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Design & Simulation of 3-Phase, 27-Level Inverter with Reverse Voltage Topology

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ABSTRACT

Multilevel inverters have been widely accepted for high-power high-voltage applications. Their performance is highly superior to that of conventional Seven-level inverters due to reduced harmonic distortion, lower electromagnetic interference, and higher dc link voltages. In this paper, a new topology with a reversing-voltage component is proposed to improve the multilevel performance. This topology requires fewer components compared to existing inverters (particularly in higher levels) and requires fewer carrier signals and gate drives. Therefore, the complexity is greatly reduced particularly for higher output voltage levels. The Proposed 27-level inverter is modeled and simulated in Matlab 2012b using Simulink and Sim Power Systems set tool boxes

KEYWORDS: *Multilevel inverter, power electronics, SPWM, topology.*

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I. INTRODUCTION

Advancement in the research of Power electronic inverters is still increasing with the rapid demands in electrical systems. The emergence of multilevel inverters has been in increase since the last decade. These new types of converters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum [12].

Multilevel converters are mainly utilized to synthesis a desired single- or three-phase voltage waveform. Another important feature of multilevel converters is that the semiconductors are wired in a series-type connection, which allows operation at higher voltages. However, the series connection is typically made with clamping diodes, which eliminates overvoltage concerns. One clear disadvantage of multilevel power conversion is the higher number of semiconductor switches required. It should be pointed out that lower voltage rated switches can be used in the multilevel converter.

Another disadvantage of multilevel power converters is that the small voltage steps are typically produced by isolated voltage sources or a bank of series capacitors. Isolated voltage sources may not always be readily available, and series capacitors require voltage balancing [2]. To some extent, the voltage balancing can be addressed by using redundant switching states, which exist due to the high number of semiconductor devices. However, for a complete solution to the voltage-balancing problem, another multilevel converter may be required [3].

Nowadays, there exist three commercial topologies of multilevel voltage-source inverters: neutral point clamped (NPC), cascaded H-bridge (CHB), and flying capacitors (FCs)[4].
Some applications for the senew converters include industrial drives, flexible ac transmission systems (FACTS), and vehicle propulsion[13],[14]. One area where multilevel converters are particularly suitable is that of renewable photovoltaic energy that efficiency and power quality are of great concerns for the researchers[15].

For increasing voltage levels the number of switches also will increase in number. Hence the voltage stresses and switching losses will increase and the circuit will become complex. By using the proposed topology number of switches will reduce significantly and hence the efficiency will improve.

This paper presents an overview of a new multilevel inverter topology named reversing voltage (RV). This topology requires less number of components compared to conventional topologies. It is also more efficient since the inverter has a component which operates the switching power devices at line frequency. Therefore, there is no need for all switches to work in high frequency which leads to simpler and more reliable control of the inverter. This paper describes the general multilevel inverter schematic.

A general method of multilevel modulation phase disposition (PD) SPWM is utilized to drive the inverter and can be extended to any number of voltage levels. Here, in this paper the proposed multilevel scheme extended up to 27-levels.. In this work, the asymmetric 27 level inverter is presented. This inverter is designed to avoid the regeneration problem - power flow from the load to the inverter - in some of the power cells. This is achieved by obtaining the firing angles associated with the power cells considering a minimum load voltage THD. The simulation and experimental results of the proposed 27-level inverter topology are also presented. Finally, a power flow analysis is accomplished and simulated results show the feasibility of this approach.

II. Proposed 27-Level Inverter

The power semiconductor switches are combined to produce a high-frequency waveform in positive and negative polarities. However, there is no need to utilize all the switches for generating bipolar levels. This idea has been put into practice by the new 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 part and is responsible for generating the polarity of the output voltage, which is the low-frequency part operating at line frequency. The topology combines the two parts (high frequency and low frequency) to generate the multilevel voltage output. In order to generate a complete multilevel output, the positive levels are generated by the high-frequency part (level generation), and then, this part is fed to a full-bridge inverter (polarity generation), which will generate the required polarity for the output. This will eliminate many of the semiconductor switches which were responsible to generate the output voltage levels in positive and negative polarities.

