International Conference on Mechanical, Industrial and Energy Engineering 2018
23-24 December, 2018, Khulna, BANGLADESH

ICMIEE18-183

An Automatic Solar Tracking System Using Programmable Logic Controller

M. E. Hoque, F. Rashid, S. Shahriar, M. K. Islam*
Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, BANGLADESH

ABSTRACT

Recent research shows that about 36% more energy can be obtained by tracking the motion of sun by using solar panel as compared to soar panel at fixed position. In this paper, the tracking process is governed and controlled by programmable logic controller (PLC) where two stepper motors are used to guide the motion of the solar panel in azimuth and elevation angle. The azimuth and solar altitude angles of sun were calculated at 24.3636ºN, 88.6241ºE (Rajshahi, Bangladesh). It is observed that automatic solar tracking is providing better performance than fixed solar panel and maximum surplus energy was obtained about 36%. The experimental results are obtained for the voltage-current characteristics and power generation at the output of solar panel both for tracking and without tracking. An automatic solar tracking system can easily be employed in industry and suitable for mass energy production.

Keywords: Tracking system, programmable logic controller, solar panel, azimuth angle, elevation angle.

1. Introduction

Human is the biggest driver of energy demand. Population and economic growth will drive higher but the world will use energy more efficiently and toward lower- carbon fuels. Most of the countries rely heavily on coal, oil, and natural gas for its energy. Fossil fuels are non-renewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. Finding sufficient supplies of clean energy for the future is one of society's most daunting challenges. Alternative renewable energy sources such as sun energy can be substituted for exceeding human energy needs[1]. In contrast, the many types of renewable energy resources-such as wind and solar energy-are constantly replenished and will never run out. Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses [2]. Renewable energy is simple enough; the electricity we need every day, created by sources that are naturally replenished. There is no definition of what renewable energy is and debate rages about which sources can produce renewable energy. The sun is regarded as the source of energy for its constant duration and hygienic state, and its remarkable efficiency of not polluting the environment, as other kinds of energy, like coal and the derivations of oil that cause the pollution of atmosphere and environment[3].

Solar energy is intermittent and changeable. Daily and seasonal changes in solar energy are possible. Furthermore, the radiation amount of solar energy is determined by atmospheric conditions. Because of all these characteristics, certain solar energy applications require the storage of energy. When compared to other conventional sources of energy, solar energy has a low density. However, it is possible to convert solar energy into mechanical or electrical (as in the PV in example) energy with adequate efficiency [4].

Solar energy conversion is widely used to generate heat and produce electricity. A comparative study on the world energy consumption released by International Energy Agency (IEA) shows that in 2050, solar array installations will supply around 45% of energy demand in the world [5] .Solar cells are systems which are composed of semiconductor materials and which convert solar energy directly into direct current electrical energy. The amount of electrical energy which will be obtained from PV systems is directly proportional to the intensity of the sun light which falls on the panel. A solar collector or photo-voltaic module receives the maximum solar-radiation when the sun's rays strike it at right angles. Tilting it from being perpendicular to the sun will result in less solar energy collection by the collector or the module. Therefore, the optimal tilt angle for a solar energy system depends on both the site latitude and the application for which it is to be used [6]. However, the change observed in sun light does not occur linearly, for this reason it is desired that the solar panels be fixed in way that they face the sun or that they have a system which tracks the sun. Sun-tracking systems are designed in a way to track the sun on a single axis (according to the azimuth angle) or in a way to track the sun on both axes (according to the azimuth and solar altitude angles) [7]. As the sun position changes throughout the day, the solar system must be adjusted so that it is always aimed precisely at the sun and, as a result, produces the maximum possible power [8]. Various studies were conducted on sun-tracking systems by using a number of different methods. The solar tracking system can be controlled by Programmable Logic Controller (PLC). The calculated required positions of the tracking surface are determined in the PLC. The PLC controls the actuator, which, in turn, moves the tracking surface into the calculated positions [9].

