Review Paper on Single Phase Grid Connected Convertor for Renewable Energy Distributed System

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Abstract— A single phase grid-connected converter is usually adopted in low power renewable systems. This paper deals with a review of the state of the art of multi level topologies and a theoretical power loss comparison with the proposed solution is compared. The proposed converter architecture is based on a full-bridge topology with two additional power switches and two diodes connected to the midpoint of the dc link. Since the two added levels are obtained by the discharge of the two capacitors of the dc link, the balancing of the midpoint voltage is obtained with a specific pulse width modulation (PWM) strategy, Multilevel converters have been under research and development for found successful industrial application. This is still a technology under development and many new contributions and new commercial topologies have been reported in the last few years advances made in modulation and control of multilevel converters are also addressed. A great part of this paper is devoted to show nontraditional applications powered by multilevel converters and how multilevel converters are becoming an enabling technology in many industrial sectors.
Keywords: Cascaded Full-Bridge, Hybrid Five-Level Topologies, SPWM, THD, DC To AC Conversion Distributed Power Generation, Grid- Connected Converters, Single – Phase System Multilevel Converters. Multilevel Power Conversion; Power Quality; Harmonic Reduction

I. Introduction

This converter topologies instead of a line frequency employing a high-frequency transformer one have been investigated in order to reduce size and weight. Power Electronics is the art of converting electrical energy from one form to another form in an efficient, compact manner for convenient used. It is the technology associated with efficient conversion, control and conditioning of electric power from its available input into the desired output form. With regard to harmonic distortion content, power factors, and dc components, the output current of grid connected power converters must comply with the requirements of electricity supply companies It has found an important place in modern technology being core of power and energy control. Low-power applications, international standards allow the use of grid-connected power converters without any galvanic isolation, thus allowing the so called transformer less architectures. This paper concerns the use of multilevel topologies for single-phase converters. The field of high power devices has been one of the most active area in research and development of power electronics in the last decades. Several industrial processes have increased their power level needs, triggering the development of new power semiconductors, converter topologies, and control methods. In order to meet the industrial demand, series connection of power switches is the solution for dealing with large voltages in order to remain linked to a practical implementation, the unipolar PWM applied to a full bridge topology is taken as reference. It is important to note that, in this paper, the term unipolar PWM refers to a three-level output voltage, whose first switching harmonic resides at twice the switching frequency concept of a multilevel converter to achieve high power is to use a series of power semiconductor switches with several low voltage sources to perform the conversion by synthesizing a staircase voltage waveforms.

II. Literatures review

[1] This paper is focused on the simulation of a RES power system before its realtime implementation. The structure of a renewable energy based generator connected to the grid through a single-phase inverter is presented. Other main results are A computer model of a grid connected single-phase inverter operating with variable input power is developed. The simulation results show flawless work of the model. The developed current controller follows exactly the current reference and the output current ripples are non-considerable. The voltage controller maintains a correct balance between the generator and the inverter power. The model presented can be developed to control also the reactive power supplied to the gird. A part of the model is tested in real-time application and the experimental results are satisfactory. The model can be used to develop a real-time system for controlling a low-power inverter for a renewable energy generator. [2] In this paper, a comprehensive review on the grid-tied PV system followed by the single-phase transformerless topologies has been presented. Due to the omission of transformer, a resonant circuit can be created and electrified by the fluctuating CM voltage that depends on the topology structure and modulation scheme. As a result, non negligible leakage current may flow through the system. Three methods have been presented based on the decoupling method and leakage current characteristics as (1) disconnecting the PV module from the grid during zero state; (2) clamping the short-circuited output voltage to the half of DC input voltage during freewheeling period; and (3) making a solid connection by connecting the neutral line to one pole of PV panels. The operation principle, advantages and disadvantages of the existing transformerless topologies have bee presented. Simulation results have been given to compare the performance of the topologies Grid-tied inverters are the key components of distributed generation system because of their function as an effective interface between renewable energy sources and utility. Recently, there has been an increasing interest in the use of transformerless inverter for low-voltage single-phase grid-tied photovoltaic (PV) system due to higher efficiency, lower cost, smaller size and weight when compared to the ones with transformer. However, the leakage current issues of transformerless inverter, which depends on the topology structure and modulation scheme, have to be addressed very carefully. A performance comparison in MATLAB/Simulink environment is done among different topologies. Also an analysis has been presented to select a better topology .Grid-tied inverters are the key components of distributed generation system because

