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Design of Maximum Power Point Tracking Method for Photovoltaic Arrays under Partial Shading Conditions

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Abstract- Photovoltaic (PV) systems have immense potential due to the abundance of available solar energy and the capability of these systems need to be implemented in a distributed manner. This clean, renewable and sustainable energy sources can provide a solution to concerns about the shortage of fossil fuels, global warming, greenhouse gas emissions and pollution in general. The main element of a PV system is a PV array which is a set of PV modules connected in series and parallel, one of the most important issues in the operation of PV system is extracting maximum power and as in the case PV array the voltage and current have a nonlinear relation, and at a single operating voltage, maximum power is generated. Under PSCs the PV characteristics of PV array will have multiple peak points only one of which is global maximum. Therefore, extracting maximum power from a PV system in all operation conditions is the main target of its control. This paper emphasis mainly on extracting MPPT during PSCs using Buck-Boost converter topology which is the simplest method to carry out MPPT regulation by comparing voltages and monitoring current values

Index Terms- Photovoltaic; MPPT; Partial Shading Conditions; Buck-Boost converter topology;.

1. INTRODUCTION

Rising fossil fuel and burning fuel such as coal, global warming and severe weather conditions have compelled many nations to look for alternative sources to reduce reliance on fossil based fuels. Solar energy is one of the most promising renewable sources that are currently being used worldwide to contribute for meeting rising demands of electric power. [1] Solar power is a conversion of sunlight into electricity, sunlight was collecting either directly by using photovoltaic or indirectly using concentrated of solar energy. [2]

Solar energy is one of the most significant renewable energy sources on the earth because of its eco-friendly behavior and never-ending amount in the nature [2, 8, 12], efficiency of this energy source is very low because of two reasons. Firstly, output power of a solar PV panel is much less as compared to its cost, and secondly, power is varying at every instant due to constantly changing solar irradiation and temperature [5, 6, 13]. But by tracking the maximum power point of the working solar PV modules at a certain instant, and by implementing various Maximum Power Point Tracking (MPPT) algorithms, we can increase the efficiency of the PV system by extracting the maximum available power form the module [5, 6, 13, 14]. Although, there are a number of MPPT algorithms, such as Perturb & Observe Method, Incremental Conductance method, Voltage Based Peak Power Tracking Method, Current Based Peak Power Tracking Method and many more.

Under uniform isolation there is only one maximum point in the P-V curve. Maximum power point trackers (MPPT) in PV systems are responsible for detecting the maximum power point (MPP) and reaching it by the PV modules [4]. Conventional MPPT techniques track well the MPP under zero-shading conditions [5], however when partial shade condition (PSC) occurs, these methods are trapped at local maximum. During PSC two or more MPP take place in P-V curves, which forces the researchers to find new techniques for MPPTs under PSC.

2. CHARACTERSITICS OF PV ARRAYS

2.1. *Single Diode Model of a PV Cell*

A solar cell model is represented by a current source, a diode, a series resistance and a shunt resistance as shown in figure 2.1(a). In most of the practical cases, the shunt resistance is quite high and often neglected in the analysis.

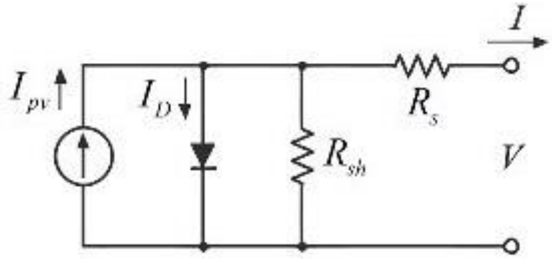

Fig 2.1(a) Equivalent Circuit of PV Cell

Since the cell model is conveniently given in terms of current source, diode and series resistance. The eq 2.1(a) is an *I-V* equation of a single model

$$I = I_L - [I_0\, e\frac{q^{(V+IRs)}}{nkT} - 1] \quad \text{.....eq 2.1(a)}$$

Where I_L is light generated current (representing the current source) I_o is reverse saturation current (representing the diode) R_s is the series resistance n is diode ideality factor k is the Boltzman constant 1.38 x 10^{-23} T is the temperature

