



Solar charge controller

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Abstract

Non-conventional power generation is one of the fastest growing sectors. Globally, all countries are busy developing and implementing non-conventional power to bridge the electricity demand and power supply gap.

The sun is the ultimate source of limitless solar energy in the form of light and heat. Light of the sun is directly converted into electrical energy without any intermediate step.

Solar Photovoltaic (PV) power is leading ahead of the other sources. In a solar power generation system, the PV cell plays a major role.

Rural coastal communities in developing countries along the equator lack electricity, due to the expenses involved with connecting them to the power grid. An affordable local solution, such as on-site micro power generation, would benefit the local communities and fulfil their basic lighting and ventilation needs. Equatorial coastal areas have constant high incident solar radiation. Therefore, these regions would be ideal to implement a solar power generation unit.

This project involves the development of a solar panel to generate direct current (DC) power that will be used to charge a battery. And this DC voltage from battery is converted into AC using inverter. This system will provide the basic electricity requirements for the house.

The initial investment may be excessive for the target population, these costs are expected to go down if the design is mass produced. Solar power source is 'free' making this system viable long-term solution for electrification. The implementation of a project such as this will make the use of hazardous items such as kerosene lamps and car batteries redundant.

Purpose of investment in solar power project is to enter in development of green energy technology, which is the only ultimate source of energy for future generations.

Keywords: solar photovoltaic, direct current

1. Introduction

In India most of the people are living in rural area where national grid transmission line is not reached till now. The existing electric grids are not capable of supplying the electricity need to those poor people. So renewable energy sources (photo voltaic panels and wind-generators) are the best option.

Solar power have the advantage of being less maintenance and pollution free but their main drawbacks is high fabrication cost, low energy conversion efficiency. Since solar panels still have relatively low conversion efficiency, the overall system cost can be reduced using a efficient solar charge controller which can extract the maximum possible power from the panel.

In solar power system, charge controller is the heart of the system which was designed to protect the rechargeable battery.

1.1 What is a Charge Controller?

A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. It directs the voltage and current hailing from the solar panels setting off to the electric cell. Generally, 12V boards/panels put out in the ballpark of 16 to 20V, so if there

is no regulation the electric cells will damaged from overcharging. Generally, electric storage devices require around 14 to 14.5V to get completely charged. The solar charge controllers are available in all features, costs and sizes. The range of charge controllers are from 4.5A and up to 60 to 80A.

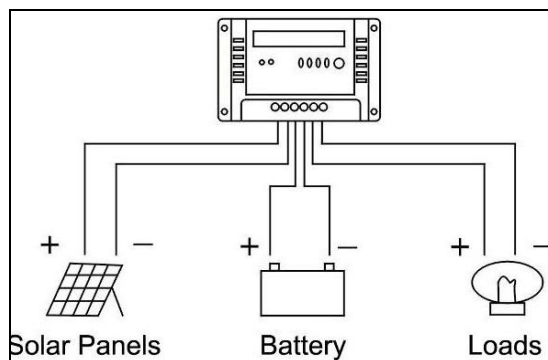


Fig 1: Solar Controller

1.2 Types of Solar Charge Controllers

The two types of charge controllers most commonly used in today's solar power systems

1. Pulse width modulation (PWM) and
2. Maximum power point tracking (MPPT).

Both adjust charging rates depending on the battery's maximum capacity as well as monitor the battery temperature to prevent overheating.

1.3 Pulse Width Modulation (PWM) Charge Controller

Pulse width modulation (PWM) charge controller is the most effective means to achieve constant voltage battery charging by adjusting the duty ratio of the switches (MOSFET). In PWM charge controller, the current from the solar panel tapers according to the battery's condition and recharging needs. When a battery voltage reaches the regulation set point, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery; yet charging continues to return the maximum amount of energy to the battery in the shortest time. The voltage of the array will be pulled down to near that of the battery.

PWM system has the following advantages:

- Higher charging efficiency
- Longer battery life
- Reduced battery over heating
- Minimizes stress on the battery
- Ability to de-sulfate a battery

A PWM controller is not a DC to DC transformer. The PWM controller is a switch which connects the solar panel to the battery. When the switch is closed, the panel and the battery will be at nearly the same voltage.

