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Comparison of Cascaded H-Bridge Multilevel Inverter connected to grid using PI and fuzzy logic controllers

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Abstract - *This paper presents a comparative study of seven-level and eleven-level Cascaded H-Bridge (CHB) inverter in power system for harmonic compensation. Integrating the photovoltaic (PV) system and grid requires power electronic converters. Inverters convert DC electricity produced by the PV system into AC electricity for loads. Multilevel inverters (MLI) replaces conventional inverters and are widely implemented in high-voltage and high-power applications due to the improved conversion efficiency, reduced stress on the switches etc... Total Harmonic Distortion (THD) is the most important power quality issue in multilevel inverters and can be reduced by SPWM technique and further reduced by using a controller that can able to withstand the static and dynamic conditions. A rule-based fuzzy logic controller design is described and produces better harmonic reduction than a PI controller. A grid connected inverter model using SPWM technique with PI controller and fuzzy logic controller will be implemented in MATLAB and the harmonic distortion analysis is evaluated at different states.*

Key Words: Fuzzy logic controller, PI controller, Grid, PV system, CHB inverter, THD, SPWM

1. INTRODUCTION

Due to the environmental concerns and energy crisis, renewable energy sources such as solar power and wind generation systems are becoming popular and are replacing the conventional power generating units for electricity generation. A photovoltaic (PV) system converts sunlight directly into electricity through solar cells. The output of solar cell is DC electricity. In integrating the PV system to the grid, an inverter is essential. The output of a conventional two-level inverter is not sinusoidal and contains THD. A multilevel inverter is commonly used over the conventional inverter. MLI reduces THD's as the level increases and thus the size and weight of the passive filter can be significantly reduced. Also, they offer even voltage sharing and reduced electromagnetic interference.

Among the various multilevel inverter topologies, a cascaded MLI is commonly used for PV systems, motor drives and battery systems. In CHB-MLI the problem of voltage unbalancing is minimized and the filter size is reduced when compared to the remaining topologies. The harmonics elimination is possible by increasing the number of levels but the dynamic behavior of the system arises the need of a suitable controller.

A conventional closed loop PI controller takes a single input command signal and generates a control signal. The controller parameters require a complete mathematical model of the system and includes linearization over a limited operating region.

Fuzzy logic controller does not require any detailed mathematical model and are more robust with wider operating range. In this controller multiple input command can be given and each rule provides different operating conditions irrespective of change in temperature, change in operating conditions or change in the system parameters with aging.

2. CASCADED MULTILEVEL INVERTER

Cascaded H-bridge inverter is a series of H-bridge inverter units. Each H-bridge is supplied with a dc source and the output of the inverter is a quasi-square waveform containing $+V_{dc}$, 0 and $-V_{dc}$. For a 7-level Cascaded H-bridge inverter, each h-bridge contains a quasi-square waveform of different time intervals and all the waveforms are added up as shown in the Figure 1. For 11-level CHB inverter, output waveforms of five H-bridge units are added.

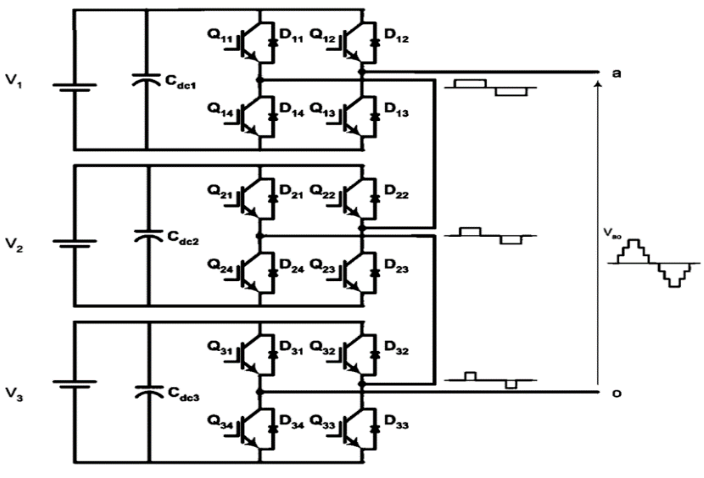


Fig -1: Single Phase 7-level CHB-MLI

The number of output phase voltage levels in a cascaded multilevel inverter is defined as n=2m+1, where 'm' is the number of H-bridge units or separate dc sources. This paper presents a three phase cascaded multilevel inverter and a simulation model for a seven level inverter is shown in the Figure 2.

