International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 11, November-2014

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

Engr. F.U ILO, Prof. G.N. Onoh, Dr. J. Eke
Department of Electronic / Electronic Engineering
ESUT Enugu Nigeria

***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 grater 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, neutral network sun position**

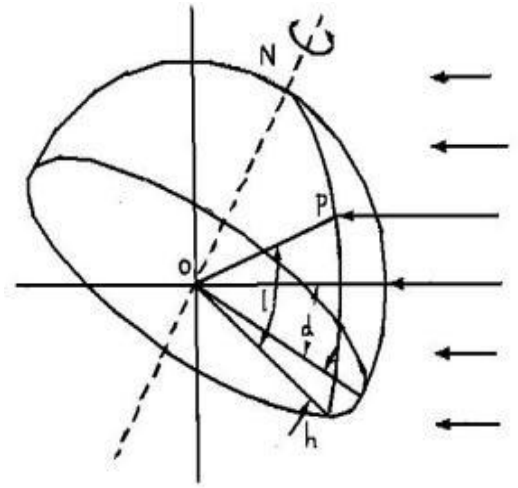
1. INTRODUCTION

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 trakectory 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



Figures 1: Latitude, hour angle and Sun's declination angles

(a) *Latitude*

Latitude, l, is the angular distance of the point P north (or south) of the equator. It is the angle between OP and the projection of OP on the equatorial plane Armstrong S. (2005). The centre of the earth is denoted by O. North latitudes are considered positive and south latitudes are considered negative.

(b). Hour Angle

The hour angle, h, is the angle measured in the earth's equatorial plane between the projection of OP and the projection of a line from the centre of the sun to the centre of the earth. It is measure from local solar noon, being positive in the morning and negative in the afternoon [Awachie .L. (2003). One hour of time is represented by 360/24=15 degrees of hour angle.

(c) Delination Angle

The plane that includes the earth's equator is called the equatorial plane. If a line is drawn between the center of the earth and the sun, the angle between this line and the earth's equatorial plane is called the declination. Henry .S. (2014).The declination is positive when the sun's rays are north of the equator and negative when they are south of the equator. At the time of dry season, the sun's rays are 23.5 degrees south of the earth's equator and the sun's rays are 23.5 degrees north of the earth's equator. At the time of the canney season, the sun's declination is zero at the two equinoxes [ ]. The declination angle is given by

d=23.45 sin [360/365(284+n)] (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 are set Ani K (2011). Time of Greenwich meridian (zero longitude) is known as Greenwich Civil Time or Universal Time. 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 east. [Armstrong .S (2005). The difference amounts to 1/15 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

$L_{ST} = G + (1/15)(L_{STD} - L_{loc}) + E_{OT} - D_T$……… (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].

D_T= 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 ……..(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 Suugur B (2007)

$h = 15(L_{ST} - 12)$………………………… (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

$I_{pv} = I_{ph} - I_d$------------------------------------- (4)

Where

$I_d = I_0 \left[\frac{q(V_{pv})}{eAKTj - 1}\right]$......................................(5)

Thus

$I_{PV} = I_{ph} - I_0 \left[\frac{q(V_{pv})}{eAKTj - 1}\right]$................................(6)

with I_{ph} is the photocurrent that is equal to short-circuit current, I_0 (A) is the reverse saturation current of the diode, q is the electron charge (1.602 x 10^{-19} C), K Botzman's constant (1.381910^{-23} J/K), A is diode ideality factor. Tj 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.

$I_{PV} = I_{sc} - I_0 \left[\frac{q(V_{pv})}{eAKTj - 1}\right]$.............................(7)

We can determine the reverse saturation current I_0 by setting I_{pv}=0 (case when
no output current).

