INTELLIGENT CONTROL OF ELEVEN LEVEL CASCADED INVERTER WITH REDUCED NUMBER OF SWITCHES USING STEP MODULATION

P.Manimala[1], Mrs.K.Esakki Shenbaga Loga[2]

PG Scholar, Francis Xavier Engineering College, Tirunelveli.

Manimala.gopalakrishnan@gmail.com,

Abstract— Multilevel inverter is widely used in high power industrial application. This paper presents a new modified cascaded H bridge multilevel inverter with reduced switching component. In conventional CHB inverter more number of components is used, it seem to more complex control circuit and bulky. In proposed MLI, output voltage level increased by using less no of switches works by the step modulation technique. The CHB 11 level inverter governed by the Fuzzy logic controller and it is powered by separate Dc sources, in order to improve the power quality by reducing the harmonic distortion at the output voltage. Hence the efficiency of the system will be improved. The results are validated using MATLAB/SIMULINK.

Keywords— FLC, Cascaded Multilevel Inverter, SPWM, PI controller.

INTRODUCTION

In recent years multi level inverters are used high power and high voltage applications. Multilevel inverter produces a staircase output waveform, this waveform look like a pure sine wave. The multilevel inverter output voltage has less number of harmonics compare to the conventional bipolar inverter output voltage.

Multilevel Inverter make it possible to achieve medium voltage generation using low to medium voltage switches, preventing high dv/dt stress and the need for series connection of switches while allowing higher converter power rating.[1] Multilevel converters have less filter requirements, generate a staircase waveform, have better harmonic profile (lower total harmonic distortion), and have less switching losses. Cascaded H-bridge (CHB), diode-clamped and capacitor-clamped are among the most common topologies, More emphasis will be given here to the features related to the CHB, since it is the topology to be used here for harmonic control. The cascade multilevel topology and its universal module have several advantages over the traditional customized converter architecture. The cascaded H-bride multilevel inverter is composed by the series connection of power cells, each one containing an H-bridge inverter and isolated dc-sources.[2] Each H-bridge cells can provide the three different voltages like zero, positive DC and negative DC voltages. One of the advantages of this type of multilevel inverter is that it needs less number of components compared with diode clamped and flying capacitor inverters. Fig (1) shows the elevel level cascaded inverter.In [4], a new approach for modulation of an 11-level cascade multilevel inverter with step modulation using fuzzy logic controller with reduced number of switches is presented.

CASCADED MULTILEVEL INVERTER

One more alternative for a multilevel inverter is the cascaded multilevel inverter or series H-bridge inverter. The CMLI has been utilized in a wide range of applications. With its modularity and flexibility, the CMLI shows superiority in high-power applications, especially shunt and series connected FACTS controllers.The CMLI synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels. By adding more H-bridge converters, the amount of Var can simply increased without redesign the power stage, and build-in redundancy against individual H-bridge converter failure can be realized. A series of single-phase full bridges makes up a phase for the inverter. A three-phase CMLI topology is essentially composed of three identical phase legs of the series-chain of H-bridge converters, which can possibly generate different output voltage waveforms and offers the potential for AC system phase-balancing. This feature is impossible in other VSC topologies utilizing a common DC link. Since this topology consists of series power conversion cells, the voltage and power level may be easily scaled.[5] The dc link supply for each full bridge converter is provided separately, and this is typically achieved using diode rectifiers fed from isolated secondary windings of a three-phase transformer.

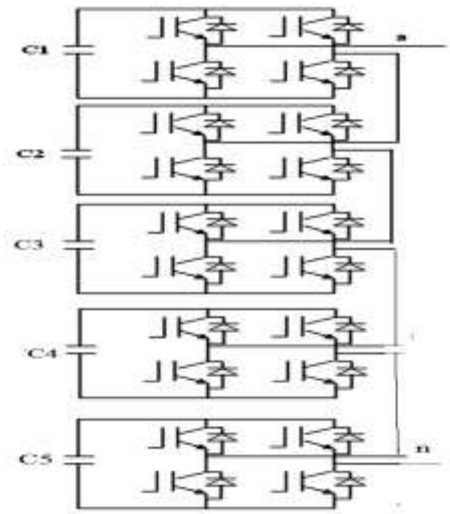


Fig.1,Single phase structures of Cascaded inverter 11-level

FUZZY CONTROL

Fuzzy control is a control method based on fuzzy logic. Just as fuzzy logic can be described simply as “computing with words rather than numbers’’,fuzzy control can be described simply as “control with sentences rather than equations’’[6]. A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants.

