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Multilevel Statcom Based on PID and Fuzzy Control

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Abstract

To investigate the performance of Multilevel STATCOM based on PID with fuzzy controller under fault conditions. Static Synchronous Compensator is used to inject voltages by regulating DC link voltages in the system which consists of two standard inverters associated in cascaded to obtain five level output. Generally DC link voltages are controlled by PI controller. When there is a fault occurrence in the system, then time response of PI controller will be slow and overshoot problems raised. To rectify this problem, PID with fuzzy controller is proposed. By using PID with fuzzy controller, DC link voltages are synchronized; a dq reference frame theory is used in this system for STATCOM to recompense the harmonics. The proposed controller gives less Total Harmonic Distortion, Response Time, Settling Time and Rise Time.

Keywords: Cascaded Multi Level Inverters, Fuzzy, STATCOM

1. Introduction

Advanced Power systems are of updated networks, with many power stations and the number of load centers is interconnected through long power transmission, grid and distribution networks[1-3]. Power distribution system should offer a reliable power supply to reach customer requirements i.e., rated supply voltage and frequency. Power Quality problem is outlined as drawback in voltage, current or resulting in changes of frequency that causes instability[4-6].

Passive components like RLC elements are used on the line for injecting voltages and filtering the harmonics in the line. But by using these components line weight & cost will increase, efficiency of the system will decrease and leakage currents will be high[7-9]. To resolve these problems Flexible AC Transmission Systems (FACTS) are suitable. There are so many FACTS devices like series compensator, shunt compensator and combination of series & shunt compensator. By series compensator only voltage can be injected, by shunt compensator current can be injected then voltage can be controlled, by the combination of series & shunt compensator both voltage and current can be injected into the line[10-13].

In this paper, analysis is done on one of the FACTS devices which is STATCOM. STATCOM can operate in both rectifier and inverter mode[14,15]. In inverter mode of operation it is injecting voltages into the line, but usually output of inverter is square wave form whose Total Harmonic Distortion is high. In order to get near sinusoidal waveform, multilevel inverters are proposed[16-19]. In this topology cascaded connection of H-bridge inverters based on multilevel STATCOM is proposed to improve the power quality and reducing harmonics in the system. DC link voltages of inverters are controlled by PID with fuzzy logic controller.

2. Proposed Working Principle

STATCOM is static compensator that can provide variable reactive power and regulation of bus voltages. The equivalent circuit of STATCOM is shown in Figure 1 and Power System with STATCOM model is shown in Figure 2. The magnitude of variable source voltage is regulated by adjusting field current. Phase angle difference between source voltage and bus voltage is assumed to be zero. By varying supply voltage magnitude E, reactive power supplied by static compensator is varied.

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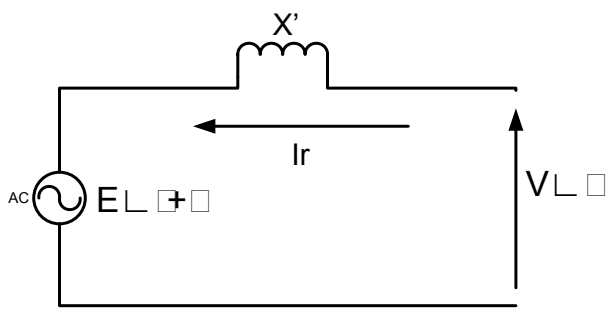

Figure 1. Equivalent Circuit of STATCOM.

When supply voltage is equal to bus voltage then reactive power is zero. When supply voltage magnitude is greater than bus voltage then STATCOM operates as capacitive mode of operation. When supply voltage is less than bus voltage then STATCOM operates as Inductive mode of operation.

STATCOM provides higher reactive power sustain at low AC voltages than SVC, because reactive power of STATCOM decreases linearly with AC voltage. STATCOM would play major role in power system stability, reactive power compensation, loss deduction, voltage regulation, voltage balancing and stability enhancement.

3. Multilevel STATCOM based on Cascaded Two Level Inverter

The cascaded Two Level Inverter as a multilevel STATCOM is shown Figure 3. The two multilevel inverters are connected on one side of transformer and another side of transformer is connected to grid. v_a,v_b,v_c are source side voltages referred to Low voltage side of transformer, L_a,L_b,L_c are leakage inductances of transformer, ea_1,ea_2,ea_3 and eb_1,eb_2,eb_3 are the load side voltages of inverter-1 and inverter-2.

