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Energy Efficiency Enhancement of Solar PV Panel by Automatic Cleaning Technique

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Abstract: ***Globally, Renewable Energy Resources (RES) are playing a vital role for satisfying energy requirements. Since, RES is more finely comparable to fossil fuels, and it delivers a very low amount of Greenhouse gases. RES includes wind, solar, biomass, tidal and hydropower. Among them, the harnessing rate of energy from solar and wind farm has rapidly increased due to its unlimited amount of renewable energy production, which can be bung in an endless manner. Recent years, solar photovoltaic panels are popular in decentralized power generation whereas the efficiency of panels are affected due to environmental factors such as environmental conditions, atmospheric temperature, deposition of dust and sand particles on solar PV panels. The research proposed a new automatic solar PV cleaning mechanism, respectively. A prototype model has been developed. The cleaning has been performed per day, two times based on LDR signals. Depends on LDR's commands, DC motor move forward direction when it reaches the relay switch, then motor reveres back to original position. From the experimental validation, the developed model working satisfactory.***

Keywords **: *Solar PV, MPPT, Dust particle, Shading effect, DC drive.***

I. INTRODUCTION

Renewable energy resources are universal inexhaustible, which is available abundant in nature, also environmentally free. RES are namely solar, wind, biomass, hydro etc.. Among them, extraction rate of electrical energy from solar and wind power plant is more. On compared to wind power plant, the energy generating rate increased from solar PV technology. Since, wind speed is not unique in all areas and more in unpredictable nature that of others. Hence, this is not technically feasible. In earlier days, power industries are facing problem to transmit the power from the generation station to remotely located peoples due to inadequate infrastructures to transmit electrical energy. So the Decentralized power generation system has been developed [4], [5]. According to MNRE report, Indian land surface received 5,000 trillion kWh per year, approximately 4-7 kWh per sq. m per day.

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In India, solar PV technology growing very fast manner. Government of India set target to 20 GW by 2020 but it is achieved by two years ahead. As of 31 march 2019, total installed capacity of solar PV technology is 28.18 [6].

However, the efficiency of solar PV panel is low which is due to deposition of dust, sand particles on PV panels, cloud crossing. Adding to, the conversion efficiency of solar PV is low. Hence, new technology has been implemented to solar PV panels which has enhanced the energy yield potential of solar PV system. MPPT technology has been developed which is tracks maximum power from PV which is rectifying non linearity and uncertainty. The several MPPT technique has been developed such as perturb and observe (P&O), incremental conductance, hill climbing, respectively. Traditionally used MPPT techniques are impossible to track the maximum power at nonlinear ecological condition. Also, it has slow dynamic response and so the problematic response under study state oscillation. Hence, soft computing method such as neural network, fuzzy logic and genetic algorithm are used to develop MPPT. However, this method is not suitable under multiple maximum occurred on the power curve of PV systems [7], [8].

In India, solar PV panels are mounted above the ground level. The major installation, roof top hence daily cleaning is practically not feasible. Therefore, in this research work we propose an automatic solar PV system which is enhancing the solar yield potential. Furthermore, a detailed discussion has been performed about recent trends in MPPT Techniques. This paper organized in following ways section 1. Introduction, Section 2 Equivalent circuit of PV, Section 3 MPPT technique, Section 4 Block diagram representation Section 4 experimental setup, Section 5 Result and discussion Section 7 conclusion.

II. EQUIVALENT CIRCUIT OF SOLAR PV

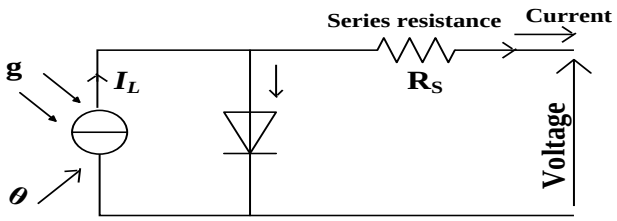

Fig. 1. Equivalent circuit of Solar PV

The solar cell is made from semiconductor materials when exposes this cell to the atmosphere, it observer the photons from sun radiations and produces the electronics to the external circuit. The solar cell is connected in two ways that is series and parallel, respectively. Suppose, solar cells are connected in series mode this type produced more voltage that of others. Whereas, solar PV cell connected in parallel this connection increases current in the array. The equivalent circuit of solar photo voltaic cell is shown in figure 1.