Assuming a discharged battery, the initial charge voltage will be around 13V, and assuming a voltage loss of 0.5V over the cabling plus controller. The voltage will slowly increase with increasing state of charge of the battery. When absorption voltage is reached, the PWM controller will start to disconnect and reconnect the panel to prevent overcharge (hence the name; pulse width modulated charge controller)

1.4 Maximum Power Point Tracking

Nowadays, the most advanced solar charge controller available is the Maximum Power Point Tracking (MPPT). It is more sophisticated and more expensive. It has several advantages over the PWM charge controller. It is 30 to 40% more efficient at low temperature. The MPPT is based around a synchronous buck converter circuit. It steps the higher solar panel voltage down to the charging voltage of the battery.

It will adjust its input voltage to harvest the maximum power from the solar panel and then transform this power to supply the varying voltage requirement of the battery plus load. It is generally accepted that MPPT will outperform PWM in a cold temperature climate, while both controllers will show approximately the same performance in a subtropical to tropical climate.

The MPPT charge controller is a DC to DC transformer that can transform power from a higher voltage to power at a lower voltage. The amount of power does not change, therefore, if the output voltage is lower than the input voltage, the output current will be higher than the input current, so that the product $P=VI$ remains constant. Hence, in order to get the

maximum out of a solar panel, a charge controller should be able to choose the optimum current-voltage point on the current-voltage curve: the Maximum Power Point. An MPPT does exactly that. The input voltage of a PWM controller is, in principle, equal to the voltage of the battery connected to its output.

The solar panel, therefore, is not used at its Maximum Power Point, in most cases.

2. Review of Literature

Energy is the key influencing factor for development in all sectors, i.e., Industrial, Commercial, Agriculture, Domestic etc. as per capita energy consumption is one of the indicators of national development status. per capita energy consumption is about 600 units in our country, where as it is 1400 units in China, 6898 units in Germany, 13,000 units in U.S.A World average is about 2430 units.

India is the sixth largest country in the world in terms of generation and consumption levels. The total installed capacity of Power projects India is 1,47,402.81 MW, of this thermal mode of power generation including coal, gas and oil contributes 64.7%, Hydro contributes 24.65%, Nuclear 2.95% and Renewable energy 7.7%. The demand-supply gap, which is denoted as 'energy shortage' is 8.8% of the total energy requirement in 2009 and the peak shortage, which is a measure of shortage during peak power consumption hours is approximately 14 percent of installed capacity. The Government of India has initiated several reform measures to create a favourable environment for addition of new generating capacity in the country. The Electricity Act 2004 has put in place a highly liberal framework for generation. There is no requirement of licensing for generation and technology economic clearance from CEA for thermal generation projects.

The fast diminishing world reserves of fossil fuels, increasing demand for energy, particularly in developing countries, and the damage to the environment caused by; the consumption of large quantities of fossil fuels in the preceding century have encouraged intensified search for renewable and environment friendly sources of energy.

The use of renewable energy resources involves the tapping of natural flows of energy in the environment. If the resource is used in a sustainable fashion, the energy is removed at a rate comparable to that at which energy is being replenished. Renewable energy is thus inexhaustible as opposed to conventional sources of energy, which has a limited lifespan.

The use of conventional sources of energy such as fossil fuels has many adverse side effects. Their combustion products produce pollution, acid rain and global warming which are currently major global concerns. Conversion to clean energy sources can improve the quality of life throughout the planet earth, not only for humans, but for its flora and fauna as well. Consequently, the use of renewable energy can contribute to environmental protection not only for the present generation but for future generations as well.

Because of the foregoing, there is a need to develop method of renewable energy conversion systems and then to substitute it where application of fossil fuels are most vulnerable. With renewable energy technologies, a secure and diverse supply of energy can be secured and resources can be restored.

Additionally, renewable energy is widely distributed and is available and indigenous to almost every region of the world. Currently, the World energy Council predicts that the contribution from renewable will rise to 30% and that biomass will continue to be the dominate source of renewable energy.