* Corresponding author. Tel.: +88-01
E-mail addresses: frrashed10@gmail.com

PLC is used as a device for controlling the output for the motor. If the sun is not visible during a short period due to cloudy weather, the PLC is set with a program which will engage the motor rotation to halt which only will be reactivated due to a sensor which will detect availability of the sun to continue its next cycle. In this experiment PLC-100 trainer is used. It has the following specification [10]:

- AC power supply (100V-240VAC,50/60Hz)
- PLC main unit (Fatek FBs 24MC)
- Digital input(14points)
- Digital output (10 points)
- Support 16high speed counter
- Support 0.1 ms high speed counter
- Execution speed (Average): 0.33 micro seconds/sequential instruction
- Four communication port (USB, RS-232, RS-485, Ethernet, Expansible up to 5 ports
- One 4-digit thumb wheel switch
- One stepped motor
- One encoder
- One 24dc motor
- One micro switch
- One buzzer
- One 4*4 keypad
- One 24-dc expansion power
- Provide I/O module expansion port& DIO extension port
- traffic light control module
- tank filling device module

2. Methodology

The factor in which design criteria depends are dimension of the panel, capacity of the panel, weight of the panel, selection of structural material, selection of stepped motor and space available.

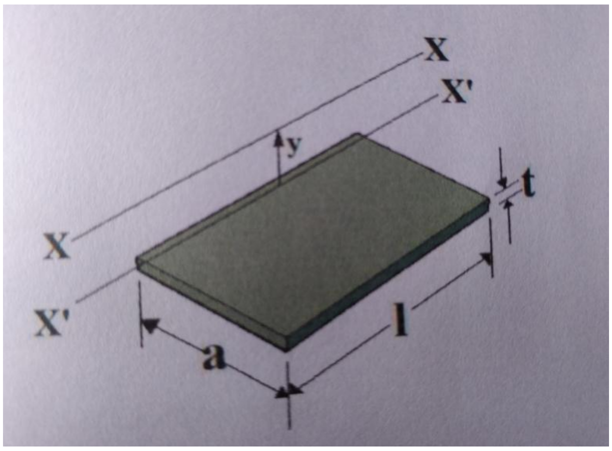

Fig. 1: PV panel

Length, l=0.1651m
Width, a=0.1397m
Thickness, t=0.0089m

Programmable Logic Controller (PLC) is a special computer device used in industrial control systems. Due to its robust construction, exceptional functional features like sequential control, counters and timers, ease of programming, reliable controlling capabilities and ease of hardware usage – this PLC is used as more than a special-purpose digital computer in industries as well as in other control-system areas [11], The main purpose of this project is two. One is control the solar panel and other is to obtain the maximum output from the solar panel by tracking with PLC. It has 14 digital input and 10 digital outputs. At first a ladder diagram was downloaded to PLC which is based on timer. The timer setup in such a way that the panel will turn 15º per hour. In this experiment, two stepper motor is used each having 5 wires.

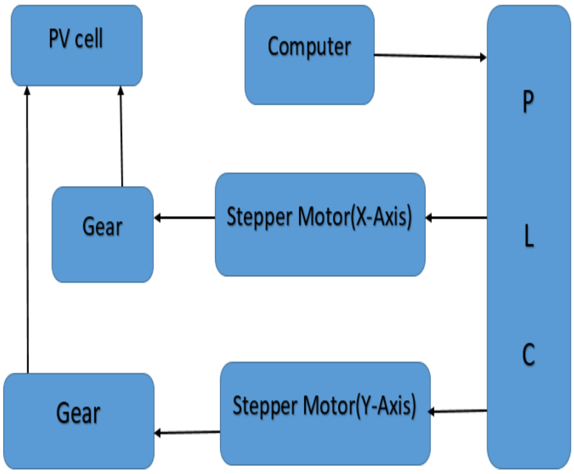

Fig.2: Schematic arrangement of the project

The polarity of the motor is White>Ash>Violate>Green>Blue and another motor is Gray>Black>Red>Orange>yellow. The wires are connected to the output port of the PLC. After checking all the connection with PC, PLC and stepper motors, the program is initialized and makes it online to the PLC. Then run the program and turn on the input switch. Then the solar panel will start moving according to program and getting required tracking values from multi-meter.

