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Design and Construction of a Wi-Fi-controlled solar inverter System

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Abstract

Electricity generation from solar energy is made possible with the use of a solar power system consisting of solar panels that absorb sunlight, an inverter that converts DC to AC, and batteries that store extra electricity. In this study, a 1 KW inverter system controlled by a Wi-Fi network is constructed. ESP8266 Wi-Fi module is set up to allow ATMEGA 328P microcontroller to connect to a 2.4 GHz Wi-Fi network by generating an IP address from any web server. The ESP8266 Wi-Fi module is programmed on an Arduino platform to have a HIGH (ON) and LOW (OFF) state to serve as a switch for controlling the inverter. This is accomplished by connecting pin D5 of the ESP8266 Wi-Fi module to the base of BC547 transistor, with the emitter of the transistor connected to the negative terminal of the battery and the collector is connected to one of the power pins of a 5 V relay, the other power pin is connected to the positive terminal of the battery. The relay is activated to switch when the transistor collector receives a command from the base to change state. The high state opens the transistor's channel to the relay, turning ON the inverter; the low state turns the relay OFF, turning OFF the inverter. The system is secured with a password to limit its use to those that have the password. The inverter converted a 12V DC input into a 220V AC output voltage at 50Hz. Switching the inverter to the ON and OFF states is simple as it is controlled by a secured Wi-Fi connection.

1. Introduction

The need for energy, especially electrical energy, is increasing as a result of rising population and economic growth [1]. Power consumption is increasing every day in developing countries, increasing the energy crisis [2]. The growing awareness of fossil fuel depletion and its impact on climate change has resulted in the development of clean renewable energy [3], [4]. Because it is environmentally beneficial, the development and use of renewable energy have exploded in recent years all over the world [5], [6], [7]. Solar energy [8], [9], [10], [11], [12], [13], acoustic energy [14], [15], [16], wind energy [17], [18], [19], [20] thermal energy [21] and vibrational energy [22], [23] are some of the sources of renewable energy. Among them, solar energy has attracted a lot of attention from all over the world [24] and is seen as the most prominent renewable energy option in the future due to its cleanliness, inexhaustibility [25], and nonpolluting nature in comparison to the scarce fossil fuels, coal, petroleum, and natural gas [26]. Solar energy may be able to meet worldwide electrical needs due to its limitless and endless nature [27], [28]. The two ways by which solar energy can be converted to electrical energy are: through photovoltaic material that generates an electrical potential when exposed to light and through a thermal process that uses the Sun's energy to heat a working fluid in an electricity-generating cycle [29]. When considering photovoltaics, a solar power system is required to capture solar energy from the Sun.

A solar power system is a device that uses the energy from the Sun to generate electricity. It is made up of solar panels for absorbing sunlight, an inverter to convert DC to AC, and batteries for storing excess electrical power. Photons of energy from the Sun are allowed to hit the solar panel and are absorbed by semi conductive semiconductors like silicon. Negatively charged electrons are ejected from their atoms, allowing them to move freely through the material and generate energy. In a silicon panel, the opposite positive charges which are also formed are referred to as holes, and they flow in the opposite direction of the electrons. The photovoltaic cell turns the energy into usable direct current (DC) electricity through this process. Because this energy is required for immediate and subsequent usage, it is briefly stored in a battery before being delivered to an inverter circuit, which converts DC electricity into the 220-240volt alternating current (AC) that is needed in houses to power some electronic devices.

In this study, a Wi-Fi-controlled inverter system has been designed and implemented with the help of ESP8266 Wi-Fi module, ATMEGA 328P microcontroller, and other electronic components. The ATMEGA 328P microcontroller is programmed to connect to a 2.4 GHz Wi-Fi network to control the inverter using ESP8266 Wi-Fi module. The ESP8266 Wi-Fi module is configured with a HIGH (ON) and LOW (OFF) state on an Arduino platform to function as a switch to operate the inverter. The system is password-protected, limiting access to those with the password. This study attempts to simplify switching the inverter to the ON and OFF states by using a Wi-Fi connection and reduce electrical energy wastage by limiting the number of people who can access and operate the solar inverter system.

