

Design and construction of a 1.5kva Solar-powered inverter with iot capabilities

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Abstract

The increasing global demand for sustainable and reliable energy sources has accelerated the development of solar-powered systems. This paper presents the design and construction of a 1.5kVA solar-powered inverter integrated with Internet of Things (IoT) capabilities. The proposed inverter utilizes a photovoltaic (PV) array to harness solar energy, converting it to a stable AC output suitable for household or small business applications. The design encompasses critical components including a Maximum Power Point Tracking (MPPT) algorithm to optimize energy extraction from the PV system, and a robust inverter topology, ensuring efficient power conversion.

To enhance functionality, the inverter is equipped with IoT technology, allowing real-time monitoring and control through a user-friendly mobile application (Blynk IoT). This integration enables users to access performance data, manage energy consumption, and receive alerts for system anomalies. The IoT module communicates with cloud services to provide remote access and analytics, facilitating proactive maintenance and improving system reliability.

Overall, this work contributes to the field of renewable energy by presenting a practical solution for utilizing solar power effectively, with added dimensions of accessibility and convenience through IoT integration. The findings indicate that such advancements can promote the adoption of solar technologies, leading to enhanced energy sustainability and reduced dependency on conventional power sources.

Keywords: Solar-powered inverter, Internet of Things (IoT), Maximum Power Point Tracking (MPPT), renewable energy, energy sustainability.

Background of The Study

The quest for sustainable and renewable energy sources has gained substantial instigation in recent times due to the adding enterprises over environmental declination and the reduction of fossil energies. Solar energy, being abundant and environmentally friendly, has surfaced as a crucial result to these challenges. Integrating solar power systems in domestic, marketable, and artificial operations is getting decreasingly popular. Among these systems, solar-powered inverters play a pivotal part in converting the direct current(DC) generated by solar panels into interspersing current(AC) used by utmost electrical appliances. In our contemporary

world, nearly every exertion makes use of electrical and electronic bias, whether it's for general ménage use or specialized artificial use. The operation of these bias requires a nonstop force of electrical power to enhance the effective delivery of power to these bias. In advanced countries, the power force is of good quality and is largely dependable without any of the problems of interrupted power force [1].

Still, in developing countries like Nigeria, there appear to be problems associated with the provision of power force by electricity companies, including earthing problems, motor

overloading, and bridging of power lines, performing in power outages. These problems are endured more during the stormy season due to showers and too important breath during downfall. Also, during the dry season, the inadequate water affects power generation due to its incapability to drive the turbine at a veritably high speed in a hydro power generation system. The inadequate power force endured in developing countries, utmost especially in Nigeria, necessitates an uninterruptible power force as an indispensable source of power. Standby creators originally used as an indispensable source of power suffer from noise, air pollution, and high conservation costs, which makes them less effective [2].

Since the mileage company can not give the continued power demanded at present, and a standby creator is less effective, an indispensable source of power using an inverter with solar backup will be most applicable. Inverters are bias that convert the electrical energy of Direct Current(DC) form into Alternating Current(AC) needed by utmost electronic bias. DC power is simply the operation of a steady, constant voltage across a circuit, performing in a 2 constant current. A battery is the most common source of DC transmission as current overflows from one end of a circuit to the other. Interspersion current, unlike DC, oscillates between two voltage values at a specified frequency, and its ever- changing current and voltage make it easy to step up or down the voltage [3]. In high- voltage and long- distance transmission situations, all that's demanded to step up or down the voltage is a motor. An Inverter is a device able of converting a D.C power source to A.C affair at a asked affair voltage and frequency. It makes use of one or further batteries in confluence with an electronic circuit to supply power to the cargo. It offers a better fresh power source to a standby creator considering its long duration, cost effectiveness, and maintainability. It's classified into three grounded on the affair

waveform, videlicet square surge, modified sine surge, and pure sine surge. Pure sine surge inverter provides better performance when compared with the other two waveforms, but at the expenditure of high cost [4]. This exploration composition focuses on the design and construction of a 1.5 kVA solar- powered inverter system enhanced with Internet of effects(IoT) capabilities. The addition of IoT in solar inverter systems facilitates remote monitoring, control, and optimization, thereby perfecting effectiveness and trustability.

