An Extensive Analysis on Three Phase Multi-Level Inverter Topology

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Abstract - Various mechanical applications have started to require higher power device as of late. For a medium voltage power grid, it is troublesome to interface just a single power semiconductor switch straightforwardly. Accordingly, a multilevel power converter structure has been presented as an option in high power and medium voltage circumstances. Power electronic converters, especially dc/ac PWM inverters have been expanding their scope of utilization in industry since they give lessened vitality utilization, better framework proficiency, enhanced nature of item, good maintenance, and so on. As the power level increases, the voltage level also increases accordingly to obtain satisfactory efficiency. Multilevel Inverters have been drawing in consideration as of late because of high power quality, high voltage ability, low switching losses and low Electro Magnetic Interference (EMI) concerns. A multilevel inverter can be implemented in different topology with its own advantages and limitations. This work present a brief survey on multilevel inverter topologies for effective power conversion.

Indexed Terms- Multi-Level Inverter, Inverter Topologies, Pulse width Modulation (PWM), dc/ac Converter, sinusoidal pulse width modulation (SPWM), Low Frequency Operation.

I. INTRODUCTION

Multilevel inverters have been under research and development for more than three decades and have found successful industrial applications. However, this is still a technology under development, and many new contributions and new commercial topologies have been reported in the last few years. The aim of this dissertation is to group and review recent contributions, in order to establish the current state of the art and trends of the technology to provide readers with a comprehensive and insightful review of where multilevel converter technology stands and is heading. This chapter first presents a brief overview of well- established multilevel inverters strongly oriented to their current state in industrial applications and then centers the discussion on the new multilevel inverters that have made their way into the industry. Multilevel inverters have been attracting increasing interest recently the main reasons are; increased power ratings, improved harmonic performance, and reduced electromagnetic interference (EMI) emission that can be archived with multiple dc levels that are synthesis of the output voltage waveform. In particular multilevel inverters have abundant demand in applications such as medium voltage industrial drives, electric vehicles, and grid connected photovoltaic systems. The present work provides a solution to design an efficient multilevel topology which is suited for medium and high power applications. In the subsequent sections the research background is discussed in detailed. Motivation and objectives are clearly outlined.

There are different power converter topologies and control strategies used in inverter designs. Different design approaches address various issues that may be more or less important depending on the way that the converter is intended to be used. The issue of waveform quality is one the important concern and it can be addressed in many ways. In practice capacitors and inductors can be used to filter the waveform [1-2]. If the design includes a transformer, filtering can be applied to the primary or the secondary side of the transformer or to both sides. Low-pass filters are applied to allow the fundamental component of the waveform to pass to the output while limiting the passage of the harmonic components. Thus quality of waveform can be adjusted. Note that, normal inverters always generate very low quality output waveforms. To make the output waveform qualitative, low pass (LC filter) are often added in the circuit. Thus, at this point of time readers might have a question that, why the quality of converter output is low? And why Low pass filter are frequently added in the circuit. Further, what kinds of solutions are available to increase quality of output waveform without losing its efficiency? All this are open problems associated with present day inverters. However, eventually all this will be addressed in this work. But at first try to figure out the converter applications from low power to high power and then summarize the requirements to meet the high power demand. Finally try to present the problems and solutions available to meet the high power demand.

At present there is tough competition between the use of classic power converter topologies using high-voltage semiconductors and new converter topologies using medium- voltage devices.

In past, these inverters are only viable options for medium and high-power applications. But in present scenario, multilevel technology with medium voltage semiconductors are fighting in a development race with classic power inverters using high- power semiconductors, which are under continuous development and are not mature. Although, classical inverters are good for low power applications, but they fail to fill the requirements of high-power levels.

II. MULTILEVEL INVERTER STRUCTURES

A voltage level of three is considered to be the smallest number in multilevel converter topologies. Due to the bi-directional switches, the multilevel VSC can work in both rectifier and inverter modes. This is why most of the time it is referred to as a converter instead of an inverter in this dissertation. A multilevel converter can switch either its input or output nodes (or both) between multiple (more than two) levels of voltage or current. As the number of levels reaches infinity, the output THD approaches zero. The number of the achievable voltage levels, however, is limited by voltage-imbalance problems, voltage clamping requirements, circuit layout and packaging constraints complexity of the controller, and, of course, capital and maintenance costs.