Disadvantages and Limitations of Conventional Energy Sources

- Resources are limited.
- Environmental problems, emission of greenhouse gases.
- Dependency on imports.
- Dependency n global oil prices, which effect country economy.
- Transmission & distribution losses

Advantages of non-conventional energy:

Conservation of limited conventional energy resources which can be made available for futurist generation.

Reducing imports and avoided cost can be invested for other development activities.

Reduction of G.H.G and other emissions for protecting environment.

Use of in-exhaustible energy sources like Solar, Wind, Biomass, Tidal etc.

3. Methodology

Solar charge controller performs 4 major functions:

- Charges the battery.
- Gives an indication when battery is fully charged. Monitors the battery voltage and when it is minimum, cuts off the supply to the load switch to remove the load connection.
- In case of overload, the load switch is in off condition ensuring the load is cut off from the battery supply.

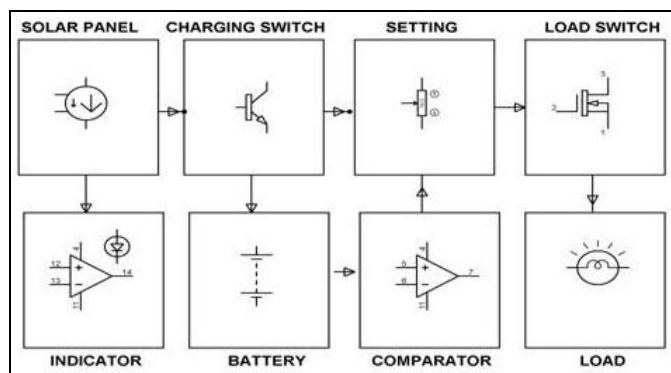


Fig 2: Symbols

A solar panel is a collection of solar cells. The solar panel converts the solar energy into electrical energy. The solar panel uses Ohmic material for interconnections as well as the external terminals.

So the electrons created in the n-type material passes through the electrode to the wire connected to the battery. Through the battery, the electrons reach the p-type material. Here the electrons combine with the holes.

When the solar panel is connected to the battery, it behaves like other battery, and both the systems are in series just like

two batteries connected serially. The solar panel has totally consisted of four process steps overload, under charge, low battery and deep discharge condition.

The out from the solar panel is connected to the switch and from there the output is fed to the battery. And setting from there it goes to the load switch and finally at the output load. This system consists of 4 different parts-over voltage indication and detection, over charge detection, over charge indication, low battery indication and detection. Incase of the over charge, the power from the solar panel is bypassed through a diode to the MOSFET switch. Incase of low charge, the supply to MOSFET switch is cut off to make it in off condition and thus switch off the power supply to the load.

3.1 Comparison between MPPT and PWM

If maximizing charging capacity is the only factor considered when specifying a charge controller, everyone would use a MPPT controller, but two technologies are different, each with its own advantages. The decision depends on site conditions, system components, size of array, load and cost of a particular solar panel system. They are compared as follows.

- Temperature conditions An MPPT controller is better suited for colder conditions. The MPPT controller is able to capture the excess module voltage to charge the batteries. It produces up to 20-25% more charging than a PWM controller.
- The PWM type is unable to capture excess voltage because the pulse width modulation technology charges at the same voltage as the battery. But when solar panels are deployed in warm or hot climates, there is no excess voltage to be transferred making the MPPT unnecessary and negating its advantage over a PWM.
- Array Voltages PV array and battery voltages should match for PWM but PV array voltage can be higher than battery voltage for MPPT.
- Battery Voltage- PWM operates at battery voltage, so it performs well in warm temperature and when battery is almost full while MPPT operates above the battery voltage, so it can provide “boost” in cold temperatures and when the battery is low.
- System Size- PWM is typically recommended for use in smaller systems where MPPT benefits are minimal, while MPPT is recommended for a 150W-200W or higher sized systems to take advantage of its benefits.
- Cost- MPPT controllers are typically more expensive than PWM controllers but are more efficient under certain condition, so they can produce more power with the same number of solar modules than a PWM control.

