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MPPT Solar Charge Controller

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Abstract: *In this proposed system, the design of a controlled DC-DC boost converter for PV charger application is presented. The duty cycle of the designed boost converter, which operates at 50 KHz, is controlled directly to track the maximum power point of the PV panel that is changing in response to variation insolation of a sunny day. The designed Boost converter is used as an interface unit for matching a 24V battery bank (20AH, 12V, C/5) with a Solar panel. The overall system is built and validated by using MATLAB SIMULINK. The simulation results show that the average efficiency of the proposed MPPT-controlled DC-DC converter is with good result which is calculated by comparing the tracked PV power by the designed converter and the proposed maximum power of the panel for different levels of insolation. The results express the effective operation of the designed converter system by tracking MPP for PV panels in different insolation situations.*

Keywords: MPTT, PV, Duty Cycle, Converter, Power.

I. INTRODUCTION

Non-renewable energy sources have a limited supply, often releasing harmful gases and their prices are increasing continuously. These have become the main driving forces to use renewable energy sources, such as solar, wind, biomass and hydropower energy. As compared to other sources, solar energy is more attractive since it is environmentally clean, abundantly available, cheap, and easily transferrable to other forms of energy. One practical application of solar energy is solar photovoltaic panels as a source of electricity. PV systems can be grouped into stand-alone and grid-connected systems. Stand-alone systems are not part of the grid and are essential for regions that are remote from the public grid. These systems contain energy storage systems such as rechargeable batteries to supply energy in case of dark or low insolation conditions [1].

However, PV systems have many major problems. Firstly, the efficiency of converting solar energy into electricity is low (10 to 16% efficiency for amorphous silicon solar cells). Secondly, the i-v characteristics of solar cells are highly nonlinear and depend on temperature and insolation level. Further, because of the dependence of energy produced by the solar system on the energy required by the load; the direct connection of the PV panel and load reduces the conversion efficiency of the PV panel if the impedance of the load line and optimal impedance of PV array, which corresponds to maximum power point of i-v curve of PV panel, are not in concurrence. Therefore, the power generated from the solar cells is not always completely extracted.

A. Problem Statement

"Increasing the efficiency and effectiveness of solar power generation systems through the development of an advanced MPPT solar charge controller that can accurately track the

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maximum power point of solar panels under varying environmental conditions, such as changes in temperature and sunlight intensity. The controller should be cost-effective, easy to implement, and compatible with a wide range of solar panel technologies and system configurations." With the increasing demand for power and energy, energy conservation and use of renewable resources has become a crucial necessity. Solar energy will become the ultimate and prime source of energy soon. Therefore, highly efficient and low energy-consuming solar-powered equipment and applications will soon be a major requirement. In this paper, solar charge controllers using Maximum Power Point Tracking (MPPT) and Pulse Width Modulation (PWM) have been analyzed and compared, which is needed in all solar-powered systems that utilize batteries. Its role is to regulate the power going from the solar panel to the batteries. Most of the modern charge controllers include PWM and MPPT. These charge controllers are designed such that the solar battery gets recharged quickly and does not get over-discharged, thereby ensuring the prolonged lifespan of the battery.

B. Objectives

- To design and model of MPPT system by using SIMULINK.
- To represent the ideal parameter of constant voltage, through the MPPT system.
- To compose a boost converter of which its duty cycle is controlled directly.

II. LITERATURE SURVEY

Hiwale et. al. states that a Maximum power point tracker battery charger is proposed for extracting maximum power from a photovoltaic panel to charge the battery. The output power of the PV system continuously varies with changes in irradiance and temperature. It is very important to improve the efficiency of the charger. There are several maximum power point tracking (MPPT) methods available to operate the PV system at maximum power point. The proposed system has used Perturb & Observe (P&O) MPPT algorithm for the design and implementation. When irradiance and temperature are constant or slowly varying, the P&O method tracks MPP steadily and calculates the operating point at which the battery is capable of producing maximum power. In this method, the controller provides the PWM signal to adjust the voltage, adjustment is done by Buck converter and measures power, if the power increases, further adjustments in that direction are tried until power no longer increases. Solar energy is one of the most important renewable energy sources that has been gaining increased attention in recent years. Solar energy is plentiful; it has the greatest availability compared to other energy sources.