2. Methodology

2.1. Design Principle of the Inverter

A block diagram showing the stages involved in the design of the conversion of Direct Current (DC) to Alternating Current (AC) is shown below. When the AC mains supply is available, the supply goes to the relay and battery charging section of the inverter. AC mains activate a relay and this relay will directly pass the AC mains to the Load. Also, the voltage is used to charge the 24V battery until it is fully charged. The charge controller stops the battery from further charging to prevent overcharging. When the AC mains power supply is not available, the oscillator circuit inside the inverter produces a 50Hz MOS drive signal. This MOS drive signal will be amplified by the driver section and sent to the output section. MOSFETs are used for the switching operation. These MOSFETs are connected to the primary winding of the inverter transformer. When these switching devices receive the MOS drive signal from the driver circuit, they start switching ON and OFF at a rate of 50Hz. This switching action of the MOSFETs will drive the primary of the inverter transformer, and this results in 230V AC at the secondary of the inverter transformer. This voltage is made available to the Load by the changeover relay.

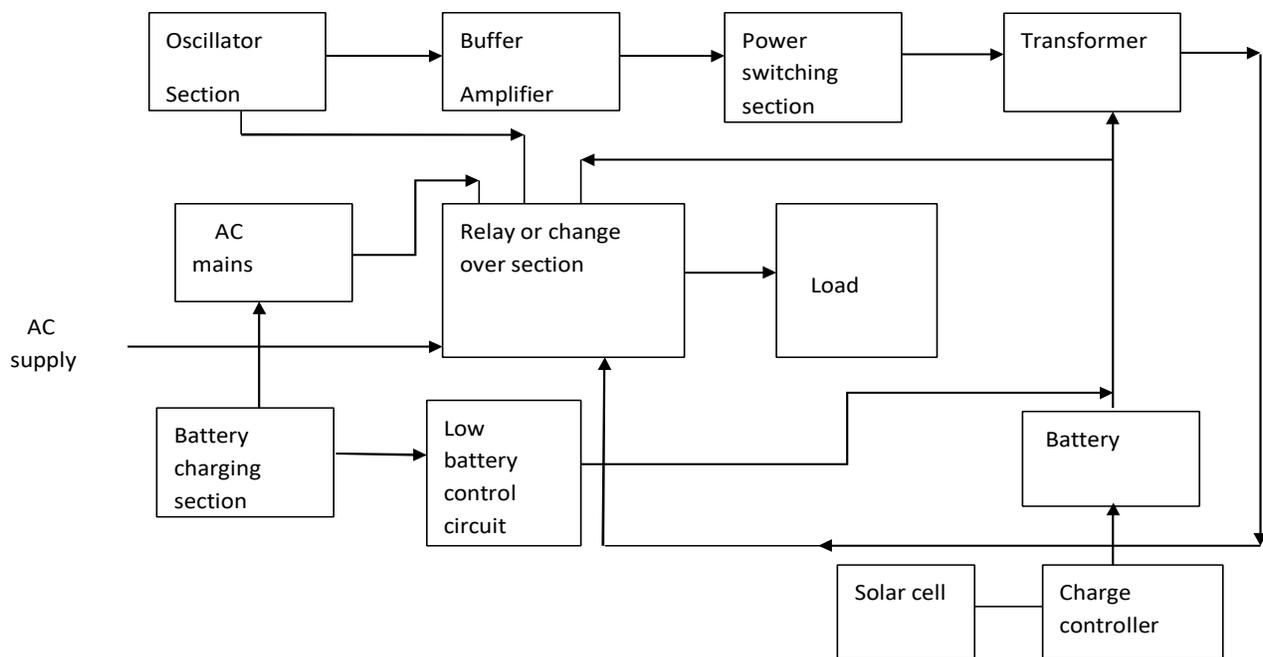
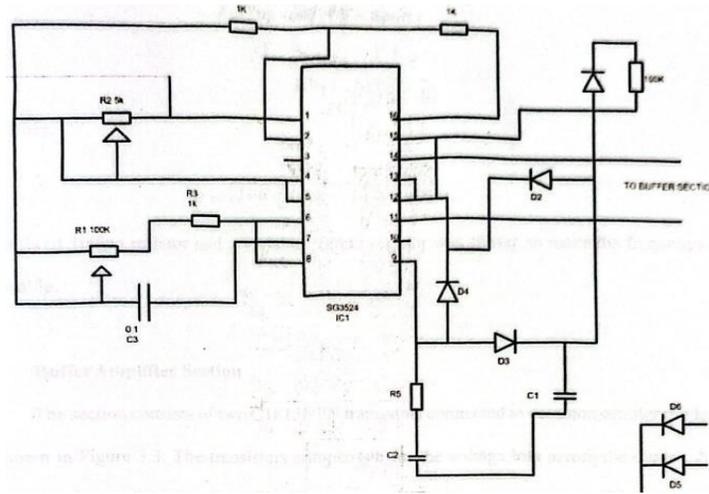


