TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 13, No. 3, March 2015, pp. 467 ~ 475
DOI: 10.11591/telkomnika.v13i3.7140

Multi-Carrier based 27-level Hybrid Multi-level Inverter Interface with PhotoVoltaic

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Abstract

This paper presents a Multi-Carrier Pulse Width Modulation control for a Single-phase 27-level Hybrid Multi-Level Inverter for photovoltaic systems. Multi-Carier Pulse Width Modulation technique uses a easy mapping to generate gate signals for the inverter.The Maximum Power Point Tracking is capable of extracting maximum power from PV array connected to each DC linkage voltage stage. The Maximum Power Point Tracking algorithm is solved by Perturb and Observer method.This is done to accomplish high energetic performance with low Total Harmonic Distortion.The grades are compared with conventional Multi-Level Inverter in terms of inferior THD is obtained and the 27-level Hybrid Muti-Level Inverter is simulated by using MATLAB/simulink.Simulated results are available to verify the usefulness and accuracy of the proposed method. This proposal can be easily extended to an n-level inverter for PV system

Keywords*: multi-level inverter, multi-carrier pulse width modulation, photovoltaic system, total harmonic distortion*

1. Introduction

As the world is apprehensive with fossil-fuel exhaustion and ecological problems caused by conventional power production, renewable energy sources, mainly solar and wind energy, have become very trendy and difficult. Photovoltaic (PV) sources are used today in many applications because they have the advantages of being protection and free contamination [1-5]. Solar-electric-energy obligation has developed consistently by 20%–25% per annum over the past 20 existence, which is mainly due to the diminishing expenses and price. It has some conditions such as an growing competence of solar cells, manufacturing and technology improvements.

The mechanism of PV production systems is quickly rising due to concerns related to surroundings, global warming, energy precautions, technology improvements and decreasing costs. However, PV production systems have two main troubles that is little conversion energy in little irradiation conditions and the quantity of electric power generated by PV arrays varies constantly with weather conditions. The solution of solving these problems are discussed [3-4]. A lot of Maximum Power Point Tracking (MPPT) algorithms are there but here Perturb and observer (P&O) method can be used because they are simple and easy to extract maximum power from the panel.

A PV inverter, which is an important element in the PV system, is used to change dc power from the solar module into ac power. The need of several sources on the DC side of the converter makes multilevel technology gorgeous for PV applications. Because the Multi-Level Inverters (MLI) [6-7] are classified into two types namely Distinct source and Multisource MLI. Distinct source MLI has only one DC source and remaining are the Capacitors or Clamping Diodes.One type of Distinct source MLI is the Neutral Point Clamped (NPC) MLI or also known as Diode Clamped Inverter (DCI). The DCI create the small step of staircase output voltage from several levels of DC capacitor voltages. The other type of Distinct source MLI is Flying Capacitor (FC) MLI. It requires huge number of capacitors to clamp the device voltage to one capacitor voltage level [8]. Multisource MLI has number of DC sources depending upon the voltage levels each with one H-bridge connected to a DC source. Depending on the voltage levels the magnitude of the voltage source will change. By using the H-bridge topology, three habitually used voltage synthesis based multilevel inverters are Cascaded H-bridge (CHB),

Received December 4, 2014; Revised January 15, 2015; Accepted January 27, 2015

Hybrid (H) and New Hybrid (NH) MLI. The functions of these MLIs are identical as that of the Distinct source MLI. This type of multilevel inverter can avoid extra clamping diodes or voltage balancing capacitors.Many methods of Pulse Width Modulation (PWM) techniques are used to control the inverter.In this 27-level HMLI choosing a Multi-Carrier Pulse Width Modulation technique [9-11] (MCPWM) because it can be used to eliminate the side-band harmonics and In conventional 15-level HMLI, the THD considerably high when compare to the 27-level HMLI. It is concluded that the THD will be reduced with increases of levels. Then only proposed method can be used for the high power applications.