4. Proposed Control Strategy of STATCOM

The control diagram is as shown in Figure 4, consists of phase locked loop (PLL), the usage of PLL is to measure exact phase angle between each phase even though fault occurs in the line. Control diagram consists of current controller, voltage controller, and DC link voltage regulator. Source voltage is connected to PLL to generate synchronous reference frame (sinωt, cosωt) for abc - dq transformation. Load side current is given to abc-dq transformation block, it converts three phase stationary reference frame to two phase rotational reference frame, after the transformation it is given to low pass filter to remove small ripples. Ripple free i_{dref} and i_{qref} is given to gain block for amplifying purpose. V_{dc1} is compared with V_{dc2} by an error block from this it is given to hybrid PID with fuzzy controller for voltage regulation purpose. If controller is not present capacitor voltages will be unequal, this results to produce negative currents. The output of controller generates a reference waveform; it is compared with triangular waveforms to get five level operation of a STATCOM.

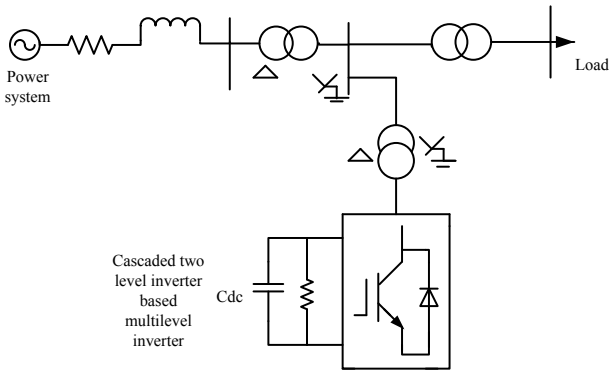

Figure 2. Proposed Power System STATCOM.

5. Fuzzy Logic Control

Fuzzy logic is a controller that controls based on fuzzy rules, it changes analog input values to 0's & 1's and it performs based on it. The schematic diagram of fuzzy controller is shown in Figure 5. Different types of fuzzy logics are used; usually Sugeno and Mamdani type of fuzzy is used. The main distinction between Sugeno and Mamdani is, Sugeno type is mathematical analysis process and Mamdani is human input type. In this project Mamdani type fuzzy logic controller is used.

v_{dcref} and v_{dc} measured value are given to the comparison for fuzzy logic controller, from this it is connected to the error block. The error block provides difference between two voltages then it is connected to the fuzzy controller for regulating voltages. The secondary controller controls DC link capacitor voltage by adjusting the phase angle of STATCOM output voltage. By using fuzzy control, system works accurately and it will quickly respond when fault occurs in the system.

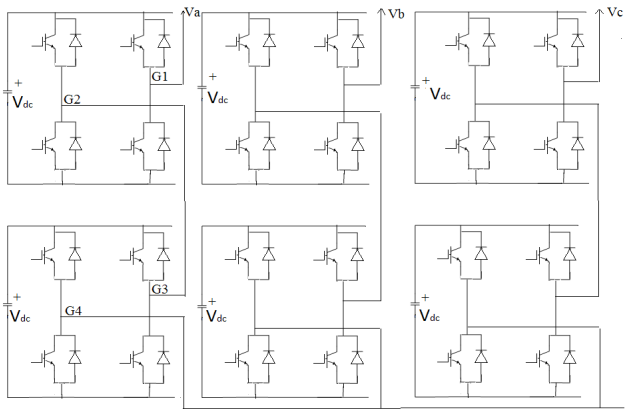

Figure 4. Cascaded two-level inverter.

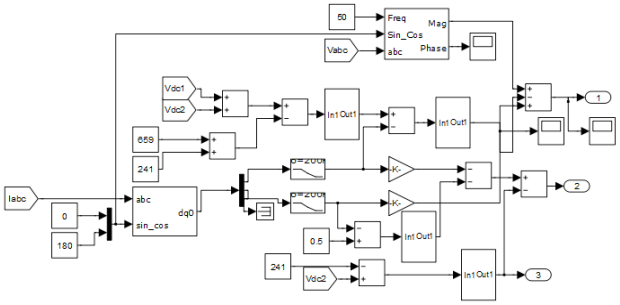

Figure 4. Proposed Control System for STATCOM.

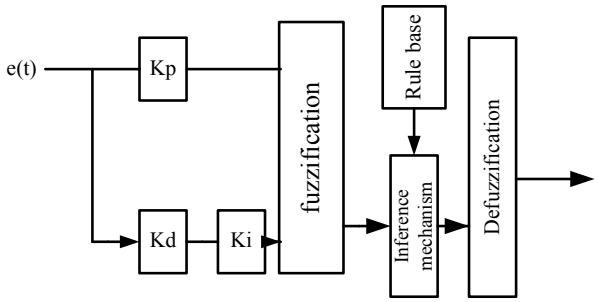

Figure 5. Structure of fuzzy controller.

