Photovoltaic based on Single-Stage Transformer less Inverter

RAMESH NENAVATH
Department of Electrical Engineering, University College of Engineering, Osmania University, Hyderabad, Telangana, India

Abstracts- In this paper we deal with a bidirectional transformer less solar based inverter on the High Frequency Leg technique is proposed which can work on Dis-continuous Current Mode / Continuous Current Mode (DCM/CCM) having greatly enhanced reliability. With the high frequency leg, the ripple-free ac current is achieved as the higher equivalent switching frequency can reduce the inductor's current ripple which decreasing the passive components' volume.

Keywords- P-Cell, N-Cell, High Frequency Leg,Transformer less Photovoltaic inverter, Bidirectional Capability

I. INTRODUCTION

Nowadays, grid-connected Photovoltaic (PV) systems, particularly low-power transformer less single-phase systems are becoming more important worldly. The Transformer less grid-tied inverter has many advantages such as high efficiency, low cost, smaller size, and low weight. However, there is a galvanic connection between the power grid and the PV module due to the omission of transformer. This project consists of the PV panel, the battery, the inverter, AC grid and the users' load. Among them, the inverter is the core of the whole system. In the daytime, PV panels produce the power to the grid or the users directly, and the redundant power is brought to the battery for charging at the same time. At night, PV panels stop working without sunlight, while the grid and users rely on the battery supplying power.

When the PV panels and the battery both don't work, there is a need that the grid charges the battery through the inverter. Therefore, it is necessary for the central inverter to have the function of bidirectional power flow. Carrier-based modulation technique has been used in [1] to provide a short circuit current path on the dc side to magnetize the inductor after every operation mode. The photo-voltaic inverter with no transformer for isolation has become more attractive due to higher efficiency and lower weight. However, it leads to dc-offset current problem and is critical to the power system [2]. Two four leg three-phase inverter circuit, together with dc micro-sources and non-linear loads, are employed to construct a general series and parallel grid-interfacing system [3]. A single phase series-connected inverter to interconnect ac loads with the micro-grid. The control strategy is designed to stabilize the load voltage irrespective of the grid voltage magnitude as well as transfers a specific amount of renewable source based power to the load. Besides, the inverter is forced to operate in such a way that, grid always sees a leading power factor load even at the presence of lagging power factor load. A nonlinear SRC is also proposed that tracks as well as eliminates the harmonics in the load voltage facilitating the control strategy. The controller is implemented based on position domain of the fundamental micro grid phase angle. The requirement of auto synchronization issue of maintaining un-distorted nominal load voltage, with the grid voltage [4]. Two basic switching cells, the P-NPCC, and the N-NPCC for the grid-tied inverter topology generationis used to build NPC topologies. A family of single phase transformerless full-bridge NPC inverter topologies with low leakage current based on the basic switching cell is derived. The PN-NPC topology has the following advantages and evaluated by experimental results. 1) The common-mode voltage is clamped to a constant level, so the leakage current can be well suppressed effectively. 2) The excellent differential mode characteristic is achieved like the isolated full-bridge inverter with uniploar SPWM. 3) The PN-NPC topology features the best conversion efficiency compared to that of H5 and FBDCBP [5]. The H5 inverter structure basically consists of a bridge with the upper switches operating at grid frequency and the lower ones operating at high frequency while the additional switch operating at both half-waves together with the same high frequency signals of the lower switches. The disadvantages of this topology are the higher conduction losses by the series association of three switches during the active powering period. In this project, a novel transformer less PV single-phase inverter topology is proposed based on HFL (high-frequency-leg) concept which can easily increase the power capacity.

II. PROPOSED SYSTEM

In this paper, the HFL concept is proposed. The novel transformer less PV single-phase inverter topology and the steady state analysis of the converter is presented, the detailed power stage operation principle and Pulse Width Modulation (PWM) scheme are described. Besides the topology proposed in this paper is a bidirectional inverter, can also work as a rectifier. With the advantages all above the proposed topology is very engagingfor transformer less PV inverter applications. In the end the experimental results of laboratory prototype have verified the attainable and effectiveness of the proposed transformer less PV (Photovoltaic) inverter under standalone mode.

