Indian Journal of Natural Sciences *www.tnsroindia.org.in ©IJONS*

Vol.12 / Issue 69 / December / 2021 *International Bimonthly (Print)* *ISSN: 0976 – 0997*

RESEARCH ARTICLE

Cascade Multilevel Inverter with Reduced Harmonic Distortion for Renewable Energy Application

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Received: 24 Aug 2021 Revised: 17 Sep 2021 Accepted: 12 Oct 2021

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ABSTRACT

In recent years the user demand gets increase with respect to its trend on environment. The Fossil fuel based power generation system can’t handle the user demands in single hand manner. The Main objective of this paper is to develop an effective power quality of grid. This Grid is connected with photovoltaic power system via cascade H-bridge multilevel inverter. The Process of this system is carried out with MATLAB software. The Performance of system is recorded at different operating conditions. Then the recorded THD values of system are made to comparison in order to establish proposed system efficiency.

Keywords: power quality, grid, photovoltaic power, H-bridge, multilevel inverter, THD

INTRODUCTION

In Advanced photovoltaic cells or inverters, power plants can be connected to grid in direct manner [1]. So system can be enclosed with maximum power and voltage levels [2] [3].A Modular multilevel inverter provides an effective overall performance on various performance parameters. The Demand of system are in peak with rising population of users. The Smart grid makes the designer to control at central location [4]. The Smart grids are improved to advanced form known as micro grid [5]. The Micro grid can produce energy by itself for each user. The Micro grid utilizes the energies produced by the renewable sources. The Micro grids can withstand upto 10KW energy [6]. An inverter has been utilized to integrate micro grids blocks for direct current to alternate current conversion. The Residential micro grids can be placed as individual manner or it will be connected with a PV grid. The PV inverters can be accessed with single or three phase connections [7]. The PV inverter grasps high power from the PV blocks. When it is connected with grid, it passes sinusoidal currents. The Inverters powers are categorized based on their power stages, capacitors placements and usage or absence transformer. By this effective power utilization can be achieved.

PHOTOVOLTAIC SYSTEMS

The Photovoltaic systems are enclosed with several number of inter linked blocks. These blocks helps to achieve certain performance level ratings. The Power supply design plays vital role. Each block in this grid system are powered based on the blocks requirement level. The Photovoltaic systems are classified based on their blocks and user demands. Figure 1 represents the Classification of PV systems [8]

PV module

The Solar cell connections are connected with respect to application requirements [9]. A Series string of cells (approximately 36 or 72) are utilized to obtain effective output voltage. A Complete package of entire blocks design is said to be module. This Prevents each cells from external environment factors such weather, dust etc [10]. Multiple cells are connected in series connection and sometimes in parallel connection as well. Figure 2 represents PV module structure with 36 cells in a series connection. All cells in the system will achieve same current. The Output voltage at module terminals will be the sum of each cell voltages. The String series of cells determines power for the entire system. In parallel connection system current will be sum of each cell and the output voltage at module terminals will be equal to a single cell.

Array

An Array is defined as a structure of PV module structure with 36 cells fabricated on the same plane with proper power supply with respect to the applications. Arrays can with stand power capacity between 100w to 100kw. The Single module cells connection is similar to connection given for modules in an array. For high level voltage, modules will be in series connection. Similarly, for high current they will be in parallel connection [11-12]. The Array structure in figure 3 consists of four parallel connections of four module strings in a series connection.
The Voltage for n modules in series connection is expressed as:

$$V_{series} = \sum_{j=1}^{n} V_j = V_1 + V_2 + ... + V_n \quad for \quad I > 0 \qquad (1)$$

$$V_{seriesOC} = \sum_{j=1}^{n} V_j = V_{oc1} + V_{oc2} + ... + V_{ocn} \quad for \quad I = 0 \qquad (2)$$

The Current and voltage for m modules in parallel connection is expressed as:

$$I_{parallel} = \sum_{j=1}^{n} I_j = I_1 + I_2 + ... + I_m \qquad (3)$$

$$V_{parallel} = \sum_{j=1}^{n} V_j = V_1 = V_2 = ... = V_m \qquad (4)$$

The Array connection of modules has to be in a proper connection. So that effective performance can be obtained from system. If not it leads to noises, heat and malfunctions etc. The Bypass diode prevents the failure issues in connection terminals. The Bypass diode in a system leads to high cost in design. If the bypass diode gets damages replacement will be crucial at the moment.

