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"A 4 Switch Multi – Stage Single Phase CUK Inverter"

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Abstract

Renewable energy sources such as solar photovoltaic (PV) and emphasis on storage systems such as fuel cell (FC) in the current energy scenario are faced with the ubiquitous challenge of conditioning the dc output into grid quality ac power. Inverter circuits, which execute this function, boost and invert the variable output dc voltages from these and cost advantages. This problem can be mollified by using bipolar pulse width modulation (PWM) technique. But this brings problems such as large grid current ripple, high harmonic content, and poor efficiency of the inverter. This paper presents a new single-stage, single-phase, buck boost inverter, with both input and output ports sharing a common terminal. This eliminates the problem of common mode voltage in grid connected PV applications, which helps to

increase productive life of PV systems. It uses four switches and two inductors, which ensures minimum part count among reported topologies of comparable rating. Design of the energy storage elements, loss and efficiency calculations have been presented. A 300 W, 110 V, 50 Hz prototype was developed based on the developed design and experimental results, in standalone and grid-connected mode, show excellent steady-state and transient performance

Key words: Renewable energy, mollified, poor efficiency, productive life

CHAPTER 1

1.1 INTRODUCTION

Renewable energy sources such as solar photovoltaic (PV) and emphasis on storage systems such as fuel cell (FC) in the current energy scenario are faced with the ubiquitous challenge of conditioning the dc output into grid quality ac power. Inverter circuits, which execute this function, boost and invert the variable output dc voltages from these PV or FC devices to ac voltages with tightly controlled magnitude and frequency for interfacing with utility grid. PV inverter topologies, without any galvanic isolation, are due to their size and cost advantages. However, these non isolated inverters are associated with problems such as dc current injection to the grid and common mode leakage current (CMLC), the latter impairing PV panel life .Half or full Bridge inverters are the most common topologies employed for grid-connected PV systems, though these suffer from the problem of CMLC. This problem can be mollified by using bipolar pulse width modulation (PWM) technique. But this brings problems such as large grid current ripple, high harmonic content, and poor efficiency of the inverter.

1.2 LITERATURE REVIEW

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1.Abramovitz, A.; Ben Zhao; Smedley, K.M., "High-Gain Single-Stage Boosting Inverter for Photovoltaic Applications," IEEE Transactions on Power Electronics, This paper introduces a high-gain single-stage boosting inverter (SSBI) for alternative energy generation. As compared to the traditional two-stage approach, the SSBI has a simpler topology and a lower component count. One cycle control was employed to generate ac voltage output. This paper presents theoretical analysis, simulation and experimental results obtained from a 200 W prototype. The experimental results reveal that the proposed SSBI can achieve high dc input voltage boosting, good dc-ac power decoupling, good quality of ac output waveform, and good conversion efficiency.

2.W. Li, Y. Gu, H. Luo, W. Cui, X. He and C. Xia, "Topology Review and Derivation Methodology of Single-Phase Transformer less Photovoltaic Inverters for Leakage Current Suppression," in IEEE Transactions on Industrial Electronics, Single-phase voltage source transformer less inverters have been developed for many years and have been successful commercial applications in the distributed photovoltaic (PV) grid-connected systems. Moreover, many advanced industrial topologies and recent innovations have been published in the last few years. The objective of this paper is to classify and review these recent contributions to establish the present state of the art and trends of the transformer less inverters. This can provide a comprehensive and insightful overview of this technology. First, the generation mechanism of leakage current is investigated to divide the transformer less inverters into asymmetrical inductor-based and symmetrical inductor-based groups. Then, the concepts of dc-based and ac-based decoupling networks are proposed to not only cover the published symmetrical inductor-based topologies but also offer an innovative strategy to derive advanced inverters. Furthermore, the transformation principle between the dc-based

and ac-based topologies is explored to make a clear picture on the general law and framework for the recent advances and future trend in this area. Finally, a family of clamped highly efficient and reliable inverter concept transformer less inverters is derived and tested to offer some excellent candidates for next-generation high-efficiency and cost-effective PV grid-tie inverters.

