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Application of Five Level Inverter for PV Grid

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***Abstract* - This paper reveals a Five-level inverter topology for photo-voltaic (PV) power generation system. The 7- level inverter created by cascading single phase full and half bridge inverter topology sustained with three separate PV strings. The output has 5-levels: +Vdc, +2/3Vdc, +Vdc/3, 0, Vdc/3, -2Vdc/3, -Vdc. The 5-level inverter function is possible by using seven semi conductor switches. The designed inverter configuration has able to maintain consistent operation as inverter even though there is source and semiconductor switch breakdown. The developed inverter is differentiating with conventional multilevel inverters in terms of number of components, losses and reliability. The result of a 5-level inverter topology is confirmed by using MATLAB/SIMULINK software.**

Keywords— 5*-level inverter, PV generation system, reliability, P&O, PV Grid.*

1. INTRODUCTION

As the energy demand is increasing day by day due to industrialization and population growth, people are investing in alternate energy solutions to meet those energy requirements thereby improving energy efficiency and power quality issues. In this technical era, renewable energy resources are playing revealingly progressing role in electricity generation. Many types of renewable resources such as solar (PV Cell) energy, geothermal, wind energy etc are exploiting for electric power generation. The main challenge in substitute running systems with newer more environmentally friendly alternatives is how to generate the maximum power and deliver the maximum power at a minimum reliable cost for a given load. Photovoltaic power generation is growing very fast. The use of photovoltaic energy is considered to be a primary resource, because there are several countries located in tropical and temperate regions, where the direct solar density may reach up to 1000 W/m^2.The solar energy received by the earth from the sun is so boundless that the total energy consumed annually by the whole world is supplied in as short interval of time as in half an hour.

Presently, Solar panels are not efficient. They have only 15 to 28% efficiency in their ability to convert sun rays to electrical power. The efficiency may be decrease due to other factors like load conditions and temperature of solar panel. Therefore, Maximum Power Point Tracker (MPPT), by providing its maximum power to the PV system and as an energy storage element helps in extracting more stable and reliable power from the PV system for both load as well as utility grid and hence improves the steady and dynamic behaviour of the whole system.

The proposed model, the entire components and control systems are simulated under MATLAB/Simulink Software. Block diagram of developed hybrid generation system has been given in below fig. 1.1.

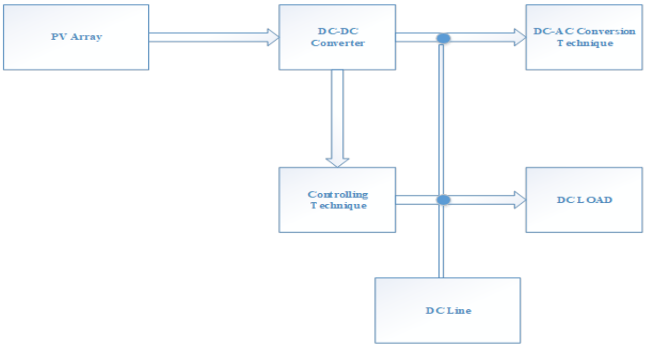


Fig.1.1 Block Diagram

2. METHODOLOGY

The modeling and simulation of the equivalent circuitry is done at once in the second stage. The following three figures namely fig. 1.2, fig. 1.3 & fig. 1.4 elaborates the complete methodology of developed hybrid generation system using flowchart.

