# Prototype Development and Testing of a Low-Cost Off-Grid PV Inverter for Sustainable Energy Solutions in Remote Regions

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***Abstract*- This study details the process of creating, modeling, and testing a novel off-grid photovoltaic (PV) inverter system for use in distant, small-scale energy applications. Solar photovoltaic (PV) modules, a battery pack, a charge controller, and a low-power inverter make up the system's structure. A dependable source of electricity for electronics like lights and phone chargers, the inverter transforms direct current (DC) from solar panels into alternating current (AC). The design focuses on optimizing energy storage and conversion for off-grid systems, with a special emphasis on handling variable loads. The effective energy conversion and reliable power production are highlighted by the simulation results, which indicate the inverter's electrical performance. The inverter's practicality and efficacy for renewable energy applications off-grid were demonstrated by the development of a physical prototype, which served to verify these results. Research like this shows that even modest solar power systems have the ability to help find long-term answers to our energy problems. In order to facilitate the widespread use of renewable energy sources, future research may investigate ways to scale these systems and incorporate more sophisticated energy management techniques.**

***Keywords - Off-grid photovoltaic inverter; Small-scale energy applications; Renewable energy storage; DC to AC conversion; Energy efficiency improvement***

## I. Introduction

Solar energy is becoming more important in fulfilling the energy needs of the world because of the increasing concern in adopting technology in the generation of sustainable energy in the world. Tapping solar energy form solar technologies as photovoltaic (PV) offer an effective and sustainable means of meeting people's power needs for utilities power, to back up and remote rural electrification mainly using L Reactive. Because of cheap production costs of PV modules made available by modern technology, increased efficiency and availability of solar energy is feasible for small scale systems especially the stand-alone systems. These systems are more useful in the rural areas where grid connection is unavailable or where the connection is intermittent.

Importantly, off-grid solar inverters help in addressing issues of storage and conversion of the captured solar power within the most effective means of AC power. Solar inverter system connecting with PV panels, a control charge, a battery store and an inverter circuitry complete a micro solar power plant suitable for operating small but necessary electrical devices without any fluctuation or interruption. These systems are intended to power low wattage items like light bulbs and charging of mobile devices as the vital amenities lacking grid electricity. Off grid solar companies literally bring life, light, and opportunity to communities that was not possible before and supports the shift towards distributed energy systems at a global scale.

This study aims at proposing a single-phase off-grid pure sine wave PV inverter system that can supply reliable AC power to the small appliances with desired efficiency levels and system dependability. This electric power generation and reception is achieved by installing PV modules to generate DC power from sunlight; a battery charge controller to feed the DC power into a battery bank. Supplied energy is then converted to AC by the invert circuit thus being suitable for the household appliances. The simulation of project also concerns the electrical characteristic aspect of the inverter including the efficiency characteristic under different load conditions, the stability characteristic of output voltage, and the time response of the system. Such observations inform the prototype development, making it possible to accomplish the provision of stable AC power in real-world circumstances.

This work makes certain unique observations in real off-grid inverter system design, including the problem of the irregular variations in the amount of sun light, inadequate dc-ac inverter conversion, and poor energy storage. This research will, therefore, seek to establish, through simulating and further by prototyping, the possibility of using small scale solar-power systems for off-grid systems, all in a bid to advance renewable energy research and spur the adoption of green energy at a village level.

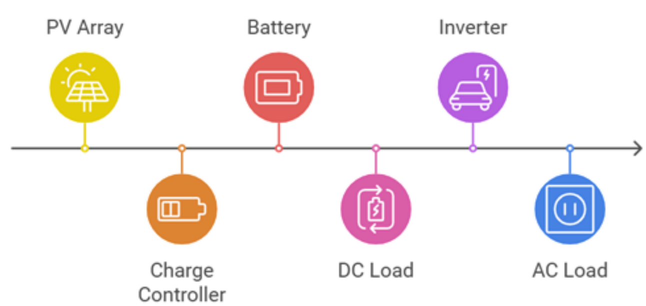


Fig. 1 Block diagram of Off grid solar powered inverter system

Fig. 1 presents the block diagram of off grid solar powered inverter system. In Fig. 1, various block shows the structure and working of the off-grid solar powered inverter system. The PV Array absorbs the sun's energy and turns it into direct current (DC) power. This DC power passes to charge controller which controls the current as well as voltage for charging the batter safely and effectively without overcharging the battery or over discharging the battery. The battery storage system gives power during the times of either low or no sun exposure and during periods of high-power usage. The charge controller also provided a DC Load so that the system can supply direct power output to any DC load appliances. For AC applications, DC stored energy of the battery is supplied to an Inverter to convert it into AC power that is commonly used in power outlets or any other usual load like a light bulb or electric fan. This configuration makes it universal as it avails a DC and AC power source making it appropriate for use in off-grid and backup power applications.