An inverter is a device that can convert Direct Current (DC) electricity to Alternate Current (AC) electricity [30]. It is made up of a series of electronic components. Even when the AC mains supply is unavailable, it delivers a continual AC supply at its output socket. When the mains supply is available, the charger circuit keeps the battery charged, and when there are no mains supply, the inverter circuit converts the DC power stored in the battery into a 220V/50Hz AC supply, which may be used to power any typical electronic equipment. The inverter is a better extra power source since it uses semiconductor power devices such as thyristors and bipolar transistors for voltage amplification, and MOSFETs as power switches. The inverter makes less noise, has a fully automatic switchover function, poses no environmental risks, costs less to maintain, and is more compact [31].

2. Methodology

In this work, the ATMEGA 328P microcontroller is used to control the inverter's duty cycle and the dead time for better efficiency in terms of power delivery and stability. Two Pulse Width Modulation (PWM) signals are generated from pin 15 and pin 16 of the ATMEGA 328P microcontroller as outputs. These two output signals are two halve cycles that are combined to form a perfectly sinusoidal waveform with a frequency of 50 Hz. The signals are fed into the buffer circuit which consists of three Metallic Oxide Semiconductor Field Effect Transistors (MOSFET) that are connected in such a way that their drain and source are in parallel on both sides and the gate of each MOSFET is limited with a 4.7KΩ resistor and connected to pin 15 and pin 16 of the ATMEGA 328P microcontroller for current amplification.

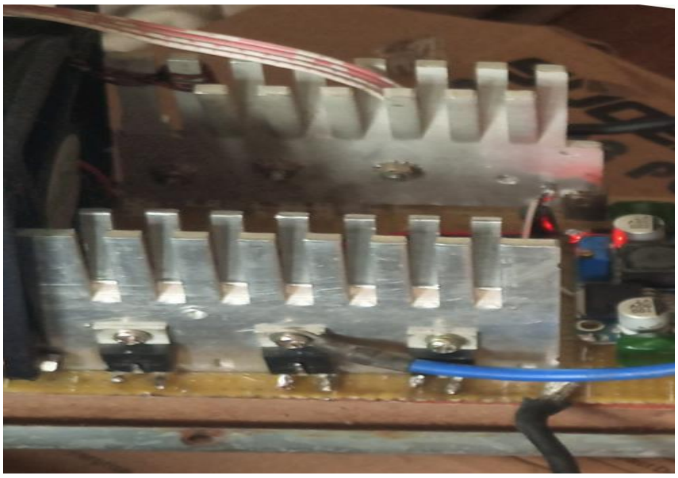


Fig 1: MOSFET placed on a heat sink

The control of the inverter is achieved by using the ESP8266 Wi-Fi module. ESP8266 Wi-Fi module is programmed to enable the ATMEGA 328P microcontroller to connect to a 2.4 GHz Wi-Fi network by popping up an IP address on any web server. The ESP8266 Wi-Fi module is programmed on an Arduino platform to have a HIGH (ON) and LOW (OFF) state to serve as a switch for controlling the inverter. The switching is achieved by connecting pin D5 of the ESP8266 Wi-Fi module to the base of BC547 transistor while the emitter is connected to the negative terminal of the battery and the collector is connected to one of the power pins of the 5 V relay, the second power pin is connected to the positive terminal of the battery.

Fig 2: ESP8266 Wi-Fi module

The transistor serves as a switch where the collector activates the relay to switch after receiving the command at the base of the transistor to change the state to high or low using a toggle switch from an IP address. The high state will open the transistor's channel to the relay thereby switching ON the inverter, the low state will switch the relay from the ON-state to the OFF-state and the inverter is switched OFF. Charging the inverter involves using the Double Pole Double Throw (DPDT) relay which is wired in such a way that an incoming voltage from the mains is readily detected at the output socket of the inverter so that the available load on the inverter can use the same voltage while part of it is transferred to the input of the transformer in the inverter. The inverter system is automatically converted to a charger by allowing current to flow into the transformer.