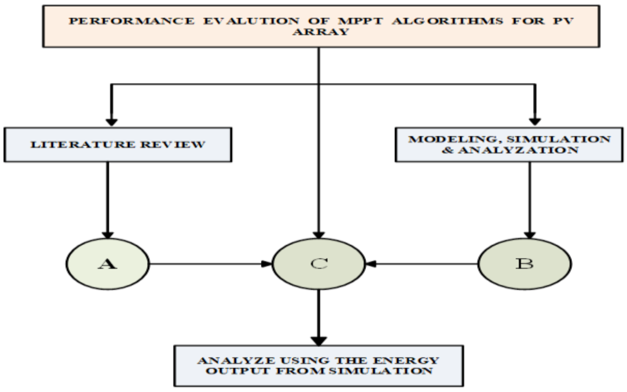


Fig.1.2 Methodology flowchart

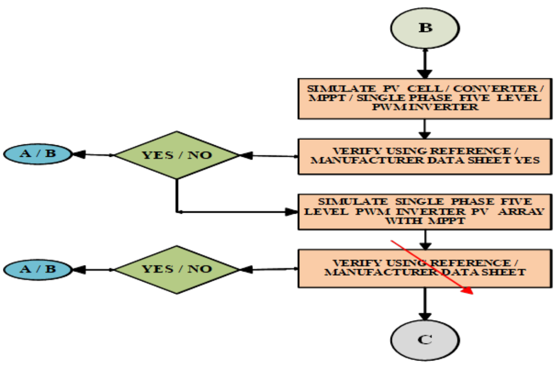


Fig. 1.3 Flowchart for Simulation

3. Fundamentals Of PV System & Their Components

Photovoltaic cells are electronic devices that are capable of generating electricity from a light source by the photovoltaic effect. An electric current generated when photons in light hit the photovoltaic cell and absorbed by the semiconducting material. After absorption, electrons knocked loose from the atom and passage through the material, generating an electric current. Photovoltaic cells, or solar cells, typically arranged in two forms:

Photovoltaic Module

Two or more interconnected cells encapsulated in a weatherproof material. The cells connected in series to increase the voltage output or in parallel to increase its current output. A single cell has a relatively low voltage handling capability on the order of 0.57 Volt at . While a multiformity of connection schemes present for a multitude of applications, a common scheme for P-V modules used in power generation is a connection of 36 or 72 cells in series.

Photovoltaic Array

A photovoltaic array is composed of series and parallel connections of solar modules. Two or more interconnected modules connected in series to increase the voltage output or in parallel to increase its current output. Grid connected systems require an inverter which in order to successfully interface with the grid requires a specific DC input voltage range generally on the order of 200-600 Volts DC. PV arrays are designed to generate a voltage close to the top of this range at rated power generation. This permits the inverter to operate for the maximum possible range of DC voltage input and therefore the maximum range of environmental conditions. Once the voltage requirement is met, power handling capability can be raised by connecting additional module strings in parallel. This is done by first connecting the correct number of modules in series to accomplish the voltage requirement composing a string of modules. Next, additional strings of the same number of modules may be added to increase the current production. It is important that each string is composed of an identical number of modules of the same brand and power rating. If strings are not same, the production of voltage of each string may not be identical.

In this case the voltage output of the array will be lower than that of the highest producing string.

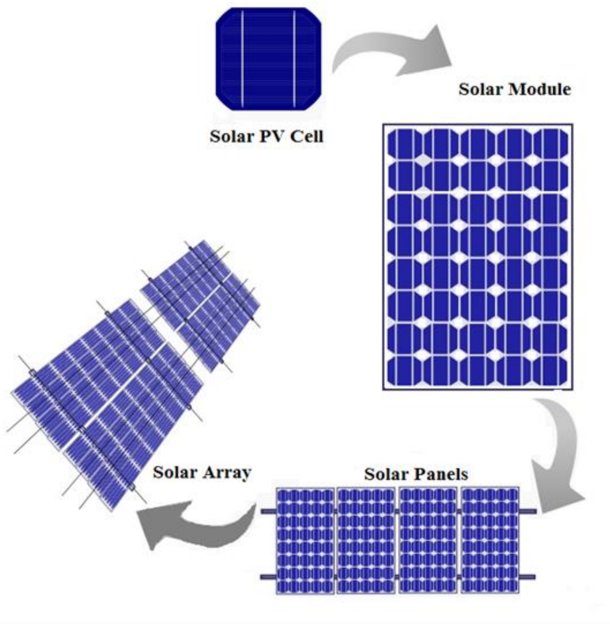


Fig.3.2 PV Cell, Module Array

Circuit Model for PV Cell & Their Characteristics

The Ideal photovoltaic cell equivalent circuit is shown in fig.-3.4. The basic equation from the theory of semiconductors that mathematically represents the I-V characteristic of the ideal photovoltaic cell is

$$I = I_{pv,cell} - I_{o,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]$$