Figure 1

2.2. Block Diagram of Power Inverter Oscillator Section

As shown in the diagram below, the capacitor to be used at pin 7 should be within the range of $0.001\mu F - 0.1F$ according to the data

sheet and $0.1\mu F$ was chosen. $1.8 F = RC$ And a frequency of $50Hz$ needs to be generated from both outputs at pin11 and pin 14.



Oscillation Section circuit

Figure 2

2.4. Buffer Amplifier Section

The section consists of two C1815 NPN transistors connected in common-emitter mode as shown in the diagram below. The transistors compensate for the voltage loss across the diodes. A

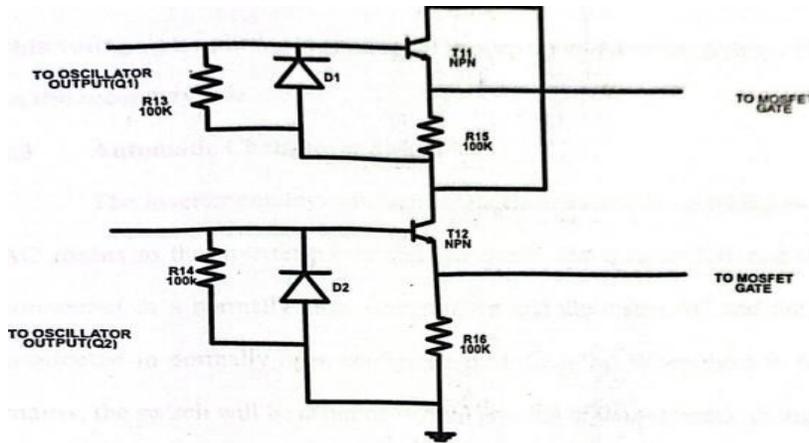
$1k\Omega$ voltage of $4.5V$ appears across pin 14; it is divided by two $1k\Omega$ resistors, i.e. $\frac{4.5V}{2}$

$$\times (1k\Omega + 1k\Omega) 4.5V$$

Therefore, the $2.25V$ flows into the base of the transistors. For the C1815 NPN transistor, the cut-off voltage is $5V$. $I_b = (V_b - V_{be}) / R_b$, where $V_b = 4.5V$, $V_{be} = 0.6V$, $R_b = 1k\Omega$

$$I_b = \frac{4.5V - 0.6V}{1k\Omega} = 3.92mA$$

Since $I_c = \beta I_b$ And $\beta = 100$ for C1815 NPN transistors therefore $I_c = 100 \times 3.92 = 3.92A$ The output is used to drive the MOSFETs.



