An Artificial Intelligent Based Solar Tracking System for Improving the Power Output of a Solar Cell

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Abstract- This paper presented the use of artificial intelligent based neural network control tracking system for better harnessing of sun's energy. The sun tracking algorithm is developed to track sun position to receive maximum solar radiations. Robotic arm with four degree of freedom was used as a mechanical structure to position the solar cell under the sun for greater flexibility. The implementation of the artificial intelligent control solar tracking system was done while the testing was conducted through experimental measurement. From the result, the power output of solar cell placed on artificial intelligent robotic arm tracking system produced twenty percent increase when compared with that of fixed position solar cell.

Keyword- solar tracking, solar cell, neural network sun position

1. INTRODUCTION

The world demand of electrical power has been increasing rapidly every day. In Nigeria, the major source of electricity generation is through Hydro and thermal. The fact that the product of petroleum products and gases were converted into electricity makes the cost of petroleum products expensive in Nigeria, Aninuchi R. (2006). The sun being a renewable and unlimited source of energy has been found to be vital alternative. Extracting usable electricity from the sun was made possible by the discovery of the photoelectric effect and subsequent development of solar cell, a semi-conductive material that convert visible light into electricity directly. Researchers in the field of photovoltaic are faced with the task of looking for solutions that can make solar cells more efficient. One of the reliable ways that can enhance the power output of a solar is the use of solar tracking systems Armstrong S.S. (2005). Although our conventional tracking systems have their own limitation. Recently, new control technique and technological have appeared suggesting that new approaches could be found on the basis of intelligent mechatronic systems.

Since the maximum amount of solar energy, captured by the solar cell, is related to the accuracy for tracking sun’s position (Henry S. (2014), then a high efficient sun tracking controller should be considered. In previous years several methods have been proposed to improve tracking systems for following the trajectory of the sun based on orientation and tilt motion control Awachie L. (2003). These methods includes: optimizing tilt and orientation angles of solar cells by using geographical latitudes information Canberra. S. (2004), mathematical models Suugur . (2007), and tracking algorithms Henry S. (2004). In this paper, the most relevant and prominent control method, in solar applications have been introduced in the field of artificial intelligent which include; robotic arm tracking systems using neural network control based on light sensors, ambient temperature and electric load variations Hughes R.O. (2004). The characteristic of the solar radiation are constantly variable. The atmospheric conditions, the climate, the geographic characteristics, among others, are the most important to parameters that determine the solar radiation quantity that is received on a given point of the earth Romanaova P. (2012). The characteristics above were considered in the implementation of the robotic arm sun tracking system. Experimental results validate the performance of the tracking system.

2. SUN POSITION MODEL

The position of a point P on the earth’s surface with respect to the sun’s rays is known at any instant if the latitude, l, and hour angle, h, for the point, and the sun’s declination angle, d, are known. It is explained in Figure. 1
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Calculation of sun position must be made in terms of solar

Where

d=23.45 sin \(\frac{360}{365}(284+n)\)

The declination angle is given by

\(d = 23.45 \sin \left[\frac{360}{365}(284+n)\right]\) (degrees)

Where n is the day of the year.

3. CALCULATION OF CLOCK TIME AND SOLAR TIME

Calculation of sun position must be made in terms of solar
time. In order to know sun position, we are to convert local
clock time into solar time. The conversion between solar
time and clock time requires knowledge of the location, the
day of the year, and the standards to which local clocks
longitude) is known as Greenwich Civil Time or Universal

Such time is expressed on an hour scale from zero to 24.

Local Civil Time is found from the precise longitude of the
observer. On any particular meridian, Local Civil time is
more advanced at the same instant than on any meridian
further west and less advanced than on any meridian further
hour (4 minutes) of time for each degree difference in
longitude.

Clocks are generally set to give the same reading
throughout an entire area with a span of about 15 degrees
of longitude. The time kept in each such area or zone is the
Local Civil Time of a meridian near the centre of the area.
Such time is called Standard Time. In many parts of the
world, clocks are advanced beyond Standard time in
Daytime and such time is called Daylight saving time.

Time measured with respect to the apparent diurnal motion
of the sun is called Apparent Solar time, Local Solar Time,
or simply Solar time. A solar day is slightly different from
a 24 hours civil day due to irregularities of the earth’s
rotation, obliquity of the earth’s orbit and some other
factors. The difference between Local Solar Time, L-ST
and Local Civil Time, L-CT is known as the equation of
time.

The solar time and the clock time can be related as

\[L_{ST} = G + \left(\frac{1}{15}\right) (L_{STD} - L_{loc}) + EOT - DT\] \hspace{1cm} (1)

Where,

- \(L_{ST}\) = Local solar time [hr]
- \(C_T\) = Clock Time [hr]
- \(L_{STD}\) = Standard meridian of the local time zone.
- \(L_{loc}\) = Longitude of actual location [degrees west]
- \(EOT\) = Equation of time [hrs].
- \(DT\) = Daylight Savings Time correction. (DT=0 if not on

Daylight savings time, otherwise DT is equal to the number
of hours that the time is advanced for daylight savings
time, usually 1hr).

Values of the Equation of Time, E, are calculated as [2]

\[E = 0.165 \sin 2B - 0.126 \cos B - 0.025 \sin B \] \hspace{1cm} (2)

Where, \(B = \frac{360(n-81)}{364}\) and n is the day of the year.

Thus, in order to relate local solar time with clock time, we
are to consider two correction factors apart from daylight
saving time, which are longitude correction and equation of
time.