2. Photovoltaic System

A photovoltaic system is a system which uses one or more solar panels to convert solar energyinto electricity. It consists of numerous components, as well as the photovoltaic modules, mechanical and electrical associates and mountings and means of regulating and/or modifying the electrical output [12-14]. PV cells are made of semiconductor equipment as silicon. For solar cells, a skinny semiconductor wafer is particularly treated to form an electric field, optimistic on one side and depressing on the other. While light energy strikes the solar cell, electrons are knock shapeless from the atoms in the semiconductor fabric but electrical conductors are emotionally involved to the positive and negative sides, form an electrical circuit, the electrons can be captured in the shape of an stimulating current - that is, electricity. This electricity can then be used to power a load. In Figure 1 shows the PV system structure.

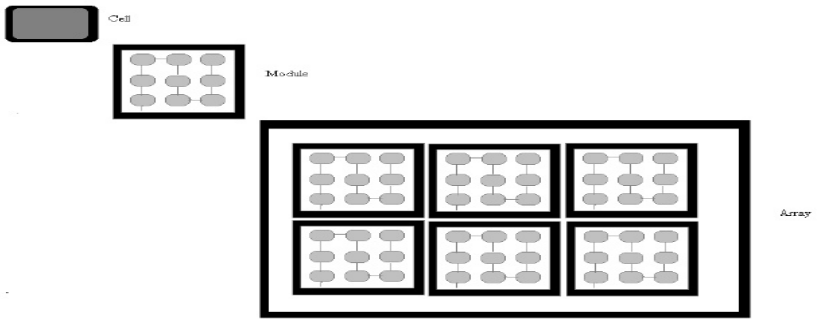

Figure 1. PhotoVoltaic System

2.1. Equivalent Circuit of PV

The basic equivalent circuit of a PV cell is given in the Figure 2. An ideal is modeled by acurrent source in parallel with a diode. However no solar cell is ideal and thereby shunt and series resistances are added to the model.Single-crystal silicon, Polycrystalline silicon, Gallium Arsenide(GaAs), Cadnium Telluride(CaTe), Copper Indium Diselenide these are the materials are used in the solar cell.

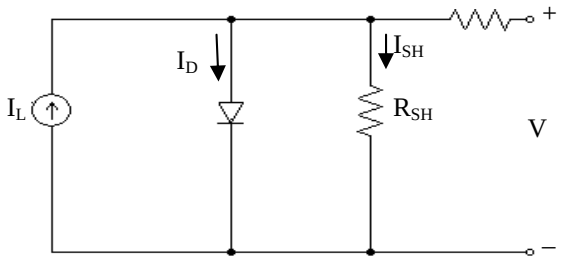

Figure 2. Equivalent Circuit of Solar Cell

In the Equation (1) shows the solar cell parameters to the output current and output voltage,

$$I = I_{L-}I_0\left\{exp\left[\frac{q[V+IRsh]}{nkT}\right]-1\right\}-\frac{V+IRs}{Rsh} \quad (1)$$

2.2. Characteristics of PV

This point is mostly the knee point of the curve. This point at which the maximum power that can be obtained from the PV module is known as MAXIMUM POWER POINT usually referred as MPP. This can be inferred from that the Power vs. Voltage Characteristics that there is only one point at which the power is maximum. Figure 3 shows the P – V characteristics of a PV module.

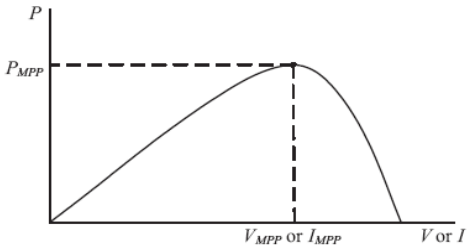

Figure 3. P-V Characteristics of PV Module

2.3. Maimum Power Point Tracking Algorithm

To extort the maximum power from the panel Maximum Power Point Tracking Method can be used. This MPP varies with change in temperature, irradiance and load.