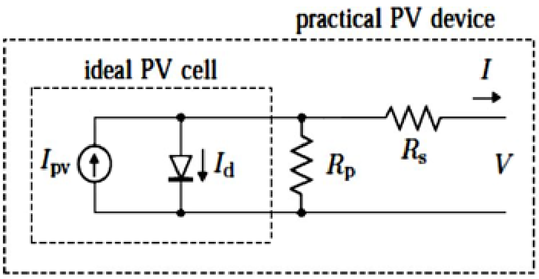


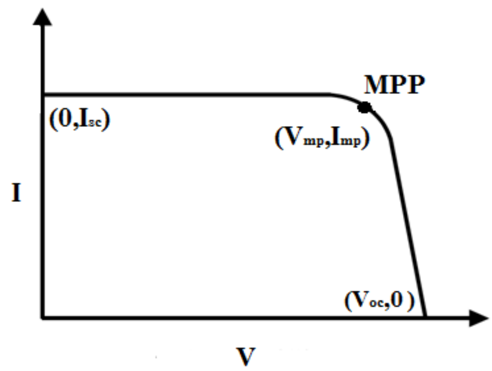
Fig.3.4 Single Diode Model

The basic equation (3.1) of the elementary photovoltaic cell does not represent the I-V characteristic of a practical photovoltaic array. Practical arrays are composed of several connected photovoltaic cells and the observation of the characteristics at the terminals of the photovoltaic array requires the inclusion of additional parameters to the basic equation (3.1).

$$I = I_{pv} - I_o\left[\exp\left(\frac{V + R_s I}{V_t a}\right) - 1\right] - \frac{V + R_s I}{R_P}$$

Where, I_{PV} and I_0 are the photovoltaic and saturation currents of the array and $V_t = N_s kT/q$ is the thermal voltage of the array with N_s cells connected in series. Cells connected in parallel increase the current and cells connected in series increases output voltages. If the array is composed of N_P parallel connections of cells the photovoltaic and saturation currents may be expressed as $I_{PV} = I_{PV}$, cell N_P, $I_0 = I_0$, cell N_P. In equation (3.2) R_S is the equivalent series resistance of the array and R_P is the equivalent parallel resistance. This equation originates the I-V curve seen in Fig. 3.5, where three remarkable points are highlighted: short circuit (0, I_{sc}), maximum power point (V_{mp}, I_{mp}) and open-circuit (V_{oc}, 0).

Equation (3.2) describes the single-diode model presented in Fig. 3.3.



The photovoltaic model explained can be improved if equation (3.4) is replaced by:

$$I_o = \frac{I_{sc,n} + K_I \Delta T}{\exp\left(\frac{V_{os,n} + K_v \Delta T}{aV_t}\right) - 1}$$

This modification objective to match the open-circuit voltages of the model with the tentative data for a very large range of temperatures.

A method for adjusting and based on the fact that there is an only pair (,)that warranties that at the ( ) point of the I-

V curve, i.e. the maximum power calculated by the I-V model of equation (3.2), is equal to the maximum tentative power from the datasheet, at the maximum power point (MPP). Conventional modeling methods found in the literature take care of the I-V curve but forget that the P-V (power vs. voltage) curve must match the tentative data too.

The relation between and , the only unknowns of equation (3.2), may be found by making and solving the resulting equation for , as equation (3.8) and equation (3.9) show

$$P_{max,m}=V_{mp}\left\{I_{pv}-I_o\left[\exp\left(\frac{q}{kT}\frac{V_{mp}+R_sI_{mp}}{aN_s}\right)-1\right]-\frac{V_{mp}+R_sI_{mp}}{R_p}\right\}=P_{max,e}$$

$$R_p=V_{mp}\left(V_{mp}+I_{mp}R_s\right)/\left\{V_{mp}I_{pv}-V_{mp}I_o\exp\left[\frac{\left(V_{mp}+I_{mp}R_s\right)}{aN_s}\frac{q}{kT}\right]+V_{mp}I_o-P_{max,e}\right\}$$

Equation (3.9) explains that for any value of R_S there will be a value of R_P that makes the mathematical I-V curve cross the tentative (V_{mp}, I_{mp}) point.