III. CIRCUIT DIAGRAM

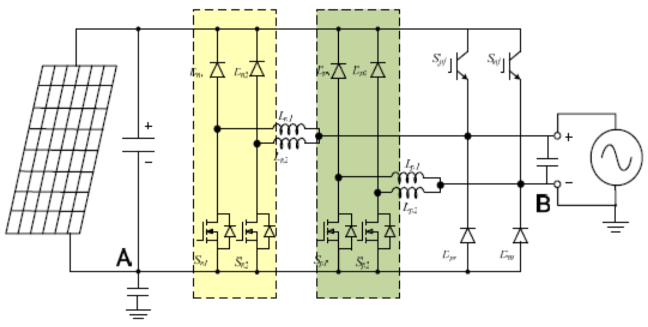


Fig1: circuit diagram

IV. INTERLEAVING HIGH FREQUENCY LEG

An electronic ballast for dual high-intensity-discharge (HID) lamps is presented. The electronic ballast is composed of a boost pre-regulator to achieve high power factor and a three-leg inverter to drive two HID lamps. One leg of the inverter is operated at a less frequency with a 50% duty ratio to drive the HID load or lamps with low-frequency square-wave current pulse signal in order to avoid acoustic resonance.

The other two legs of the inverter are operated at a high frequency which is to modulate the lamp current with constant lamp power. Also, interleaving control is applied to the high-frequency legs to decrease the current pulse stress on the low frequency leg.

To verify the feasibility of the proposed methodology, a laboratory setup is implemented to drive the two or three 35-W HID lamps that is shown in figure1. The overall efficiency of the proposed electronic ballast is about 90%.

This paper presents a hybrid modulation technique consisting of singe reference six pulse modulation (SRSPM) for front-end dc to dc converter and 33% modulation for three-phase inverter. Employing proposed SRSPM to control front-end dc to dc converter, high-frequency (HF) pulsating dc voltage waveform is produced, which is equivalent to six-pulse output waveform at 6 line frequency (rectified 6-pulse output of balanced three-phase ac signal waveforms) when it gets averaged.

It decreases the control complexity owing to single-reference three-phase modulation than the conventional three-reference three-phase Sinusoidal PWM. In addition, it relives the need of dc-link capacitor reducing the cost and size. Eliminating dc- link capacitor helps in retaining the modulated information at the input of the three-phase inverter circuit.

It needs only 33% (one-third) of modulation of the inverter devices to generate balanced three-phase voltage waveforms resulting in advance saving in (at least 66%) switching losses of inverter semiconductor devices.

During the line-cycle, two switches are required to switch at high frequency and remaining switches retain their unique state of commutation process. Besides, inverter devices are not commutated when the current through them is at its peak value. Drop in switching loss tends to be around 86.6% in comparison with a standard voltage source inverter (VSI) circuit employing standard three-phase sinusoidal pule width modulation.

This paper explains working principle and analysis of the high frequency two-stage inverter modulated by the proposed novel modulation scheme. Analysis has been successfully examined by simulation outputs and by using those results it demonstrates the effectiveness of the proposed modulation.

V. OPERATION ANDANALYSIS OF THE CONVERTER

In this section, steady state working operation and analysis of the modulation technique have been explained. Two full-bridge converters have inter-leaved connection at front-end in parallel input series output to increase the power handling capacity. Both full bridge circuit are modulated using identical six pulse modulation technique which was producing high frequency pulsating dc voltage (Vdc), which is fed to a standard three-phase inverter circuit.

Modulation of the two levels is planned, developed, and implemented, so as to reduce the switching losses of the inverter while making no dc- link capacitor. The three-phase inverter is modulated to shape this high frequency pulsating dc-link voltage to obtain balanced three-phase sinusoidal inverter output voltages of required frequency and amplitude after filtering processes.

The following specifications are considered for the analysis of the converter:

1) All semi-conductor devices and components are ideal and loss-less in nature.

2) Leakage inductance of the transformers have been neglected.

3) Dc-dc converter cells are switched at high frequency signal compared to the inverter.

STEADY-STATE OPERATION

The converter's operation during different intervals of a high frequency switching cycle is highlighted by wave-forms. Gating signals of dc/dc full-bridge converters are shown, where each switch is operated at 50% duty ratio and complementary to other switch in the same leg.

