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Chapter - 6

Implementation of Fuzzy Logic Controller for Multilevel Inverter Fed D-STATCOM

P. Venkata Kishore and M. Kondalu

Abstract

The implementation of fuzzy logic controller for multilevel inverter fed DSTATCOM was used for the synthesis of the regulated voltage. The control strategy used for the space vector modulation is meant to track the reference voltage from the inverter using a PI and fuzzy logic controller. This helped speedy achievement of a fast response time of three-phase system voltage with reduced THD and regulation of voltage. The comparative results of MLI fed DSTATCOM with SV modulation and the results have been seen and verified. The prototype model of cascaded H-bridge five-level inverter supported DSTATCOM was implemented using a design parameter.

Keywords: Fuzzy, DSTATCOM, PI

I. Introduction

This work presents the implementation of Cascaded H-bridge five-level inverter fed D-STATCOM. Modulation strategies were used for the space vector to track the reference voltage. The feedback control of the inverter was simulated by a PI controller with the application of grid-connected inverter. The result showed the extraction of switching signals which synthesized the balanced set of three-phase output voltages. Hence, the fast response of system voltage with reduced THD and overshoot voltage of fuzzy logic controller helped in achieving good performance compared to the proposed PI controller.

II. Cascaded h-bridge five-level inverter fed D-STATCOM

As the name suggests, this type of multilevel inverter requires full H-bridges which are connected in series producing an inverted output voltage from separate dc sources. The dc sources may be any natural resource as, for example wind energy or fuel cell. It does not require any filter and power transformer. The output of each cell can be obtained by connecting the dc source voltage to the ac output voltage by different combinations of the four switches S11, S12, S31 and S32. The switches S11and S31 are turned on for obtaining +Vdc, whereas −Vdc can be obtained by turning on switches S12 and S32.The output voltage is 0 when S11 and S12 or S31 and S32 are turned on. The output voltage was generated by the no of levels 2(m+1) in each cell of the inverter.

Where m-no of cells in the output voltage

The single H-bridge level of output voltage as follows:

$$v_0(t) = \sum_{k=1}^{n} v_{0k}(t) \tag{4.1}$$

Where k is a number of the k^{th} cells.

Table 1: Switching states of CHBMLI

Switching States						
S11	**S31**	**S12**	**S32**	**VH1**	**VH2**	**VH3**
0	0	0	0	0	0	0
0	0	0	1	0	-Vs	-Vs
0	0	1	0	0	+Vs	+Vs
0	0	1	1	0	0	0
0	1	0	0	+Vs	0	-Vs
0	1	0	1	-Vs	-Vs	-2Vs
0	1	1	0	-Vs	+Vs	0
0	1	1	1	-Vs	0	-Vs
1	0	0	0	+Vs	0	0
1	0	0	1	+Vs	-Vs	0
1	0	1	0	+Vs	+Vs	+2Vs
1	0	1	1	+Vs	0	0
1	1	0	0	0	0	0
1	1	0	1	0	-Vs	-Vs
1	1	1	0	0	+Vs	+Vs
1	1	1	1	0	0	0

The output voltage of the inverter is almost sinusoidal and with less than 5% of total harmonic distribution with each leg of the H-bridges at the o fundamental frequency. The phase voltage was shifted by 90, the average value of each dc capacitor over a cycle was found to be zero. The switching states of CHBMLI are shown in Table. 1.

Table 2: Component of m-level cascaded H-bridge inverter

m-level Cascade H-Bridge	No. of Elements
DC bus Capacitors	3 (m-1)/2
Main Diodes	6 (m-1)
Main Switches	6 (m-1)

The components of m-level cascade H-bridge inverter are shown in Table. 2.

III. Modeling of multilevel inverter fed-dstatcom

A model of Cascaded H-bridge MLI fed DSTATCOM is shown in Figure. 1. D-STATCOM has six H- bridge cells, six dc-link capacitors *C* that provides the dc voltages to H-bridge cells and a coupling inductance with an inverter. The voltage provided by MLI was used for reducing the number of levels and synthesis the average switching frequency. The terminal voltage and the load current are used for compensating and balancing the voltage regulation. The PLL was synchronized to the fundamental voltage of the primary transformer for generating the desired frequency. The integral part of the controller which is a feedback to the controller to generate the average switching frequency of the inverter, when turn-off the switching pulses.