The main function of a multilevel inverter is to produce a desired AC voltage level from several DC voltage sources. This DC voltage source may or may not be equal to one another. The AC voltage produced from this DC voltage appears to be a sinusoidal. One pitfall of using multilevel inverter is to approximate sinusoidal waveforms concern with harmonics. The staircase waveform produced by a multilevel inverter contains sharp transitions.

In a multilevel VSI, the dc-link voltage Vdc is obtained from any equipment which can yield stable dc source. Series connected capacitors constitute energy tank for the inverter providing some nodes to which multilevel inverter can be connected. Primarily, the series connected capacitors will be assumed to be any voltage sources of the same value.

Three different major multilevel converter structures have been applied in industrial applications: cascaded H-bridges converter with separate dc sources, diode clamped, and flying capacitors. Although each type of multilevel converters share the advantages of multilevel voltage source inverters, they may be suitable for specific application due to their structures and drawbacks. Operation and structure of some important type of multilevel converters.

Fig. 2.1 shows a schematic diagram of one phase leg of inverters with different number of levels, for which the action of the power semiconductors is represented by an ideal switch with several positions. A two-level inverter generates an output voltage with two values (levels) with respect to the negative terminal of the capacitor, while the three-level inverter generates three voltages, and so on.

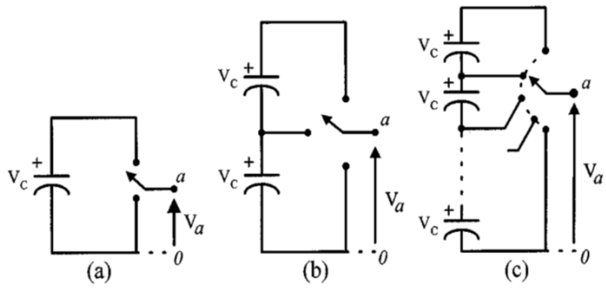

Figure 2.1 One phase leg of an inverter with (a) two levels, (b) three levels, and (c) n levels.

III. LITERATURE REVIEW

SR. NO.	Title	Author	Year	Approach
1	Novel three phase multi-level inverter topology with symmetrical DC-voltage sources	A. Salem, E. M. Ahmed, M. Ahmed and M. Orabi,	2016	the sinusoidal pulse width modulation (SPWM) and staircases modulation are effectively executed.
2	A comparative study between different multi level inverter topologies for different types of bus clamping PWM techniques using Six Region Selection Algorithm	R. K. Dhal and T. Roy,	2015	Type-1, Type-2, Type-3 and Type-4 BCPWM for three-level Voltage Source Inverter (VSI).
3	A new switching scheme for a new multi level inverter topology for grid connected PV systems,	G. K. N. Kumar and K. P. P. Vadhiraj,	2015	a new switching scheme for a new topology of MLI with reduced number of switches for interfacing PV modules with the grid.
4	A modified switching scheme for a new multi	G. K. N. Kumar and Y. Pal,	2014	Fuel cell generation systems are expected to see practical usage

	level inverter topology for fuel-cell microgrid,			
5	A new multi level inverter topology for grid interconnection of PV systems	V S Prasadarao K, P. Sudha Rani and G. Tabita	2014	a new type of multi level Inverter which converts the dc into ac using less number of switches when compared to conventional multilevel Inverters
6	Modeling and analysis of single phase multi string five level inverter for distributed energy resources,	B. N. V. Angirekula and O. Ojo,	2013	Karnaugh mapping technique (which was rarely used in power electronic converters)
7	A New Multi-level Inverter with FACTS Capabilities for Wind Applications,	P. Sotoodeh and R. D. Miller,	2013	a new single-phase MMC-based D-STATCOM inverter for grid connection