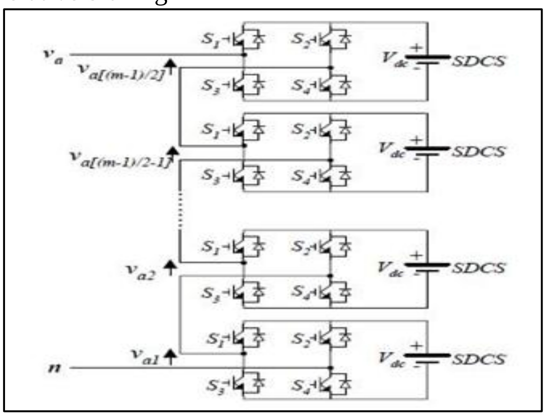
of their function as an effective interface between renewable energy sources and utility. However, the leakage current issues of transformerless inverter, which depends on the topology structure and modulation scheme, have to be addressed very carefully. An examination of demand for the inverter, the utility grid, and the PV module are presented. A performance comparison in MATLAB/Simulink environment is done among different topologies. [3] Maximum power point tracking (MPPT) is used in photovoltaic (PV) systems to maximize the photovoltaic array output power, irrespective of the temperature and irradiation conditions and of the load electrical characteristics. A new MPPT system has been developed, consisting of a Buck-type dc/dc converter, which is controlled by a microcontroller-based unit. The main difference between the method used in the proposed MPPT system and other techniques used in the past is that the PV array output power is used to directly control the dc/dc converter, thus reducing the complexity of the system. The resulting system has high-efficiency, lower-cost and can be easily modified to handle more energy sources (e.g., wind-generators). The experimental results show that the use of the proposed MPPT control increases the PV output power by as much as 15% compared to the case where the dc/dc converter duty cycle is set such that the PV array produces the maximum power at 1 kW/m2 and 25 CThe proposed system can be used in a hybrid system where the microcontroller performs simultaneously the MPPT control of more than one renewable energy source. Furthermore, it can be coupled with an uninterruptible power supply system in commercial buildings or it can be used to supply power to the electrical grid through a dc/ac converter. [4] Multilevel inverter technology has emerged recently as a very important alternative in the area of high-power medium-voltage energy control. This paper presents the most important topologies like diode-clamped inverter (neutral-point clamped), capacitor-clamped (flying capacitor), and cascaded multi cell with separate dc sources. Emerging topologies like asymmetric hybrid cells and soft-switched multilevel inverters are also discussed. This paper also presents the most relevant control and modulation methods developed for this family of converters: multilevel sinusoidal pulsewidth modulation, multilevel selective harmonic elimination, and space-vector modulation. Special attention is dedicated to the latest and more relevant applications of these converters such as laminators, conveyor belts, and unified power-flow controllers. The need of an active front end at the input side for those inverters supplying regenerative loads is also discussed, and the circuit topology options are also presented. Finally, the peripherally developing areas such as high-voltage high-power devices and optical sensors and other opportunities for future development are addressed [5] In this paper several single-phase, multilevel topologies suggested for PV grid connected sys- tems have been reviewed. Amongst the topologies for transformerless systems, the HBDC and CC have been identified as the most promising topologies. However, with the CC topology (when applied in a transformerless system) measures are necessary to decrease the capacitive earth currents which are caused by potential differences imposed on the PV array earth capacitance. An additional step-up conversion stage between PV array and inverter can increase the flexibility but reduced the overall efficiency [6]This paper presents a new reduced common mode hysteresis current regulation technique for the control of multilevel inverters. The proposed technique is based on restricting the inverter phase-leg switching states to achieve reduced common mode voltages. By further compensating for dead-time delays across two phase-legs, common mode transitional spikes can also be eliminated. [7] The multilevel voltage source converters typically synthesize the staircase voltage wave from several levels of dc capacitor voltages. One of the major limitations of the multilevel converters is the voltage unbalance between different levels. The techniques to balance the voltage between different levelsThe multilevel converters can immediately replace the existing systems that use traditional multipulse converters without the need for transformers, All three multilevel converters can be applied to SVG's without voltage unbalance problems because the SVG does not draw real power. The application on which the multilevel voltage source converter may have the most impact is the adjustable speed drive inverters not only solves harmonics and EM1 problems, but also avoids possible high frequency switching dvldt induced motor failures. With a balanced voltage stress in devices and utility compatible features [8] Cascaded multilevel inverters synthesize a medium-voltage output based on a series connection of power cells which use standard low-voltage component configurations. This characteristic allows one to achieve high-quality output voltages and input currents and also outstanding availability due to their intrinsic component redundancy. Due to these features, the cascaded multilevel inverter has been recognized as an important alternative in the medium-voltage inverter market [9] An overview on recent developments and a summary of the state-of-the-art of inverter technology in Europe for singlephase grid-connected Photovoltaic (PV) systems for power levels up to 5 kW is provided in this paper. The information includes details not only on the topologies commercially available but also on the switching devices employed and the associated switching frequencies, efficiency, price trends and market share. Finally, the paper outlines issues associated with the development of relevant international industry standards affecting PV inverter technology. [10] Abstract—Multilevel voltage source inverters offer several advantages compared to their conventional counterparts. By synthesising the AC output terminal voltage from several levels of DC voltages, staircase waveforms can be produced, which approach the sinusoidal waveform with low harmonic distortion, thus reducing filter requirements. The need of several sources on the DC side of the converter makes multilevel technology attractive for photovoltaic applications. This paper provides an overview on different multilevel topologies and investigates their suitability for single-phase grid connected photovoltaic systemsAvailability of PV modules with higher operating voltages is desirable since this would reduce system costs.