Fuzzy Logic Control System

In contrast to conventional control techniques, Fuzzy Logic Control (FLC) is best utilized in complex ill-defined processes that can be controlled by a skilled human operator without much knowledge of their underlying dynamics. The basic idea behind FLC is to incorporate the "expert experience" of a human operator in the design of the controller in controlling a process whose input – output relationship is described by collection of fuzzy control rules (e.g., IF-THEN rules) involving linguistic variables rather than a complicated dynamic model.[7] The utilization of linguistic variables, fuzzy control rules, and approximate reasoning provides a means to incorporate human expert experience in designing the controller.

In this project I have used an FLC of the Mamdani model with 25 rules based on the 5 segments of the error and error rates. The centroid type of defuzzification is adopted. The rule matrix used is of the sliding rule method.

PROPOSED MULTILEVEL INVERTER TOPOLOGY

The performance of Multilevel inverter is highly superior to that of conventional two-level inverters due to reduced harmonic distortion, lower electromagnetic interference, and higher dc link voltages. However, it has some disadvantages such as increased number of components, complex pulsewidth modulation control method, and voltage-balancing problem. In this project, a new topology with a reversing-voltage component is proposed to improve the multilevel performance by compensating the disadvantages mentioned. This topology requires fewer components compared to existing inverters (particularly in higher levels) and requires fewer carrier signals and gate drives.[8] Hence this new topology is named as Reversing Voltage (RV) topology. This topology is a hybrid multilevel topology which separates the output voltage into two parts. One part is named level generation part and is responsible for level generating in positive polarity. This part requires high frequency switches to generate the required levels. The switches in this part should have high-switching-frequency capability. The other part is called polarity generation and is responsible for generating the polarity of the output voltage, which is the low-frequency part operating at line frequency.

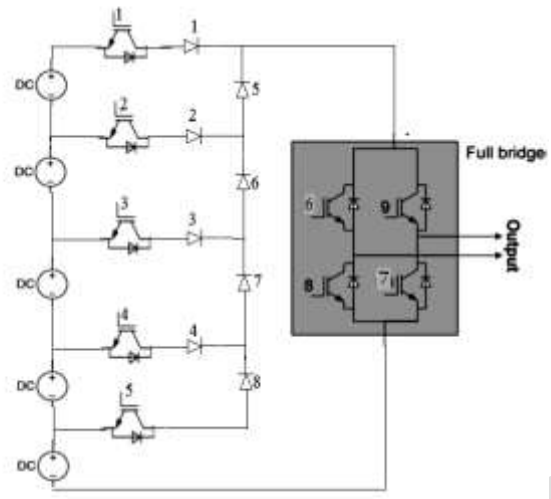


Fig.2, Circuit Diagram of Eleven level Inverter With Reduced number of switches

The proposed circuit diagram is shown in fig.2. which consists of 9 switches and 5 dc sources instead of using conventional Eleven level cascaded H-bridge inverter with 20 switches and 5 dc sources.

Table.1. Switching states for eleven level inverter using RV Topology with fuzzy logic controller

Output Voltage	S1	S2	S3	S4	S5	S6	S7	S8	S9
$5V_{dc}$	1	1	1	1	1	1	1	0	0
$4V_{dc}$	1	1	1	1	0	1	1	0	0
$3V_{dc}$	1	1	1	0	0	1	1	0	0
$2V_{dc}$	1	1	0	0	0	1	1	0	0
$1V_{dc}$	1	0	0	0	0	1	1	0	0
$0V_{dc}$	0	0	0	0	0	1	0	1	0
$-1V_{dc}$	1	0	0	0	0	0	0	1	1
$-2V_{dc}$	1	1	0	0	0	0	0	1	1
$-3V_{dc}$	1	1	1	0	0	0	0	1	1
$-4V_{dc}$	1	1	1	1	0	0	0	1	1
$-5V_{dc}$	1	1	1	1	1	0	0	1	1

In table 1, switches S1 to S5 indicates level generation part which are high frequency switches and S6 to S9 indicate polarity generation part which are low frequency switches. According to the switching state the required levels and output voltages are generated at the inverter output. Also the inverter output is controlled by fuzzy logic control with the help of PIC microcontroller.

The function of the fuzzy logic controller in this context is that it monitors the actual value of the output voltage and compares it with the set point. Based on the error and error rate a decision is made by the Fuzzy Logic Controller in association with a decision making tool that consists of the rule base.