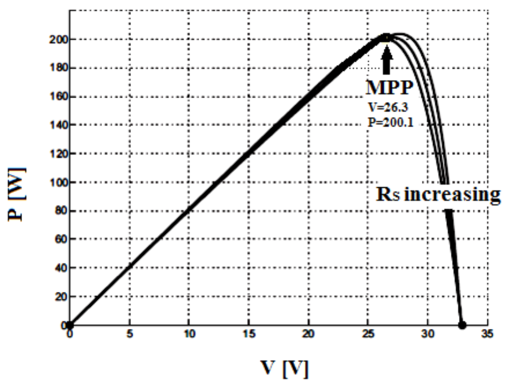


Fig. 3.6 P-V curves plotted for different values of R_S and R_P

POWER CONDITIONING UNIT

The efficiency of the solar PV module is weak and so it is necessary to operate the module at the peak power point so that the maximum power can be delivered to the load under changing temperature and Insolation situations. Hence maximization of power improves the utilization of the solar PV module. MPP is used for extracting the maximum power from the solar PV module and transferring that power to the load / inverter. A DC/DC converter (step up or step down) uses the purpose of transferring maximum power from the solar PV module to the load / inverter. A DC/DC converter works as an interface between the load and the module. By changing the duty cycle the load impedance seen by the source is changed and matched at the point of the peak power with the source so as to transfer the maximum power.

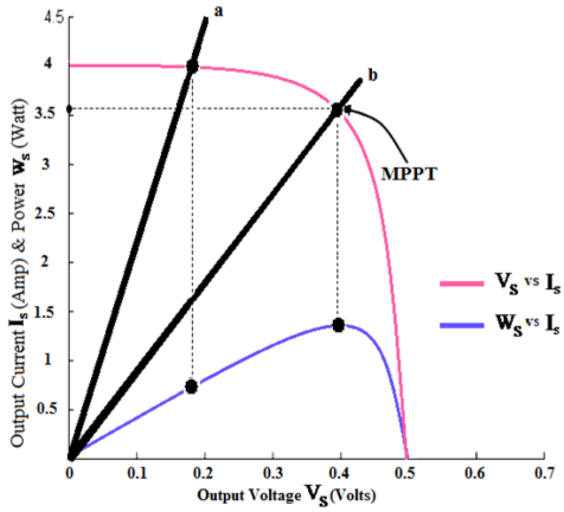


Fig. 4.1 Operating Point of PV Array

In most applications, the MPPT is a DC-DC converter controlled through a scheme that permits inflicting the photovoltaic module operation point on the Maximum Power Point (MPP) or near to it. On the literature, many studies describing techniques to improve MPP algorithms were published, permitting more velocity and precision of tracking. On the other hand, there is no a theory to guide the designer to choose, among the DC-DC converters family, the best one to operate as MPPT, thus, in most cases, the designers are tempted to use the simplest DC-DC converters, namely buck converter or boost converter.

The effectiveness of MPPT is given by

$$\eta_{MPPT}=\frac{\int_0^t P_{measured}(t)dt}{\int_0^t P_{actual}(t)dt}$$

MPPT performs a very important role in PV power generation system that it extracts maximum possible power from PV panel by varying the duty cycle of DC/DC converter and that duty cycle is controlled by different MPPT techniques and its algorithms. Some are listed below.

- Open Circuit Voltage
- Short Circuit Current
- Constant Voltage
- Perturb and Observe
- Incremental Conductance
- Temperature Method
- Intelligence MPPT Techniques
  a) Fuzzy Logic Based
  b) Artificial Neural Network Based

In this paper very renowned Perturb and Observe is chosen by considering the features of MPPT techniques especially simplicity, number of sensors required, reliability and cost effective.

Perturb & Observe

Perturb and Observe (PO) technique, also known as perturbation method, is the most commonly used MPPT algorithm in commercial PV products. This is practically a “trial and error” method. The PV controller increases the reference for the inverter output power by a small amount, and then detects the actual output power. If the output power is virtually increased, it will increase again until the output power starts to decrease, at which the controller decreases the reference to avoid downfall of the PV output due to the non-linear PV characteristic. Although the PO algorithm is easy to implement, it has a number of problems, including

- PV system cannot always work at the maximum power point due to the slow trial and error process, and in this manner solar energy from the PV module not fully utilized.