Grid connected systems

Grid connected PV systems can standalone with its own requirements of energy [13]. In 2004, grids implementation for a systems gets increased in Germany about 1 GW. [14]. The Failure issues in PV system connections for utilizing grid are solved with IEEE standard 929-2000 in 2000 [15]. The Standard integration was made on PV systems for power networks are revealed at 2 major categories namely,1) Safety and 2) Power quality. The IEEE Standard 929 reveals that it has limitation on PV systems mainly on total harmonic distortion at the point of common coupling (PCC) with Clause 10 of IEEE Std 519-1992.

The Limits will be applicable upto 6 pulse converters. In normal distortion cases, if pulse counts are above 6 it has to undergo with certain conversions [16]. The Distortion limits are listed in Table 1. The Issue of islanding is defined as inverter will get turns off automatically when the power source gets absent from the network. If it does not occurs the safety of staff and common people has to meet consequences. Radio frequency suppression also needs effective shield and filters.

CONVENTIONAL CASCADE H BRIDGE

A Multilevel inverter with direct current source within H- bridge cells has series connection [17]. Each cell encloses an individual DC source. It also has 2 branches in a parallel connection. Where each branch has 2 switches (complement to each other) [18-20]. The Second branch alignment has been utilized for the switch implementation. Based on cells counts the output voltage level can be determined. Figure 6 represents a single cell with 3 parameters namely, -Vdc, 0, Vdc [21-23]. For obtaining maximum output voltage level, a cells count in a system has to larger in amount.

$$m = 2n + 1 \tag{5}$$

Where, n denotes the number of H –bridge; m denotes the number of levels

NEW 21 LEVEL CASCADE H-BRIDGE MULTILEVEL INVERTER FOR PV SYSTEM

The Inverter is utilized for converting DC electrical energy into an AC electrical energy. The Inverter plays major role in conventional energy sources connected with grids. The Principle of DC-DC rectifiers and inverters are same at its control units. The Proposed 21 level inverter contains of two parts namely, 1) Level marker and 2) H- bridge. The Level marker has 10 DC sources and 20 switches. If switches and DC source are set then the voltage levels gets generated. The Output voltage polarity will be limited by H-bridge part. So that H-bridge alters the polarity of switches (S1, S2) performed at positive half cycle when (S3, S4) switches are performed at negative half cycle. The MOSFETs trigger pulses are processed with respect to pulse generators. Figure 8 represents the proposed multilevel inverter with 21 level output voltage. Figure 9 represents THD values of 21 levels inverter. The Proposed multilevel inverter consists of minimum number of switches when compared with conventional cascade inverter. The Proposed multilevel inverter can be further updated to high level output voltage with support of equations expressed below:

$$\begin{aligned} N_{levvel} &= 2n+1 \\ N_{switch} &= 2n+3 \\ N_{o\max} &= 2n \end{aligned} \tag{6}$$

Where, n denotes the number of DC sources.
N_{level} denotes the number of output voltage levels.
N_{switch} denotes the number of switches.
V_{omax} denotes the maximum output voltage.

RESULT AND DISCUSSION

The Proposed multi level inverter for PV power system has been carried out using MATLAB/SIMULINK software. The Proposed multi level inverter efficiency has been compared with traditional inverter designs [24-25], When off-grid was performed on load (RL). Figure.10 (a) represents the PV Module Characteristic Curve of I-V curve. Figure.10 (b) represents the PV Module Characteristic Curve of P-V Curve. Figure.11 represents the output voltage waveforms of proposed inverter. Figure.12 represents output current waveforms of proposed inverter. In load terminal, post filtering output voltage waveform and output current waveforms are in sinusoidal form. In Pre-filtering, the output voltage waveforms are in quasi sinusoidal form. Figure.13 (a) and Figure.13 (b) represents the harmonic order of the output. The Output voltage THD was observed to be 13.5%. At these states the output current THD was also 1.34%. The Simulation was executed upto 0.08 s for obtaining operations 4 cycles. The Table 2 compares the proposed TCHB with different inverter topologies with load (RL) and THD parameters.

