Modeling and Simulation of Multilevel Svpwm Invertor using Photo Cell as DC Source

Mr. Gaurav D. Ghode[1]
PG Student, M.Tech IV SEM [Power Electronics & Power System]
S. D. College of Engineering, Selukate, Wardha

Prof. Mahadeo Gaidhane[2]
Professor [Electrical Engineering Department]
Priyadarshani College of Engineering, Nagpur

Prof. K. N. Sawalakhe[3]
HOD [Electronics & Communication]
S. D. College of Engineering, Selukate, Wardha

Abstract- **The paper firstly introduces the structure and operational principle of the present grid-connected PV generation system. And then describes the two inverter control methods including the voltage source inverter control method and the power type PWM inverter control method which are common used at present. Based on the above two kinds of inverter control methods, the second step is to present an improved PWM inverter control system that can be applied in grid-connected PV generation. Finally, it constructs a single-phase grid-connected PV generation system, and uses MATLAB/Simulink software to simulate and analyze. The result of the simulation shows that the improved inverter control system can effectively control the grid current waveform which tends to sine wave, meanwhile it can achieve the maximum power point tracking, besides it is able to put the arbitrary power out to the load or to the grid, while the control system has a good stability. This study systematically analyzes multilevel space vector pulse width modulation for a multiphase voltage source inverter (VSI). The instantaneous output voltages of the VSI, which are called space vectors, can be classified according to the switching states of the VSI. This paper proposes a new software implementation for Two Level Inverter using Space Vector Modulation technique. The switching pattern generation and sector identification for space vector modulation technique is generated using list of MATLAB codes. The simulation study of space vector modulation technique of two level Inverter reveals that space vector modulation technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with SPWM technique. Simulation results are presented to demonstrate the validity of space vector modulation technique. Multilevel inverters have received considerable attention for their capability to realize high power ratings and high-quality waveforms, at low switch stress and losses. The method is based on an explicit minimization of the harmonic injected to over modulate a voltage, which is achieved by using all the degrees of freedom provided by the SVM in a VSI. The performance and feasibility of the method are evaluated through simulations and experiments.**

Keywords- **Grid-connected PV Generation, pulse width modulation (PWM), space vector, voltage source inverters (VSI).**

I. INTRODUCTION

In 21 century powers harvesting using non-conventional sources are very important for human being. Renewable energy source become one of the most widely studied electric power applications since fossil fuels are decreasing and oil prices and global warming are increasing. Photovoltaic cells are the most popular renewable sources. A photovoltaic system has advantages such as being static and quite since it has no moving parts. The output characteristic of photovoltaic cells depends on parameters as temperature, the solar insolation and output voltage. Conventional power generation, grid-connected PV power station and its security, stability, reliable operation became new challenges which power grid and PV power plant need to face.

Inverters are power electronics devices which converter DC power to AC power. When load has high impedance against to harmonic current, VSI must be used there, while the load with small impedances against to harmonic current requires CSIs to be used. In recent years, various pulse width modulation (PWM) techniques have been developed beside inverters. The total harmonic distortion of output voltage can be controlled by SVPWM techniques. Also load current waveforms can be controlled too. In this technique, switching pulses are generated by comparing a sinusoidal waveform with a reference triangle waveform. However it is difficult to regularly sampling of sinusoidal waveform for digital application. For this reason, interest in other PWM techniques has been increased. Selective Harmonic Elimination PWM (SHEPWM), minimum current ripple PWM, third harmonic injection PWM (THIPWM) are some alternatives of the PWM techniques. However space vector PWM (SVPWM) technique is recently showing popularity for inverter applications. The developments in power electronics and semiconductor technology have triggered the improvements in power electronic systems. So, different circuit configurations namely multilevel inverters have become popular and considerable interest by researcher are given on them. The output voltage waveforms in multilevel inverters can be generated at low switching frequencies with low distortion and high frequency. The paper describes two inverter control methods including the voltage source inverter control method and the power type PWM inverter control method which are common used at present. Voltage source inverter control method regulates phase angle of the grid mainly through receiving voltage signals from DC side of inverter which is called the outer loop to control the grid voltage, while it regulates the voltage reference from the AC side load voltage to control the inverter output current which is called the inner loop. However, the process of the inner loop will not affect the results of the outer loop. Power-type PWM inverter bridge circuit formed by the two groups, which uses two reverse diodes synchronized transformation. Required power can be got by changing the modulation rate of PWM inverter.

