DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY DELHI

A Minor Project Work Report

On

Design and Simulation of Transformer less Single-Phase Photovoltaic Inverter without battery for Domestic Application

In

Electrical and Electronics Engineering

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APPROVAL SHEET

This project work entitled Design and Simulation of Transformer less Single-Phase Photovoltaic Inverter without battery for Domestic Application

By Piyush Kumar, Nishant Kumar and Nikhil Raj is approved for the minor project work

Supervisor

Dr. Pankaj Mukhija

Date:

Place:

DECLARATION

In all our modesty, we wish to record here that this Project Report work is an authentic record of our own work as requirements of Project work for the minor project of B. Tech (EEE), National Institute of Technology, Delhi and a sincere attempt have been made for the presentation of this project report.

We also declare that honesty and integrity have been maintained while preparing this project and violation of any rules will cause for disciplinary action by the Institute. We also trust that this study will not only prove to be an academic interest but also will be able to provide an insight into the area of technical knowledge.

Signature of Project Supervisor	**Signature of Students**
Dr. Pankaj Mukhija	Piyush Kumar (201230029)
	Nishant Kumar (201230027)
	Nikhil Raj (201230025)

Date: 02/05/23

CERTIFICATE

This is to certify that the work entitled, **Design and Simulation Transformer less Single-Phase Photovoltaic Inverter without battery for Domestic Application**

submitted by **Piyush Kumar** (201230029), **Nishant Kumar** (201230027) and **Nikhil Raj** (201230025) in partial fulfilment of the minor project in Bachelor of Technology in **Electrical and Electronics Engineering** at the National Institute of Technology Delhi is an authentic work carried out by them under my supervision and guidance. To the best of my knowledge, the matter embodied in the project work has not been submitted to any other University Institute for the award of any project.

Supervisor

Dr. Pankaj Mukhija

Assistant Professor, NIT DELHI

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ACKNOWLEDGEMENTS

We are very thankful to our project work guide Dr. Pankaj Mukhija, Assistant Professor, Department of Electrical and Electronics Engineering, National Institute of Technology, Delhi, to introduce us to this topic and for their inspiring guidance, constructive criticism and valuable suggestions throughout this project work.

We would also like to thank all the supporting staff of the Department of Electrical and Electronics Engineering and all other departments who had been helpful directly or indirectly in making our project a success.

Last but not the least, we would like to thank all our friends who came across us and indirectly taught us for this project and for supporting and motivating us to pursuing our interest throughout this project work.

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ABSTRACT

Solar energy is an excellent renewable energy source due to its sustainability, adaptability, long lifespan, and low maintenance costs. This project focuses on using solar energy as the input source. The photovoltaic (PV) cell converts solar energy into DC electrical energy, which is then boosted to the desired voltage level using a DC-DC converter or boost converter, driven by a MOSFET. The boosted DC voltage is then fed into a PWM inverter, which converts the DC input into AC output, and this output is supplied to the load.

To extract the maximum power from a PV module, a Maximum Power Point Tracking (MPPT) algorithm is implemented. A boost converter is also used to increase the DC voltage level to the desired level, and an inverter with controlled PWM scheme is employed to convert the DC input into AC supply.

The simulation is carried out using MATLAB simulation software, specifically the SIMULINK/SimPowerSystems tool. The simulation results show a transformer-less single-phase inverter that uses a photovoltaic array as the input. The inverter with DC-link is designed to convert DC input into AC supply.

To make the solar energy system more efficient, the project incorporates a blend of MPPT controller, which tracks the point where the solar panel can produce maximum output power, and a feedback system that increases the efficiency of the PV Inverter. Overall, this project aims to develop a more efficient method of using solar energy directly for household applications.

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1. INTRODUCTION

Electricity is an essential commodity that is mostly generated using non-renewable sources such as coal at thermal and hydro power plants. The limited availability of coal results in a shortage of power supply. Therefore, renewable sources such as solar energy are a viable alternative. Solar energy is abundantly available, clean, and eco-friendly, and the application of this source could minimize the energy crisis. Additionally, solar energy is dominant among renewable sources due to the increasing efficiency of solar cells, improvement in manufacturing technology, and minimal maintenance requirements. Therefore, photovoltaic (PV) arrays are used to harness solar energy.

To design a cost-efficient system for domestic use, we propose a transformer-less inverter that eliminates leakage current. The objective is to design an inverter that directly converts PV power to AC power without the use of battery storage devices or middle linkages. Many researchers have developed various inverters for PV applications with different structures, functions, and topologies. Some inverters achieve up to 98% efficiency, while others introduce the concept of hybrid inverters.

However, there is less focus on converting PV energy directly into AC power. Therefore, in this simulation, we designed an inverter topology to extract power from a PV array and convert it to the desired level without the need for battery storage devices. This approach directly converts PV power into AC voltage, reducing the overheads on backup.

2. PROPOSED WORK

Already proposed work is happened in this field, we will show that work which is implemented by us to show how its works and what will be its problem.