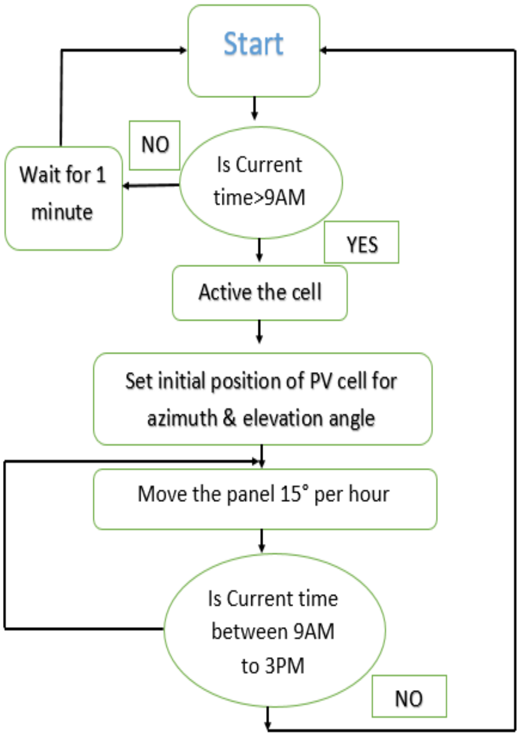

Fig. 3: Flow chart of working process

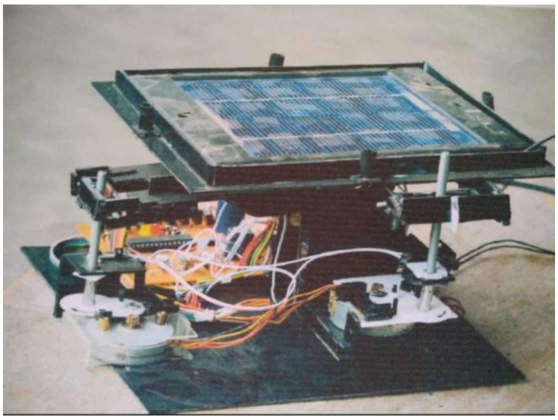

Fig. 4: Designed solar tracker

Designed solar tracker consists of two stepper motor,rack,pinion, light sensor and flexible stand. Flexiblestand holds the solanr panel. Stepper motor from the two side of the panel rotate the pinion so that the panel can turn in a desired angle with the help of the rack.

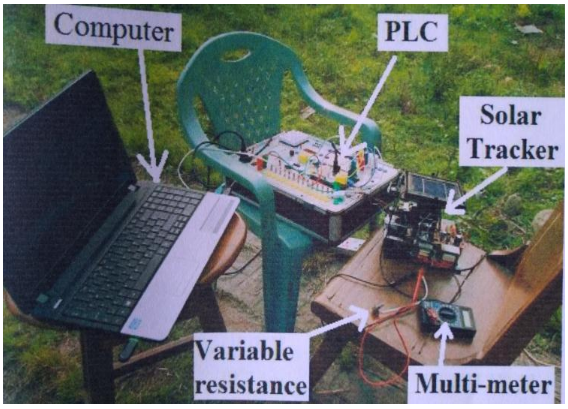

Fig. 5: Experimental setup

Experimental setup consists of a computer, PLC, solar tracker and a multimeter. When direction of sunlight changes the sensor mounted will identify a change in the intensity of light. The sensor output and corresponding program logic will then force the solar panel to adjust accordingly in the direction of high intensity of sunlight by using stepper motor, pinion and rack. PLC is controlled and programmed by using a computer.

3. Results & Discussion

Figure 6 shows the tracking results with and without using programmable logic controller.