$$I_{out} = I_{SC} - ID \tag{1}$$

$$I_D = Io * (e^q k \frac{(V + IR_s)}{nKT} - 1) \tag{2}$$

$$I_{out} = I_L * (e^q k \frac{(V + IR_s)}{nKT} - 1) - \frac{(V + IR_s)}{R_p} \tag{3}$$

It has current source, series and parallel resistance, diode as shown in figure. Both the resistance is representing the loss. The series resistance corresponding to the loss of metal grid, contacts and current collecting bus. The value of series resistance is low that's few ohms only. Although, shunt resistance denotes loss which small leakage current flow through the parallel port. The value of this resistance much higher that of others. Also, diode D represents the cross current which accompanying with p-n junction, semiconductor devices. The relation between the output current and PV module is equation (1) to (3).

Let IL is the current of photovoltaic array
I_0 is the PV array reverse saturated currents
q is the electron charge
K is the Boltzmann constant (1.38*10−23 J/K)
T is the the temperature of the p-n junction
n is the the p-n junction curve constant.

Each solar PV cell capable of produced 1-1.5 W depends on power ratting we can connect number of PV cells connected together in parallel or series connections, respectively.

III. MPPT TECHNIQUE

To extract the maximum power is a critical task in photovoltaic systems. Because of photovoltaic system generate electrical energy depends on environmental conditions such as temperature or irradiation. Globally, atmospheric temperature not uniform thereby output of solar PV also no uniform which causes voltage stability in power systems. Several research involved or developed a new technique which are used to track the maximum power on PV system. Such technique is helping to PV system continues operating with maximum power, respectively. Also, the available maximum power has been varied not only environmental condition also shading effect, respectively. For example, cloud crossing over the solar panel, which changes available solar irradiations. This circumstances maximum power tracking comes under the time varying problem. Therefore, Maximum Power Point Tracking Technique has been developed (MPPT) which tracks the optimal power point under nonlinear weather or shading condition [9],[10]. Following MPPT technique are developed by researchers (1) Perturb and Observe (2) Incremental Conductance (3) Maximum Power Point Estimating Technique (4) Artificial Neural Network (5) Fuzzy Logic Technique.

A. Perturb and Observe

In this method voltage, current and duty ratio acts as a control variable to track the maximum power. In P&O technique used perturbation in voltage whereas current also used in very rare case since it has slow transient response under a change in irradiations also it affected by noise in the signals. Due to easy to implementation, simple in operation and low cost P&O / HC technique has been popularly used. Nonetheless, these methods offer very poor performance under frequent changes in irradiations, depends on step size these methods have slow convergence or huge fluctuation. Added to, it causes oscillation under steady state condition due to step size. This method voltage sensor is used to measure the PV voltage. Once P&O to reach the maximum power, it's not stopping the tracking and continue perturbation in both directions, therefore we set an error limit else we set an error function [11].

B. Incremental Conductance (IC)

The basic principle IC is based on P&O but it considers how current and voltage changed. The implementation IC method is entirely differing that of P&O. It uses a couple of voltage and current sensors, for measuring PV open circuit voltage and short circuit current, respectively.

$$\frac{dp}{dv} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \approx I + \frac{V\Delta I}{\Delta V} \tag{4}$$

The above equation 4 shown the relation between derivatives of power with respect to voltage with the growth and prompt voltage and current constituents. Yet, the IC method affected by the exchange between steady state, swaying, tracking speed also incapability to discriminate among global and local maxima. Resend development proved that, measurement of noise also possible because of control decision based on two distinct variables such as voltage and current, respectively [11].

C. Maximum Power Point Estimating Technique

$$V_{mpp} \approx k_1 Voc \tag{5}$$

$$I_{mpp} \approx k_2 I_{sc} \tag{6}$$

The proportionally constant K1= 0.78 and K2=0.92. Moreover, MPPET uses six measurements for approximating I-V characteristics under uniform condition, this is allowing to predicting the MPP. MPPET depends on the characteristics of I-V and P-V of solar PV cell. These sampling data are obtained by voltage and current measurement by sensors.

