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Design of Standalone Solar PV System Using MPPT Controller and Self-Cleaning Dual Axis Tracker

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***Abstract*—Electrical energy has become the most vital resource in our modern world. However, its access to all parts of the world especially rural areas has not been accomplished. At the same time, rapid exhaustion of fossil fuels, GHG emissions have posed a threat to energy generation. Thus, there is great need to not only find alternate means of energy generation, but also to make it available to all parts of the world. Solar energy is a potential energy source capable of completely resolving our energy demands, but still remains the most underutilized energy resource. In this paper, a standalone solar PV system is developed for a village school as a part of project and awareness initiative for solar energy. The system is designed and simulated using PVsyst 6.7 software. To enhance the system efficiency, maximum power must be extracted. To obtain this, Maximum power point (MPP) tracker is designed, and simulated using MATLAB/SIMULINK. For more enhancement in extraction of solar power, a prototype model for dual axis tracker with self-cleaning feature is designed and simulated on PROTEUS 8 software.**

***Keywords— Standalone Solar PV System, PVsyst 6.7, Maximum Power Point Tracker(MPPT), Proteus 8, Dual Axis Tracker*.**

I. INTRODUCTION

The world is facing energy crisis due to depleting stock of conventional fuel sources along with problems like global warming. At the same time there are areas where even today electricity is not accessible. City areas and industries continue to exploit most of the share of electricity, rendering almost no electricity to remote places. Thus, there is greater need to not only find sustainable means of generating electricity but also to increase the access of electricity to all parts of the world [1]. In India, sunlight is available throughout the year making it an ideal resource to exploit for our energy demands [1]. In this paper, as a part of project and awareness initiative for use of renewable resources, a standalone Solar PV system is designed for a school in rural area in Maharashtra, India. Even though being close to a big city like Mumbai which almost faces no power-cuts, this rural area is still facing problems due to regular power cuts and poor electricity supply. The paper is divided into three sections. First section discusses the design calculations and optimization of stand-alone Solar PV system using software PVsyst 6.7. In the second section, to maximize the system efficiency, a MPPT converter is designed and simulated using MATLAB/SIMULINK. Third section discusses design and simulation of a prototype Dual Axis mechanical tracker with a self-cleaning feature.

II. DESIGN AND SIZING OF SYSTEM

A. Location and Geographical Condition

The system is designed for a rural school in Raigad district, Maharashtra, India. The location co-ordinates are 18.72261 ^{0}N, 72.92115 ^{0}E. The location receives sunlight for 2650 hours in a year with an average solar irradiation of 5.7 kWh/m^2[2].

B. Load Calculation and distribution

The Load calculation and distribution is optimized using PVsyst 6.7 software.

TABLE 1. LOAD SPECIFICATION

Loads	Number	Power	Usage	Energy
Lamps(LED)	4	10W/lamp	8h/day	320Wh/day
PC	1	240W/app	4h/day	960Wh/day
Fan	2	60W/app	8h/day	960Wh/day
Street Bulb	1	40W/lamp	24h/day	960Wh/day
Stand-by Consumers			24h/day	24Wh/day
Total Daily Energy				3.224kWh/day

TABLE 1. represents the load specification, type of appliances and daily energy consumption by the loads in a tabular form.

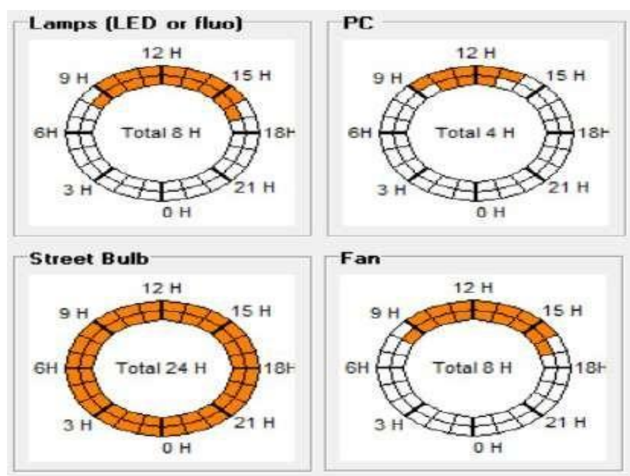

Fig. 1. Hourly Distribution of the load

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Fig. 1 represents the hourly load distribution. There is a base load – a bulb operating for 24 hours. Other fan/bulb loads operate for 8hrs between (9am-5pm) and PC operates for 4hrs (9am-2pm).