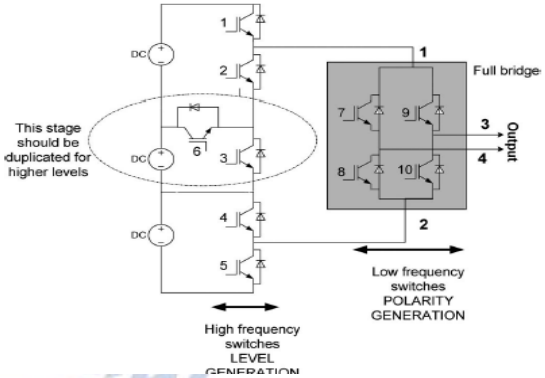

Fig.1. Schematic of seven level inverter in single phase

The RV topology in seven levels is shown in Fig. 1. As can be seen, it requires ten switches and three isolated sources. The principal idea of this topology as a multi level inverter is that the left stage in Fig. 1 generates the required output levels (without polarity) and the right circuit (full-bridge converter) decides about the polarity of the output voltage. This part, which is named polarity generation, transfers the required output level to the output with the same direction or opposite direction according to the required output polarity. It reverses the voltage direction when the voltage polarity requires to be changed for negative polarity.

It can also be applied for three-phase applications with the same principle. This topology uses isolated dc supplies. Multi level positive voltage is fed to the full-bridge converter to generate its polarity. Then, each full bridge converter will drive the primary of a transformer. The secondary of the transformer is delta (Δ) connected and can be connected to a three-phase system.

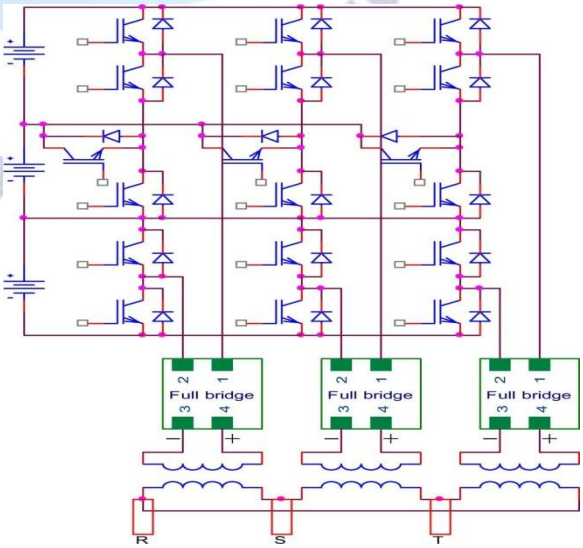

Fig.2.Three phase RV multilevel topology

This topology requires fewer components in comparison to conventional inverters. Another advantage of the topology is that it just requires half of the conventional carriers for SPWM controller. SPWM for seven-level conventional converters consists of six carriers, but in this topology, three carriers are sufficient. The reason is that, according to Fig. 1, the multilevel converter works only in positive polarity and does not generate negative polarities. Therefore, it implements the multilevel inverter with a reduced number of carriers, which is a great achievement for inverter control. It is also comparable to single-carrier modulation, while this topology requires the same number of signals for PWM. However, this topology needs one modulation signal which is easier to generate as opposed to the single-carrier modulation method which needs several modulation signals [16]. Another disadvantage of this topology is that all switches should be selected from fast switches, while the proposed topology does not need fast switches for the polarity generation part.

A. Switching Sequences:

In order to avoid unwanted voltage levels during switching cycles, the switching modes should be selected so that the switching transitions become minimal during each mode transfer. This will also help to decrease switching power dissipation.

INVERTER TYPE	NPC	FLYING CAPACITOR	CASCADED	RV
Main switches	6(N-1)	6(N-1)	6(N-1)	3((N-1)+4)
Main diodes	6(N-1)	6(N-1)	6(N-1)	3((N-1)+4)
Clamping diodes	3(N-1) (N-2)	0	0	0
Dcbus capacitors/isolated supplies	(N-1)	(N-1)	3(N-1)/2	(N-1)/2
Flying capacitors	0	3/2(N-1)(N-2)	0	0
Total numbers	(N-1) (3N+7)	½(N-1)(3N+20)	27/2(N-1)	(13N+35)/2

Number of Components for 3-Phase Inverter

TABLE.1.SWITCHING PATTERN FOR 27 LEVEL,3 -PHASE INVERTER

Level	ON-State Switches
0	2,5,7,9,11,13,15,17,19,21,23,25,3
1	4,25,23,21,19,17,15,13,11,9,7,5,2
2	4,26,23,21,19,17,15,13,11,9,7,5,2
3	4,24,21, 19,17,15,13,11,9,7,5,2
4	4,22,19,17,15,13,11,9,7,5,2
5	4,20,17,15,13,11,9,7,5,2
6	4,18,15,13,11,9,7,5,2
7	4,16,13,11,9,7,5,2
8	4,14,11,9,7,5,2
9	4,12, 9,7,5,2
10	4,10,7,5,2
11	4,8,5,2
12	4,6,2
13	1,4

In order to produce 27- levels by Sinusoidal Pulse Width Modulation (SPWM), three saw-tooth waveforms for carrier and a sinusoidal reference signal for modulator are required as shown in Fig. 3.