Here, Fig. 1 shows the generalized block diagram of proposed PV inverter system. System will take power from PV module. Then it will give to boost converter to boost its voltage up to 100-200 times. The output of a boost converter is given to an inverter to obtain AC power. PWM scheme is used for switching of inverter switches. LCL filter is used to filter an output of an inverter to reduce harmonics and THD.

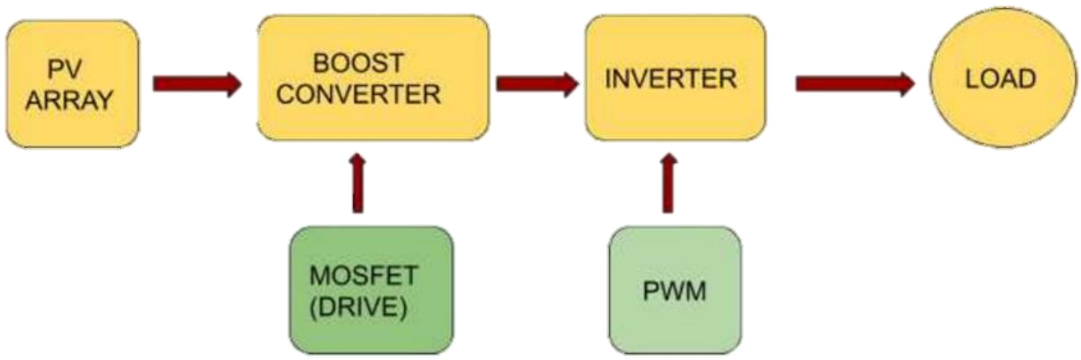


Fig.1.Block Diagram of PV inverter.

Simulation model of proposed PV inverter system. A simulation model of proposed inverter system is shown in Fig. 2. The simulation is carried out in MATLAB/ SIMULINK the model contains various blocks such as PV cell, Boost converter, Inverter, PWM generator and Filter.

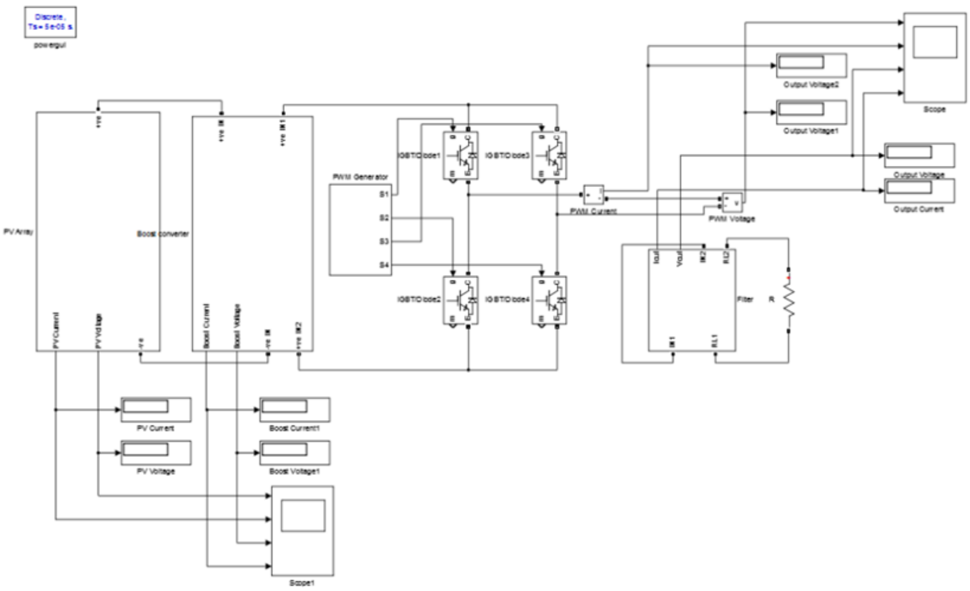


Fig. 2 Simulation model of proposed PV inverter system.

The simulation model of boost converter is as shown in Fig. 3; it has an input inductor which stores energy from PV cell and is delivered to an output capacitor by controlling the switching of MOSFET. To avoid back effect of charge stored by capacitor, a Schottky diode is used. In designing process, the switching frequency fs and duty cycle D plays an important role which is calculated by expression 1.

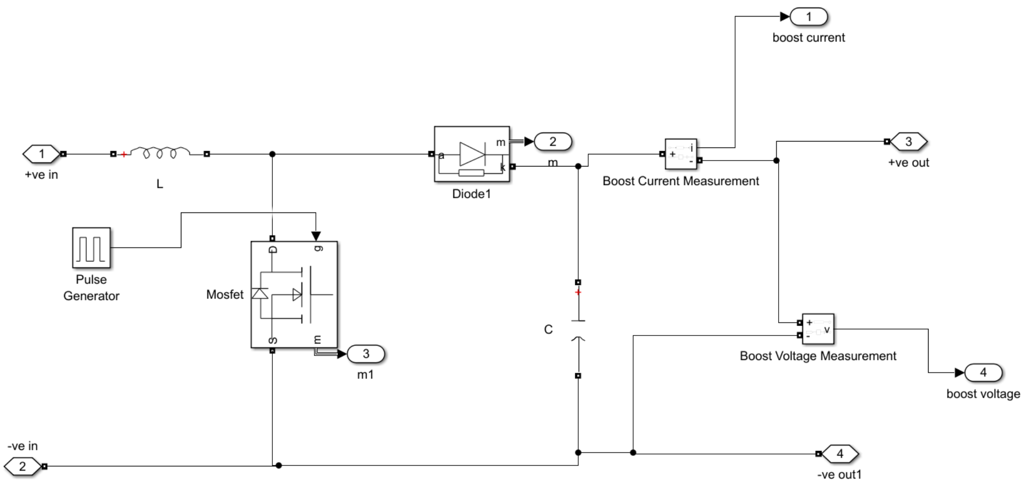


Fig.3 Simulation model of Boost Converter.