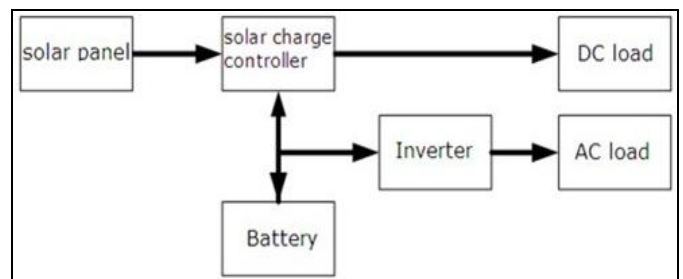


Fig 3

Solar charge controller is a key component in any photo voltaic system that uses batteries to store energy. The main function of solar charge controller it to reduce the overall system maintenance and prolongs the battery life by regulating the charging voltage and current coming from the solar panels. It also protects the battery from both overcharging and deep discharging.

Today, most of the solar charge controllers utilize the Pulse Width Modulation (PWM) technique to adjust the charging voltage and current according to the charging status of the batteries. For instance, if the battery gets closer to fully-charged condition, the amount of solar power delivered to the batteries is lowered by lowering the duty cycle of the PWM signal. This approach has lesser stress on batteries during charging and thus extends their battery life

This design uses Arduino for PWM generation and other measurements and control features.

The Arduino Solar controller uses a simple resistor-divided-network to construct a voltage feedback system to sense the battery terminal voltage.

The feedback signal is then used to adjust the duty cycle of the PWM signal.

The charge controller also implements an energy monitor system, which is really a cool feature. A 4×20 character LCD is used in the project to display the key parameters like voltage, current, power, energy, and ambient temperature.

An automatic load control feature disconnects the load from the battery to prevent it from deep-discharging.

4. Working Principle

The principle behind a solar charge controller is simple. There is a circuit to measure the battery voltage, which operates a switch to divert power away from the battery when it is fully charged. Because solar cells are not damaged by being short or open-circuits, either of these methods can be used to stop power reaching the battery.

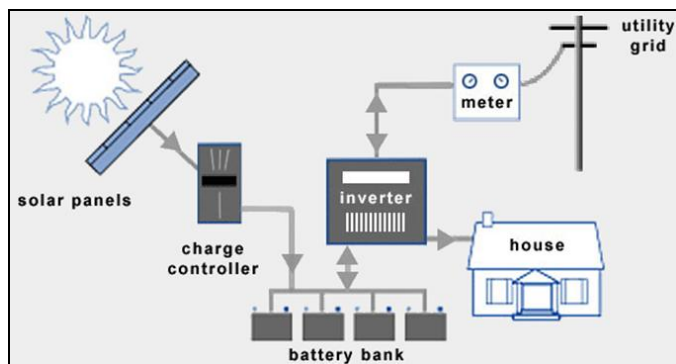


Fig 4

A controller which short-circuits the panel is known as a *shunt regulator*, and that which opens the circuit as a *series regulator*. Optionally there may also be a switch which automatically disconnects the power from the appliances or *loads* when the battery voltage falls dangerously low. This is known as a *low-voltage disconnect* function.