Buffer Amplifier Section circuit

Figure 3

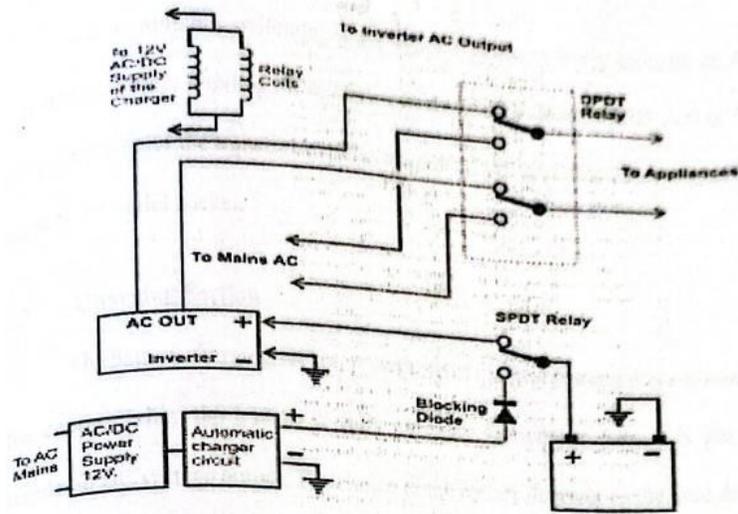
2.5. Automatic Changeover Switch

The inverter employs an automatic transformation switch in switching its operation from the AC mains to the inverter power and vice versa. The inverter live and the $12V$ battery are connected

in a generally closed configuration, and the mains AC and the charger circuit are connected in a generally open configuration of the relay. When there is an AC force from the mains, the switch will be in the generally open position of the automatic transformation

switch, hence supplying the outlet socket. also, the coliseum will keep on charging the battery until the battery is fully charged. When there is a power failure from the mains, the relay moves from the generally open to the generally closed position, making

the inverter switch on. The same thing with the temperature sensor, directly the heater temperature hits the rated outside, the inverter will open, and vice versa.



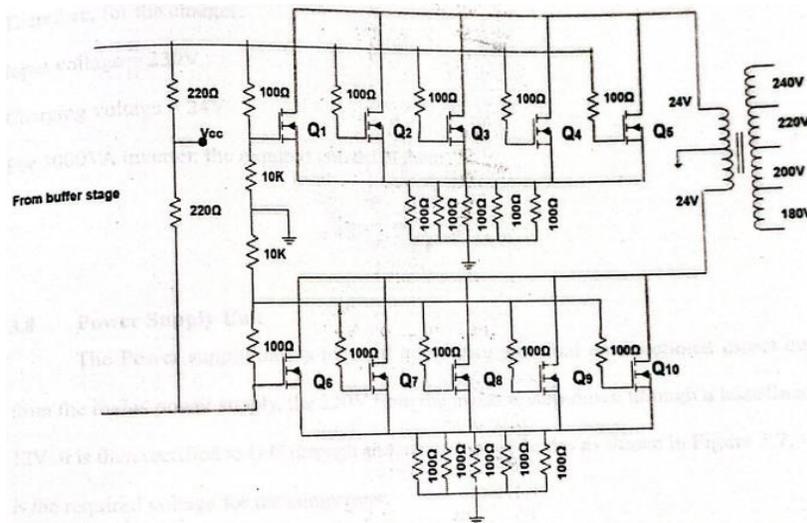
Automatic Changeover switch circuit

Figure 4

2.6. Power Switching Stage

Power switching MOSFETs are employed in the power driver stage since they have high switching speed. The input to the power

MOSFETs is fed from the buffer amplifier through a parallel path. IRFP250 MOSFETs are selected for the design of this stage and they give power dissipation of 250W.



Power Switching Stage circuit

Figure 5

To determine the number of MOSFETs required and the current they can withstand;

$$P = IV$$

$$P 2500 I = = 104.17A$$

$$V 24$$

Which is the current that will flow through the MOSFETs. Since each of the MOSFETs has a current rating of 30A, the number

required is then calculated:

$$\text{number of MOSFETs} = \frac{104.17}{25} = 4.2$$

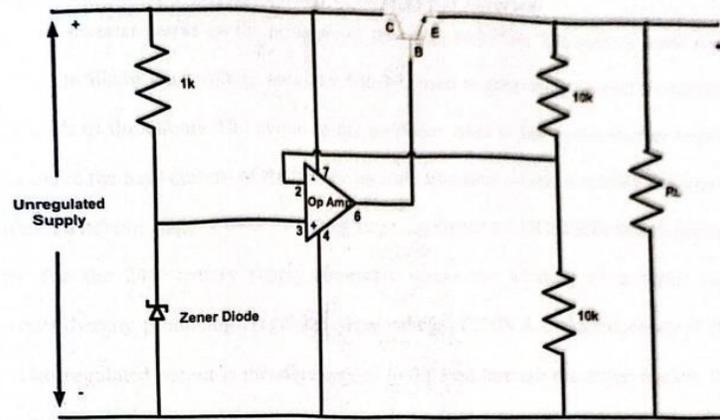
From the calculation, five MOSFETs are required at each segment of the power switching stage, but in order to prevent the MOSFETs from burning and to boost the performance of this stage, a total of fourteen power MOSFETs (IRFP250), seven each for the two