Space Vector modulation (SVM) technique was originally developed as a vector approach to pulse-width modulation (PWM) for three-phase inverters[1].It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. It confines space vectors to be applied according to the region where the output voltage vector is located. A different approach to PWM modulation is based on the space vector representation of voltage in the α-β plane. The α-β components are found by transformations [2]-[4]. The determination of switching instant may be achieved using space vector modulation technique based on the representation of switching vectors in α-β plane. The Space vector modulation technique is an advanced, computation intensive PWM technique and is possibly the best among all the PWM techniques for drives applications. Because of its superior performance characteristics, it is been finding wide spread application in recent years. The purpose of this paper is to present the space vector modulation technique and then to simplify the explanation of how it can be implemented using software packages.

II. MOTIVATION

According to the demand of electric power in commercial and industrial development, we need photovoltaic energy and related technology. At present, large scale photovoltaic power generation and scale of renewable energy has become parts of development strategy, meanwhile it is the way to guide the development of photovoltaic industry. However, because of its own characteristics different from conventional power generation, grid-connected PV power station and its security, stability, reliable operation became new challenges which power grid and PV power plant need to face. So we need to develop and improve the power conversion technic using recent technology like SVPWM, multilevel invertor.

III. LITERATURE REVIEW

A. Yanqing Li, [1], Cheng Chen, Student, Qing Xie, Member, IEEE " Research of An Improved Grid-connected PV Generation Inverter Control System".

The paper firstly introduces the structure and operational principle of the present grid-connected PV generation system. And then describes the two inverter control methods including the voltage source inverter control method and the power type PWM inverter control method which are common used at present

B. Jwu-Sheng Hu, Member, IEEE, Keng-Yuan Chen, Student Member, IEEE, Te-Yang Shen, and Chi-Him Tang [2] "Analytical Solutions of Multilevel Space-Vector PWM for Multiphase Voltage Source Inverters"

This study systematically analyzes multilevel space vector pulse width modulation for a multiphase voltage source inverter (VSI). The instantaneous output voltages of the VSI, which are called space vectors, can be classified according to the switching states of the VSI. By applying the Eigen space decomposition of the system matrix, the n-phase VSI control problem can be solved analytically.

C. Hirak Patangia, [3] 2010 IEEE "An Efficient Cascaded Multilevel Inverter Suited for PV Application"

Two level inverters are common in PV applications. Due to large voltage swings in such a modulation, the switching losses are high reducing its conversion efficiency. Multilevel inverters employ smaller voltage steps and are preferred over 2-level modulation to obtain a higher dc to ac efficiency. The paper presents a novel multilevel inverter where the modulation strategy has provided "best possible performance" with an acceptable advantage in its implementation. Based on this strategy, a 1KW inverter was built and tested to evaluate its efficiency. The efficiency has been found to be in 99 percent range. For comparison, a commercial unit was tested for its efficiency and found to have a lower performance than the proposed multilevel inverter.

D. Prajna Paramita Dash, Student Member, IEEE, Mehrdad Kazerani, Senior Member, IEEE 2012 [4] "Harmonic Elimination in a Multilevel Current-Source Inverter-based grid-connected Photovoltaic System"

Multilevel inverters have received considerable attention for their capability to realize high power ratings and high-quality waveforms, at low switch stress and losses. Multilevel inverter based on Voltage-Source Inverter (VSI) topology is more thoroughly researched when compared to Current-Source Inverter (CSI)-based multilevel inverter. In this paper, a multilevel structure based on CSI topology is presented. Each inverter unit in the multilevel structure is equipped with its own Maximum Power Point Tracker (MPPT) and DC-side current controller. On the AC-side, a combined dq-frame current controller is adopted. Operation of the multilevel structure is investigated under equal and unequal irradiation level conditions.

E. Yan Zhou, Student Member, IEEE, and Hui Li, Senior Member, October 2014 IEEE [5] "Analysis and Suppression of Leakage Current in Cascaded-Multilevel-Inverter-Based PV Systems"

The transformer less cascaded multilevel inverter (CMI) is considered to be a promising topology alternative for low cost and high-efficiency photovoltaic (PV) systems. However, the leakage current issue resulted from the parasitic capacitors between the PV panels and the earth remains a challenging in designing a reliable CMI-based PV system. In this paper, the leakage current paths in PV CMI are analyzed and the unique features are discussed.