$I_{ph} = 0$

$V_{pv} = V_{oc}$

$0 = I_{ph} - I_0 \left[\frac{q(V_{pv})}{eAKTj - 1}\right]$...............................(8)

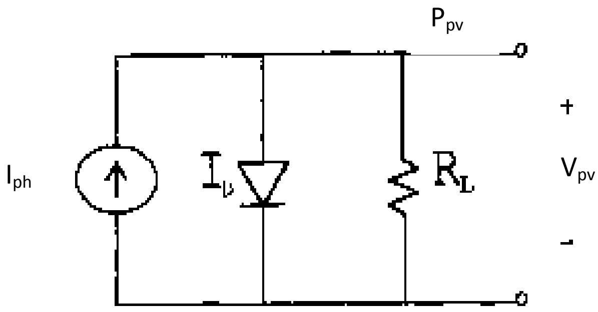


Figure 2: Solar Cell Model

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

$I_o = \frac{I_{sc}}{\left[q\frac{V_{oc}}{\frac{AKT}{e} - 1}\right]}$..(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):

$V_{out} = \frac{DV_{in}}{I-D}$ .... (10)

$V_{out} = \frac{(1-D)I_{in}}{D}$ .... (11)

The inductor (L) and capacitor (C) values are calculated by using equation (a) and (b) respectively

$L = \frac{(V_{out} - V_{in})V_{in}}{F\Delta IV_{out}}$................................ (12)

$C = \frac{(V_{out} - V_{in})V_{in}}{F\Delta IV_{out}}$.................................(13)

V_{in} and V_{out} are input and output voltages respectively F= switching frequency.
ΔI and ΔV are current and voltage ripples respectively

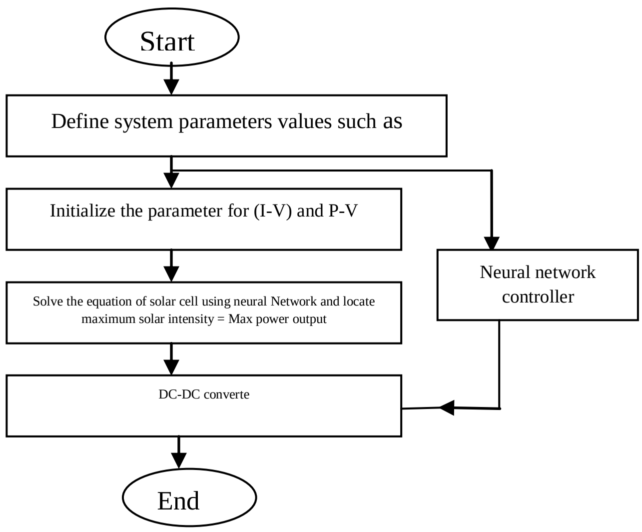
6. ARTIFICIAL NEURAL NETWORK

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)

$\partial_i = \sum_{j=i}^{n} W_{ij}\, x_j$ .... (14)

∂_i = output of neural network at mode i
wi_j = weight between the node i and j
x_j = state variable evaluated by activation function.

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



Figures 3: Flow chart of the system.

7. IMPLEMENTATION OF ARTIFICIAL NEURAL NETWORK.

The technique we adopted in the implementation of Artificial Neutral 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.

