International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 6, September-October 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Design of Transformer less Single-Phase Inverter

Stebana Rose Mary. G, Swathy. V, Nisha. K, Anandhi. M

Student, B.E. Electrical and Electronics Engineering,
Loyola-ICAM College of Engineering and Technology, Chennai, Tamil Nadu, India

ABSTRACT

Solar energy is the top of all renewable energy systems because of its pollution free, adaptable, long life, low maintenance cost and favoured options for sustainable development. Thus, this is used as the source of input for this model. The PV cell converts the solar energy into electrical energy. This energy is in DC form. This DC voltage is raised to the desired level with the help of boost converter (dc-dc converter).The boost converter is driven with the help of MOSFET. The boosted DC voltage is fed to the PWM inverter which converts the dc input into ac output. And finally, the output is given to the load. The proposed inverter system converts DC power into single-phase AC power efficiently without using transformers and batteries. In this, the simulation results of a transformer-less single-phase inverter which uses a photovoltaic array as the input are shown. An inverter with DC-link is designed for conversion of DC input into AC supply. The simulation is carried out with the help of MATLAB simulation software. The harmonic distortion is found to be 2.73% in the FFT analysis.

KEYWORDS: *Single-phase inverter, Boost converter, MOSFET, PWM, MATLAB*

How to cite this paper: Stebana Rose Mary. G | Swathy. V | Nisha. K | Anandhi. M "Design of Transformer less Single-Phase Inverter" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-6, October 2021, pp.1142-1150, URL: www.ijtsrd.com/papers/ijtsrd47549.pdf

IJTSRD47549

1.1. INTRODUCTION

Electricity, being in high demand, is generated at thermal and hydro power plants. These plants depend mainly on coal (non-renewable source) for fuel, which is available in limited quantities and thus causes shortage of power supply. To overcome this, renewable sources could be used. Solar energy is abundantly available. Application of this source would minimize the energy crisis. Solar energy is a clean source of energy. The power generation is also easy and eco-friendly. Among other renewable sources, solar energy is dominant because of the following factors: (1) increasing efficiency of the solar cells (2) improvement in the manufacturing technology (3) less or no maintenance. Thus, we use PV arrays. Here, a transformer-less inverter is proposed for a cost-efficient system to eliminate the leakage current in an inverter. This inverter is proposed for domestic purposes. In this model we aim to design an inverter that converts PV power directly to AC power without using battery storage devices and middle linkages. In the simulation we have implemented an inverter topology that extracts power from a PV array and converts it to the desired level.

1.2. PROPOSED METHODOLOGY

1.2.1. BLOCK DIAGRAM

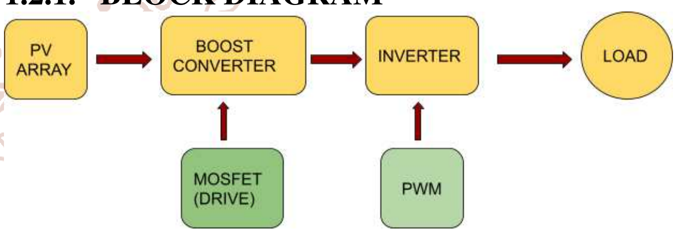


FIG 1.2.1 BLOCK DIAGRAM

The block diagram of a single-phase PV based inverter for household electric supply is as shown in fig 1.2.1.

1.2.2. WORKING

The solar panels obtain the solar energy via photovoltaic cells and convert it to a DC output of smaller range, around 24V. Thus, we use a boost converter which has MOSFET as their switching device. They are triggered using drivers which work based on the desired duty ratio. The duty ratio is decided by the input voltage and the desired output voltage. Thus, it is used to raise the dc voltage around 326V. The boost converter is a DC-DC converter that steps up the voltage. It has two distinct states of operation:

(a)At ON-state: The current flows through the inductor in clockwise-direction. The inductor stores energy by generating a magnetic field. The polarity is positive (left-side of the inductor).

(b)At OFF-state: The current is reduced as impedance increases. The magnetic field created previously is reduced in energy in order to maintain the current towards the load. Thus, the polarity is reversed (negative in the left side of the inductor).

A DC link is connected between the boost converter and the inverter. It compensates the switching losses caused by MOSFET switches and reduces the ripples. And gives a filtered output from the boost converter to the inverter. For this model we use a full bridge inverter that converts the DC voltage to AC voltage. This generates a square wave AC output voltage. We also use a pulse width modulator (PWM) which generates gate signals. A PWM signal is generated by feeding a reference and a carrier signal through a comparator which gives the output signal based on the difference between the two inputs. The reference is sinusoidal and the carrier wave is a triangle wave. When the carrier wave exceeds reference, the output is at one state and when the reference exceeds the carrier, it is at the opposite state. Finally, the output from the inverter (desired AC output) is fed to drive loads.

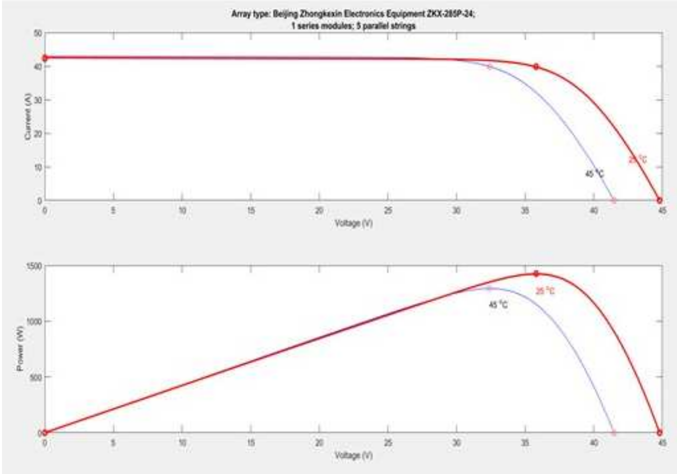
1.3. SOFTWARE DEVELOPED

1.3.1. SOLAR PV ARRAY

A photovoltaic (PV) cell directly converts sunlight to electricity through a process known as photovoltaic effect. The PV cells absorb the photons emitted by the sun and generate a flow of electrons. These electrons move to the n-side, while the holes are drifted towards the p-side. Thus, a direct current is established between the contacts. Since a typical photovoltaic cell produces less than 3 watts at approximately 0.5volt dc, cells must be connected in series-parallel configurations to produce enough power for high-power applications. Cells are configured into modules and modules are connected as arrays. Here we are using Beijing Zhongkexin Electronics Equipment ZKX – 285 – 24 type array module as an input to the inverter.