A. Salem, E. M. Ahmed, M. Ahmed and M. Orabi,[1] In this exploration, a novel three phase modular multi-level inverter (MMLI) is proposed. The proposed inverter consists of primary cell and repetitive modular cells which are connected in series arrangement with the primary cell. Therefore, the proposed topology is able to get more output voltages levels number by adding extra modular cells. Both the sinusoidal pulse width modulation (SPWM) and staircases modulation are effectively executed. The proposed inverter is distinguished by several advantages such as: reduction in the number of semiconductor power switches, reduced Dc-voltage sources count, high utilization factor of the used Dc-voltage sources, and the control execution simplicity. Accordingly, the installation cost and size are reduced. It is simulated using MATLAB software package-tool. In addition, a prototype is developed and examined, to verify both control techniques and performance of the topology. Moreover, experimental results are provided to authenticate the simulation results and it show high similarity with it.

R. K. Dhal and T. Roy,[2] This exploration presents a modified region selection algorithm called “Newly-Modified Six-Region (NMSR)” selection technique for implementing different types of Bus-Clamped PWM (BCPWM) techniques i.e. Type-1, Type-2, Type-3 and Type-4 BCPWM for three-level Voltage Source Inverter (VSI). The novelty of the proposed algorithm is that it can be applied to any level of inverters with much easier and lesser computations. An extensive comparison study between different topologies of Multilevel Inverters (MLI) has been done with different types of BCPWM techniques implemented by the proposed NMSR technique. It has been observed that the advantages of BCPWM compared to Conventional Space Vector PWM (CSVPWM) technique remain unaltered which signifies the effectiveness of the proposed technique. Further it also observed that the flying capacitor topology performs better compare to other conventional topologies and Type-4 BCPWM technique gives better quality of output waveforms with lesser Total Harmonic Distortion (THD).

G. K. N. Kumar and K. P. P. Vadhiraj,[3] Among Renewable Energy Systems, Photovoltaic systems are widely used as they are clean and easily installable. These PV cells convert sunlight into electricity in the form of dc. A suitable converter is usually needed to convert the dc power into ac power, which is then injected into the power grid. Recently the use of multilevel inverters (MLIs) in modern drives and for interfacing the renewable generation systems to the grid have given a wide scope for designing new topologies of MLIs. This exploration presents a new switching scheme for a new topology of MLI with reduced number of switches for interfacing PV modules with the grid. Among the different switching schemes, this exploration uses Unipolar pulse width modulation (PWM) technique for the switching of H-bridge switches, while for the outer switches sinusoidal modulating wave is compared with dc component for its switching. From the obtained Matlab/Simulink environment results the THD of output voltage of 21-level MLI is within limits specified by IEEE 519 standard. In addition, a comparative analysis of this new topology of MLI with conventional topologies in terms of number of switches for seven-level, thirteen-level and twenty-one level has been presented. It is also observed that this PV module fed new MLI fed to micro grid satisfies the grid requirements and conditions such as amplitude of Grid voltage, phase angle and frequency.

G. K. N. Kumar and Y. Pal,[4] Recently the use of multilevel inverters (MLIs) in modern drives and for interfacing the renewable generation systems to grid have given wide scope for designing new topologies of MLIs. Fuel cell generation systems are expected to see practical usage due to several advantages over conventional generation systems. This exploration introduces a new switching scheme for a new topology of MLI with reduced number of switches for interfacing Fuel-cell with the grid.

The unipolar pulse width modulation (PWM) technique is used for the switching of H-bridge switches, while for the outer switches sinusoidal modulating wave is compared with DC component. With this modified switching scheme the Total Harmonic Distortion (THD) in the output voltage of MLI decreased. It is also observed from the simulation results that the THD of output voltage of 21-level MLI is within limits as specified by IEEE 519 standard. A comparative analysis of proposed switching scheme with the reported switching scheme is carried out for the seven and thirteen levels of new topology in terms of the THD in the output voltages. Moreover, a comparison of new topology with conventional reported MLI topologies is also made in terms of the number of switches and required DC sources for different levels. It is also observed from simulation results that during the integration of the Fuel-cell with the grid, the grid requirements such as phase angle, frequency and amplitude of grid voltage are also satisfied.

