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TRANSFORMER LESS INVERTER WITH ZETA CONVERTER TO REDUCE LEAKAGE CURRENT IN GRID CONNECTED PV SYSTEMS

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Abstract— A three-phase grid-connected PV topology (named H8) is proposed to address the leakage current issue. AC common-mode voltage and earth leakage current causes problems in the transformerless grid-connected photovoltaic (PV) systems. It increases the distortion of the current injected into the grid and the losses, also it generates unwanted radiated and conducted electromagnetic interference (EMI). The voltage source full-bridge (FB) inverter, which is also known as B6-type converter is widely used for three-phase PV systems. The B6-type inverter suffers from the leakage current, which limits its application to transformerless grid-connected PV systems. The proposed H8 topology reduces the leakage current as well as common-mode voltage variations through the separation of the PV array from the grid during the zero voltage states. Through analysis, simulations, and experimental results, a comparison between the proposed topology and the conventional B6-type topology is performed. Results validate the performance improvements of H8 inverter in terms of leakage current and total harmonic distortion (THD) of the output currents injected into the grid. Experimental results are presented for a 2 kW grid-connected PV system.

I. INTRODUCTION

HOTOVOLTAIC (PV) systems are among the most popular sources of renewable energy. The investment and generation costs of grid-connected photovoltaic (PV) system has been decreased continuously in recent years. Therefore, the grid-connected PV inverters need to be carefully designed in order to achieve the goals of low cost, high efficiency, low weight, and small size. Galvanic isolation can be achieved for safety concerns by employing line-frequency (LF) or high-frequency (HF) transformers. However, the line-frequency transformers are bulky and costly. Also, using high-frequency transformer, the PV systems usually consist of several power stages, which reduce the system efficiency and increase the system complexity and cost. In contrast, the transformer less grid-connected PV systems benefit from improved size, cost, weight, and efficiency. Consequently, the transformer less grid-connected PV systems have become very popular in recent years. Due to the lack of galvanic isolation in transformer less grid-connected PV systems, they are prone to the leakage current problem.

The leakage current arises because of variations in AC common-mode voltage on stray capacitor between PV panels and ground; this stray capacitance can have a typical value of 60–110 nF/kW for modules with crystalline silicon cells (monocrystalline, polycrystalline); and 100-160 nF for modules with thin-film cells. The variations of the stray capacitor voltage causes the leakage current. The leakage current should be strictly limited, since it can lead to safety issues, increased the total harmonic distortion (THD) of the injected currents, and also electromagnetic interference (EMI) problems; all of which, may violate the grid standards. According to the VDE 0126-01-01 standard, the RMS value of the leakage current has to be limited below 300 mA.

In case of the traditional full-bridge (FB) inverter (also named as B6- type inverter), the leakage current is more than the regulated limit. There are two approaches to eliminate or reduce the leakage current issue: one is to block the leakage current and the other is to reduce the common-mode voltage variations.

The first approach is achieved by employing additional switches, which can effectively separate the PV side from the grid side whenever a zero-switching state is produced. The second approach is to keep the common-mode voltage constant over the time or reduce its variations. In order to separate the PV panels from the grid, several topologies have been proposed including the Highly Efficient and Reliable Inverter Concept (HERIC)], and H7. HERIC topology is a single-phase inverter, which employs two extra switches on the AC side of the inverter to decouple the PV array from the grid during the intervals that a zero state is generated. H5 and H7 topologies are single-phase and three-phase inverters in which, the PV array is disconnected from the

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grid through an extra switch on the DC side of the inverter. In , a Z-Source inverter (ZSI) with an additional fast-recovery diode (ZSI-D) is proposed that its modulation intends to maintain a constant common-mode voltage. If the array voltage is too low and boost ratio of much more than 2 is required, ZSI would not be an effective solution.