## II. Literature review

There is much written on the topic of solar power harvesting and inverter design and its application. In the following sections, an effort has been made to point out different design aspects, comparison of different architectures and to discuss and conclude with a strategy which would be most appropriate as far as design of a solar based inverter which is cost effective and efficient is concerned. The power inverters of various types are presented in this paper [1]. They include; the current source and voltage source inverters, standalone inverters, grid tie inverters, square wave, modified sine wave and pure sine wave inverters. Open loop strategy is adopted for MATLAB simulation of the various types of PWM inverter. A brief idea about battery, charge controller and PV array is given at the initial stage of the project. The maximum power from solar array is traced using a technique called Maximum Power Point Tracking or MPPT algorithm. A comparative analysis of various types of PWM techniques in terms of cost, size, load type and application is provided. Among the inverter types namely, grid-tied micro-inverter has been deemed the most efficient. The MPPT means that active power control is achieved at an individual PV panel level [2]. It incorporates a design of single-phase grid- tied PV inverter proposed in the following. In this work, to exercise the MPPT technique, a boost converter has been used to avail the maximum power from the PV array. In this method, using SPWM technique with PI controller, the current flow into the grid is regulated. For simulation purposes MATLAB Simulink is utilized and the result.

Solar Based Inverter Design: Differences in version as the basis for diverse cases are provided below: A Brief Review 465 Finally, it is realized from the simulation studies that the grid-tied system performs the best under various test conditions [3]. The design of a single-phase PV inverter without galvanic isolation is discussed in. The output of the PV array is connected to the DC-to-DC boost converter for optimum power point tracking. From the result it is observed that, the gate pulse of the IGBT of boost converter is controlled by using MPPT control technique. To get more efficient conversion from the dc to ac, the boosted output is supplied to the highly efficient and reliable inverter concept (HERIC) inverter. This is due to the many switches in the HERIC inverter, thereby making it much more complex than other inverters. To minimize the leakage current, the concept of HERIC configuration is introduced in this paper. MATLAB is used to carry out the analysis and verification of the simulation mentioned above [4]. The proposed single-phase inverter with a new control approach is described in this. The control unit used here is the Multiple Pulse Width Modulation (MPWM), which facilitates the waveform of the output with low harmonics. The use of Microcontroller 8051 is aimed at giving the triggering pulse and this has a way of simplifying the overall circuits. In the context of the harmonic analysis, computation of the dummy power circuit is done in MATLAB. Such load conditions are incorporated and for the high current inductive load, snubber parameters are determined.

A short description of the single phase photovoltaic pure sine wave inverter with reduced harmonic distortion is provided in [5]. The generated power from the PV panel is in direct current form and needs a voltage regulation, and then it sends it to the inverter. For the MOSFET driver, PIC16F876 microcontroller offers half-wave sine patterned SPWM. By using a sensor, the output of the inverter is measured and supplied to the microcontroller of the system. For any delay in the pre-set value, the compensation voltage is given by the microcontroller. The result is highly accurate since it adopts closed end items only with the exception of concurrent measurement" loop. The output waveform is therefore this sine wave distorted as shown below. Hence, LC filter is involved in order to minimize the effects of harmonic interference. At the output of the design, a transformer is incorporated in a bid to minimize cases of eddy current loss. Compact structure, reduced harmonic distortion, and low-cost inverter are achieved in this case [6]. Solar-PV has considerable share based on the other renewable generating units of current importance, and the Solar-PV farms are the emerging industry in the renewable segment and tend to grow without FAST. increasing their proportion. There is increased overall efficiency of big PV-farms due to the increased installation of WPPs (Wind Power Plants) though the present B2G PV penetration level is miniscule in relation with the optimum demand [7]. To reduce power oscillations in solar grid connected system, Abdulrahman et al. have put forward an adaptive time-delay compensation technique. From the wide-area measurements, the method improves the stability by varying the control parameters with time. Simulation results reveal that use of the suggested method yields higher system stability compared to conventional techniques [8]. Khayyatzadeh and Kazemzadeh [9] discuss sub-synchronous resonance in power systems with a high degree of photovoltaic (PV) plants. They put forward higher level control approaches for the PV inverters to mitigate SSR effectively. The result of the simulation proves that these strategies cannot only increase the stability of grid but also reduce SSR problems that high-penetration PV system may cause. Renewable energy is vital in the shift from conventional power or fluid generated by fossil fuel sources. With world energy demand growing, renewable power such as separated photovoltaic systems (PV) and focusing solar power (CSP) turn into invaluable. PV technology has been found suitable for different uses and solar thermal energy, albeit costly, is financially viable. Energy storage means the generation of electricity even when the sun is not shining or not bright enough to produce electricity. The basic difference between PV and solar thermal is the area of application which depends on regional requirements. In sum, the increasing popularization of solar technology makes solar energy technology an essential part of future energy plans to combat climate change [10].