3.Yu Tang; Xianmei Dong; Yaohua He, "Active Buck-Boost Inverter," IEEE Transactions on Industrial Electronics, The voltage range of a renewable energy source, such as the photovoltaic cell, is influenced by the environment, light, temperature, and so on. The power conditioning system should adapt to the wide input voltage and have buck-boost ability. Based on the structure of the "ac/ac unit," this paper presents a novel active buck-boost inverter (ABI) topology suitable for wide-range input, which can realize buck-boost conversion in a quasi-single-stage inverter. The ac/ac unit composed of active switches is utilized to perform voltage boost without introducing additional passive elements, which is in favour to the system power density and efficiency. Operational analysis in buck and boost modes are presented, and the modulation strategy applied in the ABI is also developed. Simulation and experimental results are presented to verify the operational principle and its modulation strategy.

4.Yu Tang; Yaohua He; Xianmei Dong, "Active Buck-boost inverter with coupled inductors," in Energy Conversion Congress and Exposition (ECCE), 2014 IEEE , Due to the duty cycle restriction, the boost ratio of the conventional Boost converter is limited. In order to get a constant output voltage, the input voltage cannot be too low. This paper presents an active Buck-Boost inverter with coupled inductors. The operation modes, voltage stress of the switches and the voltage gain of the circuit are analyzed. By properly setting the turns ratio of the coupled inductors, the inverter can generate AC voltage whose peak value is much higher than the input voltage. When the input voltage is very high, the inverter can work in buck mode to get a constant output voltage. The voltage gain of the Boost AC/AC part based on coupled inductors can be constant if the duty ratio is corrected timely. Simulation and experimental results are presented to verify the proposed inverter can achieve buck-boost inversion with wide range of input voltage.

5.Chamarthi, P.; Rajeev, M.; Agarwal, V., "A novel single stage zero leakage current transformer-less inverter for grid connected PV systems," IEEE 42nd Photovoltaic Specialist Conference (PVSC), In this paper a single stage, single phase transformer-less inverter with zero leakage current is proposed for grid connected systems with PV as a source. The proposed inverter has inherent buck-boost capability and also has common ground between the negative terminal of the PV array and the grid neutral. This ensures low dc input voltage and zero leakage current through the parasitic capacitance of the PV array. The modes of operation of the inverter, its design and the simulation results are presented in detail. Losses and efficiency of the proposed inverter are compared with the existing transformer-less topologies and results are presented. Experimental validation is done and the results are included.

1.3 OBJECTIVE

The presented topology has one common terminal in input and output ports which eliminates common mode leakage current problem in grid connected PV applications. Although it uses four switches, its operation is bi-modal and only two switches receive high frequency PWM signals in each mode.

1.4 ORGANISATION OF PROJECT

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This thesis has been broadly divided in to 4 chapters. The chapter 1 being introduction, chapter 2 is a system description and operation of Solar Photo Voltaic Array. Chapter 3 hardware description and implementation, chapter 4 is on conclusion of proposed system in appendix the simulation model are presented. Finally the references for Solar Photo Voltaic Array.

1.5. EXISTING SYSTEM

Half or full bridge inverters are the most common topologies employed for grid connected PV systems, though these suffer from the problem of CMLC. This problem can be mollified by using bipolar pulse width modulation (PWM) technique. But this brings problems like large grid current ripple, high harmonic content and poor efficiency of the inverter [2]. This problem was proposed to be resolved by disconnecting positive and negative terminals of PV from free-wheeling path during zero output voltage level generation [3]. Networks that perform this task are classified in two categories based on the method of decoupling, i.e. dc or ac. The dc-based decoupling configurations incorporate the decoupling network in the dc side to provide the decoupled freewheeling path, examples being H5 [4], H6 [5]. Solutions like HERIC [6], on the other hand, include the decoupling network in the ac side to provide the decoupled freewheeling path. However, due to the presence of junction capacitance of switches, a high frequency common mode voltage is generated. Moreover, there is a chance of high frequency resonance during freewheeling mode [3]. A class of reported topologies share one common terminal between PV and grid, which ensures zero CMLC. In [7], one such topology is proposed with buck boost capability. But since it uses two input voltage sources for positive and negative halves of output voltage, this leads to underutilization of PV panel. In [8] and [9], differential connection of two buck boost and

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boost converters were proposed. These converters have simple configuration with four active switches suitable for renewable energy application. However, hard switching of all the devices at high frequency reduces the efficiency and increases its affinity towards EMI problems. The inductors in [8] are replaced by coupled inductor pairs in [10]. This provides high voltage gain capability but the problems of its parent topology persist. Topologies like [4]- [6], [11]- [14], which operate only in buck mode, require high input voltage for grid connected applications.