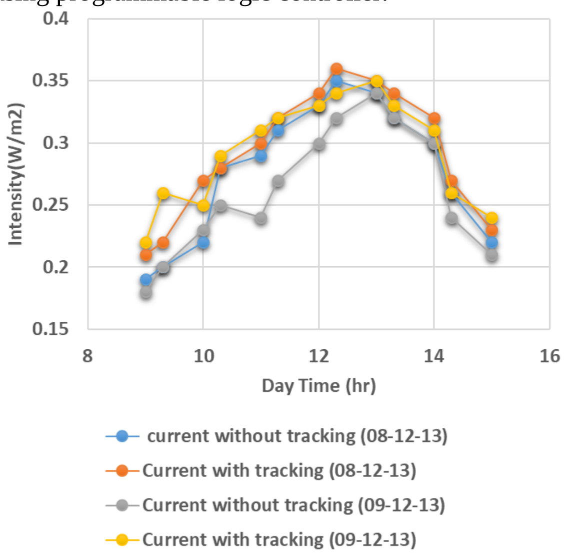

Fig.6: Intensity Vs Day Time Curve

Figure 6 shows the relation between daytime and intensity. At the beginning of the day the intensity of light is low. As hour advances the intensity of light increases and becomes maximum in the afternoon period after that intensity decreased. Figure 6 also represents that with tracking system using programmable logic controller, the intensity is greater compared to without tracking system.

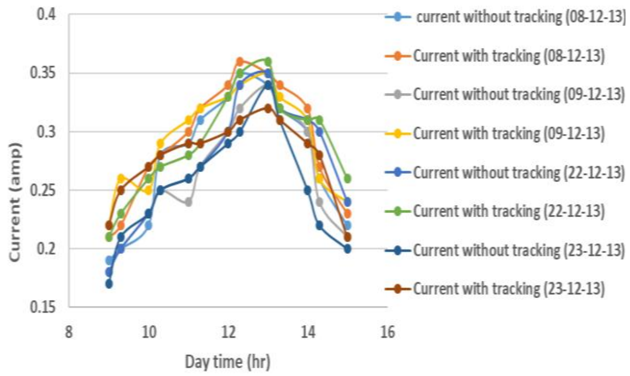

Fig.7: Current vs Day Time Curve

Figure 7 shwos the day time vs current relation. As the day advances the amount of current that are producd is increasing. Tracking solar panele produed more cuurrent as compared without tracker panel. Since tracking panel changes it's direction with respect to high intensity of sunlight.

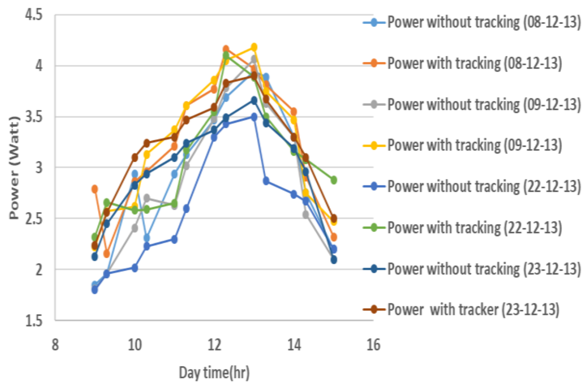

Fig.8: Power vs Day Time Curve

Figure 8 shows the relation between day time and power. It is seen that the power produced is maximum in the afternoon and after that it decreased gradually. Tracking panel produces more power than the panel without tracker.

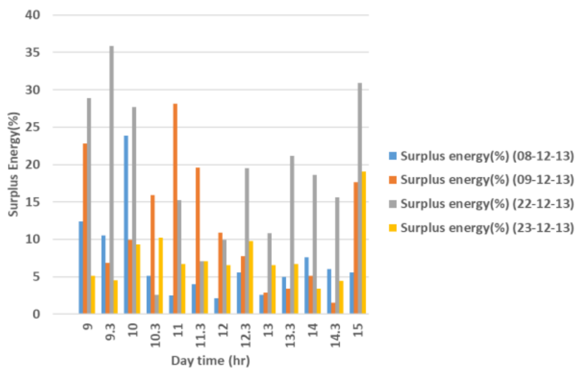

Fig.9: Surplus energy vs Day time

Figure 9 shows the relation between surplus energy and day time for various days.