segments, are used for the project in order to meet the project specification. In this stage, the power MOSFETs alternatively switch the 12V battery supply across the windings of a center-tapped transformer, thereby producing 220V AC at a frequency of 50Hz as shown in Automatic Changeover switch circuit. It should be noted that 10K resistors are used in the circuit to create high input impedance when no load is applied to the output socket. This is to prevent the MOSFETs from burning, while resistors R1, R2, R3, R4, R5 protect the MOSFETs from inrush current and also allow all MOSFETs to switch ON and OFF at the same time. The continuous switching of the MOSFETs alternatively generate an AC voltage across the primary windings of the transformer,

which induces a 220V AC of 50HZ at the secondary side of the transformer. The secondary voltage is therefore connected to a load through an outlet socket.

2.7. Charging Section

The battery charging section is made up of a sensing circuit that automatically shuts down the charger when the battery is fully charged. The charging circuit is designed to maintain a constant regulated DC voltage output. The choice of the battery depends on the time duration of the power outage and the desired backup time of the inverter, as shown in circuit below.



Charging Section circuit

Figure 6

Therefore, for the charger;

Input voltage = 230V

Charging voltage = 24V

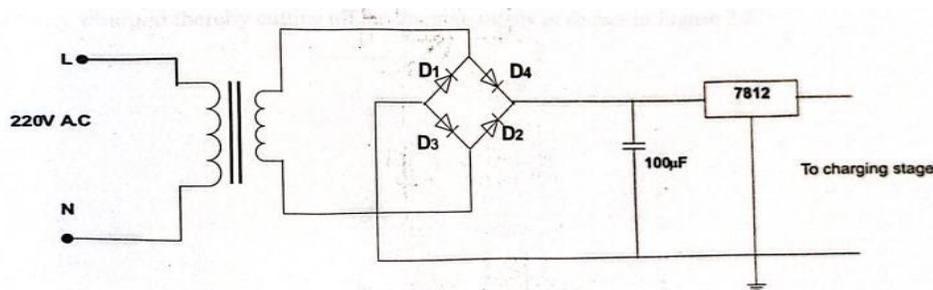
For the 1.5KVA inverter, the required current is;

$$P = 1500 \text{ W} \quad I = \frac{P}{V} = \frac{1500}{12} = 125 \text{ A}$$

V 12

2.8. Power Supply Unit

The Power supply unit is required to produce a desired unidirectional direct current from the mains power supply. The 220V from the mains is step-down through a transformer to 12V; it is then rectified to DC through an arranged set of diodes as shown in the power supply unit circuit below, which is the required voltage for the comparator.



Power supply circuit

Figure 7

2.9. Operation of the Complete Circuit of Solar Power Inverter

An inverter works on the principle of push-pull amplifier. The battery bank supplies 12V to the Oscillator via a voltage regulator, which is used to generate a desired frequency of 50Hz at each of the outputs. The output of the oscillator stage is fed to the Buffer

amplifier stage to drive the base current of the bipolar junction transistor, which amplifies the signal to the power switching stage. The power switching stage comprises MOSFETs, which serve as switches for the 12V battery supply, alternately across the windings of a center-tapped transformer, thereby producing a

regulated output voltage of 220V AC at a frequency of 50Hz. The regulated output is therefore applied to the load through the outlet socket. When there is a utility power outage, the relay switches from the main supply to the inverting circuitry, this is achieved through the automatic changeover switch. When there is a utility power supply, the relay will cut off the DC supply from the battery and switch to the mains and finally to the load. During this period, the charger will keep charging the 12V battery until the batteries are fully charged thereby cutting off the charging supply.

