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Solar Inverter with Maximum Power Point Tracking

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Abstract: *The main purpose of this project is to design an inverter that will enable the inversion of a DC power source, supplied by Solar (SOLAR) Cells, to an AC power source that will be either used to supply a load or connected directly to the utility grid. The system will be controlled to operate at maximum efficiency using Maximum Power Point Tracking (MPPT) algorithm. The benefit of this project is to give access to an everlasting and pollution free source of energy. The world demand for electric energy is constantly increasing, and conventional energy resources are diminishing. Their prices are rising. For these reasons, the need for alternative energy sources has become required, and solar energy in particular has proved to be a very promising alternative because of its availability and pollution-free nature. Due to the increasing efficiencies and decreasing cost of Solar cells and the improvement of the switching technology used for power conversion, we are interested in developing an inverter powered by SOLAR panels and that could supply stand-alone AC loads. .*

I. Introduction

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy. Solar energy is quite simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650,000,0001tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions. Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The exceptions are geothermal energy, and nuclear fission and fusion. Even fossil fuels owe their origins to the sun; they were once living plants and animals whose life was dependent upon the sun. Much of the world's required energy can be supplied directly by solar power. More still can be provided indirectly. The practicality of doing so will be examined, as well as the benefits and drawbacks. In addition, the uses solar energy is currently applied to will be noted. Due to the nature of solar energy, two components are required to have a functional solar energy generator. These two components are a collector and a storage unit. The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of energy (either electricity and heat or heat alone).

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1. 1 Basic Principle of Solar Inverter

A solar inverter, or PV inverter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

1.2 Need of Solar Inverter

There are two types of sources for electrical power generation. One is conventional and other is non- conventional. Today to generate most of electrical power conventional sources like coal, gas, nuclear power generators are used. Some of conventional source are polluted the environment to generate the electricity. And nuclear energy is not much preferable because of its harmful radiation effect on the mankind. After some of ten years conventional sources will not sufficient enough to fulfill the requirements of the mankind. So some of the electrical power should be generated by non-conventional energy sources like solar, wind .With the continuously reducing the cost of PV power generation and the further intensification of energy crisis, PV power generation technology obtains more and more application.

Conventionally, there are two ways in which electrical power is transmitted. Direct current (DC) comes from a source of constant voltage and is suited to short-range or device level transmission. Alternating current (AC) power consists of a sinusoidal voltage source in which a continuously changing voltage (and current) can be used to employ magnetic components. Long distance electrical transmission favors AC power, since the voltage can be boosted easily with the use of transformers. By boosting the voltage, less current is needed to deliver a given amount of power to a load, reducing the resistive loss through conductors.

The adoption of AC power has created a trend where most devices adapt AC power from an outlet into DC power for use by the device. However, AC power is not always available and the need for mobility and simplicity has given batteries an advantage in portable power. Thus, for portable AC power, inverters are needed. Inverters take a DC voltage from a battery or a solar panel as input, and convert it into an AC voltage output.

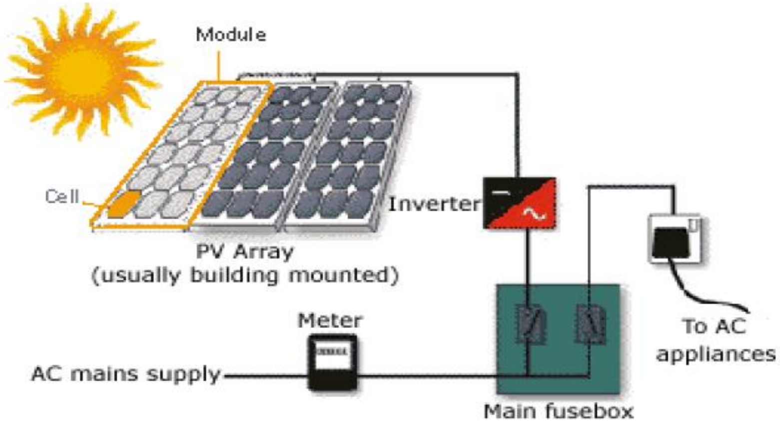

Figure 1 Layout

II. Types of Solar Inverter

Solar inverters may be classified into three broad types.
Stand Alone Inverters
Grid Tie Inverters
Battery Backup Inverters

2.1Stand Alone Inverters

Stand-alone inverters, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.

2.2 Grid Tie Inverters

Grid-tie inverters, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.

