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Development and Implementation of Seven Level Inverter Using Space Vector Modulation Technique for PV Application

G.Indumathi[1], Dr.S.U.Prabha[2]

PG Scholar, Sri Ramakrishna Engineering College, Coimbatore, Tamilnadu, India[1]

Head of the Department, Department of EEE, Sri Ramakrishna Engineering College, Coimbatore, Tamilnadu, India[2]

Abstract: Multilevel Inverters (MLI) play an important role in medium / high voltage and high power applications due to its capability to convert DC input voltage to AC output voltage with reduced Total Harmonics Distortion (THD) and low Electromagnetic Interference (EMI). Multilevel inverters generate sinusoidal voltages from discrete voltage levels, and Pulse Width Modulation (PWM) strategies accomplish this task of generating sinusoids of variable voltage and frequency. Modulation methods for Hybrid Multilevel Inverter can be classified according to the switching frequency methods. Many different PWM methods have been developed to achieve the following: Wide linear modulation range, less switching loss, reduced Total Harmonic Distortion (THD) in the spectrum of switching waveform Differential Evolution (DE) algorithm is a new heuristic approach mainly having three advantages; finding the true global minimum regardless of the initial parameter values, fast convergence, and using few control parameters. DE algorithm is a population based algorithm like genetic algorithms using similar operators; crossover, mutation and selection. In this work, we have compared the performance of DE algorithm to that of some other well-known versions of genetic algorithms. The three-dimensional space vector modulation schemes are supersets of, and thus are compatible with, conventional two-dimensional space vector modulation schemes. An LC Filter is used to eliminate the output voltage harmonics. A conventional Proportional Integral (PI) controller is used to control the output load voltage.

Keywords: Genetic Algorithm, Differential Evolution, Multilevel Inverter

I. INTRODUCTION

Increasing needs for energy in addition to the traditional sources drawbacks are motivations for green energy evolution. Among the Renewable Energy Sources (RESs), Photovoltaic Generation Systems (PVGSs) have been spread due to modern developments in solar cells manufacturing .The generated power from these systems is DC that requires power electronic inverters Voltage Source Inverters (VSIs) are widely used in industrial applications to perform the dc to ac conversion with three levels output voltage. Multilevel Inverters (MLIs) have become more attractive to researchers due to their advantages in high power and high voltage applications. They provide stepped voltage with low harmonic contents. Increasing the number of output voltage levels minimizes the included Total Harmonic Distortion (THD). Moreover, low T stress is gained and hence, avoids the need for high rating of individual devices. Finally, the switching loss can be decreased .There are three conventional topologies for MLIs. The three topologies are classed into: (1) Diode Clamped Multilevel Inverters (DCMLI) (Flying Capacitors Multilevel Inverters(FCMLI) Cascaded H-bridge Multilevel Inverters (CHBMLI).In the optimization process of a difficult task, the method of first choice will usually be a problem specific heuristics. These techniques using expert knowledge achieve a superior performance. If problem specific technique is not applicable due to unknown system parameters, the multiple local minima, or non-differentiability, Evolutionary Algorithms (EAs) have the potential to overcome these EAs are a class of direct search algorithms.

A conventional direct search method uses a strategy that generates variations of the design parameter vectors. Once a variation is generated, the new parameter vector is accepted or not. The new parameter vector is accepted in the case it reduces the objective function value. This method is usually named the greedy search. The greedy search converges fast but can be trapped by local minima. This disadvantage can be eliminated by running several vectors simultaneously. This is the main idea of Differential Evolution (DE) algorithm. The most popular EA is genetic algorithm. Although many genetic algorithm versions have been developed, they are still time consuming. In order to overcome this disadvantage, the evolution strategy called DE has been recently proposed by DE is the mutation scheme that makes DE self adaptive and the selection process. In DE, all solutions have the same chance of being selected as parents without dependence of their fitness value. DE employs a greedy selection process: The better one of new solution and