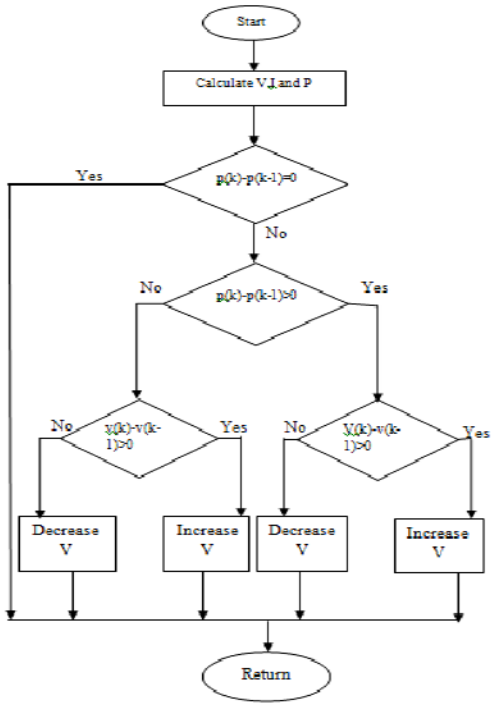

Figure 4. Flow Chart for P&O Algorithm

Many of the MPPT method are available but we are choosing Perturb and observer (P&O) method because it is simple. The P&O algorithms activate by sporadically Incrementing or decrementing the array terminal voltage or current and comparing the PV output power with that of the earlier perturbation cycle. Time complication of this algorithm is very less. Cost of execution is less and hence easy to execute.

3. Topology of the Hybrid Multilevel Inverter

A fundamental construction of a single phase HMLI is shown in Figure 5. Every inverter uses a dc voltage to spawn a modulated voltage at the output terminals. The entire output voltage is obtained by the sum of each individual output voltage. Every inverter is talented to produce three output voltage levels, that is, +vdc, −vdc, and 0. The level of HMLI can be considered by using the given formula 3^s. Where S is a number of stages, therefore 3^3=27 level HMLI [15]. To propose the number of switches according to the Stages that is 3H-bridge inverter modules with different dc voltage sources .Every H-bridge have 4 switches and the quantity of switches used in the HMLI is 12. Here, Figure 5 shows the construction of the hybrid multilevel inverter.

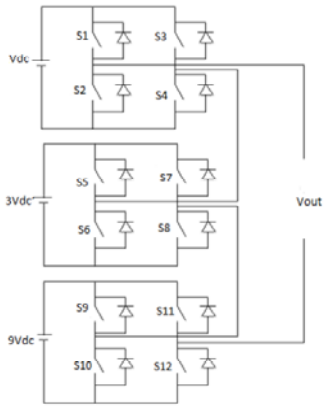

Figure 5. Single Phase Hybrid Multi-Level Inverter

The inverter uses a ordinary three-leg inverter and an H-bridge with its DC source in series with each phase leg. The output voltage v_1 (3v) of this first leg of the top inverter is goes to ON state. For a depressing half cycle this leg is connected in series with a full H-bridge, which, in revolve, is complete by a supply voltage. 27 output levels can be obtained by various switching states of each H-bridge cell. The switching states and the output values hybrid inverter are given in Table 1.

Table 1. Output Voltage And Switching States Of The Hybrid Multi Level Inverter S=3

Vdc	Vout - 13 V	-12V	-11V	-10V	-9V	-8V	-7V	-6V	-5V	-4V	-3V	-2V	-1V	0V	+1V	+2V	+3V	+4V	+5V	+6V	+7V	+8V	+9V	+10V	+11V	+12V	+13V
1V	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P
3V	N	N	N	0	0	0	P	P	P	N	N	N	0	0	0	P	P	P	N	N	N	0	0	0	P	P	P
9V	N	N	N	N	N	N	N	N	N	0	0	0	0	0	0	0	0	0	P	P	P	P	P	P	P	P	P

4. Multi-Carrier Pulse Width Modulation Technique

To Control the output voltage of the inverter, we can go for the PWM technique. It can be used to carrying information on a educate of pulses, the information is encoded in the width of each pulse. This technique helps in maintaining a constant voltage [16]. A modulation approach for MLI is given in Figure 6.