IV.OBSERVATION & IDENTIFICATION FROM LITERATURE REVIEW

Many of the literature reviewed above has evaluated performance of grid connected invertor with PV cell as input using different method and discus on improvement of different important parameters regarding stability, THD, efficiency of power electronic devices.

V. PROBLEM DEFINITION

Efficiency of a multilevel inverter that appears to be well suited for PV application. Improvement in efficiency is essential to impact the cost of conversion of solar energy to electricity. In present technique there are some problems regarding stability (o/p voltage), THD and efficiency (temperature control). Due to direct interfacing of PV cell to invertor leakage current arise capacitance between the PV panels and the earth, circulating leakage currents can flow through the panels and grid ground, leading to increased output harmonic content, higher losses, safety, and electromagnetic interference (EMI) problems.

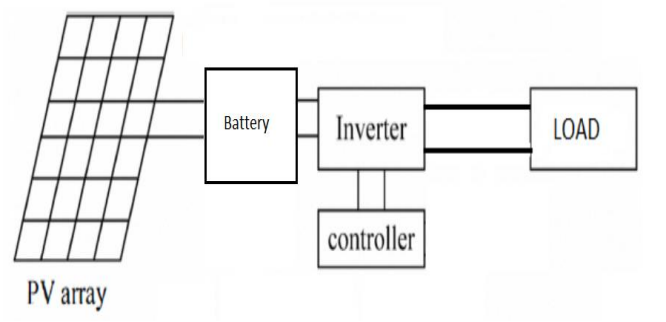


Fig. 1: Basic block diagram of solar power system with PV cell as I/P.

Inverters are power electronics devices which converter DC power to AC power. AC voltage can be produced at desired output frequency and voltage level by using inverters as shown in Fig. [1]
The o/p of invertor is not sufficient due to
a. Total Harmonics Distortion.
b. Temperature variance in photo voltaic cell.
c. Current variance by load.

VI. PROPOSED METHODOLOGY

Design of SVPWM based multilevel invertor for improvement in stability (o/p voltage), THD and efficiency (temperature control) of grid connected system with based of PV cell as input.
1. Design power circuit and control circuit which basically inverter consists.
2. Design and verification of basic power circuit blocks such as SVPWM, multilevel invertor.
3. Integration of all basic building blocks.
4. Simulation studies
5. Performance Evaluation

By using SVM topology for switching of multilevel invertor as shown in Fig. [2] we can overcome following problems a. Total Harmonics Distortion.
b. Temperature variance in photo voltaic cell.
c. Current variance by load.

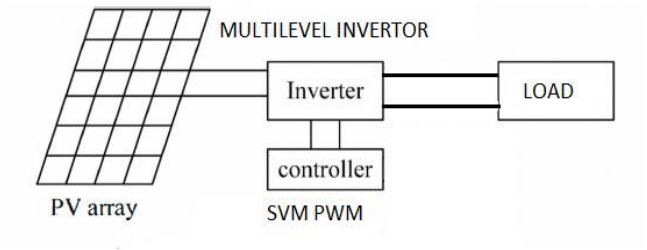


Fig. 2: Schematic and control diagram of a MULTI-STAGE SVM PWM INVERTOR using PV cell as dc source.

VII. MULTI-LEVEL INVERTERS (MLI)

The concept of Multi-Level Inverters (MLI) do not depend on just two levels of voltage to create an AC signal. Instead several voltage levels are added to each other to create a smoother stepped waveform as shown in Fig. [3]

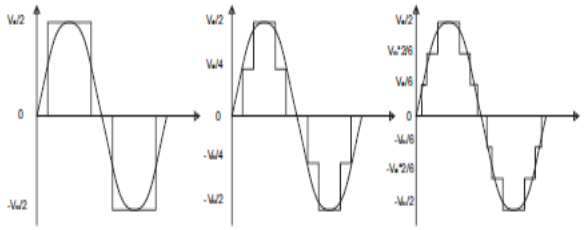


Fig. 3 Waveform of MLI

The unique structure of voltage source inverters allows them to reach high voltages with low harmonics without the use of series-connected synchronized switching devices or transformers. The elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected. A multilevel converter can be implemented in many different ways. The simplest techniques involve the parallel or series connection of conventional converters to form the multilevel waveforms. More complex structures effectively insert converters within converters. The voltage or current rating of the multilevel converter becomes a multiple of the individual switches, and so the power rating of the converter can exceed the limit imposed by the individual switching devices.