2.1 Circuit Construction

The following steps were taken during the construction: -
Step 1: The perf board is thoroughly cleaned to remove dirt that may interfere with soldering.
Step 2: All the components are collected and laid out.
Step 3: Components are placed on the non-copper side of the perf board and held down with some masking tape before flipping to the copper side of the perf board.

Step 4: The soldering iron is heated up to a temperature that can melt the soldering lead before the components are soldered to the board.
Step 5: After soldering, the remaining component lead was cut off as close as reasonably possible to prevent bridging.
Step 6: Check for continuity is carried out after traces of excess hair size soldering lead were removed.

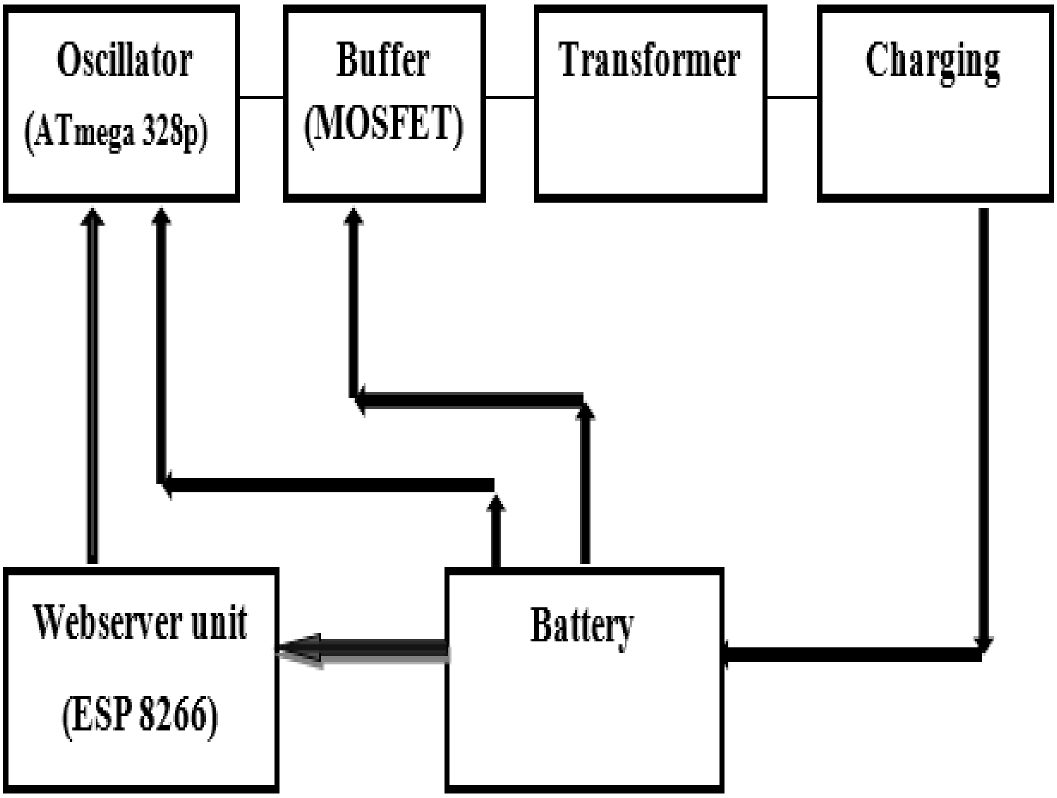


Fig 3: Block diagram of Wi-Fi controlled inverter

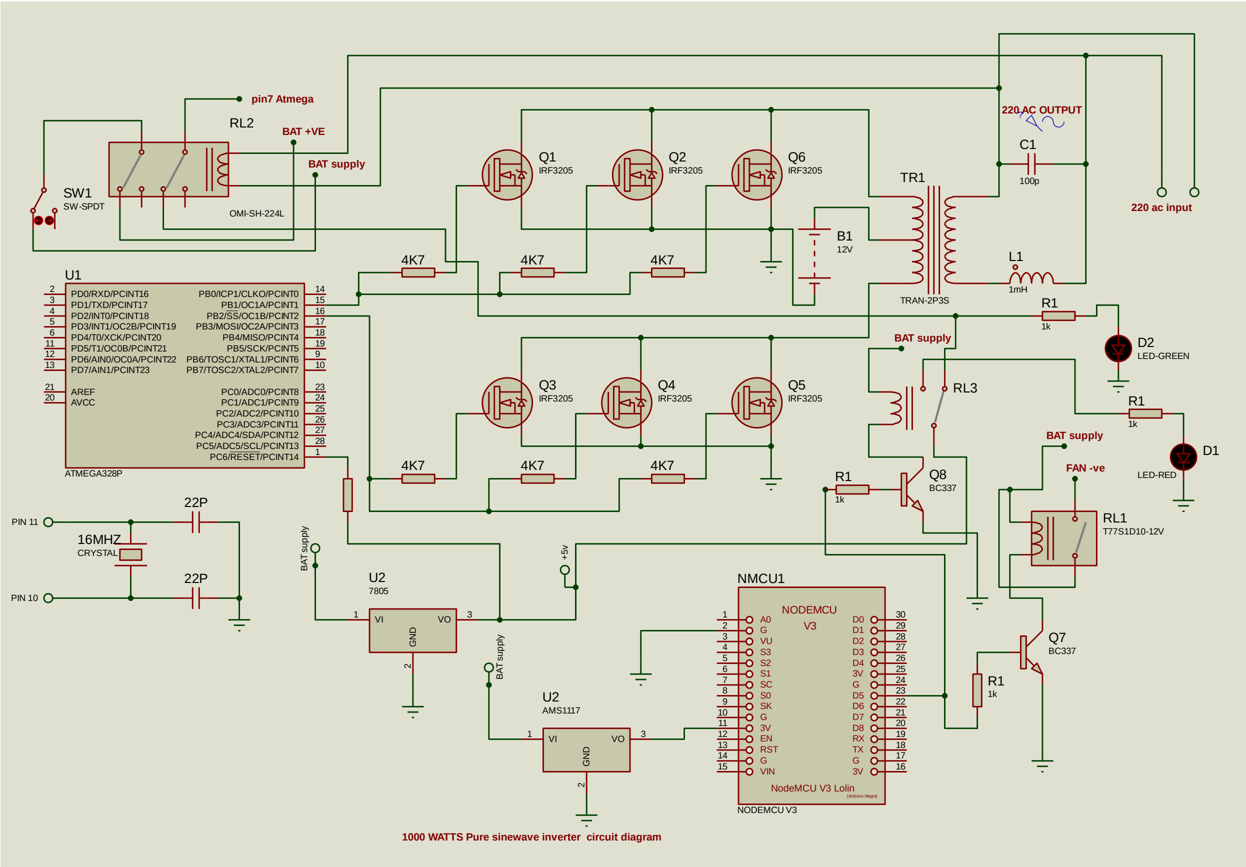
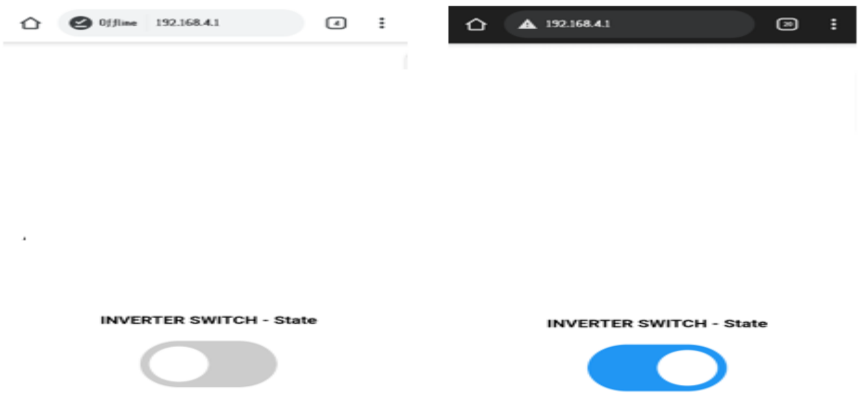