1.6. PROPOSED SYSTEM:

This paper proposes a CUK converter based single-phase inverter with only four switches, two inductors and two capacitors. It also shares a common terminal between the input and output ports, which practically eliminates CMLC problems and reduces possibilities of consequent panel degradation. It is basically a combination of two dc-dc buck-boost converters operating sequentially to generate an ac voltage output. Principle of operation and AC voltage generation is explained with the assistance of modal equivalents for both polarities of the ac voltage. Current programmed mode (CPM) based controller is designed to achieve the desired control constraints. Finally, experimental results under different load conditions and in grid connected mode are showcased to validate the performance of the inverter.

CHAPTER 2

SYSTEM DESCRIPTION

2.1. SOLAR PHOTO VOLTAIC ARRAY

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Solar energy is available 365 days and energy produced from it (both heat and light) can be used to power homes. In most parts of India the energy that can be harnessed on any given day, exceeds total energy requirements of a home. During summer the energy from sun light is in the range of 1000W pwe sq meter, which means that a house with a terrace area of 100 sq mts (10mts X 10mts) can produce energy equivalent to 100 Kw. This is possible only if we harness all the light energy falling on our roof top. It has high efficiency and exceeds the total energy requirements. The initial solar Photovoltaic experimentation were done by French physicist Antoine-Cesar Becquerel in 1839. During his research he observed that he can produce electric current by shining light on an electrolytic cell with two electrodes. The German scientist Heinrich Hertz and others observed the PV effect ? the conversion of light into electricity ? in solids during the 1870's, and the first primitive PV cells were built in the 1800s, with about 1-2 percent efficiencies. In 1954, Bell Labs in the U.S. introduced the first solar photovoltaic device that produced a useful amount of electricity, and by the late 1950s solar cells were being used in small-scale scientific and commercial applications, especially for the U.S. space program. Today PV cells are manufactured in many parts of the world including in India. At this time industries have achieved a PV cell efficiency of 18% for mono crystalline cells. There is increased effort in research labs to increase this efficiency to 40%. PV modules generate direct current (DC) electricity and has better efficiency in it. Photovoltaic, or PV for short, is a technology in which light is converted into electricity using photovoltaic modules that have no moving parts, operate quietly without emissions, and are capable on long-term use with minimal maintenance. Crystalline silicon, the same material commonly used by the semiconductor industry, is the material used in 94 % of all PV modules today. PV modules generate direct current (DC) electricity. For residential use, the current is fed through an inverter to produce alternating current (AC) that can be used to power the home appliances. The main barrier to widespread use of this technology is the initial high equipment cost. PV technology has been advancing over the last few decades and prices have steadily declined

2.1.1 PV Cell

A solar cell is made by creating a sandwich of 2 sets of silicon materials, which are sensitive to sun light. These two layers are called P and N junction layers and will generate electricity when exposed to sun light. Solar cells are characterized by maximum open circuit voltage (Voc) at zero output current and a short circuit current (Isc) at zero output voltage. Power generated by any PV cell cal be calculated (in watts) using the equation P (power) = V (voltage) x I (current)

Solar PV panel is an array of multiple cells. Each PV cell consists of a positive and negative terminals, and will produce a predefined voltage (0.5 to 1.5 V) and current when exposed to sun light. These cells are connected in series to increase total voltage of a panel. If we arrange the cells in parallel, then voltage will remain same and total current output will increase. For example, a 12 V Panel (Module) will have 36 cells connected in series and a 24 V Panel (Module) will have 72 cells connected in series.

There are 3 types of solar PV installations:

O Solar PV roof top installation with battery backup

O Solar PV Grid-Tie installations

O Solar PV MW scale installation for power plants

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To enable a solar home, we can deploy PV modules of capacity ranging from 40W to 120W facing south on roof tops and balconies. Typical roof tops receive maximum sunlight for 8 hours and that can be harnessed to power our home.

2.1.2 Solar PV roof top installation with battery backup

Solar PV modules produce DC power and this can be stored directly in batteries. This type of a setup is known as PV battery backup systems. One of the core components of a battery backup system is a ?charge controller?, which controls the voltage and current from a PV module in accordance with the battery system. A charge controller is required to ensure that the voltage of the PV module does not exceed maximum voltage supported by batteries. Also, the controllers will ensure that the power from battiery storage is not passed back to the panels during night. If there is a power surge from batteries to the panels, then it will damage the solar cells. A typical 100W PV system can generate an average of 600W of power on a sunny day. This can power six 15W lights and one 60W fan for 4 hours time.

