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Multi-Range Solar Inverter

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***Abstract*: The aim of this project is to design and implement sine wave inverter which can convert DC voltage to AC voltage at high efficiency and low cost. Nowadays, the world is facing a problem of global warming and depletion of fossil fuels, as the world increasingly focuses on environmental concerns and these problems can be reduced by using renewable resources to generate electricity. Solar and wind-powered electricity generation is being favored. Renewable energy is an infinite source of energy. It is quite simple the energy is produced directly by the environment and is collected by the respective collecting elements. This generated energy is in the form of direct current (DC). An inverter is required to convert the generated DC into useable AC. The proposed project is a prototype of the multi-range inverter. This technique helps to increase the range of the inverter load capacity for not only one load and for the future increase of system load.**

***Keywords*: solar inverter**

1. Introduction

As the demand for electrical power and the constant depletion of fossil fuels is increasing. So, the focus is shifted to Renewable Energy Sources. however, batteries and renewable sources produce a DC voltage. But, the electrical appliances run on AC power. So, it is necessary to convert the voltage, so that the appliances can use that energy. Hence, we need an inverter to smoothly operate electrical and electronic appliances. Basically, inverters are categorized into three groups: square wave, modified sine wave, and pure sine wave. Most of the available inverters are a square wave and modified sine wave. Electronic devices run by this inverter will damage due to harmonic contents. Available sine wave inverters are expensive, and their output is not so good. Considering power, efficiency and harmonics produced pure sine wave inverters are the best among the three. For getting pure sine wave we must apply sinusoidal pulse width modulation (SPWM) technique. The pulse width modulation inverter has been the main choice in power electronics because of its simplicity. Sinusoidal pulse width modulation is the most used method in motor control and inverter application to generate this signal, the triangular wave is used as a carrier signal is compared with a sinusoidal wave at the desired frequency.

Sinusoidal pulse width modulation (SPWM) is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off the power switches. SPWM switching technique is commonly used in industrial applications or solar electric vehicle applications. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of these pulses is modulated to obtain inverter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation is the mostly used method in motor control and inverter application. To generate this signal, the triangular wave is used as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. The proposed alternative approach is to replace the conventional method with the use of a microcontroller.

2. Components

- *Solar Panel:* Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. Photovoltaic modules constitute the pv array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications.

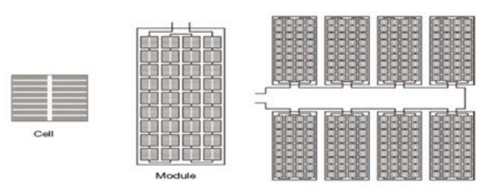

Fig. 1. Solar panel

- *Charge Controller:* A solar charge controller manages the power going into the battery bank from the solar array. A solar charge controller is available in two different technologies, PWM and MPPT.

Fig. 2. Charge controller

- *Battery:* A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smartphones, and electric cars. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy

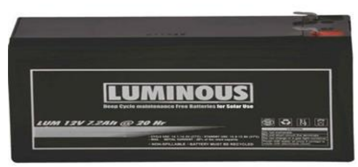

Fig. 3. Battery

- *MOSFET:* The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET is a four-terminal device with the source(S), gate (G), drain (D) and body (B) terminals. The body of the MOSFET is frequently connected to the source terminal so making it a three-terminal device like field effect transistor.

Fig. 4. MOSFET

- *Microcontroller:* The DSPIC is a 16-bit microcontroller with high-performance and the high computation speed of a fully implemented digital signal processor (DSP). It is for signal conditioning too. There are some features and motor control facility and peripherals in DSPIC to facilitate control applications and signal processing.

Fig. 5. Microcontroller

- *Transformer:* A step-up transformer is often used to increase the alternating current (AC) voltage before transmission of electricity from a power generating station. That way the transmission line losses are minimized for greater efficiency. Step up transformers are used to increase the voltage.

Fig. 6. Transformer

- *Electric Load:* The device which takes electrical energy is known as the electric load. In other words, the electrical load is a device that consumes electrical energy in the form of the current and transforms it into other forms like heat, light, work, etc. The electrical load may be resistive, inductive, capacitive or some combination between them. The term load is used in the number of ways.