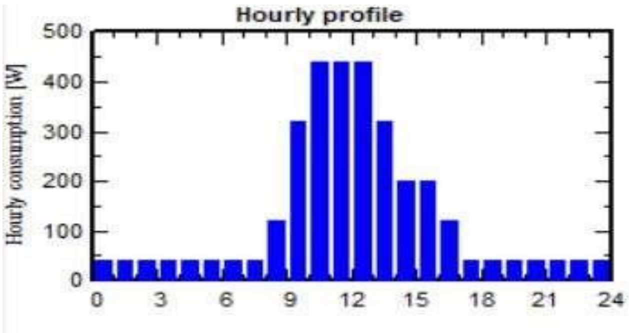


Fig. 2. Daily Hourly load profile

Fig. 2 represents the daily load profile which is calculated based on total energy consumed by the loads on hourly basis.

C. Sizing of the System

Based upon the load specification and load consumption the system is required to generate 3.224 kWh/day. The PV system is integrated with battery backup and days of autonomy is decided to be 1. The PV system plant capacity is calculated to be 0.8 kWp. For the system, 4 Monocrystalline solar panels each of 200Wp nominal rating are used. For the battery backup, 3 Lead- Acid batteries of 12 V and 160Ah rating are used. Based on the system designed, its performance is optimized and simulated using PVsyst.

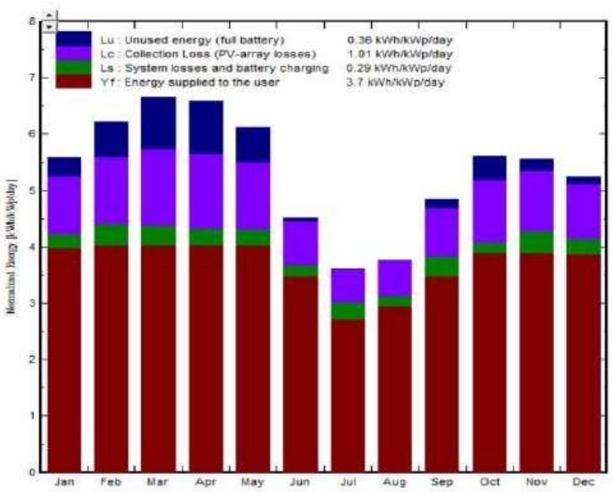


Fig. 3. Normalized Production of the System

Fig. 3 represents the normalized production of the system. It can be seen from the Fig. 4 that the system is able to suffice the energy requirement of 3.224 kWh/day after considering the collection losses from the panel and system losses. Thus, the sizing of the system is appropriate and can be implemented.