In a new space-vector modulation was proposed to reduce leakage current for 3-level three-phase T-type inverters. T-type inverters are three level inverters that require 4-quadrant switches. Reduced common-mode voltage pulse width modulation (RCMV-PWM) methods are also proposed to reduce the leakage current through omission of the zero switching states, which decreases the common-mode voltage variations. In RCMV-PWM methods, the output line-to-line voltage is bipolar; the drawbacks are high dv/dt, large current ripples across filter inductors, and high switching losses that reduce the system efficiency. In, a four-leg inverter with a new modulation method has been presented to reduce the leakage current by adding two switches paralleled with three-phase legs. Besides, a fourth leg of the inverter is connected to the midpoint of the LCL filter. In the four-leg inverters, the output line to line voltage is bipolar. In a modified full-bridge single-phase inverter named FB-DCB (full bridge inverter with DC bypass) has been presented to reduce the leakage current by adding two switches and two diodes to the full bridge inverter.

II. REVIEW OF LITERATURE SURVEY

1) R. R. Karasani, V. B. Borghate, P. M. Meshram, H. M. Suryawanshi, and S. Sabyasachi, "A Three-Phase Hybrid Cascaded Modular Multilevel Inverter for Renewable Energy Environment,"

A modified three phase symmetrical 5-level multilevel inverter structure, derived from a propounded auxiliary (AUX) inverter leg, is presented. The switch count and gate driver requirements are reduced compared to conventional topologies. An attempt is made to optimize the source requirement. The low switching frequency Selective Harmonic Elimination (SHE) method based on Bee algorithm is employed for generating gating signals. Simulations analysis is accomplished by MATLAB/SIMULINK To support the simulation results, experiment is conducted on a low power prototype.

2) E. Afshari, G. R. Moradi, R. Rahimi, B. Farhangi, Y. Yang, F. Blaabjerg, and S. Farhangi, "Control Strategy for Three-Phase Grid Connected PV Inverters Enabling Current Limitation under Unbalanced Faults,"

Power quality and voltage control are among the most important aspects of the grid-connected power converter operation under faults. Nonsinusoidal current may be injected during unbalanced voltage sag, and active or/and reactive power may include double frequency content. This paper introduces a novel control strategy to mitigate the double grid frequency oscillations in the active power and dc-link voltage of the two-stage three-phase grid-connected photovoltaic (PV) inverters during unbalanced faults. With the proposed control method, PV inverter injects sinusoidal currents under unbalanced grid faults.

In addition, an efficient and easy-to-implement current limitation method is introduced, which can effectively limit the injected currents to the rated value during faults. In this case, the fault-ride-through operation is ensured, and it will not trigger the overcurrent protection. A non-maximum power point tracking (non-MPPT) operation mode is proposed for the dc-dc converter. The mode is enabled under severe faults when the converter cannot handle the maximum PV power. Finally, experimental validation is provided by implementing a method in an experimental setup, including a 2 kW PV inverter.

3) C. Anandababu and B. G. Fernandes, "Neutral Point Clamped MOSFET Inverter With Full-Bridge Configuration for Nonisolated Grid-Tied Photovoltaic System,"

The no isolated full-bridge neutral point clamped (NPC) inverters for a single-phase grid-tied photovoltaic (PV) system have limitations such as shoot-through and low European Union (EU) efficiency. In order to address these limitations, an NPC superjunction MOSFET nonisolated inverter with full-bridge configuration (NIIFBC) is proposed in this paper. This inverter reduces the possibility of shoot-through, thereby improving the reliability of the grid-tied PV system. It controls the grid current by energizing two coupled inductors individually during positive and negative half-grid cycles.

This obviates the possibility of reverse recovery loss in switches due to their body diodes. Furthermore, two external silicon carbide diodes of a clamping branch cause negligible reverse recovery loss in switches besides a constant common-mode voltage. Therefore, the main claims of NIIFBC are low leakage current, high EU efficiency, and reliability. A generalized leakage current model for the proposed inverter is developed. In order to validate the veracity of the model and the claims of NIIFBC, a 1-kW prototype is designed and developed. The experimental results of NIIFBC validate

the claims made by the authors. Its performance comparison with the existing nonisolated full-bridge inverters is given. Furthermore, a variant circuit of NIIFBC operating at nonunity power factor

