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A Review on 7 Level Symmetrical Inverter for Photovoltaic System

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Abstract: The input source for the multilevel inverter is a series combination of three PV arrays. In this paper we compare the outputs of three phase bridge inverter and seven level multilevel inverter for input of a PV system. Here two cases are considered. In first case, PV module output is applied to three phase full bridge inverter. In second case, PV module output is applied to symmetrical seven level inverter. The more the number of PV modules the more the number of voltage levels, the more faithful is the output sinusoidal waveform. Multi level inverters (MLI) are being preferred over conventional two level inverters as the former topologies have minimum harmonic distortion, electromagnetic interference and higher DC link voltages. On the other hand, these devices have some inherent drawbacks like increased number of switches, complicated control techniques and requirement of many voltage sources. A conventional topology uses 12 switches for a 7-level MLI design.

Keywords: Symmetrical, multilevel inverter, photovoltaic system, review

I. Introduction:

Renewable energy resource (RES) has become more attractive and fascinating due to the advancement of technology. RES like solar energy, wind energy, biomass, hydropower and geothermal etc are attractive in meeting the demands of consumer than the conventional sources. By economic point of view these RESs are contributing much well due to priceless quality of solar energy. The implementation of RESs in hybrid system gives rise a tremendous regime in the domain of energy. The collective advantage of maximum efficiency and minimum losses is achieved by photovoltaic, wind turbine and fuel cell. Power electronic devices MLI, converter, chopper etc play an important role with the collaboration of these RESs and distributed grid system. The concept of optimization of micro grids with distributed system is a good opportunity in gaining flexibility, reliability, control mechanism and efficient quality of power. DC to AC power conversion is a key technology in the modern set-up of generation, transmission, distribution, and utilization of electric power. With the advent of recent power electronics devices, digital controllers, and sensors, the role of power inverters is also envisaged and acknowledged in frontiers such as futuristic smart grids and greater penetration of renewable energy sources-based power generation. Conventional two level inverters have been used. However, these inverters give pulsating waveforms of current and voltage at their outputs and filters are needed to get fundamental frequency sinusoidal waveforms.

Efficiency of this process is low since energy contained in the higher order harmonics is wasted. Keeping in view the disadvantages of conventional two level inverters, it is important to devise new inversion methodologies.

There has been increase in demand for electrical energy all over the world. With increase in population, industrialization and globalization, the per capita consumption of electrical energy demand is more. To meet the increased demand, there is increase in requirement for installation of alternative energy sources. Therefore renewable energy sources (RES) have been in demand and installed at distribution level in the power system to support supply-demand balance equation. Solar power plant is widely used nowadays to support the power system. But the main issue is the dynamic nature of input for RES . In prime mover based generators, turbines are rotated at constant speed to maintain constant frequency. The frequency mismatch is the main challenge when solar power plant is installed and connected to grid. Rated frequency can be obtained by designing a proper inverter. Photo voltaic (PV) module is modeled and the output is provided to inverters. Conventional inverters produce two levels in the output voltage which has high harmonic content. There evolves the concept of production of multilevel in the output of the inverter. There are many multilevel inverters in usage but they are operating at high switching frequency. Therefore a new symmetrical multilevel inverter is designed to operate at line frequency of 50Hz so that switching losses are reduced. The pulse width modulation (PWM) technique is used in which phase and level shifted reference modulation technique is applied.

II. Literature Survey:

M.S. Sivagamasundari et al. (2013) proposed the photovoltaic energy conversion becomes main focus of many researches due to its promising potential as source for future electricity and has many advantages than the other alternative energy sources like wind, solar, ocean, biomass, geothermal etc. In Photovoltaic power generation system multi level inverters can be used as an alternative configuration for the dc to ac inverter. Diode clamped inverter, Cascaded H-bridge inverter and Flying capacitor inverter are the three widely used configurations of multilevel inverters. Among these three configurations, Cascaded H –bridge multilevel inverter is mostly used for photovoltaic system because each cell of Cascaded H –bridge multilevel inverter requires separate DC sources which can be easily supplied by individual PV arrays and each H-Bridge cell will be available in a single module . This research paper deals with a comparative study of harmonic analysis in different levels of Symmetrical Cascaded H –bridge multilevel inverter employing multicarrier pulse width modulation technique for photovoltaic system. From this study it is found that the total harmonic distortion is low for higher levels of Symmetrical Cascaded H –bridge multilevel inverter and hence the efficiency of the system will be improved . The harmonic contents in output voltage and load current has been analyzed upto 7th harmonics in different levels of symmetrical cascaded h-bridge multilevel inverter and has been studied by the MATLAB/Simulink. The simulated output shows very favorable results.