2.3 Battery Backup Inverters

Battery backup inverters, are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.

III. Design of Solar Inverter

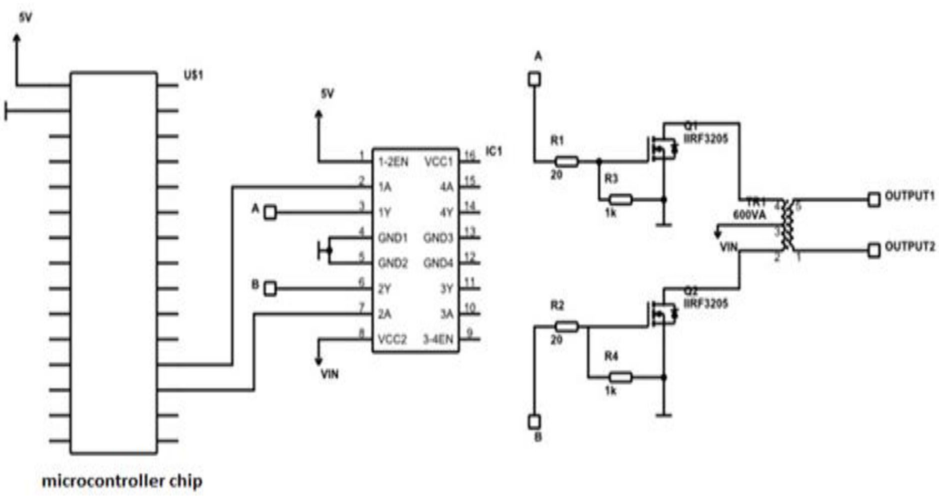

Figure 2 Circuit Diagram of Inverter

This project is all about designing an inverter from scratch, I am always fantasized by the projects which involves a software controlling an hardware. With this inverter, you can power up various electronic Appliances like TV, Fan Etc
The aim of the inverter circuit is to convert 12VDC to 220VAC, Now to achieve this, we have to first convert 12VDC to 12VAC first followed by 12VAC to 220VAC using a step up transformer.

In short, we can classify the designing of inverter circuit into three stages:

1. Driver stage
2. Power stage
3. Transformer
4. Driver stage

The tasks that are performed in driver stage are generation of modified sine wave, monitoring the battery voltage, handling the other housekeeping tasks such as short circuit protection, etc. Here I have used an Arduino NANO to accomplish all these tasks.
Arduino is generating a modified sine waveform of 5V which is amplified to a level of 12V using L293D IC. Battery voltage is monitored every 20ms using timer interrupt.
Now this current amplification task is performed by the power stage. In this stage, two N-MOSFETs are configured in push-pull topology to amplify the current. MOSFET Chosen are IRF3205.
Now this is very simple, the output waveform from the push-pull topology is fed into the transformer to generate the 220V.

IV. Maximum Power Point Tracking

There are many charge controllers available in market, but ordinary cheap charge controllers are not efficient for use with maximum power from solar panels. And the ones which are efficient are very costly. So decided to make my own charge controller to be efficient and smart enough to understand the battery needs and solar conditions. It takes appropriate actions to draw maximum available power from solar and put it inside the battery very efficiently.
Step 1: What Is MPPT and Why Do We Need It?
Our solar panels are dumb and not smart enough to understand the battery conditions. I have a 12v/100 watt solar panel and it'll give an output between 18V-21V depending upon manufactures, but batteries are rated for 12v nominal voltage. At full charge conditions they will be 13.6v and will be 11.0v at full discharge. Now let's assume our batteries are at 13v charging, panels are giving 18v, 5.5A at 100% working efficiency (not possible to have 100% but let's assume). Ordinary controllers have a PWM voltage regulator circuit which drops the voltage to 13.6 without any gain in current. It only provides protection against overcharging and leakage current to panels during nights.
So have 13.6v*5.5A = 74.8 watt. We lose approx. 25 watt.
To counter this issue, I have used SMPS buck converter. This kind of converter has above 90% efficiency. Even 90% is considered poor. Second problem that we have is non-linear output of solar panels. They need to be operated at a certain voltage to harvest maximum available power. Their output varies through the day. To solve this issue MPPT algorithms are used. MPPT (Maximum Power Point Tracking) as the name suggests this algorithm tracks the maximum available power from panels and varies the output parameters to sustain the condition. So by using MPPT our panels will be generating maximum available power and buck converter will be putting this charge efficiently into batteries.
Step 2: How Does MPPT Work?
Si in this we have given detail about MPPT
What is MPPT?
In this project I have tracked the input V-I characteristics and output V-I, also. By multiplying the input V-I and output V-I we can have the power in watts. Let's say we have 17 V 5 A, i.e. 17x5 = 85 watt, at any time of the day. At the same time our output is 13 V 6A, i.e. 13x6 = 78 Watt.
Now MPPT will increase or decrease the output voltage to by comparing to previous input/output power. If the previous input power was high and the output voltage was lower than present, then output voltage will be lowered down again to get back to high power. And if the output voltage was high, then present voltage will be increased to the previous level. Thus it keeps oscillating around the maximum power point. These oscillations are minimized by efficient MPPT algorithms.
Step 3: Buck Converter
We have used N-channel MOSFET to make the buck converter. Usually people choose P-channel MOSFET for high side switching and if they choose N-channel MOSFET for the same purpose than a driver IC will be required or boot strapping circuit.
But I modified the buck converter circuit to have a low side switching using N-channel MOSFET. I'm using N-channel because these are low cost, high power ratings and lower power dissipation. This project uses IRFz44n logic level MOSFET, so it can be directly drive by an Arduino PWM pin.
For higher load current, one should use a transistor to apply 10V at gate to get the MOSFET into saturation completely and minimize the power dissipation. I have done the same.