- PV system might dependably work in an oscillating mode even with a steady-state daylight condition, prompting fluctuating inverter output.

- Operation of the PV system may fail to track the maximum power point due to the sudden changes in daylight

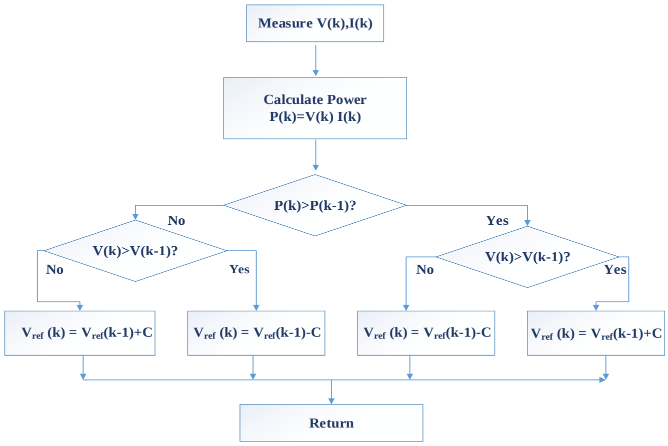


Fig.4.2 Perturb & Observe flowchart

Single Phase Five Level PWM inverter

A multilevel power converter fabrication has been acquainted as an alternative in medium voltage and high power situations. A multilevel converter not only obtains high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, fuel cells, and wind can be easily interfaced to a multilevel converter system for a high power application. Demerits of inverter are low efficiency, higher cost, and high switching losses. Due to these demerits, we are going to multilevel inverter. In this work five level multilevel inverter is define. The term Multilevel started with the three-level converter. In recent years multi level inverters are used high power and high voltage applications. Multilevel inverter output voltage produce a staircase output waveform, this waveform look like a sinusoidal waveform. The multilevel inverter output voltage having less number of harmonics compare to the conventional bipolar inverter output voltage. If the multilevel inverter output increase to N level, the harmonics decreased to the output voltage value to zero.
Single-phase inverters adopt the full-bridge type using approximate sinusoidal modulation technique as the power circuits. The output voltage of them has three values: zero, positive and negative supply dc voltage levels. Therefore, the

harmonic components of their output voltage are obtained by the carrier frequency and switching functions.

configuration of the proposed single-phase five-level PWM inverter. One switching element and four diodes added in the conventional full-bridge inverter are connected to the center-tap of dc power supply. Proper switching control of the auxiliary switch can produce half level of dc supply voltage. The proposed single-phase five-level PWM inverter involves various steps of operation.

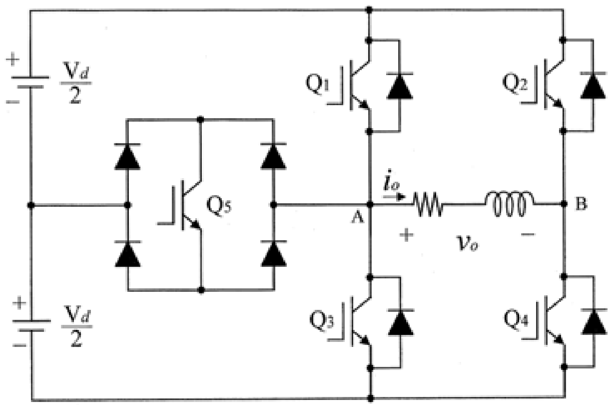


Fig.4.7 Configuration of the proposed single-phase five-level PWM inverter

The operation of proposed inverter can be divided into 10 switching modes, Figure Operational modes according to the switch ON/OFF conditions and the direction of load current.

