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Experimental Assessment Of An Intelligent Sun Tracking System For Photovoltaic Module Under Variable Weather Conditions

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***Abstract*— Solar energy is one of the most reliable alternative energy sources in this modern era. Thousand researches on improving the efficiency of photovoltaic (PV) system are ongoing to make it more competitive among all other available renewable energy sources. Photovoltaic panels are used to collect solar energy or any source of visible light and convert it into electrical energy. But these photovoltaic panels energy produced are inefficient as they are fixed only at a particular angle. we can easily overcome this problem by using sun tracking PV panel system. This thesis presents the design and development of an intelligent single axis solar tracker. moreover, the major components those are used in the prototype of the designed tracker are: Arduino UNO, Photo resistors (LDRs), servo motor, and Liquid Crystal Display (LCD). the tracking system can track the sun within 180⁰ from East to West. It was noticed that there is a percentage power gain up to 50% when using the solar tracker as compared to when it is not used.**

Keywords—Renewable Energy, photovoltaic Energy, Intelligent system, Solar tracker, Arduino, single axis tracking

I. INTRODUCTION

Energy is the prime factor for the development of a nation. An enormous amount of energy is extracted, distributed, converted and consumed in the global society on daily bases. There exist two types of energy namely renewable energy, and non-renewable energy. Renewable energy is the energy that uses natural sources like: sunlight, wind, rain, waves, tides, and geothermal heat. The most popular renewable energy sources currently are: solar energy, wind energy, hydro energy, Tidal energy, Geothermal energy, and Biomass energy while Non-renewable energy sources use: oil, natural gas, coal and nuclear energy to produce electrical energy. Oil, natural gas, and coal are collectively called fossil fuels. Moreover, non-renewable are not infinite. In addition to that, they release carbon dioxide into our atmosphere which contributes to climate change and global warming. However, non-renewable energy resources are decreasing, use of renewable energy resources for producing electricity are increasing. Solar Photovoltaic (PV) energy is a clean, renewable source of energy that uses solar radiation to produce either electricity or thermal energy and it is accessible everywhere compares to others renewable energy sources. The term solar energy refers to the energy that is harvested directly from the sun. Every day, the sun emits a massive amount of energy onto the earth's surface. That is, about 172000TWh of sun energy in an hour, more than enough to supply the world's energy demands if properly collected (El Hammoumi et al. 2022). In addition to that, Photovoltaic (PV) panels are becoming more popular while their price keeps on decreasing. Solar PV panel absorbs the energy from the Sun or any visible light, converts to electrical energy and this energy can be use directly or stored in a battery or battery bank to be use when required or can be process as a direct alternative to the grid supply. Although Solar energy is one of the best sources of renewable energy for producing electricity, but the efficiency of these PV panels are very low due to the materials used in fabricating these panels. On the other hand, due to the movement of the sun across the sky, solar PV panels could not capture more energy within a day when the panels are fixed. For an efficient usage of the solar energy, most commonly used techniques to optimize the power output of PV systems are required. These techniques are; Solar Tracker: Maximize solar energy collection from PV panels by keeping them perpendicular to the incident solar radiation using a mobile structure. (Mohamad et al.,2004; Abdallah et al., 2004; Hyacinthe Tchakounté et al. 2019 ; Rogalla et al., 2022 ; Saymbetov et al.,2021 ; Rousan et al.,2021) Cooling System : Cool down the PV panels to keep the temperature of the PV cells close to the nominal operating value, which will enhance their electrical efficiency and produce more energy. (Shukla et al.,2017; Ahmadietal.,2021; Panda et al.,2022) Cleaning System: Clean the PV panes of dust, dirt, bird droppings, or other impurities on the surface of the panels that may cause a reduction in their efficiency and in their energy production. 15%–30% reduction of power output. (Bansal, et al., 2015; Kazemetal.et al., 2020; Siyuan et al., 2021). Floating PV System: Installing PV panels on a floating structure on water bodies such as dams and irrigation ponds to take advantage of the natural water-cooling effect and consequently improve their efficiency. (Ranjbaran et al.,2019; Hammoumi et al.,2021). MPPT Controller: Extract and maintain the maximum power from PV panels at any environmental condition, matching its I-V operating point to the load characteristic through a DC/DC converter. (Gregor et al.,2015; Kamta et al., 2018; Tchakounté et al., 2019). From the optimization techniques to improve the efficiency of PV system mention about, the floating system is needed only when the panel temperature is high and same with the cooling system (resolve problem excess heat on the panel surface), cleaning system is requiring only when the surface face of the panel is dirty, MPPT is needed only when the panel is producing enough energy to power ON the charge control components in order to give out a specified voltage and current, and solar tracker is needed to capture more sun light which is the key of solar energy system. PV panels capture sun energy and convert in to another form of energy, be it thermal energy or electrical energy. The panel output depends on the amount of sun or light energy falling on the surface of the panel. Despite the fact that solar trackers are expensive they have more advantages compares to others optimization techniques. The above mention techniques of PV system efficiency improvement exit but is a series of tanks of which the technologies behind it are trying to have better Accuracy and proper optimization than the existing one which is also part of our objectives. For PV panels should absorb energy to a maximum extent, the panels are continuously placed towards the direction of the Sun especially at the central of the sun beam. Moreover, PV panel should continuously rotate in the direction of Sun. This article describes about circuit and mechanism that form a single axis sun tracking system to rotates a PV panel as sun goes by always placing the panel at sun beam. Solar tracking system is among the best approaches to harvest more solar energy from PV system compared to fixed panel system. Single axis Solar tracker follows the position of the sun throughout from east to west, or North to South daily.