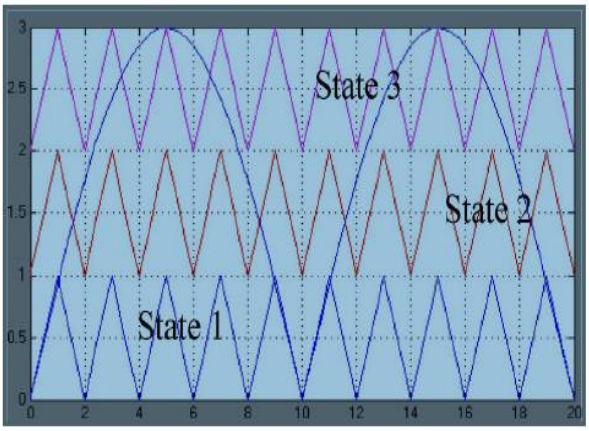

Fig. 3.SPWM carrier and modulator for proposed 27-level inverter

III. MATLAB BASED SIMULATION AND RESULTS

A. MATLAB based simulation :

Fig.4. shows the complete MATLAB based simulation masked diagram of the proposed 27-level, 3-phase inverter.

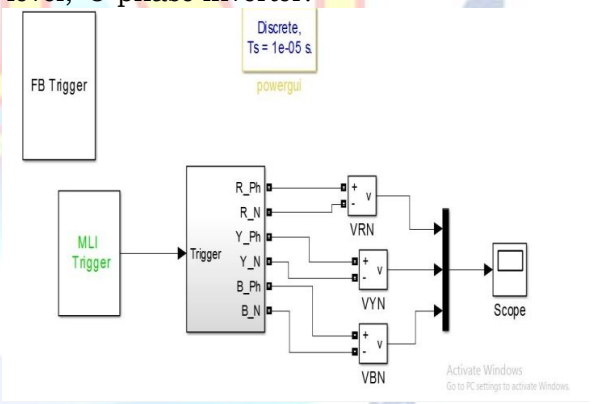

Fig.4.MATLAB based simulation masked diagram of the proposed 27-level, 3-phase inverter

Fig.5. shows the input DC voltage source to the proposed 27-level, 3-phase inverter

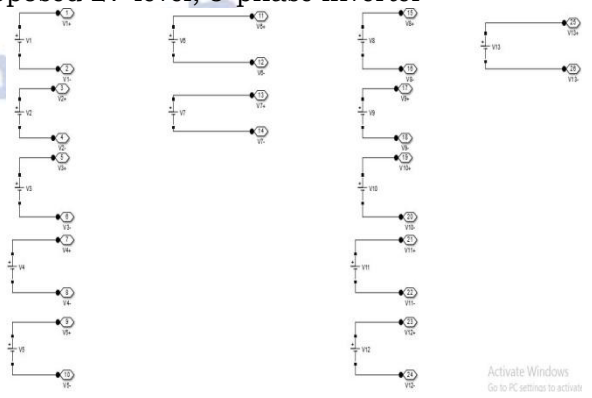

Fig.5. Input DC voltage source to the proposed 27-level, 3-phase inverter

Fig.6. shows power electronic based bridge circuit of the proposed 27-level, 3-phase inverter

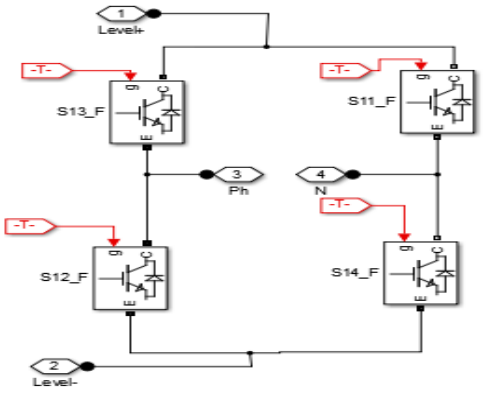

Fig.6. Simulation diagram of power electronic based bridge circuit of the proposed 27-level, 3-phase inverter

Fig.7. shows the gate controlled pulse to the proposed 27-level, 3-phase inverter

Fig.8.shows the inversion of DC to 3-phase MATLAB based simulation diagram.

