Microcontroller Based Photovoltaic MPPT Charge Controller

A.Harish[1], M.V.D.Prasad[2]

[1]ece, Kluniversity, India

[2]asst. Professor, Ece, Kluniversity, India

***Abstract*— In the present world there is a lot of increase in energy demand. It is time for us to come up with innovative solutions as we are going short of our available resources. Though the utilization of solar energy is very less compared to other available resources at present, it is going to double in future. This paper describes a technique for extracting maximum power from a photovoltaic panel to charge the battery. We make use of MPPT (Maximum Power Point Tracking) algorithms for achieving maximum power point. The power from the solar panels is fed to charge controllers, which is output to a battery where energy is stored. An inverter is present at the outlet of battery to access stored power. A DC-to-DC converter is present inside the charge controller to match the PV module voltage to battery voltage. A microcontroller is programmed to always output maximum power. It performs this work by taking input voltage and current from solar panel, output voltage and current from DC-to-DC converter, irradiance levels from light sensor and temperature from temperature sensor. An additional feature here is to transmit the data from the microcontroller to a remote location via RS485 interface so that this functionality aids in remotely monitoring and logging the data.**

***Keywords*— Photovoltaic panel, MPPT, DC-to-DC converter, Microcontroller, RS485.**

I. INTRODUCTION

In the present world of increasing demand for energy resources, it is crucial to come up with innovatory ideas to reduce and conserve usage of energy. The word Photovoltaic is a combination of the Greek word for Light and the name of the physicist Allesandro Volta. It identifies the direct conversion of sunlight into energy by means of solar cells [1]. Though the utilization of solar energy is little at present, it is going to double in upcoming days, even though it today this type of energy is not widely used as other available resources like thermal, wind, or hydroelectric. Solar power has many advantages over other non-renewable energy sources. It has even advantages over renewable energy sources like wind and water. However the drawback here is that it produces energy when there is sun shine. To overcome this problem, photovoltaic panels are usually coupled with a battery to store energy. This battery is connected to an inverter where the DC to AC conversion takes place. This AC power is utilized for our household applications or is send to the grid for distribution.

II. SOLAR CELL EQUIVALENT CIRCUIT

A photovoltaic array consists of several photovoltaic cells connected in series and parallel. Series connections are responsible for increasing the voltage of the module whereas parallel connections are responsible for increasing the current in the array. Typically a solar cell can be modelled by a current source and an inverted diode connected in parallel to it. The equivalent circuit of solar cell is shown in Fig.1. [2]

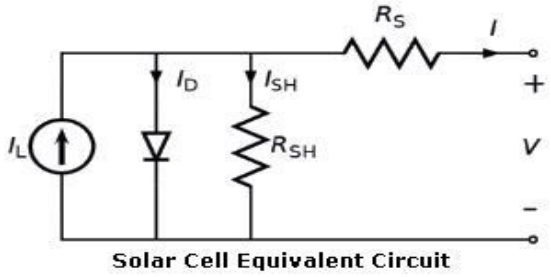

Fig.1 solar cell equivalent circuit

III. MAXIMUM POWER POINT TRACKING

To maximize a PV module output power, we need to continuously track maximum power point of the system. But the maximum power point depends on the irradiance levels, the panel's temperature, and the load connected. Using a charge controller without MPPT is like connecting the battery directly to the solar module. A traditional charge controller may charge a battery with the voltage that is dictated by battery. Typical VI characteristic of a solar panel is shown in Fig.2. [2], [8].

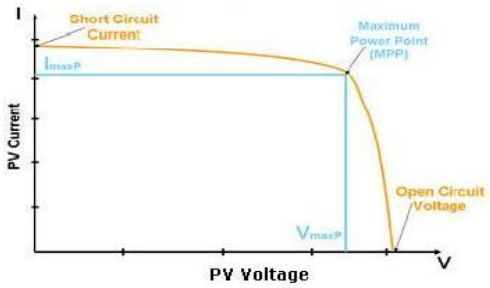

Fig.2 solar panel voltage/current characteristic

Maximum power point tracking (MPPT) algorithms provide the means to achieve the maximum power point of solar panels. These algorithms can be realized in many different forms of hardware and software.

The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). [3], [6] .MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery.

A. Main Features of MPPT Charge Controllers

MPPT solar charge controller is necessary for any solar power systems need to extract maximum power from PV module; it forces PV module to operate at voltage close to maximum power point to draw maximum power.

