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Efficiency Optimization of Dual-Axis Solar Tracker

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Abstract
Energy crisis is a cardinal issue which is being felt across the globe. According to studies, the world will run out of fossil fuels by the year 2112 if we continue using them at the current rate. A switch to renewable sources of energy can help drastically reduce greenhouse gas emissions and thus global warming. Power harvested from sunlight is one of the most widely used form of renewable energy with an immense scalability potential in tropical countries like India. A dual-axis solar tracker is currently the most efficient form of solar energy system but external factors such as relative terrain temperature, dust, humidity, and other pollutants still govern its efficiency in terms of power generation. Delhi-National Capital Region (NCR) of India is one of the most polluted regions in the world. This paper studies the impact of dust and pollutants on the efficiency of a Dual-axis solar tracker in the context of Delhi-NCR.

Keywords—*Photovoltaic (PV),Power loss, Dual Axis tracker, Pollutant, Optimization of efficiency.*

I. INTRODUCTION

Today, the availability of electrical energy is a major factor in the socio-industrial growth of countries around the world. However, the world is facing an energy crunch because of diminishing fossil fuel resources along with the problem of climate change due to the Greenhouse Gas (GHG) emissions that such fuels generate. Exploitation of renewable sources of energy like solar and wind energy, hydropower, geothermal and biomass energy etc. can help address this problem over the conventional sources of energy. They are not only inexhaustible but also provide cleaner energy than their alternatives.

Energy received by theearth's surface perpendicular to the Sun's rays at sea level on a clear day is approximately 1000 W/m^2. [1] This energy, if converted to electricity can be used to meet the energy requirements globally.India being an tropical country, receives sunlight throughout the year, making sunlight an ideal resource to exploit for our energy requirements. [2] A photovoltaic (PV) cell is used for the purpose of conversion of solar energy into electrical power. The sunlight comprises of photons whose energy the semiconductor material of the PV cell absorbs. Such electrons enter the valence band and thus contribute to electricity. PV cells absorb about 12-18% of the light in the visible range. Solar radiation captured by the PV module is maximum when the sun's rays strike perpendicular to the surface of the solar cell. [3] Some modifications to the design of the conventional standalone solar cell aims to increase the efficiency of the system by exploiting this fact.

Standalone systems are those which are positioned at a constant angle. They are thus able to produce energy only for a certain number of hours every day when they are irradiated by Sun's rays. The efficiency of such solar energy systems can be increased by using a solar tracker, which augments the system's complexity and cost. Solar trackers can be primarily divided into single-axis and dual-axis trackers. Single-axis solar trackers have only one axis of freedom - either horizontal or vertical whereas dual-axis trackers have both axis of freedom – vertical and horizontal. [4] Thus, the efficiency of the system can be increased by up to 25% by using a single axis tracker. Adding a second axis of freedom can further improve efficiency by 5-10%. [5]

But even the dual-axis solar tracker's efficiency is affected by factors such as global solar radiation intensity,relative terrain temperature, dust storms, shading and other pollutants in the air spectrum and angle of

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irradiance. [6] This paper studies the effects of such factors on the efficiency of solar tracker energy systems equipped with dual axis rotation control in Indian context with a focus on the Delhi-NCR region.

II. Solar Energy in India

In emerging country like India, we don't have adequate electric energy. Calculated solar energy incidence on India's land area is approximately about 5 EWh/yr or 5000 trillion kilowatt-hours(kWh) per annum spread over about 300 clear and sunny days in a year. [7] The solar energy received in a year is more than the possible energy output of all the fossil fuel energy reserves in India. The Indian government has been recognizing this immense potential and has thus changed an initial target of solar capacity of 20GW by 2022 to 100 GW by 2022. [8] India increased its solar-generation capacity by 8 times(2,650 MW to over 20 GW)in a duration of less than 4 years from 26 May 2014 to 31 January 2018. [9] India has successfully added 3GW, 5GW and over 10GW in the years 2015-16, 2016-17 and 2017-18 respectively. Also, the current average price of solar electricity has dropped to 18% below the average price of its counterpart coal-fired electricity generation which is a significant improvement. [10] As of September 2019, India has successfully installed more than 82,500 MW of renewable energy capacity. Also around 31,150 MW of capacity has been installed in India under various stages of installation. [11]

III. Dual-axis Solar Tracker

A lot of research has been done to maximize the energy generated by the solar cell. Effect of temperature, pressure and other parameters are some of the parameters that affect the efficiency of the power generated.