Fig 4: Circuit diagram of Wi-Fi controlled inverter simulated from Proteus

3. Results and Discussion

The Wi-Fi-controlled inverter is tested and found to be working as expected. It is controlled with a toggle switch from a Wi-Fi network generated on a web browser. The Wi-Fi network is generated by programming ESP8266 module and ATMEGA 328P microcontroller in such a way that an IP address is popped up on the web browser. The programming is done on an Arduino platform to have an ON and OFF switch (toggle) on a web browser encoded in the program. When the inverter is connected to a 12v battery, it automatically enters a standby mode with a secured Wi-Fi connection. An android phone was used to connect to the Wi-Fi network by typing in the correct password. The interface shown in Fig. 3 popped up from Google Chrome web browser with the IP address 192.168.4.1. The Wi-Fi connection of the ESP 8266 module can be seen within a distance of 10m from the inverter. The inverter power can be activated and deactivated by multiple users if only they have the password to generate the required IP address that will display the toggle which serves as a switch for the inverter on any web server.



(a) **(b)**

Fig 5: Inverter (a) Off state, (b) ON state.

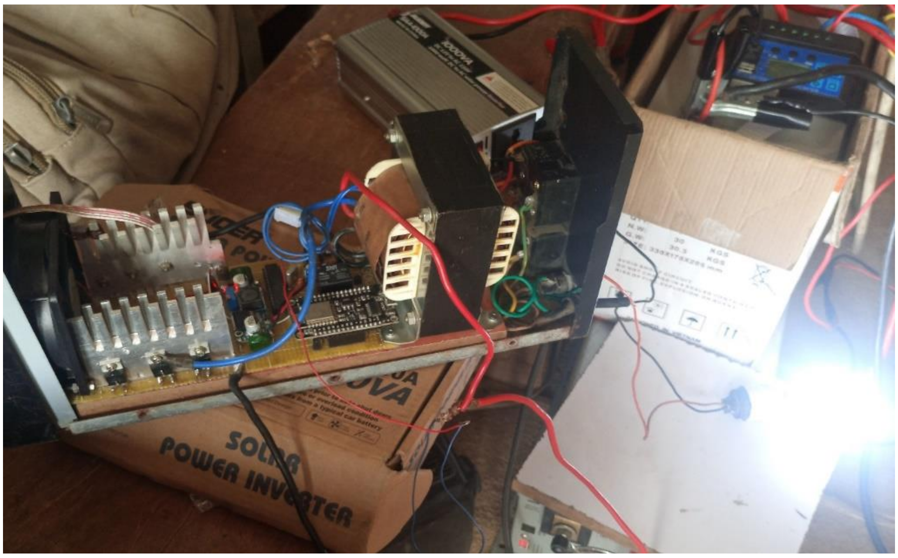


Fig 6: Inverter output with load

4. Conclusion

The inverter was able to convert a 12V DC input into a 220V AC output voltage with a 50Hz frequency. Depending on the capacity of the battery, it can power electrical equipment rated at 1000W and below. Because of its inexpensive pricing and low maintenance cost when compared to other power supply options on the market, the inverter will help save money on energy usage. It is not compatible with three-phase equipment and appliances with voltages between 240 and 220 volts, or devices that operate at 60 Hz. Switching the inverter to the ON and OFF states is simple as it is controlled by a secured Wi-Fi and can only be controlled by persons who know the password.

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