Single Phase 21-Level Inverter with Reduced Number of Switches for PV System

MERIN ROSE MATHEW
PG Scholar, Department of Electrical and Electronics
SNS College of Technology, Coimbatore

Abstract:
This paper proposes a single phase twenty one level diode clamped inverter with reduced number of switches to achieve desired level of output voltage for solar system. Considerable switching losses and the gating requirements have been reduced by selecting less number of switches to achieve the desired level of output. The control logic for the inverter is suitably designed with the help of fuzzy logic controller with proper set of fuzzy rules and decision table. The sinusoidal output is obtained by properly filtering the output of inverter and connected to grid. The simulation of the entire circuit has been carried out in MATLAB Simulink to validate the results and also the harmonic profile also studied.

Index Terms–Photo Voltaic (PV), Sinusoidal Pulse Width Modulation (SPWM), Multilevel Inverter (MLI), Total Harmonic Distortion (THD)

I. INTRODUCTION
The demand of clean energy is pushing toward a large diffusion of electric generators supplied by wind, solar, hydro, and other renewable energy sources. This trend will continue during the next years because the energy produced by renewable sources is expected to satisfy 20% and 50% of the total needs in 2020 and 2050, respectively. A significant consequence of this situation is a change of the electric power system from the present one, consisting of a relatively low number of very high power ac generators, to a distributed one, characterized by an extremely large number of small–medium power dc and ac generators supplied by renewable. This new scenario introduces many technical, economic, and political challenges because it is changing the way in which the electrical energy resources (generators and transmission/ distribution networks) are designed and managed. From the technical viewpoint, the use of electronic power converters Introduces new and challenging issues, including increased topological complexity, additional power losses, and electromagnetic interferences (EMIs), thus reducing the overall quality of service, efficiency, and network stability. For such a reason, many researchers are addressing their efforts in proposing new inverter topologies or in modifying the existing ones, aiming at improving the quality of the energy available at the inverter terminals. Among them, pulse width modulated (PWM) multilevel inverters (MLIs) are gaining both popularity and applications, becoming an effective alternative to current inverter topologies [1]. In their early stage, they were employed mainly in high-voltage high-power industrial and traction applications because they distribute the applied voltage among a number of cascaded power devices, thus overcoming their voltage limits and allowing the elimination of output transformers in medium–high voltage systems. Since their output voltage is a modulated staircase, they outperform two-level PWM inverters in terms of total harmonic distortion (THD), without the use of bulky expensive and dissipative passive filters. Therefore, recently, they have been proposed in the field of renewable energies, including photovoltaic (PV) generators grid specifications. Diode-clamped converters with higher (four or more) levels has not been analysed for the production of wind power.

In this paper, a diode clamped multilevel inverter is cascaded with the H-bridge forming a hybrid topology [4]. The DC input to the inverter is fed from four independent PV systems. This constant obtained from each is given as the input of inverter [2]. The output voltage of the inverter is controlled by generating pulse from the control circuit. A Fuzzy Logic controller is used for the purpose. Fuzzy logic control enables better control by controlling the harmonics [10]. The Harmonic profile also been monitored and presented. A suitable logic developed in the fuzzy eliminates the harmonics and reduced the THD. The rest of the paper is organized as follows section II describes the wind generator powered multilevel inverter. Section III describes Pulse Width Modulation. Section IV describes Fuzzy Logic Controller, Simulation results are discussed in section V, Section VI FFT Analysis and finally, concluding remarks are given in section VII.

II. PV MODULE POWERED MULTILEVEL INVERTER
In order to meet the demand, a wind power with high quality is obtained using the converter; multilevel converters are good alternative to the conventional converters for these systems. A multilevel converter enables the ac voltage to be increased without an output transformer, reducing the output voltage and currents harmonic content and make the output waveform closer to sine wave.[6] In addition, the cancellation of low frequency harmonics from the ac voltages at the different levels means that the size of the ac inductance can be reduced, thus a consequent decrement in the expenses of the overall system.