On the other hand, when other diagonal pair M2a and M3a are conducting, −NV in is obtained at the secondary terminals, where 'n' is the turns ratio of the transformer.

Another full-bridge unit is also operated in similar manner applying similar gate pulses to symmetrical devices. Bipolar pulsating voltage is converted to uni-polar using full-bridge rectifier circuit (ie.,diodebridgerectifier). Rectifier's outputs from two cells are connected in series to add the voltage level.

Reduction in switching losses is obtained from and the switching loss in the inverter devices reduces by around 7.5 times for the proposed modulation method as compared to the standard sine pulse width modulation (SPWM). Based on the aforementioned analysis, the designed equations for the converter were derived and presented in the next Section.

The switch is kept in the on-state for 1/3 rd. of the cycle conducting the peak current of the output line current where the output power factor is unity and is in the OFF state for the rest 1/3rd of the line cycle. Similarly, line current is at its negative peak during off-state of the top switch and on state of the bottom switch.

Filter inductance is calculated such that the voltage drop across the inductor is lower than 2% of the nominal voltage during the full-load condition.

The balanced three-phase output is obtained even at such a reduced load with distortion. Single reference modulation still works with excellence as discussed and explained. It is well known fact that the series connected inductance or leakage inductance of the transformer limits the power transfer capacity from input to output or source to load.

H6 TOPOLOGY:

One more extra switch s6 is introduced into the h5 inverter topology to improve the efficiency and it is connected between the pv array and the new current path.

As a result, a novel h6 transformer less full bridge inverter topology is derived and it is shown in the fig2. The h6 inverter topology

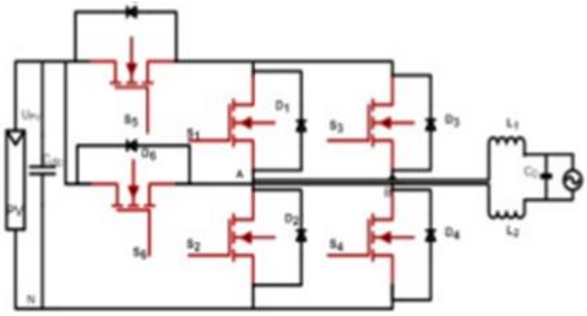


Fig2: H6 Topology

There are four modes of operation modes as shown. in the first mode of operation, the gate pulses are given to the switches s1,s4 and s5 , this is the first active mode of operation a voltage v+ is apply across the output end of the inverter is obtained.

In the second mode of operation s1 is kept on and all the other switches are kept off. Due to this operation this mode is called us first freewheeling mode; the energy stored is free wheeled through diode d3 and switch s1.

In the third mode of operation gate pulse is given to the switches s2, s3, and s6 and then the other switches are goes to off state. The inductor current is flowing through s3 and s6. Although s3 is turned on, there is no current flowing through it, and actually the switch s3 has no conduction loss in this mode. But still, in the h5 topology, the inductor current flows through s2, s3 and s5. Therefore the conduction loss of proposed topology this is the second active mode of operation, and a negative voltage (v-) across the output is obtained.

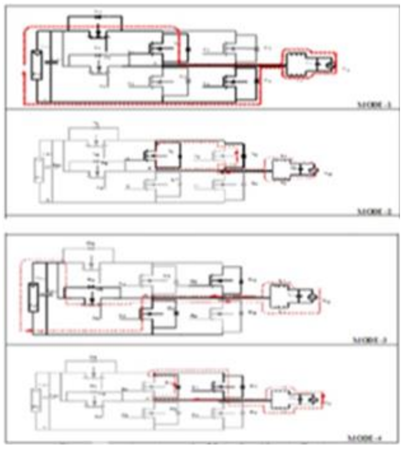
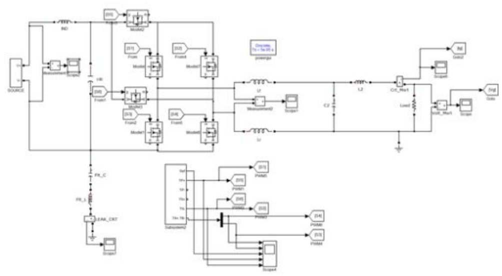


Fig3: Different Operating Modes of H6 Topology

The three mode of H-6 operation is given and diagram is shown in fig 3. In the last mode of operation switch S3 is kept on and all the other switches are kept OFF. This mode is called us the second freewheeling mode; the energy sored is free wheeled through diode d1 and switch S3. The CM voltage of the proposed topology in each operation mode is equal to 0.5 UPV, and it results in low leakage currents. The H6 topology with unipolar SPWM method not only can achieve UPF, but also has the ability to maintain the phase shifts between voltage and current waveforms.