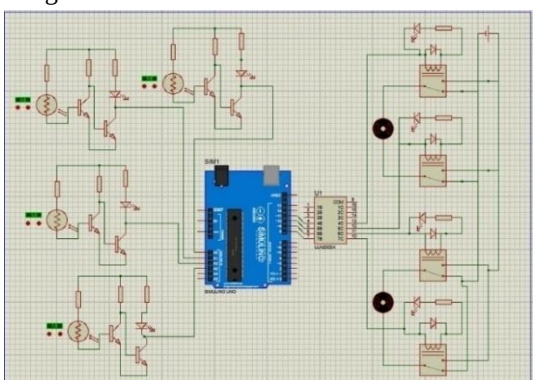

Fig 1. Circuit Model of Dual-axis Solar tracker

Solar trackers can be categorized into two basic categories: Single axis trackers and dual-axis trackers. Single-Axis Trackers are trackers which can rotate in only one direction, and thus have only one degree of freedom.Thus, they follow the path of the sun from east to the west.

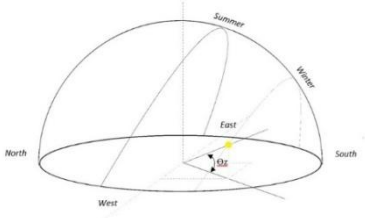

Fig 2. Position of Sun at different times in a year

The motion of the earth can be described in two parts, one is the rotation and the other revolution which is based on the year.

So, it is required to track the sun with the location and hence we go for the advanced version which is Dual-axis solar Tracker. [12]

Dual-Axis Trackers have two degrees of freedom which they use for rotation.These axes are generally normal to one another.Thus, theyare free to rotate simultaneously both invertical and horizontal directions, for added power output. [13]Irrespective of the position of the sun, dual axis trackers can align themselves to receive maximum power from the sun. Dual-axis operates on two angles, (1) the solar azimuth angle and (2) the solar altitude angle. Solar altitude angle is the angle between the earth surface's horizontal plane and the sun's position, and the angle between a vertical plane containing the solar disk and a line passing through south is called azimuth angle as shown in the figure 2. [14]

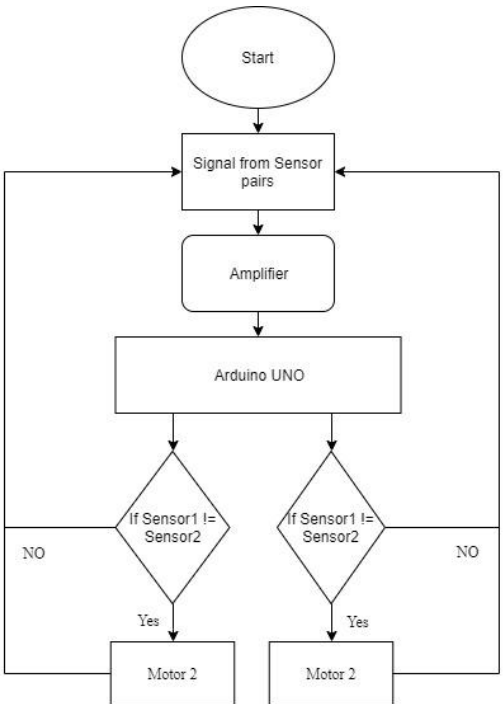

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Fig 3. Flow Chart of Dual-axis solar tracker

The figure 3 shows the flow chart of the Dual-axis solar tracker. In our experimental setup, four (LDR) light dependent resistors for tracking the intensity of the Sunlight, two gear motors controlled by Arduino Uno micro controller have been used as shown in the figure 1.