Maximum Power	285.326W
Open circuit Voltage Voc	44.8V
Voltageat maximum power point Vmp	35.8V
Short circuit current Isc	8.45A
Current at maximum power point Imp	7.97A
Cells per module	72
Series connected module sperstring	1
Parallel strings	5

MODULE DATA



PV ARRAY PLOT

The Irradiance and temperature values are adjusted such that we obtain a DC voltage of approximately 24V for which the system is designed. Here the values of Irradiance and temperature used are shown in table below.

Irradiance	1000W/m²
Temperature	25deg.C.

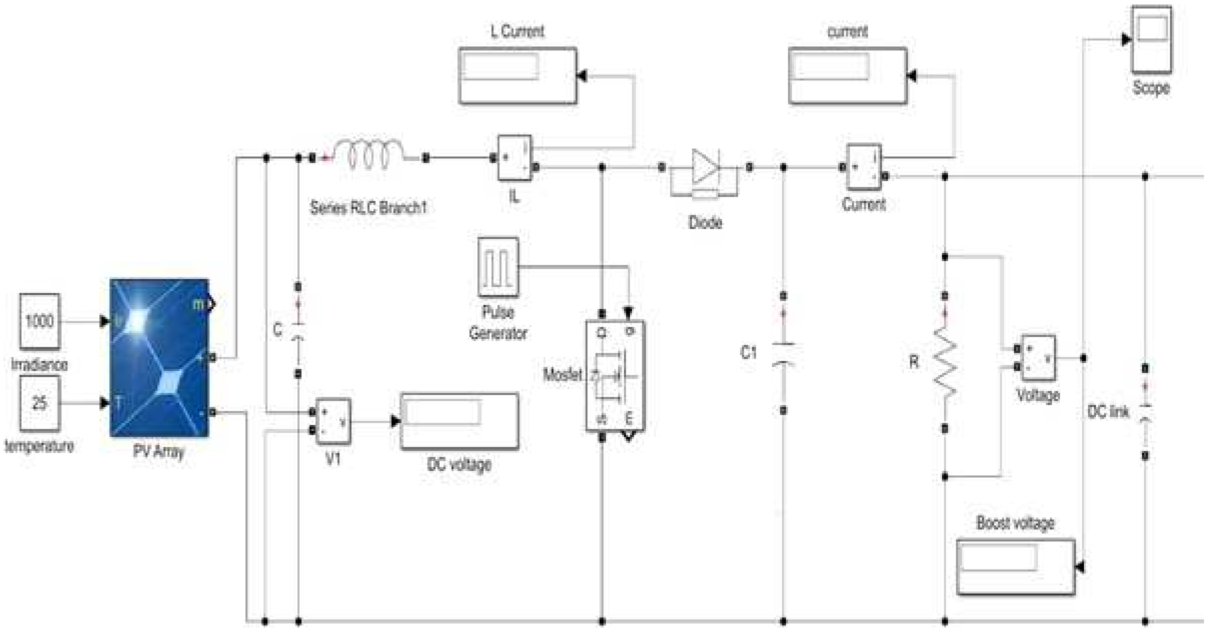
ARRAY INPUT DATA

1.3.2. BOOST CONVERTER

A DC-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. The DC-DC converters are widely used in regulated switch-mode dc power supplies and in dc motor drives applications. Often the input of these converters is an unregulated dc voltage, which is obtained by rectifying the line voltage, and therefore it will fluctuate due to changes in the line voltage magnitude. The boost converter is used to step up the input voltage to a desired value which is greater than the input supply. It consists of an inductor (L) in series with the supply voltage (Vs). A semiconductor switch is connected across the inductance and supply. A filter capacitor (C) is used across the load to remove the ripples from the output voltage (Vo). The diode blocks the reverse flow of output current when the switch is turned on.The semiconductor is turned ON at the calculated duty cycle and hence, the current flows through the inductor from the supply and thus, stores energy. The capacitor maintains the output voltage and supplies the current (Io) when the switch is ON. Hence the diode is reverse biased and does not conduct. When the switch is turned OFF, the inductance generates a large voltage Ldi/dt to maintain the current in the same direction. Here, the diode is forward biased and it starts conducting. Thus, the output voltage will be as eqt(1).

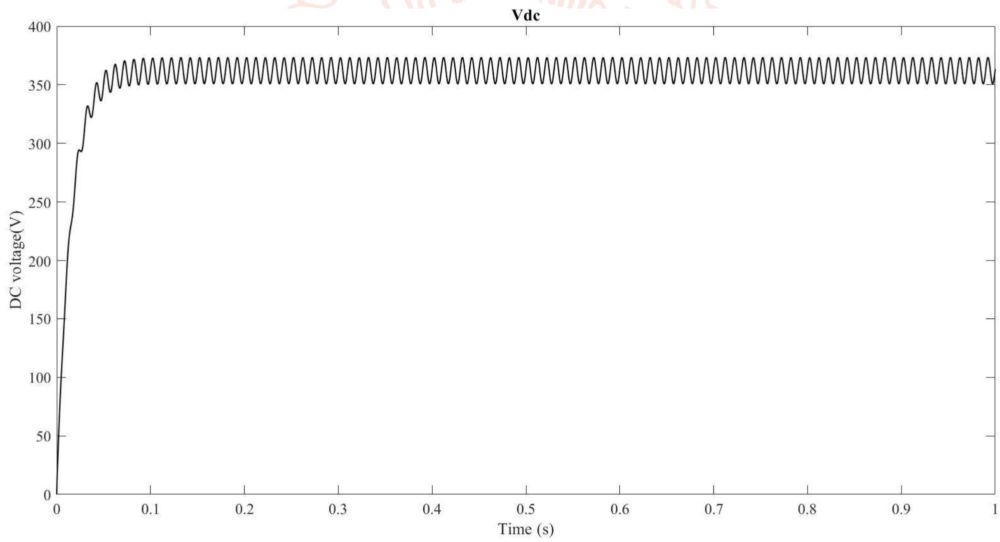
$$Vo = Vs + Ldi/dt \text{ ----------------------(1)}$$

Hence a greater output voltage is obtained than the supply voltage.