Fig. 7. Electric Loads

3. Techniques

A. Sinusoidal Pulse Width Modulation (SPWM)

The SPWM technique is carried out by using two types of waveform, one is reference waveform and the other is carrier waveform. The reference waveform is the sinusoidal waveform with the fundamental frequency and the carrier waveform is a triangular waveform with high frequency. The frequency of the carrier waveform is to decide the switching frequency of the inverter. When the frequency of the carrier wave increases the switching frequency also increases. The frequency of the reference waveform determines the inverter output frequency. The output frequency is generated as the compared output of the carrier waveform and the reference waveform. The fundamental frequency component of the output voltage can be controlled by the modulation index.

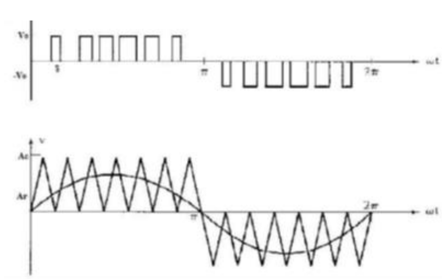

Fig. 8. Sinusoidal pulse width modulation

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B. Maximum Power Point Tracking

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side, we are using a boost converter connected to a solar panel to enhance the output voltage so that it can be used for different applications like a motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

C. Different MPPT techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

1. Perturb and Observe (hill climbing method)
2. Incremental Conductance method
3. Fractional short circuit current
4. Fractional open circuit voltage
5. Neural networks
6. Fuzzy logic

Table 1
Characteristics of different MPPT techniques

MPPT technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, current
Fractional V_{oc}	Medium	Low	Yes	Voltage
Fractional I_{sc}	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

4. Assembling & operation

A. Block diagram

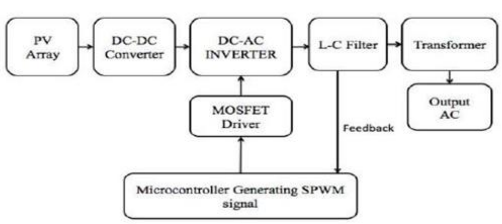

Fig. 9. Block diagram

In this first the solar energy is captured by the solar panels and the output is given to the DC-DC converter and that energy is given to the battery to store that energy. That dc voltage is given to the DC-AC inverter, it is operated by the MOSFET driver which is controlled by the microcontroller. The output is given to the L-C filter to reduce harmonics. This voltage is given to step-up transformer and is given to the load.

B. Circuit description

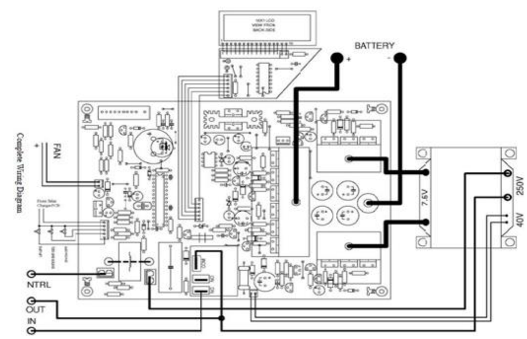

Fig. 10. Circuit description

The designed inverter will have the following steps to sense & operate the inverter

1. AC input and output sensing
2. Load Sensing
3. Battery Sensing
4. Temperature Sensing
5. Sensing of switches
6. Relay driving
7. MOSFET driving signals and display handling
8. MOSFET driving and short circuit sensing
9. Current sensing
10. Overload sensing
11. Cut off mode

C. Operation

Normally the ON/OFF switch is provided in the front panel. The UPS/Inverter selection switch is placed at the rear panel. When the solar charger is active and charging the battery (there is sufficient sunlight to charger the battery) the solar charger will make the solar charger selection pin low. At this time the inverter will disable mains charger. The Automotive battery / Tubular battery selection switch can be placed at the rear panel of the system. The +ve connection of the battery taken from the big heatsink and the -ve wire taken from the PCB should have enough thickness to carry the battery current. When the battery is connected, the system will start with a special beep, like beep-beep-beep-beep. This indicates the power ON of the controller. This beep will be heard only when the battery is connected. After that, this kind of beep will not be heard until the battery is disconnected and connected again.