II. MATHEMATICAL MODELLING OF PV MODULE

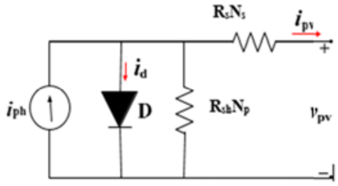


Figure1: one diode PV cell module.

$$i_{pv} = N_p i_{ph} - N_p i_o \left[e^{\frac{q\left(\frac{V_{pv}}{N_s} + \frac{R_s\, i_{pv}}{N_p}\right)}{KTa}} - 1 \right] - \frac{\frac{V_{pv}}{N_s} + R_s\, i_{pv}}{R_{sh}}$$

Since our PV module Np=1, then the expression of I will be as follows:

$$i_{pv} = i_{ph} - i_0 \left[e^{\frac{q\left(\frac{V_{PV}}{N_S} + R_S I\right)}{KTa}} - 1 \right] - \frac{\frac{V_{pv}}{N_s} + R_s I}{R_{sh}}$$

Where;

i_{pv}: is the solar module output current
V_{pv}: is the solar module output voltage
i_{ph}: is the photo-generated current.
i_o is the diode reverse saturation current.
a: is the ideality factor.
q: is the elementary electron charge ($q = 1.6 \times 10^{-19}$C).
K: is the Boltzmann constant ($k = 1.38 \times 10^{-23}$ J/K)
T: is the surface temperature of the solar cell.
R_s: is the cell series resistance
R_{sh}: is the cell shunt resistance
N_p: Number of cells connected in parallel
N_s: Number of cells connected in series

III. METHODOLOGY

The tracking system is made up of power supply module, sleep mode module, voltage regulator module, sensors module, Arduino module, and actuator combined with tracking mechanism module, Liquid Crystal Display (LCD) module and photovoltaic panel module as shown on functional diagram. This system tracks the sun path from East to West. The system goes to sleep whenever the is not sufficient light falling (dark sky), the tracker places the panel at the direction with the highest light intensity and go to sleep. When the light comes back the tracker track move the panel horizontal at an angle of 90^0 for the

LDR sensors to easily detect the direction with more light intensity.

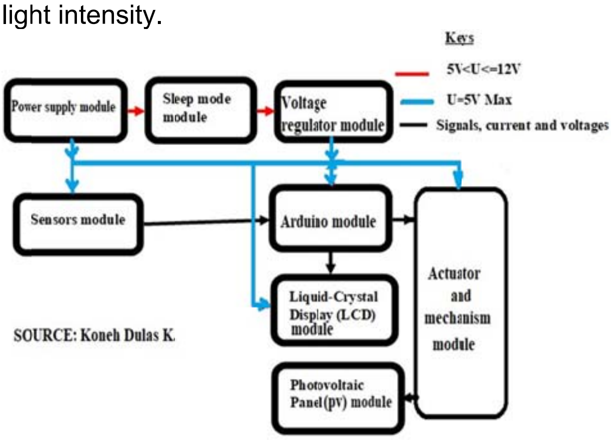


Figure:2 Functional diagram show how the various modules that combined to form an intelligent sun tracking system.