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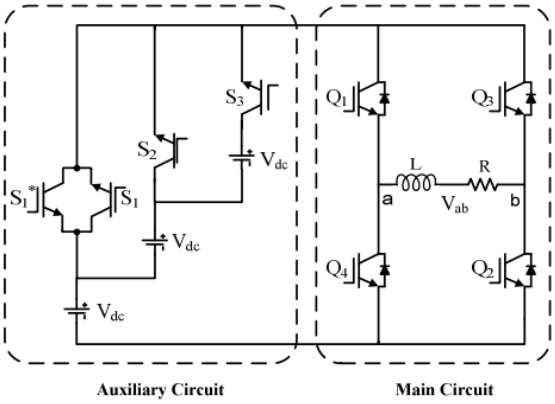
its parent wins the competition providing significant advantage of converging performance over genetic algorithms. DE algorithm is a stochastic optimization method minimizing an objective function that can model the problem's objectives while incorporating constraints. The algorithm mainly has three advantages; finding the true global minimum regardless of the initial parameter values, fast convergence, and using a few control parameters [2]. Being simple, fast, easy to use, very easily adaptable for integer and discrete optimization, quite effective in nonlinear constraint optimization including penalty functions and useful for optimizing multi-modal search spaces are the other important features of DE



Proposed Single-Phase Seven-Level Inverter

II. PROPOSED SINGLE-PHASE SEVEN-LEVEL PWM INVERTER

The proposed circuit consists of the main and the auxiliary circuit. The main circuit is a full H-bridge inverter circuit. The auxiliary circuit has four identical power switches and three identical and separate DC sources which control the output voltage levels. Assuming that all the components are ideal and the circuit operates in steady-state, the output load voltage level depends on the Modulation Index (MI). The load output voltage,. On the other hand, the main circuit is an H-bridge cell utilizing four identical power switches with body diodes which control the output voltage polarity.

III.THE SWITCHING SCHEME

Multilevel inverters generate sinusoidal voltages from discrete voltage levels, and pulse width modulation (PWM) strategies accomplish this task of generating sinusoids of variable voltage and frequency. Modulation methods for Hybrid Multilevel Inverter can be classified according to the switching frequency methods. Many different PWM methods have been developed to achieve the following: Wide linear modulation range, less switching loss, reduced Total Harmonic Distortion (THD) in the spectrum of switching waveform: and easy implementation and less computation time. The most widely used techniques for implementing the pulse with modulation (PWM) strategy for multilevel inverters are Sinusoidal PWM (SPWM) and space vector PWM (SPWM). The SVPWM is considered as a better technique of PWM implementation as it has advantages over SPWM in terms of good utilization of dc bus voltage, reduced switching frequency and low current ripple

SVPWM is considered a better technique of PWM implementation, as it provides the following advantages,
(i) Better fundamental output voltage
(ii) Useful in improving harmonic performance and reducing THD. 62
(iii) Extreme simplicity and its easy and direct hardware implementation in a Digital Signal Processor (DSP).
(iv) SVPWM can be efficiently executed in a few microseconds, achieving similar results compared with other PWM methods.

In this chapter, a space vector is defined in a two-dimensional (2-D) plane and a SVM is performed in the 2-D plane. Furthermore, a three dimensional (3-D) space vector has been defined in this chapter for cascaded H-bridge multilevel inverter. All the existing space vector modulation schemes are implemented in a two-dimensional, and are therefore unable to deal with the zero-sequence component caused by unbalanced load. Complexity and computational cost of traditional SVPWM technique increase with the number of levels of the inverter as most of the space vector modulation algorithms proposed in the literature involve trigonometric function calculations or look-up tables. Previous works on three-dimensional space vector modulation algorithms have been presented. Meanwhile, the first 3-D space vector modulation for cascaded H-bridge inverter

