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Microcontroller based maximum power point single axis Tracking System

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Abstract

Positioning a photovoltaic (PV) panel in the plane of maximum irradiation can increase the power output up to 57%. An automatic microcontroller based system for maximum power point tracking (MPPT) was designed and analyzed. The system was based on positioning the PV panel perpendicular to the solar irradiation. Photosensors were used to measure the difference of solar radiation intensity among three planes. The tracking system used an 8051 microcontroller to control a stepper motor which rotated the panel towards the plane with highest radiation intensity. The MPPT system was found to be 25.9% more effective in capturing solar power than a fixed panel with the same rating. This system would be useful to increase the power output of currently operating solar panels with minor modifications in mounting.

Keywords: Heliotracker; Solar tracking; 8051 microcontroller; Solar cell mounting.

Introduction

Tracking system for solar panels follow the path of the sun to maximize the exposure of the panels to solar radiation in order to convert sunlight to energy. In the case of a fixed solar collector the projection of the collector area into the plane perpendicular to the radiation direction, is given by the cosine of the angle of incidence (Fig. 1). The higher is the angle of incidence, the lower is the power. The solar tracker, a device that keeps photovoltaic or photo thermal panels in an optimum position perpendicular to the incident solar radiation during daylight hours, can increase the collected energy by up to 57%.

Theoretical calculation of the energy surplus in the case of tracking collectors is as follows: assuming the maximum radiation intensity is I=1100 W-m^2 falling on the area which is oriented perpendicularly to the direction of radiation. It is assumed, the day lengths t=12h=43000s as well as the night length and it is compared, the tracking collector which is all the time optimally oriented to the sun with the fixed collector which is oriented perpendicularly to the direction of radiation only at noon. Mark the collector area S_0.

a) For fixed collector: The projection of this area on the area, which is oriented perpendicularly to the radiation direction,

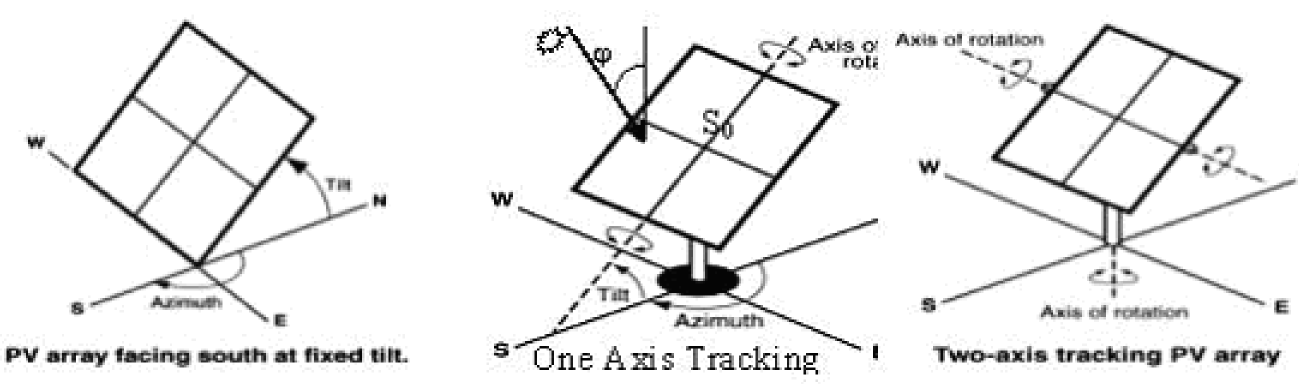

Fig. 1. Fixed PV array, one axis tracking and two axis tracking PV array.