An output of boost converter is regulated and delivered to next stage i.e. inverter. H-bridge inverter is simulated in this model. Transformer is not used in the simulation as it causes losses and makes the system bulky. Transformer less inverter topology is simulated. PWM scheme is used to switch IGBTs shown in inverter section of Fig.4.

$$D = 1 - \frac{V_{in\,(min\,)} \times \eta}{V_{out}}$$
$$L = \frac{V_{in} \times (V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}}$$
$$C_{out\,(min)} = \frac{I_{out(max)} \times D}{f_s \times \Delta V_{out}}$$

Exp1. Design Calculation of Boost Converter

At an output of inverter LCL filter is employed shown in Fig. 4, to get a sinusoidal output. LCL filter is designed using expression 2.

$$F = \frac{1}{2\pi} \sqrt{\frac{L_1 + L_2}{L_1 L_2 C_f}}$$

Exp2. Design Calculation of LCL Filter

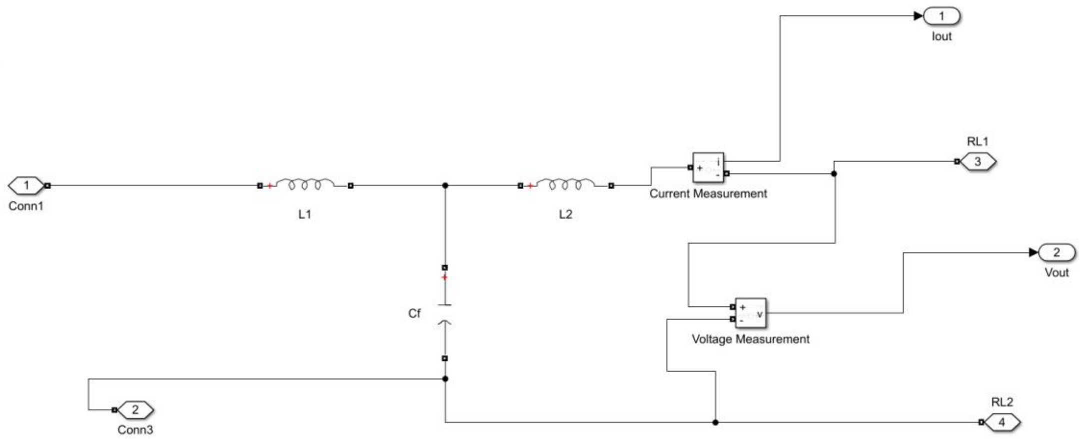


Fig.4 Simulation model of Boost Converter.

3. PROBLEMS OF PROPOSED WORK

A transformer less inverter can be an affordable and compact option for converting DC power to AC power, but it comes with some potential problems.

Firstly, a transformer less inverter can produce high voltage spikes that may damage sensitive electronic devices connected to it. Secondly, it can produce a square wave output that can create electromagnetic interference and affect other electronic equipment in the vicinity.

Thirdly, the absence of a transformer can make the inverter more susceptible to voltage fluctuations and surges, which can lead to equipment failure. A transformer less inverter may not be able to handle high power loads due to its smaller size and lower capacity.

Lastly, Boost converter will heat extensively so it will become problem to control the flow of heat only by Heat sinks of MOSFET.

Therefore, it is important to eliminate all the errors or high voltage fluctuation as it directly damages the load during operation of PV inverter.

4. UPDATED PROJECT WORK

So, to tackle some problems of transform less PV inverter, we have developed a feedback control system to analyze and monitor the ingoing voltage to outcoming voltage through boost converter.

It is considered by studying the PV solar charging which uses the pv voltage to control it to charge the battery, so using this idea we have add this to our work to directly convert for household purposes.

The maximum power point (MPP) describes the point on a current voltage (I-V) curve at which the solar PV device generates the largest output i.e. where the product of current intensity (I) and voltage (V) is maximum. The MPP may change due to external factors such as temperature, light conditions and workmanship of the device.

In order to ensure maximum power output (Pmax) of a solar PV device in view of these external factors, maximum power output trackers (MPPT) may be operated to regulate the resistance of the device.