VI. SIMULATION OF THE CONVENTIONAL SYSTEM

The circuit diagram of the conventional system (H6 inverter topology) is simulated in the MATLAB and its pulse generation system is shown in Figure 4



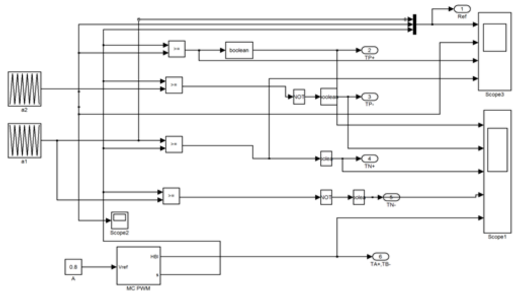


Fig4: circuit diagram

INPUT VOLTAGE:

The waveform of the input dc voltage from the panel is shown in Figure 5. The input voltage is approximately 380V

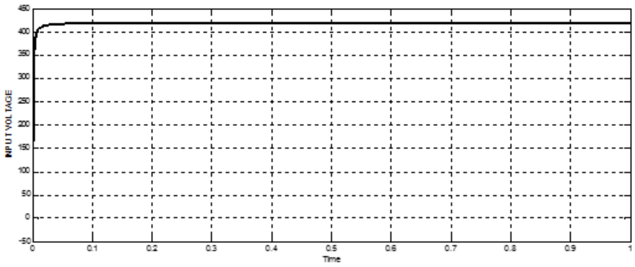


Fig5: input voltage

LEAKAGE CURRENT:

The waveform of the Leakage current is shown in Figure 6. The leakage current is roughly around 6A

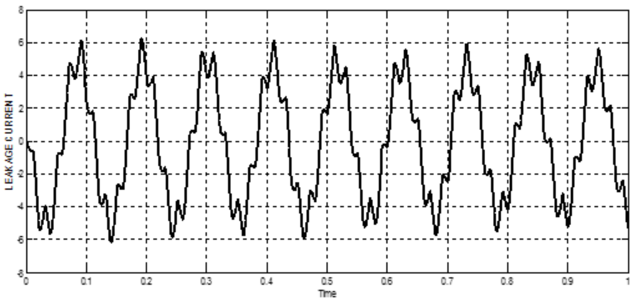


Fig6: leakage current

OUTPUT VOLTAGE:

The waveform of the output voltage across the load is shown in Figure 7. The output voltage is approximately 225V

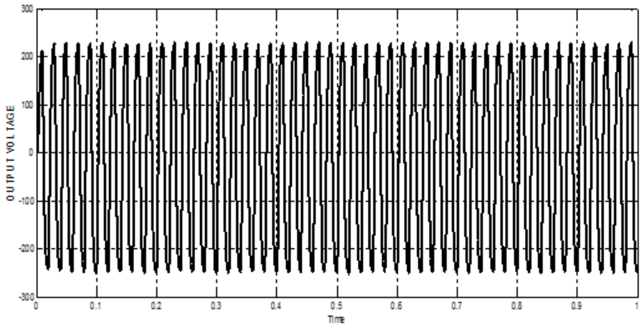


Fig7: output voltage

OUTPUT CURRENT:

The waveform of the output current to the load is shown in Figure 8. The output current is approximately 33V

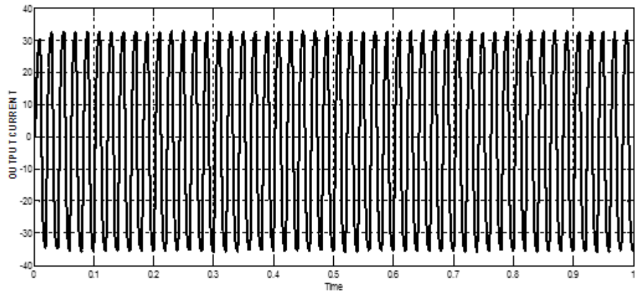


Fig8: output current

FAST FOURIER ANALYSIS:

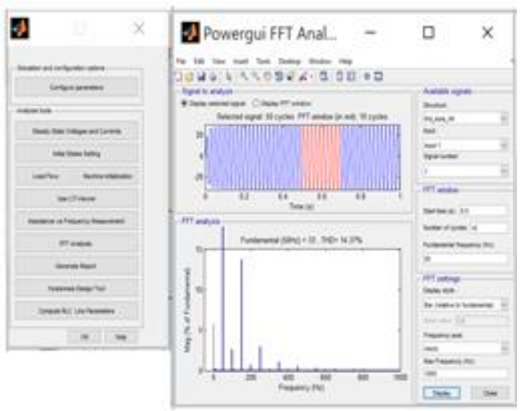


Fig9: THD of proposed system

The THD level for 10 cycles is found using the Fast Fourier Analysis and the screen shot is given in Figure 9. The THD value is 14.37 %

VII. SIMULATION OF THE PROPOSED SYSTEM WITH 4 HF LEGS

CIRCUIT DIAGRAM:

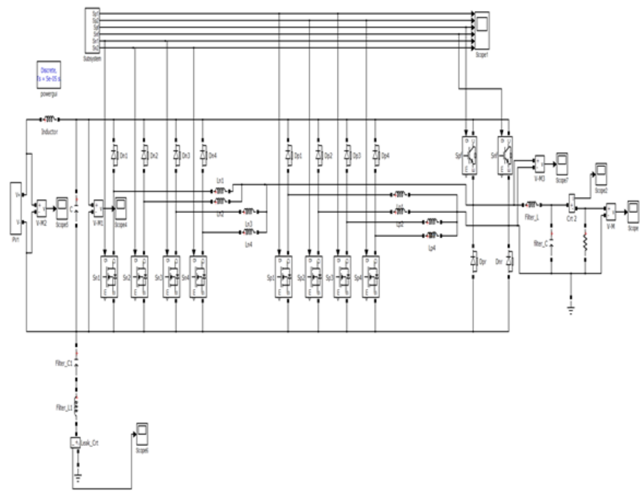


Fig10: four leg circuit diagram for existing system

SIMULATION BLOCK DIAGRAM (WITH four HF LEGS):

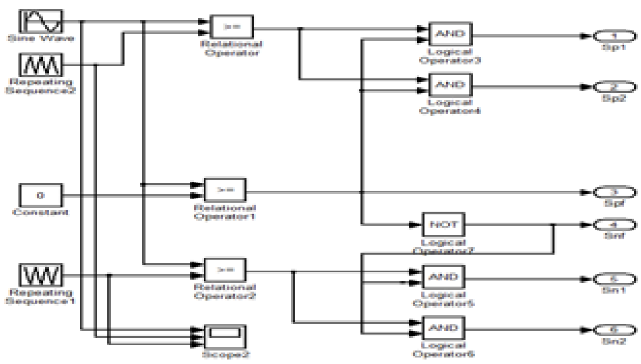


Fig11: block diagram with four HF legs

PWM GENERATED SIGNALS:

The waveform of the PWM generated signals for the switches are shown in Figure12

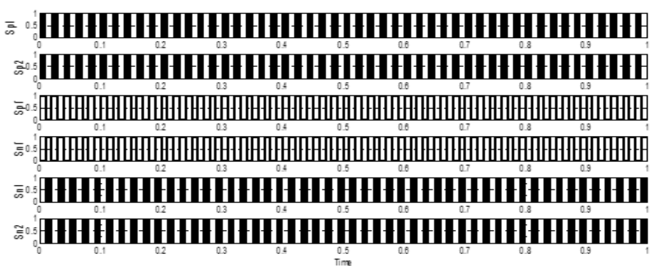


Fig12: PWM of existing system

INPUT VOLTAGE:

The waveform of the input DC voltage from the panel is shown in Figure 13. The input voltage is approximately 380V.