IV. Dust and pollutants in Delhi-NCR

The level of pollutants and dust has been increasing rapidly with time all over the world. In Delhi-NCR, the air quality has been deteriorating since 1980. [15] Survey conducted in 1990s by World Health organization (WHO) shows the suspended particles in air with peak levels as high as 10 times the standard limit. [16] The levels of PM2.5 and PM10 particulate have been inflated to 999 micrograms per cubic meter, whereas the safe limit for the same are 60 and 100 respectively. [17]

The gradual gathering of dust and pollutants deteriorates the overall performance of the module. This can drastically decrease the power generated by the PV module as the photons cannot be absorbed by the panel effectively. These particles along with dust lead to decrease in the solar energy production because of shading of the PV Panel with these pollutants and dustthus decreasing the total solar energy transmittance to photovoltaics. The effect is more prominent in regions that experience higher levels of dust and pollution. Cleaning mechanisms are not easily applicable in urban areas like Delhi-NCR as the whole system is not easily accessible.

V. Effects of Dust and pollution on the efficiency of the Solar Panel

The two major problematic factors related to Solar energy generation are pollutants and dust. Most importantly it is more destructive toplaces like Delhi-NCR, where the energy required is greater in number. Traditional cleaning mechanisms are not easily applicable in the urban regions since the panels installed are not easily accessible. The amount of dust and pollutants accumulated on the PV panel varies from season to season, the amount of dust increases in the dry season due to the dust storms all over Delhi-NCR and the pollutants in the air is usually high throughout the year reaching its peak in the month of November and December. [18] The effect of dust and pollutants on the PV panel is observed and measured, and the conclusion is drawn from the same.

VI. Results and Discussion

The impact of dust and pollutants on solar power generated is analyzed. The model estimates the difference in efficiency of two models. The above tables 1, 2 and 3 show the different parameters recorded after 1-day, 1-week, and 1-month respectively.

Table 1: After 1-day parameters

Measured Value	PV Panel without Pollutants	PV Panel with Pollutants
I_{sc} (A)	2.84	2.73
V_{oc} (V)	17.92	17.97
I_m (A)	2.49	2.36
V_m (V)	13.09	13.57
Efficiency (%)	12.48457	12.26667

Table 2: After 1-week parameters

Measured Value	PV Panel without Pollutants	PV Panel with Pollutants
I_{sc} (A)	2.84	2.59
V_{oc} (V)	17.92	17.32
I_m (A)	2.49	2.24
V_m (V)	13.09	13.76
Efficiency (%)	12.48457	11.80596

Table 3: After 1-month parameters

Measured Value	PV Panel without Pollutants	PV Panel with Pollutants
I_{sc} (A)	2.84	2.33
V_{oc} (V)	17.92	17.92
I_m (A)	2.49	2.10
V_m (V)	13.09	14.42
Efficiency (%)	12.48457	11.59897

The existing studies shows that even minute amount of pollutants on PV panel surface affects the sunlight transmission. The data gathered shows the decrease in current with increase in pollutants as it shades the solar cell. This is obvious because of decrease in the number photons absorbed which is responsible for generation of photocurrent. The decrease of around 6% is visible in the efficiency of the panel with pollutants from the very first day and it goes up to 17% in a month. In order to check the reliability of the

data gathered and calculations done, it has been compared to other models as well. [19]

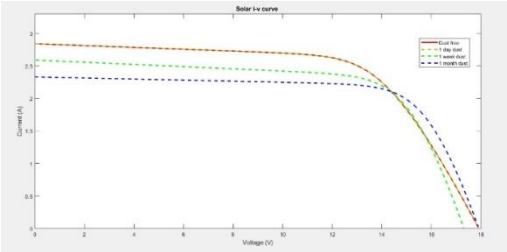

Fig 4. Graph of different parameters

The plot between current and voltage of panel without dust and with dust after 1-day, 1-week and 1-month is shown in Fig 4. It is observed that as the intensity of dust increases, the current decreases.