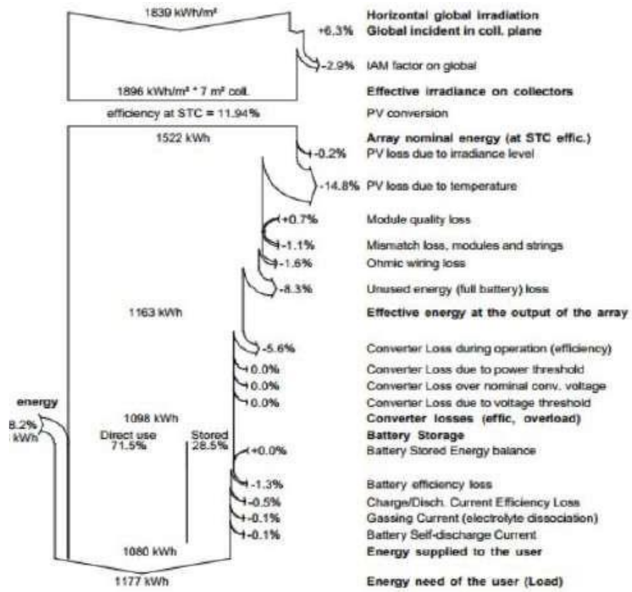


Fig. 4. Loss Diagram

Fig. 4 represents the Loss diagram of the system. The diagram provides the losses at each stage of the power from the incident solar irradiation to energy supplied to the user [1,3]. The major loss contributed is due to temperature factor in solar PV panel. The system is found to be operating at performance ratio of 69.1%.

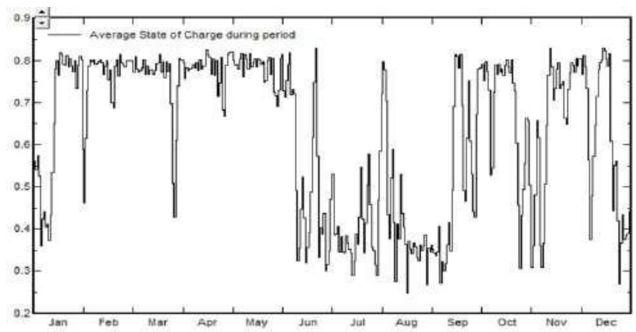


Fig. 5 State of Charge Distribution

Fig. 5 represents State of charge of the battery. From Fig. 5 it can be observed that SoC during June to September is low indicating that a battery energy is used. It can be verified from the fact that solar radiation during monsoon is less. Therefore, battery has to provide required balance energy to the system.

III. Design of MPPT Controller

To get an AC output voltage of 230V at output of inverter the DC link voltage at the input side of the inverter can be calculated as,

DC link Voltage $= 1.2 \times \sqrt{2} \times 230 = 391\ V$ (1)

Here, we consider a factor of 1.2 as a margin value to take into account the losses at the inverter side. For the calculation we can consider the value of DC link voltage between (391-400V).

A. Design of Boost Converter

The input voltage at PV side is 84 V and we require DC link voltage at the output of DC-DC converter to be 400V. Thus, a boost converter is required [4,5].

TABLE II. DESIGN PARAMETERS

Parameters	Value
Input Voltage Vi	84 V
Output Voltage Vo	400 V
Output Power Po	440 W
Output Current Io	1.1 A
Total Load Resistance Ro	363.63 Ω
Duty Cycle D	0.7875
Inductor Ripple Current ΔIl	1.571 A
Inductor L	0.168 H
Output Ripple Voltage ΔVo	0.3571 V
Capacitor Value Co	9.703 mF

TABLE II gives the design values for the components in boost converter.

B. Stability Analysis of the Boost Converter

The stability of the converter can be checked by checking the closed loop stability of the system. The switched- converter transfer function of the converter can be effectively calculated using the Small- Signal Analysis (SSA).
The transfer function of the system is calculated by using the expressed as:

$$\frac{Vo(s)}{d(s)} = \frac{Vo}{1-D}\left[\frac{-sL+R(1-D)^2}{s^2RLC+sL+R(1-D)^2}\right] \quad (2)$$

$$\frac{Vo(s)}{d(s)} = \frac{-533.54s+52148.09}{s^2+0.2834s+27.70} \quad (3)$$

By finding the step response it can be found that the system has a very large overshoot of 91.90.