2.10. Internet of Things

IOT can be used to control and monitor digital appliances remotely. For example, doorbell, smoke detectors, fire detectors, water heater etc. But in this case it is used to control a solar inverter. Where, sensor and actuator sends signals in form of MQTT/HTTP to the Gateway. The Gateway sends the signal information through Wifi, Bluetooth, ZigBee or GSM to the clouds where it is accessed on the phone.

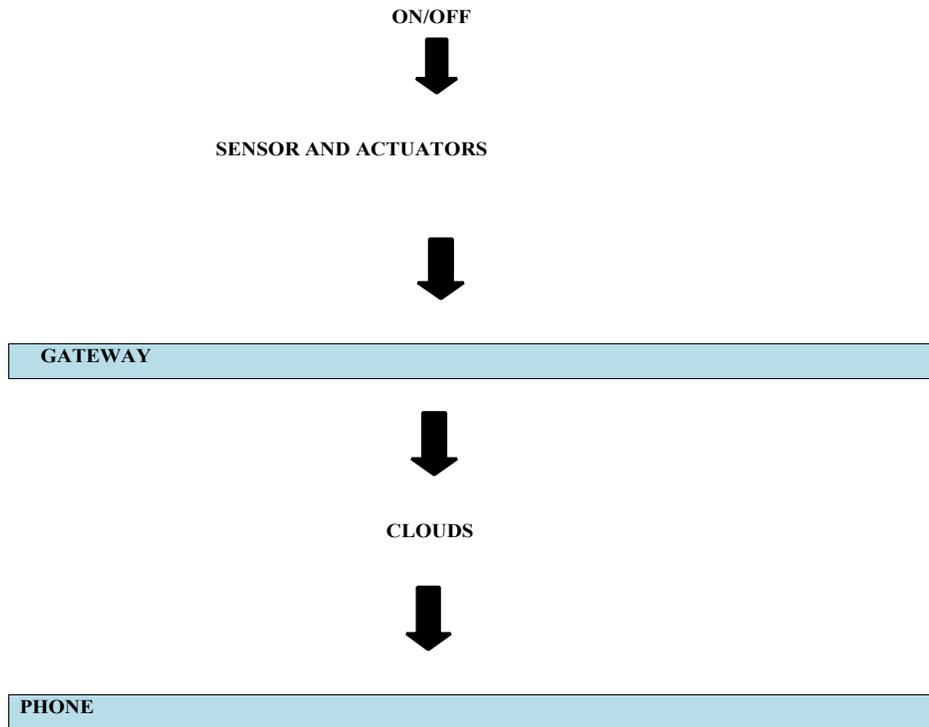


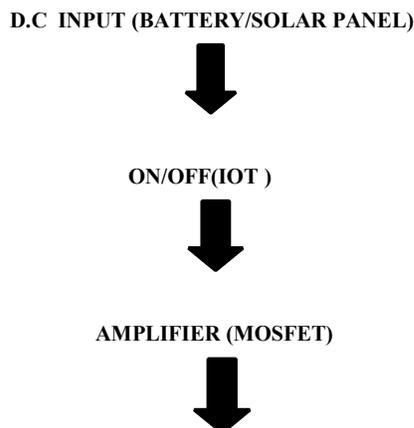
Figure 8

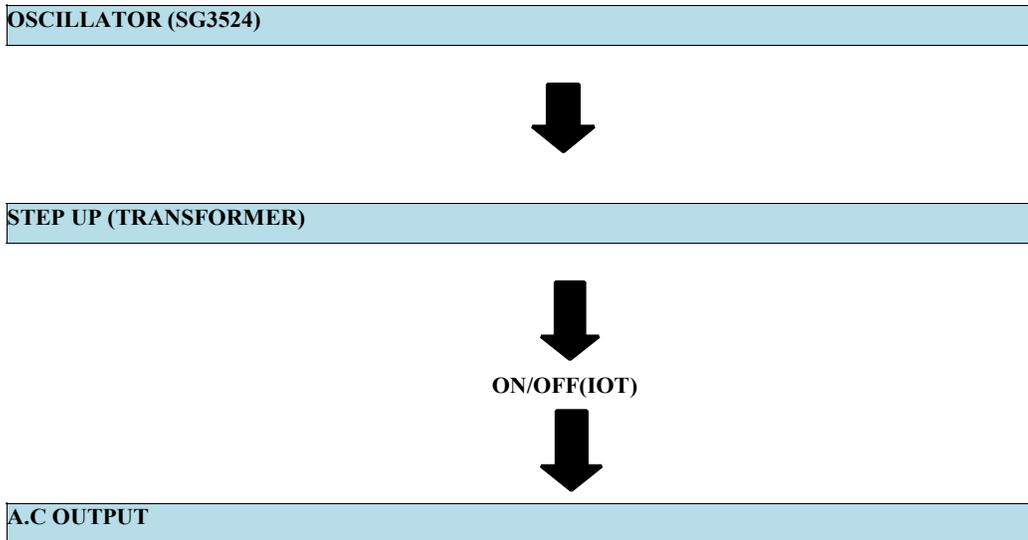
3. Iot Mode of Data Transfer.