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is equal $S = S_0.\cos\ \varphi$ and the angle φ is changing in the intervale $\varphi\varepsilon[\pi/2,-\pi/2]$ during the day. The angular velocity of the sun moving cross the sky is equal $\omega = 7.27\times10^{-5}s^{-1}$ and the differential of the incident energy is equal dW=I.S dt. When we do not consider the atmospheric influence, we can calculate the incident energy on the collector with area $S_0=1m^2$ during one day

$$w = \int_{-21600}^{+21600} I.S_0.\cos\omega t dt = I.S_0\left[\frac{\sin\omega t}{\omega}\right]_{-21600}^{+21600} = \frac{2I.S_0}{\omega}$$

$$= 303.10^7 W.s......................(1)$$

b) For the tracking collector which is all the time optimally oriented to the sun we calculate: When it isn't considered the atmosphere influence, it can be calculated the energy, which is fallen on the collector area $S_0=1m^2$ during one day

$W = I.S_0 t = 475.\ 10^7\ W.s$ .... (2) (Since $\varphi = 0^{O}$)

Comparison Eq. (1) and Eq. (2) shows the energy surplus 57% when it isn't considered the atmosphere influence. It would be really obtained this surplus for example on the Moon surface.

Materials and methods

Tracking algorithm

The tracking algorithm depended on maximization of incident light intensity on a sensor in the same plane of the solar panel with respect to two sensors on planes declined at 150 on each side. (Fig. 2, 3) The intensity was converted into digital form using ADC. Then the values were compared by a microcontroller. Afterwards the solar panel was rotated clockwise or anticlockwise 0.4^{O} if the intensity of incident light was higher on either side than the solar panel. (Fig. 4)

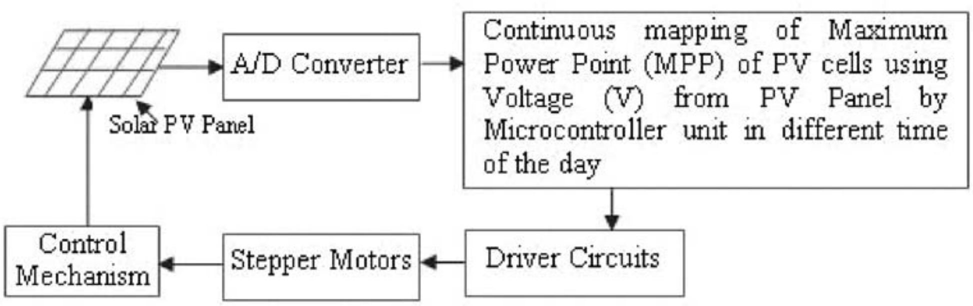

Fig. 2. Block diagram of the designed system.