The block Diagram for new model is –

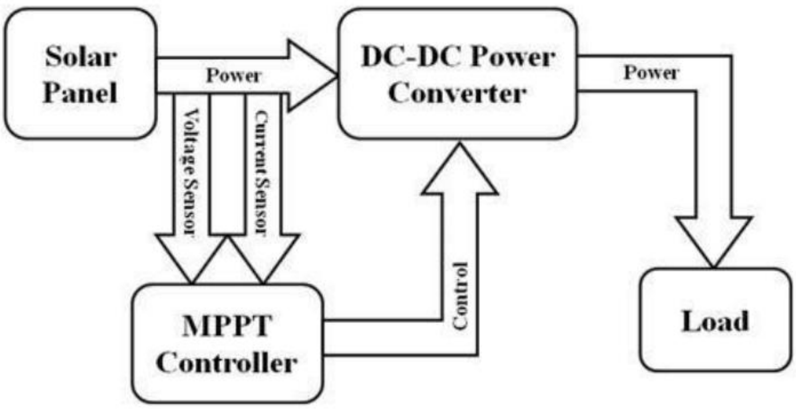
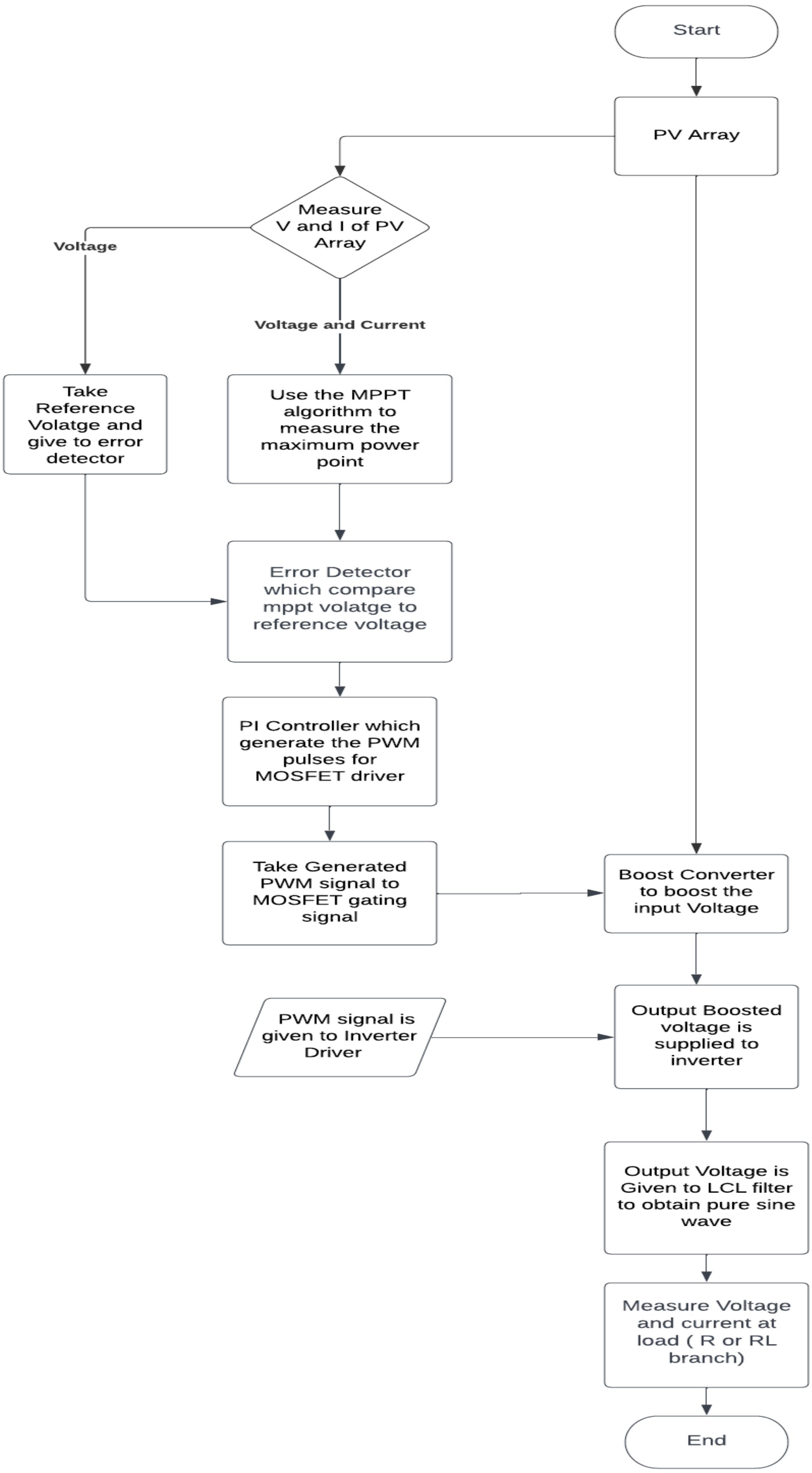


