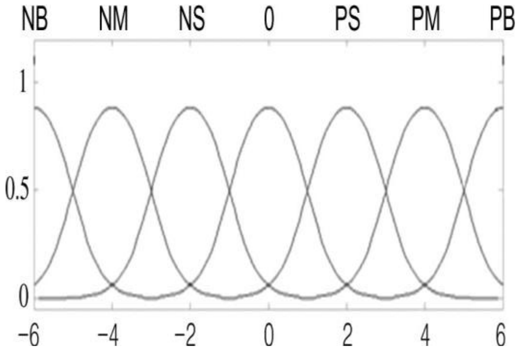


Fig. 5. Membership functions of fuzzy variables

The inference method employs the MAX–MIN method. The imprecise fuzzy control action generated from the inference must be transformed to a precise control action in application.

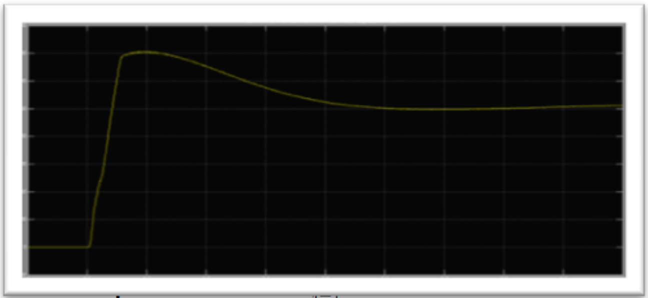
TABLE I
ADJUSTING RULES OF ΔK_P PARAMETER

ΔK_P / e \ e_c	NB	NM	NS	0	PS	PM	PB
NB	PB	PB	NB	PM	PS	PS	0
NM	PB	PB	NM	PM	PS	0	0
NS	PM	PM	NS	PS	0	NS	NM
0	PM	PS	0	0	NS	NM	NM
PS	PS	PS	0	NS	NS	NM	NM
PM	0	0	NS	NM	NM	NM	NB
PB	0	NS	NS	NM	NM	NB	NB

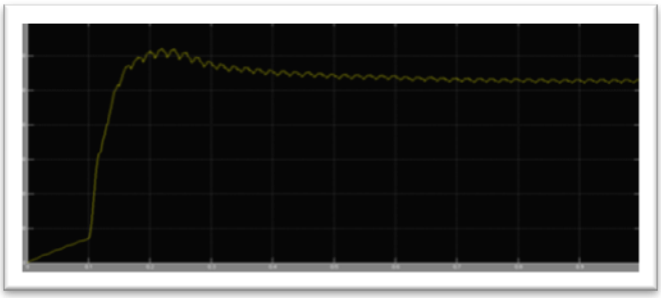
TABLE II
ADJUSTING RULES OF ΔK_I PARAMETER

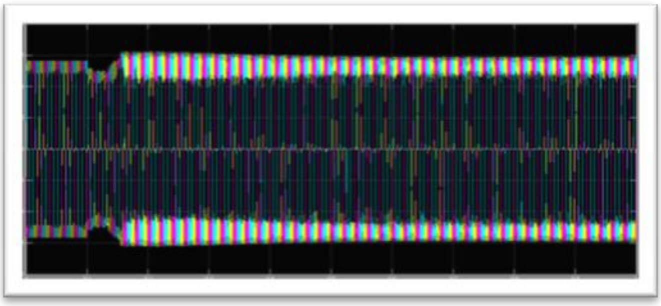
ΔK_i / e \ e_c	NB	NM	NS	0	PS	PM	PB
NB	0	0	NB	NM	NM	0	0
NM	0	0	NM	NM	NS	0	0
NS	0	0	NS	NS	0	0	0
0	0	0	NS	NM	PS	0	0
PS	0	0	0	PS	PS	0	0
PM	0	0	PS	PM	PM	0	0
PB	0	0	NS	PM	PB	0	0