4) G. R. Moradi, E. Afshari, R. Rahimi, B. Farhangi, and S. Farhangi, "Improvement of the modulation method for single-phase transformerless photovoltaic conergy inverter for reactive power injection capability,"

The Conergy power converter is among single-phase transformer-less topologies that have been proposed to mitigate the leakage current problem in photovoltaic (PV) systems. It is an NPC derived structure, which significantly reduces the leakage current and improves the efficiency. Conergy includes fewer switches compared to other single-phase transformer-less topologies. The reactive power generation capability contributes to power quality of the grid. In this paper, the capability of the Conergy inverter to inject reactive current into the grid is investigated. The conventional modulation method is evaluated according to this capability, the leakage current issue, and efficiency. Moreover, two novel modulation methods are proposed enabling the reactive power generation. The advantages of the proposed methods are validated using MATLAB/SIMULINK simulations.

5) V. Sonti, S. Jain, and S. Bhattacharya, "Analysis of the Modulation Strategy for the Minimization of the Leakage Current in the PV Grid-Connected Cascaded Multilevel Inverter".

A pulse width modulation (PWM) technique for the minimization of the leakage current in the grid-connected/stand-alone transformerless photovoltaic (PV)-cascaded multilevel inverter (CMLI). The proposed PWM technique is integrated with the MPPT algorithm and is applied to the five-level CMLI. Furthermore, using the proposed PWM technique the high-frequency voltage transitions in the terminal and common mode voltages are minimized. Thus, the proposed PWM technique minimizes the leakage current of the PV array and electromagnetic interference filter requirement in the system without addition of any extra switches.

Furthermore, this paper also presents the analysis for the terminal voltage across the PV array and the common mode voltage of the inverter based on the switching function. Using the given analysis, the effect of the PWM technique can be analyzed, as it directly links the switching function with the common mode voltage and leakage current. Also, the proposed PWM technique requires reduced number of carrier waves compared to the conventional sinusoidal pulse width modulation technique for the given CMLI. Complete details of the working principle and analysis with the support of simulation and experimental results of the proposed PWM technique.

III. PROPOSED SYSTEM:

- ❖ The H8 inverter proposed to reduce the leakage current and improve the output current THD for three phase transformer less grid-connected PV systems.
- ❖ There are two method to eliminate or reduce the leakage current issue:
- ❖ One is to block the leakage current and The other is to reduce the common- mode voltage variations.
- ❖ In order to separate the PV panels from the grid, several topologies have been proposed including the highly efficient.

A. ZETA CONVERTER

- ❖ It is a fourth order DC-DC converter, made up of two inductors and two capacitors and capable of operating in either step up or step down mode.
- ❖ ZETA converter topology provides the positive output voltage from an input voltage. It is a fourth order DC-DC converter, made up of two inductors and two capacitors and capable of operating in either step up or step down mode.
- ❖ Semiconductors switching devices are considered to be ideal.
- ❖ Converter operating in continuous inductor current mode.

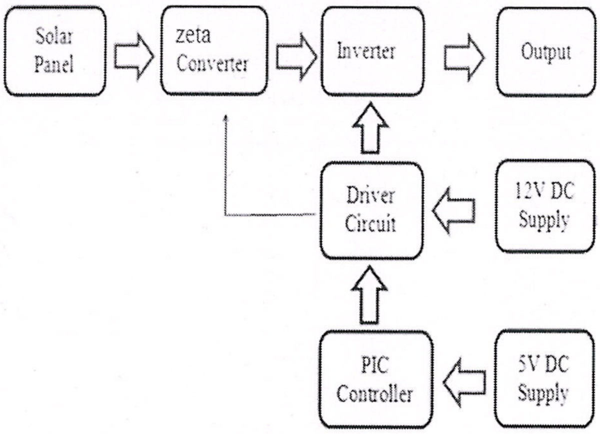
B. B6 TYPE INVERTER

- ✓ The B6 type inverter which is also known as full bridge inverter.
- ✓ This type inverters are 2-level 3-phase inverters.
- ✓ Common mode voltage is used to reduce the leakage current.