The paper "Design and Simulation of a Stand-Alone Solar Inverter" is concerned with the advancement in efficiency and power quality for residential consumption. When implemented using MATLAB Simulink, it assesses other important factors and outputs such as RMS, THD and Vrms. This innovative and simple inverter enables various loads to be supplied with substantial power quality while reducing the harmonic distortion, thereby demonstrating solar energy to meet the rising electricity needs and identifying a future prototype [11]. The project of "New Design of the Solar Inverters for Better Performance" seeks to increase total efficiency of PV systems and decrease the level of the total harmonic distortion. Due to improvements such as single phase full-bridge inverters and enhanced ways of PWM, energy loss can be minimized up to 81% which will improve on the inverters used in DC-AC conversion as well as support small designs of modern energy [12]. Author worked on an Introduction to Home Solar Inverters. It is written by Digi Dileep describes the importance of solar inverters and bifurcates inverters into micro inverters and grid-tie inverters. They showcase the micro-inverters' efficiency compared to string inverters, MPPT, and explain why it is better to install the micro-inverters in shaded conditions. The paper also provides a positive comparison of PWM controllers to switching controllers for battery management as well as changes in different inverters [13].

## III. MATERIALS AND METHODOLOGY

These materials and specifications offer a good starting point as to what you should expect to obtain for constructing your one phase grid connected Solar PV Inverter. Fig. 2 shows the components of PV array system. Also, Fig. 2 shows the main parts of a photovoltaic (PV) inverter, which are responsible for transforming the DC power generated by PV panels into useable AC power that may be used in places where grid electricity is not available. Interconnected solar panels make up a PV array, which is able to transform solar energy into DC power. The system's main energy source, its output powers the conversion and regulation phases that follow. This device, known as a DC-DC converter, modifies the DC voltage that the PV array produces so that the inverter can handle it. Importantly, it optimizes the power output of the PV panels by making use of methods such as Maximum Power Point Tracking (MPPT) to guarantee maximum energy extraction regardless of the weather. The PV array and DC-DC converter provide direct current (DC), which the inverter circuit transforms into alternating current (AC) fit for typical residential and business AC loads. At its heart, this part allows DC electricity to be converted into AC power. The Pulse Width Modulation (PWM) block regulates the voltage level and output waveform by controlling the inverter's switching activity. It creates a steady and clean AC waveform by pulsing the inverter switches on and off.

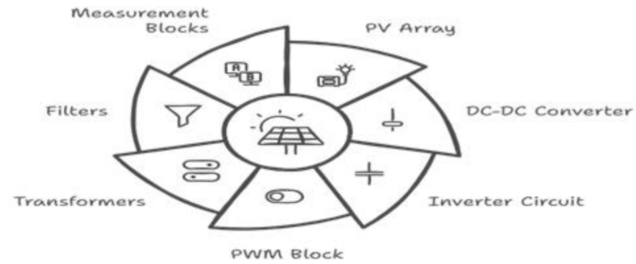


Fig. 2 Components of PV array system

The AC voltage may be adjusted by using transformers, which can either increase or decrease the voltage. They make the PV inverter more versatile by ensuring that its output voltage is compatible with that of the loads or storage systems connected to it. A more steady and cleaner sine wave is produced by applying filters to the AC output, which smooth out any ripple or noise. Important for delicate electrical equipment, this guarantees that the power output is up to par. Blocks for Measurement: These blocks keep an eye on the system's voltage, current, and frequency in real time. In order to manage and optimize the inverter's performance, they supply crucial data that is necessary for safe and efficient operation. This image showcases a comprehensive PV inverter system that is ideal for off-grid applications. It shows how each part works together to efficiently convert solar energy, regulate it, and then produce reliable AC power.