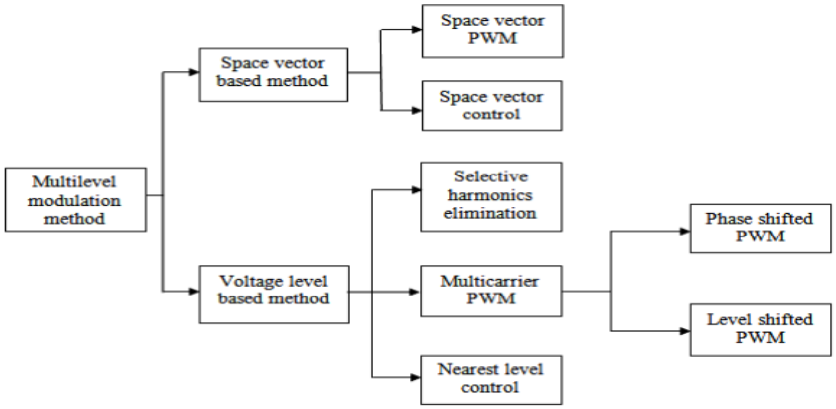

Figure 7. Modulation Approaches for MLI

In the level-shifted PWM methods, the carriers of the modules have a frequency off car = 1/Tsw where the frequency of the carrier signal is inversely proportional to the switching period of the device.The reference voltage, on the other hand, can have values of the range −MVdc and MVdc. To wrap the total voltage range, the carriers are shifted vertically, so that the carrier of the first module covers the range from zero to Vdc, while the second covers the range from Vdc to 2Vdc. The last module covers the voltage from (M−1)Vdc to MVdc. There are three kinds of level shifted modulation techniques, namely Phase Opposition Disposition, Alternative Phase Opposition Disposition ,Phase Disposition.In this we are choosing the phase opposition disposition (POD) because the carriers above the reference point, are out of phase with those below zero, by 180 degree.

5. Analysis of Simulation Results

At the instant proposed 27- level HMLI can be simulated by using Matlab/Simulink tool box. Here compare the THD result of conventional 13 level into proposed 27-level HMLI with MCPWM method using MATLAB/Simulink system. In the conventional MLI, carrier wave PWM method can be used to be pulse generation division.In the Figure 7 shows that the simulation block of the MCPWM and also it will given the pulses for each switches. Here 12 switches are available because of the Hybrid MLI. So we need 12 pulses for each switches. In Figure 8 shows the simulation output of the POD method.

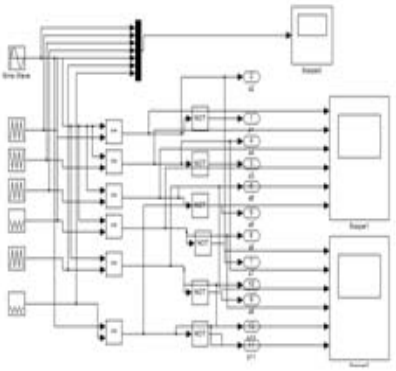

Figure 7. Multi-Carrier Pulse Width Modulation technique

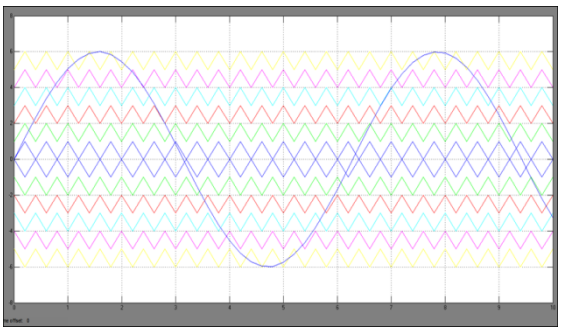

Figure 8. Simulation Output of Pulses from Phase Opposition Disposition Method

Table 2. Comparision of Conventional and Proposed Method

Parameters	Conventional Topology	Proposed Method
Number of Switches	28	12
Switching Losses	More	Less
Energy Conversion Efficiency	Less	More
Switching Stress	More	Less
THD(%)	13.58	3.02

In Figure 9 shown that the THD value of 15 level HMLI by Fast Fourier Transform analysis.In the conventional method THD value is high compared to that of the proposed 27-level Hybrid Multilevel Inverter is shown in Figure 10.