Advantages

- ✓ Reduce the leakage current
- ✓ Improve the output current THD
- ✓ Lower stress
- ✓ Does not need clamping diode

IV. BLOCK DIAGRAM



A. PULSE WIDTH MODULATION (PWM)

There are many forms of modulation used for communicating information. When a high frequency signal has an amplitude varied in response to a lower frequency signal we have AM (amplitude modulation). When the signal frequency is varied in response to the modulating signal we have FM (frequency modulation. These signals are used for radio modulation because the high frequency carrier signal is needs for efficient radiation of the signal. When communication by pulses was introduced, the amplitude, frequency and pulse width become possible modulation options. In many power electronic converters where the output voltage can be one of two values the only option is modulation of average conduction time.

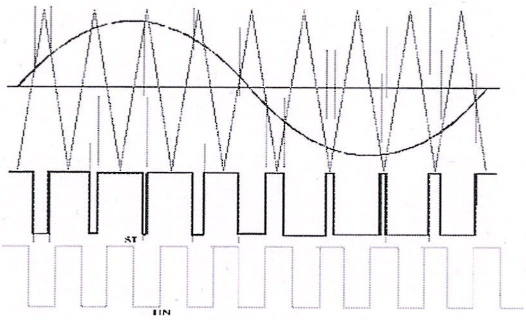


Figure 1: Unmodulated, sine modulated pulses

B. Linear Modulation

The simplest modulation to interpret is where the average ON time of the pulses varies proportionally with the modulating signal. The advantage of linear processing for this application lies in the ease of de-modulation. The modulating signal can be recovered from the PWM by low pass filtering. For a single low frequency sine wave as modulating signal modulating the width of a fixed frequency (fs) pulse train the spectra is as shown in Fig 2. Clearly a low pass filter can extract the modulating component fm.

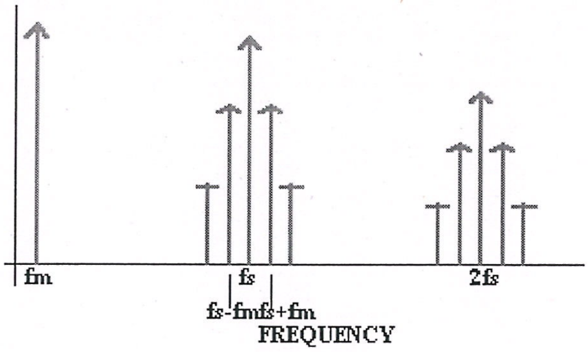


Figure 2: Spectra of PWM

C. Sawtooth PWM

The simplest analog form of generating fixed frequency PWM is by comparison with a linear slope waveform such as a sawtooth. As seen in Fig 2 the output signal goes high when the sine wave is higher than the sawtooth. This is implemented using a comparitor whose outputvoltage goes to a logic HIGH when ne input is greater than the other.

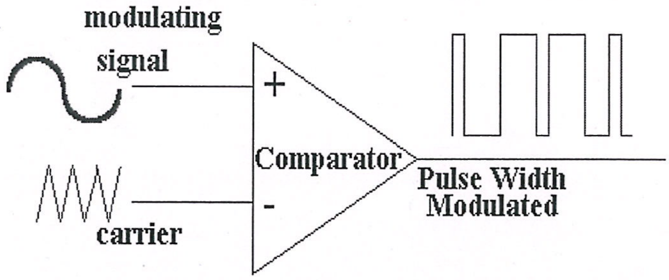


Figure 3: Sine Sawtooth PWM

Other signals with straight edges can be used for modulation a rising ramp carrier will generate PWM with Trailing Edge Modulation.