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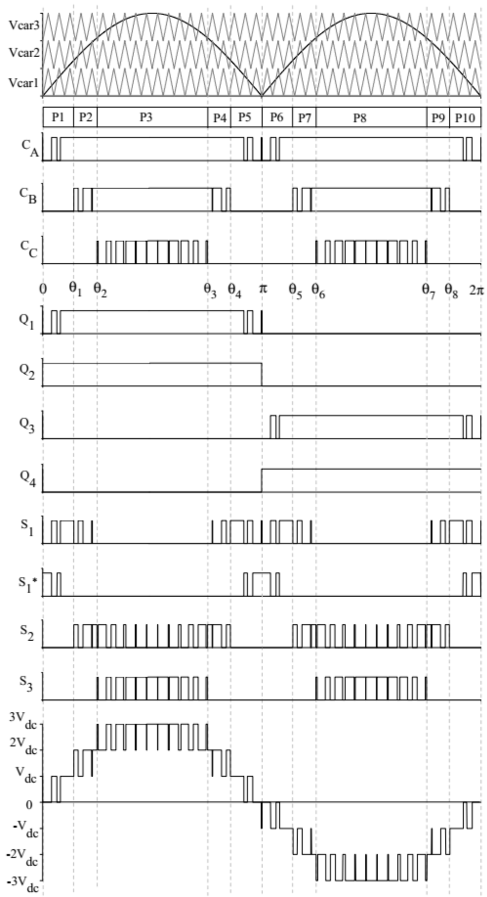
OUTPUT VOLTAGE LEVELS ACCORDING TO SWITCHING STATES.

Output levels	Switching states						
	S_1	S_2	S_3	Q_1	Q_2	Q_3	Q_4
$3V_{dc}$	0	0	1	1	1	0	0
$2V_{dc}$	0	1	0	1	1	0	0
V_{dc}	1	0	0	1	1	0	0
0	0	0	0	0	1	0	1
$-V_{dc}$	1	0	0	0	0	1	1
$-2V_{dc}$	0	1	0	0	0	1	1
$-3V_{dc}$	0	0	1	0	0	1	1

The periods according to reference signal amplitude

The DE algorithm has a few control parameters: number of population NP , scaling factor F , combination coefficient K, and crossover rate CR. The problem specific parameters of the DE algorithm are the maximum generation number Gmax and the number of parameters defining the problem dimension D. The values of these two parameters depend on the problem to beoptimized. In the simulations, it was observed that the value of scaling factor significantly affected the performance of DE. This can be seen in Table 2. In the table, 10000+ represents the number of generations which are higher than 10000. In order to get the best performance from the DE, the scaling factor value, F, must be optimally tuned for each function. Of course, this is a time-consuming task. For the simplicity and flexibility, the value of F was randomly



Mode1: $P_1 = 0 < \omega t < \theta_1$, $P_5 = \theta_4 < \omega t < \pi$
Mode2: $P_2 = \theta_1 < \omega t < \theta_2$, $P_4 = \theta_3 < \omega t < \theta_4$
Mode3: $P_3 = \theta_2 < \omega t < \theta_3$
Mode4: $P_6 = \pi < \omega t < \theta_5$, $P_{10} = \theta_8 < \omega t < 2\pi$
Mode5: $P_7 = \theta_5 < \omega t < \theta_6$, $P_9 = \theta_7 < \omega t < \theta_8$
Mode6: $P_8 = \theta_6 < \omega t < \theta_7$

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Switching pattern for generating seven-level output voltage

By logical combinations of CA, CB, CC and Pn, the switching signal can be generated by using ten intervals and the logical operators AND, OR and NOT. The resultant gating signals can be summarized as follow:

$$S_1 = (P_1 + P_5 + P_6 + P_{10} +).C_A + (P_2 + P_3 + P_4 + P_7 + P_8 + P_9).\overline{C_B}$$
$$S_1^* = (P_1 + P_5 + P_6 + P_{10}).\overline{C_A}$$
$$S_2 = (P_2 + P_4 + P_7 + P_9).C_B + (P_3 + P_8).\overline{C_C}$$
$$S_3 = (P_3 + P_8).C_C$$
$$Q_1 = (P_1 + P_2 + P_3 + P_4 + P_5).C_A$$
$$Q_2 = (P_1 + P_2 + P_3 + P_4 + P_5)$$
$$Q_3 = (P_6 + P_7 + P_8 + P_9 + P_{10}).C_A$$
$$Q_4 = (P_6 + P_7 + P_8 + P_9 + P_{10})$$