BOOST CONVERTER

Here, the boost converter is designed to provide a stepped-up output voltage of 326 V which is fed with an input supply of 24 V from the PV array. The proposed converter is designed for a power rating of 500 W.



DC OUTPUT VOLTAGE OF BOOST CONVERTER

PARAMETERS	VALUES
Inductor(L)	30μH
Capacitor(C)	0.1mF
Resistor(R)	212.5Ω

CONVERTER PARAMETERS

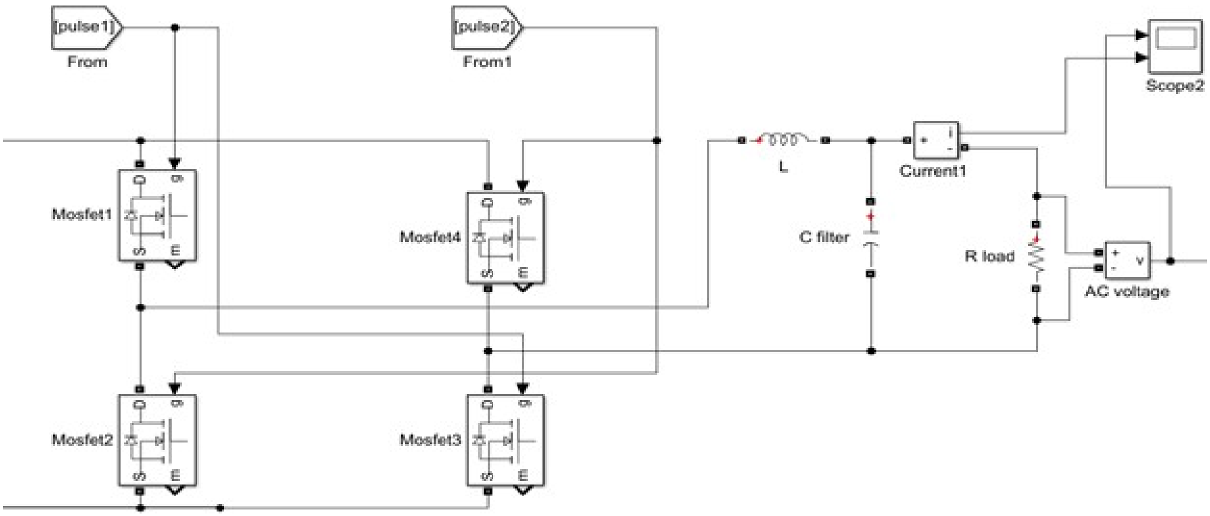
1.3.3. DC LINK

The DC link capacitor (C) is common to the boost converter and the single-phase inverter. It is used to filter the ripples from the output of the boost converter and provides a steady DC voltage to the inverter circuit.

$Idc/(2 * w * \Delta Vdc)$ -------------------------(2)