S. Umashankar et al. (2013) presented though the multilevel inverters hold attractive features, usage of more switches in the conventional configuration poses a limitation to its wide range application. Therefore, a renewed 7-level multilevel inverter topology is introduced incorporating the least number of unidirectional switches and gate trigger circuitry, thereby ensuring the minimum switching losses, reducing size and installation cost. The new topology is well suited for drives and renewable energy applications. The performance quality in terms of THD and switching losses of the new MLI is compared with conventional cascaded MLI and other existing 7-level reduced switch topologies using carrier-based PWM techniques. The results are validated using MATLAB/SIMULINK.

Sathish Kumar et al. (2014) presented a novel fuzzy PWM switching scheme for the proposed multilevel inverter. It utilizes three reference signals and a triangular carrier signal to generate PWM switching signals. The three reference signals are obtained by fuzzy controller. The behavior of the proposed fuzzy logic controller multilevel inverter was analyzed in detail. By controlling the modulation index, the desired number of levels of the inverter's output voltage can be achieved.

Mohana Sundar Manoharan et al. (2017) proposed a new architecture for a cost-effective power conditioning systems (PCS) using a single-sourced asymmetric cascaded H-bridge multilevel inverter (MLI) for photovoltaic (PV) applications is proposed. The asymmetric MLI topology has a reduced number of parts compared to the symmetrical type for the same number of voltage level. However, the modulation index threshold related to the drop in the number of levels of the inverter output is higher than that of the symmetrical MLI. This problem results in a modulation index limitation which is relatively higher than that of the symmetrical MLI. Hence, an extra voltage pre-regulator becomes a necessary component in the PCS under a wide operating bias variation. In addition to pre-stage voltage regulation for the constant MLI dc-links, another auxiliary pre-regulator should provide isolation and voltage balance among the multiple H-bridge cells in the asymmetrical MLI as well as the symmetrical ones. The proposed PCS uses a singleended DC-DC converter topology with a coupled inductor and charge-pump circuit to satisfy all of the aforementioned requirements. Since the proposed integrated-type voltage pre-regulator circuit uses only a single MOSFET switch and a single magnetic component, the size and cost of the PCS is an optimal trade-off. In addition, the voltage balance between the separate H-bridge cells is automatically maintained by the number of turns in the coupled inductor transformer regardless of the duty cycle, which eliminates the need for an extra voltage regulator for the auxiliary H-bridge in MLIs. The voltage balance is also maintained under the discontinuous conduction mode (DCM). Thus, the PCS is also operational during light load conditions. The proposed architecture can apply the module-integrated converter (MIC) concept to perform distributed MPPT. The proposed architecture is analyzed and verified for a 7-level asymmetric MLI, using simulation results and a hardware implementation.

K. Dhineshkumar et al. (2018) discussed in this paper the solar based boost converter integrated Nine level multilevel inverter presented. It uses 7 switches to produce nine level output stepped waveform. The aim of the work to produce 9 level wave form using solar and boost converter. The conventional inverter has multiple sources and has 16 switches are required and also more number of voltage sources required. The proposed inverter required single solar panel and reduced number of switches and integrated boost converter which increase the input voltage of the inverter. The proposed inverter simulated and compared with R load using Mat lab and prototype model experimentally verified .The proposed inverter can be used in n number of solar applications.