MPPT solar charge controller reduces complexity of the system while output of system is high efficiency.

MPPT solar charge controller can be applied to other renewable energy sources such as small water turbines, wind-power turbines, etc. [3], [6]

B. MPPT Algorithms

Various algorithms may perform MPPT. Important factors to consider when choosing a technique to perform MPPT are the ability of an algorithm to detect multiple maxima, costs, and convergence speed. [2]

The various algorithms available are perturb and observe method, Incremental conductance method, parasitic capacitance and constant voltage method. Out of all the available methods perturb and observe method is the most recognized because of its simplicity in design. A more complex but typically more accurate procedure is known as the incremental conductance method. The constant voltage method is also simplest one. The parasitic capacitance algorithm is similar to incremental conductance, except that the effect of the solar cells' parasitic junction capacitance CP, which models charge storage in the p–n junctions of the solar cells, is included. [4], [8].

IV. PERTURB AND OBSERVE METHOD

There are various algorithms which perform MPPT function. But perturb and observe method is widely used because of its ease of implementation. If the operating voltage of the PV array is perturbed in a given direction and if the power drawn from the PV array increases, this means that the operating point has moved toward the MPP and, therefore, the operating voltage must be further perturbed in the same direction. Otherwise, if the power drawn from the PV array decreases, the operating point has moved away from the MPP and, therefore, the direction of the operating voltage perturbation must be reversed. If increasing the voltage to a panel increases the power output of the panel, the system continues increasing the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreases to get back to maximum power point. Thus the power output oscillates around a maximum power point [8]. The flow chart for perturb and observe method is shown in Fig.3 [2]

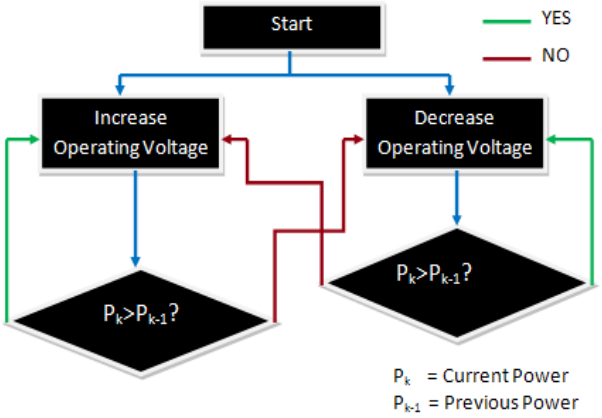

Fig.3 Perturb and Observe method

V. BLOCK DIAGRAM

The overall system block diagram consists of PV panel, charge controller, battery and inverter. The charge controller contains a DC-to-DC converter which matches the PV module voltage to battery voltage. Voltage and current sensors are present to sense the voltage and current and give them to microcontroller. The microcontroller is pre programmed to operate at maximum power point by using perturb and observe method. The data from the microcontroller can be transmitted to remote location through RS 485 interface. This helps in data logging and monitoring the data from a remote place. The overall block diagram is shown in Fig.4 [4]

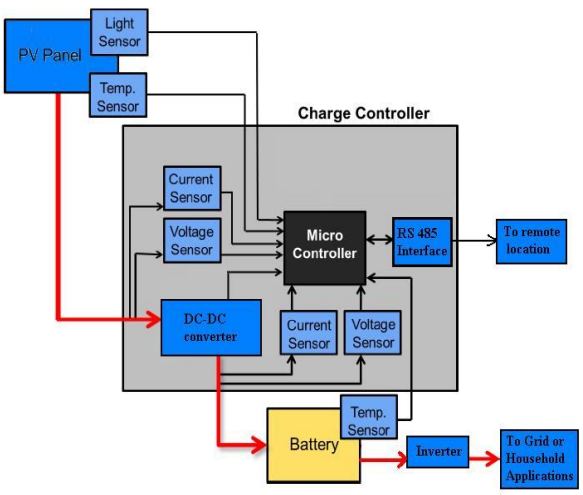

Fig.4 overall system block diagram

A. PV Panel

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. There are different types of solar panels available but the two most popular technologies used in today's solar energy market are silicon, which is consider a first-generation technology and thin film which is a second-generation technology.