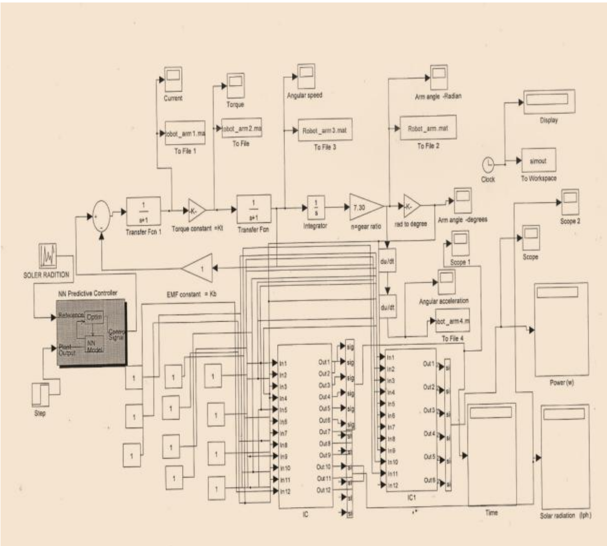


Figure 4: Shows the Simulink Model of Robotic Arm with Four Degree of Freedom

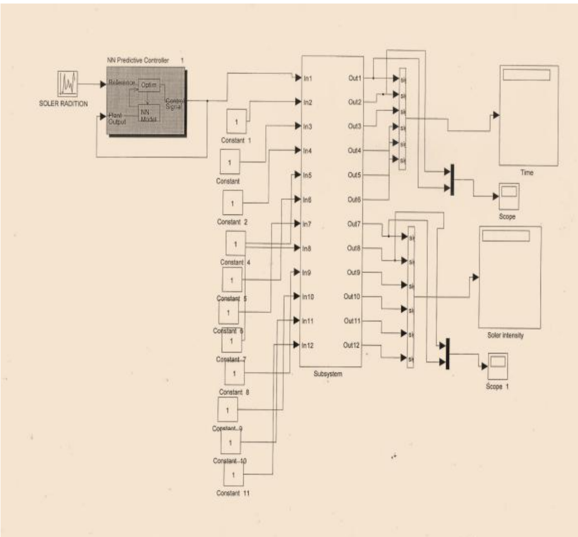


Figure 5: Shows the Simulink Model of Solar Intensity with Time of the Day

8. EXPERIMENTAL SETUP

This experimental work was performed at Abakpa Nike Enugu Nigeria. The Geographical location include:- Latitude between 6.20^0N and 10.40^0N and Longitude between 8.20^0E and 11.50^0W. 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.

Figure 6: Test Bed for Measurement Set Up

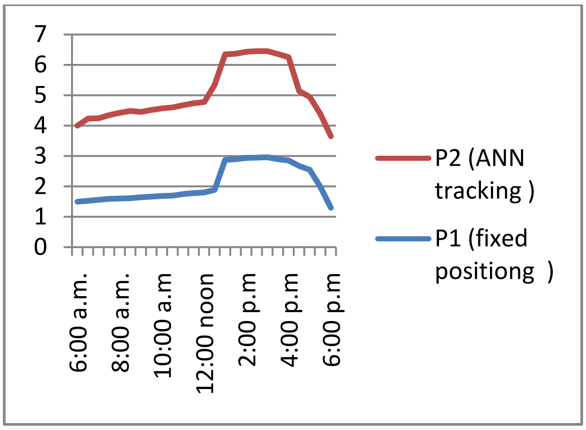


Figure 7: Graph of Power Comprision between p_1 and p_2

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

1. Ainuchi R. (2006): "Grid Connected Photovoltaic Generation System with Adaptive Step- Perturbation method and active sun tracking Scheme" IEEE.
2. Ani K. (2011) "Simulation Model of ANN based Maximum Power Point tracking controller for solar PV system" Solar Energy material and solar cell pages(4) 773-778.
3. Armstrong .S (2005)' "Sun-Tracking System with PLC Control for Photo-Voltaic Panels" International *Journals of Green energy,* pages (): 635-643.
4. Awachie .L. (2003): "Solar Energy in Progress and Future Research Trends". USA Addison Wesley Publishing.
5. Canberra S. (2004): "Design of a Traditional Solar Tracking System". AIP Conference Proceedings 6/15/2004 page 151-158.
6. Femia N. (2005) "Optimization of perturb and Observe Maximum power point tracking method". IEEE Transaction on Power Electronics pages 963-973.
7. Henry S. (2014): "Maximum Power Tracking for Photovoltaic Power System: Development and Experimental Comparison of two algorithms. Renewable Energy, 35, 2381-2387.
8. Hughes R.O. (2004): "Robust Tracking and Model following the certain dynamic Delay systems by Memoryless Linear Controllers". IEEE Transactions on Automatic Control, page 1473-1481.
9. Romanaova P. (2012): "Theoretical Investigation of Energy Gain by Absorption of Solar Radiation in Clouds pergamon Press England.
10. Suugur B. (2007): "A Modified Tracking Algorithm for Maximum Power Tracking of Solar Array. Energy Conservation and Management, page (s) 911-925,