III. INVERTOR TOPOLOGY

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. electronic oscillator. It is mechanical AC to DC converters was made to work in reverse, and thus were "inverted", to convert DC to AC.Invertor is work opposite function of rectifier

A. Cascaded H-Bridges Inverter

A single-phase structure of an m-level cascaded Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $–V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches.To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, when S2 is active –Vdc is obtain and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels n in a cascade inverter is defined by n = 2s+1, where s is the number of separate dc sources Multilevel cascaded inverters used for static var generation, an interface with renewable energy sources. Three-phase cascaded inverters can be connected in wye, as shown in Figure, or in delta. Peng has demonstrated a prototype multilevel cascaded static var generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system. The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected. Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, because of the need for separate dc sources, which is the case in applications such as photovoltaic’s or fuel cells. Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as SDCSs. The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in FigureCascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as SDCSs. The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in Figure. Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking



1) Advantages:

1) The number of possible output voltage levels is more than twice the number of dc sources (m = 2s + 1)
2) The series of H-bridges makes for modularized layout and packaging. This will enable the manufacturing process to be done more quickly and cheaply.

2) Disadvantages:

1) Separate dc sources are required for each of the H-bridges. This will limit its application to products that already have multiple SDCSs readily available.

B. Diode-Clamped Multilevel Inverter

The neutral point converter proposed by Nabae, Takahashi, and Akagi in 1981 was essentially a three-level diode-clamped inverter. In the 1990s several researchers published articles that have reported experimental results for four-, five-, and six-level diode-clamped converters for such uses as static var compensation, variable speed motor drives, and high-voltage system interconnections. for the three phases of the inverter shares a common dc bus, which has been sub divided by five capacitors into six levels. The voltage across each capacitor is V_{dc}, and the voltage stress across each switching device is limited to V_{dc} through the clamping diodes. Table lists the output voltage levels possible for one phase of the inverter with the negative dc rail voltage V_0 as a reference. State condition 1 means the switch is on, and 0 means the switch is off. Each phase has five complementary switch pairs such that turning on one of the switches of the pair requires that the other complementary switch be turned off. For a six-level inverter, a set of five switches is on at any given time.

1) Advantages:

1) All of the phases share a common dc bus, which minimizes the capacitance requirements of the converter. For this reason, a back-to-back topology is not only possible but also practical for uses such as a high-voltage back-to-back inter-connection or an adjustable speed drive.
2) The capacitors can be pre-charged as a group.
3) Efficiency is high for fundamental frequency switching.

2) Disadvantages:

1) Real power flow is difficult for a single inverter because the intermediate dc levels will tend to overcharge or discharge without precise monitoring and control.
2) The number of clamping diodes required is quadratically related to the number of levels, which can be cumbersome for units with a high number of levels.