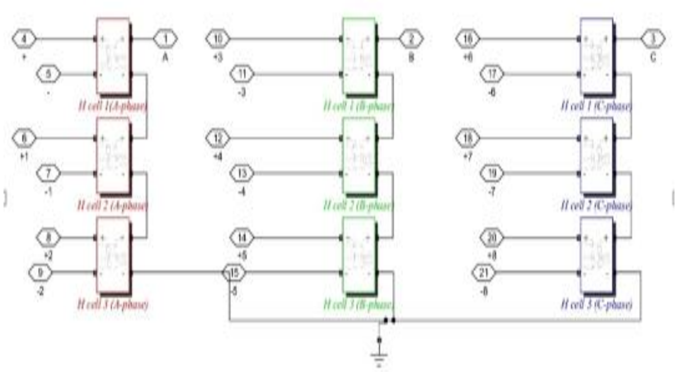


Fig -2: Three Phase 7-level CHB-MLI

3. CASCADED H-BRIDGE INVERTER WITH FUZZY LOGIC CONTROLLER

A Fuzzy Logic Controller (FLC) is easy to design and does not require a detailed mathematical model of the system being controlled. However, an understanding of the system and its control requirements is necessary. The controller designer must define what information flows into the system, information processed and what information flows out of the system. A FLC design consists of three important stages namely fuzzifier, inference engine and defuzzifier.

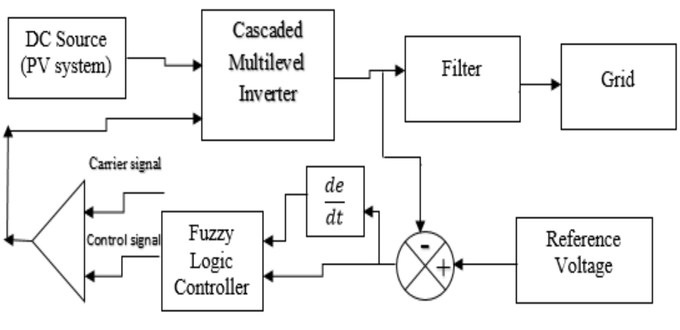


Fig -3: Cascaded Multilevel Inverter with FLC

3.1 Fuzzifier

Firstly, the appropriate input and output variables should be selected for designing a fuzzy logic controller. Fuzzy logic uses linguistic variables for processing the information instead of numeric variables. The function of a fuzzifier is to convert these crisp sets into linguistic variables (fuzzy sets). Five classes of linguistic labels (NB (Negative Big), NS (Negative Small), ZE (Zero Error), PS (Positive Small), PB (Positive Big)) are characterized by membership grade that are used to decompose each variable into fuzzy regions.

In this Paper two input variables (error and rate of change in error) and one output variable (control signal) is chosen. Figure 4 represents the linguistic label of an input variable.

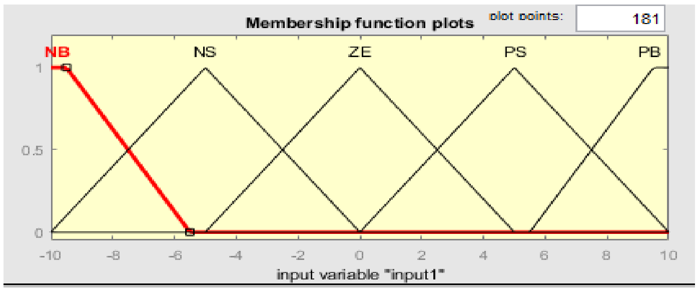


Fig -4: Input variable membership function

3.2 Inference System

A set of rules are provided for control action and this function is performed in inference system. A decision matrix table using the input and output variables is shown in the Table 1. For example, if error voltage is NB and rate of change of error is NB, then the controller output is ZE. Similarly 25 rules are formed from the decision matrix and each rule in the table is used to decide an appropriate control action.

Table -1: Decision matrix

C/CE	NB	NS	ZE	PS	PB
NB	ZE	NS	NB	NB	NB
NS	ZE	NS	NB	NS	NS
ZE	PB	PS	ZE	NS	NB
PS	PB	PS	PS	ZE	NS
PB	PB	PB	PB	PS	ZE

3.3 Defuzzification

The Linguistic variables (fuzzy sets) are converted into crisp solution sets through a defuzzifier. There are several methods of defuzzification. The most commonly used method is centroid method or center of area (COA), as it is very accurate. The center of area is provided under the curve of membership function and it puts high demands on computation for complex membership functions.

4. CASCADED H-BRIDGE INVERTER WITH PI CONTROLLER

The steady state error can be eliminated by using a PI controller but does not have ability to predict the future errors of the system. A cascaded H-bridge inverter connected with a PI controller is shown in the Figure 5.