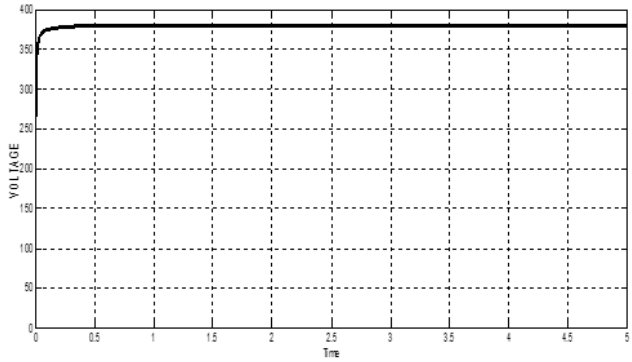


Fig13: Input voltage of existing system

LEAKAGE CURRENT:

The waveform of the Leakage current is shown in Figure14. The leakage current is roughly around 1.5A.

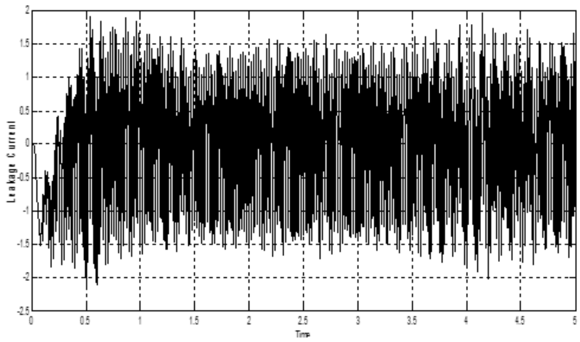


Fig14: leakage current of existing system

OUTPUT CURRENT:

The waveform of the output current to the load is shown in Figure15. The output current is approximately 34V.

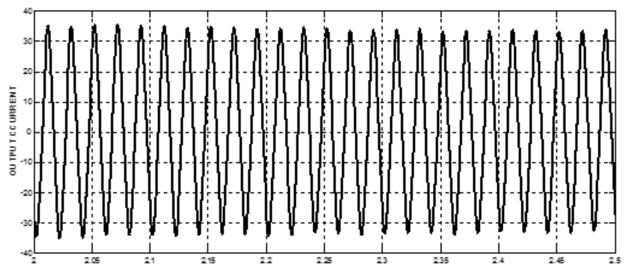


Fig15: Output current

OUTPUT VOLTAGE:

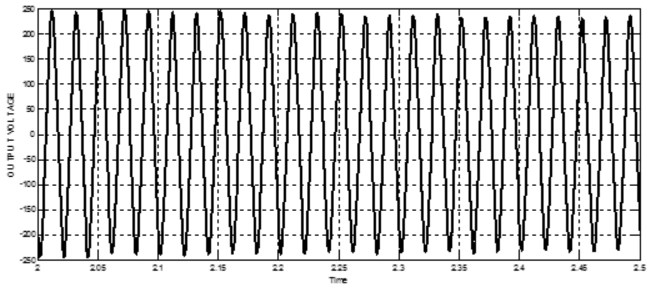


Fig16: output voltage

The waveform of the output voltage across the load is shown in Figure 16. The output voltage is approximately 240V.

FAST FOURIER ANALYSIS:

The THD level for 10 cycles is found using the Fast Fourier Analysis

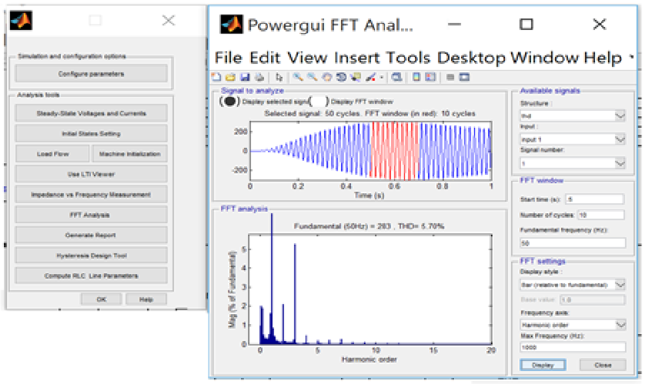


Fig17: THD of existing system

And the screen shot is given in Figure 17. The THD value is 5.70 %

EXISTING SIMULATON RESULTS:

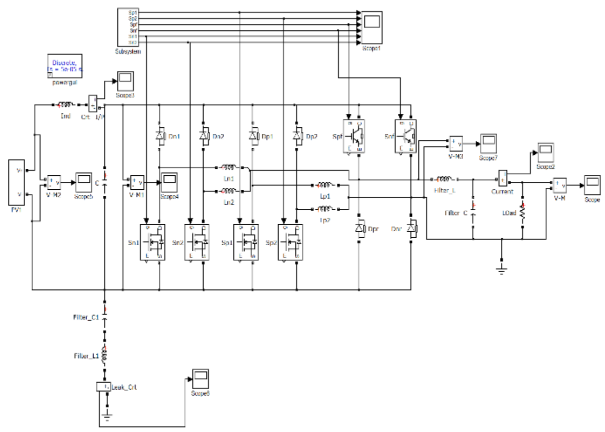


Fig18: two leg circuit diagram for existing system

SIMULATION BLOCK DIAGRAM (WITH TWO HF LEGS):

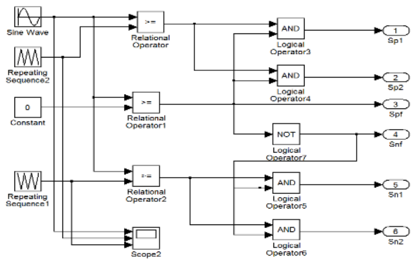


Fig19: block diagram with two HF legs

PWM GENERATED SIGNALS:

The waveform of the PWM generated signals for the switches are shown in Figure 20

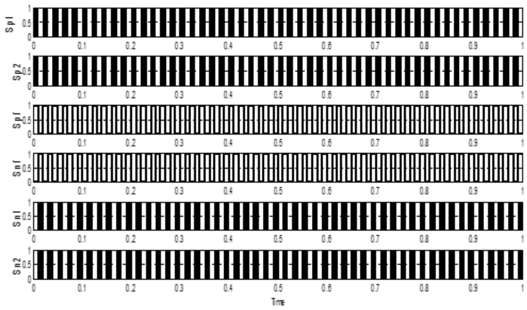


Fig20: PWM pulse with modulation of existing system

INPUT VOLTAGE:

The waveform of the input DC voltage from the panel is shown in Figure 21. The input voltage is approximately 380V.

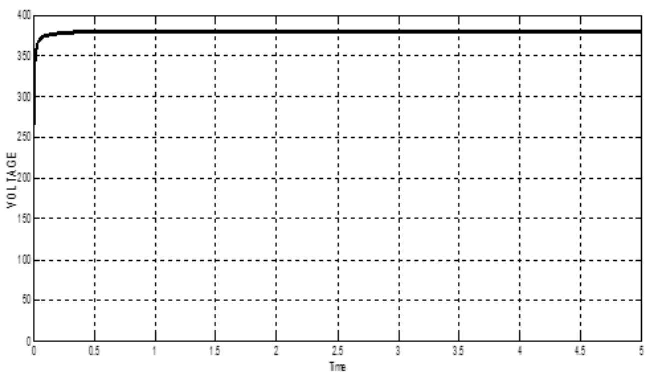


Fig21: input voltage

LEAKAGE CURRENT:

The waveform of the Leakage current is shown in Figure 22. The leakage current is roughly around 1.5A

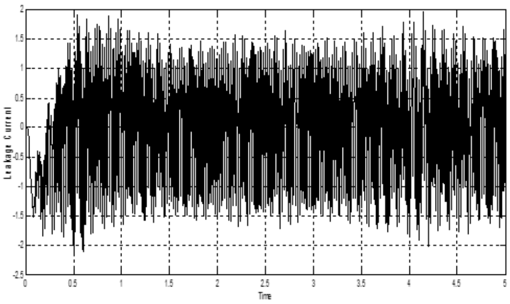


Fig22: leakage current

OUTPUT CURRENT:

The waveform of the output current to the load is shown in Figure 23. The output current is approximately 32V

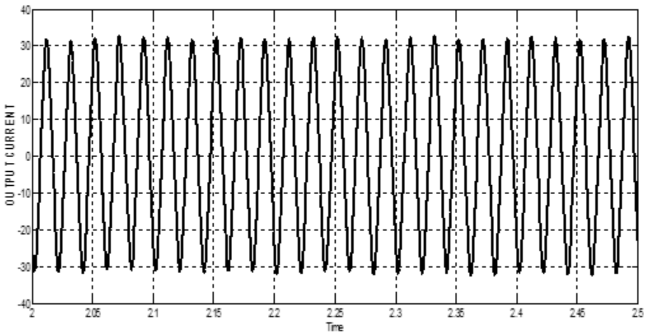


Fig23: output current

OUTPUT VOLTAGE:

The waveform of the output voltage across the load is shown in Figure 24. The output voltage is approximately 225V.