C. Flying Capacitor Multilevel Inverter

Meynard and Foch introduced a flying-capacitor-based inverter in 1992 The structure of this inverter is similar to that of the diode-clamped inverter except that instead of using clamping diodes This topology has a ladder structure of dc side capacitors, where the voltage on each capacitor differs from that of the next capacitor. The voltage increment between two adjacent capacitor legs gives the size of the voltage steps in the output waveform. One advantage of the flying-capacitor-based inverter is that it has redundancies for inner voltage levels; in other words, two or more valid switch combinations can synthesize an output voltage. Unlike the diode-clamped inverter, the flying-capacitor inverter does not require all of the switches that are on (conducting) be in a consecutive series. Moreover, the flying-capacitor inverter has phase redundancies, whereas the diode-clamped inverter has only line-line redundancies These redundancies allow a choice of charging/discharging specific capacitors and can be incorporated in the control system for balancing the voltages across the various levels In addition to the (m-1) dc link capacitors, the m-level flying-capacitor multilevel inverter will require (m-1) × (m-2)/2 auxiliary capacitors per phase if the voltage rating of the capacitors is identical to that of the main switches. One application proposed in the literature for the multilevel flying capacitor is static var

1) Advantages:

1) Phase redundancies are available for balancing the voltage levels of the capacitors
2) Real and reactive power flow can be controlled.
3) The large number of capacitors enables the inverter to ride through short duration outages and deep voltage sags.

2) Disadvantages:

1) Control is complicated to track the voltage levels for all of the capacitors. Also, pre charging all of the capacitors to the same voltage level and startup are complex.
2) Switching utilization and efficiency are poor for real power transmission.
3) The large numbers of capacitors are both more expensive and bulky than clamping diodes in multilevel diode-clamped converters. Packaging is also more difficult in inverters with a high number of levels

D. Nuetral Point Clamped (NPC) Inverters

NPC converters also known as three-level inverters. Problems of 2-level inverter in high-power. applications. High DC link voltage requires series connection of devices. Difficulty in dynamic voltage sharing during switching. These problems are solved by using NPC inverter or multilevel inverter. The below fig shows the NPC inverter circuit DC link capacitor split to create neutral point 0□Q_{11}, Q_{14} : main device(2-level inverter)□Q_{12}, Q_{13} : auxiliary devices– clamp output potential to neutral point with help of clamping diodes□D10 D10' Apply all PWM techniques NPC inverter operation Consider HEPWM technique to eliminate 2 lowest significant harmonics (5^{th} and 7^{th}) and control fundamental voltage Phase voltage waveform (v_{a0}) and corresponding gate signal Each output potential clamped to neutral potential in off periods of PWM control For positive phase current +ia, Q_{11}, Q_{12} : when v_{a0} positive D_{13}, D_{14} : when v_{a0} negative D_{10}, Q_{12} : at neutral clamping condition For negative phase current -ia, D_{11}, D_{12} : when v_{a0} positive Q_{13}, Q_{14} : when v_{a0} negative O_{13}, D_{10}' : at neutral clamping condition Operation mode gives : 3 levels waveform for phase voltage (v_{a0}) □ +0.5 Vd, 0 , -0.5 Vd Levels of line voltage (v_{ab}) waveform of □ +Vd, -Vd, +0.5 Vd, -0.5 Vd and 0 Prove that each device has to withstand 0.5 V_d voltage D_{10}, D_{10}' conducting : voltage across main device clamped to +0.5 Vd When lower devices conducting : V_d appears across the upper devices in series (devices share 0.5 V_d statically) At any switching, voltage step size across the series string = 0.5 V_d □ permits series connection of devices without exceeding 0.5 V_d rating Each leg has 3 switching states State A : Upper switches ON State B : Lower switches ON State C : Auxiliary switches ON Available switching states = 3^3 = 27 (8 for two-level inverters)

1) Advantages:

1) Allows voltage clamping
2) Improve PWM harmonic quality
3) Based on HEPWM technique, lower significant harmonics of NPC inverter attenuated considerably compared to two-level inverter
4) Can be extended to more voltage levels for higher voltage/power levels

2) Disadvantages

1) Extra devices required
2) Fluctuation of neutral point voltages with finite size of DC link capacitors (voltage level redundancies permits manipulation of PWM signals without diminishing quality)

3) Applications

Multi Megawatt induction /synchronous motor drives for industrial applications

E. Line-Commutated Inverters

In Line-Commutated Inverter (LCI) the commutation process is carried out by the parameters of the utility grid, that is, the reversal of AC voltage polarity and the flow of negative current (or zero current) initiates the commutation process. The LCI in general uses the commutating thyristors as power switching devices, which are semi-controller devices. The gate terminal of the device control the turn-on operation, whereas the turn off cannot be controlled by the same mechanism as it depends on the line current or grid voltage for its turn-off. Thus, if a forced cummutation is necessary, an external circuitry is added to the semi-controlled devices to control the turn-off process as well. For example, an anti-parralel diode is added in the case of half-bridge LCI converter for enabling the process of forced commutation.