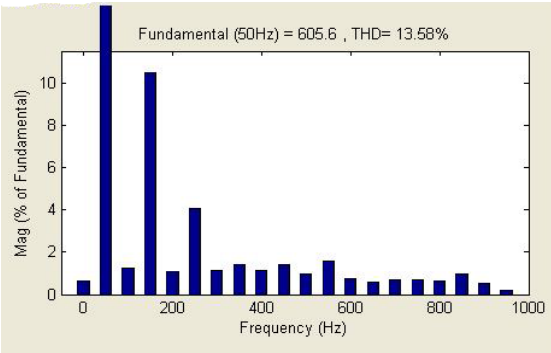

Figure 9. THD Results of 15-level Inverter

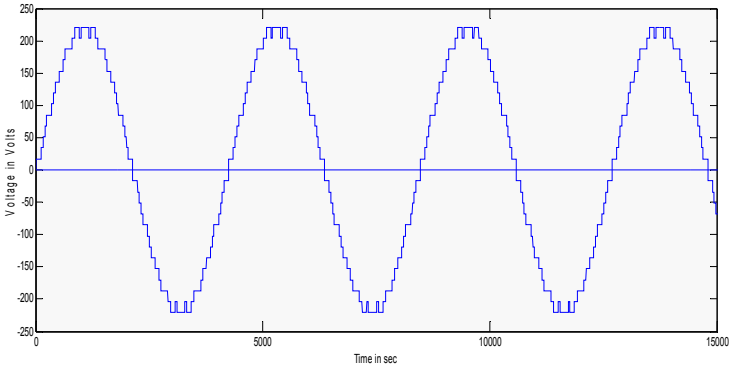

Figure 10. Output Voltage of the 27-level Hybrid MLI

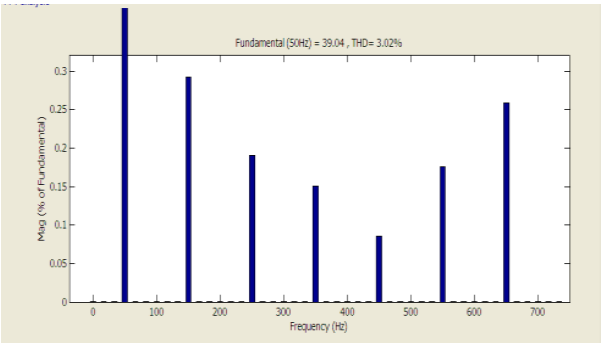

Figure 11. THD Results of 27-level Inverter

In the Figure 9 shows the conventional THD value that is the THD value is 13.58% and the Figure 11 shows proposed THD value that is 3.02%.Here the THD value will be decreases by increasing the level of the MLI.

5.1. Solar Radiation Resource Assesment

The intensity of solar radiation reaching earth surface which is 1369 watts per square meter is known as Solar Constant, by using solar irradiance tracking the maximum power from the panel. Free horizon, Strong network connectivity, Safety & Security, Electromagnetic interference, Easy accessibility to site, these are the availability of the site selection. Based on this Tamilnadu has 7 number of stations that is Karaikudi, Kayathar, Chennai, Ramanathapuram, Vellore, Trichy, Erode. These stations are selected due to their latitude and longitude.Here we are in erode district station ID is 1827. So we can analysis the SRRA datas for proposed system. Based on the following parameters SRRA can be calculated. Global Horizontal Irradiance (GHI), Air Temperature (AT), Wind direction (WD), Direct Normal Irradiance (DNI), Relative Humidity (RH), Atmospheric Pressure (AP), Diffuse Horizontal Irradiance (DHI), Rain Accumulation (RA*), Wind Speed (WS).

Table 3. SRRA Data for June 2014

2014-06	GHI*	GHI	DNI*	DNI	DHI*	DHI	AT	RH	AP	RA*	WS	WD
	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[°C]	[%]	[hPa]	[mm]	[m/s]	[°]
average	5.52	230	3.29	137	2.87	119	31.6	69	999	4.5	3.9	216
min	1.36	0	0.03	0	1.36	0	24.5	32	993	0.0	0.7	37
max	6.73	936	5.95	797	3.68	507	40.4	100	1005	41.8	21.1	349

In the Table 3 shows the SRRA data for the June month and the Table 4 shows the SRRA data for the October month. By using this datas easily obtain, the maximum power.