2.2. CUK CONVERTER

The **Cuk converter** (pronounced Chook; sometimes incorrectly spelled as **Cuk**, **Čuk** or **Cúk**) is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy. Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated Cuk is typically also inverting, and can be lower or higher than the input. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor. It is named after Slobodan the Cuk of Cuk of California Institute of Technology, who first presented the design.

2.2.1 NON-ISOLATED CUK CONVERTER

There are variations on the basic Cuk converter. For example, the coils may share single magnetic core, which drops the output ripple, and adds efficiency. Because the power transfer flows continuously via the capacitor, this type of switcher has minimized EMI radiation. The Cuk converter allows energy to flow bidirectionally by using a diode and a switch.

Notches are introduced in the pole voltage waveform at pre-computed angles to selectively eliminate a particular harmonic from the phase voltage. Selective harmonic elimination (SHE) requires intensive offline as well as online computation, which in many applications is a limitation to be implemented. Moreover, notches introduced in She does not allow the six-step operation of the two-level inverter, limiting the speed range of the drive. Inverters switching dodecagonal (12-sided polygon) voltage space vectors have been shown to completely eliminate the fifth and seventh-order harmonics from the phase voltage even for extreme 12-step operation. The works in have proposed several schemes for realization of multilevel dodecagonal voltage space vectors for high voltage, high power induction motor drives. However, multiple dc supplies are used in those topologies which add up to the size of the inverter for voltage generation at specific ratios. The work in shows a condition when additional dc supplies can be replaced by capacitors for implementation of dodecagonal voltage space vectors for open-end winding configuration of IM drives. Hence, use of multiple dc supplies is avoided in for open-end winding induction motor drives.

2.2.2 OPERATING PRINCIPLE:

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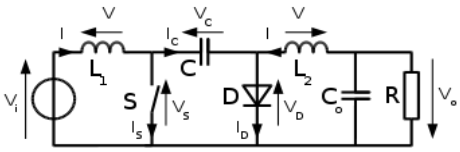

Fig 2.2: Schematic of a non-isolated Cuk converter.

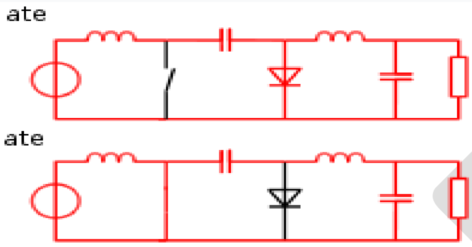

Fig 2.2(A): The two operating states of a non-isolated Cuk converter.

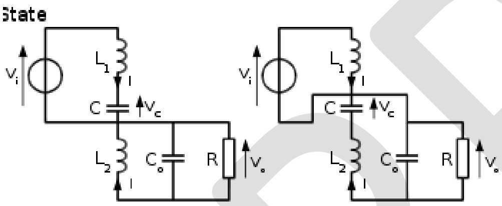

Fig 2.2(B): The two operating states of a non-isolated Cuk converter.

In this figure, the diode and the switch are either replaced by a short circuit when they are on or by an open circuit when they are off. It can be seen that when in the off-state, the capacitor C is being charged by the input source through the inductor L_1. When in the on-state, the capacitor C transfers the energy to the output capacitor through the inductance L_2.

A non-isolated Cuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in figure 1. It is an inverting converter, so the output voltage is negative with respect to the input voltage.

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The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode (see figures 2 and 3). It shows the flow direction of the communication in the desired format. The two inductors L_1 and L_2 are used to convert respectively the input voltage source (V_i) and the output voltage source (C_o) into current sources. At a short time scale an inductor can be considered as a current source as it maintains a constant current. This conversion is necessary because if the capacitor were connected directly to the voltage source, the current would be limited only by the parasitic resistance, resulting in high energy loss. Charging a capacitor with a current source (the inductor) prevents resistive current limiting and its associated energy loss.

As with other converters (buck converter, boost converter, buck–boost converter) the Cuk converter can either operate in continuous or discontinuous current mode. However, unlike these converters, it can also operate in discontinuous voltage mode (the voltage across the capacitor drops to zero during the commutation cycle).