B. Sensors

The implementation of sensors in the charge controller was essential to achieve desired functionality of the system. The sensors are the devices that are going to be in charge of monitoring and communicating everything that was happening in the system to the microcontroller. [4]

C. DC-DC Converter

The DC voltage from the panel varies depending on the light intensity, which varies based on the time of the day and solar panel temperature. A DC-to-DC regulator is needed to increase or decrease the input panel voltage to the required battery level.

Boost converter is power converter which DC input voltage is less than DC output voltage. That means PV input voltage is less than the battery voltage in system.

Buck converter is power converter which DC input voltage is greater than DC output voltage. That means PV input voltage is greater than the battery voltage in system.

D. Microcontroller

The microcontroller is responsible for all input and output processing of the entire photovoltaic system. The tasks included reading sensor values, controlling battery-charging circuitry, monitoring system performance and anomalies, along with transmitting data [7]. It is programmed such that the system always operates at the maximum power point. The pseudo code for perturb and observe method is given below. [2]

```
next_pwr = calcpwr(adc_voltage,adc_current);
   switch(voltage_direction)
    {
     case PV_RIGHT:
        if(next_pwr > prev_pwr)
            incDuty();
        else if(next_pwr <= prev_pwr)
            {
              decDuty();
              voltage_direction=PV_LEFT;
            }
        break;
     case PV_LEFT:
         if(next_pwr >= prev_pwr)
           decDuty();
         else if(next_pwr < prev_pwr)
           {
             incDuty();
             voltage_direction=PV_RIGHT;
           }
         Break;
    }
Prev_pwr = next_pwr;
```

It is just a pseudo code for perturb and observe methodology to achieve maximum power point. The full code can be developed based on the available pseudo code.

E. Battery

The batteries used in photovoltaic MPPT charge controller served as a way to store energy so that devices can be powered in the event that the sun is not shining and when more power is needed than can be provided by the solar arrays at a given time. The battery bank should provide a large energy capacity, run at 12V, and provide a large output current to handle high power loads.

F. Inverter

The inverter is the final stage of the system. It is through the inverter that the user has the opportunity to access the power stored in the batteries that was originally generated in the solar panel. The main functionality of the inverter is to take the DC voltage stored in the batteries and transform it into AC voltage that can be used by small household appliances or sent to grid for commercial purpose.

G. RS485 Interface

The RS485 interface is responsible for communicating the sensor and performance values to a remote computer over cables. These devices should be able to provide a long enough range for a typical homeowner to be able to receive data from a photovoltaic system located near the house.

The advantage of RS485 is that it supports long distance communication and multiple receivers may be connected to such a network in a linear, multi-drop configuration.

VI. WORKING

The main part of the system is the PV module. The solar panels in all the various makes and models are not very efficient at converting solar energy. So panel performance and means to increase it were very important. Every solar panel has an I-V curve or I-V characteristics associated with it. The area under the I-V curve is approximately the maximum power that that a panel would produce if it would operate at maximum voltage or open-circuit voltage and maximum current or short-circuit current.

MPPT is an indirect method of maximizing the efficiency at which the solar panels deliver electricity to an on-grid or off-grid scenario like charging a bank of batteries. The voltage, current, temperature and irradiance levels are sensed by the sensors. The DC-DC converter is responsible for optimizing the output voltage of the panel to match the required voltage level of battery. The DC-DC converter used is the Buck-Boost converter because if the battery requires a lesser voltage from the panel the Buck converter reduces the

voltage and if the battery requires more voltage the Boost converter boosts the voltage. Thus the utilization of maximum power from the panel is done effectively.

The current, voltage, temperature from the panel and the current and voltage from the DC-DC converter are sensed by the sensors and are given to microcontroller. The microcontroller is pre programmed to always output maximum power by using perturb and observe method. Thus the battery is always charged at maximum power. The battery is connected to the inverter where AC to DC conversion takes place. The AC power is utilized for household applications or is sent to grid for commercial purpose.

The additional facility provided here is RS485 interface to the microcontroller. This helps to monitor the data from a remote place and also data logging [5].

VII. CONCLUSION

The MPPT charge controllers can be used to utilize maximum power out of solar panels instead of investing in more number of solar panels. The addition of RS485 interface is the most significant change made to the earlier available system. This helps the user to monitor the data from a remote place. It also helps in data logging. The proposed idea can be further upgraded by incorporating wireless technology so that we can wirelessly transmit the data.

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