F. Self-Commutated Inverter

The Self-Commutated Inverter (SCI) is the fully controlled power-electronic converter. These devices used in the SCI include MOSFET and IGBT. For medium to high power application exceeding 100 kW and low- frequency range of 20 kHz, IGBTs are used. On the other hand, for a high frequency typically in the range of 20-800 kHz and a low power less than 20 kW, MOSFETs are employed. For generating the output voltage waveform and for controlling the SCI, the Pulse Width Modulation (PWM) switching technique is used. For grid-connected inverter applications, high switching frequency is required to allow the reduction in weight of the inverter, reduce the output current and voltage harmonics, and also to decrease the size of the output filter The SCI is a fully controller power electronic converter, thus it controls both inverter output current and voltage waveform. Furthermore, it is highly robust to the utility grid disturbances, suppress the current harmonics and improves the grid power factor. Nowadays, SCI is preferred over LCI for grid-connected PV systems due to the advancement made to the control system for SCI and in addition, due to the evolution of advance switching devices similar to that of the power IGBTs and MOSFETs. The SCI can further be divided in to voltage source converters and current source converters.

G. Voltage Source Inverter

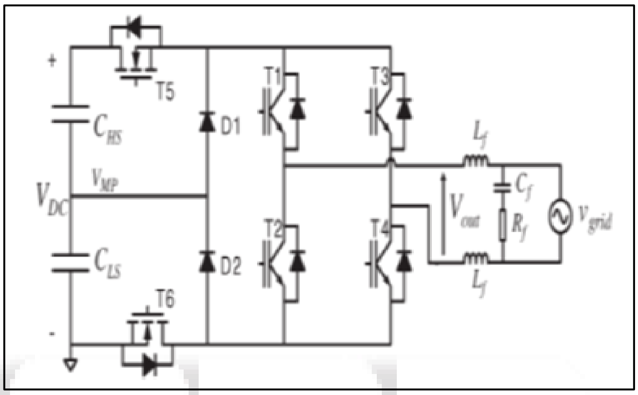
In Voltage Source Inverter (VSI), the DC voltage source is at the input side of converter, thus the polarity of the input voltage remains the same. However, the polarity of the input DC current determines the direction of average power flow through the inverter. At the output side, an AC voltage waveform of a variable width and a constant amplitude can be obtained. A tie-line inductor is used along with the VSI to limit the current flow from the inverter to the utility grid. In case of grid disturbances, the transient current suppression is possible with CCM and a high- power factor can be acquired by simple control structure that is why inverters with the CCM are extensively utilized in grid-connected PV systems. Thus, the preferred inverter for a grid-connected PV system is the VSI operated in current control mode.

1) Proposed Multi Level Convertor

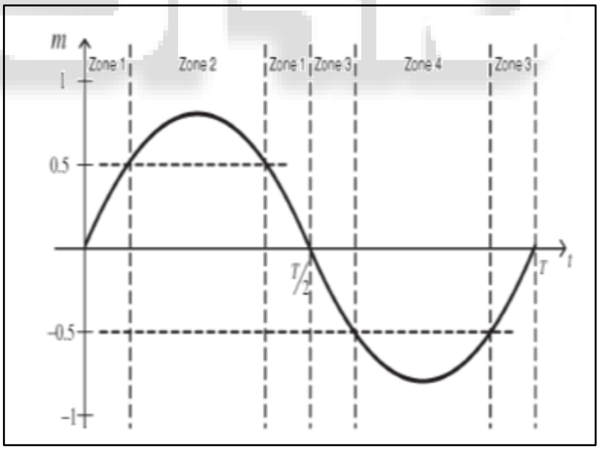
Multilevel converter allow to reduces the harmonic content of the converter output voltage, allowing the use of smaller and cheaper output filters. Moreover, these converters are usually characterized by a strong reduction of the switching voltages across the power switches, allowing the reduction of switching power losses and electromagnetic interference. The cascaded full-bridge allows multiple PWM strategies.