2.2.3 CONTINUOUS MODE

In steady state, the energy stored in the inductors has to remain the same at the beginning and at the end of a commutation cycle. The energy in an inductor is given by:

$$E = \frac{1}{2}LI^2$$

This implies that the current through the inductors has to be the same at the beginning and the end of the commutation cycle. As the evolution of the current through an inductor is related to the voltage across it:

$$V_L = L\frac{dI}{dt}$$

it can be seen that the average value of the inductor voltages over a commutation period have to be zero to satisfy the steady-state requirements. The converter operates in on state from t=0 to t=D·T (D is the duty cycle), and in off state from D·T to T (that is, during a period equal to (1-D)·T). The average values of V_{L1} and $V_{L2}$are therefore: It can be seen that this relation is the same as that obtained for the buck–boost converter.

2.4 POWER INVERTER

An Inverter is basically a converter that converts DC-AC power. Inverter circuits can be very complex so the objective of this method is to present some of the inner workings of inverters without getting lost in some of the fine details. The word „inverter‟ in the context of power electronics denotes a class of power conversion circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. Even though input to an inverter circuit is a dc source, it not uncommon to have this dc derived from an ac source such as utility ac supply. Thus, for example, the primary source of input power may be utility ac voltage supply that is „converted, to dc by an ac to dc converter and then „inverted‟ back to ac using an inverter. Here, the final output may be of a different frequency and magnitude than the input ac of the utility supply [1]. Typical Applications such as Un-interruptible Power Supply (UPS), Industrial (induction motor) drives, Traction, HVDC.

Multi-Level Inverters (MLI).Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application. Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level [26]. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations [65]. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The concept of multilevel converters has been introduced since 1975. The term multilevel began with the three-level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected.

Although multilevel inverters were basically developed to reach higher voltage operation, before being restricted by semiconductor limitations, the extra switches and dc sources (supplied by dc-link capacitors) could be used to generate different voltage levels, enabling the generation of stepped waveform with less harmonic distortion, reducing dv/dt and common-mode voltages. These characteristics have made them popular for high-power medium-voltage applications but the large number of semiconductor switches in these inverters, result in a reduction both of the reliability and efficiency of the drive. Therefore,

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many power electronic researchers have made great effort in developing multilevel inverters with the same benefits and less number of semiconductor devices.

IMPORTANCE OF MULTILEVEL INVERTER

The importance of multilevel inverters has been increased since last few decades. These new types of inverters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum and with less Total Harmonic Distortion (THD). Numerous topologies have been introduced and widely studied for utility of non-conventional sources and also for drive applications. Amongst these topologies, the multilevel cascaded inverter was introduced in Static VAR compensation and in drive systems.The Multi-Level Inverter [MLI] is a promising inverter topology for high voltage and high power applications. This inverter synthesizes several different levels of DC voltages to produce a stepped AC output that approaches the pure sine waveform. It has the advantages like high power quality waveforms, lower voltage ratings of devices, lower harmonic distortion, lower switching frequency and switching losses, higher efficiency, reduction of dv/dt stresses etc. It gives the possibility of working with low speed semiconductors in comparison with the two-level inverters.

2.5 HYBRID AND ASYMMETRIC MULTI LEVEL INVERTERS

The topologies mentioned before are typically called “symmetric multilevel inverters”, because the dc link capacitors have the same voltages [66]. Asymmetric multilevel inverters have the same topology as symmetric ones; the only difference is in the dc link voltages. However, the asymmetric multilevel inverters can generate higher number of output voltage levels with the same number of semiconductor switchers in symmetric ones. Therefore, in these inverters the efficiency is improved by using less semiconductor devices [32] and more

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complicated switching algorithms; while, output filters are very small or even removed. One leg of an asymmetric multilevel inverter is shown in Fig. Since the different cells of asymmetric inverter work with different dc link voltages and different switching frequencies, it is more efficient to use appropriate semiconductor devices in different cells. For example, using IGCT integrated (Gate-Commutated Thyristor) switches which are suitable for high voltages low frequency applications, in higher voltage cells decreases the power losses. These inverters are called "hybrid multilevel inverters [31]". A hybrid inverter which uses several types of semiconductors has many advantages Active power is transferred by semiconductors with low losses and high reliability and the output harmonic spectrum is improved by other semiconductors.