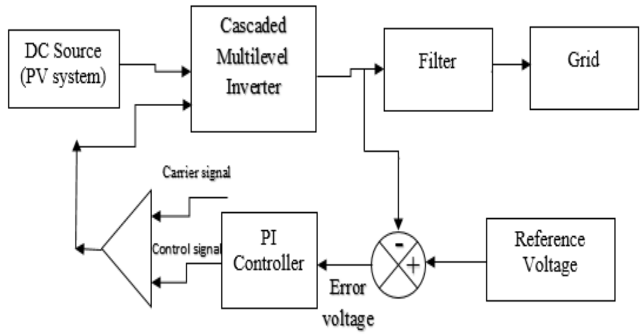


Fig -5: Cascaded Inverter with PI controller

5. SIMULATION DETAILS

A Grid connected PV system is shown in the Figure 6. PV system voltage of 220V is given to the inverter. A Cascaded inverter uses a separate dc source for each H-bridge. Thus, the voltage given to each H-bridge is given as

$V_{H-B} = \frac{220}{m}$ Volts, 'm' is the number of H-bridge units.

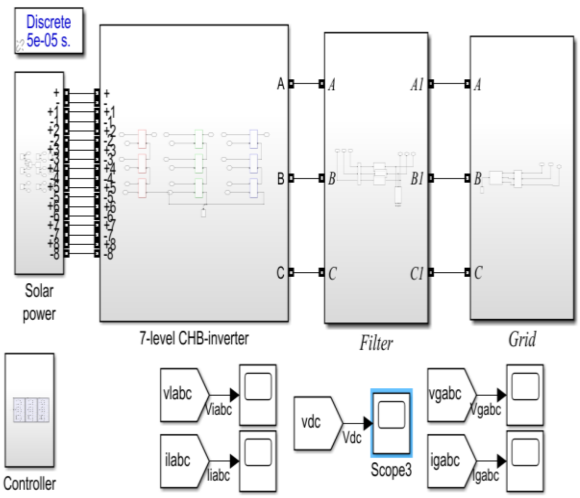


Fig -6: Schematic diagram of grid connected inverter

Sinusoidal pulse width modulation (SPWM) technique is widely employed. In SPWM, the control signal produced by the controller is compared with the triangular signal as in Figure 7 and the pulses are generated. This pulses control the inverter output voltage.

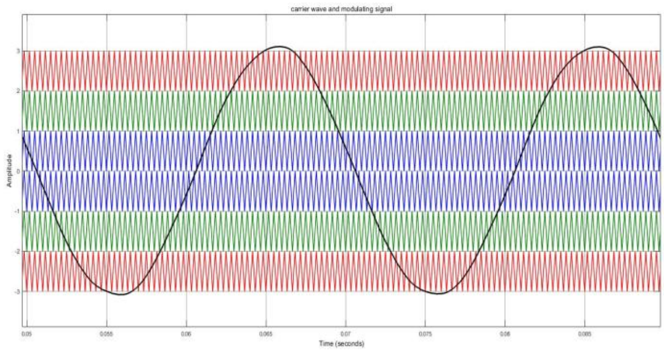
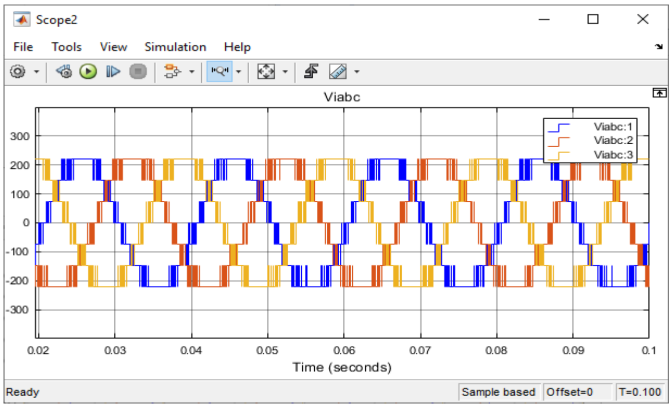


Fig -7: carrier wave and modulating signal

5.1 Cascaded multilevel inverter with PI controller

A grid connected multilevel inverter using PI controller is designed and the simulation results are provided. A PI controller provides better performance under steady state but the dynamic performance is not satisfactory.



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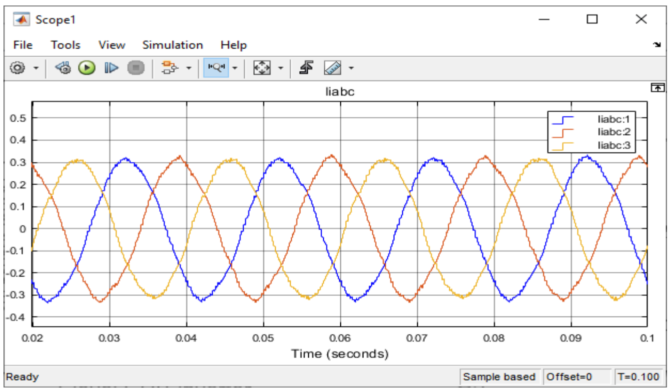