Depending upon the output of the FLC the duty cycle of each level is adjusted automatically in the making of the eleven level inverter and thus the average output voltage is made equal to the required voltage.The Mamdani type of fuzzy logic is used in this project. The error and the error rates have been segmentised into five and the total number of rules was 25. The method of defuzzification used in this project is of the centroid method.

SIMULATION RESULTS

A Eleven level inverter using RV topology model was implemented in MATLAB / SIMULINK software with PD-SPWM technique. Figure.3 presents the output voltage and current waveform of eleven level inverter using RV topology .The simulation results are obtained for the output voltage and output current of the single phase eleven level RV Topology inverter for PD-SPWM Technique. FFT spectrum of the output voltage and current waveform of 11-level inverter using RV topology is shown in fig.4, and fig.5, respectively.

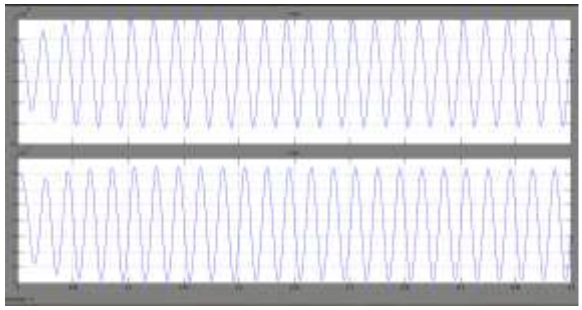


Fig.3, Output voltage and current waveform of the eleven level inverter using RV Topology

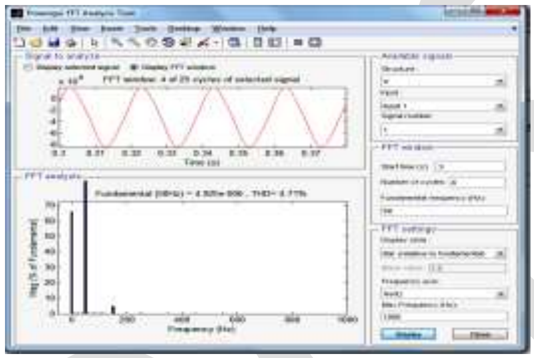


Fig.4, FFT spectrum for the output voltage waveform of eleven level RV topology inverter

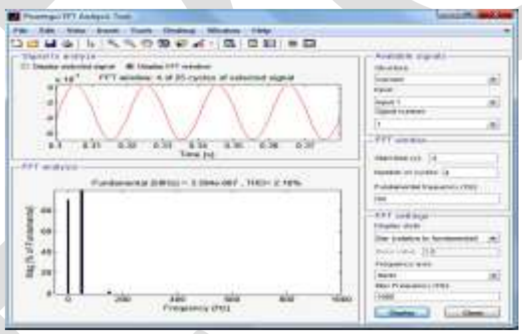


Fig.5, FFT spectrum for the output current waveform of eleven level RV topology inverter

A Eleven level inverter using RV topology with PI controller model was implemented in MATLAB / SIMULINK software with PD-SPWM technique. Figure.6. presents the simulation model of eleven level inverter using RV topology with PI Controller and is developed using MATLAB/ SIMULINK. The simulation results are obtained for the output voltage and output current of the single phase eleven level RV Topology inverter with PI Controller for PD-SPWM Technique. FFT spectrum of the output voltage and current waveform of 11-level inverter using RV topology with PI controller is shown in fig.7, and fig.8, respectively.

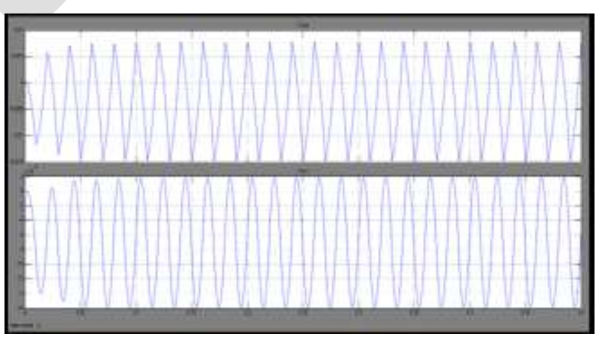


Fig.6, Output voltage and current waveform of the Eleven level inverter using RV Topology with PI controller