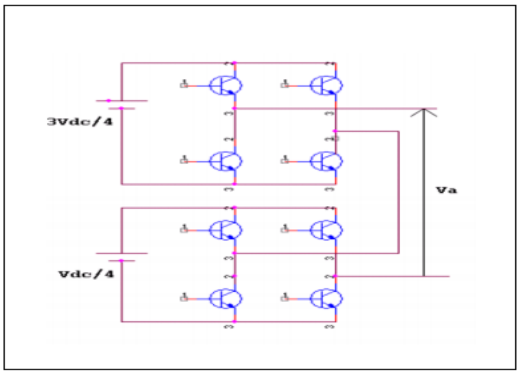

Fig2.9:Asymmetric multilevel inverter.

2.5.1 SYMMETRIC MULTI-LEVEL INVERTERS

Symmetric multilevel inverters are characterized by the fact that the voltages across the different dc link capacitors are equal[59], importance to mention that the switches applied in the symmetric inverter have the same off-state voltage.

1.4 Different Switching Methods to Reduce Harmonic Distortion

Together with the converter topology, great effort has been addressed from the research community in investigating different switching methods for these inverters. This is mainly due to the fact that the adopted switching strategy impacts the harmonic spectrum of output waveforms as well as the switching and the conduction power losses. In case of multilevel converters, three switching methods are usually used.

2.5.2 ADVANTAGES OF CMLI

1. The regulation of the DC buses is simple.
2. Modularity of control can be achieved. Unlike the diode clamped and capacitor clamped inverter where the individual phase legs must be modulated by a central controller, the full-bridge inverters of a cascaded structure can be modulated separately.
3. Requires the least number of components among all multilevel converters to achieve the same number of voltage levels.
4. Soft-switching can be used in this structure to avoid bulky and lossy resistor capacitor-diode snubbers. These advantages are our motivation to work on the harmonic analysis of the cascaded Three-level, Five-level, Seven-level, Nine level &Twenty seven level inverters.

2.5.3 CASCADED H-BRIDGES MLI (MULTI LEVEL INVERTER)

Cascaded H-Bridge (CHB) configuration has recently become very popular in high-power AC supplies and adjustable-speed drive applications. A cascade multilevel inverter consists of a series of H-bridge (single-phase full bridge) inverter units in each of its three phases. Each H-bridge unit has its own dc source, which for an induction motor would be a battery unit, fuel cell or solar cell.vin such a way each and every SDC (separate D.C. source) is associated with a single-phase full-bridge inverter. The ac terminal voltages of different level inverters are connected in series. Through different combinations of the four switches, S1-S4, each converter level can generate three different voltage outputs, $+v_{dc}$, $-v_{dc}$ and zero.

The AC outputs of different full-bridge converters in the same phase are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs. Note that the number of output -phase voltage levels is defined in a different way from those of the two previous converters (i.e. diode clamped and flying capacitor). In this topology, the number of output-phase voltage levels is defined by m= 2N+1, where N is the number of DC sources. A seven-level cascaded converter, for example, consists of three DC sources and three full bridge converters. Minimum harmonic distortion can be obtained by controlling the conducting angles at different converter levels. Each H- bridge unit generates a quasi-square waveform by phase shifting its positive and negative phase switching timings. Each switching device always conducts for 180° (or half cycle) regardless of the pulse width of the quasi-square wave.

This switching method makes all of the switching devices current stress equal. In the motoring mode, power flows from the batteries through the cascade inverters to the motor. In the charging mode, the cascade converters act as rectifiers, and power flows from the charger (ac source) to the batteries. The cascade converters can also act as rectifiers to help recover the kinetic energy of the vehicle if regenerative braking is used. The cascade inverter can also be used in parallel HEV configurations. This new converter can avoid extra clamping diodes or voltage balancing capacitors.

The combination of the 180° conducting method and the pattern-swapping scheme make the cascade inverter's voltage and current stresses the same and battery voltage balanced. Identical H-bridge inverter units can be utilized, thus improving modularity and manufacturability and greatly reducing production costs. Battery-fed cascade inverter prototype driving an induction motor at 50% and 80% rated speed both the voltage and current are almost sinusoidal. Electromagnetic interference (EMI) and common mode voltage are also much less than what would result from a PWM inverter because of the inherently low dv/dt and sinusoidal voltage output.