Mode	Output Voltage (V_o)	Output Current (i_o)
a	$V_o = V_d$	i_o=Positive(+)
b	$V_o = V_d$	i_o=Negative(-)
c	$V_o = -V_d/2$	i_o=Positive(+)
d	$V_o = -V_d/2$	i_o=Negative(-)
e	$V_o = 0$	i_o=Positive(+)
f	$V_o = 0$	i_o=Negative(-)
g	$V_o = -V_d/2$	i_o=Positive(+)
h	$V_o = -V_d/2$	i_o=Negative(-)
i	$V_o = -V_d$	i_o=Positive(+)
j	$V_o = -V_d$	i_o=Negative(-)

Operational modes of the conventional inverter are shown in Fig.4.2 (a), (b), (e), (f), (i), and (j) in sequence, and additional states in the proposed inverter synthesizing half level of dc bus voltage are shown in Fig.4.2 (c), (d), (g), and (h). The additional switch must be properly switched considering the direction of load current. Basic principle of the proposed switching strategy is to produce gate signals by comparing the reference signal with the two carrier waves having same frequency and in phase, but different offset voltages. Largely, there are two switching methods according to the output voltage levels. If the required output voltage for a certain load can be generated using only the half of dc bus voltage, only the lower carrier wave is compared with the reference signal the lower dc bus voltage is used to generate the output voltage. Namely, the modulation index is equal or less than 0.5, the behavior of proposed inverter is similar to the conventional full-bridge three-level PWM inverter, and the distribution of harmonic components in output voltage is similar to that of the conventional inverter having the values of two times the modulation index. The mentioned above is the first operational mode. On the other hand, if the required output voltage is increased beyond the modulation index 0.5, it comes into the second mode using the upper bank of capacitor. In this case, the switching function produced by upper carrier wave is prior to that of the lower. According to the amplitude of the voltage reference, the operational interval of each state varies within a certain period.

4. Output voltage according to the switch on-off condition

Where m is a pulse number, The Fourier series coefficient of the conventional single-phase full-bridge inverter by sinusoidal PWM is given as