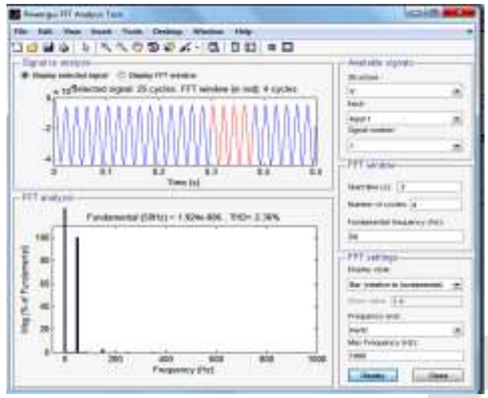
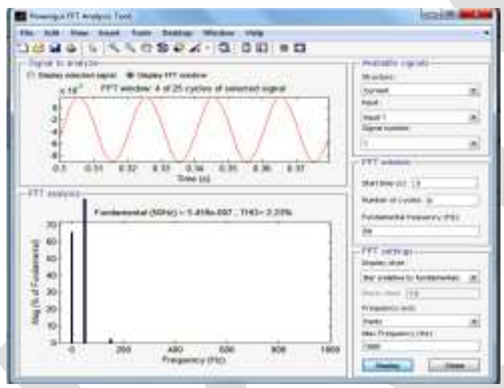


Fig.7, FFT spectrum for the output voltage waveform of eleven level RV topology inverter with PI Controller



Fig,8,FFT spectrum for the output voltage waveform of eleven level RV topology inverter with PI Controller

A Eleven level inverter using RV topology with fuzzy logic controller model was implemented in MATLAB / SIMULINK software with PD-SPWM technique. Figure.9 presents the output voltage and current waveform of eleven level inverter using RV topology with fuzzy logic Controller and is developed using MATLAB/ SIMULINK. The simulation results are obtained for the output voltage and output current of the single phase eleven level RV Topology inverter with fuzzy logic Controller for PD-SPWM Technique. FFT spectrum of the output voltage and current waveform of 11-level inverter using RV topology with fuzzy logic controller is shown in fig.10, and fig.11, respectively.

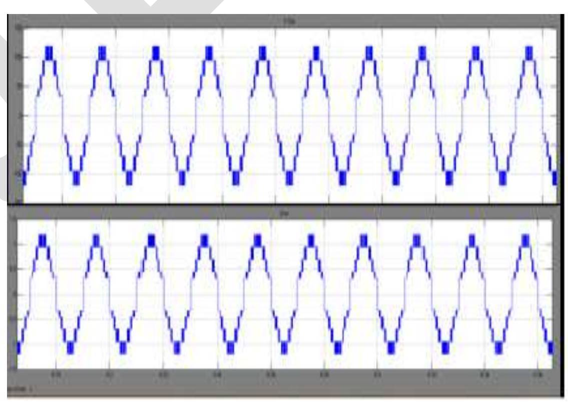


Fig.9, Output voltage and current waveform of the eleven level inverter using RV Topology with fuzzy logic controller

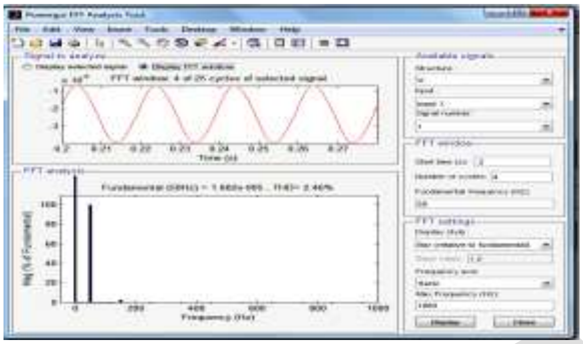


Fig.10, FFT spectrum for the output voltage waveform of eleven level RV topology inverter with fuzzy logic Controller

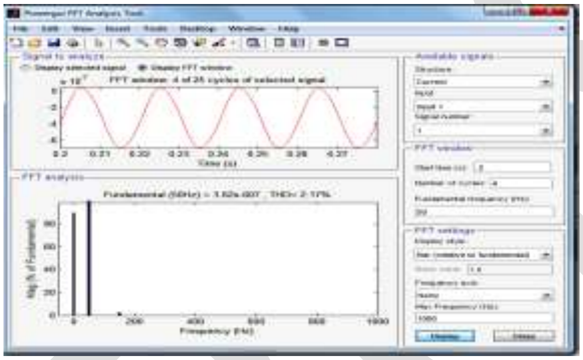


Fig.11, FFT spectrum for the output current waveform of seven levels RV topology inverter with fuzzy logic Controller

From the above FFT spectrum analysis, the percentage THD values for each scheme are noted in the table.2.The percentage THD values for output voltage and output current for eleven level RV Topology inverter without control scheme and also with PI and FLC schemes are analyzed. From the table 2, it is observed that the output current percentage THD value is minimum for Fuzzy Logic Control scheme over the other schemes.