2.6 TOTAL HARMONICS DISTORTION (THD)

Harmonic currents, generated by non-linear electronic loads, increase power system heat losses and power bills of end-users. These harmonic-related losses reduce system efficiency, cause apparatus overheating, and increase power and air conditioning costs. As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation. Harmonic currents can have a significant impact on electrical distribution systems and the facilities they feed. It is important to consider their impact when planning additions or changes to a system. In addition, identifying the size and location of non-linear loads should be an important part of any maintenance, troubleshooting and repair program [2].

2.6.1 SOURCES OF HARMONIC DISTORTION

Non-linear equipment or components in the power system cause distortion of the

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current and to a lesser extent of the voltage. These sources of distortion can be divided in three groups:

1. Loads
2. The power system itself (HVDC, SVC, transformers, etc)
3. The generation stage (synchronous generators)

Subdivision can also be made regarding the connection at different voltage levels. In general, loads can be considered connected at lower voltage levels, the power system exists at all voltage levels and the generation stage at low and medium voltage levels. The dominating distortion-producing group, globally, are the loads. At some locations HVDC-links, SVC's, arc furnaces and wind turbines contributes more than the other sources. The generation stage can, during some special conditions, contribute to some voltage distortion at high voltage transmission level.

The characteristic behavior of non-linear loads is that they draw a distorted current waveform even though the supply voltage is sinusoidal. Most equipment only produces odd harmonics but some devices have a fluctuating power consumption, from half cycle to half cycle or shorter, which then generates odd, even and inter harmonic currents. The current distortion, for each device, changes due to the consumption of active power, background voltage distortion and changes in the source impedance.

2.6.2 HARMONICS IN ELECTRICAL SYSTEMS

One of the biggest problems in power quality aspects is the harmonic contents in the electrical system. Generally, harmonics may be divided into two types: 1) voltage harmonics,

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and 2) current harmonics. Current harmonics is usually generated by harmonics contained in voltage supply and depends on the type of load such as resistive load, capacitive load, and inductive load. Harmonic currents can produce a number of problems, namely: Equipment heating, Equipment malfunction, Equipment failure, Communications interference, Fuse and breaker disoperation Process problems, Conductor heating. Both harmonics can be generated by either the source or the load side.

Harmonics generated by load are caused by nonlinear operation of devices, including power converters, arc-furnaces, gas discharge lighting devices, etc. Load harmonics can cause the overheating of the magnetic cores of transformer and motors [54]. On the other hand, source harmonics are mainly generated by power supply with non-sinusoidal voltage waveform. Voltage and current source harmonics imply power losses, Electro Magnetic Interference (EMI) and pulsating torque in AC motor drives. Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. By applying Fourier transformation, these components can be extracted. The frequency of each harmonic component is an integral multiple of its fundamental.

2.6.3 CURRENT DISTORTION

On three-phase star systems, current distortion causes higher than expected currents in shared neutrals. A shared neutral is one that provides the return path for two or three-phases. Currents as high as 200% of the phase conductors have been seen in the field. This large level of current can easily burn up the neutral creating an open neutral environment. This open neutral creates voltage swells and overvoltage. These voltage conditions easily destroy equipment, particularly power supplies.

Another indirect problem introduced by current distortion is called resonance. Certain current harmonics may excite resonant frequencies in the system. This resonance can cause extremely high harmonic voltages, possibly damaging equipment. There is one additional comment about current distortion. When the current is non-sinusoidal, our conventional ammeters and voltmeters will not respond accurately. To accurately measure currents that are harmonically distorted, use a True- RMS meter. This applies equally to distorted voltages.

2.7 THE PROTOBOARD

The protoboard allows you to assemble circuits by placing components into the holes, officially called contact points but usually just points, which are connected internally in various patterns.

2.7.1 MEASURING RESISTANCE

1.1 Use the resistor color code scheme on page 6 to identify the resistance of the given resistor.

1.2 Use the multimeter to find the resistance of the above resistor.

2.7.2 MEASURING CURRENT AND VOLTAGE

Connect the resistor in 1.1, the DC power supply (used as a constant voltage source) and the multimeter using the protoboard as shown below. Use red and black banana leads to connect the power supply to the binding posts and red and black wire from the binding posts to the contact points. Assemble a coaxial cable with a BNC/banana adapter on one end and a BNC/minigrabber on the other. Insert the banana plug into the current measuring connectors on the multimeter. Place the resistor on the protoboard by pressing one lead into a point in a horizontal row and select another row for the other lead. Clip the red minigrabber to the red wire coming from the positive power binding post. Clip the black minigrabber to one of the resistor leads. Use a black wire to connect the other resistor lead to the binding post used for power supply common.