The center gravity method is used to defuzzify fuzzy variables into their physical domains



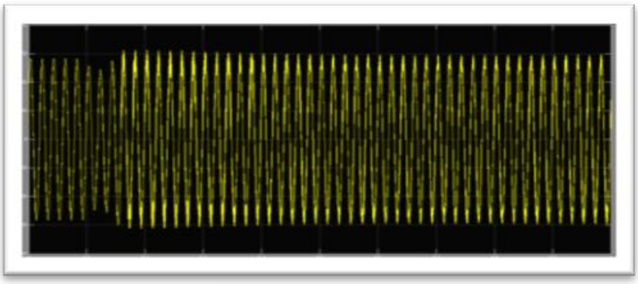
$$K_I = K_I^* + \frac{\sum_{j=1}^{n} \mu_j(e,\Delta e)\Delta K_{Ij}}{\sum_{j=1}^{n} \mu_j(e,\Delta e)}$$





(5)

where μ denotes a membership function of fuzzy sets.



V. SIMULATION RESULTS

Fig:6Summation of capacitor voltages using PI

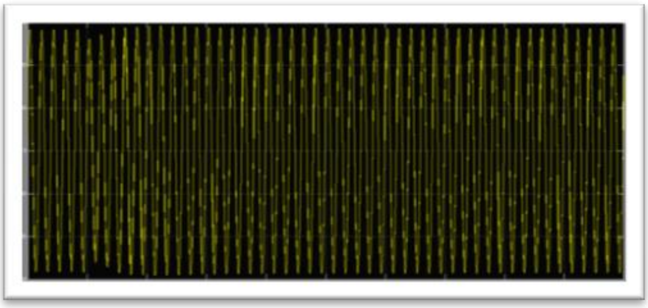


Fig:6 shows summation of capacitor voltage using PI, taking time in X axis and voltage in Y axis. In this figure cell V1 is one single phase H- bridge cell is controlled as high voltage converter with dc link voltage of 110V and the other cell V2 is single phase H-bridge cell act as a low voltage converter with dc link voltage of 65V.

Fig:7Summation of capacitor voltages using fuzzy

Fig:7 shows summation of capacitor voltage using fuzzy. By using fuzzy controller harmonics are eliminated than PI.

Fig:8Three phase load current response using PI

Fig:8 shows three phase load current response using PI . By using PI controller the current at the load side with harmonic distortion

Fig:9Three phase load current response using fuzzy

Fig 9 shows three phase load current response using fuzzy , taking time in in X axis and current in Y axis in this fig shows current at the load without harmonic distortion.

Fig:10Statcom output voltage of phase A using PI

Fig 10 shows STATCOM output voltage of phase A using PI controller. By using PI controller we cannot obtain pure sinusoidal wave.

Fig:11Statcom output voltage of phase A using fuzzy

Fig 11 shows STATCOM output voltage of phase A using Fuzzy controller , taking time in X axis and STATCOM output voltage in Y axis.

VI.CONCLUSION

This project has analyzed the fundamentals of DC voltage control based on cascaded hybrid multilevel h bridge converters . and then a hybrid modulation for hybrid multilevel converter has been proposed and the control algorithm has also been designed in detail .This control method along with the STATCOM using Fuzzy controller producing high quality out put wave forms , reducing THD and improving whole systems efficiency compared to STATACOM by using PI controller.

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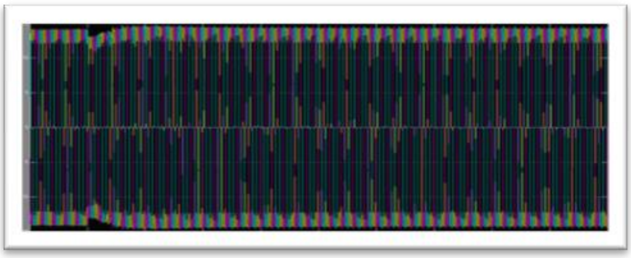

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