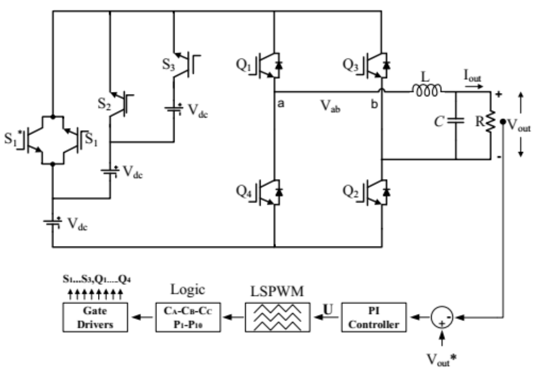
The switching angle (ș) according to modulation index (MI) is shown in Table-II. The modulation index MI is calculated as:.

$$MI = \frac{A_m}{3\,A_c}$$

.SWITCHING ANGLES ACCORDING TO MODULATION INDEX

Modulation index (MI)	MI < 0.33	0.33 > MI > 0.67	MI > 0.67
θ_1	$\pi/2$	$sin^{-1}(\frac{A_c}{A_m})$	$sin^{-1}(\frac{A_c}{A_m})$
θ_2	$\pi/2$	$\pi/2$	$sin^{-1}(\frac{A_c}{2A_m})$
θ_3	$\pi/2$	$\pi/2$	$\pi - \theta_2$
θ_4	$\pi/2$	$\pi - \theta_1$	$\pi - \theta_1$
θ_5	$3\pi/2$	$\pi + \theta_1$	$\pi + \theta_1$
θ_6	$3\pi/2$	$3\pi/2$	$\pi + \theta_2$
θ_7	$3\pi/2$	$3\pi/2$	$2\pi - \theta_2$
θ_8	$3\pi/2$	$2\pi - \theta_1$	$2\pi - \theta_1$
θ_9	$\pi/2$	$\pi/2$	$sin^{-1}(\frac{A_c}{2A_m})$
θ_{10}	$\pi/2$	$\pi/2$	$\pi - \theta_2$

The closed loop scheme for voltage control is shown in An LC filter is used to reduce the ripple content in the output voltage. A PI controller is applied to regulate the output voltage to the reference voltage. The output from the PI controller is applied to the LSPWM to develop the switching gate signals. type CAM cells with the single-ended ML, the proposed novel NANDCAM cell with the differential ML



Voltage control scheme of single-phase seven-level

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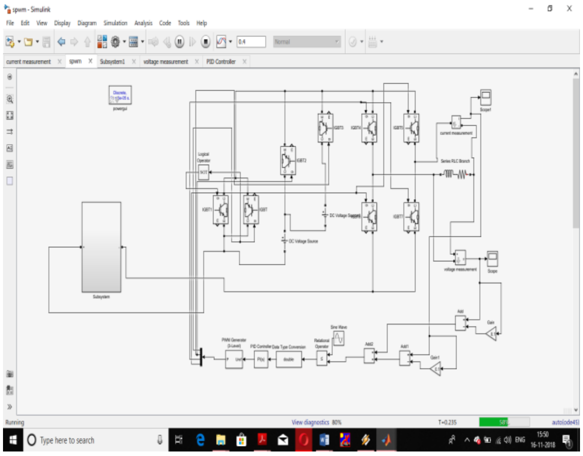
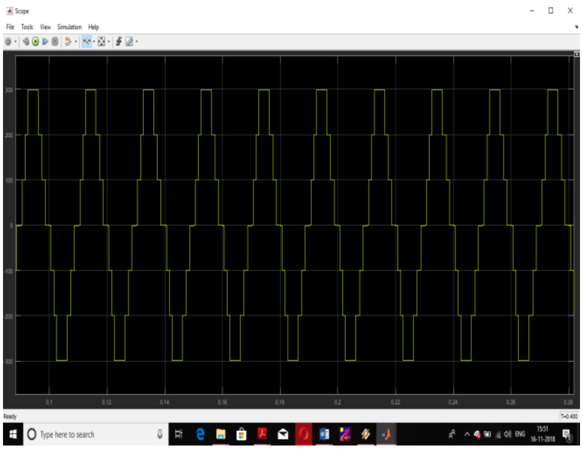
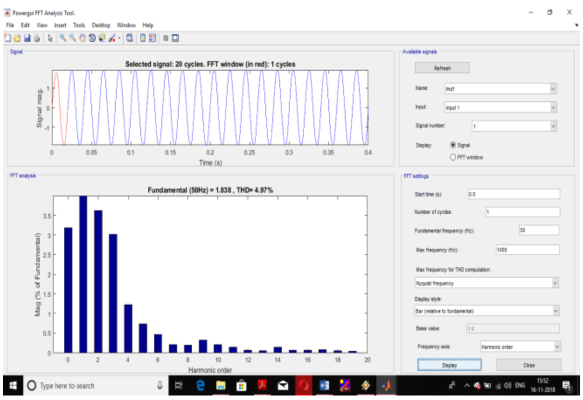
IV.SIMULATION RESULTS