By using simple linear equation built a relation between PV open circuit voltage or short circuit current to the MPP voltage and current, respectively. Equation 5 and 6 shows the relation between open circuit voltage and maximum voltage, maximum current and short-circuit current [12].

D. Artificial Neural Network

At present, several researchers to develop an MPPT by Artificial Neural Networks (ANN). The ANN has three layers such as the input layer, hidden layer and output layer. The PV output is depending on the atmospheric temperature and available irradiations. So, temperature and irradiation act an input variable of ANN and voltage is out variables. Albeit, L.M et al proposed an ANN based MPPT technique which has PV array, boost converter and controller, PV voltage and current measurement. In this architecture has two cascaded ANN used for approximating reference PV array voltage at which the maxim power is possible, by detecting array voltage and current. The first ANN has two inputs such as current and voltage. Also, it has ten neurons in the hidden layer and so the activation function is transit. Yet, the output function is two porcelain neurons, respectively. The same activation functions are used in second ANN. This ANN trained with current and voltage input data for predicting temperature and irradiation. These two quantities are input for second ANN. It is used to predict the maximum output voltage. This voltage is the reference voltage for the boost converter controller. The difference between the reference voltage and actual output voltage is produced an error signal which fed to PI controller then this signal is feed to the PWM for tuning according the boost converter has been performed. Levenberg Marquardt (LM) algorithm has been used in ANN. The proposed model enhances the performance of PV panel under changing in environmental conditions [13],[14].

E. Fuzzy Logic Technique

On compared to all other MPPT, FLT need not require any precise mathematical model and it works with inaccurate data's and need not required any additional structure as well it's easy adopt with the existing PV system. Also, it handles nonlinearity very effective manner, high tracking speed, respectively. The main component of fuzzy system is fuzzification, Rule base, inference and defuzzification. The function of falsification is converting input data into linguistic variable, this is the data sets. These data sets are fed to the inference engine for getting output fuzzy set, it is produced based on the fuzzy rule. Then, according to the output of fuzzy sets, numerical variable can be generated. The Mamdani model used for inference where max-min for fuzzy While for defuzzification we can use center of gravity. The output variable is variation of duty cycle. Fuzzy based MPPT are adopted to following Negative Big, Negative small, zero and positive big and positive small because of the curve between changes in power and voltage is extremely unequal at the MPP. Over all fuzzy MPPT has 25 fuzzy rules due to that which is increased complexity for FLC design and implementation. Henceforth, membership, function and fuzzy rules are optimized by artificial intelligence, particle swarm optimization. Usually, MPPT technique has been developed to change in power and change in voltage, but a new parameter has been introduced that is β parameter such that articulated by cell number, temperature, and the diode construction. These parameters minimums and maximum values are depended on the environmental parameters that is temperature and irradiations. The range of β is within the certain range, which is indicating operating point is very close to MPP range. So, this type of fuzzy logic controller has three inputs and out output controller [15],[16],[17],[18].

IV. BLOCK DIAGRAM

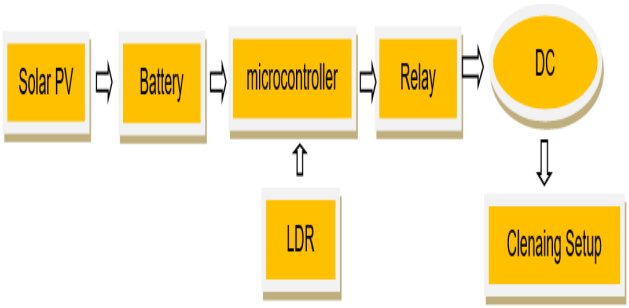

Fig 2. Block Diagram Representation

The block diagram representation of the solar PV cleaning setup as shown in figure 2. It has a solar PV for generating electricity, battery used to store the generated energy as well as transfer, micro controller to control the entire cleaning systems, relay used to change the polarity of supply and DC motor which in drive the cleaning system