From the key;

- ♣ U=5V DC supply source: is the minimum supply voltage to power tracker only in maintenance mode through the USB Pot.
- ♣ 5<U≥24V DC and 220V AC supply source: When the system is being connected to any of this supply source the system can operate in the two main mode of operations simultaneously. that is, Normal operating Mode (NOM) or Maintenance operating Mode (MOM).

III.1 The Elevation and azimuth angles plots of Sun's path of Ngaoundere data recoded on Thursday October 31st,2020.

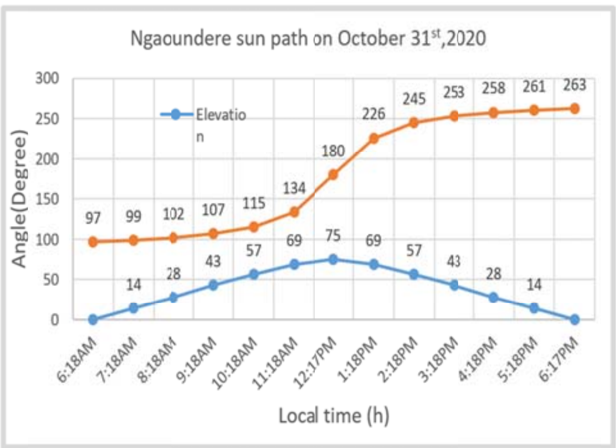


Figure 3: The local time sun path for Ngaoundere on the October 31st 2020.

Variation in the elevation angle and zenith angle on *October 31st 2020*. (Bini of Ngaoundere). As seen in the accompanying illustration, the sun reaches its greatest point at 12:18 PM, which is after noon (12:00PM). The elevation angle was roughly 75^0. The sun rises at 6:18Am in the North East (azimuth=97^0). At time goes by the Elevation increases progressively with Azimuth angle up still 12:18PM noon, where the sun was at top with an elevation angle is approximately 75^0 and azimuth angle of 180^{0}S. From 12:18PM to 6:17PM, The elevation(attitude) decreases down to zero degree while the heading angle increases up to 263^0 progressively in the North West direction as sun set. The Day length 12:05:34. The sun light path slightly change in seasonally in Ngaoundere as whereas, research shows that sun seasonal trajectory in most Africa counties are slight change.

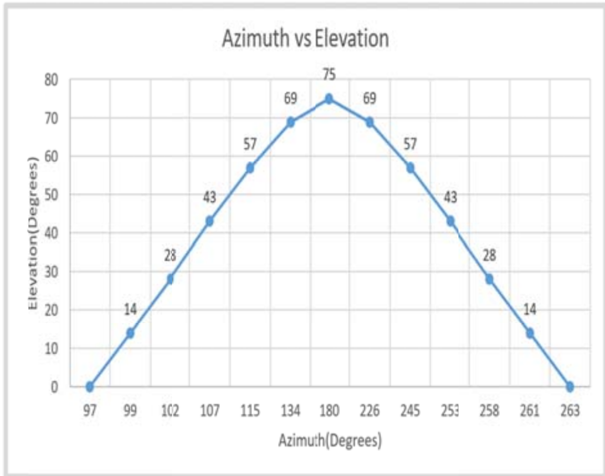
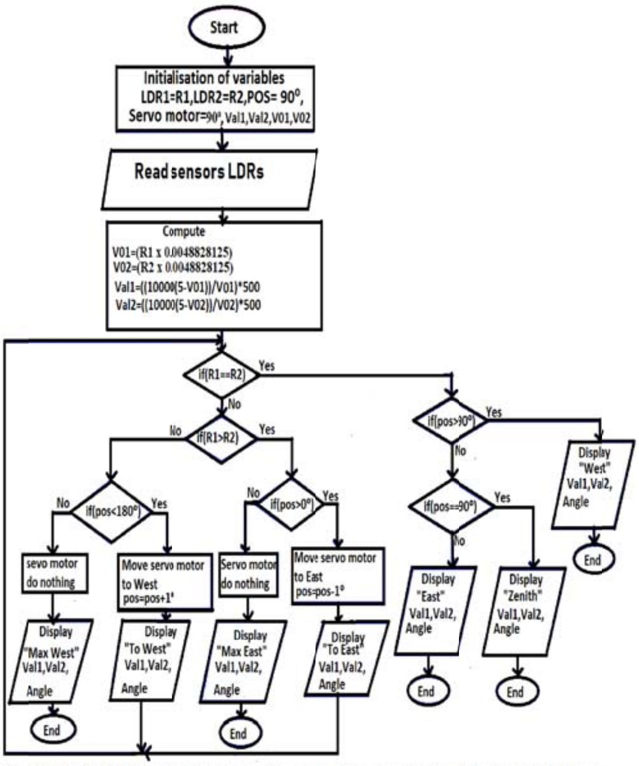