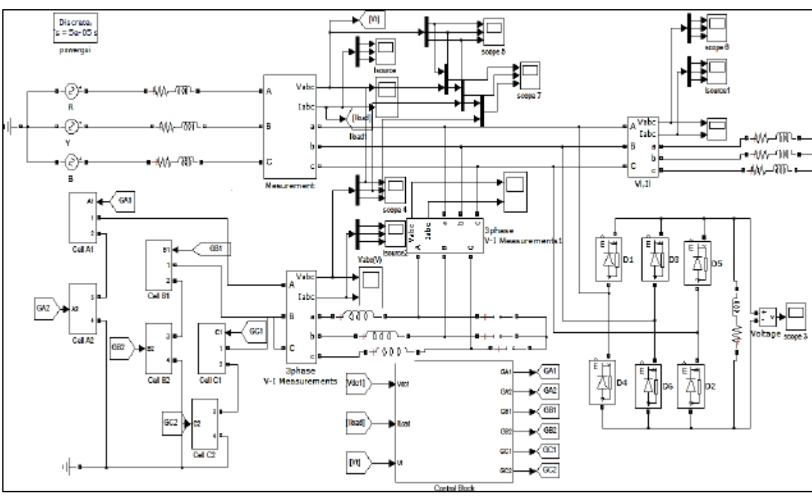

Fig 1: Cascaded H-Bridge MLI fed DSTATCOM

IV. Closed loop control of mli fed DSTATCOM using PI controller

The closed-loop control of MLI fed DSTATCOM for reduction of THD in the terminal voltage of the inverter was analysed. The Proportional Integral controller was designed and simulated using MATLAB. The performance of

DSTATCOM was validated for the distribution system. The magnitude of the load current was unbalanced and distorted due to non-linearity in before compensation of terminal voltage and load current which is shown in Figure. 2.

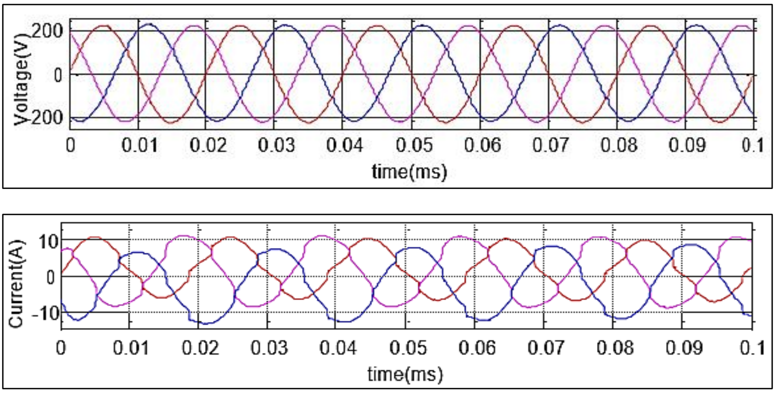

Fig 2: Before compensation of terminal voltage and load current

The Cascaded H-bridge five-level inverter fed DSTATCOM regulated the voltage and improved the THD. The reactive power exchange between MLI fed DSTATCOM and grid maintained the unity power factor balancing the power system.