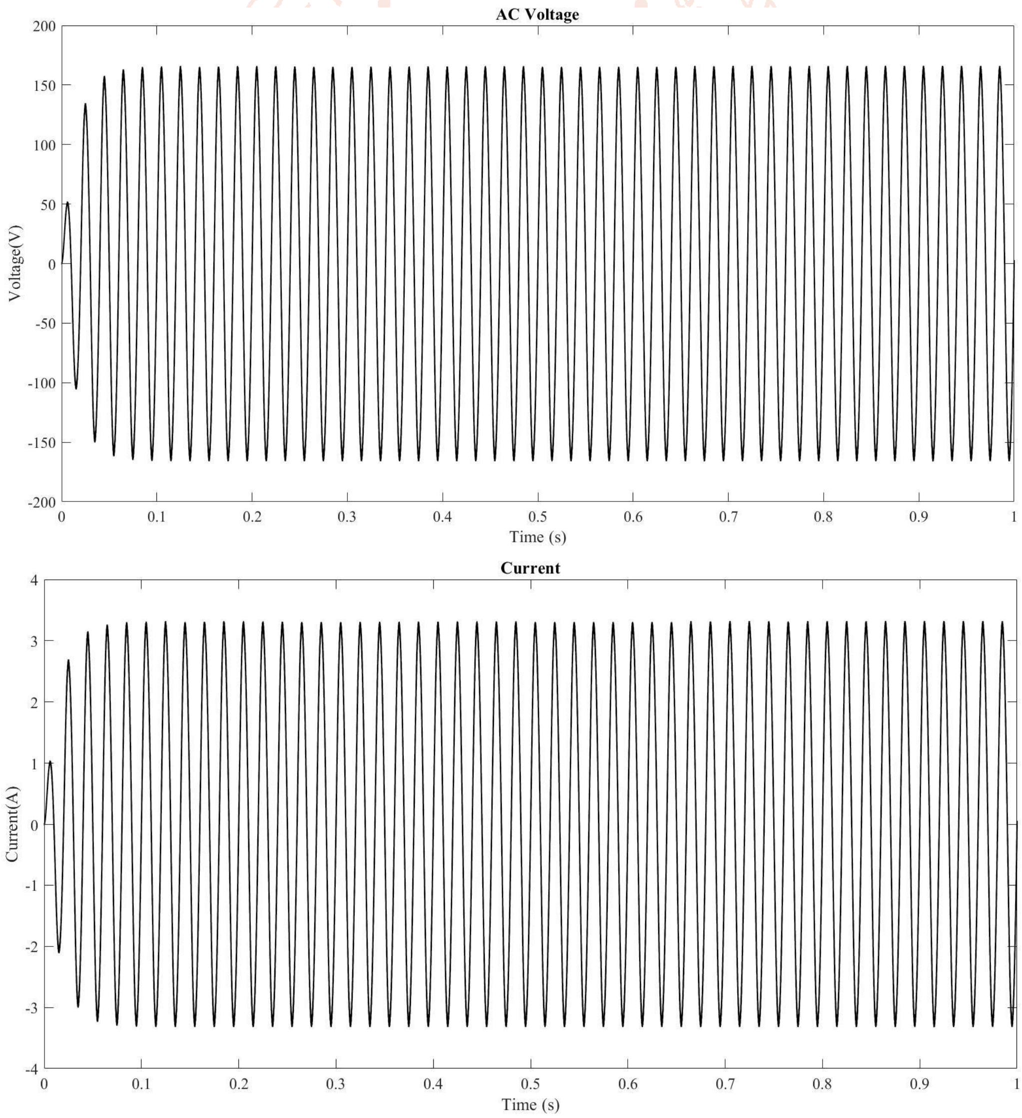
1.3.4. SINGLE PHASE INVERTER

An inverter is used to change the input DC supply to a symmetric AC voltage of desired magnitude and frequency. A variable output voltage is obtained by varying the input DC voltage and maintaining the gain of the inverter constant. If the DC voltage is fixed and it's not controllable, a variable output voltage can be obtained by varying the gain of the inverter. Here, the gain of the inverter is varied by using a pulse width modulator (PWM). The inverter gain is defined as the ratio of output voltage to the DC input voltage. An inverter is called a voltage fed inverter (VFI) if the input voltage remains constant, a current fed inverter (CFI) if the input current is maintained constant and a variable DC linked inverter if the input voltage is controllable. These inverters are used in various industrial applications like variable speed AC motor drives, induction heating, standby power supplies and uninterruptible power supply. The typical single and three phase outputs are, 120 V at 60 Hz, 220 V at 50 Hz, 115 V at 400 Hz, 220 to 380 V at 50 Hz, 120 to 208 V at 60 Hz and 115 to 200 V at 400 Hz.



SINGLE-PHASE INVERTER

The proposed model here, has a single-phase inverter with MOSFET as the semiconductor switch such that it converts the 326 V DC supply from the boost converter to an AC voltage of range 150 to 220 V. The MOSFETs are triggered using a pulse width modulator circuit. The inverted voltage is then passed through a filter circuit to reduce the ripples and provide a steady AC supply to the load.