Figure 4: Plot of Sun trajectory in Ngaoundere on October 31st 2020

The sun trajectory for the day shows the sun rise from North East with elevation angle of 0^0 and Azimuth angle approximately 97^0. The two axis angles increase progressively up still the maximum elevation angle of the day which is 75^0 at 12:00PM. When the elevation Angle is at maximum by noon it starts dressing as time goes by where the Azimuth angle keep increases. That is, from morning to noon; the elevation and Azimuth angles increases while from noon to evening the elevation angle decreases progressively with increases in Azimuth angle.

III.2 Flowchart of Control Algorithm of the intelligent single axis tracking system.



SOURCE: Koneh Dulas Kului derived from the knowledge of C++ programming language gotten from school and applied with respect to how my system needs to operate.

Figure 5: Flowchart of Control Algorithm of the intelligent single axis tracking system.

IV. RESULTS AND DISCUSSION

IV.1 Circuit diagram of sun tracking system

Below on figure is circuit diagram of a Sun-Tracking System for photovoltaic panels

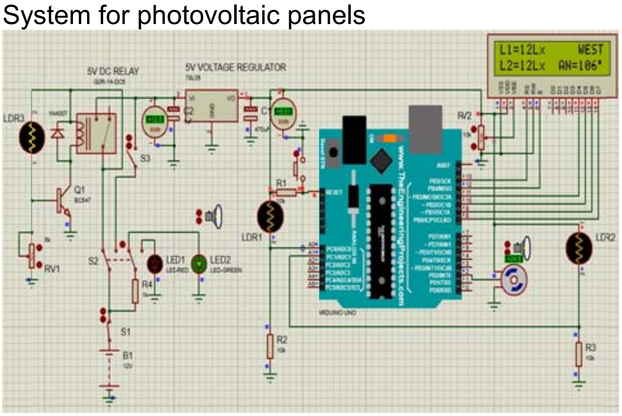


Figure 6: Simulation Schematic diagram of a complete intelligent tracking system in proteus.

IV.2 Principle of an intelligent sun tracking system for PV panels

The Sun tracking solar PV panel system consists of Arduino Uno, servo motor, three Light dependent resistors (LDRs), solar photovoltaic panel, Liquid crystal display (LCD) and etc.

The servo motor shaft is being coupled to the rotating part of the tracker mechanism that carries the PV panel and the sensors LDR1 and LDR2 who reads values are compered to move the panel to the central of the Sun light beam. The two 10kΩ help in reducing the current and voltage entering into the Arduino analog pins (using voltage and current divider role). The

5kΩ variable resistor connected to the LCD pins 1,2 and 3 is use to varies the contrast of the LCD. The LCD is to display the converted values of light intensity read from LDR1 and LDR2 sensors in luminous(lux), it also displays the angle and direction of the PV panel toward the sun position. The 10kΩ resistor connected to the Arduino reset pin is to reduce the voltage entering the Arduino reset memory pin by digitally setting it high (1) while the push button connected across the Arduino reset pin to the ground is to set the reset pin digitally low (0) by resetting the program running in the Arduino board to restart incrementing from initial.

IV.3 Testing the prototype project with sun light source in real life

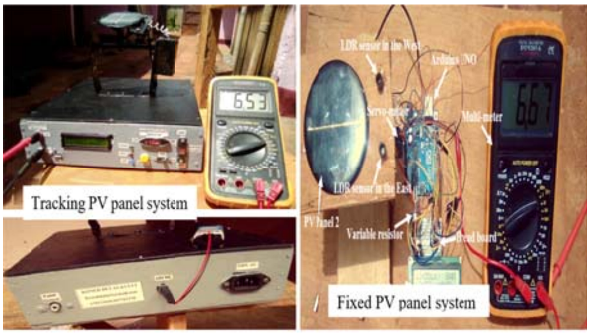


Figure 7: Photo of a fixed PV system and the proposed tracker prototype tested under the sun light and data was been recoded within a day. See table 1 and 2.

Table 1: Recoded data of a fixed 4V Photovoltaic panel on a bright sunny day October 31st,2020.