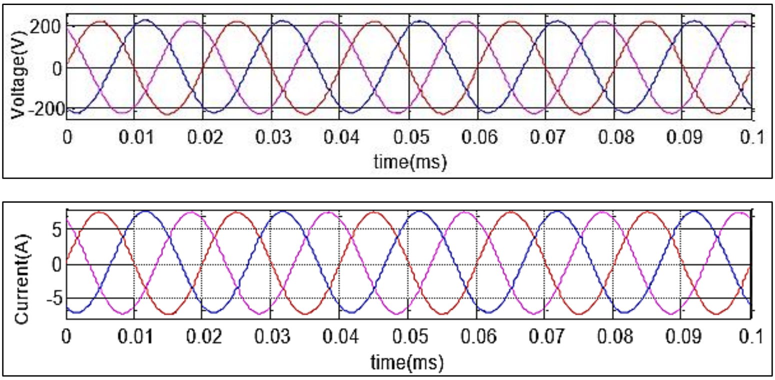

Fig 3: After compensation of terminal voltage and load current

The terminal voltage and load current of after compensation are shown in Figure. 3. The dc voltage of MLI fed DSTATCOM using a PI controller is shown in Figure. 4.

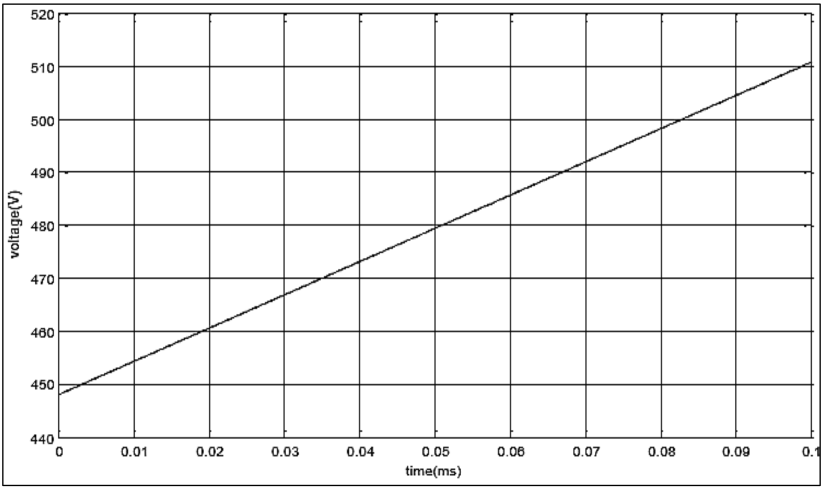

Fig 4: DC voltage of MLI fed DSTATCOM of PI controller

A steady state was attained by t=0.1 sec and the magnitude of the reference voltage was 510 V. The THD was found to be 3.87% of inverter voltage at a fundamental frequency of 50 Hz. The frequency spectrum of inverter voltage with PI controller is shown in Figure. 5.

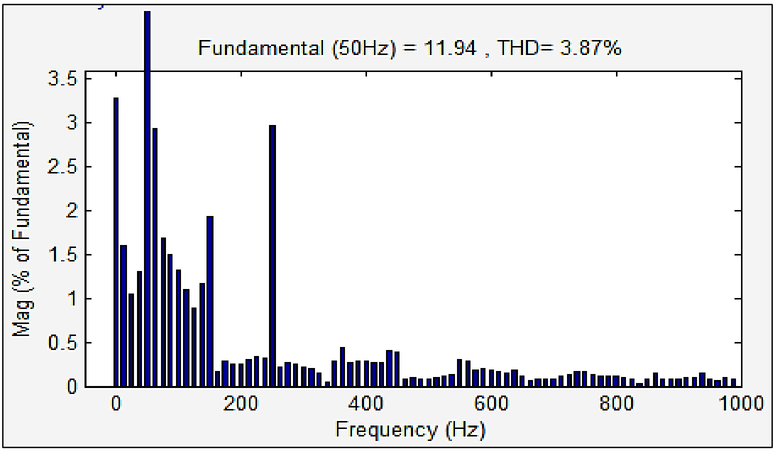

Fig 5: Frequency spectrum of inverter voltage with PI controller

V. Proposed model of MLI fed DSTATCOM using fuzzy logic controller

The fuzzy control system is a real-time control and symbolic representation of rule base function. It provides fast response and interpretation of mathematical modelling in a simple manner. The structure of Fuzzy logic controller is shown in Figure. 6.