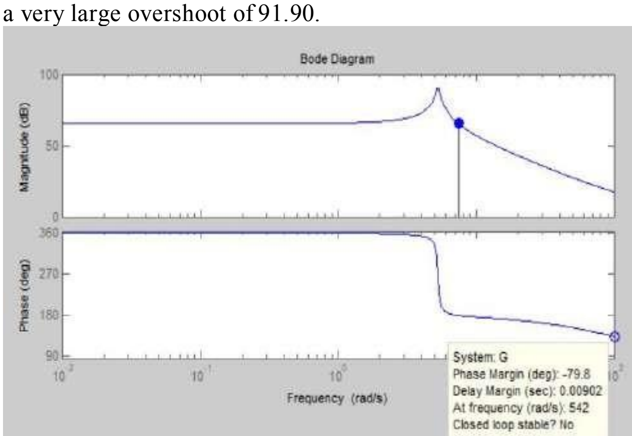


Fig. 6. Bode Plot of the system

From the transfer function we can evaluate that due to the presence of zero on RHP and two imaginary poles, the system is unstable in closed loop which can be verified by plotting the Bode plot. To obtain a desired response a PI controller is designed
The Transfer function of PI controller is given by:
Gp = (sKp +Ki)/s
The Kp and Ki values can be found out using the Ziegler-Nichols tuning method.
After designing a suitable controller, the overshoot decreases to an acceptable limit and system becomes stable in close loop.

C. Maximum Power Point tracking

For the system to operate at maximum possible efficiency, it is necessary that maximum amount of power is extracted from solar irradiation [4,5]. To extract maximum power, many algorithms are developed. For the design purpose, we adopt (P&O) Perturb& Observe algorithm to extract maximum power as it is easy to follow and design [5,6].

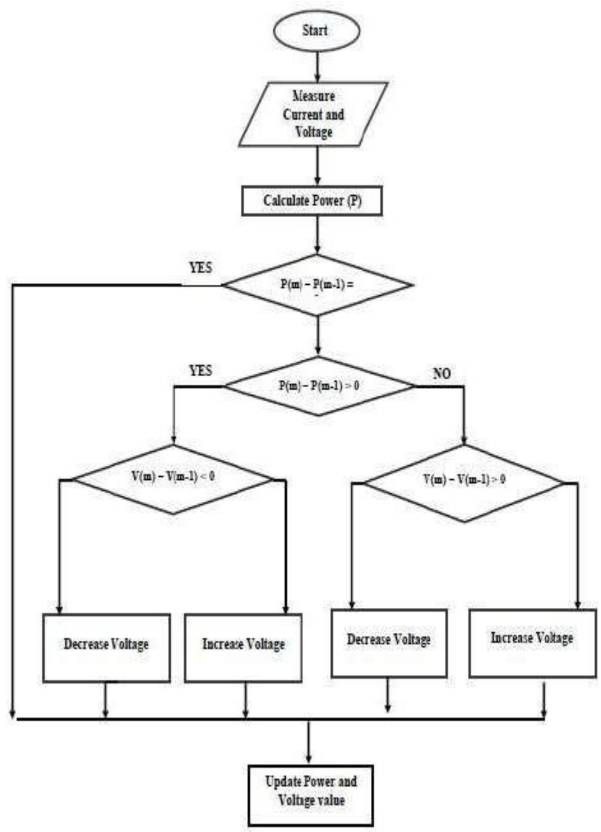


Fig. 7. P&O algorithm

Fig. 7 represents the algorithm for Perturb and Observe algorithm. Based on the algorithm a P&O based MPPT controller is designed and simulated using MATLAB/Simulink. [5]. Fig. 8 represents the Simulink model for MPPT based DC-DC converter.