The amount of energy supplied to the earth in one day by the sun is sufficient to power the total energy needs of the earth for one year. Solar energy is clean and free of emissions since it does not produce pollutants or by-products harmful to nature. The conversion of solar energy into electrical energy has many application fields. Recently, research and development of low-cost flat-panel solar panels, thin-film devices, concentrator systems, and many innovative concepts have increased. Soon, the costs of small solar-power modular units and solar power plants will be economically feasible for large-scale production and use of solar energy.

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In this paper, we have presented the photovoltaic solar panel's operation. The foremost way to increase the efficiency of a solar panel is to use a Maximum Power point Tracker (MPPT), a power electronic device that significantly increases the system efficiency. By using it the system operates at the Maximum Power Point (MPP) and produces its maximum power output. Thus, an MPPT maximizes the array efficiency, thereby reducing the overall system cost. In addition, we attempt to design the MPPT by using the algorithm of a selected MPPT method which is "Perturb and Observe" and implement it by using a DC-DC Converter. We have found various types of DC-DC converter. Among them, we have selected the most suitable converter which is the "BUCK" converter, for our design. PV generation systems generally use a microcontroller-based charge controller connected to a battery and the load. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array, the charge controller regulates the charge to the batteries preventing any overcharging.

III. SUSTAINABLE ENERGY

The rapidly growing environmental issues and global warming have attracted the attention of researchers around the globe to overcome these issues in such a way that the increasing energy demand can not only be met but also be made environment-friendly. The current trend of energy generation is through fossil fuels, fossil fuels are hydrocarbon deposits like coal, natural gas or oil which are formed in the depths of the earth. These non-renewable energy sources are burnt to extract energy, the burning of these substances results in the emission of hazardous gasses which are the main cause of the greenhouse effect and the main reason for rapidly growing environmental pollution and global warming.

The best way of avoiding these issues is through renewable energy, which is the energy which is produced by renewable sources like wind, solar, wave, biomass, tides, geothermal heat etc. The use of such energy sources cannot only secure long-term energy supplies and enhance diversity in the energy supply market, but it also massively helps reduce atmospheric emissions, making this world a clean and better place to live.

A. Solar Energy

Solar energy is the energy produced from the radiation of the sun. Solar energy also known as solar power can be used to produce electricity, heat, hot water, and even cooling. This process of converting sunlight into useful energy is called 'photovoltaic', or PV in short. The energy which is provided by the sun is so long-lasting and enormous that it can provide enough energy can be consumed annually by the whole world in just half an hour, the sun is the most renewable and clean energy source, which can produce radiation of 3000 watts per square meter on the earth's surface on a clear day, depending on the location. [1, 2]

Solar energy has been emerging tremendously in the past few years, The total generation of solar energy around the globe in 2011 was recorded to be about 1.5 GW which was just 1.5GW in 2000. This massive growth continues to grow with an average rate of 50% every year [3].

B. Solar Cell, Module and Panel

The solar cell is a solid-state semiconductor device that is the basic building block of a solar panel, it converts light into electricity by photovoltaic effect. They are mostly made up of silicon, with traces of some other elements in it. The solar cell acts as a semiconductor, as the silicon material is doped with p-type and n-type elements, separated by a junction. When light (photon) with a certain amount of energy hits the solar cell, it frees the electron-hole pairs sending free electrons to n- the side and holes to the p- side causing more disruption to the electrical neutrality and if an external circuit is made, the electrons will pass through that path to their original side (p- side) uniting with the holes electric field sent there. With this passage of current and voltage caused by an electric field of the cell results in the formation of power. The figure below describes the whole process [15, 16].