V. EXPERIMENTAL SETUP

Fig. 3. Prototype model

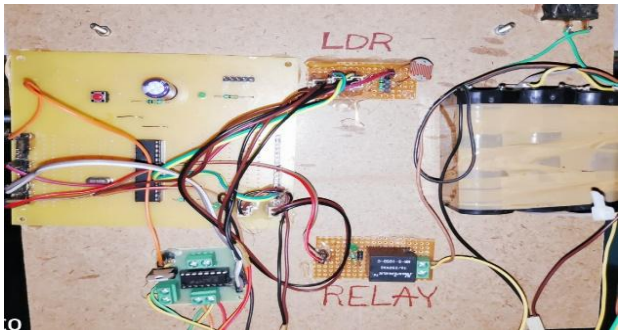

Fig. 4. Control Circuit

Commercially there are three types of solar PV panel has been used such as poly crystalline, Mon crystalline and thin film. The proposed system has a 40Wp polycrystalline solar panel. Since, polycrystalline panel is best choice for all ecological condition that of mono and thin film solar PV panel [19]. The technical specification of solar PV panel is shown in table 1 and DC motor specification as shown in table 2.

Table 1. Specification of Solar PV Panels

S.no	Type of Module	Rating
1.	Maximum Power	40W
2.	Tolerance	± 3%
3.	Open Circuit Voltage	22.2V
4.	Short Circuit Current	2.37A
5.	Maximum Power Voltage	18.2V
6.	Maximum Power Current	2.2A
7.	Module Efficiency	12.84%
8.	Solar Cell Efficiency	17.3%
9.	Series Fuse Rating	15A
10.	Terminal Box	IP65
11.	Maximum system voltage	1000V DC
12.	Operating Temperature	-40°C - 85°C
13.	Dimensions	465mm x 670mm x 25mm
14.	Weight	4kg

Table 2. DC Motor Technical Specification

Parameter	Range
Voltage	12 V
Speed	30 rpm
Current	0.5- 1 A
Power	6W

The cleaning step-up has been driven by a brushless DC motor. On comparing to brush types DC motor, cost wise brushless DC motor is low as well as technically best choice due to absence of brushes therefore motor size is less that of others [20]. It is mounted on two sides of PV panel as shown in figure 3. Furthermore, two sides of the panel have a track of linear movement of cleaning systems. Since DC motor has been mechanically coupled with gear system. This gear move forward as well as backward direction depends on the polarity of DC motor. The polarity of supply has been controlled by limit switch and relay. The combination of microcontroller, LDR and relay switch has been acting as a control circuit as shown in figure 4. The limit switch is mounded on the panel at starting and ending end. It is working based on the electromechanical principles, which has actuators and it physically coupled with contacts. When a thing contact with the actuators, the limit switch gets enabled results break and makes an electrical connection. Correspondingly, a relay circuit has been used in the proposed systems. It works or changes the status of electrical circuit from one state to another state. An LDR can be used in the system to senses the sun radiation. It is a high resistance, semiconductor. The principle of LDR is when the light is falling on the surface of the LDR subsequently material's conductivity has been reducing and so electron in the valence band get excited to the conduction band.

VI. RESULT AND DISCUSSION

When sunlight falls on the surface of LDR, it gets energized. Henceforth, it feed the signal to the microcontroller. This micro controller received one more input from solar panels, this is the source. When sunlight falls on the solar PV panel, it gets generated electrical energy. Then this energy can transfer to micro controller through battery setup. When sun radiation is adequate the micro controller closes the limit switch. Then, DC motor gets input supply, therefore DC motor run in forward direction. When it reached to second limit switch, which is placed at the other end of the panel. Which has closed relay switch so the supply voltage gets reversed, according the DC motor direction reversed. Results, the cleaning setup move in reverse direction.

VII. CONCLUSION

From the critical study, we found that MPPT technique is used to keep solar PV at maximum level. Due to technology development soft computing technique such as fuzzy logic, ANN and genetic algorithm also used to enhance the yield potential of solar PV. Moreover, fuzzy based MPPT techniques are easy to implementation and robust to others. Furthermore, the prototype solar cleaning mechanism has been developed. From the experimental verification, we found that, the cleaning mechanism working properly as well as increases efficiency of the panel. This developed model working based on the sun radiations which is sensed by LDR. From LDR signal is transferred to microcontroller, this is triggered the motor then it starts and move forward direction when it reach a relay circuit which is reverse the motor polarity subsequently the motor will move in a negative direction. Finally, motor reaches an original position. This project is very helping in domestic application since solar PV panels are mounted in roof top.

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