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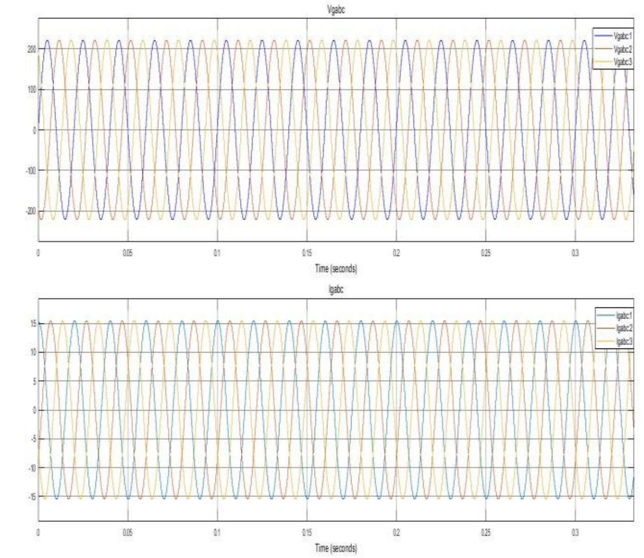
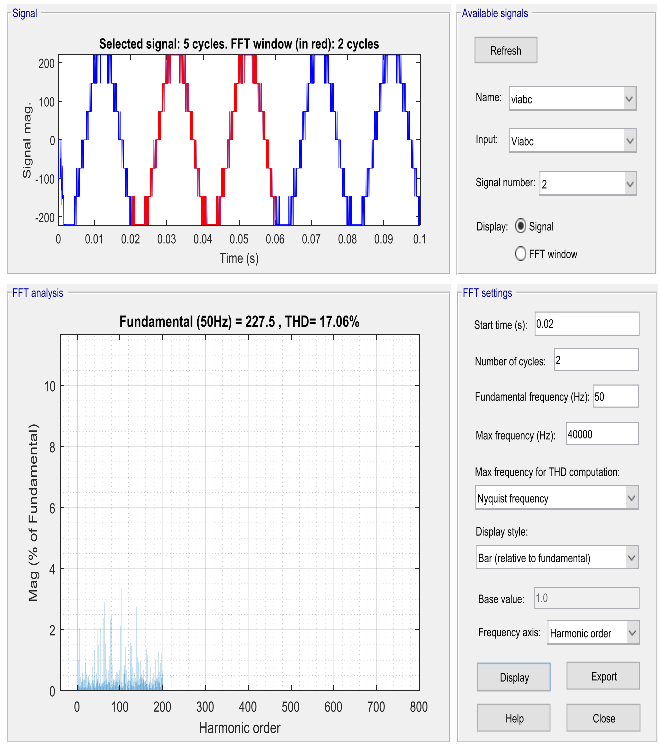


(c)

Fig -8: 7-level output waveforms (a) Inverter output voltage (V_{i_abc}) (b) Inverter output current (I_{i_abc}) (c) Grid voltage (V_{g_abc}) and grid current (I_{g_abc}) (d) FFT Analysis



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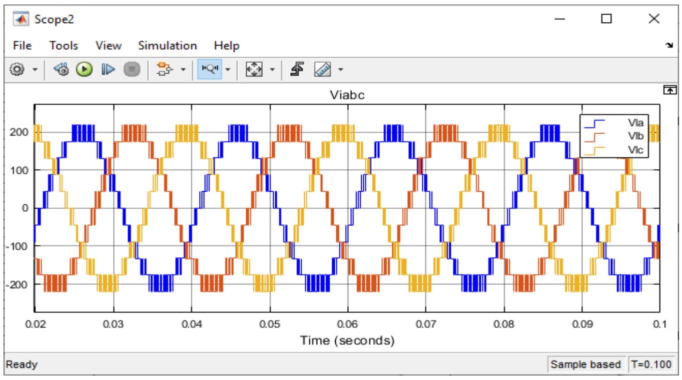
In PI controller Kp and Ki values are obtained by trial and error method. This paper uses a closed loop PI controller and the output waveforms are shown in the Figure 8 and 9.