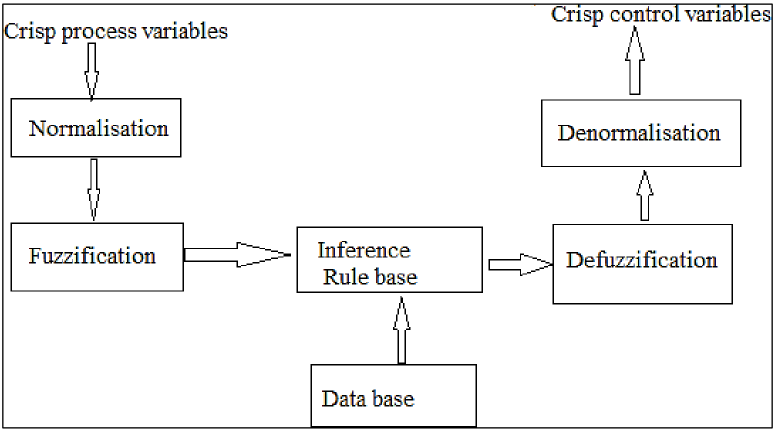

Fig 6: Structure of Fuzzy logic controller

Fuzzy logic controller was used for overshooting the terminal voltage and getting a fast-dynamic response. The basic control was determined by a set of linguistic rules which are determined by the system and numerical variables were converted into linguistic variables. The implementation of fuzzy logic control was designed to overshoot the voltage and attain the steady state in a faster response of DSTATCOM. The control block of DSTATCOM is shown in Figure. 7. There was delay in getting the input signal due to sampling time and the change of error was provided a feedback to the controller for generating the switching pulse of the inverter which was provided a fed back to PV. The rule base of fuzzy logic controller is shown in Table. 3.

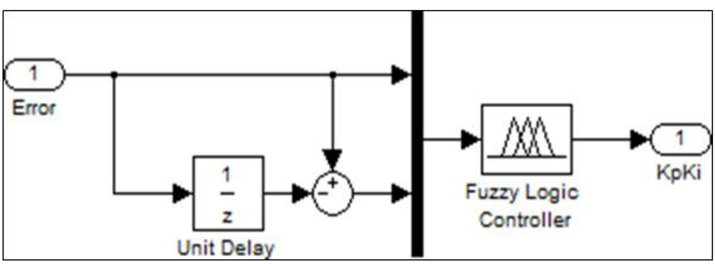

Fig 7: Control block of DSTATCOM

Table 3: Rule base of Fuzzy logic controller

E	**AE**				
	NM	**NS**	**ZE**	**PS**	**PM**
NM	ZE	ZE	NM	NM	NM
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS

PS	PS	PS	PS	ZE	ZE
PM	PM	PM	PM	ZE	ZE

The fuzzy logic control for cascaded H-bridge five inverter of MPPT was simulated. In this case, five fuzzy levels were used: NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), and PB (Positive Medium). The membership function of fuzzy logic controller is shown in Figure. 8.

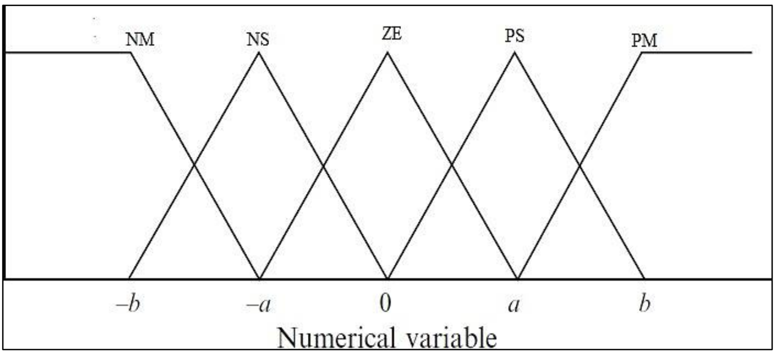

Fig 8: Membership function of Fuzzy logic controller

It is mainly based on a range of values of numerical variables to create accuracy. The input of fuzzy logic controller for MPPT was considered as error E and change of error as ΔE. Due to the elimination of $\partial P/\partial V$ at the MPP, to control the power inverter.

$$E(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)}$$

$$\Delta E(n) = E(n) - E(n-1)$$

Similarly $e = \frac{I}{V} + \frac{\partial I}{\partial V}$ has been calculated by numerical variables of rule function shown in Table 4.3 by different combination of E and ΔE respectively.