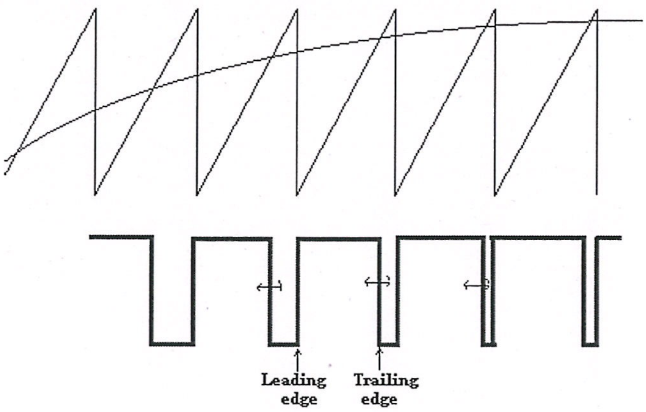


Figure 4: Trailing Edge Modulation

It is easier to have an integrator with a reset to generate the ramp in Fig 4 but the modulation is inferior to double edge modulation.

D. Regular Sampled PWM

The scheme illustrated above generates a switching edge at the instant of crossing of the sine wave and the triangle. This is an easy scheme to implement using analog electronics but suffers the imprecision and drift of all analog computation as well as having difficulties of generating multiple edges when the signal has even a small added noise.

Many modulators are now implemented digitally but there is difficulty is computing the precise intercept of the modulating wave and the carrier. Regular sampled PWM makes the width of the pulse proportional to the value of the modulating signal at the beginning of the carrier period. In Fig 5 the intercept of the sample values with the traingle determine the edges of the Pulses. For a sawtooth wave of frequency fs the samples are at 2fs.

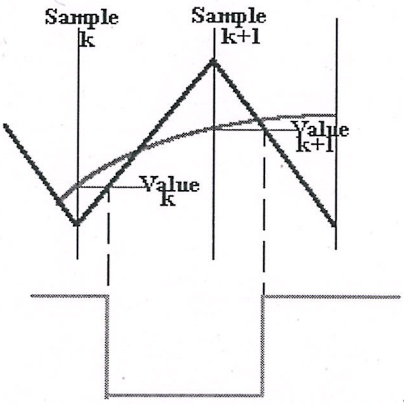


Figure 5: Regular Sampled PWM

There are many ways to generate a Pulse Width Modulated signal other than fixed frquency sine sawtooth. For three phase systems the modulation of a Voltage Source Inverter can generate a PWM signal for each phase leg by comparison of the desired output voltage waveform for each phase with the same sawtooth. One alternative which is easier to implement in a computer and gives a larger MODULATION DEPTH is using SPACE VECTOR MODULATION.

E. Modulation Depth

For a single phase inverter modulated by a sine-sawtooth comparison, if we compare a sine wave of magnitude from -2 to +2 with a traingle from -1 to +1 the linear relation between the input signal and the average output signal will be lost. Once the sine wave reaches the peak of the transgle the pulses will be of maximum width and the modulation will then saturate. The Modulation depth is the ratio of the current signal to the case when saturation is just starting. Thus sine wave of peak 1.2 compared with a triangle with peak 2.0 will have a modulation depth of m=0.6.

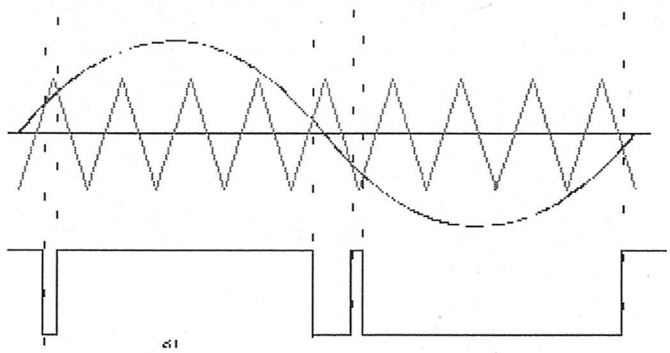


Figure 6: Saturated Pulse Width Modulation

F. INVERTERS

The inverter working principle as shown in Figure 1. The main device is a transformer. Which have 12V-0-12V, a common iron core. But instead we use the power input as 220 volts. Then power output as 12 volts. The way the switch differential is power AC input as 12 volts and output to AC 220 volts.