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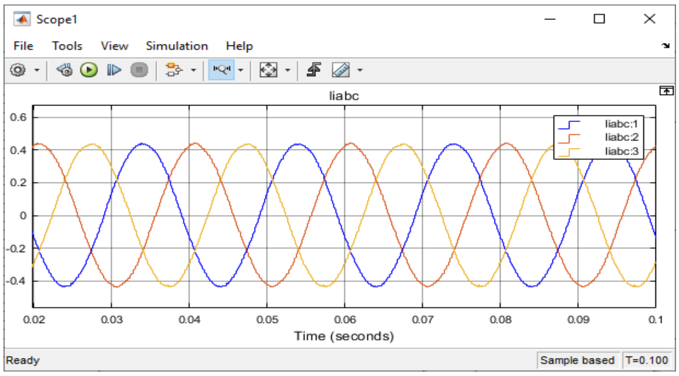

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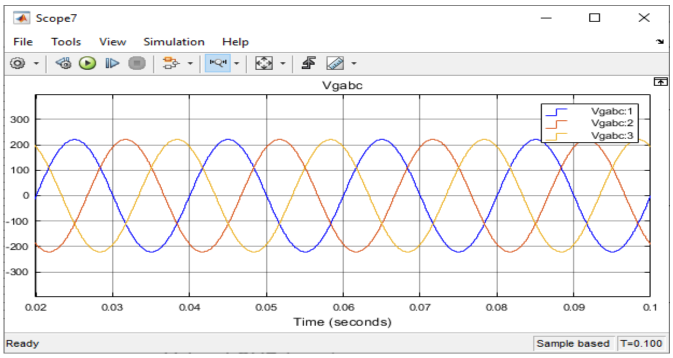

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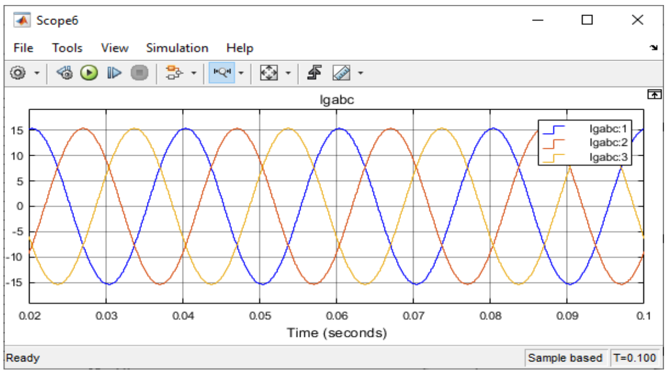

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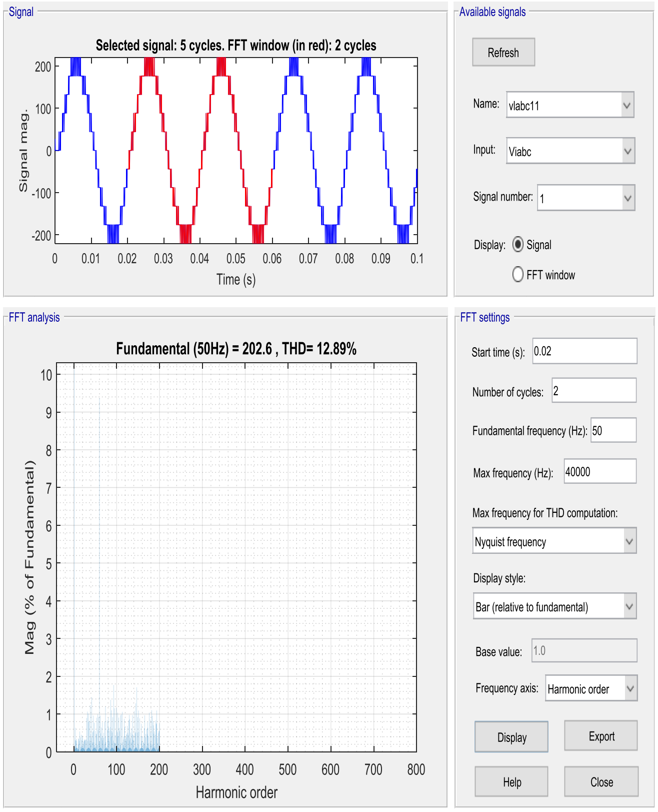
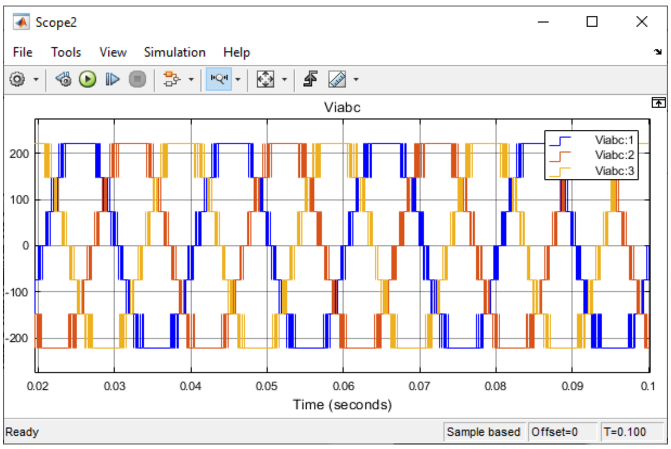


(e)

Fig -9: 11-level output waveforms (a) V_{i_abc} (b) I_{i_abc} (c) V_{g_abc} (d) I_{g_abc} (e) FFT Analysis

5.2 Cascaded multilevel inverter with Fuzzy logic controller

Fuzzy logic controller uses multiple input commands and thus it is more accurate when compared to PI controller. Based on the information collected a rule based fuzzy logic controller is designed in Matlab / Simulink model.