As see in circuit above, I have placed the MOSFET on negative voltage, thus using +12v from panel as ground. This configuration allows me to use an N-channel MOSFET for buck converter with minimum components. But it also has some drawbacks. As you have both sides negative voltage separated, you don't have a common reference ground anymore. So measuring of voltages are very tricky. I have connected the Arduino at solar input terminals, using its negative line as ground for Arduino. We can easily measure the input voltage at this point by using a voltage divider circuit as per our requirement. But we can't measure the output voltage as easily as we don't have a common ground.
Now to do this there is a trick. Instead of measuring the voltage across the output capacitor, I have measured the voltage between two negative lines. Using solar negative as ground for the Arduino and output negative as the signal/voltage to be measured. The value that you got with this measurement should be subtracted from the input voltage measured and will get the real output voltage across output capacitor.
Vout_sense_temp=Vout_sense_temp*0.92+float (raw_vout)*volt_factor*0.08;
Measure voltage across input ground and output gnd.
Vout_sense=Vin_sense-Vout_sense_temp-diode_volt; //change voltage difference between two grounds to output voltage.
For current measurements I have used ACS-712 current sensing modules. They have been powered by Arduino and connected to input GND.
Internal timers are modified to gain 62.5 KHz PWM at pin D6, which is used to drive the MOSFET. An output blocking diode will be required to provide reverse leakage and reverse polarity protection use Schottky diode of desired current rating for this purpose. The value of inductor depends upon frequency and output current requirements. You can use online available buck converter calculators or use 100uH 5A-10A load. Never exceed the maximum output current of inductor by 80%-90%.

V. Modelling of Solar Inverter

A successful design involves accurate knowledge of daily electrical load calculation and accounts for all worst case scenarios which might possibly occur during operation. A good designer will be pragmatic and keep the costs down by cutting on unnecessary over sizing the system.

Selection of battery size and solar panel
Total load = 50 watt
Design inverter for 12 volt
Voltage = 12 volt
Power = voltage * current
Current = 50/12=4.16 ampere
Battery = total load * no of hours/voltage
= 40*5/12
= 16.66
= 16 Ah or 17 Ah
But efficiency of inverter 85% & DOD = 80%
A-hr=(16A-hr/(0.85*0.8))=23A-hr battery
Solar panel
Charging current = 1/10 th of its total Ah
= 1/10 * 23
= 2.3 Ah
Solar panel need 2.3 amps current to feed our battery bank
= 2.3 + 4.16
= 6.46
= 6.46 amps
Solar panel should make 6.46 amps
Here 2. 3amps need to feed battery and 4.16 to run electrical load through solar
Power =12 * 5
= 60 watt
50 watt pane give output of approx. 35 watt so we need 100 watt panel.

VI. Conclusion

From this project observed that this solar inverter is producing electricity free of cost by using solar energy so, its eco-friendly, and pollution free and can be used for domestic appliances as well as for industrial purpose on three phase. In this project, made an inverter which is sufficient to supply the power to domestic load Photovoltaic power production is gaining more significance as a renewable energy source due to its many advantages.

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