4.1 Circuit Diagram

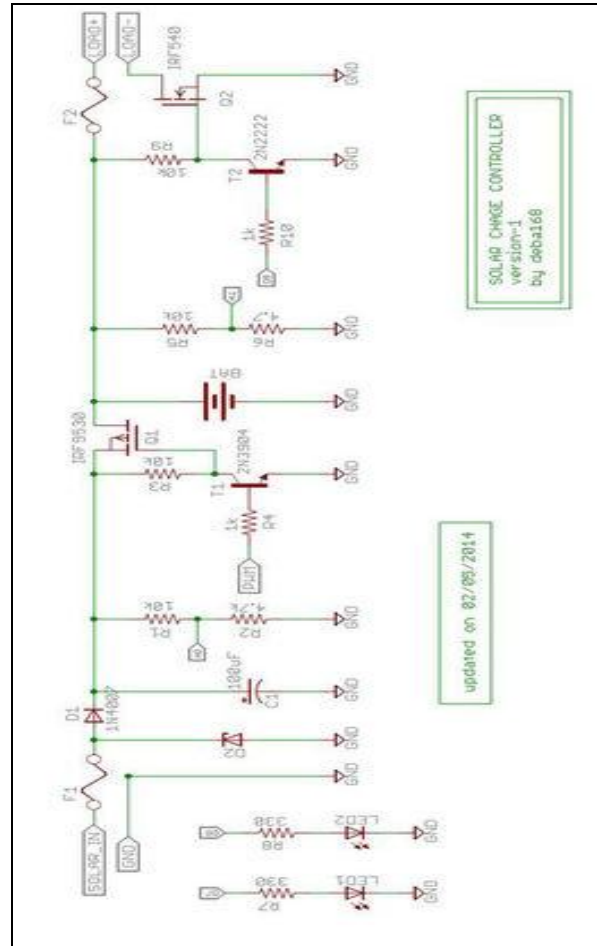


Fig 5

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.

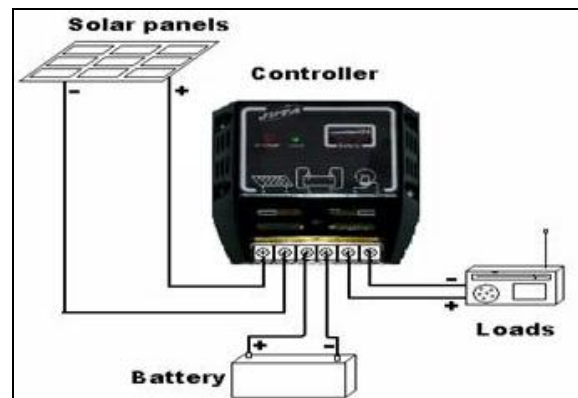


Fig 6

Generally solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery. The charge voltage could be kept at a best level while the time needed to completely charge the electric storage devices is lessened. This permits the solar systems to work optimally constantly. By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally.

The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.



Fig 7

5. Design Overview

Hardware Components for Solar Power Charge Controller

- Solar panel
- Op-amps
- voltage sensor
- MOSFET
- Diodes
- LEDs
- Potentiometers
- Battery

1. Solar Panel

Expose the cell to light, and the energy from each photon (light particle) hitting the silicon, will liberate an electron and a corresponding hole.

If this happens within range of the electric field's influence, the electrons will be sent to the N side and the holes to the P one, resulting in yet further disruption of electrical neutrality. This flow of electrons is a current; the electrical field in the cell causes a voltage and the product of these two is power.

