



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 5, May 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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Design of an Intelligent MPPT Charge Controller Based on ANN using a Photovoltaic System

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ABSTRACT: This Paper presents detailed design, implementation and testing of an economical microcontroller based MPPT charge controller with a maximum charging rate of 20A to be used in a standalone PV systems which is able to monitor the power generated by the photovoltaic array and deliver the maximum amount into charging the battery under varying atmospheric conditions whilst simultaneously charging the battery in three stages for higher charging efficiency and healthy battery operation. The charge controller is also designed to display the system status by LCD and LEDs for user friendliness. The MPPT charge controller was designed using a DC/DC buck-boost converter whose switch was controlled by a Pulse-Width-Modulated (PWM) signal generated by the microcontroller to regulate its output. The microcontroller generates the PWM signal after its MPPT algorithm analyzes the sensor inputs connected to the solar panel and battery and decides the on the PWM signal that would make the solar panel operate at its maximum power point whilst also accounting for the battery's charging stage. Basically the solar panel is deemed the energy source, the DC-DC converter is used for maximum power transfer by optimal resistance matching of source to battery and the microcontroller has MPPT algorithm used to track maximum power operation of the solar panel; the MPPT algorithm varies the duty cycle appropriately and that alters the load seen by the solar panel hence making it output different voltage and current for more power to go into charging the battery.

KEYWORDS: Arduino UNO, Current Sensor, DHT 11, solar panel

I. INTRODUCTION

Renewable energy sources are fast becoming an alternative to traditional fossil fuels due to their advantages of being clean and inexhaustible mainly. Solar power is one of the renewable energy sources and although it has a high potential its generation efficiency (conversion of solar energy to electricity) is low with most commercial solar panels having efficiencies of less than 30%. With this already low power generation efficiency of solar panels it is only necessary that the maximum power is sourced from that generated by solar panels to ensure high efficiency in delivering power to the load to make solar power an effective alternative and justify its high installation costs too. Since the I-V characteristics of solar panels vary with atmospheric conditions such as irradiance, more power can be got out of solar panels by direct methods e.g. solar tracking to track the sun as it moves across the sky or by indirect methods e.g. Maximum power point tracking the latter being in the purview of this project. Using MPPT charge controllers reduces the number of PV modules that need to be installed to generate a certain power by maximizing the power generated from the critical number of PV modules needed to generate the power at high efficiency.

Problem statement: There are inherent power losses that occur when the solar is connected directly to a load/battery without matching their internal impedances for which in addition to the non-linear (I-V) operating characteristics of a PV module and variations in its output power with solar insolation and operating temperature; an MPPT charge controller is used in most solar power harvesting systems to ensure maximum rated power is drawn from the solar panel and delivered to the battery while charging it in a healthy mode to increase its lifespan and for efficiency purposes under varying atmospheric conditions. Many are available commercially for high current ratings and relatively expensive so we are building a simple cheap, adaptable, elementary and durable one from first electronic principles that does the job quite as well and has the lucrative advantage that it can be deployed in rural homes and developing areas of the world for enterprises and households cheaper than conventional MPPT charge controllers from the leading industrial manufacturers.

II. RELATED WORK

With increasing global population, energy demand has grown exponentially leading to depletion of natural resources we have heavily been relying on e.g. coal, oil and natural gas. This has not only depreciated the longevity of these resources but has also detrimentally affected our global climate. Clean, renewable energy sources are thus becoming more desirable throughout the world in an effort to reduce greenhouse emissions. The main renewable sources are biomass, geothermal, tidal, hydro, solar, and wind. Unfortunately, solar energy is not as efficient as traditional energy sources such as coal, but advances in the electronics field can be used to create more stable and efficient sources to compensate the problems associated with using solar panels.

PV power systems have the following advantages:

- i. Their installation is static (i.e. no moving parts)
 - ii. They are simple and quick compared to other renewable sources.
 - iii. They have longevity, (are durable typically more than 20 years)
 - iv. They have low operational and maintenance costs hence they provide a significant solution for powering remote areas.
 - v. They are not noisy.
 - vi. Suitable for Distributed Generations (DGs) which permits small-scale generators to be installed at the distribution level of the power system close to the end which come in handy when there is insufficient transmission capacity, constraints in building new transmission lines and untapped emerging electricity markets hence boosting the Grid from remote areas .
 - vii. Solar energy is abundant, virtually available everywhere in the world and is the most plenteous energy source. Earth receives 3.85 million Exajoules of energy per year at the surface, about 50% of total incident solar radiation or insolation.
 - viii. PV modules are pollution free-they have “zero-emission” factor However, PV power systems have some disadvantages:
 - i. Solar energy is not constant even during the daytime. Due to Earth’s atmosphere and its atmospheric conditions, it is approximated that only 50% of solar energy that is directed to the planet reaches its surface the other half is reflected back and absorbed by elements in the atmosphere such as dust and water vapor.
 - ii. Solar energy is not available at night.
 - iii. The current available technologies place on the efficiency at which this energy is harvested and utilized.
- Even though there are numerous solar panel and solar cell technologies available,

the highest efficiency at which these devices convert solar energy to electricity is lower than 30% and the costs per kilo-watt-hour (kWh) are not usually competitive enough to face off petroleum energy sources.