VIII. SPACE VECTOR PWM

The principle of SVPWM method is that the command voltage vector is approximately calculated by using three adjacent vectors. The main aim of any modulation technique

is to obtain variable output having a maximum fundamental component with minimum harmonics. During the past years many PWM techniques have been developed for letting the inverters to possess various desired output characteristics to achieve the following aim:

- wide linear modulation range
- Less switching loss.
- Lower total harmonic distortion.

The space vector modulation (SVM) technique is more popular than conventional technique because of the following excellent features:

- It achieves the wide linear modulation range associated with PWM third-harmonic injection automatically.
- It has lower base band harmonics than regular PWM or other sine based modulation methods, or otherwise optimizes harmonics.
- 15% more output voltage then conventional modulation, i.e. better DC-link utilization.
- More efficient use of DC supply voltage.
- SVM increases the output capability of SPWM without distorting line-line output voltage waveform.
- Advanced and computation intensive PWM technique.
- Higher efficiency.
- Prevent un-necessary switching hence less commutation losses.
- A different approach to PWM modulation based on space vector representation of the voltages in the plane.

The concept of space vector is derived from the rotating field of AC machine which is used for modulating the inverter output voltage. In this modulation technique the three phase quantities can be transformed to their equivalent 2-phase quantity either in synchronously rotating frame (or) stationary frame. From this 2-phase component the reference vector magnitude can be found and used for modulating the inverter output. The process of obtaining the rotating space vector is explained in the following section, considering the stationary reference frame shown in Fig. [4]

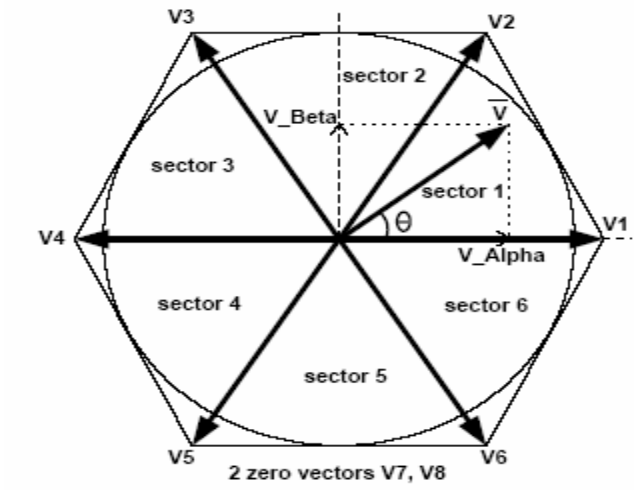
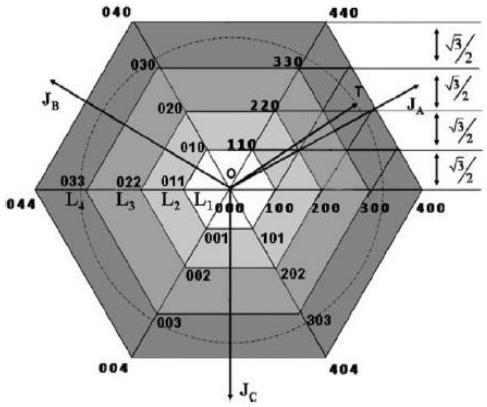


Fig. 4 .Representation of Rotating Vector in Complex Plane

A) Principle of space vector PWM

- Treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency.
- This PWM technique approximates the reference voltage Vref by a combination of the eight switching patterns (V0 to V7).
- Coordinate Transformation (abc reference frame to the stationary d-q frame): A three-phase voltage vector is transformed into a vector in the stationary d-q coordinate frame which represents the spatial vector sum of the three-phase voltage.



IX. CONCLUSION

The structure of improved PWM inverter control system is very simple which is based on the voltage type control method and the PWM power type control method. From the result of simulation, conclusions are come to as follows.

First, the improved PWM inverter control method can make the voltage and the current waveform of the grid tend to sine wave effectively and quickly, and the power factor will reach to one.

Second, the power can be sent to the grid or load arbitrary through controlling the PWM regulator, while the control system has a good stability.

Third, as the increasing number of inductive load penetrate to the grid, the load waveform distortion is produced, but it will not affect the reliability of power supply.

Compared with sinusoidal PWM, space vector PWM can work with a higher modulation index (m>1) and the harmonic content of the inverter voltage is less in the space vector PWM than in sinusoidal PWM. The SVPWM technique can be further applied to three level, four leg and multilevel inverters. This software implementation used in this paper can be extended further to over modulation region i.e. modulation index m>1which will be a future enhancement.

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