V S Prasadarao K, P. Sudha Rani and G. Tabita,[5] Renewable energy sources (RES) gain an importance in recent decades because they are pollution free, easily erectable, and limitless. Among RES, Photovoltaic systems are mostly used as they are light, clean and easily installable. Normally PV cells converts sunlight into electricity in the form of dc. A suitable converter is usually needed to convert the dc power into ac power, which is then injecting into the power grid. The Multilevel Inverters [MLI] can be used to convert the dc into ac for integration of renewable energy sources into the conventional grids. But the conventional MLIs such as Diode Clamped MLIs requires extra diodes in conjunction with the active switches, Flying capacitor MLIs requires extra Capacitors and control also difficult if the levels increases and the Cascaded H-bridge MLIs requires separate dc sources which limits its use. This exploration proposes a new type of multi level Inverter which converts the dc into ac using less number of switches when compared to conventional multilevel Inverters. The proposed Inverter can be used to integrate the Photovoltaic system into Grid, with satisfying the grid requirements such as phase angle, frequency and amplitude of the Grid voltage. Seven level and thirteen level proposed MLI is simulated using Matlab/Simulink environment and the corresponding results are presented in this exploration.

B. N. V. Angirekula and O. Ojo,[6] The main objective of this exploration is to study a five level multi string converter topology for distributed energy resources based DC-AC conversion system. The modeling and analysis of multi string multi-level converter has not been presented anywhere else before. This exploration proposes the Karnaugh mapping technique (which was rarely used in power electronic converters) for modeling the multi string five level converter. The proposed method can also be extended to `n' level converter. This exploration also proposes the double Fourier series analysis to determine the expressions for modulation signals with particular reference to five level design. This exploration also compares the switching losses between cascaded and multi string multi-level inverters. The studied multi-level inverter topology offers strong advantages such as less switching losses, improved output voltage waveforms, lower EMI and lower THD.

P. Sotoodeh and R. D. Miller, [7] The modular multilevel converter (MMC) is an attractive topology for HVDC/FACTS systems. In this exploration a new single-phase MMC-based D-STATCOM inverter for grid connection is proposed. The proposed inverter is designed for grid-connected wind turbines in the small- to mid-sized (10kW-20kW) range using the most advanced multi-level inverter topology. The proposed MMC D-STATCOM inverter controls the DC link voltage as well as the active and reactive power transferred between the renewable energy source, specifically wind turbine, and the grid in order to regulate the power factor (PF) of the grid regardless of the input active power from wind turbine. The goal of this exploration is to present a new inverter with D-STATCOM capability in a single unit without any additional cost. The 5-level D-STATCOM inverter is simulated and the results are presented to verify the operation of the proposed system. The simulation studies are carried out in the MATLAB/Simulink environment. To validate the simulation results, an experimental configuration of a 5-Level DSTATCOM inverter has been built and tested.

IV. PROBLEM STATEMENT

the worldwide energy consumption has increased in high rates, driven mainly by growing demand in developing countries for both industrial and residential fields, and also by emergence of new promising markets. In order to overcome the world excess energy demands, the world trend is replacing the traditional energy sources (TES) which based on non-sustainability sources such as fossil fuels and nuclear fission by utilizing new efficient and clean energy resources, that are based on natural sources, such as sunlight power, wind power, and geothermal power, in addition to ocean energy, and bioenergy. All these energy sources decrease carbon emission, and it classified as renewable energy sources [8]. Number of semiconductor power switches, reduced Dc-voltage sources count, Dc-voltage sources utilization, and the control execution are the major points of concern in a renewable energy sources RES [1].

V. CONLUSION

The properties discussed in this brief make a multilevel inverters very attractive to the industry and, nowadays, researchers all over the world are spending great efforts trying to improve multilevel converter performances such as the control simplification and the performance of different optimization algorithms in order to enhance the THD . The choice of topology for each inverter should be based on what is the usage of the inverter. Each topology has some advantages and disadvantages. By increasing the number of levels, the THD will be decreased but on the other hand cost and weight will be increased as well. Also since the switching angles for switches are not the same, the drive circuit for each switch is separate from other switches. These work summaries a brief on multilevel inverter and its topologies.

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