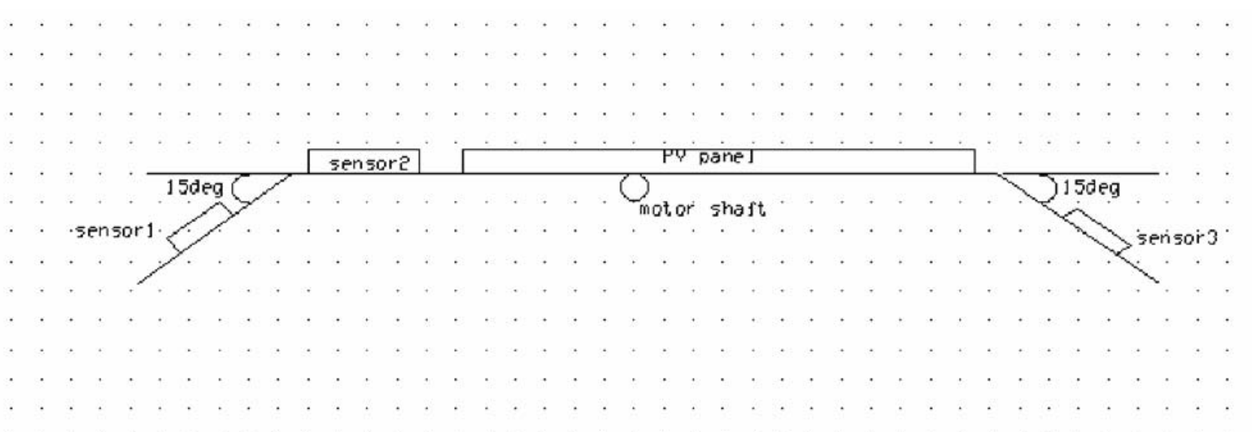

Fig. 3. Positioning of sensors and PV panel in the tracking setup

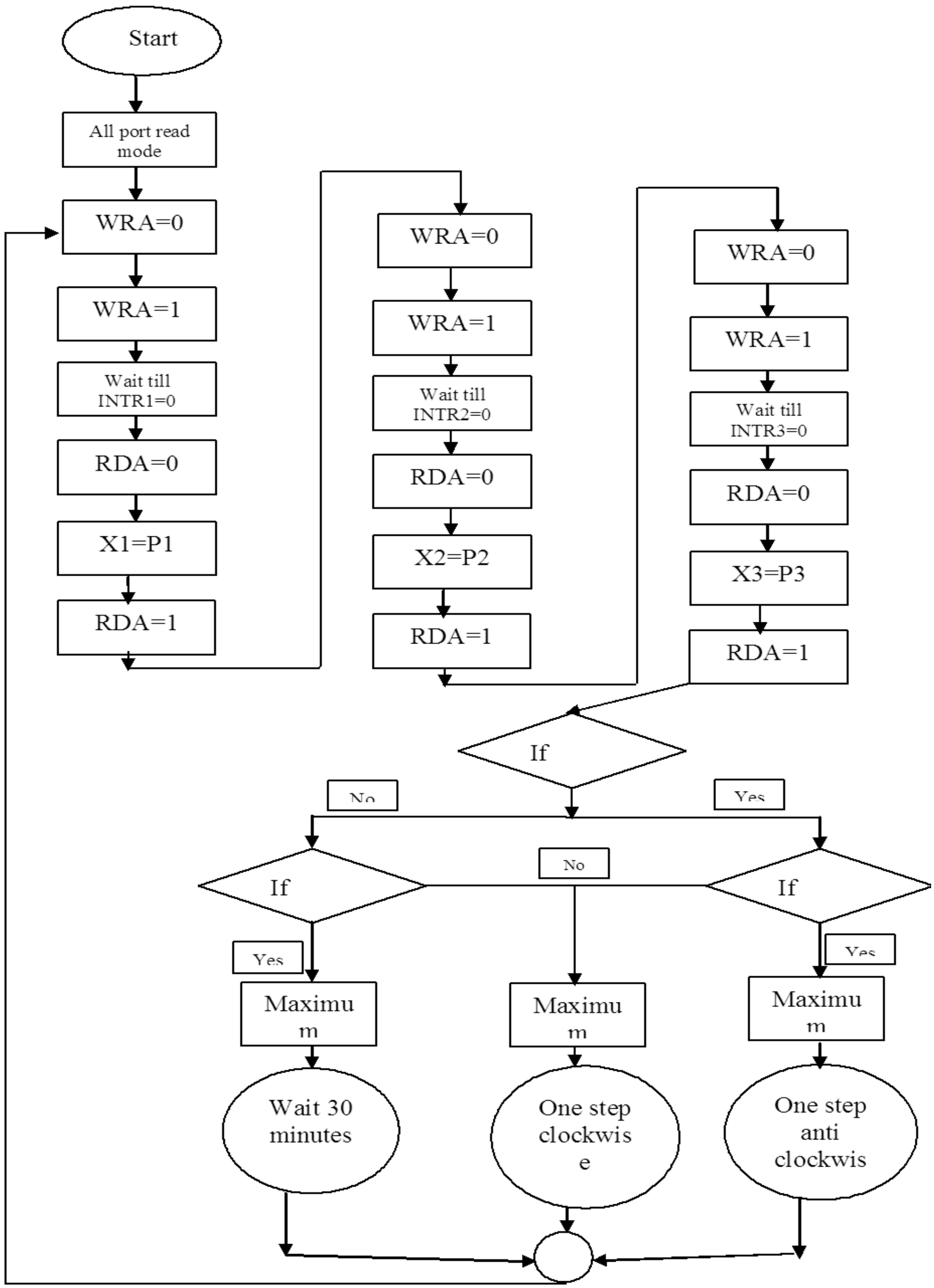

Fig. 4. Flow chart for algorithm of MPPT

Design of Automatic Solar Tracking System

Components

The main components of the control circuit are

(1) sensor with ADC (ADC0804)

(2) stepper motor driver (ULN2003)

(3)AT89C51ED2 microcontroller (ADC0804 2008, ULN2003 2008, AT89C51ED2 2008)

Assembly

The components were assembled according to the schematic diagram following standard interfacing procedures advised by their manufacturers (ADC0804 2008, ULN2003 2008, AT89C51ED2 2008, Mazidi *et al.,* 2006) (Fig. 5)

Code

The code [additional material] was written and compiled in microvision (KEIL 2008) . Then hex file was downloaded to microcontroller with ATMEL Flip (FLIP 2008).

Observation

The system was placed at the open field in the Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh whose coordinate is 24º22'00˝ N 88º35'60˝ E. Surface temperature of the panel, incident solar radiation intensity were recorded from 08.30am to 02.00pm for 28 days of them 17 days were partially cloudy .The data presented here is the average of 17 sunny days.