iv. Their installation cost is high and they still need dc/dc converters to charge batteries and inverters for load interface. Since Photovoltaic (PV)modules still have relatively low conversion efficiency With the cost of the solar cells decreasing, the shift to solar energy use is increasingly becoming viable. This is particular true in tropical and desert countries where there is abundant solar energy available throughout the year. Also as solar power increases in popularity, the need for this power to become more efficient is incumbent. Photovoltaic sources are used vastly in many operations such as battery charging, water pumping ,powering equipment in marine boats ,electric and recreational vehicles, home power supply, hybrid system incorporating solar and other renewable energy sources, swimming-pool heating systems, in space and powering satellites, military applications, solar power plants and some applications where nonlinear power source is needed. .

III. METHODOLOGY

As stated before, the aim of the project is to design and build an MPPT charge controller to deliver maximum power from the solar panel. The project consists of three main structures which are the input, controller and output. The first step in developing the Maximum Power Point Tracker is to decide the type of solar panel and battery ranges it would be connected to, based on the maximum charging current desired. The DC/DC converter topology for the MPPT will then be selected and designed based on the maximum solar panel voltage, the battery voltage and the switching frequency by the microcontroller using the least power consuming but efficient components. The microcontroller will then be chosen and should be low-power, have fast processing speed to run the algorithm in shortest time while also

multitasking communication with the various I/O devices in real-time and contain enough programming space for all project objectives. The sensors in the MPPT charge controller are the devices that are going to be in charge of monitoring and communicating the system status to the microcontroller will then be designed. The current and voltage sensors are going to be needed in the design to calculate power which is vital in achieving maximum power point tracking. These sensors on the battery side, in addition to the battery temperature sensor, will also be used to determine the battery charging status ensuring healthy battery operation. The sensors are to be designed to be as sensitive as possible while consuming minimal power. The design of the software will then be done using an MPPT & charge control algorithm to ensure that the solar panel is operating at the highest power point while charging the battery efficiently. The charge control part of the algorithm will implement a 3-stage charging process for the lead-acid battery based on the battery voltage and solar panel output voltage. It will have the bulk, absorption and float charging stages with the MPPT algorithm being implemented in the bulk charging state. The actual quantitative set-points of the operating modes will be based on characteristics of the battery and PV module that will be implemented finally. The software should be able to display the vital parameters quickly and easily through the LCD and LEDs incorporated to the system so that the user can interpret the status of the system..