The above equation can be written in terms of voltage of a single solar cell

$$V = -IR_S + Kln(I_L - I + I_0)/(I_0) \quad \text{....eq 2.1(b)}$$

Where K is a constant (= nkT/q).Let us consider that I_{mo} and V_{mo} are the current and voltage of a solar PV module, respectively. Therefore the relationship between I_{mo} and V_{mo} will be similar to that of solar cell's *I-V* relationship. Hence it can be represented as follows

$$V_{mo} = -I_{mo}R_{smo} + K_{mo}\ln(I_{Lmo} - I_{mo} + I_{omo})/(I_{omo})\text{.......} \quad \text{eq2.1(c)}$$

Where I_{Lmo}light-generated current of the module is, I_{omo} is the reverse saturation current of the module, R_{smo} is the series resistance of the module and K_{mo} is a constant for the module. If there are N_s cells connected in series in a module then its series resistance will be sum of each cell's series resistance (due to additive in nature) i.e R_{smo} =N_s x R_s. Similarly the module constant can be written as K_{mo} = N_s x K (due to temperature constant, the overall temperature effect on the module will be sum of its series connected individual cells). But since the same current flows in series connected cells the current terms in eq 2.1(a) will be same as the individual cells i.e. I_{mo} = I_0 and I_{Lmo} = I_L Thus the model I_{mo} - V_{mo} equation of N_s series connected cells will be written as follows

$$V_{mo} = -I_{mo}N_sR_s + N_sKln(I_L - I_{mo} + I_0)/I_0\text{........} \quad \text{eq 2.1(d)}$$

The above equation can be applied to series connected cells,modules and arrays. In similar way the current and voltage equation can be written for the parallel connected cells module or arrays. If there are N_p cells connected in parallel in a module then the relationship between the current and voltage of the module I_{mo} - V_{mo} can be given as follows

$$V_{mo} = -I_{mo}\frac{R_s}{N_p} + Kln\,(N_{sh}I_L - I_{mo} + N_pI_0)/(N_pI_0)\text{.....} \quad \text{eq 2.1(e)}$$

In the case of parallel connection the series resistance is divided by the number of cells connected in parallel (N_p) and the light-generated current and the reverse saturation current get multiplied by the N_p. In case of parallel connected cell the value of K remains unaffected. If we consider large PV applications where a number of modules connected together to make a PV array. The modules will be connected in series and parallel combination to achieve the desired current and voltage levels. Under this condition where N_s modules connected in series and N_p modules connected in parallel so the combined array current *Ia* and the array voltage *Va* of the arrangement can be given as follows

$$V_a = -I_a\frac{N_SR_S}{N_p} + N_sKln(N_{sh}I_L - I_a + N_pI_0)/N_pI_0\text{......} \quad \text{eq 2.1(f)}$$

2.2. *Partial Shaded Conditions*

It is not possible to have the uniform illumination [5] of PV panel all the time because of buildings or trees shades, atmosphere fluctuation, the existence of clouds and daily sun angle changes [7]. Power loss occurs from the shade, also current mismatch within a PV string and voltage mismatch between parallel strings. Typically, a crystalline silicon module will contain bypass diodes to prevent damage from reverse bias on partially shaded cells.

For simplicity, it is initially supposed that the array under PSC is subjected to two different irradiance levels. Modules that receive high irradiance level (HS) are called insolated modules and those which receive lower irradiance level (LS) are named shaded modules.

The insolated modules of a string drive the string current [2]. Therefore, portion of the string current that is greater than the generated current of shaded modules passes through parallel resistance of the shaded modules and generates negative voltage across them. Thus, the shaded modules consume power instead of generating it. In this condition, not only the overall efficiency drops, but also the shaded modules may be damaged due to hot spots. To prevent this condition, a bypass diode [3] is connected in parallel to each module, to let the extra current of the string pass through it. Consequently, the voltage across that module will be about and efficiency of the string will improve.

