Performance Analysis of Dual Axis Solar Tracker, Single Axis Solar Tracker and Fixed Array Configuration

Karma Norbu, Sonam Jamtsho, Tashi Zangpo, Kinley Tenzin and Gom Dorji

DOI: https://doi.org/10.17102/bjrd.rub.se2.041

Abstract

Solar energy has become popular source of renewable energy owing to its cheap electricity generation and relatively low construction cost. With integration of solar PV tracking system, the electricity generation has boomed in its operating lifetime. This paper present performance analysis of dual axis solar tracker, single axis solar tracker and fixed array configuration in terms of energy generation and efficiency. Three solar experimental setups are designed, fabricated and tested. The experiment was conducted in Thimphu (27.415647N, 89.621183E) and obtained power generation data from 15-21 of March 2022. The sun tracking and data logging is performed by Arduino Uno microcontroller. The data obtained is analyzed to obtain results using Microsoft excel.

Key words – *Dual axis solar tracker, single axis solar tracker, fixed panel, power generation, efficiency.*

Introduction

Renewable energy has become hot topic for research and development since a few decades ago. Solar energy plays a vital role in renewable energy mix. However the sun shifts its position from east to west with time. This leads to increasing solar irradiance received by horizontal plane from morning till mid-day and declining solar irradiance from mid-day to evening. Moreover commercial solar panel efficiency lies between 15-20%, which is very low as 80-85% of solar energy is reflected, absorbed and produce heating effect.

Dual axis solar panel will track sun in both east-west and north-south direction. While single axis solar tracker will track in east west direction only. The static panel is oriented in fixed direction. The actuation of the solar tracking is done by geared DC motor linear actuator and servo motor. The sensor is constructed using LDR and a resistor in voltage divider circuit configuration. The analogue signal from sensor is fed to analogue inputs of the Arduino Uno microcontroller. The microcontroller receives the signal from sensors and analyze the signal using preprogramed algorithm and produce output signal for relays and servos.

The three setups is feed to common resistive load to have common operating voltage. The data is collected and stored in SD card after every set time interval. The data consist of common voltage, individual current of static panel, single axis solar and dual axis solar setups separated by commas. The current is measured by ACS712 module which converts current signal to 0-5VDC voltage signal.

The three setup's data logging system and solar tracking system is powered by rechargeable lithium ion cell which is charged by solar power itself. The solar will track the sun in the steps of 2.5^0.

Methodology

Single microcontroller is used to control tracking of sun for both single axis and dual axis setup. Figure 1 and 2 shows block diagram of tracking control system and data logging system respectively. It consist of six LDR sensors. Two LDR for east-west tracking for dual axis tracker, two for dual axis north-south tracking and last two for single axis east-west tracking. The east west tracking uses linear actuator powered by geared DC motor. The north south tracking is done by servomotor. Each linear actuator is controlled by two double pole single throw relay assembly. The relay is activated by 5V digital signal from microcontroller.

When panel is oriented towards the direct sun ray, the illumination in two of the LDR is equal. However when sun shift its position, one of the two LDR will be in shade and there is difference in illumination. This creates difference in analogue output voltage from each LDR. The voltage output from two LDR is compared to find error voltage.