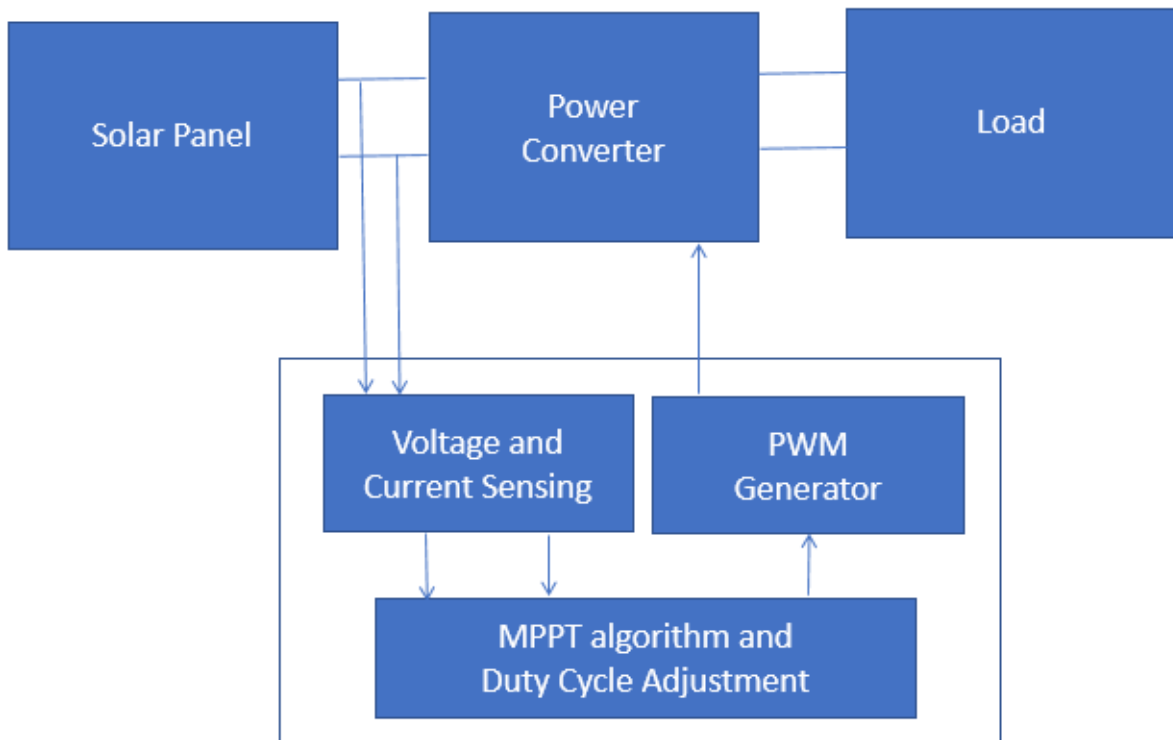


Fig 1 Block diagram Of proposed system

This project is based on improving efficiency of solar panels by the indirect method of Maximum Power Point Tracking (MPPT) as discussed under PV cell characteristics. The non-linear power curve of Figure 2-2 for a PV panel was seen to change primarily as dictated by the factors of solar insolation level and operating temperatures. This means the maximum power point shifts a lot from the rated point; this is why a capable MPPT algorithm must not be static and must be constantly tracking the power point. Maximum power point tracking has been shown to increase the efficiency of the system by approximately 30% over charge controllers that do not implement MPPT. In a nutshell, the MPPT charge controller algorithm should be able to monitor voltages from both the photovoltaic array and the battery in order to determine the various charging states of a battery whilst still maintaining maximum efficiency from the solar panel. Additional power harvested from the panel is then made available as increased battery charge current. There are several MPPT algorithms that have been designed in order to perform this task and the major and common ones are discussed below. These techniques differ in many aspects like complexity, convergence speed, hardware implementation, sensors required, cost, range of effectiveness and need for parameterization.

IV. EXPERIMENTAL RESULTS

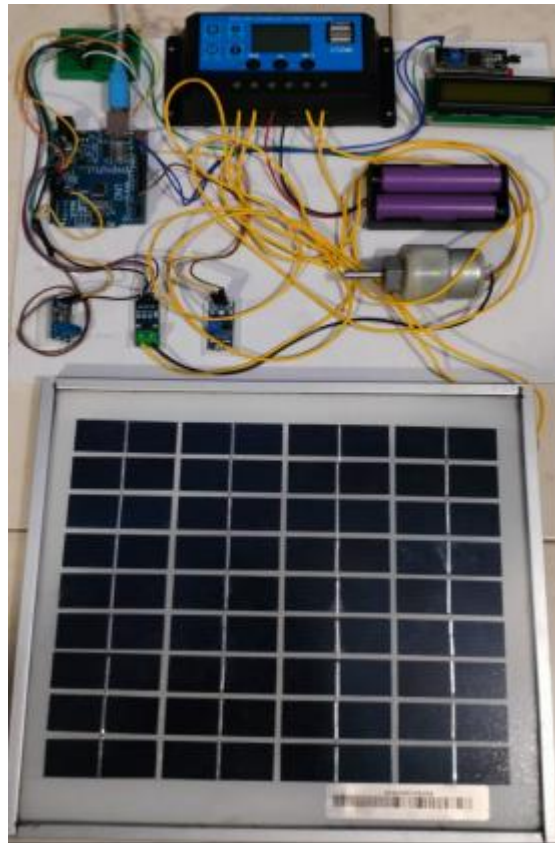


Fig 2 Final Model Snapshot

V. CONCLUSION

The project goal focused on creating a MPPT charge controller with a maximum charging current of 20A to help encourage the use of renewable energy in the form of solar power throughout the world by building a basic, cheap, adaptable, elementary and durable one. An introduction to solar panels and their electrical characteristics has been presented in the literature review. The P-V and I-V curves of the solar panel were of noteworthy importance and based on these characteristics, the significance of maximum power point tracking has been shown. This was followed by carefully designing the hardware and software that constitute an MPPT charge controller in order to address the challenges of the nonlinearity in a solar panel power curve.

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Impact Factor: 8.423



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