VII. Conclusion

Dust and other pollutants adversely affect the energy generation efficiency of solar cells. The obtained data concludes that such pollutants significantly influence the power output from a solar power plant. Further, the decrease in efficiency increases with time and thus warrants regular cleaning of the solar panels.

VIII. Future scope

The world is increasingly moving towards renewable energy sources like solar energy and thus future research work in the domain should be emphasized on escalating the efficiency of solar power generation. In this direction, research can be pursued to explore the most efficient cleaning technique/system. Also, current Dual-axis solar trackers depend on LDRs, whose performance decreases significantly due to pollutants. Thus, further research can take place on a substitute or a modified version of it.

References

[1] Joshi. A. S., Tiwari A, Tiwari. G. N. Dincer I, Reddy.B. V.,evaluation of a hybrid photovoltaic thermal(PV/T) (glass-to-glass) system. Int J Thermal Sci 48:154(2009).
[2] Dubey S, Sandhu G S, Tiwari G N, Analyticalexpression forelectrical efficiency of PV/T hybrid air collector. Appl Energy8: 697-705 (2009).
[3] Rupali Nazar, Improvement of efficiency of solar panel usingdifferent methods, International Journal of Electrical &electronics Engineers, ISSN-2321-2055(E), vol. 7, issue 01,Jan-June 2015
[4] R. Ferdaus, M. Mohammed, S. Rahman, S. Salehin, M.Mannan, Energy efficient Hybrid Dual Solar TrackingSystem, HPC Journal of Renewable Energy, vol 2014, ArticleID 629717, 12 pages.
[5] Jacob Barin, Emily Vang, Design of Energy Efficient Sensors, International Journal of Electrical & ElectronicsEngineeringAdvanced Research, vol. 1, issue 1, dec 2013.
[6] B. Balamuralikrishnan, B. Deepika, K. Nagajothi, S.
[7] Shubaashree, P. T. Subasini, Efficiency EnhancementofPhotovoltaic Cell, International Journal of AdvancedResearch in Electrical, Electronics and InstrumentationEngineering, vol. 3, special issue 4, May 2014. "Physical Progress (Achievements)". Ministry of New & Renewable Energy. Retrieved 18 July 2019.
[8] ["India becomes lowest-cost producer of solar power". Retrieved 1 June 2019.
[9] "Race Heats Up For Title Of Cheapest Solar Energy In The World". Retrieved 28 October 2019.
[10] Jump up to:a b "Achieving 2022 target four years ahead of schedule". Retrieved 4 February2018.
[11] Jump up to:a b "India hits 20 GW solar capacity milestone". Retrieved 4 February 2018.
[12] D.F.Fam, S.P.Koh, S.K.Tiong and K.H.Chong, "Qualitativeanalysis of stochastic operations in dual axis solar trackingenvironment", Research Journal of Recent Sciences, vol 1, no.9, pp. 74-78, 2012.
[13] A.M.Sharan and M.Prateek, "Automation of minimum torquebased accurate solar tracking systems using microprocessors",Journal of the Indian Institute of Science, vol.86, no.5, pp.415-437, 2006.
[14] C. Alexandru and M. Comsit, Virtual Prototyping of the solarTracking Systems, Department of Product Design andRobotics, University Transilvania of Brasov, Brasov,Romania
[15] A. Hsing, Solar Panel Tracker, Senior Project, ElectricalEngineering Department, California Polytechnic StateUniversity, San Luis Obispo, Calif, USA 2010.
[16] M.B. Omar, Low Cost Solar Faculty of Electrical & Electronics Engineering, University Malaysia Pahang, 2009
[17] S. Ahmad, S. Shafie, M. Kadir, "Power feasibility of a lowpower consumption solar tracker", Procedia EnvironmentSciences 17 (2013) 494-502.
[18] P. D. Burton and B. H. King, "Artificial Soiling of Photo voltaic Module Surfaces using Traceable Soil Components," in 39th IEEE Photovoltaic Specialist Conference, Tampa, Florida, 2013.
[19] K. Brown and N. Jing, "Soiling Test Methods and their use in predicting performance ofPV modules in soiling Environments," in 38th IEEE Photovoltaic Specialist Conference, 2012.