When using a multimeter to measure current the meter must be connected in series within the circuit, as shown below. This is because current must flow through the meter just like water must flow through the water meter in a house to determine how much water is used in a year. When ever you make a measurement you want to make sure the measuring device, in this case an ammeter, does not effect the actual measurement. When measuring current the internal resistance of the meter is very nearly zero ohms. This makes sense because you wish to measure all the current flowing through the circuit and if you meter reduces the current flow then your measurement is not accurate.

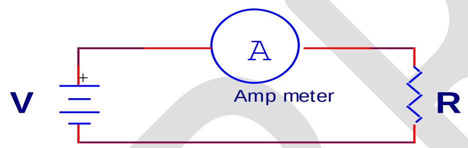

Fig2.10:Current Measuring circuit

When measuring voltage the meter is connected in parallel with the circuit. This is because voltage can be considered as electrical pressure. A pressure gage connected to a water pipe is closed at one end. Therefore, its resistance to flow is infinite since no water flows through it at all. A meter that measures voltage has a similar characteristic in that the input impedance of voltmeter is very large, typically 10 megaohms or larger. This is considered large enough to not allow current to flow through the meter when measuring voltage and thereby not influencing the measurement. If current flowed through a volt meter when making a voltage measurement then the voltage measured in the circuit would be less than the actual voltage if the meter were not there since the current in the circuit which causes the voltage to be produced would be reduced by the amount going through the meter.

CHAPTER-III

RESULT & CONCLUSION

SIMULATION CIRCUIT A 4-SWITCH MULTI-STAGE SINGLE-PHASE CUK INVERTER

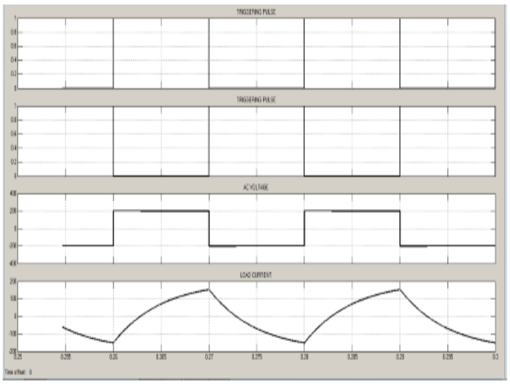

Fig 2.17: INVERTER OUTPUT

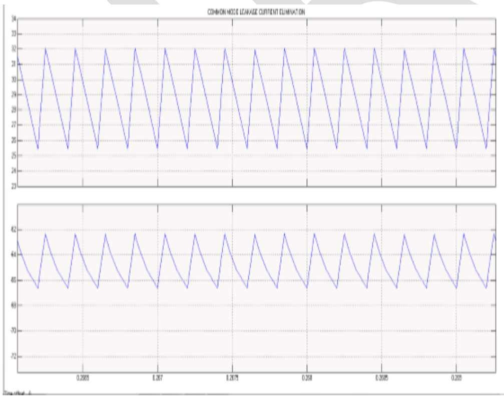

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Fig 2.18: COMMON MODE LEAKAGE CURRENT ELIMINATION

CONCLUSION

This paper presents a new single-stage, single-phase, buck boost inverter, with both input and output ports sharing a common terminal. This eliminates the problem of common mode voltage in grid connected PV applications, which helps to increase productive life of PV systems. It uses four switches and two inductors, which ensures minimum part count among reported topologies of comparable rating. Its bi-modal operation principle is explained in detail through steady-state and dynamic analyses. A two-loop controller structure is used, with the inner current loop realized by CPM. Outer loop design is based on a minimal constraint on phase-margin, applied to the set of small-signal plants derived from the large-signal inverter model. All controller design aspects are presented in detail. Power decoupling at low input voltage side requires a large capacitor, which adds to the overall size and slightly increases cost. Design of the energy storage elements, loss and efficiency calculations have been presented. A 300 W, 110 V, 50 Hz prototype was developed based on the developed design and experimental results, in standalone and grid-connected mode, show excellent steady-state and transient performance

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