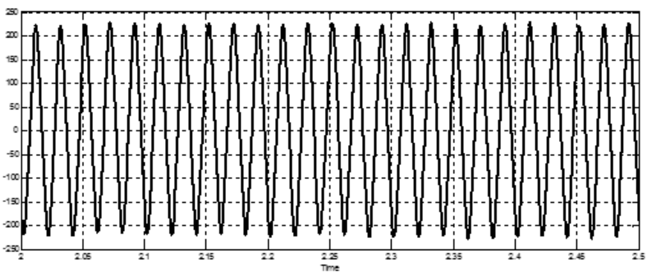


Fig24: output voltage

FAST FOURIER ANALYSIS:

The THD level for 10 cycles is found using the Fast Fourier Analysis and the screen shot is given in Figure 25.The THD value is 5.70%

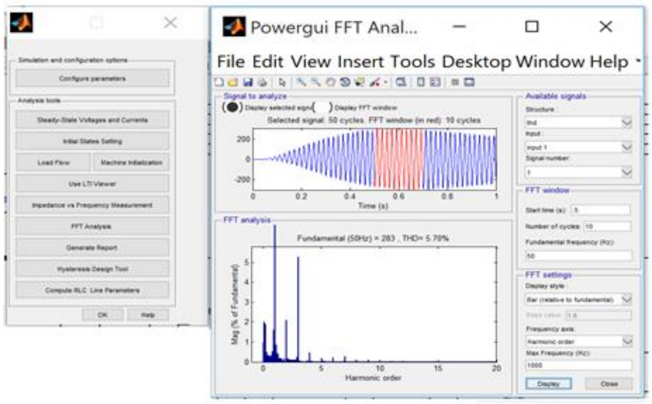


Fig25: THD of existing system

TABLE 1.1 COMPARISON BETWEEN H6 TOPOLOGY AND THE PROPOSED SYSTEM

PARAMETERS	H6 TOPOLOGY	INVERTER WITH TWO HF LEGS	INVERTER WITH FOUR HF LEGS
INPUT VOLTAGE	380 V	380 V	380 V
INPUT CURRENT	22 A	22 A	22 A
OUTPUT VOLTAGE	200 V	225 V	240 V
OUTPUT CURRENT	33 A	32 A	34 A
LEAKAGE CURRENT	6 A	1.5 A	1.4 A
EFFICIENCY	78.94 %	86.1 %	97.6 %
TOTAL HARMONIC DISTORTION	14.37	5.70	5.70

VIII. CONCLUSION

The modulation technique SRSPM is proposed to control front end full-bridge converter to generate HF unit polar pulsating voltage pulse signal at dc-link having six-pulse information if averaged at HF cycle over line frequency. The three-phase inverter device switched at HF during 33.33% (1/3 rd.) of the line cycle and residue to stay at steady switching state of ON for 33.33% and OFF for rest the 33.33% of line cycle. But It's results is very low average switching frequency or 66.66% it will reduced the switching transition losses and improved the efficiency. Reduction in switching loss up to 86.6% is accomplished than conventional three phase inverter. It is suitable for high-power applications like PVCVs and EVs, three-phase uninterruptible power supply (UPS), islanded or standalone micro grid, and solid-state transformer. Eliminates the need for clink capacitor and feeds directly HF pulsating dc voltage to a three-phase inverter. Under normal steady state conditions, the system does not have effect on PV cell output current usually; a large ultra-capacitor is placed across the PV cell stack to handle transients to suppress slow PV cell dynamic response

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Author Profile:

RAMESH NENAVATH,

Completed Master of Engineering in University College Of Engineering, Osmania University.