The MATLAB/SIMULINK is applied to confirm the validity of the proposed seven-level PWM inverter when it is connected to a resistive load. The results are shown in Fig. 5 at MI of 0.33, 0.67, summarizes all the simulation parameters. The output voltage from inverter can be three, five or seven levels according to the modulation index. At *MI = 0.33*, for a peak value of reference voltage *VP=50 V*, three levels is obtained, as shown in SIMULATION PARAMETER



Full model with spwm and pi control





Output voltage of existing system, Fft analysis of exe system.

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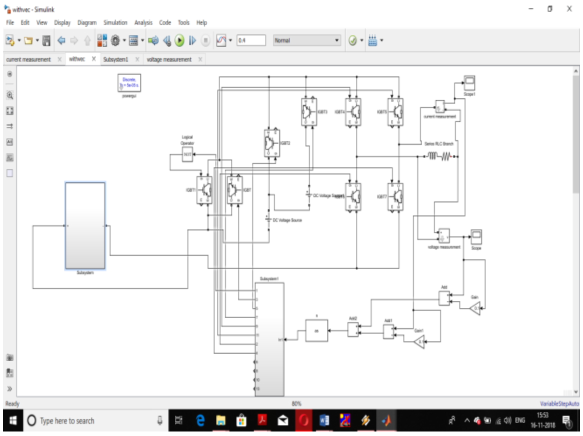
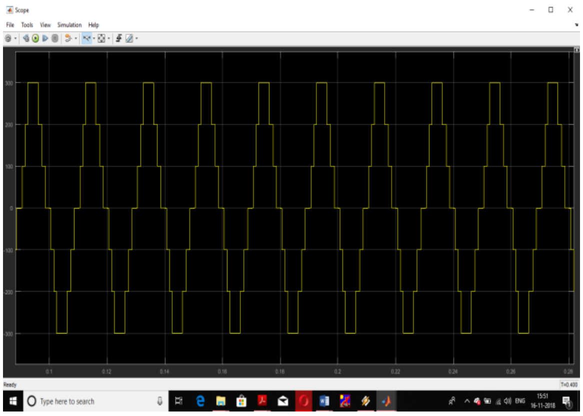
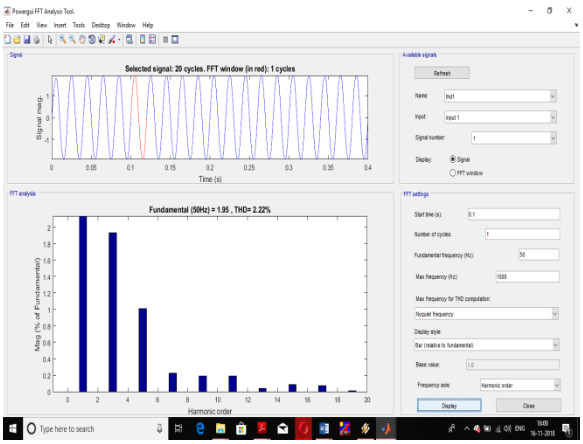


Proposed model with differential evaluation algorithm with vector switching



Output voltage of proposed system



Thd of proposed system

V.CONCLUSIONS

This paper proposes a novel single-phase seven-level inverter. The proposed topology has increased number of output levels with less power electronics components. The DE algorithm is a new heuristic approach mainly having three advantages; finding the true global minimum regardless of the initial parameter values, fast convergence, and using a few control parameters. In this work, the performance of the DE algorithm has been compared to that of some other well known genetic algorithms. From the simulation studies, it was observed that the convergence speed of the DE is significantly better than the GAs presented in this work. In order to obtain seven-level output voltage, the proposed inverter has used only three voltage sources and eight switches. Investigated by Simulations, while real time simulation has been applied to experimentally validate the proposed inverter using dspace-1103. Major advantages of the proposed inverter are summarized as follow:

- Reduced cost by circuit components reduction.
- Less stress on the auxiliary switching devices.
- Low size of filter.
- Low THD can be obtained.
- High power density converter

REFERENCES

[1] E. Koutroulis and F. Blaabjerg, "A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions," IEEE Journal of Photovoltaics, vol. 2, pp. 184-190, 2012.
[2] M. A. Sayed, E. E. Mohamed, and A. I. Ali, "Maximum Power Point Tracking Technique For Grid Tie PV System," in 7th International Middle-East Power System Conference,(MEPCON'15), Mansoura University, Egypt, 2015.
[3] M. Kaliamoorthy, V. Rajasekaran, and G. PraveenRaj, "novel single phase cascaded multilevel inverter for hybrid renewable energy sources," in Advanced Computing and Communication Systems, 2015 International Conference on, 2015, pp. 1-10.
[4] A. I. Ali, M. A. Sayed, and E. E. Mohamed, "Maximum Power Point Tracking technique applied on partial shaded grid connected PV system," in Power Systems Conference (MEPCON), 2016 Eighteenth International Middle East, 2016, pp. 656-663.
[5] J. Rodriguez, J.-S. Lai, and F. Z. Peng, "Multilevel inverters: a survey of topologies, controls, and applications," IEEE Transactions on Industrial Electronics, vol. 49, pp. 724-738, 2002.
[6] G. P. Adam, S. J. Finney, A. M. Massoud, and B. W. Williams, "Capacitor balance issues of the diode-clamped multilevel inverter operated in a quasi two-state mode," IEEE Transactions on Industrial Electronics, vol. 55, pp. 3088-3099, 2008.
[7] M. Marchesoni and P. Tenca, "Diode-clamped multilevel converters: a practicable way to balance DC-link voltages," IEEE Transactions on Industrial Electronics, vol. 49, pp. 752-765, 2002.
[8] D.W. Kang, B.-K.Lee, J.-H.Jeon, T.-J.Kim, and D.-S. Hyun, "A symmetric carrier technique of CRPWM for voltage balance method of flying-capacitor multilevel inverter," IEEE Transactions on Industrial Electronics, vol. 52, pp. 879-888, 2005
[9] M. Malinowski, K. Gopakumar, J. Rodriguez, and M. A. Perez, "A survey on cascaded multilevel inverters," IEEE Transactions on Industrial Electronics, vol. 57, pp. 2197- 2206, 2010.
[10] K. K. Gupta and S. Jain, "A novel multilevel inverter based on switched DC sources," IEEE Transactions on Industrial Electronics, vol. 61, pp. 3269-3278,2014.
[11] D. Atkar, P. S. Udakhe, S. Chiriki, and V. Borghate, "Control of seven level cascaded H-Bridge inverter by hybrid SPWM technique," in Power Electronics, Drives and Energy Systems (PEDES), 2016 IEEE International Conference on, 2016, pp.
[12] N. A. Rahim, K. Chaniago, and J. Selvaraj, "Single-phase seven-level grid-connected inverter for photovoltaic system," IEEE Transactions on Industrial Electronics, vol. 58, pp. 2435-2443, 2011.
[13] J.-S. Choi and F.-s. Kang, "Seven-level PWM inverter employing series-connected capacitors paralleled to a single DC voltage source," IEEE Transactions on Industrial Electronics, vol. 62, pp. 3448-3459, 2015.
[14] K. Sato, H. Haga, and S. K. Nagaoka, "Single-phase 7-level inverter for reducing number of switches," in Telecommunications Energy Conference (INTELEC), 2015 IEEE International, 2015, pp. 1-6.
[15] J.-C. Wu and C.-W.Chou, "A solar power generation system with a seven-level inverter," IEEE transactions on power electronics, vol. 29, pp. 3454-3462, 2014.