After calculating Local Solar Time, the solar hour angle, h
can be calculated. As hour angle varies by 15 degrees per
hour and as it is zero at solar noon, and negative before
solar noon, the equation for the hour angle can be given by

\[h = 15(L_{ST} - 12)\] \hspace{1cm} (3)

4. MODELLING OF SOLAR CELL

The simplified equivalent circuit of a solar cell consists of a
diode and a current source connected in parallel (Fig. 2.).
The current source produces the photocurrent \(I_{ph}\), which is
directly proportional to solar irradiance. The two key
parameters often used to characterize a solar cell are its
short-circuit current and its open-circuit voltage which are
provided by the manufacturer’s data sheet. The equation of
the current voltage $I_{pv} - V_{pv}$ simplified equivalent circuit is derived from Kirchhoff’s law.

We have

$$I_{pv} = I_{ph} - I_{D}$$  \hspace{1cm} (4)

Where

$$I_{D} = \frac{\alpha(V_{pv})}{e^{\alpha AKT} - 1}$$  \hspace{1cm} (5)

Thus

$$I_{pv} = I_{ph} . I_{D} = \frac{\alpha(V_{pv})}{e^{\alpha AKT} - 1}$$  \hspace{1cm} (6)

with $I_{ph}$ is the photocurrent that is equal to short-circuit current, $I_{D}$ (A) is the reverse saturation current of the diode, $\alpha$ is the electron charge ($1.602 \times 10^{-19}$ C), K Botzman’s constant ($1.38196 \times 10^{-23}$ J/K), A is diode ideality factor. $T_j$ is junction temperature of the panels (K), Id is the current shunted through the intrinsic diode.

$V_{pv}$ is the voltage across the solar cell.

$$I_{pv} = I_{sc} . I_{D} = \frac{\alpha(V_{pv})}{e^{\alpha AKT} - 1}$$  \hspace{1cm} (7)

We can determine the reverse saturation current $I_{D}$ by setting $I_{pv}$=0 (case when no output current).

$$I_{D} = \frac{V_{pv}}{I_{sc} . \frac{\alpha(V_{pv})}{e^{\alpha AKT} - 1}}$$  \hspace{1cm} (8)

Thus we obtain, taking into account the fact that, with this model, the photocurrent is equal to the short-circuit current:

$$I_{D} = \frac{V_{sc}}{\alpha AKT}$$  \hspace{1cm} (9)

5. DC TO DC CONVERTER MODEL.

The Boost converter can be modeled by the equations relations input and output, input and output voltage and current as follows Hughes R.O. (2004):

$$V_{out} = \frac{V_{in} \cdot I_{ph}}{F \Delta V_{out}}$$  \hspace{1cm} (10)

$$V_{in}$$ and $$V_{out}$$ are input and output voltages respectively F= switching frequency.

$\Delta I$ and $\Delta V$ are current and voltage ripples respectively.

6. ARTIFICIAL NEURAL NETWORK.

A neuron is a cell made up of a cellular body and a cone in which the cellular body ramifies to form the dendrites dendrites transfer the information between the neuron and the soma, body of the neuron. There is an intercellular space between the axon of the related neuron works like a valve controlling the rate of flow of information and is called as synapse. It is necessary to parameterize all these synapse to achieve a goal. The neural network works according to equation (13). $\sum_{i=1}^{n} W_{ij} x_{j}$

$$\partial_{\delta} = \sum_{i=1}^{n} W_{ij} x_{j}$$  \hspace{1cm} (14)

$w_{ij}$ = weight between the node i and j

$x_{i}$ = state variable evaluated by activation function.

Figure 3: shows the neural Network flow chart of the system operation.

7. IMPLEMENTATION OF ARTIFICIAL NEURAL NETWORK.

The technique we adopted in the implementation of Artificial Neural network is called perturb and observe (P and O) method. In this method, power output of the solar cell is monitored every cycle and is compared to its Value before each Perturbation is made. If a change (either positive or negative) in the duty cycle of the DC-DC converter causes output power to increase, the duty cycle is changed in the same direction. If it causes the output power
to decrease, then it is reversed to the opposite direction. Femia N (2005). Perturb and observe method is simulated in Math lab Simulink. Figure 3.2 shows the simulink model of solar intensity with time of the day. The model illustrates the variation of solar intensity with respect to time. The neutral network was trained to understand the behavior of solar radiations with time. This was done by using the values of measured solar radiations during the training process. Figure 3.3 shows the simulink model of robotic arm with four degree of freedom. The robotic arm was designed in such a way that the movement of the arm is controlled by neural network.

8. EXPERIMENTAL SETUP
This experimental work was performed at Abakpa Nike Enugu Nigeria. The Geographical location include:- Latitude between 6.20°N and 10.40°N and Longitude between 8.20°E and 11.50°W. In this experiment, a solar cell rating of 4w was used. The power output of the solar cell place on fixed position and that of solar cell placed on artificial Neural Network robotic tracking system was compared control.

The experimental measurement on this work was done in the month of June 2014. The experiment setup was shown in figure 6. Figure 7 shows the graph of values obtained.

CONCLUSION
A method for optimal use of solar energy generated has been developed. An advanced technology of artificial intelligent based on the neural network control or robotic arm tracking system was implemented. Experimental measurements, that validates the performance of the system was conducted. From the result, the power output of a solar cell placed on ANN robotic arm tracking system shows 20% increase when compared to that of solar cell placed on the fixed position.
REFERENCES