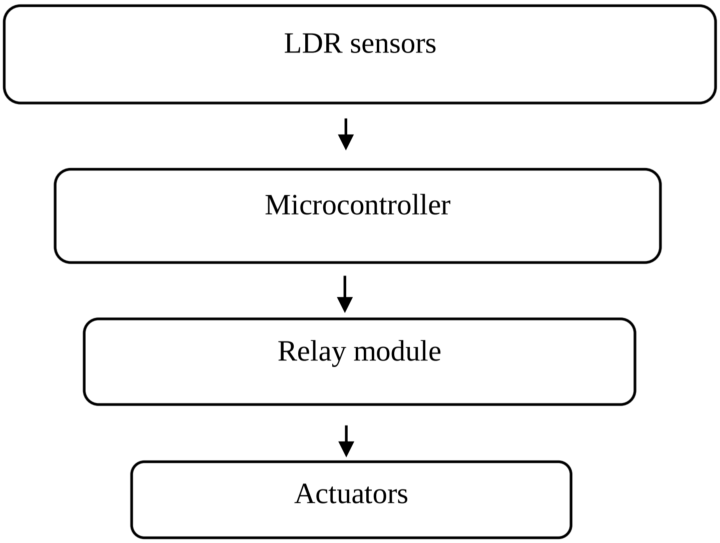

Fig.1 *Tracking system*

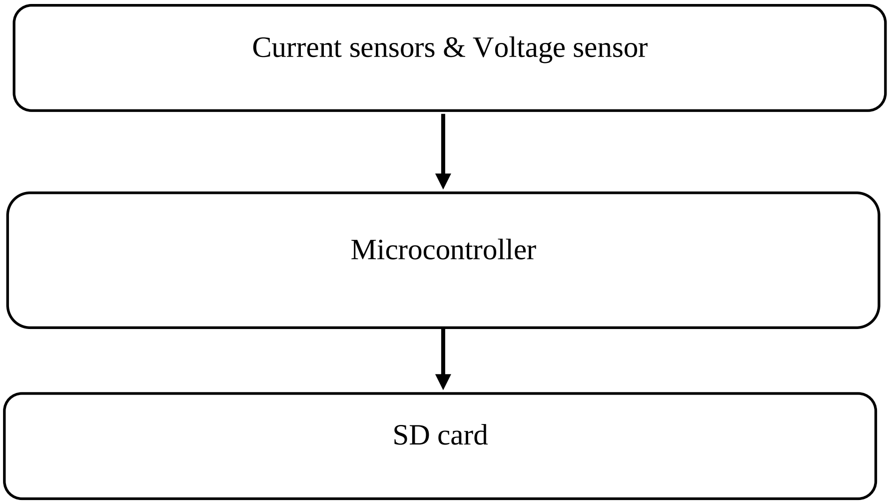

Fig.2 *Data logger*

The direction of rotation of actuator depends upon whether error voltage is positive or negative. The signal towards actuator is in such a way that, the change in orientation of the PV panel by actuator reduce voltage error from sensors. When voltage error of zero is achieved, the panel is said to be oriented towards direct rays of the sun and further actuation stops.

Literature review

In Performance analysis of solar systems-single axis versus fixed system, comparison is made between single axis and fixed solar array in varying weather conditions. (Katrandzhiev & Karnobatev, 2021)

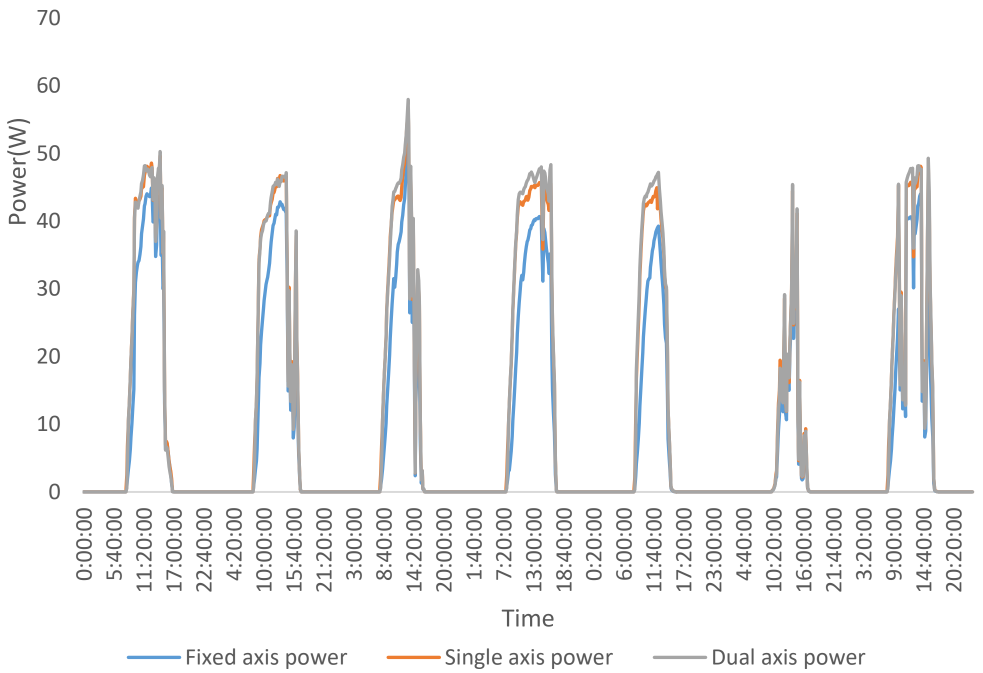

Fig.3 *Power versus time curve*

The solar tracking system makes sense only in bright sunny day. As sky gets cloudy, the tracking system and the fixed one generates almost equal solar energy. Therefore solar tracking system is more economical in place where sunshine days is more in the year.

In an experimental comparison study between Single-Axis Tracking and Fixed Photovoltaic Solar Panel Efficiency and Power Output, a Case Study in East Coast Malaysia has compared single axis and fixed solar panel. Efficiency were calculated and found out to be 66.7% for single axis and 39.9% for fixed array. PIC microcontroller was used and optical sensor for tracking system. The additional power gained by tracking system over fixed array is maximum in the morning and evening. The single axis tracking system is more efficient than the fixed one however the fixed panel is more cost beneficial than the tracking system during installations.