### A. MATLAB /Simulink Model

For off-grid uses, you may convert the DC output of PV panels to AC using the MATLAB Simulink model of a PV solar inverter system. Fig. 3 shows the MATLAB/SIMULINK model of PV based solar inverter system. The inverter takes the output of the DC-DC converter and uses MPPT to maximize energy output; the power quality of the AC power is then improved by filtering. Optimizing performance and evaluating efficiency are both made easier by the model's ability to support testing across a wide range of load and environmental circumstances. Solar power systems that are both dependable and efficient might benefit from its use as a teaching and research tool to validate prototypes and improve control strategies. This demonstrates a Simulink model of a PV inverter system. In a power inverter simulation, what something represents solar panels, producing DC electric from sunlight's likely used.

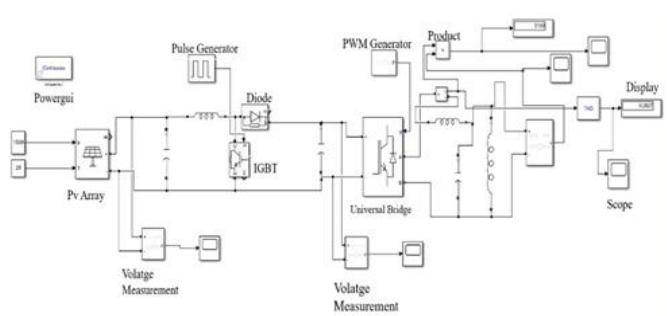


Fig. 3 MATLAB/SIMULINK model of PV inverter system

In Fig. 3, power inverter simulations aren't complete without the PV array block, which stands in for solar panels. These blocks convert sunlight into DC electricity and let you tweak the settings to test how well your system works in various environments. The inverter's power devices, such as transistors or IGBTs, are controlled by the pulses produced by the pulse generator block, which transforms the DC input into an AC waveform. An improved PWM generator level 2 block offers superior control, which is essential for successful DC-to-AC conversion. To convert AC to DC, inverters use diodes, which are often organized in rectifier circuits. IGBTs are perfect for power inverters' high-frequency switching because they are high-voltage, high-current switches that combine the features of bipolar transistors and MOSFETs. The Universal Bridge block represents flexible bridge circuits used in converters and inverters, while the Scope block shows signal waveforms for performance investigation. Last but not least, the Power GUI is a user interface that lets you configure and test electrical circuits. You may alter parameters and track their progress throughout simulation.

In total, these tools assist engineers to design, simulate and analyze power inverter systems using MATLAB Simulink, and enhance the performance of inverter systems.

This MATLAB/Simulink model is used to model a PV inverter system, explaining the process of converting sunlight into clean AC power for domestic or grid utility. The simulation covers the fundamental components of a PV system, where the PV array converts direct current electricity proportionate with light intensity. In order to maintain a stable DC, output the voltage is regulated but with a DC-DC converter. This well-regulated DC is then fed to an inverter which employs asymptotic control and switching elements such as transistors to generate an AC waveform by Pulse Width Modulation. An introduction again assumes this AC voltage to higher voltage by means of a transformer, sufficient to required electrical appliances. The filters, which are a combination of capacitors and inductors, are incorporated to refine the waveform to discharge unnecessary harmonic and generate near-sinewave. Qualitative outputs are usually indicated by measurement blocks which include THD or oscilloscopes, which help in subjecting output signals to analysis as well as waveform visualization. In conclusion, this simulation demonstrates the highly efficient method of converting solar power from DC to clean, high quality AC for usage purposes. In this simulation model, the process through which solar energy is changed from DC to well stabilized AC power is shown through the use of a DC-DC converter, an inverter, pulse width modulation control, transformers, and filters. Regarding, the measurement blocks they assist in the process of monitoring the quality of the product being produced.