The block diagram for the constant output multilevel inverter is shown in figure 1. In this diagram it consists of wind farm, an inverter, fuzzy logic controller and sinusoidal pulse width modulation block. Four DC source voltages are given as input to the hybrid inverter which combines the diode clamped multilevel inverter and H-bridge inverter. By using twelve switches in hybrid multilevel inverter with each switch having different voltage to generate the eleven step voltage of symmetrical output. The eleven step output is applied to fuzzy controller to maintain the constant output, by giving reference voltage to the fuzzy logic controller. If there any deviation in output, the controller is used to compensate the output voltage and SPWM signal for the switch is varied. The constant dc supply for the inverter is from the wind farm and the pulses for each switch are obtained from Sinusoidal Pulse Width Modulation Technique. The Diode Clamped Inverter switching states is given in the Table 1. The number of output phase voltage level is defined by \( m = 2s + 1 \), where \( s \) is the number of DC source.

![Fig.1. Block Diagram of Overall System](image)

| TABLE.1: SWITCHING STATES OF DIODE CLAMPED INVERTER |
|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| LEVEL | S4 | S3 | S2 | S1 | S4’ | S3’ | S2’ | S1’ |
| I | ON | OFF | OFF | OFF | ON | ON | ON | ON |
| II | ON | ON | OFF | OFF | OFF | OFF | OFF | ON |
| III | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| IV | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| -I | ON | ON | ON | OFF | OFF | OFF | OFF | ON |
| -II | ON | ON | OFF | OFF | OFF | OFF | OFF | ON |
| -III | OFF | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| -IV | OFF | OFF | OFF | OFF | OFF | ON | ON | ON |
The term H Bridge is derived from the typical graphical representation circuit. An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 are closed (and S2 and S3 are open) a positive voltage will be obtained across the load. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse voltage across the load. Using the nomenclature above, the switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4 [9]. This condition is known as shoot-through.

III. PULSE WIDTH MODULATION

In sinusoidal PWM instead of maintaining the width of all pulses the same as in the case of multiple PWM, the width of each is varied in proportion to the amplitude of a sine wave evaluated at the same pulse. The distortion is reduced significantly compared to multiple PWM. In order to generate pulses for twelve switches a sinusoidal wave is compared with twelve carrier wave having different amplitude as shown in the figure. A Fuzzy Controller Output is given as an input to the PWM in order to maintain constant output voltage from multilevel inverter.

Inverter output voltage, \( V_{ao} = V_{dc}/2 \), when \( V_{control} > V_{tri} \), and \( V_{ao} = -V_{dc}/2 \), when \( V_{control} < V_{tri} \). PWM frequency is the same as the frequency of \( V_{tri} \). Amplitude is controlled by the peak value of \( V_{control} \) and Fundamental frequency is controlled by the frequency of \( V_{control} \). Modulation Index (m) is given by:

\[
m = \frac{V_{control}}{V_{tri}} \left( \frac{\text{peak of } (V_{A0})}{V_{dc}/2} \right)
\]

IV. FUZZY LOGIC CONTROLLER

Fuzzy Logic Control uses non-mathematical decision based algorithms that use operator’s experiences. This Type of control strategy is well suited for non-linear systems. Fuzzy Logic Control is developed in this work to obtain desired output voltage of the chosen inverter. In order to obtain the fuzzy control surface for non-linear, time varying and complex dynamic system, there are a number of steps to be followed as discussed below. The block diagram of Fuzzy Logic Control scheme developed for the chosen single phase PWM Inverter is shown in the figure 3. The FLC is divided into five modules. Fuzzifier, Database, Rule base, Decision maker and Fuzzifier.

Fig. 3 Fuzzy Logic Control Scheme for Single Phase Multilevel Inverter

The inputs to the FLC are the error \( e = V_{ref} - V_0 \) and the change in error \( ce = e_n - e_{n-1} \), where \( V_0 \) is the actual output voltage of the MLI. \( V_{ref} \) is the desired output voltage and subscript \( n \) denotes sampling instances. \( \delta m_n \) is the change of modulation index inferred by the FLC at the \( n \)th sampling instant using \( \delta m_n \).