$$A_n = -\frac{4V_{dc}}{n\pi}\sum_{m=1}^{p}\left[(-1)^m \sin(n\alpha_m)\right]$$

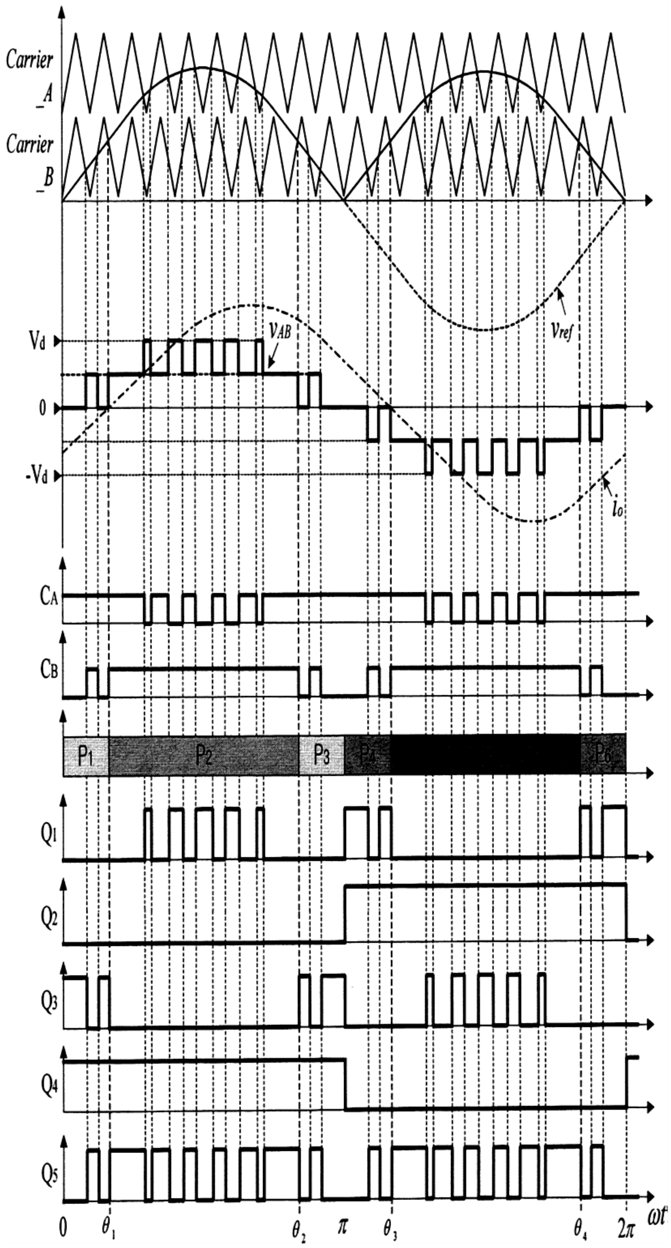


Fig 4.1 Switching patterns of the proposed single-phase five-level PWM inverter

5. CONCLUSION

In this paper a 5-level fault tolerant inverter is presented for photovoltaic grid. The configuration shows that it needed a reduced amount of switching components than conventional multilevel inverters and some recently developed topologies. The topology not having capacitors and clamping diodes unlike flying capacitor multi-level inverter and diode clamped multilevel inverters. There is no capacitor voltage balancing and neutral point voltage balancing issues. The topology has less power loss because of lower number of switching devices. It also has the extra advantage of fault tolerance in terms of switch open circuit fault and source failure.

REFERENCES

[1] www.weforum.org/agenda/2018/05/onesimple- chart-shows-why-an-energy-revolutionis-coming- and-who-is-likely-to-come-out-on-top

[2] M. H. Rashid, Power Electronics Circuits Devices and Applications, Pearson/Prentice-Hall, 2004.

[3] H. Valderrama-Blavi, M. Munoz-Ramirez, J. Maixe, R. Giral and J. Calvente, "Low frequency multilevel inverters for renewable energy systems," Proceedings of the IEEE International Symposium on Industrial Electronics (ISIE), 2005. Dubrovnik, Croatia, 2005, pp. 1019-1024 vol. 3.

[4] Filho, F., Yue Cao, and Tolbert, L.M., "11-Level cascaded H-bridge grid-tied inverter interface with solar panels," Twenty-Fifth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), pp.968-972, 21-25 Feb. 2010.

[5] A. Kahwa, H. Obara and Y. Fujimoto, "Design of 5-level reduced switches count H-bridge multilevel inverter," 2018 IEEE 15th International Workshop on Advanced Motion Control (AMC), Tokyo, 2018, pp. 41-46.

[6] B. P. Reddy, B. S. Umesh, A. M. Rao, B. V. R. Kumar and K. S. Kumar, "A five speed 45-phase induction motor drive with pole phase modulation for electric vehicles," 2017 IEEE International Conference on Industrial Technology (ICIT), Toronto, ON, 2017, pp. 258263.

[7] M. R. Airineni and S. Keerthipati, "DC offset minimisation of three-phase multilevel inverter configuration under fault and DC link voltage unbalance conditions," in IET Power Electronics, vol. 11, no. 2, pp. 293-301, 20 2 2018.

[8] A.,M.R. and Sivakumar, K., "A Fault Tolerant Single Phase Five-level Inverter for Grid Independent PV systems," IEEE Trans. Ind. Electron., vol.PP, no.99, pp.1,1 doi: 0.1109/TIE.2015.2455523.

[9] Ehsan Najafi and Abdul Halim Mohamed Yatim, "Design and Implementation of a New Multilevel Inverter Topology," IEEE Trans. Ind Electron., vol. 59, no. 1 1, pp. 4148 -4154, Nov. 2012.

[10] Tahri, Ali & Draou, Azeddine. "A Comparative Modelling Study of PWM Control Techniques for Multilevel Cascaded Inverter", Leonardo Journal of Sciences, 4, 2005.

[11] P. Lezana, J. Pou, T. A. Meynard, J. Rodriguez, S. Ceballos and F. Richardeau, "Survey on Fault Operation on Multilevel Inverters," in IEEE Transactions on Industrial Electronics, vol. 57, no. 7, pp. 2207-2218, July 2010.

[12] M. Derakhshanfar, "Analysis of different topologies of multilevel inverters", Master. Chalmers University of Technology, 2010.

[13] B.P McGrath and D.G Holmes, "Multi carrier

PWM strategies for multilevel inverters", IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 858867, Aug. 2002.