Time	Fixed panel voltage and power	LDR1 (Lux)	LDR2(Lux)	Angle (Degree)
06:00 am	3.56V 0.0356mW	103	90	85°
07:00 am	4.95V 0.0495mW	147	135	85°
08:00 am	5.54V 0.0554mW	153	144	85°
09:00 am	5.60V 0.0560mW	163	159	85°
10:00 am	6.32V 0.0632mW	234	230	85°
11:00 am	7.12V 0.0712mW	297	296	85°
12:00 pm	7.03V 0.0703mW	288	289	85°
1:00 pm	6.89V 0.0689mW	263	260	85°
2:00 pm	6.56V 0.0656mW	239	245	85°
3:00 pm	5.32V 0.0532mW	173	180	85°
4:00 pm	4.43V 0.04.43mW	109	132	85°
5:00 pm	3.78V 0.03.78mW	100	118	85°
6:00 pm	2.96V 0.02.96mW	76	88	85°

Table 2: Recoded data of a tracking 4V Photovoltaic panel on a bright sunny day October 31st,2020.

Time	Tracking panel Output voltage and power	LDR1 (Lux)	LDR2(Lux)	Angle (Degree)
06:00 am	4.05V 0.0405mW	103	103	28°
07:00 am	5.85V 0.0585mW	175	175	34°
08:00 am	6.47V 0.0647mW	240	243	53°
09:00 am	6.48V 0.0648mW	243	243	61°
10:00 am	6.53V 0.0653mW	255	255	67°
11:00 am	7.15V 0.0715mW	275	275	79°
12:00 pm	7.24V 0.0724mW	304	304	90°
1:00 pm	7.19V 0.0719mW	303	304	104°
2:00 pm	7.13V 0.0713mW	298	298	120°
3:00 pm	7.16V 0.0716mW	301	302	138°
4:00 pm	7.08V 0.0708mW	290	290	142°
5:00 pm	6.56V 0.0656mW	241	241	154°
6:00 pm	5.98V 0.0598mW	223	224	167°

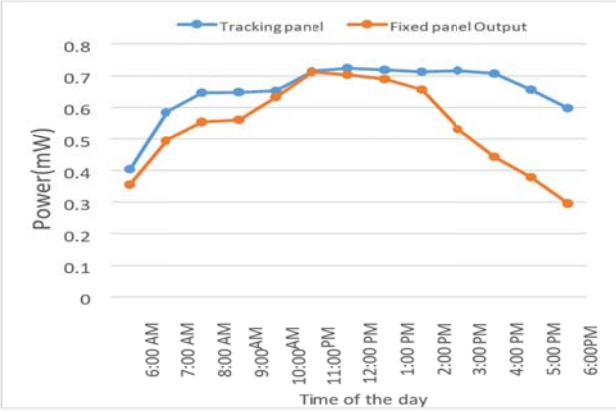


Figure 8: Power in function of time curve of a 4V PV panel

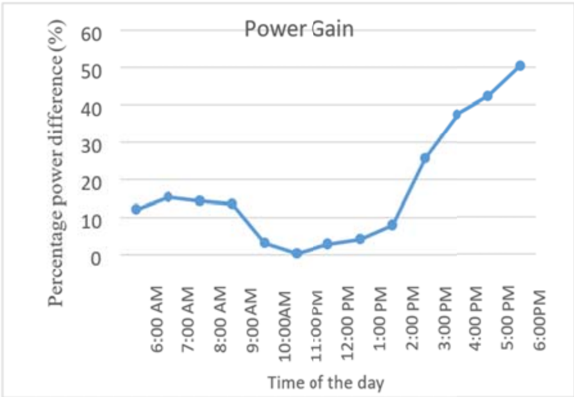


Figure 9: Curve of Power gain in function of time of of a 4V PV panel

From tables 1 and 2, and the characteristic curve in figure 9, it can be seen that the maximum sunlight occurs around midday, with maximum values obtained between 11:00 Pm and 12:00Pm for fixed panel while for tracking panel is from 11:00Am to 4:00Pm.

V. CONCLUSION AND FUTURE

This system we presented is a single axis solar tracker that can track the sun within 180º from East to West and we were able to obtain a power gain up to 50% when using solar tracker.

According to our experiment, the sun can provide almost twice as much energy to the PV consumers in the Northern part of Cameroon as it does to thus in the Littoral region.

Because a panel's output depends on the amount of solar energy it receives which most source of solar energy is from sun light, this means solar is a much better power source to be install in Northern part of Cameroon than in other parts of the country.

In future, further electronic and mechanical enhancement will be done to the prototype, to apply it in big scale as whereas, improve the system to be dual-axis.

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