C. Solar Module

When many solar cells are connected they form a solar module. They can be connected in series which will benefit in higher voltage or can be connected in parallel which will result in greater current. Configurations can also be made where solar cells can be connected in series as well as in parallel to form a single module. Usually, about 35-72 solar cells are connected in series, forming a module, which raises a peak power of 10W to 200W.

IV. PROPOSED SYSTEM

Solar power is a key energy source for space missions, providing a reliable and renewable source of electricity for satellites, spacecraft, and other space-based applications. The proposed system aims to design and optimize a solar power conversion system specifically tailored for space applications, maximizing energy efficiency, reliability, and performance in the harsh environment of space.

To design and size the components of boost converters, many factors should be considered such as input voltage to the converter, output voltage magnitude, DC-DC converter efficiency, output voltage ripple, input power, desired output power, input current, output current and duty cycle of PWM controller.

Five components should be chosen when the boost converter is designed. These are power-switching devices, diodes, inductors, output capacitors, and input capacitors. [18].

- ***Power Switching Device:*** The main switching device must withstand the maximum current and voltage stresses and also operate at the desired frequency [18].
- ***Diode:*** The diode must be characterized by the capability of withstanding the required reversed off–state voltage stress as well as the maximum and average current. In addition, it must have low forward voltage drop, reduced reverse–recovery, and fast switching capability [19].
- ***Inductor:*** the design of the boost inductor depends on the maximum required ripple current which is determined at the minimum duty cycle and maximum input voltage. The value of the boost inductor is determined for a specific load as shown in (8), where Fs is the operating switching frequency.

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- ***Output Capacitor:*** The output capacitor must be designed carefully to perform two important functions. Firstly, it must limit the output voltage ripple as well as withstand the required ripple current stress. The second function must supply the required output current to the load when the diode is in an off state.
- ***Input Capacitor:*** The minimum value of the input capacitor is necessary to regulate the input voltage due to the current requirement of the power supply. This minimum value can be increased in case of noisy input [20].

The simulation is run for different insolation and constant temperatures to simulate the real solar irradiation through a sunny day. The variation of temperature through a day could be taken constant approximately; because the decreasing open circuit voltage of the PV array is associated with the increasing short circuit current of the PV array.