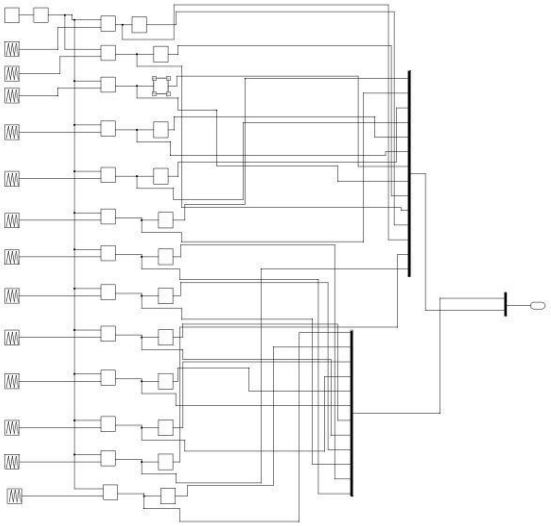

Fig.7. Gate controlled pulse to the proposed 27-level, 3-phase inverter

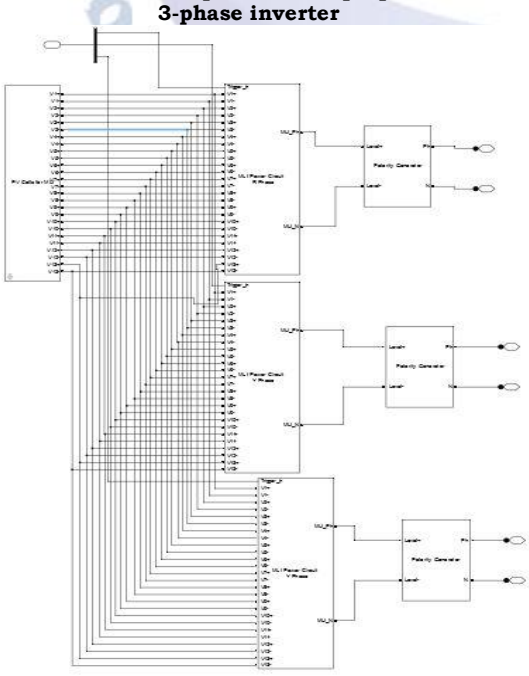

Fig.8. DC to AC 3-phase inversion MATLAB based simulation diagram.

Simulation parameters for the proposed 27-level, 3-phase inverter is given by in the Table.1

B. Simulation Results:

Fig.9. shows the 3-phase, 27-level output voltage waveform from the proposed inverter.

Fig.10. shows the THD calculation of proposed 3-phase, 27-level inverter using powergui FFT Analysis tool.

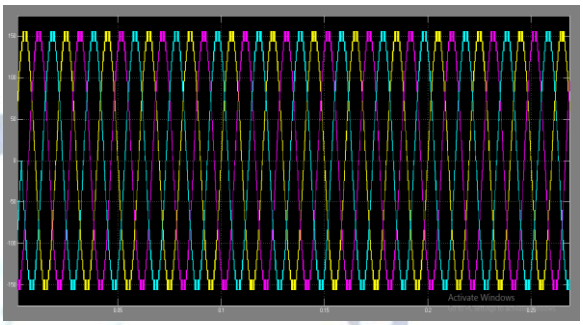

Fig.9. 3-Phase, 27-level output voltage waveform from the proposed inverter

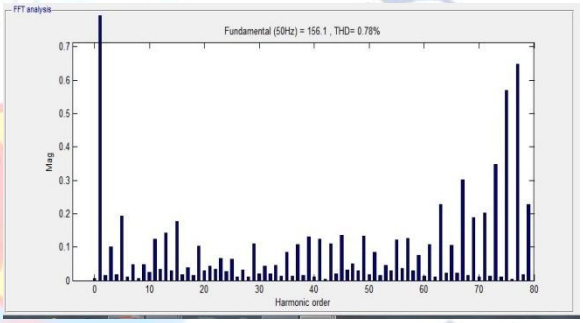

Fig.10. THD calculation of proposed 3-phase, 27-level inverter using powergui FFT Analysis tool

Fig.11. shows the 3-phase voltage and 3-phase current waveform from the proposed inverter.