The 12 volts input power source is a battery Be Supply into the center tap of the coil 12 volts. Which is now considered a power pack or coil primary. The ends of the wire on both sides (points A and B) And it will be connected via a 2-way switch to ground.

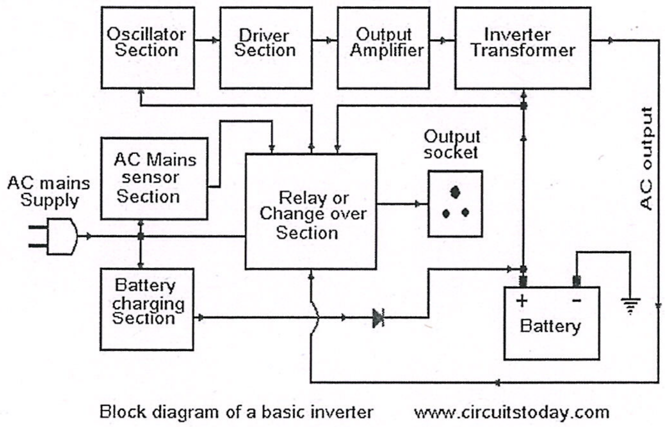


Figure 7 : Block Diagram Inverter

Which if the switch connected at A point, will cause an electric current number one, flows from the positive terminal of the battery, into the center tab point. Then flows up to the top, through the contacts A of the switch to ground.

If the switch is moved from Points of A to the Points of B, would make an electric current No. 1 has stopped. Because currents will redirect the flow an electric

current is number 2. From the center tap down below. Through contact B of the switch to ground.

The 2 way switch will be controlled on-off with the oscillator circuit that as the frequency generator of 50Hz As a result, switch off – on back and forth between Points of A and B with a speed of 50 times per second. Makes an electric current No. 1 and No. 2 alternating flow rate of 50 times per second as well. Which current flowing through the switch all the time like this.

Makes magnetic field resulting in swelling and shrinkage. And induced across to the 220 volts coil. Which is now considered to be a output power or seconary coil. The resulting voltage 220V AC 50Hz frequency winding up this series. The voltage available to be supplied to the various types of electrical voltage to 220 volts AC to operate.

G. When the AC mains power supply is not available

When the AC mains power supply is not available, an oscillator circuit inside the inverter produces a 50Hz MOS drive signal. This MOS drive signal will be amplified by the driver section and sent to the output section. MOSFETs or Transistors are used for the switching operation. These MOSFETs or Transistors are connected to the primary winding of the inverter transformer. When these switching devices receive the MOS drive signal from the driver circuit, they start switching between ON & OFF states at a rate of 50 Hz.This switching action of the MOSFETs or Transistors cause a 50Hz current to the primary of the inverter transformer. This results in a 220V AC or 110V AC (depending on the winding ratio of the inverter transformer) at the secondary or the inverter transformer. This secondary voltage is made available at the output socket of the inverter by a changeover relay.

H. Automation in an Inverter

Inverter contains various circuits to automatically sense and tackle various situations that may occur when the inverter is running or in standby. This automaton section looks after conditions such as overload, over heat, low battery, over charge etc. Respective of the situation, the automation section may switch the battery to charging mode or switch OFF. The various conditions will be indicated to the operator by means of glowing LEDs or sounding alarms. In advanced inverters LCD screens are used to visually indicate the conditions.

I. MOSFET with Working MOSFET as a Switch

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET is a core of integrated circuit and it can be designed and fabricated in a single chip because of these very small sizes.

The MOSFET is a four terminal device with source(S), gate (G), drain (D) and body (B) terminals. The body of the MOSFET is frequently connected to the source terminal so making it a three terminal device like field effect transistor.

The MOSFET is very far the most common transistor and can be used in both analog and digital circuits.