CONCLUSION

In this paper, multilevel inverter topology is implemented. The Relationships of photovoltaic systems is analyzed and simulated with Matlab software. The Proposed 21-level cascaded inverter has been designed for renewable energy applications. The Improvement of power stability and power quality in voltage source and current source, THD values are recorded then analyzed with existing design represented in Table 1. The Proposed inverter was obtained with reduced voltage THD of 13.5 % and reduced current THD of 1.34 %. From these results it has been proved that proposed inverter design provides reduced THD. In conclusion, based on evaluation results the proposed 21 level inverter is recommended for photovoltaic power system. In future efficient multilevel inverter can be developed with reduced components.

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Table 1: Distortion limits as recommended in IEEE Std 519-1992 for six-pulse converters

Odd harmonics	Distortion limit
3rd – 9th	< 4%
11th – 15th	< 2%
17th – 21st	< 1.5%
23rd – 33rd	< 0.6%
above 33rd	< 0.3%

Table 2. Total Harmonic Distortion(THD) Comparison

Inverter Topology	Level	Voltage THD %	Current THD %
Design 1 [24]	23	4.23	2.74
TCHB [25]	9	15	2.57
Proposed Inverter	21	13.5	1.34

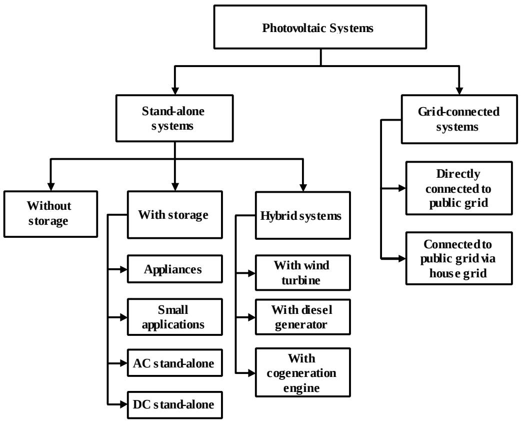