The updated modulated signal \( m_n \) obtained and fed to the SPWM generator which provided appropriate PWM signals \( m_n \). The change in modulation index inferred by the FLC at the \( n \)th sampling instant. Using this the updated modulated signal \( m_n \) is obtained and fed to the SPWM generator which provides appropriate PWM signals \( m_n \). Each universe of discourse is divided into four fuzzy subsets namely very low, very low, medium and high.
V. SIMULATION RESULTS

The overall simulated system for the proposed system is implemented below and each section is shown separately for better understanding.

The system under consideration employs PMSG-based variable speed WECS. The wind turbine converts the power of the wind to mechanical power in the rotor shaft. This is then converted to electricity using a permanent magnet synchronous generator (PMSG). The output voltage is rectified using a three-phase diode bridge rectifier. The result is fed into a PI controller whose output is compared to a triangular waveform to determine when to turn the dc-dc boost converter switch ON or OFF.

The simulation have shown that the developed waveform have less harmonics compared to the conventional system and extracting maximum power from the air stream at any wind speed without the knowledge of wind speed or rotor speed.

A) PV with Boost Converter Output Voltage

According to these criteria, a rule base is derived as in table 2.
PV connected to boost converter is simulated and corresponding output voltage is showed in the figure7. In order to make the input to inverter constant a PI controller is connected with boost converter. The outputs of the system is equal to 23V, 40V, 90V and 180V.

**B) Output of Hybrid Multilevel Inverter**

The H Bridge inverter is connected with the diode clamped multilevel inverter with switches to form a Hybrid topology. The level creator part produce output voltage which is always positive and the H-bridge part is to change the polarity of the output. Basically the inverter operation is to convert the variable DC into an AC. The input dc source is given by using batteries or photo voltaic cells to the cascaded circuit. Here fuzzy logic controller is used to control the output voltage of the inverter. By using sinusoidal pulse width modulation technique the triggering pulse given to the switches are controlled.

**VI. FFT ANALYSIS OF OUTPUT**

By using the sinusoidal pulse width modulation control we can control the output by changing the magnitude and the modulation index value of the reference and carrier waveform. Mostly the carrier wave is triangular wave and the sampling wave is either we take DC signal as reference or we take sine wave. The gate triggering is very important in the IGBT device compared to many semiconductor power devices IGBT device has the fast switching characteristics and high speed applications. So this device is mostly used in the inverter circuits nowadays. The Total Harmonic Distortion of the multilevel inverter output is equals to 15.46%, which will be more than 20% for conventional inverters by using same number of switches.

A) **Output Voltage with Filter**

In this symmetric multilevel inverter it consists of two parts as level creator part and a H-bridge part. The input voltage to the dc source is 23V, 40V, 90V and 180V. The level creator part produces a output voltage which is always positive and the H-bridge part is to change the polarity of the output. The voltage at the output of the level creator part is about 170V. The output voltage at the output is 240V. The THD get reduced to 5.56% after filtering. The filter inductance \( L = 560 \mu H \) with \( R_f = 0.34 \Omega \) and \( C = 0.5 \mu F \) with \( R_c = 8.64 \) Respectively.

**VII. CONCLUSION**

The performance of Photo Voltaic system has been demonstrated under varying conditions. The inverter is able to inject the generated power into the load with harmonic compensation. A new hybrid topology with fuzzy controller technique for the asymmetrical configuration is proposed. The cascade multilevel inverters with unequal DC sources are illustrated and the gate triggering pulse is given by fuzzy logic controller in the feedback. Here the inverter power device circuit used is IGBT device and it has the better switching frequency and gate control compared to all other semiconductor switching devices such. This fuzzy logic control technique enables us to obtain better selective harmonic reduction in the output AC voltage. Finally the better sinusoidal wave form is obtained with minimum number of switches to get the desired level output voltage.

**REFERENCES**