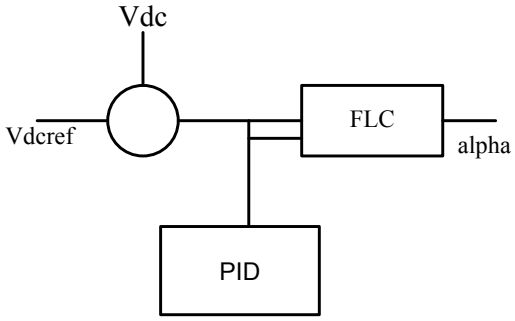

Figure 6. PID with fuzzy logic control.

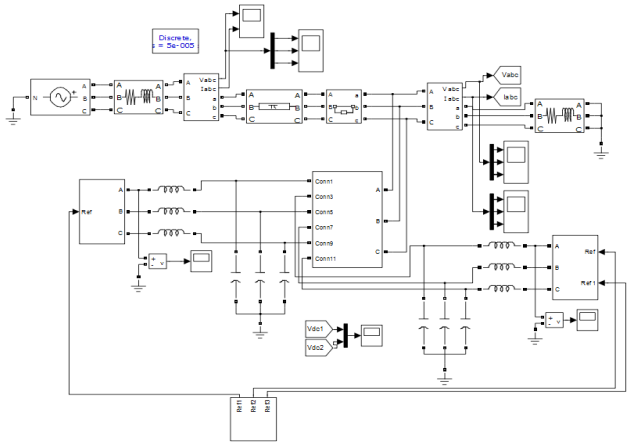

Figure 7. Simulink model with multilevel STATCOM.

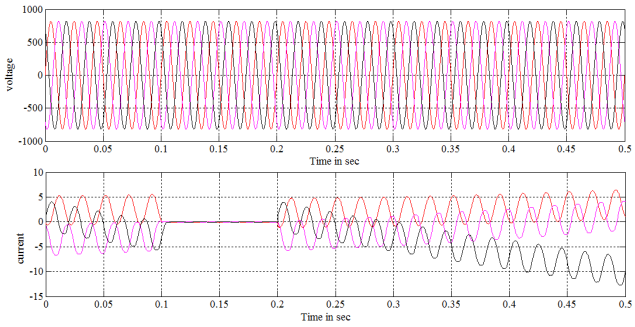

Figure 8. Source side voltage and current waveforms.

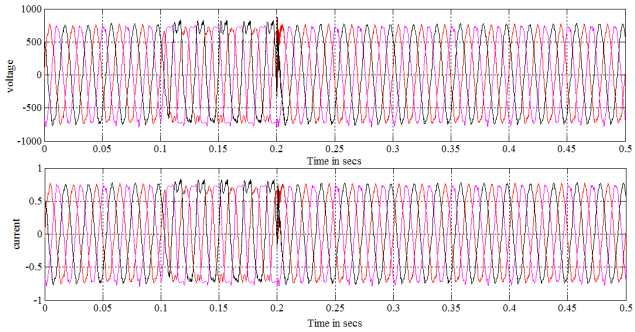

Figure 9. Load side voltage and current waveform.

6. Simulation Results

STATCOM based Cascaded two level inverter with PI and PID with fuzzy controller as shown in Figure-6 are analyzed and performance of the system is investigated its simulation is shown in Figure 7. Figure 8 shows the source side voltage and current waveforms when the fault occurs between 0.1 to 0.2 sec. In this time period ampli-

tude of the phase voltages reduces as compared to the normal state conditions. Figure 9 shows that at time of fault occur at 0.1 to 0.2 sec, STATCOM clears the fault by injecting the voltage. Total Harmonic Distortion can be calucultaed by using Fast Fourier Transform (FFT) analysis for Cascaded Multilevel STATCOM with PI controller is 11.23% as shown in Figure 10. To maintain the THD value as per the IEEE-519 standard a new hybrid PID controller (i.e., PID with Fuzzy Controller) has been proposed. The proposed controller clears the fault at 0.1 to 0.2 sec better than the conventional controller as shown in the Figure 11. Figure 12 shows that multilevel output voltage waveform of proposed converter by multilevel operation of inverter results the reducing of THD in system. Figure 13 shows the output voltage waveform of the multilevel inverter. In PI controller response time is more, thus when fault occurs in the system it takes more time to come to steady state. From Table I it is concluded that PI controller takes more Rise Time, Settling Time and Overshoot Time, but by using PID with fuzzy controller Rise Time, Settling Time decreases, so proposed controller gives best performance than conventional controller.