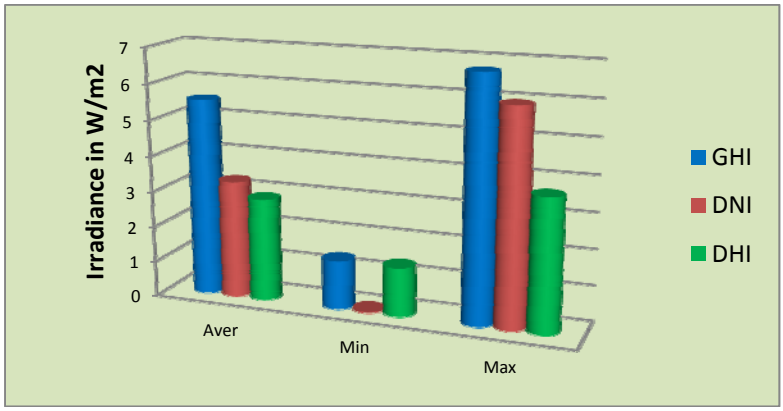

Figure 12. Comparitive Chart for June 2014

In the Figure 12 shows the Comparitive chart for solar irradiance in June. Here the Global Horizontal Irradiance, Direct Horizontal airradiance Direct Normal Irradiance are compared. GHI reaches the maximum value.So this part only we reach maximum power.

Table 4. SRRA Data for October 2014

Oct-14	GHI*	GHI	DNI*	DNI	DHI*	DHI	AirTemp	RH	AtmPr	Rain Acc.*	Wind speed	Wind dir.
	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[°C]	[%]	[hPa]	[mm]	[m/s]	[°]
average	4.15	173	2.43	101	2.46	103	26.5	78	976	9.1	1.4	203
min	1.09	0	0.04	0	1.08	0	21.6	36	970	0.0	0.2	2
max	6.29	910	7.04	855	3.20	551	34.5	100	981	74.8	20.6	331

In the Figure 13 shows the Comparitive chart for solar irradiance in october. Here the Global Horizontal Irradiance, Direct Horizontal airradiance Direct Normal Irradiance are compared.DNI reaches the maximum value.So this part only we reach maximum power.

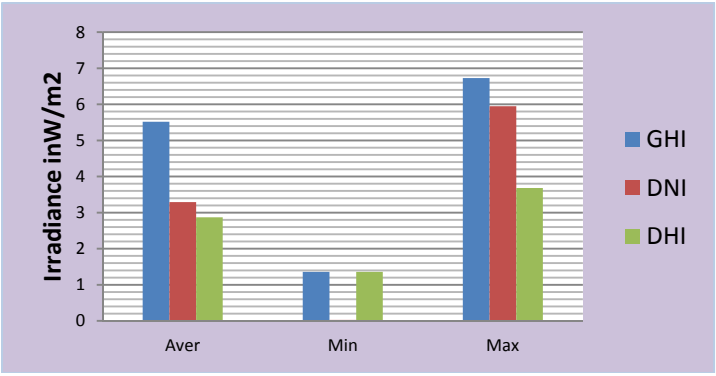

Figure 13. Comparitive Chart for October 2014

6. Conclusion

In this paper, MCPWM technique can be used to control the output voltage of the 27-level HMLI. In the proposed method exhibits that minimum THD value and get enhanced efficiency. Therefore the planned scheme can be used to develop the level of inverter and reduces the harmonics. Subsequently this proposed system can be appropriate for high voltage and high power applications due to their ability to synthesize waveforms with better harmonic spectrum and also it synthesis Little transition loss of switches due to low switching frequency and reduced EMI.

Acknowledgements

The authors want to thank AICTE New Delhi for the support given to this work through the research work and awarded the “Career Award for Young Teachers” *Dr.K.Ramani (*F.No.11.8/AICTE/RIFD/CAYT/POL-I/2013-14).

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