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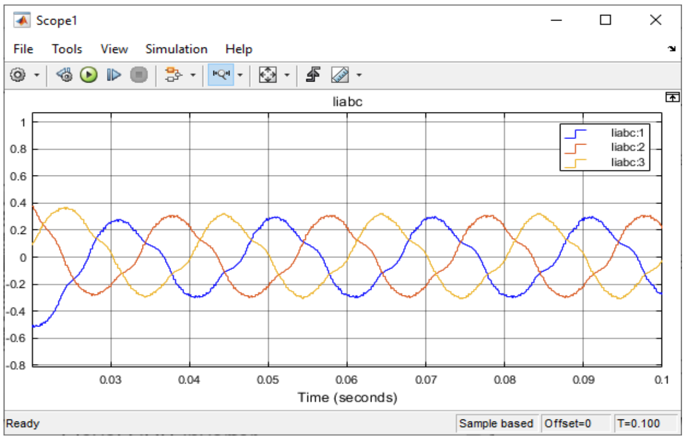

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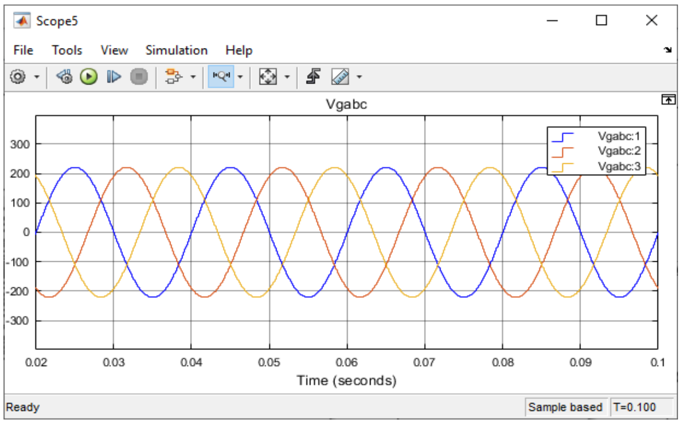

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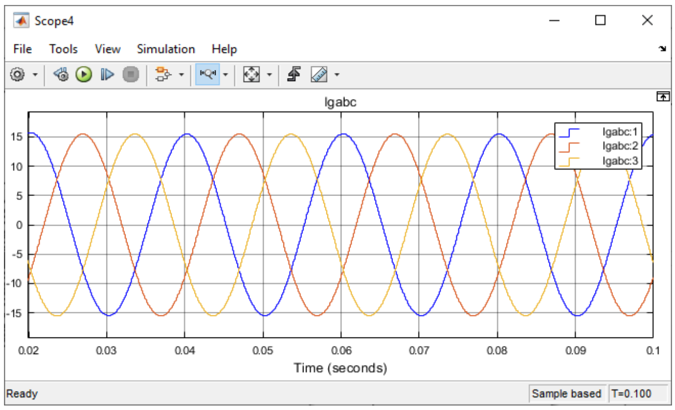

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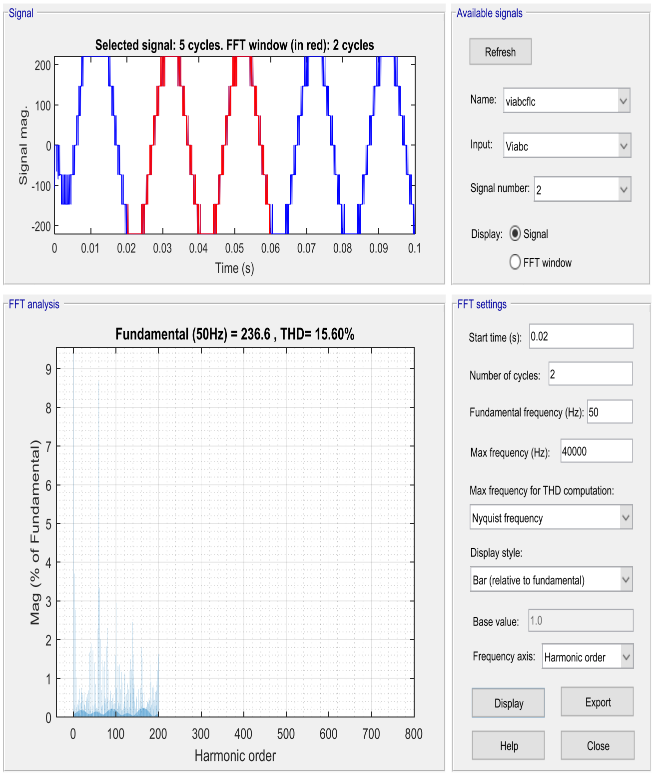