3. PWM Signal Generation

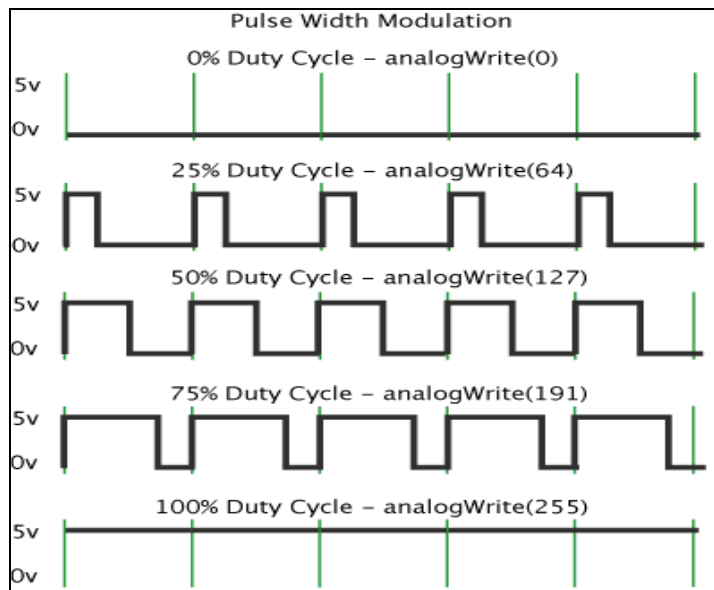


Fig 9

2. Voltage sensor

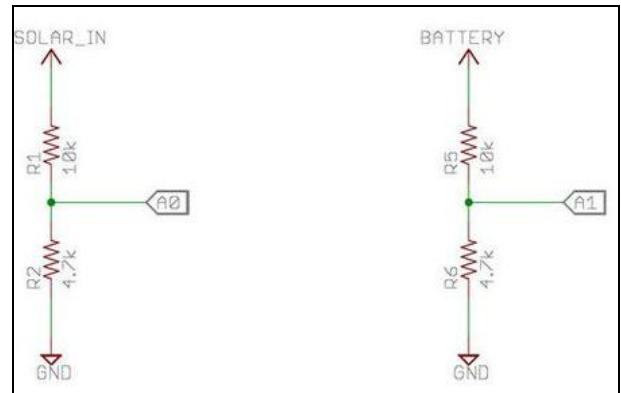


Fig 8

The main sensors in the charge controller is voltage sensors which can easily implemented by using a voltage divider circuit. We have to sense voltage coming from solar panel and the battery voltage.

PWM (pulse width modulation) is a technique by which we simply control a digital output signal by switching it on and off very quickly, by varying the width of the on/off duration, it will give the effect of varying the output voltage.

$$V_{out} = \frac{T_{on}}{T_{on} + T_{off}} * V_{in}$$

$$\text{Time period (T)} = T_{on} + T_{off}$$

So $V_{out} = \frac{T_{on}}{T} * V_{in}$
 Where $\frac{T_{on}}{T_{on} + T_{off}} * 100$ or $\frac{T_{on}}{T} * 100$ is called Duty Cycle

4. MOSFET drivers

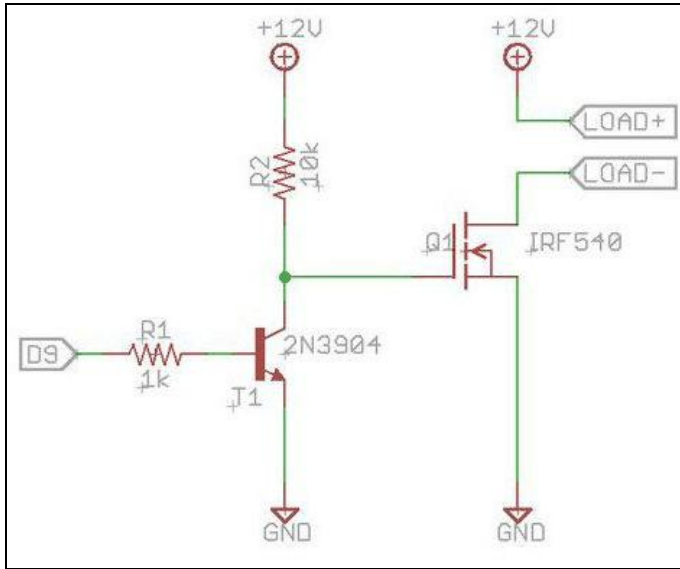


Fig 10

What is a MOSFET driver

A gate driver is a power amplifier that accepts a low-power input from a micro controller and produces a high-current drive input for the gate of a high-power MOSFET.

Why you need a MOSFET driver

MOSFETs have a large stray capacitance between the gate and the other terminals, which must be charged or discharged each time the MOSFET is switched on or off. As a transistor requires a particular gate voltage in order to switch on, the gate capacitor must be charged to at least the required gate voltage for the transistor to be switched on. Similarly, to switch the transistor off, this charge must be dissipated, i.e. the gate capacitor must be discharged.

When a transistor is switched on or off, it does not immediately switch from a non-conducting to a conducting state; and may transiently support both a high voltage and conduct a high current.

Consequently, when gate current is applied to a transistor to cause it to switch, a certain amount of heat is generated which can, in some cases, be enough to destroy the transistor. Therefore, it is necessary to keep the switching time as short as possible, so as to minimize switching loss