Table 2. Percentage THD analysis of eleven level inverter using RV Topology

Description	Output Voltage % THD	Output Current %THD
Without Controller	4.71	2.16
With PI Controller	2.36	2.23
With Fuzzy Logic Controller	2.46	2.17

CONCLUSION

A new inverter topology has been proposed which has superior features over conventional topologies in terms of the required power switches and isolated dc supplies, control requirements, cost, and reliability. It is shown that this topology can be a good candidate for converters used in power applications such as FACTS, HVDC, PV systems, UPS, etc. In the mentioned topology, the switching operation is separated into high- and low-frequency parts. This will add up to the efficiency of the converter as well as reducing the size and cost of the final prototype. The PD-SPWM control method is used to drive the inverter. The experimental results of the developed prototype for a eleven-level inverter of the proposed topology are demonstrated. The results clearly show that the proposed topology can effectively work as a multilevel inverter with a reduced number of carriers for PWM. In order to regulate the output voltage of the inverter a PI and an FLC controller were designed and tested. The results reveal that the FLC out performs the PI controller in terms of THD of the output voltage.

REFERENCES

[1] K. Jang-Hwan, S.-K. Sul, and P. N.Enjeti, "A carrier-based PWM method with optimal switching sequence for a multilevel four-leg voltage source inverter," IEEE Trans. Ind. Appl., vol. 44, no. 4, pp. 1239–1248, Jul./Aug. 2008.

[2] S. Srikanthan and M. K. Mishra, "DC capacitor voltage equalization in neutral clamped inverters for DSTATCOM application," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2768–2775, Aug. 2010.

[3] E. Najafi and A. H. M. Yatim, "A novel current mode controller for a static compensator utilizing Goertzel algorithm to mitigate voltage sags," Energy Convers. Manage., vol. 52, no. 4, pp. 1999–2008, Apr. 2011.

[4] S. G. Song, F. S. Kang, and S.-J. Park, "Cascaded multilevel inverter employing three-phase transformers and single dc input," IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2005–2014, Jun. 2009.

[5] Sathish Cherukuru, Clinton joel.C, Sahaya Jeenson Jonish.A, Dr.K.Sathiyasekar," New Modified Cascaded H-Bridge Multilevel Inverter Topology with Reduced Switches," International Journal of Engineering Trends and Technology (IJETT) – Volume 9 Number 4 - Mar 2014.

[6] M. S. Sivagamasundari, P. Melba Mary," Fuzzy Logic Based Cascaded H-Bridge Eleven Level Inverter for Photovoltaic System Using Sinusoidal Pulse Width Modulation Technique," International Journal of Electrical, Robotics, Electronics and Communications Engineering Vol:8 No:2, 2014

[7] Siva GanaVara Prasad. P, Amrutha Veena.Chandrapati, Navyata Yesodha Rao.K, Lakshmi Prasanth.K, "Fuzzy logic controlling of a single phase seven level grid connected inverter for photovoltaic system," International Journal of Engineering Research, Vol No.3, Issue No.5, pp : 299-304 , 01 May 2014

[8] Hulusi Karaca," A Novel Topology for Multilevel Inverter with Reduced Number of Switches," Proceedings of the World Congress on Engineering and Computer Science , Vol I, 23-25 October, 2013.

[9] Ehsan Najafi, Abdul Hamim Mohamed Yatim,"Design and Implementation of a New multilevel Inverter Topology,"IEEE Trans.Industrial Electron.,vol .59, no. 11, Nov 2012.

[10] H. Taghizadeh and M. T. Hagh, "Harmonic elimination of cascade multilevel inverters with nonequal DC sources using particle swarm optimization," IEEE Trans. Ind. Electron., vol. 57, no. 11, pp. 3678–3684, Nov. 2010.

[11] Y. Liu, H. Hong, and A. Q. Huang, "Real-time calculation of switching angles minimizing THD for multilevel inverters with step modulation," IEEE Trans. Ind. Electron., vol. 56, no. 2, pp. 285–293, Feb. 2009.

[12] L. G. Franquelo, J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, M. A. M. Prats, "The age of multilevel converters arrives," IEEE Industrial Electronics Magazine, vol. 2,no. 2, pp. 28-39, June 2008