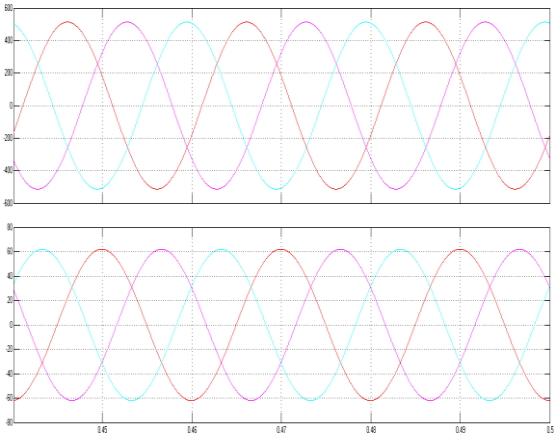

Fig.11. 3-phase voltage (upper) and 3-phase current (lower) waveform from the proposed inverter respectively

IV. Conclusion

An efficient 3-phase, 27-level inverter is presented in the paper. The resultant simulation graphs show the accuracy of the proposed inverter. High performance switches are adopted to reduce the conduction losses and improve the efficiency. 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. Experimental results that confirm the feasibility of the proposed 3-phase, 27-level inverter. Finally, MATLAB based simulink results shown the THD value at reasonable level

REFERENCES

[1] K. Gopakumar, Haitham Abu-Rub, P. P. Rajeevan and K.Sivakumar, "*A Nine-Level Inverter Topology for Medium-Voltage Induction Motor Drive With Open-End Stator Winding*" IEEE Transactions , 2013 on industrial electronics,vol.60, no.9.

[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] L. M. Tolbert, F. Z. Peng, and T. G. Habetler, "Multilevel converters for large electric drives," IEEE Trans. Ind. Appl., vol. 35, no. 1, pp. 36–44, Jan./Feb. 1999.

[4] M. N. Abdul Kadir and S. Mekhilef "*Novel vector controlmethod for three-stage hybrid cascaded multilevel inverter*" IEEE 2011, Trans. Ind.Electron., vol. 58,

[5] L. A. Córdova, L. Empringham, P. Lezana and C. A. Silva"*Implementation and control of a hybrid multilevel converter withfloating dc links for current waveform improvement*" IEEE Trans. Ind.Electron., 2011 vol. 58,no. 6.

[6] Ehsan Najafi and Abdul Halim Mohamed Yatim, "*Design and Implementation of a New MultilevelInverter Topology*", IEEETrans. Ind. Electron. November 2012, Vol. 59,no. 7, pp.no . 4148-4154

[7] L. G. Franquelo, K. Gopakumar, S. Kouro, J. I. Leon, M.Malinowski, M. A. Pérez, J. Pou and B.Wu, J. Rodríguez,"*Recent advances and industrial applications of multilevel converters*"IEEE Trans. Ind. Electron,2010,vol. 57, no. 8.

[8] G. Franquelo, S. Kouro, J. I. Leon, R. Portillo, M. A. M.Prats andJ. Rodriguez.(2008) "*The age of multilevel converters arrives*" IEEE 2008, Vol.2, no.2.

[9] E.Vellaneava,P.Correa, M.Pacas, " *Control of Single-Phase Cascaded H-Bridge Multilevel Inverter for Grid-Connected photovoltaic Systems*", IEEE trans. Industrial Eleectronics , 2009 , Vol.56,pp.4399-4406 .

[10] Malinowski Mariusz, Gopakumar K, Rodriguez Jose, Pérez Marcelo A,"*A survey on cascaded multilevel inverters*", IEEE Trans Ind Electron 2010;57(7).

[11] Malinowski Mariusz, GopakumarK, Rodriguez Jose, Pérez Marcelo A., "*A survey on cascaded multilevel inverters.*", IEEE Trans Ind Electron 2010;57(7). Convers Manage 2011;52:1114–28.

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

[13] K. Nakata, K. Nakamura, S. Ito, and K. Jinbo, "A three-level traction inverter with IGBTs for EMU," in Conf. Rec. IEEE IAS Annu. Meeting, 1994, vol. 1, pp. 667–672.

[14] A. Jidin, N. R. N. Idris, A. H. M. Yatim, T. Sutikno, and M. E. Elbuluk, "An optimized switching strategy for quick dynamic torque control in DTC-hysteresis-based induction machines," IEEE Trans. Ind. Electron., vol. 58, no. 8, pp. 3391–3400, Aug. 2011.

[15] K. Y. Lau, M. F. M. Yousof, S. N. M. Arshad, M. Anwari, and A. H. M. Yatim, "Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions," J. Energy, vol. 35, no. 8, pp. 3245–3255, Aug. 2010.

[16] C. Govindaraju and K. Baskaran, "Analysis and implementation of multiphase multilevel hybrid single carrier sinusoidal modulation," J. Power Electron., vol. 10, no. 4, pp. 365–373, Jul. 2010.