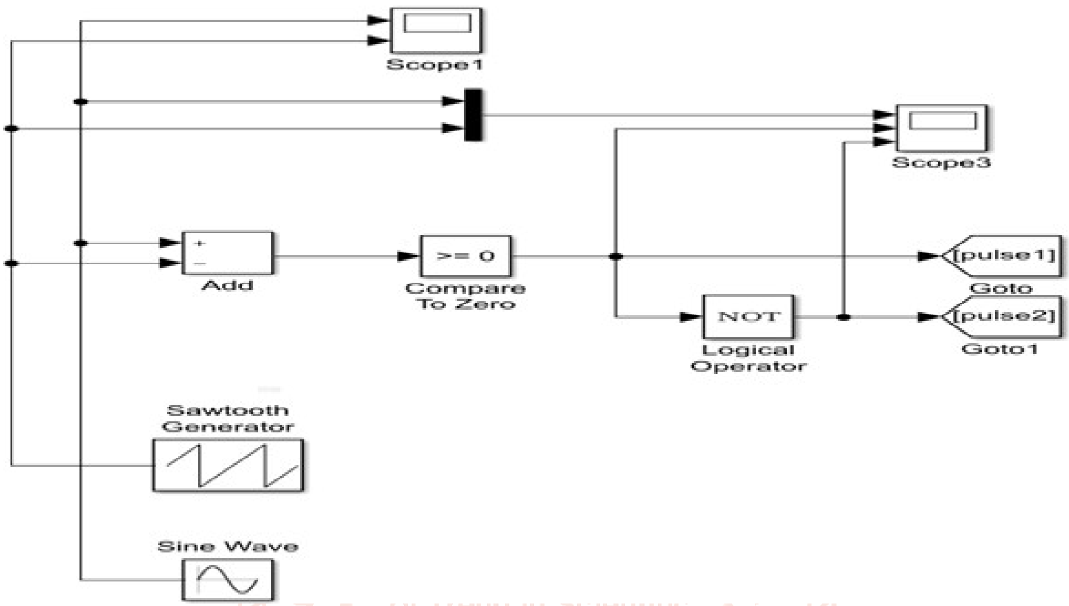
OUTPUTVOLTAGEANDCURRENTOFSINGLE-PHASEINVERTER

PARAMETERS	VALUES
Inductor(L)	0.712mF
Capacitor(C)	1.42μH

FILTER PARAMETERS

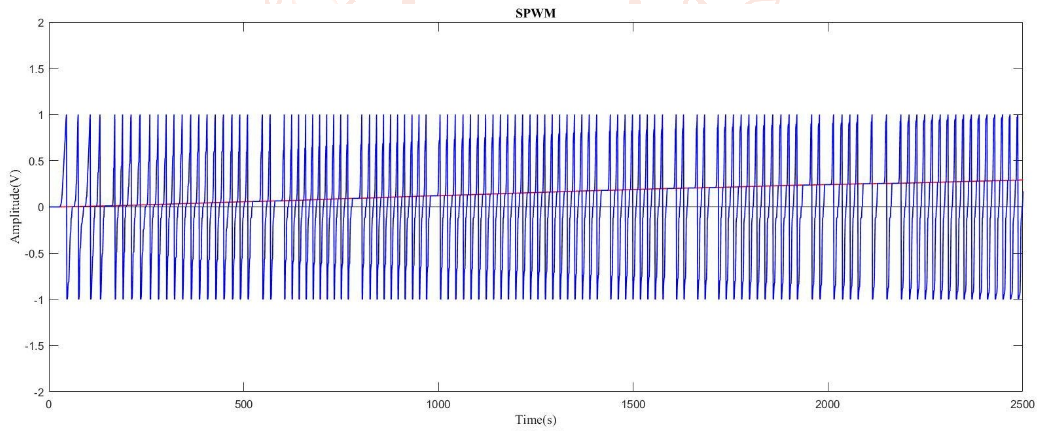
1.3.5. SINUSOIDAL PULSECWIDTH MODULATOR

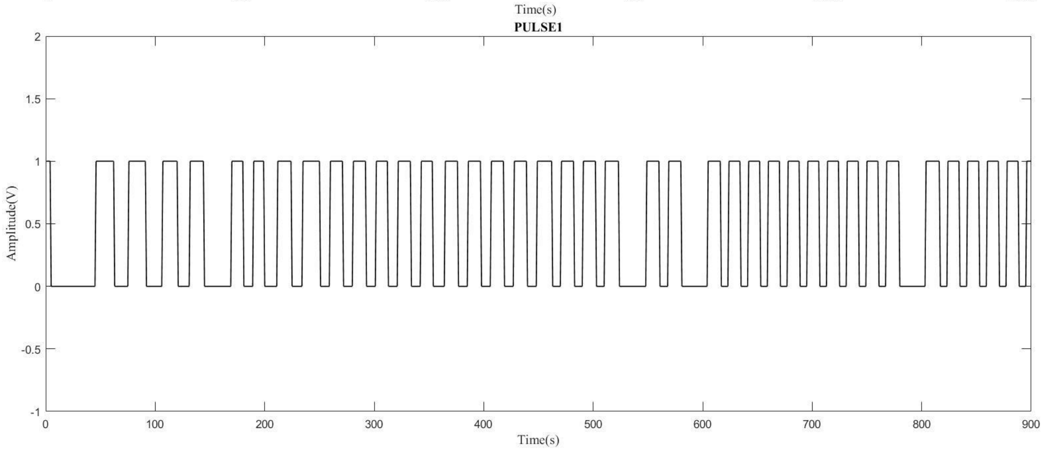
The sinusoidal pulse width modulator is used for the generation of the gating signals, to trigger the semiconductor switches in the circuit. The signals are generated by comparing a sinusoidal reference signal with the triangular carrier wave of frequency Fc. The frequency of the reference signal Fr determines the inverter output frequency Fo and its peak amplitude controls the modulation index M, and Then in turn the rms output voltage.

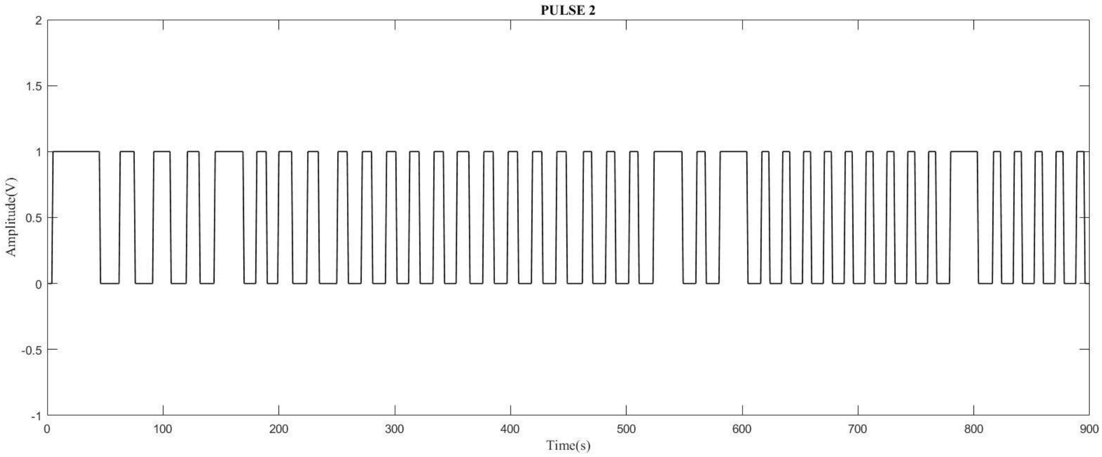


SINUSOIDAL PULSE WIDTH MODULATOR

The reference frequency Fr is taken as 50 Hz and the carrier frequency Fc is taken as 50 KHz. Both the waves are compared and the output obtained is given as a pulse to the MOSFETs 1 and 3 and the complement of the output is fed as a pulse to the other set of MOSFETs 2 and 4, as shown in single phase inverter diagram.







PULSE WAVEFORM

1.4. DESIGN CALCULATION

A. BOOST CONVERTER

Vin = 24 V; Vo = 326 V; P =500W; Io = 2 A; R = 212.5 Ω; = 80%; fs = 25 KHz

Duty cycle = $(1 - (Vin/Vo)) * \eta$ -------------------------(3)

= (1 – (24/326)) * 0.8

= 0.9411

Inductor L = $(Vin(Vo - Vin)/(\Delta IL * fs * Vo)$ ---------(4)

= (24(326 – 24)) / (29.64* 25k * 326)

= 30 µH

Capacitor C = $(Io * D)/(fs * \Delta Vdc)$ ----------------------(5)

= (1.692 * 0.9411) / (25k * 0.6369)

= 0.1 Mf

B. DC Link

Capacitor Cdc = $Idc/(2 * w * \Delta Vdc)$ ----------------------(6)

= 1.692/ (2*π * 25k * 5)

= 2.15 µH

Where, w is the line frequency in rad/s and ΔVdc is the ripple in the DC bus voltage.