A. MPPT Solar Charge Controller Simulink Design

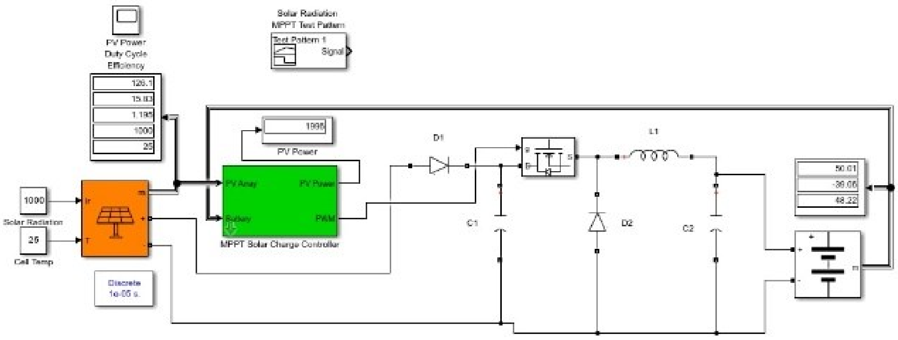

Figure 1: MPPT Solar Charge Controller Simulink layout

V. RESULT

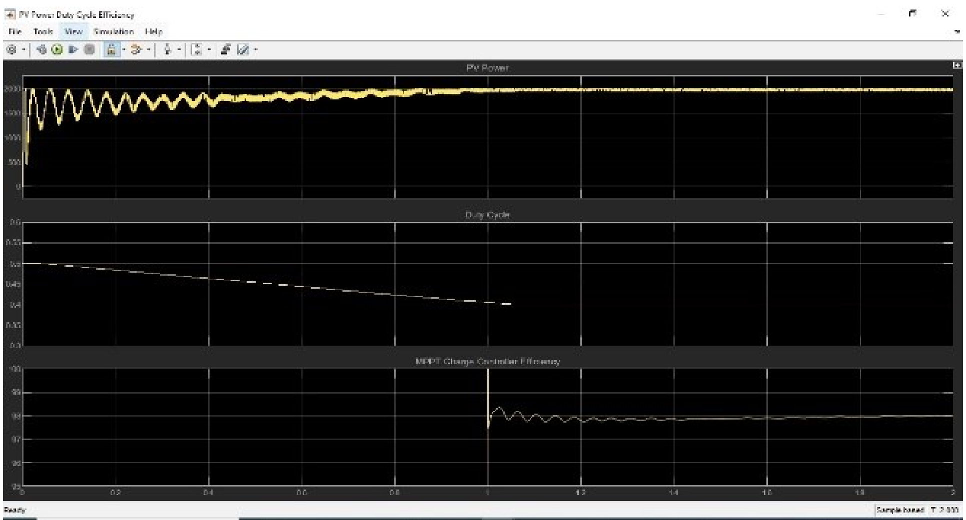

Figure 2: Graph Showing the Performance of the MPPT Solar Charge Controller

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After performing the simulation over the MPPT solar charge controller the output is comprised of three values:

- PV Power
- Duty cycle
- MPPT Charge controller efficiency

A. PV Power:

The PV (photovoltaic) power for an MPPT (Maximum Power Point Tracking) solar charge controller is the power generated by the solar panels connected to the controller. The MPPT controller's job is to optimize the power output of the solar panels by adjusting the voltage and current to ensure that the panels operate at their maximum power point (MPP). The PV power that can be handled by an MPPT solar charge controller depends on the controller's specifications, particularly its maximum input voltage and current ratings. These ratings determine the maximum power (in watts) that the controller can effectively manage from the connected solar panels.

B. MPPT Charge Controller Efficiency

The efficiency of an MPPT (Maximum Power Point Tracking) solar charge controller is a measure of how effectively it can convert the power from the solar panels into usable energy for charging batteries or powering loads. The efficiency of an MPPT charge controller is typically measured in terms of the ratio of output power to input power, expressed as a percentage. It is influenced by factors such as the quality of the components used, the design of the controller, and the operating conditions.

VI. CONCLUSION

In this project, a detailed review of MPPT is presented for solar charge controllers. It is understood that the major role of renewable energy like solar energy in today’s world is going to play a role in the global energy sector. Renewable energy sources are cost-effective, highly efficient and easy to install. With better use of charge controllers, the lighting systems’ efficiency will be increased. These charge controllers prevent reverse-current flow. When solar panels are not generating electricity, electricity flows backwards from the batteries through solar panels. Hence, when the controller detects no energy from the solar panels, it disconnects the solar panels and hence stops the reverse current flow. The comparison between the two types of controllers shows the superiority of MPPT as compared to PWM.

VII. FUTURE SCOPE

In future work, a simple and efficient MPPT solar charge controller will be designed for PV systems using MATLAB/SIMULINK. The design helps to extract maximum power from a PV cell using the P&O algorithm. The model is simulated connecting different parts such as the PV system, DC-DC converter and load. The I-V and P-V curves for one module and array at constant temperature, constant

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irradiance & specified temperature have been observed. The ideal and actual power is compared using the MPPT algorithm. The proposed method is found to be more efficient and robust as compared to the conventional method under variations of radiation and temperature. An advanced Maximum Power Point Tracking (MPPT) solar charge controller is a device used in solar power systems to optimize the efficiency of solar panels by constantly adjusting the operating point of the panels to ensure they are operating at their maximum power output.

Advanced MPPT controllers use sophisticated algorithms and circuitry to track the maximum power point of the solar panel under varying conditions such as changes in temperature and sunlight intensity. They can improve the efficiency of a solar power system by up to 30% compared to traditional PWM (Pulse Width Modulation) charge controllers. These controllers typically offer features like data logging, remote monitoring, and communication interfaces such as RS485 or Ethernet for integration into larger systems. They are widely used in off-grid and grid-tied solar power systems to maximize the energy harvest from solar panels.

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