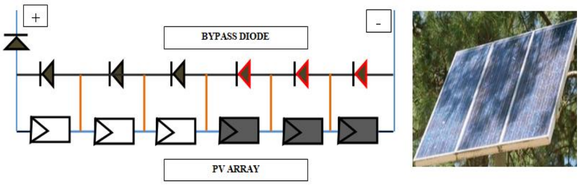

Fig 2.2(a) Partial shading condition on PV array

I-V characteristics of PV array [8] of a sample 3 x 2 array under different PSCs are shown with different MPPT [7] points availability. The characteristics show different irradiance with different IV curves. The irradiance here represent changes in environmental conditions which represents in generally partial shading condition on solar panel.

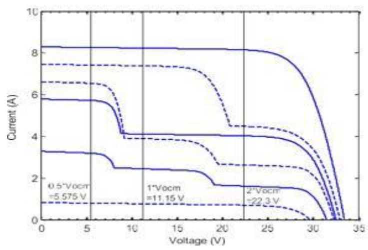

Fig 2.2(b): I-V characteristic in Partial shading condition on PV array

3. SYSTEM DESIGN

The system designed for detection partial shading condition and also to produce maximum peak power for the appliances. The block diagram here represent MPPT and PSc detection. The solar panel is so connected that it has one more connection named as PSc port for detection of shading conditions, the voltages are measured to know MPPT and also to shading conditions arrived due to environmental condition. The DC-DC converter is used with MOSFET and its driver connected with microcontroller, the microcontroller continuously monitors the voltages and current, and produces pulse width modulation signals for MOSFET. The LCD shows values of Voltage in Volts, Current in mAmps and Power in mWatt. Battery voltage is also monitored and the MPPT algorithm executed.

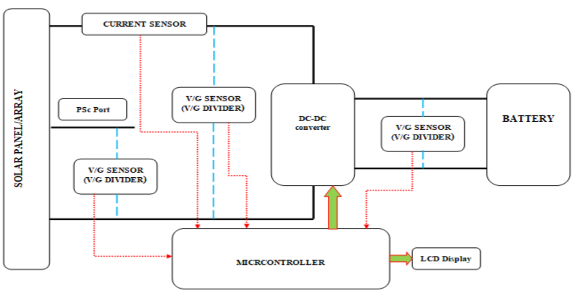

Fig 3 System Design

4. MODEL IMPLEMENTATION

4.1 *Voltage sensors*

The voltage dividers are used as voltage sensor at different points of circuitry. The voltage maximum will be 12v whereas the microcontroller reads only 5v at its analog input. The 12v is so adjusted using voltage divider to get 5v, and this 5v will be converted in to range of 0 to 1024 range.

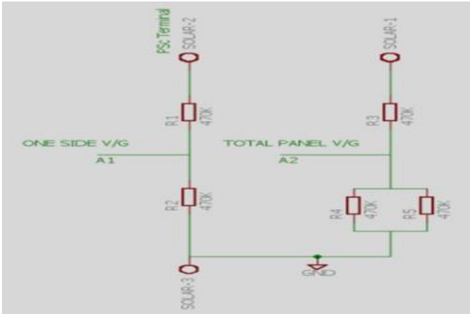

Fig 4.1 Voltage Sensors

4.2 *Irradiance measurement circuit*

Light Dependent Resistor (LDR) is used to track the irradiance value which can be correlated with power generated using solar panel. The LDR is connected in series with 470K resistor where as the maximum resistance or LDR is 5m Ohm and minimum it will be 200 Ohm. The supply here is used is again 5V for voltage divider. The analog input A0 of microcontroller connected to this voltage divider circuit.

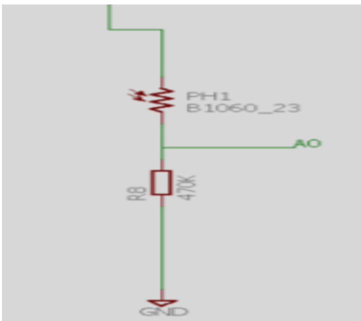

Fig 4.2 LDR circuit to verify irradiance

4.3 *DC-DC Converter*

DC-DC converter is used to Boost the voltage and also for Buck the voltage to charge the battery. The MOSFET is connected to microcontroller via MOSFET driver IR2104 is used. The MOSFET is IRFZ44N is used, the inductor of 330mH with 1N4148 diode. The voltage of battery is monitored by voltage divider before battery.