*B. Prototype Circuit (Hardware Schematic)*

To authenticate and evaluate a design, such as an off-grid solar inverter, in real-world conditions, surpassing the capabilities of simulations, a hardware schematic or prototype circuit is required. Engineers may enhance performance by optimizing components like as capacitors and resistors, addressing design difficulties including heat dissipation and component stress, and evaluating control techniques like PWM on physical hardware to ensure sufficient responsiveness during prototype development. Crucial for evaluating feasibility and potential scalability, it also provides insights on dimensions, efficiency, expenses, and total costs. Essential safety and compliance testing may also be performed on the prototype, ensuring that the final product is safe for customers and adheres to all relevant rules.

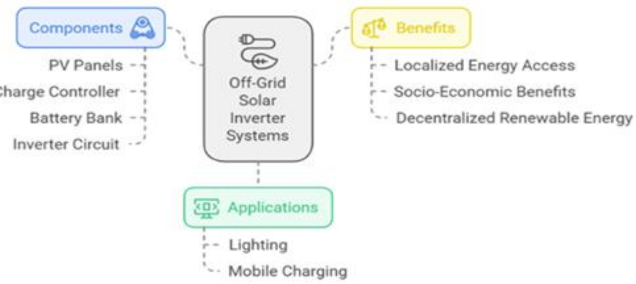


Fig. 4 overview of off-grid solar inverter systems

Fig. 4 provides an overview of off-grid solar inverter systems, detailing their components, applications, and benefits. Key components include PV panels that capture sunlight and produce DC electricity, a charge controller to regulate power flow to prevent battery overcharging, a battery bank for energy storage, and an inverter circuit that converts stored DC power into AC for household use. Common applications of these systems include powering lighting and charging mobile devices, particularly useful in remote areas without grid access. The benefits of off-grid solar systems include enabling localized energy access, supporting socio-economic development through reliable power, and promoting decentralized renewable energy, which reduces dependency on fossil fuels and aligns with sustainability goals.

Fig. 5 is showing a basic single phase hardware prototype circuit for an inverter. Key components are: IC CD4047 as a multi-vibrator IC. It is used for generating the required switching signals. Resistors (10K, 220 Ohm 5W) for operating the circuit with specific conditions and restrict current. Capacitors (1000µF, 25V and 0.1µF) for filtering and the stabilization of signals. MOSFETs (Q1 and Q2, P75N75 or IRFP3205) as switches and be capable of handling higher power levels. Transformer (12V-0-12V, 5A, for output Power 50W) which Converts the output DC to AC.

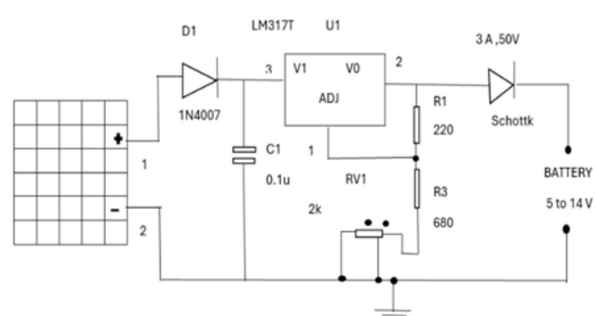


Fig. 5 overview of off-grid solar inverter systems

The general procedure of forming the solar battery charger circuit is as follows The first step is to design the circuit using relevant electronic components which can be aimed at incorporating specific characters into circuits. The aim is to design a charger for 6V, 4.5 Ah, lead-acid battery and using a 12V solar panel, voltage, and current control features shall be included. Several components are used in the circuit design they include; A 12V solar panel, a variable LM317 voltage regulator for output regulation, 1N4007 diode for current direction, a Scotty diode for efficiency, a 0.1 µF capacitor, voltage adjust resistor and a 2K potentiometer for adjustable output voltages. When the assembly is done, printed circuit board components are soldered as per the circuit diagram, and polarity for diodes has to be right. Instead, testing entails connecting the solar panel to sunlight and using the potentiometer (RV1) to set the output voltage to the charging voltage of the batter. The output voltage and current are also measured using a digital multimeter in order to ensure normal working of the device. Other features consisting of reverse polarity and breakdown voltage of static discharge improve the circuit safety. Last, potential modifications to the circuit in order to achieve the optimal charging efficiency as well as the necessary safety parameters under various sunlight conditions and loads are made. It gives a strategic framework for using solar energy for charging batteries hence enhanced battery charging.