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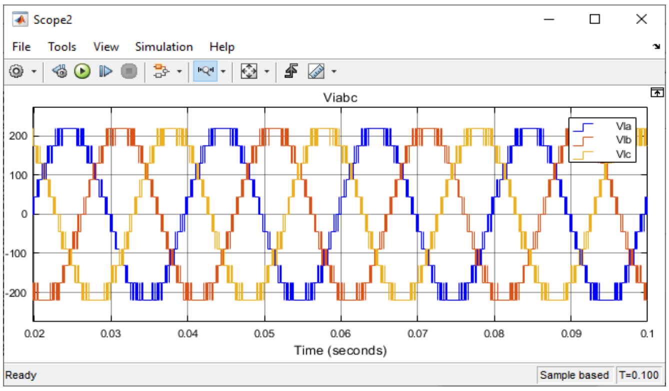
Fig -10: 7-level output waveforms (a) V_{i_abc} (b) I_{i_abc} (c) V_{g_abc} (d) I_{g_abc} (e) FFT Analysis



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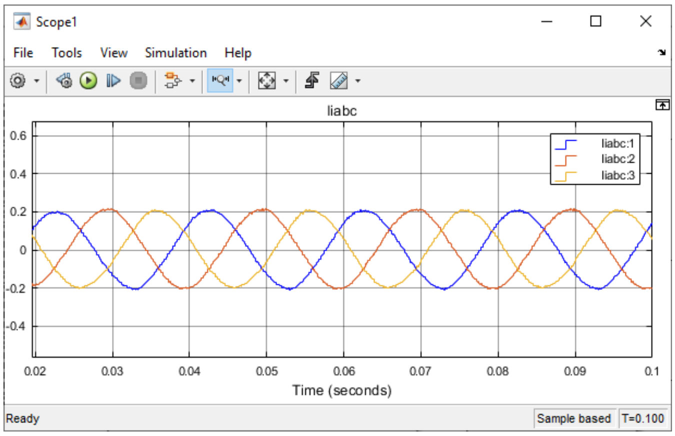
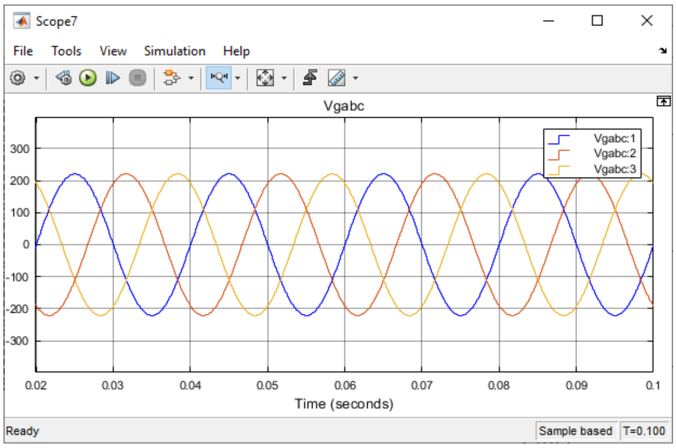


(b)

In the Figure 6, a filter circuit is used to generate a distortion less voltage to the grid. The filter circuit RLC values selected based on the trial and error method. The obtained voltage is given to grid and the output voltage and current waveforms using a rule based fuzzy logic controller is shown in the Figure 10 and Figure 11.



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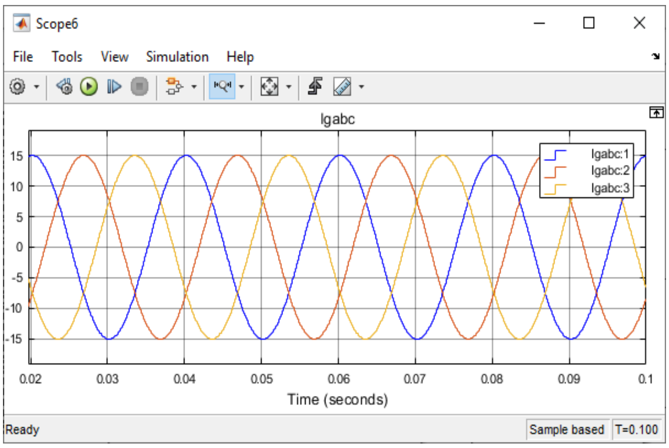