Fig.5 Block Diagram of Feedback system PV inverter

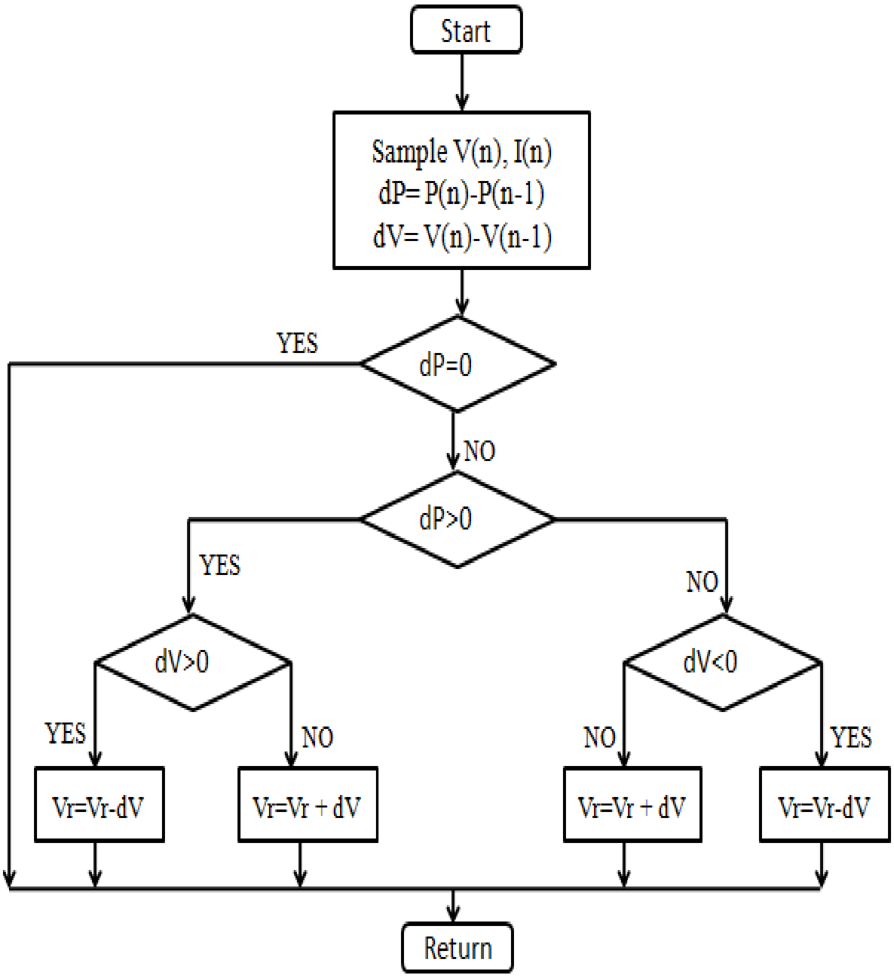
Here is the flow chart of updated work.



So, Above Flowchart showing the feedback control of MPPT algorithm to generate the desired PWM signal for MOSFET driver in boost Converter. The MPPT algorithm is also developed using updated P&O algorithm which stand for Perturbated and Observe which control the duty cycle of PV Array to to ensure maximum power at all times.

This is the most widely used algorithm in the industry. It involves perturbation of the operating voltage or the duty cycle based on a comparison of the generated power. This ensures maximum power point. This algorithm perturbs the operating voltage to ensure maximum power. While there are several advanced and more optimized variants of this algorithm, a basic P&O MPPT algorithm is shown below

This is the Flowchart of MPPT P&O algorithm



5. SIMULATIONS WORK

In order to maximize the use of solar energy, we generally focus on the PV power generation system, which includes modelling of PV systems and maximum power point tracking (MPPT) methods for PV arrays. Using the software MATLAB/Simulink, a model of solar energy power generation system with MPPT control based on fixed step perturbation and observation method is obtained. Using the Embedded MATLAB Function module, the core function of MPPT is achieved. The MPPT control is realized by means of MATLAB/Simulink simulation.