Considering this, the operating point is far away from the left of the MPP, i.e., the error E was PM and the change in error was ZE. There was an increase in the duty cycle of the inverter through variations in MPP to PM. The reverse process was done by defuzzification of membership function.

The dc voltage of MLI fed DSTATCOM using a fuzzy logic controller is shown in Figure. 9. The steady state is attained by t=0.1 sec and the magnitude of the reference voltage is 335 V.

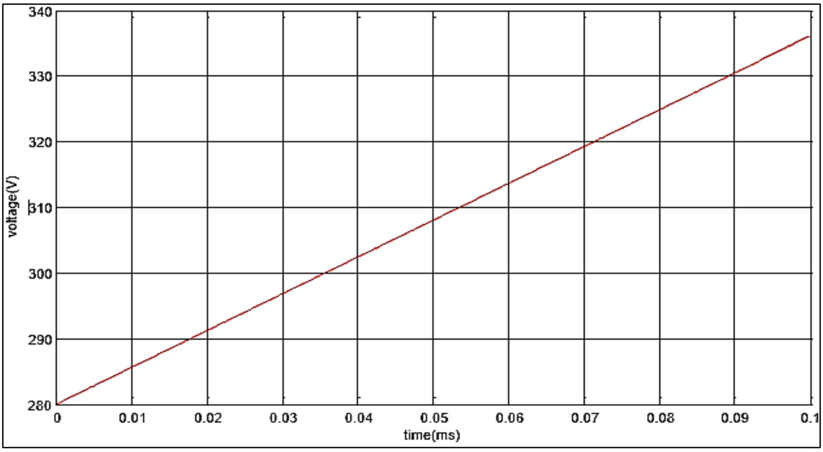

Fig 9: DC voltage of MLI fed DSTATCOM of fuzzy logic controller

The THD was found to be 1.38% of inverter voltage at a fundamental frequency of 50 Hz which is shown in Figure.10. The fast response of system voltage with reduced THD and overshoot voltage of fuzzy logic controller achieved good performance compared to the proposed PI controller.

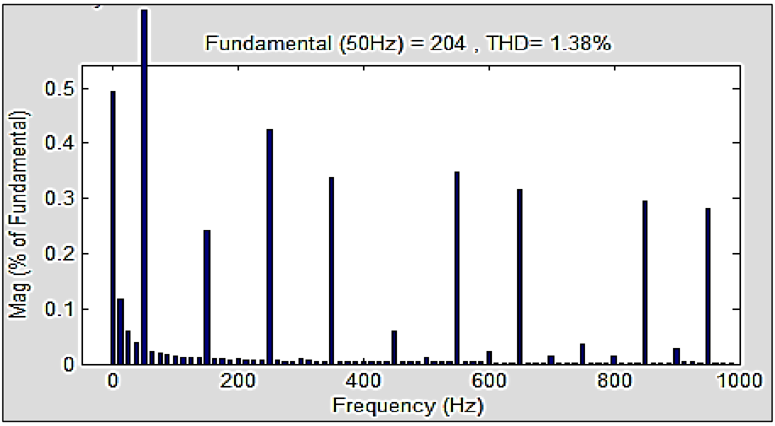

Fig 10: Frequency spectrum of inverter voltage with Fuzzy controller

VI. Conclusion

The performance of the multilevel inverter fed DSTATCOM was modelled and verified with hardware setup. The implementation of the fuzzy logic controller was meant to track the fast response time and improved THD of the system. The proposed model has been simulated with MATLAB. The hardware components of the multilevel inverter fed DSTATCOM were designed. The Cascaded H-bridge multilevel inverter fed DSTATCOM was proposed by the control strategy to mitigate the power quality problems in the distribution system.

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