An IoT inverter

An IoT inverter is a technology that allows users to control and monitor the battery voltage of the inverter, the run time of

connected loads and the status of connected loads and the status of the connected devices through a mobile application of web URL. The user can also control the connected load and connect/disconnect devices based on their requirements.





Operation of IoT Inverter

Figure 9

Result

The IoT-grounded solar inverter control system successfully demonstrated the practicality and advantages of integrating IoT technology with solar power systems. The NodeMCU microcontroller, coupled with the ESP32 Wi-Fi module, eased real-time data transmission, allowing the user to easily cover and control the system. The energy cadence provided accurate and timely readings, enabling a thorough analysis of the system's response to varying cargo conditions. The voltage drops observed with adding loads were consistent with the anticipated response of power systems under similar conditions. The system's capability to maintain stability across all tested loads, with minimum DC voltage change and constant AC voltage, confirms that the inverter and battery operation system were well-designed to handle dynamic power demands. The mobile app's ability to provide real-time feedback and remote control further enhanced the system's overall functionality, adding a layer of convenience and safety for users. The IoT integration enabled remote monitoring and control of the system, allowing users to access performance data, manage energy consumption, and receive alerts for system anomalies.

5. Recommendations

To enhance the efficiency and reliability of the solar-powered inverter, several recommendations are proposed:

1. Use of high-quality deep cycle batteries: Batteries with higher ampere-hour ratings should be used to ensure longer operation periods.
2. Optimal battery utilization: The battery's depth of discharge should not exceed 25% of its total capacity to facilitate quick recharging and prolong its lifespan.
3. Load management: Loads exceeding 1.5kVA should not be connected to the inverter to prevent overload and reduce the risk of damage. For higher load requirements, an inverter with a higher capacity should be designed and constructed.

Future research can focus on improving the energy conversion efficiency of the inverter and developing more advanced IoT functionalities for remote monitoring and control. Additionally, the cost-effectiveness of the system can be further enhanced by optimizing the design and selecting more affordable components.

6. Conclusion

The need for solar-powered inverters for domestic and industrial use is of paramount importance, especially in a place where people are experiencing epileptic power supplies like Nigeria. Going further, pure sine wave inverters, which are the emphasis of this work, provide a smooth waveform that is identical to that of an electric utility, hence making them desirable and extremely sought by both industrial and commercial consumers. In this work, a digital pure sine wave inverter with a battery level monitor that shuts down the load based on its priority has been designed and constructed. The system has been constructed for power backup that can effectively power loads of different characteristics, be it inductive, resistive, or capacitive. The digital inverter has good performance and greater efficiency with fewer loads.

The electronic components used in this work were connected in a way to achieve high power efficiency while minimizing heat losses. The environmental effects, such as temperature, thunderstorm, and wind, were considered in the design and construction of a 1.5kVA/24V solarpowered pure sine wave Inverter. The project has an output voltage of 220V and a frequency of 50Hz. It involves the use of electronic components that are connected in a way to achieve a higher power efficiency while minimizing heat losses and environmental effects at a frequency of 50Hz. The design and construction require a proper selection of materials, testing to confirm the requirements of the project on the breadboard, followed by construction on the PCB. The circuit was assembled, tested, and put to use under load conditions [5-11].

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