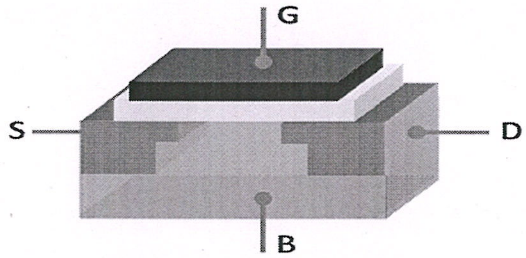


Figure 8 : MOSFET Switch

The MOSFET works by electronically varying the width of a channel along which charge carriers flow (electrons or holes). The charge carriers enter the channel at source and exit via the drain. The width of the channel is controlled by the voltage on an electrode is called gate which is located between source and drain. It is insulated from the channel near an extremely thin layer of metal oxide. The MOS capacity present in the device is the main part

V. SIMULATION RESULT

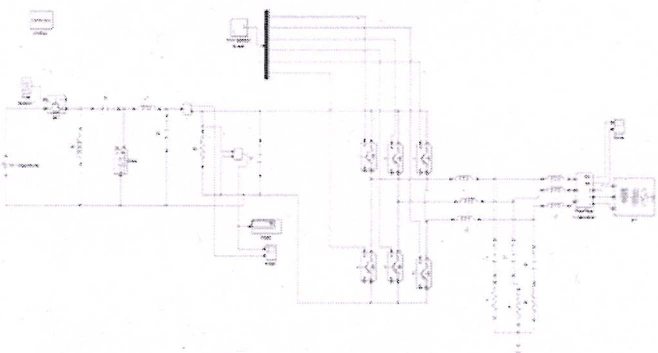
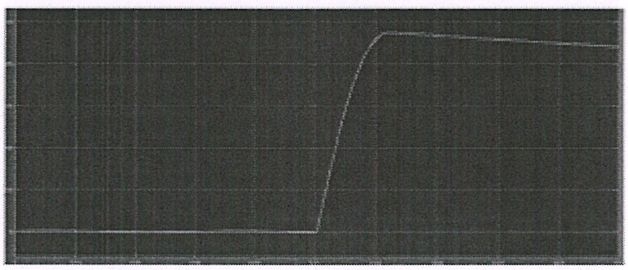
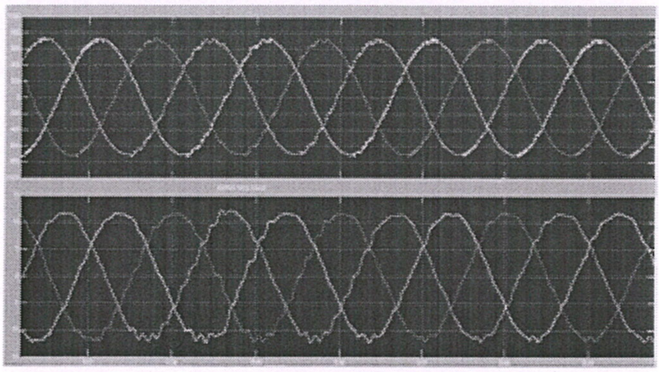


Figure 9 : Reduce Leakage Current In Grid Connected Pv Systems



VOLTAGE AND LEAKAGE CURRENT WAVEFORM



LEAKAGE CURRENT

Figure 10 : Output MATLAB Simulation for Leakage Voltage and current In Pv Systems

VI. CONCLUSION

The three-phase H8 inverter was proposed for transformerless grid-connected PV systems. The performance of the H6 and B6-type topologies were evaluated through analysis, simulations, and experiments. Due to its high leakage current, the traditional three-phase B6-type inverter is not a suitable topology for transformerless grid-connected PV systems. In contrast, the proposed H8 topology separates the PV array from the grid during zero voltage states. Thus, stray capacitor voltage variations are less than the traditional B6-type inverter. Therefore, the leakage current is reduced and meets the VDE 0126-1-1 requirements. According to experimental results, the leakage current of H8 inverter is 160 mA, which is far below of the 300 mA limit. Besides, the leakage current reduction in the H8 inverter results in an improved output current THD compared to the B6-type inverter. THD in H8 is measured as 4.5% versus 7% for B6 inverter. Simulation and experimental results validated the improved performance of the proposed H8 topology in a three phase transformerless PV inverter in terms of the leakage current and output current THD.

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