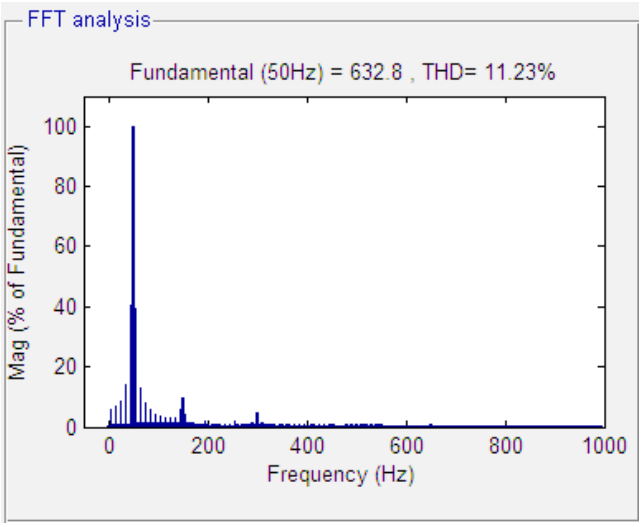

Figure 10. THD spectrum of PI STATCOM.

Table 1. With PI and PID controller of statcom

	PI	PID+fuzzy
Rise Time	2.6761	0.0533
Settling Time	3.9625	2.800
Overshoot	14.8515	0
THD	11.23	4.95

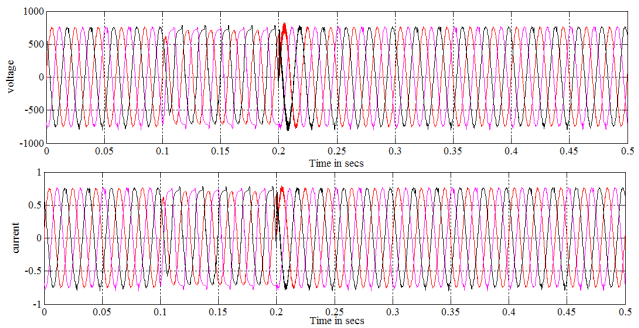

Figure 11. Load side voltage and current waveforms with proposed controller.

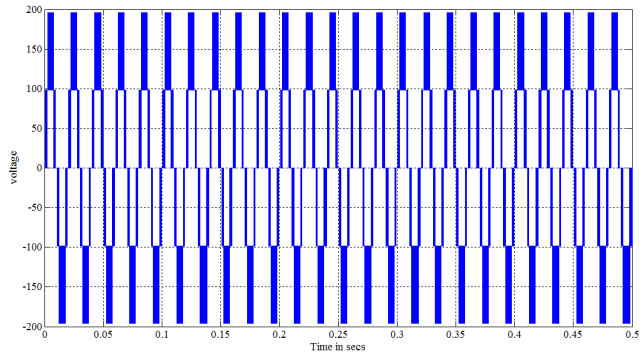

Figure 12. Five level output voltage of STATCOM.

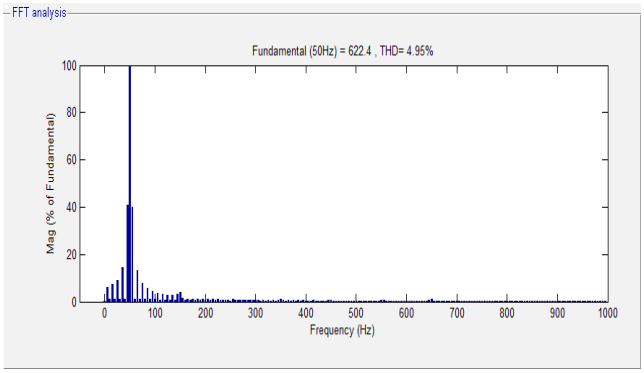

Figure 13. THD spectrum of proposed controller.

7. Conclusion

The proposed multilevel STATCOM for cascaded two level inverter based multilevel inverter is implemented by using PID with fuzzy logic controller. This proposed system clears the fault under faulty conditions. Proposed controller is compared with conventional PI controller, by this it is concluded that proposed controller gives less

Total Harmonic Distortion, response time, settling time and rise time.

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