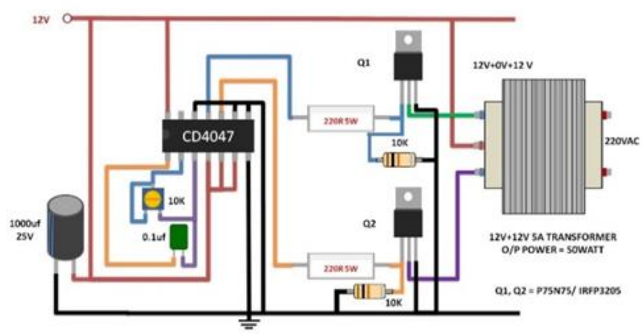


Fig. 6 Prototype inverter circuit

Fig. 6 presents working operation of a simple inverter that can convert 12V DC to 220V AC ideal for use with small appliances only. The flows begin with an input voltage of 12 Vdc, which could either be a battery or solar panel. The CD4047 IC is used as an oscillator to create a 50Hz or 60Hz frequency and this generates complementary pulses for MOSFETs namely Q1 and Q2. These MOSFETs activate to provide the function of power switching by either making the circuit ON or OFF to generate an AC from the DC source. Current limiting is done by resistors (10K and 220 Ohm) and the presence of capacitors (1000µF and 0.1µF) ensure that the voltage is regulated by smashing out fluctuations. The alternating signal obtained from the MOSFETs is passed through a step-up transformer (12V-0-12V, 5A) which steps up the voltage from 12V to 220V of a high voltage AC. This setup is very basic yet it gives clear solution to DC to AC inverter, which is an important conversion of DC to AC used in house hold appliances. Both of them perform the function of performing DC to AC conversion and the simulation allows us to virtually test while the prototype is a real physical structure. The above methodology gives total appreciation of DC-AC power conversion method using either solar or battery systems.

## IV. Results

In this section, the results demonstrate the dynamic response of a PV-based solar inverter operating at a target output power of approximately 5109 watts. The waveform analysis reveals characteristic oscillations in output power, likely due to fluctuations in solar irradiance and the inverter's maximum power point tracking (MPPT) adjustments. These periodic variations highlight the inverter's ability to stabilize output despite variable input conditions, showcasing its efficiency in converting DC power from the PV panels to a steady AC output. The results emphasize the importance of effective control strategies in minimizing power oscillations and ensuring consistent performance.

The waveform shown in Fig. 7, is characteristic of the output voltage of a photovoltaic (PV)-based solar inverter, which typically exhibits a damped oscillatory response as it stabilizes. When a PV inverter starts or reacts to a sudden change, such as a load variation, it may produce a transient response with initial oscillations. This initial sharp rise likely reflects the inverter's response to the input power surge from the PV array or a change in operating conditions. The oscillatory behavior that follows is due to the inverter's internal control system and filter circuitry, which work to smooth the DC input from the PV array into a stable AC output. The gradual decrease in oscillation amplitude indicates the inverter's damping mechanisms, designed to suppress transients and maintain stability, as it approaches steady-state. Once the transient effects are damped out, the waveform settles into a steady periodic AC output, reflecting the inverter's stable, sinusoidal output voltage at the desired frequency (typically 50 or 60 Hz). This steady sinusoidal output is essential for synchronizing with the grid or for consistent power delivery to AC loads. Thus, the waveform illustrates the inverter's process of converting variable DC power from the PV system into a stable AC output, with damping mechanisms ensuring minimal oscillations and a smooth transition to steady operation.

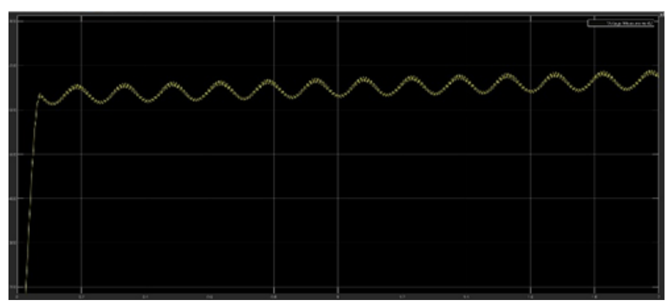

Fig. 7 Output voltage waveform of PV based solar inverter

Fig. 8 represents the waveform of Total Harmonic Distortion (THD) profile of the output voltage in a PV-based solar inverter system. This type of waveform typically appears when an inverter's output contains multiple harmonic frequencies in addition to the fundamental frequency. At startup, a PV inverter may exhibit a high THD due to the initial stabilization phase, causing a sharp peak as the inverter control systems attempt to manage and filter the incoming power from the PV panels. This initial spike reflects the presence of significant harmonic content and transient noise before the inverter stabilizes.