5.1 Simulation of PV inverter using MPPT and feedback control system-

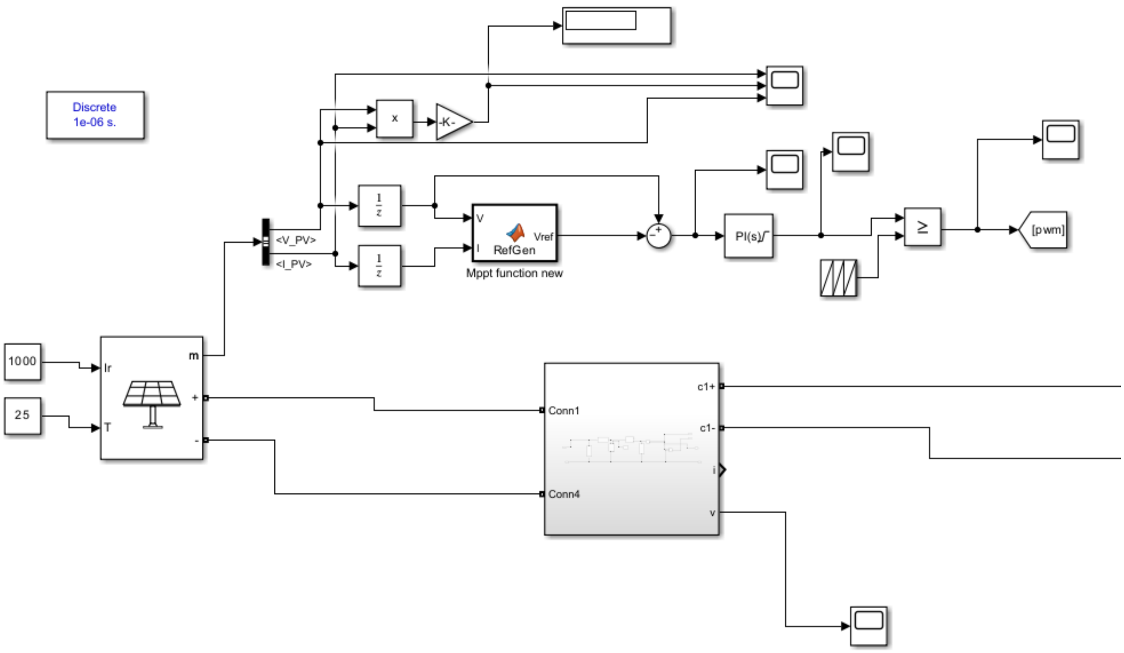


Fig.6 Simulation model of Feedback system PV inverter

5.2 Simulation of H – Bridge Inverter –

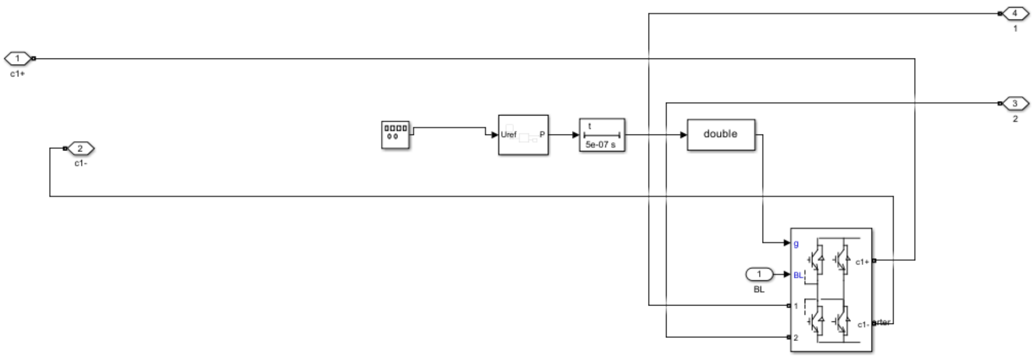


Fig.7 Block Diagram of PV H – Bridge inverter

5.3 Final MPPT Simulation Diagram-

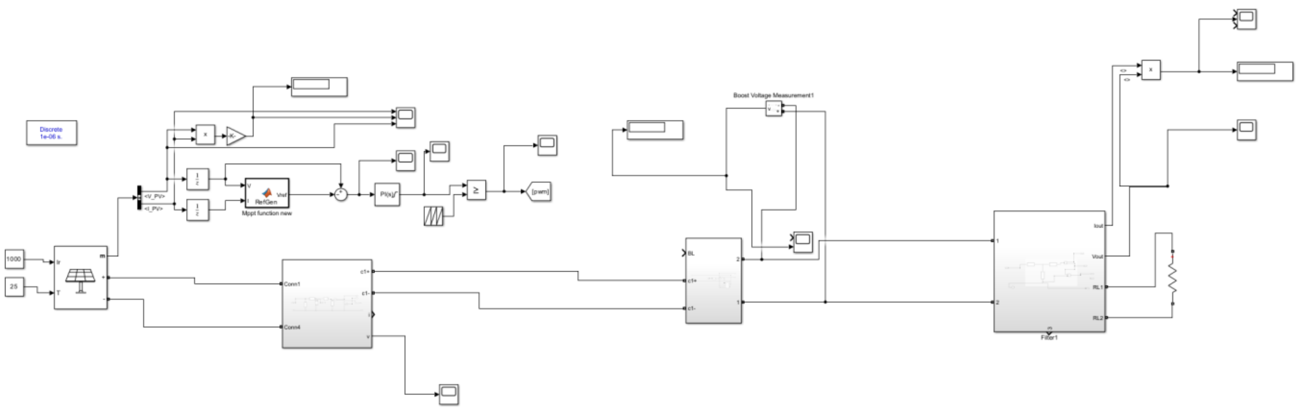


Fig.8 Simulation model of Updated PV inverter

6. DESIGN PARAMETER SPECIFICATIONS

PARAMETER	SPECIFICATIONS
PV Voltage	130V
PV Current	9A
Insolation	1000 Watt/m2
Temperature	25^0C
P & I Value	0.1 & 0.01
Boost RC Branch	0.1 Ω & 1000 µF
Boost Inductor	100 mH
Boost Capacitor	4000µF
Boost Efficiency	90 %
Boost converter PWM carrier frequency(f_c)	5Khz
Boost converter PWM modulation index (m_s)	0.92
Inverter PWM carrier frequency(f_c)	540hz
Filter Inductor(L_1)	30 mH
Filter Inductor(L_2)	20 mH
Filter Capacitor(C_2)	675.5 µF
Output Frequency (f_o)	50 Hz

7. RESULTS AND DISCUSSIONS

The results shows the different output voltages at each steps like Boost converter, Inverter and final output.