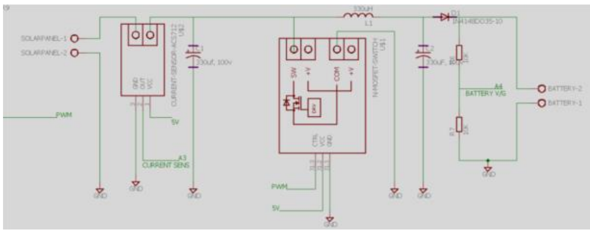

Fig 4.3 Current sensor and DC-DC Converter

4.4 LCD Display

The voltage in Volts, current in milli Amps, power in milli Watt and the partial shading condition will be displayed on Liquid Crystal Display (LCD). The LCD is connected in four wire mode for data and two pins will be used for RS (Reset) and E (Enable).

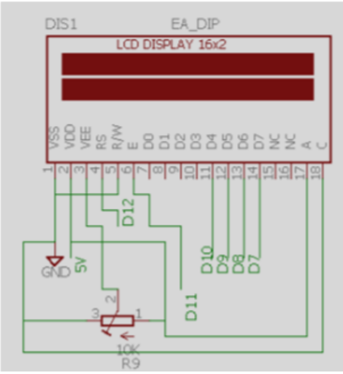

Fig 4.4 16X2 LCD Interface

4.5 *Microcontroller*

The microcontroller here we used is ATMEGA328 which will be used in Arduino Board a freeware hardware circuit for prototyping. The inbuilt programmer used to interface directly with system for programming and for also serial communication. The board will be used here is Arduino Uno.

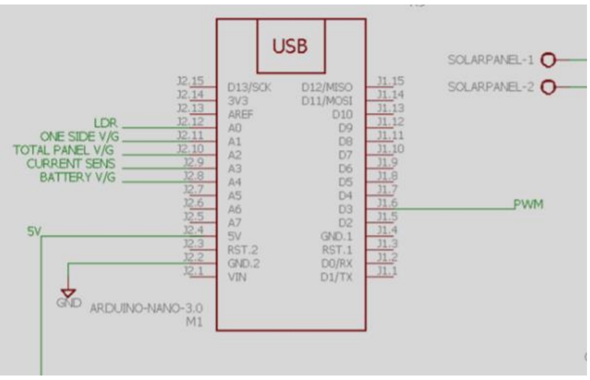

Fig 4.5 Microcontroller with MPPT and PSC detection algorithms

5 RESULTS AND OBSERVATIONS

The graph plotted here is for the conditions as, no irradiance, with full irradiance, the partial shading on one side and last one will be partial shading on other side. The graph represent irradiance value, single side voltage, total voltage, and current. The MPPT will also achieve in feed forward system which will pre detect errors or changes in power from solar panel and corrective action that is PWM value will be provided. According to the measurement the MPPT can also be maintained as well as the voltages measured is compared to detect partial shading condition and also the LDR gives irradiance so as to maintain MPPT by maintain the PWM of MOSFET

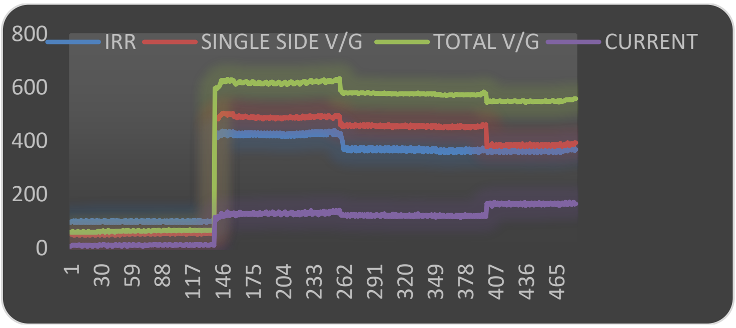

Fig 5 Results of MPPT and PSCs detection measurements

6 CONCLUSION

The MPPT and PSc can achieved using the partial port condition detection port and microcontroller and also with Buck- Boost converter circuit. The voltage will be continuously monitored at both end that is at solar panel and also at battery end to regulate voltage for charging. The partial shading condition will be detected by comparing voltages and monitoring current value. The method itself make easy and simplified circuit to improve the MPPT regulation where as to increase efficiency it will pre detect variation or environmental conditions.

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