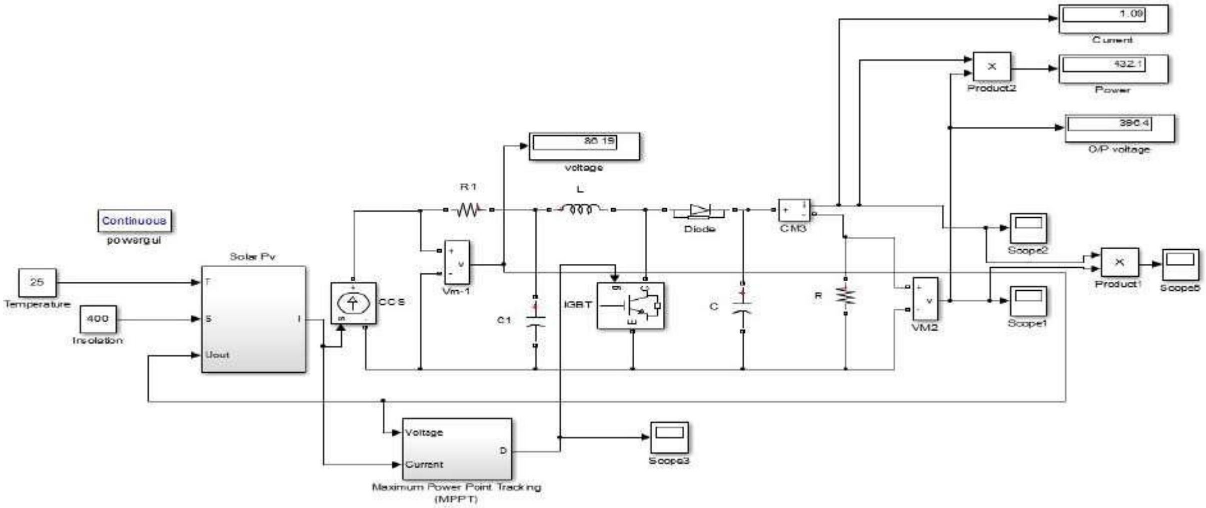


Fig. 8. Simulink model for MPPT DC-DC converter

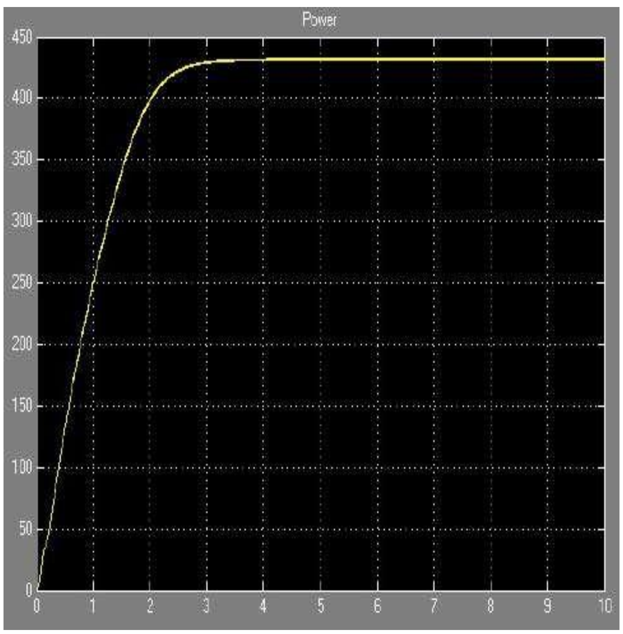


Fig. 9. Output power

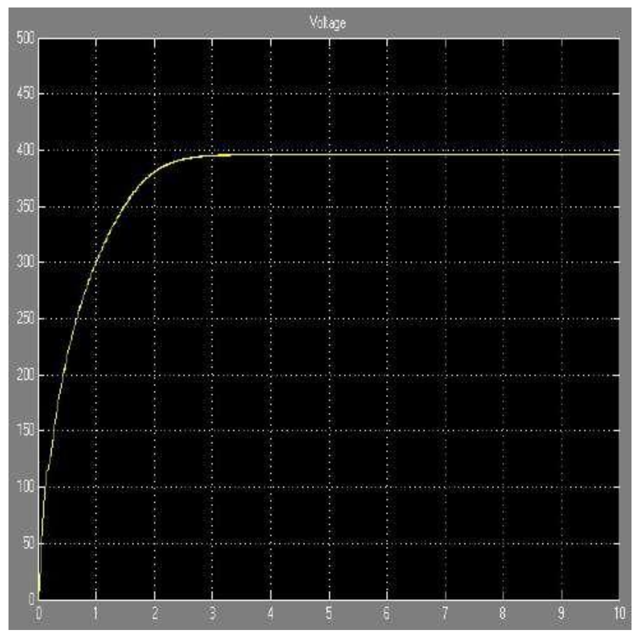


Fig. 10. Output voltage

Fig. 9 represents the output response of MPPT based DC-DC converter. It is observed that a constant output power response of 440 W is obtained according to design requirement [6,7].