C. FILTER DESIGN FOR INVERTER

Vin = 350 V; Vo = 230 V; fo = 50 Hz; fc = 50 kHz; Iripple = 20%

Inductor L = $Vdc/(4 * fc * \Delta Ippmax)$ ---------------------(7)

= 350/(4*50k*8.69*1.414*0.2)

= 0.712 mF

fc = $1/(2 * \pi * \sqrt{LC})$ fc = fc/10

Capacitor = $(10/(2 * \pi * fc))^2 * 1/L$ ----------------------(8)

= (10/2* * 50k)² *(1/0.712 m)

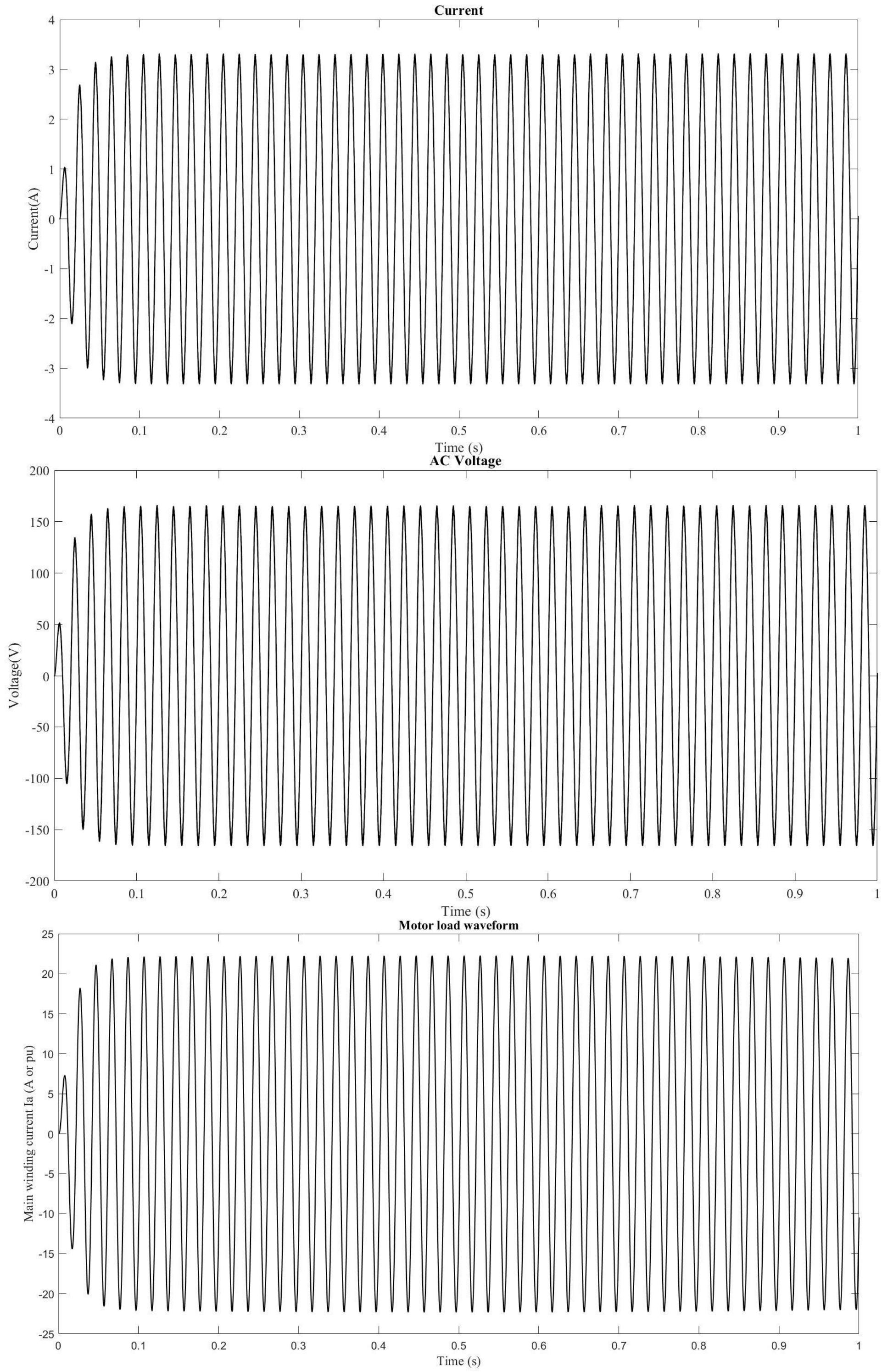
= 1.42 µH

1.5. RESULTS AND DISCUSSION

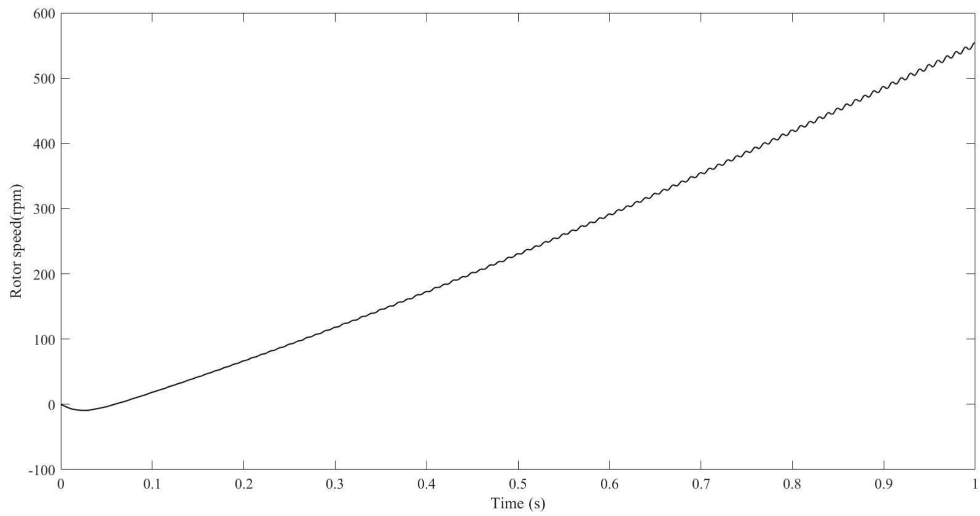
EXPERIMENTAL OBSERVATION

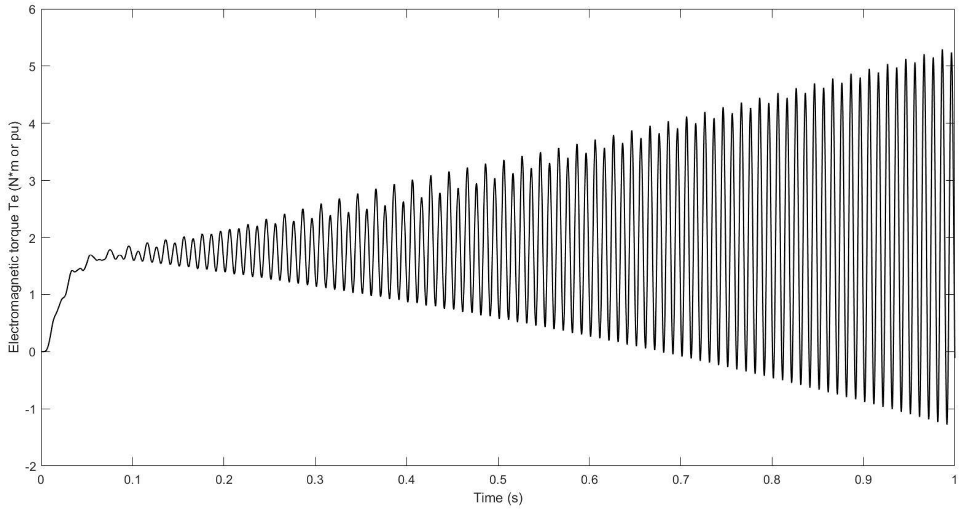
LOAD	VALUE	Vo(V)	Io(A)
R	50Ω	160	2.8

LOAD	STATORCURRENT(A)	SPEED(r.p.m)
Single phase induction motor	24	553.9



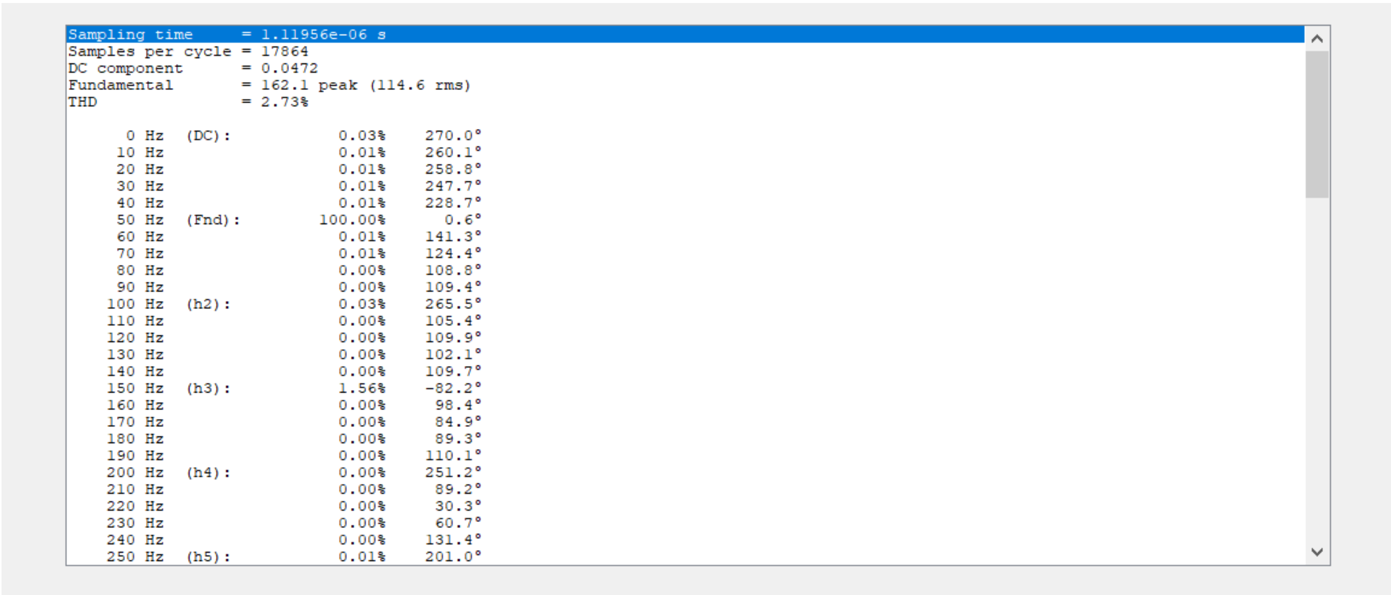
VOLTAGE AND CURRENT WAVEFORM OF RESISTIVE LOAD

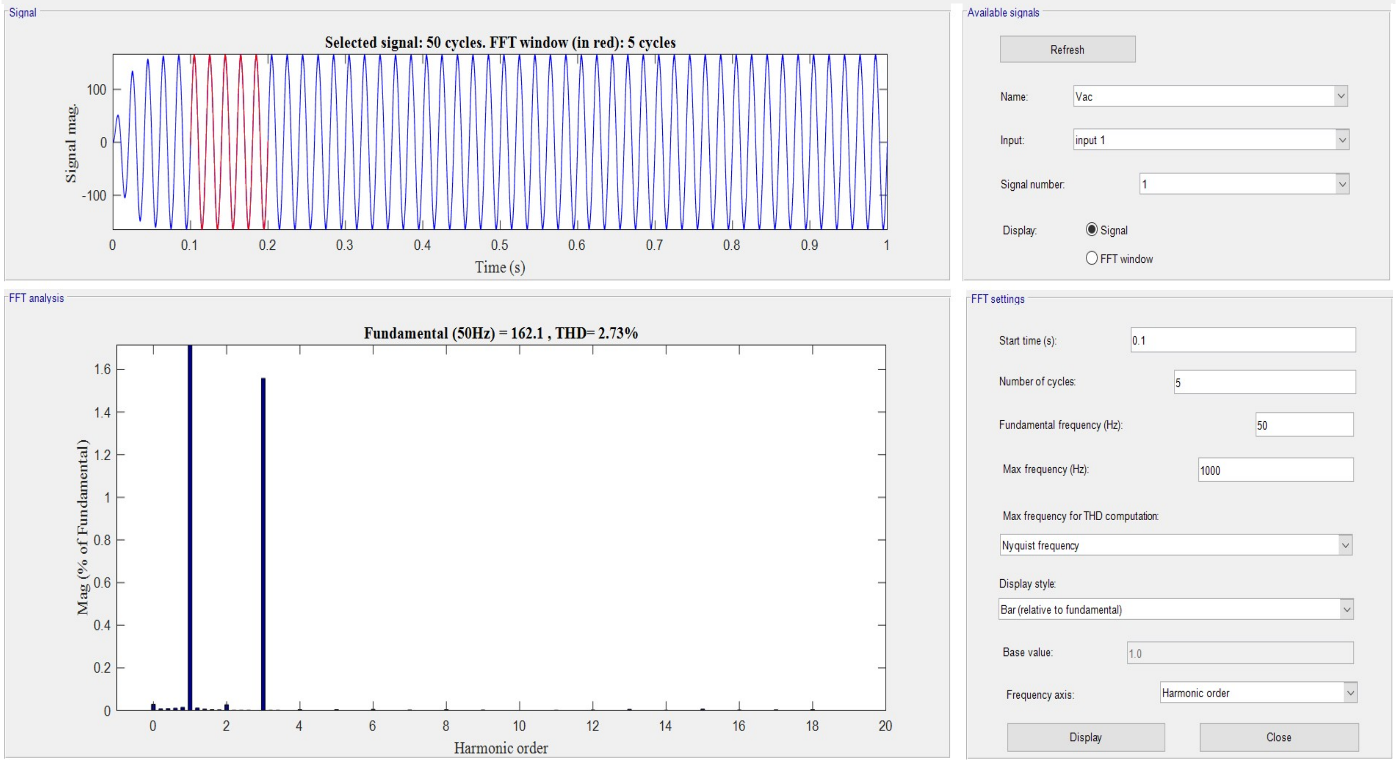




MOTORLOADWAVEFORM

1.5.1. FFT ANALYSIS





FFT ANALYSIS OF OUTPUT VOLTAGE

The FFT analysis of the obtained output voltage is shown ,which has a total harmonic distortion of 2.73 %.

1.6. CONCLUSION

PV is one of the most efficient sourcebecause it produces electric energy from a free inexhaustible source, the sun, using no moving parts, consuming no fossil fuels, and creating no pollution or greenhouse gases during the power generation Using simulation results of the proposed design, it is shown that a PV power can