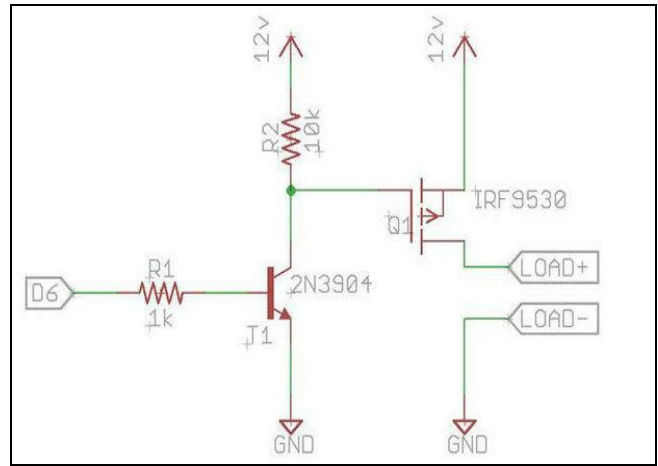


Fig 11

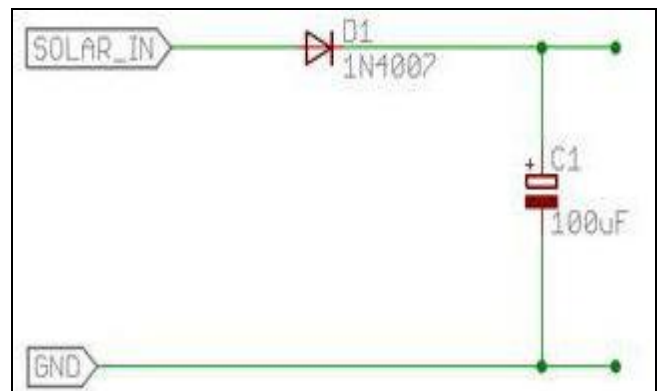


Fig 12

5. Filter and Protection:

Filter

The capacitor (C1) used after the solar panel at the input side is used as filter which removes any unwanted ripple/noise signal.

I used a 100uF, 35V.

Protection

Protections are provided in the charge controller to protect against extreme and abnormal operating condition. In commercial charge controller there are so many protection. But in my charge controller all are not included.

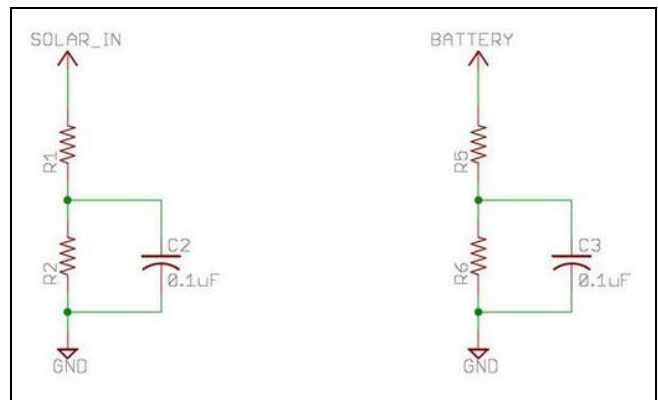


Fig 13

Following protection are used

1. **Over Voltage Protection:** During lightning and thundering over voltage occurs in the system. To protect the system a zener diode is used. I used a 11V zener diode as my solar panel open circuit voltage is 10v. When the voltage is more than 11v, it will provide the ground path to the surges.
2. **Protection to over current:** Two fuses F1 and F2 are used for over current protection. One is at the incoming side i.e after the solar panel and other is before the load. I forgot to show in the first schematics.
3. **Overcharge protection:** Over charge protection is given to improve the battery life and prevent from overheating .When the battery voltage is greater than the fully charged voltage(7.2v) ,it is disconnected from the solar panel to avoid further charging. This is also implemented through the software.

6. Display and Indication

System status display on LCD

A 16X2 char LCD is used for monitoring solar panel voltage and battery voltage. It also show the % of charge.

When the battery condition is dead it will display: "BATTERY IS DEAD!!" and when battery is discharged it will display "BAT DISCHARGED."

LED indication on system condition

2 LEDs (RED, GREEN) are used for indicating the system condition RED LED will glow when battery is discharged (< 6.2 V) GREEN LED will glow when fully charged (> =7.2 V) and will blink during charging.

When battery voltage is less than 6.2V but greater than 6V RED LED will glow indicating battery is discharged and GREEN LED will blink indicating battery is charging.