Figure.1: Classification of PV systems

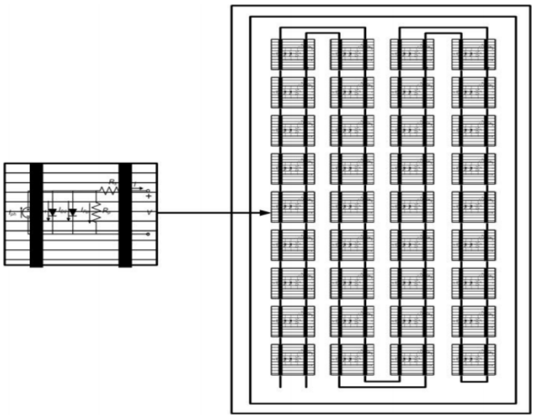


Figure 2: Structure of a PV module with 36 cells connected in series

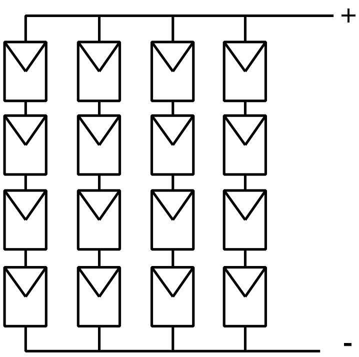


Figure 3: Structure of a PV array

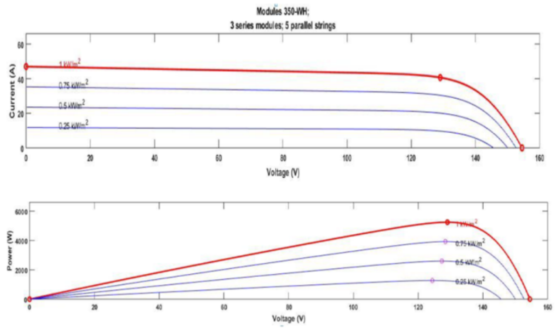


Figure 4. Photovoltaic array VI characterises

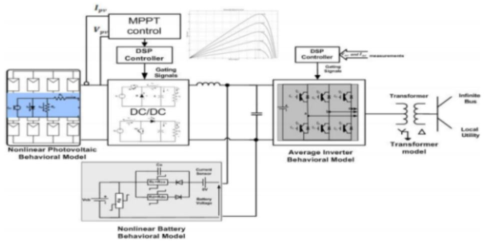


Figure 5: Grid connected PV system

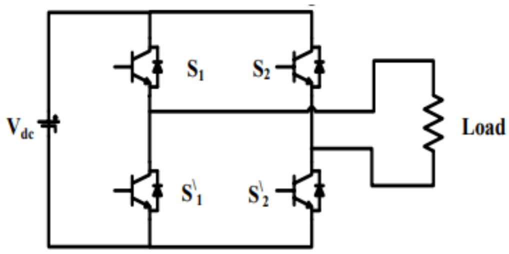


Figure 6: single cell conventional cascade three level

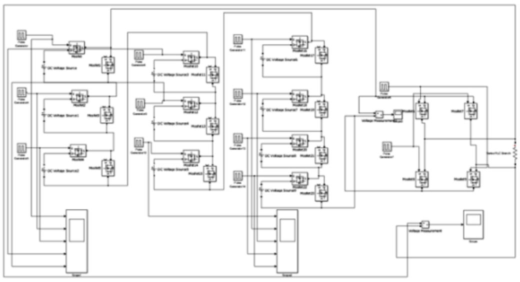


Figure 7. Simulation of 21 level inverter for PV power system

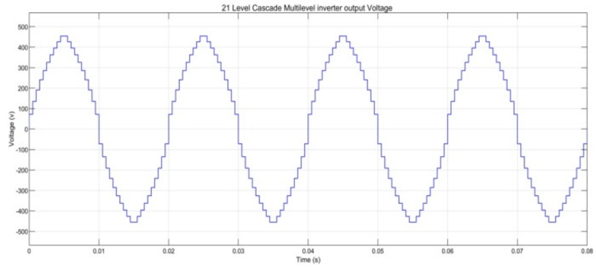


Figure 8. 21 levels inverter for PV power system output voltage waveform

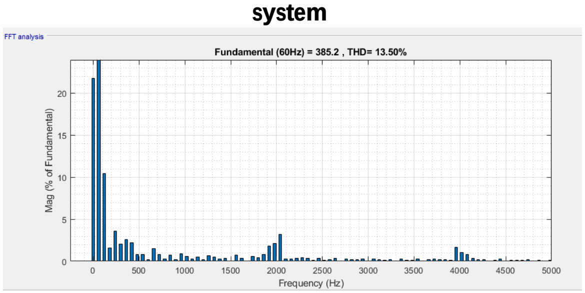
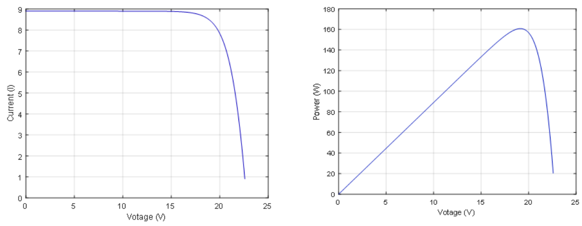


Figure 9. THD of 21 levels inverter for PV Power system



(a) (b)

Fig. 10. PV Module Characteristic Curves (a) I-V curve (b) P-V Curve

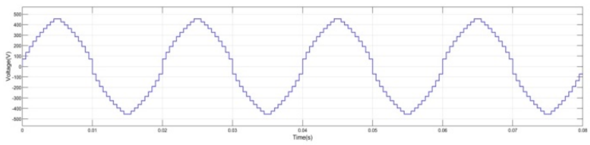


Figure 11. PV integration of Distributed grid voltage waveform

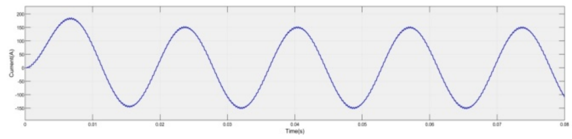
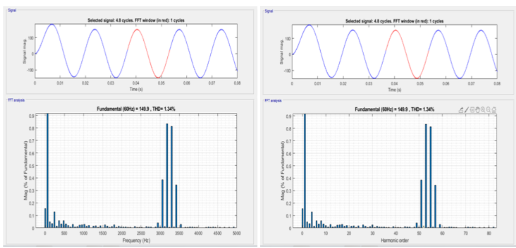


Figure 12. PV integration of Distributed grid current waveform



(a) (b)

Fig. 13. Output-Current and Voltage Results. (a) FFT analysis with frequency, (b) FFT analysis with harmonic order