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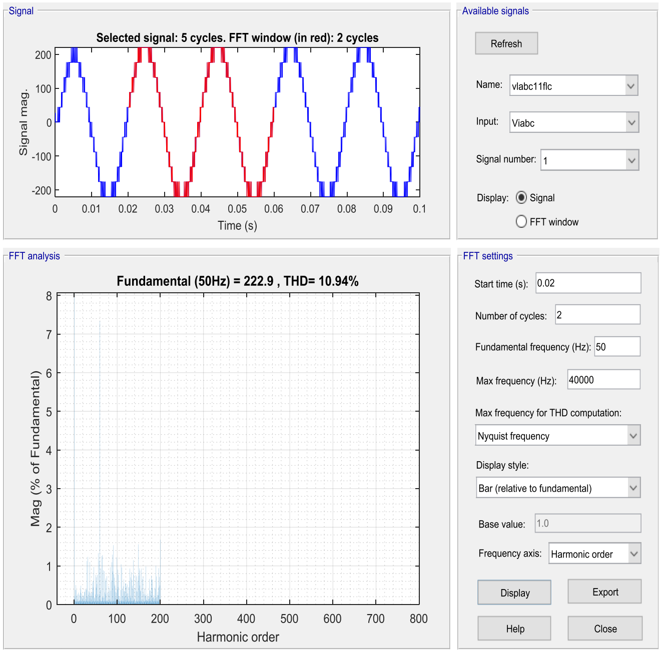

(e)

Fig -11: 11-level output waveforms (a) V_{i_abc} (b) I_{i_abc} (c) V_{g_abc} (d) I_{g_abc} (e) FFT Analysis

6. PERFORMANCE COMPARISON OF CONTROLLERS

The above discussed results reveal that fuzzy logic controller performs better than PI controller. A fuzzy logic controller is more accurate due to the multiple input command and also performs better during the dynamic conditions. The performance of 7-level and 11-level cascaded H-bridge inverter with PI controller and fuzzy logic controller is analysed and the results were tabulated. Output voltage quality is measured in THD.

Table -2: Comparison table

THD	PI	Fuzzy logic
7-level	17.08%	15.60%
11-level	12.89%	10.94%

Hence, it can be concluded that the THD is reduced when the inverter level is increased and better reduced by using a fuzzy logic controller over a PI controller.

7. CONCLUSIONS

Increase in inverter level always reduce THD but the dynamic response of the system needs to be improved. Multilevel inverter with a closed loop PI controller improves the steady state response but still the dynamic performance is substandard. To improve the system performance a rule based fuzzy logic controller is developed. The simulation results explores that a FLC performs better than a PI controller. Fuzzy logic controller offers less THD and good dynamic response under transient condition when compared to a PI controller. Thus the proposed MLI using FLC is suitable where the periodic distortion problem is present.

REFERENCES

[1] Towleong Tiang and Dahamen Ishak,''Modelling and simulation of dead beat based PI controller in a single phase H-bridge inverter for standalone applications'', Turkish journal of electrical engineering and computer sciences, 22, pp 43-56,2014.

[2] B. Suryajitt, G. Sudhakar,"Power Quality Improvement Using Cascaded H-Bridge Multilevel Inverter Based Dstatcom" Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol.4, Issue 11, pp.31-37, November 2014.

[3] B. Shanthi, S.P. Natarajan, ''FPGA based fuzzy logic control for single phase multilevel inverter'' International Journal of Computer Applications, vol.9, no.3, pp 10-18, Nov 2010.

[4] Jorge Luis Diaz Rodriguez, Luis David Pabon,Aldo Pardo Garcia," THD improvement of a PWM cascade multilevel power inverters using genetic algorithms as optimization method" WSEAS TRANSACTIONS on POWER SYSTEMS, Volume 10, pp 46-54, 2015

[5] O. M. Toledo, D. O. Filho, A. S. A. C. Diniz, "Distributed photovoltaic generation and energy storage systems: A review," Renewable Sustainable Energy Rev., vol. 14, no. 1, pp. 506–511, 2010.

[6] Gupta, K.K.; Jain, S.; "Topology for multilevel inverters to attain maximum number of levels from given DC sources," Power Electronics, IET, vol.5, no.4, pp.435-446, April 2012.

[7] Asghar Abedini, Salaheddin Zabalawi and Adel Nasiri, "A three-phase uninterruptible power supply with an adaptive reference waveform generator", Int. J. Power Electronics, Vol.1, No. 1, pp. 63-86, 2008.

[8] L. G. Franquelo, J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, M. A. M. Prats, "The age of multilevel converters arrives," IEEE Trans on Indus. Electronics, vol. 2, no. 2, pp. 28–39, Jun. 2008.