As time progresses, the waveform shows oscillations that gradually settle but continue to exhibit periodic variations. This persistent oscillatory pattern with varying amplitude indicates residual harmonics, often arising from switching components within the inverter, such as PWM switches, which can introduce higher-order harmonics. The ripples in the waveform reflect these harmonics, with each "peak" representing specific harmonic frequencies that remain in the output. Effective control strategies and filtering are critical in PV inverters to reduce THD to acceptable levels, ensuring cleaner, near-sinusoidal output voltage. Total THD is 28.27 %.

Ultimately, this waveform highlights the inverter's efforts to minimize harmonic distortion over time. The goal in PV inverter design is to reduce THD as much as possible to improve power quality for grid or load compatibility. However, achieving this requires careful tuning of control algorithms and filtering components to mitigate harmonics while handling the variable DC input from the solar panels. The remaining oscillations after the initial peak suggest that the system reaches a quasi-steady-state but still retains some harmonic distortion due to the nonlinear nature of the inverter's switching mechanisms.

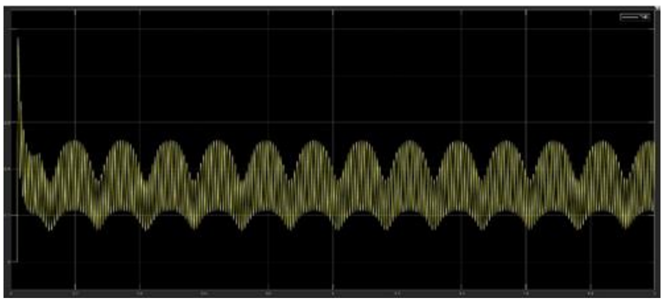

Fig. 8 Waveform of Total Harmonics Distortion (THD )i.e. = 28.27%

The waveform shown appears to represent the output power of a PV-based solar inverter system, reaching approximately 5109 watts. The oscillatory pattern with periodic peaks suggests that the power output is subject to fluctuations, likely due to the dynamic response of the inverter and variations in solar irradiance or load conditions. These oscillations could be caused by rapid changes in sunlight intensity, such as passing clouds, or by adjustments in the inverter's maximum power point tracking (MPPT) algorithm, which continuously optimizes the power output from the PV array. The amplitude of the oscillations indicates how the inverter is managing these variations to stabilize the power output. However, despite the fluctuations, the waveform stabilizes around a peak power level close to 5109 watts, which reflects the system's maximum available power under current conditions. The consistent oscillations around this level are typical in PV inverters as they adjust for real-time changes in input power while aiming to deliver as close to a steady output as possible. This behavior demonstrates the inverter's efficiency in converting variable DC power from the PV panels into a stable AC power output, even under fluctuating environmental conditions. Effective MPPT and filtering are essential for reducing the impact of such oscillations and providing a more stable power output, which is especially important for applications where steady power delivery is critical. The observed waveform emphasizes the inverter's control strategy in adapting to the dynamic nature of solar energy to maintain an output around the target power level of 5109 watts.

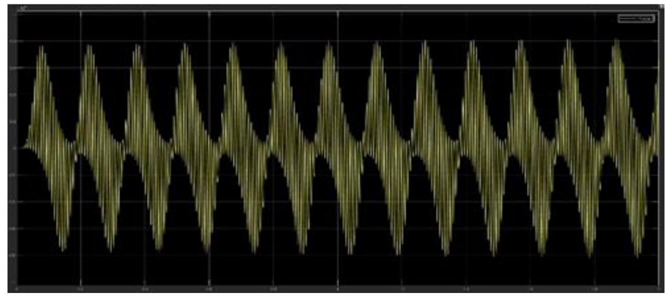

Fig. 9 Waveform of output power in 5109 watts.