From Fig. 10 we see that a constant DC voltage of 396 V is obtained at the output of DC-DC converter which according to design requirement [7].

IV. Design of Dual Axis Converter with Self Cleaning Feature

There is loss in power extraction from solar irradiance for a stationary Solar PV system as sun moves throughout the day. The loss in power extraction is maximum at sunrise and sunset.

Thus, to enhance the power extraction, a mechanical tracker is designed which will follow the suns path [6]. A typical dual axis tracker is capable of enhancing the efficiency of the system by 25-35% when compared to stationary solar PV system. The principle of operation of a dual axis tracker is sensing the light intensity [7,8]. For the project 4 LDRs are used which will sense the difference in light intensity and microprocessor will give the signal to the motor [8,9]. Fig. 11 represents the algorithm for the operation of Dual axis tracker [10].

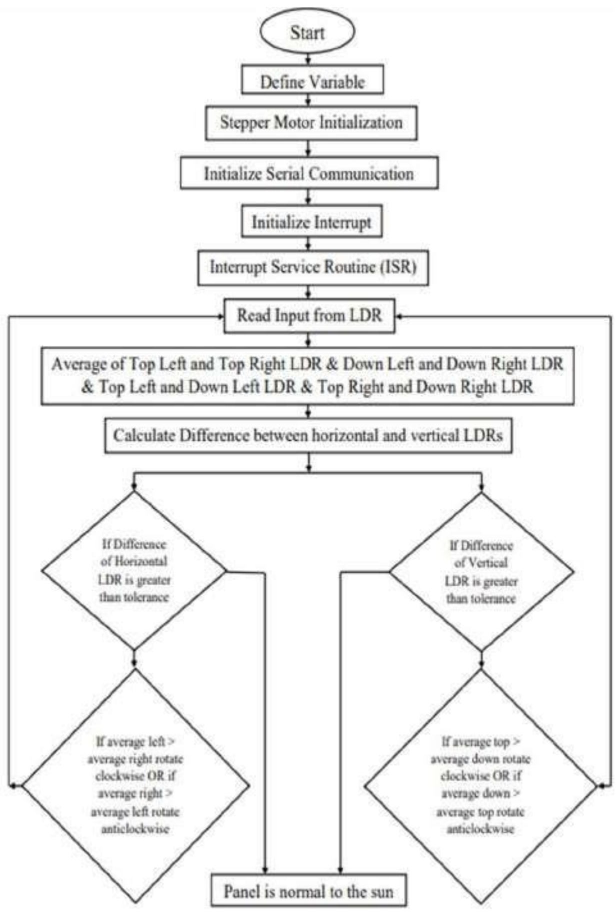
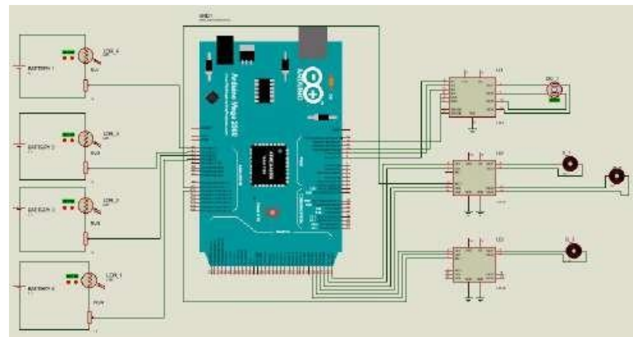


Fig. 11. Flowchart for Dual-Axis Tracker

The accumulation of dust or snow shades the solar panels. This shading of solar panel not only reduces the efficiency of the system, but also can damage the solar panel due to Hotspot creation. Thus, to avoid the problem due to partial shading, it is necessary to regularly clean the panel and prevent accumulation of snow or dust on them. However, maintenance is one of the major problems in Solar PV system. Due to irregularity in cleaning, maintaining the panels and sometimes difficulty in



accessing the solar panels, the solar PV system do not operate efficiently and may even get damaged permanently. In this project design, a self-cleaning feature is added which will clean the panels regular intervals. This feature will not only maintain the solar panels, but also minimize the maintenance cost.