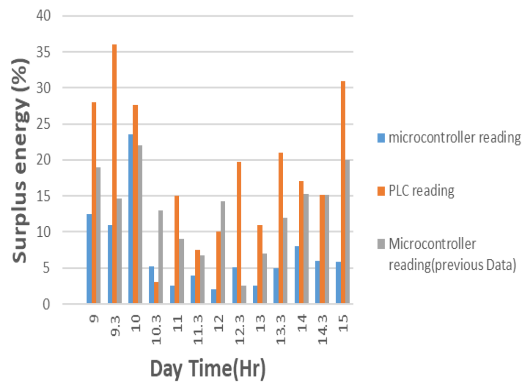

Fig.10: Comparison curve of surplus energy

Figure 10 shows the comparison of surplus energy based on micro controller reading, PLC reading and micro controller reading (previous data). From the graph it is seen that higher surplus energy from reading and lower value gets from micro controller reading (previous data), from the experimental results of variation of intensity with day time characteristic it is seen that solar irradiation increases with day. Time up to 12.30PM and then decreases and also there are some fluctuations of intensity due to flow of some cloudy sky and abnormal atmosphere. Therefore, during the central part of the day, the output fall of the solar cell will be at or near its maximum because the sun light is arriving at a regardless of the orientation of the solar cell, mainly because the sunlight has to travel obliquely through the atmosphere at these times, arriving at a low angle. This decreases the intensity of the sun.

Also since the sun travels through an angle of 15º per hour, it becomes close to perpendicular to the collector for a period of approximately 2 hours. Beyond this time the intensity of the sunlight decreases due to the increase in air mass. The angle between incident sunlight and the normal to the collector increases. These two factors cause the energy collected by the collector to decrease relatively rapid during the hours before 10AM and after 1.30PM. As a result, there are some fluctuations on PV cell characteristics

4. Conclusion

An automatic solar tracking system has been developed to study the effect of tracking system in capturing solar power. In this experiment a panel tracker has been developed to increase the amount of power generated by the solar panel as the sun traverses across the sky. A PLC was used to control the movement of the solar panel. Without the tracking system the amount of solar intensity capturing is lower than the solar intensity with using PLC tracking system. From this paper it is seen that without tracking system the maximum amount of power developed is 3.5 W/hr, on the other hand with tracking system the maximum power developed is 4.5 W/hr. In case of surplus energy, without tracking system the amount of surplus energy is lower than the surplus energy with tracking system.

REFERENCES

[1] H. Mousazadeh, A. Keyhani, A. Javadi, H. Mobli, K. Abrinia, and A. Sharifi, "A review of principle and sun-tracking methods for maximizing solar systems output," *Renew. Sustain. Energy Rev.*, vol. 13, no. 8, pp. 1800–1818, 2009.

[2] "Importance of Renewable Energy and Types of Renewable Energy Resources." [Online]. Available:https://www.renewableenergyworld.com/index/tech.html. [Accessed: 17-Sep-2018].

[3] S. Abdallah and O. O. Badran, "Sun tracking system for productivity enhancement of solar still," *Desalination*, vol. 220, no. 1–3, pp. 669–676, 2008.

[4] C. Sungur, "Sun-tracking system with PLC control for photo-voltaic panels," *Int. J. Green Energy*, vol. 4, no. 6, pp. 635–643, 2007.

[5] S. Mekhilef, R. Saidur, and A. Safari, "A review on solar energy use in industries," *Renew. Sustain. Energy Rev.*, vol. 15, no. 4, pp. 1777–1790, May 2011.

[6] A. Al-Mohamad, "Efficiency improvements of photo-voltaic panels using a Sun-tracking system," *Appl. Energy*, vol. 79, no. 3, pp. 345–354, 2004.

[7] C. Sungur, "Multi-axes sun-tracking system with PLC control for photovoltaic panels in Turkey," *Renew. Energy*, vol. 34, no. 4, pp. 1119–1125, 2009.

[8] S. Abdallah and S. Nijmeh, "Two axes sun tracking system with PLC control," *Energy Convers. Manag.*, vol. 45, no. 11–12, pp. 1931–1939, 2004.

[9] S. Abdallah, "The effect of using sun tracking systems on the voltage-current characteristics and power generation of flat plate photovoltaics," *Energy Convers. Manag.*, vol. 45, no. 11–12, pp. 1671–1679, 2004.

[10] "FBs-24MA◇Δ–◎-C / Products / FATEK AUTOMATION CORP." [Online]. Available: http://www.fatek.com/en/prod.php?act=view&no=4. [Accessed: 17-Sep-2018].

[11] "PLC Working Principle with Industrial Applications." [Online]. Available: https://www.edgefx.in/industrial-applications-of-programmable-logic-controller/. [Accessed: 17-Sep-2018].