6. Applications

- Solar street light system is system that uses PV module to convert sunlight into DC electricity. The system consumes only DC electricity and incorporates solar charge controller to store DC in the battery bank to supply during sunlight is not visible or nighttime.
- Solar home system is system that takes energy generated from PV module to supply for home appliances or other household applications. The system incorporates solar charge controller to store DC in the battery bank and suits for using in any areas where utility grid is not available.
- Hybrid system is system that consists of multiple energy sources to provide full time, backup power or other purposes. It usually combines solar array with other forms of generation such as diesel generator and renewable energy forms (wind turbine generator and hydro generator, etc.) and incorporates solar charge controller to store DC in the battery bank.
- Solar water pump system is system that uses solar power to pump water from natural and surface reservoirs for home, village, water treatment, agriculture, irrigation, livestock and other applications.

7. Result & Conclusion

In this paper, a solar power charge controller has been

discussed effectively i.e. how rechargeable battery is used to store energy with the help of solar under voltage which harm the life of a battery.

The use of solar energy is essential for providing solutions to the environmental problems and also energy demand. The vast development to improve the efficiency by the MPPT algorithms encouraged the domestic generation of power using solar panels. The available MPPT techniques based on the number of control variables involved, types of control strategies, circuitry, and applications are possibly useful for selecting an MPPT technique for a particular application for grid tied or standalone mode of operations. This review has included many recent hybrid MPPT techniques along with their benefits for mismatched conditions such as partial shading, nonuniformity of PV panel temperatures, and dust effects.

It is observed that Perturbation and Observation and Incremental Conductance methods are simple and used by many researches, but they have the slow tracking and low utilization efficiency. To overcome the drawbacks, fuzzy and neural network techniques are used in the present days by which the efficiency is increased. To boost up the voltage various DC-DC converters are used along with battery storage systems in order to store the excessive energy from solar PV panel.

The DC link voltage oscillations in the grid connected PV system can be obtained by using Cuk converters, SEPIC converters, and Zeta converters with reducing current ripple injected in the PV array and load. The harmonic content is reduced from the output of DC-DC converters using the filter circuits. The passive filters as LC, LCL, and LLCC are used for harmonic distortion as well as to improve the power quality. Filter capacitors are used to reduce high frequency current ripple.

This DC is again fed to the inverter for converting the DC to AC with various PWM techniques. These PWM inverter techniques yield the better AC outputs which are used to connect the grid interconnections and standalone AC loads.

Multilevel inverters with sinusoidal PWM and SVM are used to reduce the harmonics in the load voltage even in low switching frequency. Grid tied inverters with battery backup are preferred in hybrid systems for backup even if the grid goes down for both grid tied and off grid systems.

8. Future Scope

1. The work that had been carried out by the researchers, the designing of MPPT controller, should be extended by tracking larger number of input parameters which are varying with respect to the time such as parameters variations of the system. In order to get accurate MPPT point, the recent mathematical algorithms such as Z-infinity algorithms should be implemented.
2. We can also use it for Automatic Irrigation System as shown in figure
3. Hybrid of MPPT with mechanical tracking will give more efficiency, project can be extended in this direction.
4. Battery output is directly utilized to feed power in the dc grid which can be used for charging electronic devices like laptop, mobile directly.
5. By adding wifi module we can record our data in the

system and optimize the data for better use.

- Solar panel installed on urban and sub-urban areas with modified technology will lead in saving of our bill.

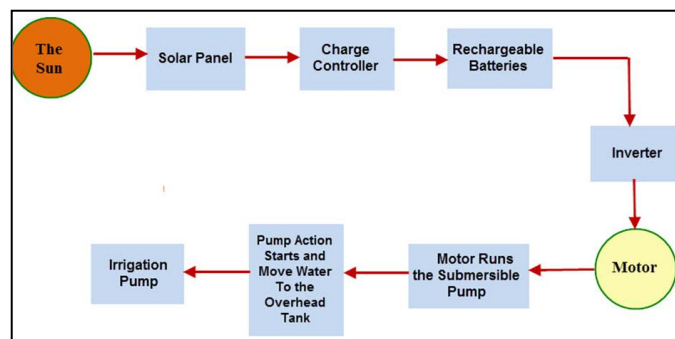


Fig 14

Acknowledgement

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