Fig. 12. Schematic for Dual-Axis Tracker

Fig. 12 represents the schematic for the dual axis tracker. The circuit is designed and simulated on PROTEUS 8.0 software. Arduino Mega is heart of the system and gives the command to the motors [10] Depending upon the changes in light sensitivity sensed by the LDR, the Arduino will command the Stepper motor to rotate. The Interrupt service routine (ISR) is used for self-cleaning of the panel. In this the rotational motion of DC motor is converted into linear motion using lead screw mechanism which will clean the panel after a time interval designated.

V. CONCLUSION

In this paper, design and simulation of Off- grid solar PV system with battery backup is done for a village school in Raigad district, Maharashtra, India. The paper emphasized on importance of implementation of renewable energy sources and need of providing access of electricity to all corners of the world. The first part of the system was on the designing and sizing of the Off-grid PV system based on the consumer requirement. The system was designed and simulated on PVsyst 6.7 software. The second part of the paper, discussed the design and simulation of MPPT controller using MATLAB/Simulink. It provided the design of DC-DC boost converter and its stability analysis. A P&O based MPPT controller was implemented to enhance the power extraction capacity of the system. The third part discussed the design and simulation of prototype dual axis mechanical tracker using PROTEUS 8 software which follows the solar path to further enhance the efficiency of the system. This design was also provided with the self-cleaning feature which ensured cleaning of solar panels at regular intervals.

References

[1] Mounir Bouzguenda, Abduallatif Al Omair, Ahmad Al Naeem, Mohammed Al-Muthaffar, and Omar Ba Wazir "Design of an Off-Grid 2 kW Solar PV System" 2014 Ninth International Conference on Ecological Vehicles and Renewable Energies (EVER).

[2] A. Al-Salaymeh et al. "Technical and economical assessment of the utilization of photovoltaic systems in residential buildings: The case of Jordan" *Energy Conversion and Management 51 (2010) 1719–1726.*

[3] C.P. Kandasamy et al "Solar Potential Assessment Using PVSYST Software". 2013 *International Conference on Green Computing, Communication and Conservation of Energy (ICGCE).*

[4] KinalKachhiya,MukeshPatel, Makarand Lokhande,"MATLAB/Simulink Model of Solar PV Module and MPPT Algorithm", National Conference on Recent Trends in Engineering & Technology.

[5] Hengyu Li et al, "An Improved PV System Based on Dual Axis Solar Tracking and MPPT," Proceedings of 2014 IEEE, International Conference on Mechatronics and Automation, August 3-6, Tianjin, China.

[6] Ahmad Al Nabulsi et al, "Efficiency of a 150 W PV System Using Dual Axis Tracking and MPPT" 2010 IEEE International Energy Conference.

[7] Abolfazl Halvaei Niasar, Zahra Zare, Fahimeh Rabiei Far, "A Low-Cost P&O based Maximum Power Point Tracking, combined with Two-Degree Sun Tracker" The 6th International Power Electronics Drives Systems and Technologies Conference (PEDSTC2015) 3-4 February 2015.

[8] Dhanalakshmi.V et al, "Dual Axis Tracker Using Arduino Uno" International Journal on Recent and Innovation Trends in Computing and Communication, Volume:4, Issue 6.

[9] Sumit K Rathor et al, "Closed Loop Buck-Boost Converter using RTW" International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT)-2016.

[10] Bajpai P et al, "Design and development Test of an Automatic Two Axis Solar Tracker System" 2011 Annual IEEE India Conference, Hyderabad, India, 16-18 Decemer 2011; pp 1-6.