Maham Fatima et al. (2018) proposed in this paper, a new cascaded module of multilevel inverter is proposed. The proposed topology produces a large number of levels with reduced total harmonic distortion (THD). This module consists of less number of MOSFETs and gate drivers which optimize the design of MLI in term of complexity, cost, control and installation. The performance analysis of proposed module is done by using a modulation technique. Simulation results for 17-level are evaluated on MATLAB/SIMULINK.

B. Dorothy Mercy Carol et al. (2020) described in this paper source is three PV arrays which are connected in series where the voltage and current of PV arrays is maintained at standard operating conditions. The output of the PV module is given to the symmetrical multilevel inverter. The output voltage of the proposed multilevel inverter is symmetrical and has seven levels. The harmonic content is greatly reduced from three phase bridge inverter to multilevel inverter. For proposed symmetrical multilevel inverter there are less number of switches compared to other topologies. As the switching speed of the multilevel inverter is less, switching losses are reduced . The low frequency switching reduces the inverter power losses leading to a better efficiency of the proposed topology. Total harmonic distortion is reduced to a great extent by the use of proposed multilevel inverter. Thus power quality is improved by the proposed seven level inverter.The proposed MLI topology can be a good solution to feed microgrids from RESs.

Hassan Salman Hamad (2020) presented the multilevel inverters (MLI) owing to the low total harmonic distortion (THD) associated with their output voltage, as well as their low electromagnetic interference (EMI). The MLI represents an effective and feasible solution for enhancing power demand and minimizing AC waveforms' harmonics as they generate a preferred level of output voltage as inputs from varying levels of DC voltages. In this paper, the performance of a seven-level cascaded H-bridge MLI with an asymmetrical number of power switches was evaluated. The simulation performance is shown to validate the operating principle of the single-phase cascaded H-bridge inverter. To control the MLI, a pulse width modulation approach was utilized. The operating principle of the MLI was verified via simulation using PSIM software.

Johny Renoald Albert et al. (2020) presented the super-lift technique is an exceptional contribution to DC–DC conversion technology. A replacement approach of symmetrical super-lift multilevel inverter (SLMLI) DC/AC technology is proposed with a reduced number of elements compared with the traditional multilevel inverter. In this method, the firefly algorithm conveys a leading task for the SLMLI topology for solar-photovoltaic applications. It generates low distortion output and consumes the harmonic band of the fast Fourier transform framework by the employment of the proposed algorithm. The simulation circuit for 15 levels output uses single switch super-lift inverter feed with different kinds of load (R, RL and RLE) conditions. The power quality is improved in SLMLI with minimized harmonics underneath the various modulation indices while varied from 0.1 up to 0.8. The circuit is designed in a fieldprogrammable gate array, which includes the firefly rule to help the multilevel output, to reduce the lower order harmonics and to find the best switching angle. As a result, the minimum total harmonic distortion from the simulation and hardware circuit is achieved. Due to the absence of bulky switches, inductor and filter elements expose the effectiveness of the proposed system.

Ahmed Ismail M. Ali et al. (2021) discussed a simple single-phase new pulse-width modulated seven-level inverter architecture for photovoltaic (PV) systems supporting home-grid with electric vehicle (EV) charging port. The proposed inverter includes a reduced number of power components and passive elements size, while showing less output-voltage

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total harmonic distortion (THD), and unity power factor operation. In addition, the proposed inverter requires simple control and switching strategies compared to recently published topologies. A comparative study was performed to compare the proposed inverter structure with the recent inverter topologies based on the number of components in the inverter circuit, number of components per output-voltage level, average number of active switches, THD, and operating efficiency as effective parameters for inverter performance evaluation. For design and validation purposes, numerical and analytical models for a grid-tied solar PV system driven by the proposed seven-level inverter were developed in MATLAB/Simulink environment. The inverter performance was evaluated considering grid-integration and stand-alone home with level-2 AC EV charger (3–6 kW). Compared with recently published topologies, the proposed inverter utilizes a reduced number of power components (7 switches) for seven-level terminal voltage synthesis. An experimental prototype for proposed inverter with the associated controller was built and tested for a stand-alone and grid-integrated system. Due to the lower number of ON-switches, the inverter operating efficiency was enhanced to 92.86% with load current THD of 3.43% that follows the IEEE standards for DER applications.