IV. PROPOSED MULTI -LEVEL SINGLE-PHASE SOLUTION

This converter architecture, known as the H6 Bridge, was originally developed in, in combination with a suitable PWM strategy, in order to keep constant the output common-mode voltage in case of a transformer less inverter for photovoltaic applications. With the same purpose, another PWM strategy for the H6 bridge was developed in and. In this paper, this converter structure is used to obtain a five-level grid-connected converter for single-phase applications. Fig. Multilevel converter allow to reduces the harmonic content of the converter output voltage, allowing the use of smaller and cheaper output filters Moreover, these converters are usually characterized by a strong reduction of the switching voltages across the power switches, allowing the reduction of switching power losses and electromagnetic interference. The cascaded full-bridge allows multiple PWM strategies, i.e., carrier-based modulations or space-vector approaches. In the field of carrier-based PWM The proposed converter is shown in Fig. 3. This converter architecture, known as the H6 Bridge, was originally developed in, in combination with a suitable PWM strategy, in order to keep constant the output common-mode voltage in case of a transformer less inverter for photovoltaic applications. With the same purpose, another PWM strategy for the H6 bridge was developed in and. In this paper, this converter structure is used to obtain a five-level grid-connected converter for single-phase applicationIn steady-state conditions, due to the low voltage drop across the inductance Lf of the output filter, the output voltage of the converter has a fundamental component very close to the grid voltage. The frequencies of these two voltages are identical, whereas the amplitude and their phase displacement are only slightly different. As a consequence, the shape of the modulation index m of the power converter is very similar to the grid voltage waveform. The output voltage of the converter can be written as Vout = m Vdc. Depending on the modulation index value, the power converter will be driven by different PWM strategies. As a matter of fact, it is possible to identify four operating zones (see Fig. 4), and for each zone, the output voltage levels of the power converter will be different, as shown in Table I. With reference to the schematic in Fig. 3, the behaviour of the proposed solution is showfor a whole period of the grid voltage, i.e., of the modulation index. During the positive semi period the transistors T1 and T4 are ON and T2 and T3 are OFF. In Zone 1, T5 is OFF and T6 commutates at the switching frequency, whereas in Zone 2 T5 commutates at the switching frequency and T6 is ON. During the negative semi period the full-bridge changes configuration, with T1 and T4 OFF and T2 and T3 ON. With similarity to Zone 1 and 2, in Zone 3 T5 commutates while T6 is OFF, and in Zone 4 T5 in ON and T6 commutates commutates



A. Modulation index waveform in steady-state conditions and definition of the four different PWM zones



Grid-tie inverters are also designed to quickly disconnect from the grid if the utility grid goes down. This is an NEC requirement that ensures that in the event of a blackout, the grid tie inverter will shut down to prevent the energy it transfers from harming any line workers who are sent to fix the power grid. Properly configured, a grid tie inverter enables a home owner to use an alternative power generation system like solar or wind power without extensive rewiring and without batteries. If the alternative power being produced is insufficient, the deficit will be sourced from the electricity grid. The simulation design of proposed converter connected to grid is shown below in fig. The closed loop system with proposed unipolar PWM gate signal generation is provided. The main advantage of the proposed system is with the balancing of the split capacitor voltage according to the requirement of the active power need is like demand verses supply with available power quantity check. The figure is the gate pulse generation using uni-polar pulse width modulation way of pulse generation i.e. reference wave verses carrier pulse of 10 kHz frequency comparison. The output voltage of the proposed five-level converter based on a full-bridge converter with two added power switches and two diodes connected to the midpoint of the dc link obtained in the Simulink model is ±400 peak-peak and the output waveforms The THD analysis is also compared for the simulation which is shown in Fig. 4.5. The total harmonic distortion in grid currents is 4.72% for the selected signals of five obtained using the FFT analysis

V. Conclusion

This paper has dealt with MULTI -level solution for single-phase grid-connected converters. The PWM strategy was chosen in order to obtain the minimum number of commutations to maximize efficiency. The converter topology uses the midpoint voltage of the dc link to provide two or more output voltage levels, decreasing switching power losses and EMI. The proposed solution was compared with the state of the art of multi-level topologies in terms of theoretical semiconductor power losses. As a matter of fact, the PWM strategy developed allows the use of MOSFETs as active devices, making it possible to reduce the conduction power losses. Moreover, an effective balancing control (i.e., MVC) was implemented. It is important to note that the multi level output voltage is guaranteed only with a unity power factor operations; otherwise, the converter can output only three voltage levels, thus increasing THD and switching loss Simulations results showed the feasibility of the proposed converter architecture and the ability of the MVC to compensate for system asymmetries. Experimental results showed the effectiveness of the proposed solution in terms of output current quality and efficiency multi level full bridge MC for single-phase grid connected converters. the feasibility of the proposed converter architecture and the ability of the MVC to compensate for system asymmetries. Experimental results showed that the effectiveness of the proposed solution in terms of THD is good about 4.7% only

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