be efficiently converted into AC power without using batteries and transformers. Also middle linkages are omitted to make the system light, compact and easy for installation. The designed single-phase inverter works well with different types of loads, hence it is also compatible to be used for domestic loads like various household appliances.

REFERENCE

[1] P Hridya, P Saritha, "High gain single stage inverter", Intelligent Computing Instrumentation and Control Technologies (ICICICT) 2017 International Conference on, pp. 387-392, 2017.

[2] Ashvini, G., S. Kamalsakthi, and J. Baskaran. "PWM based active low power boost DC-AC inverter." Computation of Power, Energy Information and Commuincation (ICCPEIC), 2017 International Conference on. IEEE, 2017.

[3] Single-Phase Bridge Inverter with Active Power Decoupling Based on Buck-Boost Converter (2018 IEEE Energy Conversion Congress and Exposition (ECCE)).

[4] Dineshkumar, T., M. Mathankumar, and M. Sundaram. "High efficient single stage single phase boost inverter with minimized harmonic distortion." Sustainable Green Buildings and Communities (SGBC), International Conference on. IEEE, 2016.

[5] Sudha Bhutada, S R Nigam, "Design & Simulation Of Boost Converter For Solar Application", CiiT International Journal of Programmable Device Circuits and Systems, Vol 7, No 01, January 2015.