Note: If the above said power-on beep is heard during normal working of the system it means that the system got an unwanted reset. This can happen if the high current / high voltage wiring is taken near the low current signal wiring (LCD / switch wiring). This also results when the capacitors from pin 9 and 10 are not soldered. There is a chance to miss this capacitor since they are SMD parts fixed under the PCB. Also, take care to fix the LCD without any electrical contact with the cabinet. It is wise to use not metal front panel and fix the LCD on it. When the mains is in acceptable range the system will bypass mains and will charge the battery. The battery charging current will depend on the set value. When the battery voltage reaches the full charge level, the charging will be stopped automatically. When the battery voltage drops by 'T' volt the charging restarts. The magnitude of T depends on the type of battery selected (Automotive battery / Tubular battery selection). If the tubular battery is selected T = 2.4V per battery. If the automotive battery is selected T = 1.44V per battery. Also note that this depends on the correctness of the resistors R43, R69 connected to pin 7 of the microcontroller.

D. Fast changeover considerations

The mains-inverter and inverter-mains changeover will be in synchronous with the mains waveform. For correct synchronous changeover, the polarity of the transformer connection should be correct. This is automatically done by the system whenever the inverter is turned on. If the polarity is OK, the inverter works normally. If the polarity is not correct the buzzer beeps continuously. If it happens, switch off the inverter and reverse the primary connection of the transformer. Even when the front panel switch is off (standby off) the system will switch on the relay and will forcefully switch off the charger if the mains voltage is very high. This is for protecting the transformer and the MOSFETs from high voltages.

E. Inverter-Mains changeover

In inverter mode when the mains are restored the system will first try to synchronous the inverter waveform with mains waveform. The ac input sensing network and the capacitor between pin 2 and 27 are very important for the proper sensing and synchronization of the waveform. When the mains and inverter waveform are in phase the system will activate the changeover. The relay will be switched off and the display will show the changeover message. If battery low or overload condition was present at the time of changeover these conditions will be stopped and buzzer beep will be paused.

5. Applications

- This inverter is financially effective, i.e. ease than generators. Apart from these, there are extra gadgets as well that make the utilization of sunlight-based vitality, for example, solar heater, cooker.
- Inverters are cost-efficient, easy to install and more affordable than generators.
- The input given to the inverter can be both solar or AC mains.
- It can be operated on both inverter mode and UPS (uninterrupted power supply) mode.
- It will run on any kind of batteries i.e., tubular or alkaline batteries.
- If 440V is applied to the AC input, the inverter will not fail. It will indicate high voltage cut-off and restart when a voltage is normal.
- If AC mains is given to the inverter output, it will not fail. It will indicate phase input-output reverse and continue to work after it is rectified.
- It has fold-back current limiting for short circuit and heavy loads. At short circuit or heavy loads, current limiting action will take place instead of tripping which will lead to more reliability.

6. Result

Multi-range solar inverter done successfully, and the result output is shown in Fig. 11.

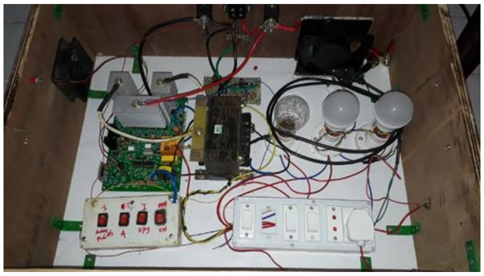

Fig. 11. Hardware setup

Fig. 12. Hardware setup (Working)

7. Conclusion

Generally, the normal inverters that we use in our daily life work for a fixed load capacity. If we add a small load to the inverter greater than it's rated capacity, the inverter will automatically shut down and restart. if we need to increase the load capacity then we have to change the inverter, battery and also solar panels for the more capacity that is added. But, this inverter will work greater than the rating. We should just have to calculate the load that we want to use and calculate the number of solar panels and battery capacity required to supply the power to that load. We don't need to change the inverter for the additional load added. The main motto of this project is to increase the load handling capacity of the inverter with the minimum cost.

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