First, the PV Voltage and Current from Array -

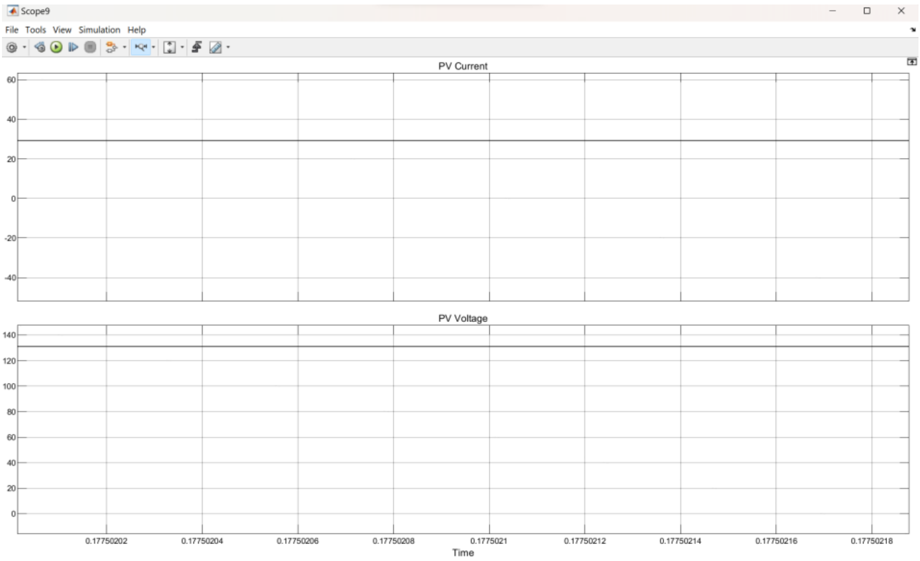


Fig.9 PV Voltage and Current

The Boosted Voltage from DC – DC step up Chopper (Boost Converter) -

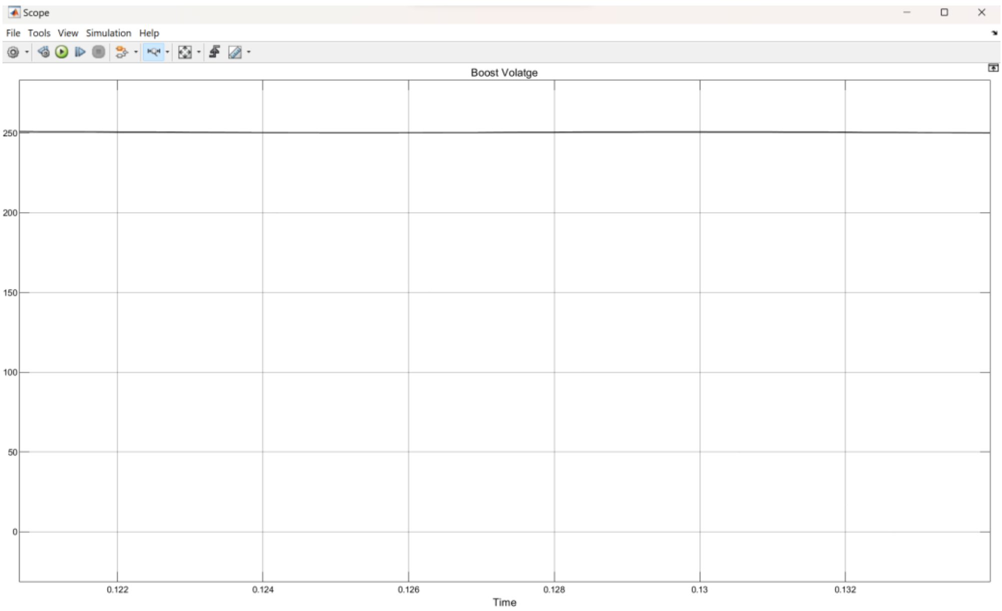


Fig.10 Boost converter output voltage

The Inverter Output or Filter less Output–

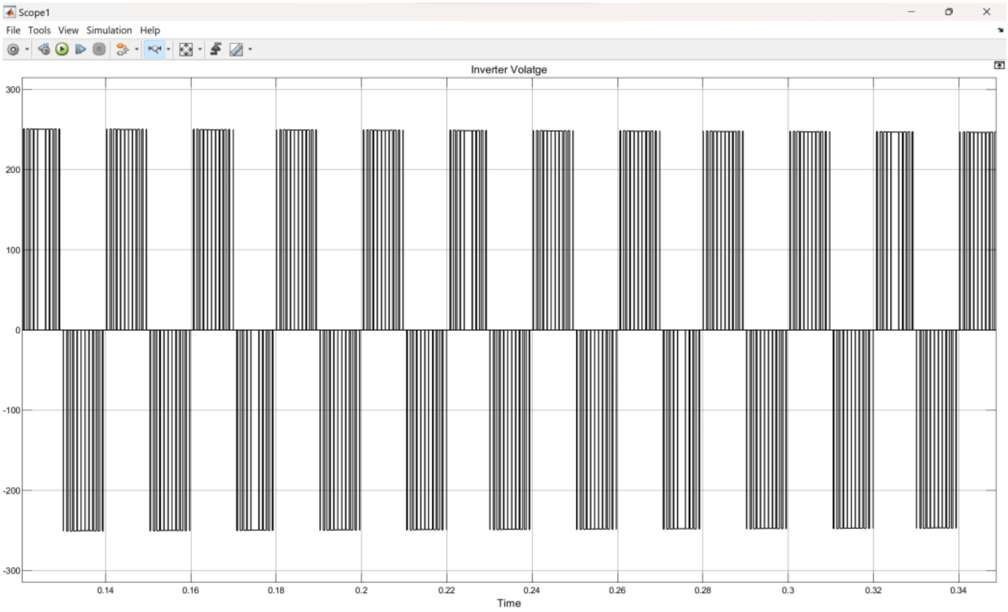


Fig.11 Inverter output voltage without filter

The Output Voltage of an inverter with LCL filter –

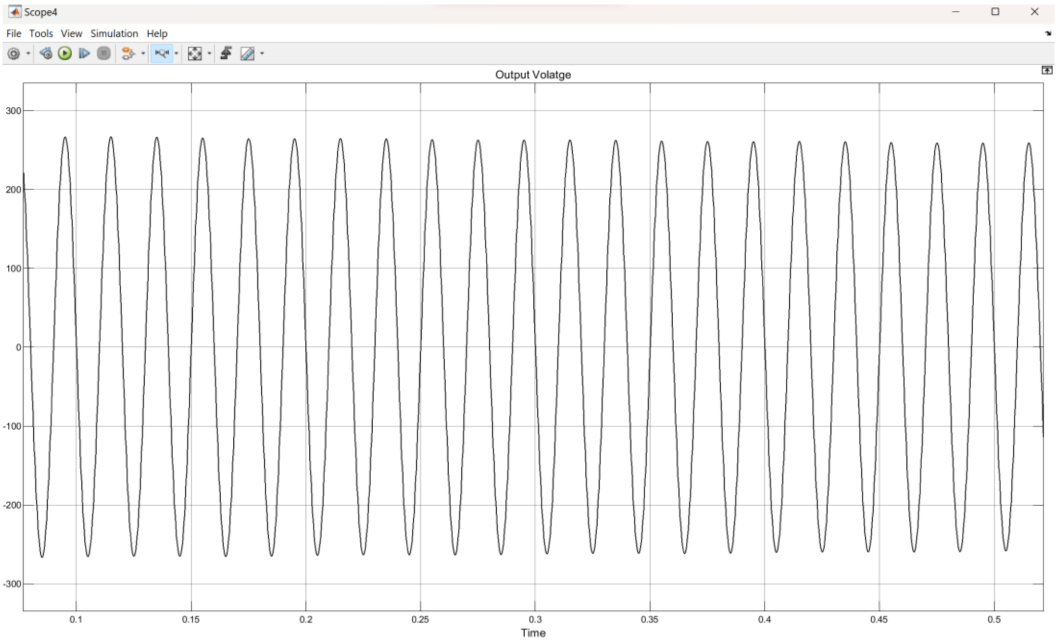


Fig.12 Output Voltage of an inverter with LCL filter

Above, show the output of inverter which is pure sine wave. Here we have analyzed and created a table for different load conditions and Rms value of output voltage.

RMS Value of Output Voltage (V)	Model	Load (R = 200 Ω)	Load (R = 500 Ω)	Load (R = 1000 Ω)	Load (R = 5000 Ω)	Load (R = 1000 Ω L = 100 mH)
1.	Proposed model	174.5	165.6	190.1	238.8	186.4
Updated feedback model						
5.	New Mppt model	190.2	230.3	221.6	200.1	176.5

Table.1- Comparison of Different Load with RMS values

The table show the different Rms voltages for different load. As we can see that as in proposed model, as load resistance increases the Rms voltage differ not significantly but in new mppt model Rms voltage tend to change close to load voltage (~230 V).

This can be explained as the new Mppt model which uses feedback system with PI controller it calculates the optimal value of voltage and generate optimal PWM signal for MOSFET driver, which results in optimal voltage surge or step-up voltage. So, after inverter and filtering the input signal it generates the optimal value of Rms voltage to load. So, load flow can be maintained properly and operate efficiently.

These results show that our new updated project is very optimal solution for PV inverter and can used in household purpose. After more analysis we can also develop proper protection schemes and reduce harmonics efficiently or in real -time environment.

8. CONCLUSIONS

With the help MATLAB Simulink environment, the energy conversion using solar pv cell and control devices can be further enhanced the system performance as well as device monitoring can be easily maintained.

Apart from this, 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.

The designed inverter uses control device which is cost effective and can be implemented using hardware like Arduino and further enhancement can be made to monitor all voltages simultaneously and if any faults occur we can overcome. hence it is also compatible to be used for domestic loads like various household-appliances.

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