The azimuth angle for solar panel located in northern hemisphere is 180^0. While zenith angle is given by formula below

$$Tilt = L - \delta$$

Where L = latitude of the place, δ = declination angle which is given by

$$\delta = 23.45 sin\left(\frac{360}{365}(n - 81)\right)$$

Where n is nth day of the year. (Mahendran, Ong, Lee, & Thanikaikumaran)

Result and analysis

The setup is experimented and the current and voltage data is collected using data logging system and stored in SD card. Data is collected over a duration of one day at sampling frequency of 1Hz and averaged at interval of 10 minutes. The voltage for all three setup is kept common so as to operate in common point in power voltage curve of the panel.

The total energy generated from both dual axis setup and single axis setup remain similar as the shift of suns position in north south direction is very small in one week. The power generated from fixed panel rise gradually from morning to mid-day and falls gradually towards evening. Single axis panel produce sharp rising power in the morning when sun falls on the panel as panel is oriented to direct sun’s rays. However the power generated is slightly lower than the peak power even the sun’s ray fall vertically on the panel. This is because the air mass is higher as zenith angle is higher.

Fig.4 *Experimental setups*.

The dual axis power curve remain similar to single axis power curve because the north south orientation of both setups remain similar for duration of one week. However the dual axis setup generate slightly more power than single axis setup because dual axis is always oriented to direct sun rays while single axis panel remain fixed in one of its axis.

The data is collected in Thimphu and the average solar irradiance in Thimphu is measured 3.504kWh/m^2 per day according to National Center for Hydrology and Meteorology (NCHM) on particular experimentation period. The energy generation efficiency is given by,

$$\eta = \frac{Electrical\ energy/m^2}{Sun's\ irradance.}$$

The generation efficiency is calculated to be 10.93% for static solar tracker setup, 13.92% for single axis solar tracker and 14.08% for dual axis tracker setup considering loses in the tracking system. The tracking loss is 0.25% for single axis tracker and 0.50% for dual axis tracker. The generation efficiency is highest in dual axis solar tracker and lowest in static panel. This because the dual axis solar tracker orients its panel towards direct rays thus collects more amount of solar energy.

Conclusions

The dual axis solar tracker generates 1.11% more energy than single axis tracker and 28.76% more energy than static panel. The single axis tracker set up generates 27.36% more energy than static panel considering energy

References

Algarrn, C. R., Castro, A. O., & Naranjo, J. C. (2017). Dual-Axis Solar Tracker for Using in Photovoltaic Systems. *International Journa of Renewable Energy Research*, 138.

Guo, L., Han, J., & Otieno, A. W. (2013). Design and simulation of a sun tracking solar power system. *Atlanta*.

Hoque, S. M., Das, B., & Has, M. A. (2019). Comparative analysis of dual and single axis solar tracker. *International Conference on Mechanical Engineering and Renewable Energy*.

Katrandzhiev, N. T., & Karnobatev, N. N. (2021). Performance analysis of solar systems - single axis vs fixed system. *International Journal on Information Technologies & Security*, 77.

Logan, P. E., & Raichle, B. W. (n.d.). Performance cpmparasion of fixed, single, and dual axis tracking system for photovoltic system with measured direct beam.

Mahendran, M., Ong, H. L., Lee, G. C., & Thanikaikumaran, K. (n.d.). An Experimental comparison study between Single-Axis Tracking and Fixed Photovoltaic Solar Panel Efficiency and Power Output: Case Study in East Coast Malaysia.

Mane, P., & Dhumal, A. (2016). Dual axis solar tracking system comparative study and mechanical design implementation. *International Journal of Mechanical And Production Engineering*, 29.

Seme, S., Štumberger, B., Hadžiselimovi´c, M., & Sredenšek, K. (2020). Solar Photovoltaic Tracking Systems for Electricity Generation: A Review. *energirs*, 4224.

Singh, D. P., Dhami, S. S., & Banwait, S. S. (2020). Performance comparasion of fixed and tracking typr solar plants. *International Journal of Inovative Technology and Exploring Engineering.*, 612.

Tiwari, N., Shivsingh, D. K., Kashmir, A. S., & Gotan, D. (2018). Simulation Studies of Single Axis Elevated Solar Tracking System; At Different Angle Implemented on Simulink Platform. *International Journal on Future Revolution in Computer Science & Communication Engineering*, 41.

About the author

Karma Norbu is a final-year Electrical Engineering student at the College of Science and Technology, Phuntsholing, Bhutan. He studied his higher school in Yadi and lower school in Serzhong under Mongar Dzongkhag. He is interested in Science, Technology, Engineering, Mathematics, Business and environment.