[6] Evaluation of DC-link Decoupling Using Electrolytic or Polypropylene Film Capacitors in Three-Phase Grid-Connected Photovoltaic Inverters Baburaj Karanayil(1), Vassilios G. Agelidis(1) and Josep Pou(1)(2) (1)Australian Energy Research Institute, The University of New South Wales, UNSW Sydney, NSW 2052, Australia.

[7] Modeling and Design of Single-Phase PV Inverter with MPPT Algorithm Applied to the Boost Converter Electrical Department, Laboratory of Renewable Energies and Intelligent Systems (LERSI), Faculty of Sciences and Technology, Sidi Mohamed Ben Abdellah University of Fez, Morocco. 2INSA, Euro-Méditerranée, EUROMED University, Fez, Morocco.

[8] Application Report SLVA372C–November 2009–Revised January 2014 Basic Calculation of a Boost Converter's Power Stage Texas Instruments.

[9] Solar Energy Fed Single Phase Inverter Through Boost Converter - Priya Panneerselvam, Lavanya Subramaniam, Vimala Perumal. International Journal of 33 Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 12, December 2014.

[10] Single phase PWM inverter with close Loop DC-DC Boost Converter For Solar Application - Vimal M. Vaniya, Jaydeep G. Gajipara Prof. Jayanti A. Jadav Department of electrical engineering, Marwadi education foundation of P. G. studies.