III. Proposed work:

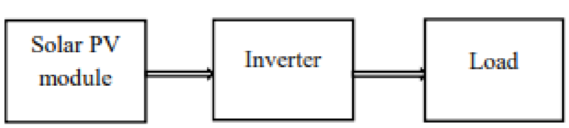

Figure 3.1: Block diagram

An ideal solar cell can be considered as a current source. The current produced by it is proportional to solar irradiation intensity falling on it. The recombination losses are represented by the diode connected parallel to the current source but in the reverse direction. The ohmic losses in the cell occur due to the series and shunt resistances denoted by Rs and Rp respectively.

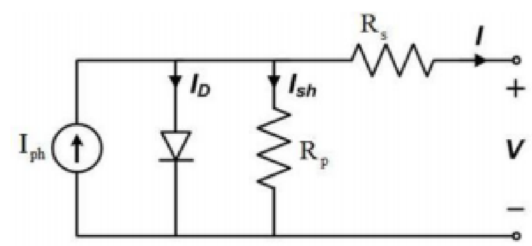

Figure 3.2: Electrical equivalent of PV cell

Where, $Iph = photon\ current$

$ID = diode\ current$

$Ish = shunt\ current$

$Rp = parallel\ resistance$

$Rs = series\ resistance$

7-Level Multilevel Inverter Configuration:

MLI is a type of power electronics device which produces large number of levels from single or multiple DC sources at the input terminal. The DC source provided at the input of MLI is obtained from different sources such as PV fuel, capacitor, dc batteries etc. MLI consists of semiconductor switches like MOSFET, IGBTs, BJTs and gate drivers etc. The main purpose of MLIs is to obtain a output waveform which is closely related to reference sine wave.

The design of cascaded MLIs can be made simple by designing a simple gate pulse generation scheme. The cascaded MLIs use bridges cascaded with each other .For a five level inverter, two bridges are required, for a seven level inverter three bridges are required and for a nine level inverter four bridges are required and so on. One bridge consists of four semiconductor switches, so the number of switches increase with the level and voltage steps. Hence the switching losses and the cost of the MLIs also increase accordingly. Therefore, an initiative is taken to reduce the number of semiconductor switches and hence the cost of MLI and a simpler switching technique is developed to control the MLIs. In this section, a method is developed to reduce the switches for a seven level inverter by using only seven switches or 6 switches. A simplified gate control circuit is also developed for the proposed topologies.

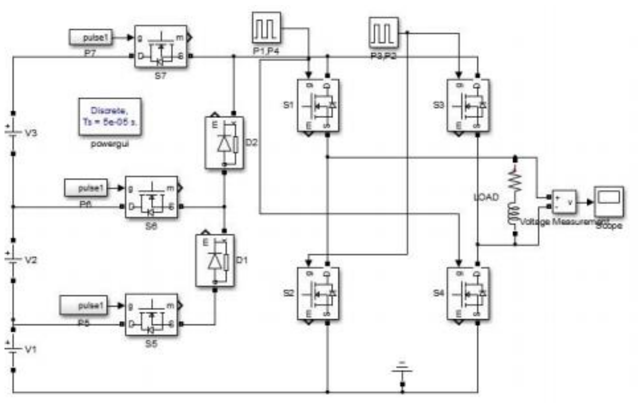

Figure 3.3: Seven level seven Switch Topology

IV. Conclusion:

Multi level inverters (MLI) are being considered as the most popular method to synthesize almost sinusoidal waveforms using multi steps. Out of three conventional topologies cascaded H-bridge type of MLIs with different dc sources are proven to be more reliable in generating higher voltage with comparatively less harmonics due to its modular nature. These types of MLIs are also very suitable for solar applications as the separate dc sources requirement is naturally available. However, there are certain drawbacks of these MLIs such as the use of large number of switches and the related gate drive circuit design as required by the corresponding semiconductor switches which create more complexity in electrical and mechanical design of the inverters.

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