Fig. 10 outlines the solar-power inverter system prototype at its first design. The setup includes key components: namely two solar panels, two rechargeable batteries, a solar charge controller circuit and an inverter circuit all connected in a single structural design. The solar panel is connected directly to the solar charger circuit to ensure that system does not over charge the batteries. The batteries function as energy storage devices supplying DC power to the inverter circuit. The inverter then steps this DC voltage to match the AC which is good for use in powering AC loads. Cabling and circuitry continuity and arrangement afford fans a glimpse of energy flow from the solar source to the inverter path then ready for various loads.

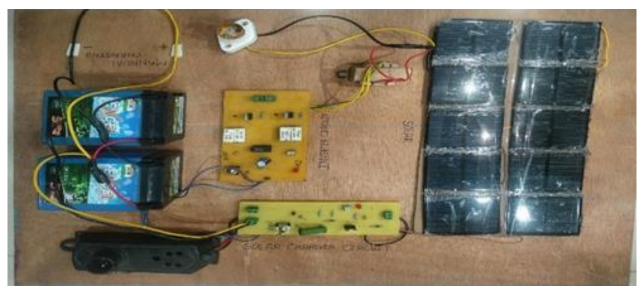

Fig.10 Prototype Configuration for Solar-Powered Inverter System

Fig. 11 illustrates the circumstances of the actual use of the prototype with an active load. For the given circuit here a load in the form of light bulb is connected to show the capability of the system in delivering the AC power developed by the inverter. The solar panels give energy which is stored in the batteries and controlled by the solar charger circuit. The inverter converts DC power stored into an AC which illuminates the bulb showing that energy conversion was successful. This configuration demonstrates how the system is capable of handling and supporting a load and confirms the viability and efficiency of the solar inverter design while under load.

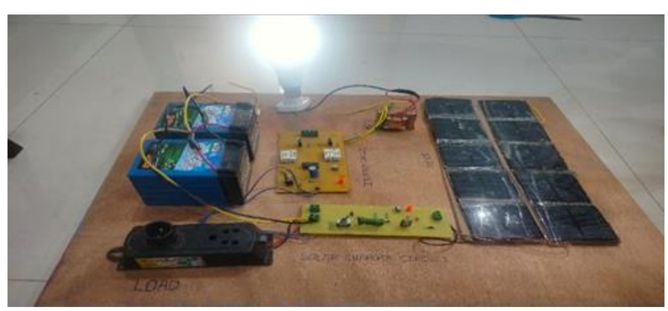

Fig.11 Working operation of solar inverter under load conditions

## V. Discussion

The efficiency of the charged solar battery circuit was also evaluated by measuring the output voltage and current during testing and compared with the simulated values. Some deviations were found especially when assaying the sample under different light brightness; more optimization is required. Regarding the performances of the charger, the energy captured by the solar panel when charging was compared with the energy stored in the battery while considering the losses due to heat dissipation by other components including the LM317 voltage regulator. Lighting conditions, including intensity and temperature and the position of the panel, affected charging rates and system reliability.

The design problem areas related to development phase include compatibility issues with constituent parts and thermal problems that were solved through design modification. The first measure of success was observed in the effectiveness of integrated safety mechanisms such as reverse polarity protection as well as safety from static discharge that helped to improve circuit reliability.

The battery charger therefore finds applications in areas of grid solar power systems to meet those of remote power and portable devices. Substantial quantitative future work could be to further enhance charging efficiency with new algorithms related to maximum power point tracking (MPPT) or the inclusion of integrated monitoring. Moreover, a benchmarking analysis with regards to the existing solutions on the market showed that though the proposed charger is less expensive, there is potential for further enhancement in terms of efficiency and system complexity.

Therefore, this project establishes a valid reason for renewable energy solutions and especially for the reduction of non-renewable resources, furthermore it provides knowledge for further work and research in the development of solar energy systems.

## VI. Conclusion

In conclusion, the development of the solar battery charger circuit demonstrates a viable solution for harnessing solar energy to charge batteries efficiently. The project successfully integrated essential components, including the LM317 voltage regulator and protective mechanisms, to create a reliable and adjustable charging system. Performance analysis indicated that the charger operates effectively under various sunlight conditions, although further optimization is needed to enhance efficiency. The study highlights the significance of renewable energy solutions in response to the declining availability of non-renewable resources. This solar charger is particularly suitable for applications in off-grid settings, contributing to sustainable energy practices. Future research can explore enhancements in charging efficiency and smart features to optimize performance further. Overall, this project not only showcases the potential of solar energy technology but also encourages ongoing innovation in renewable energy systems.

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