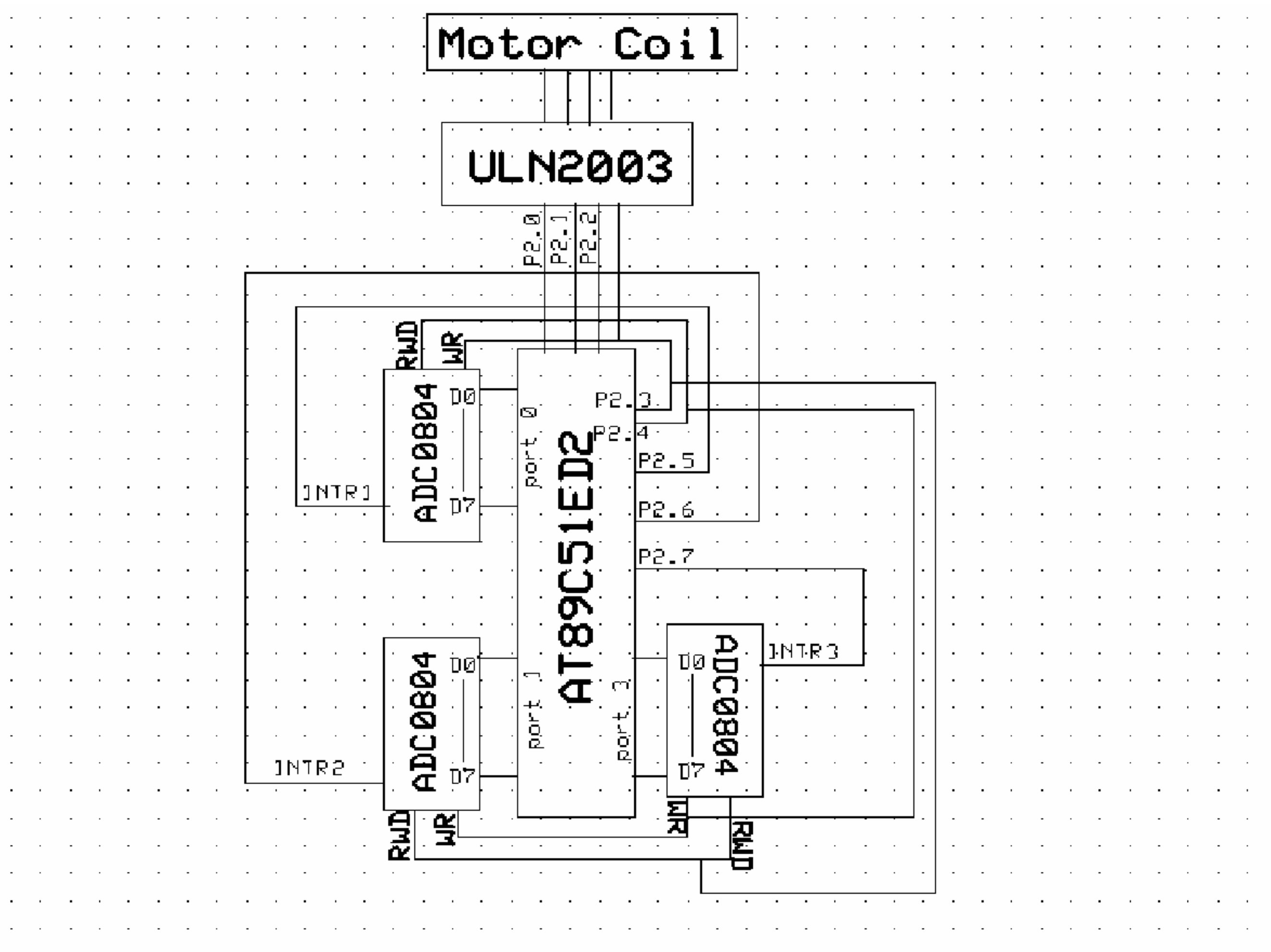

Fig. 5. Schematic diagram of the used circuit

Result anddiscussion

The incident angle of solar radiation changes at different time of the day. The intensity of incident solar radiation increases upto midday and gradually decreases upto sunset. (Fig. 6). The power output of both tracking and stationary panel followed the same pattern while the output from the tracked panel was higher. (Fig. 7).The efficiency of the tracked panel was higher when the incident solar radiation was more oblique. Nearly vertical incident light during mid-day gave the least efficiency. The efficiency of tracked panel was highest during early and late hours of the day. (Fig. 8) The maximum efficiency recorded during early morning was 57.2% while the average efficiency was 25.9%.

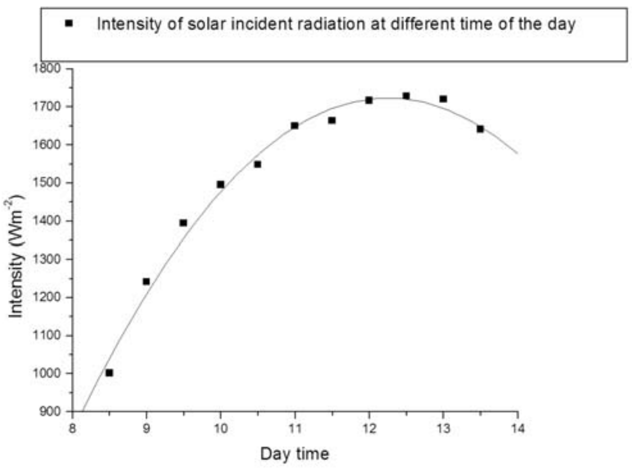

Fig. 6. Intensity of solar incident radiation at different-time of the day

MPPT is an important feature for PV panel based solar power sources. This makes possible to get the maximum power output from a given solar PV panel at a given incident solar radiation intensity.

The tracking mechanism is capable of tracking the Sun according to the time and it is possible to adjust the panel for accuracy of tracking adjustment is not needed in the circuit.

The power consumption by the system is low because of low energy consumption devices are used like as digital IC's and other electronic components. Moreover the motor also consumes a small amount of energy because it rotates only for a fraction of a minute at every interval of time. It is possible to face the panel always perpendicular to the Sun's incident rays by the software control circuit. This provides the tracked panel greater flexibility.

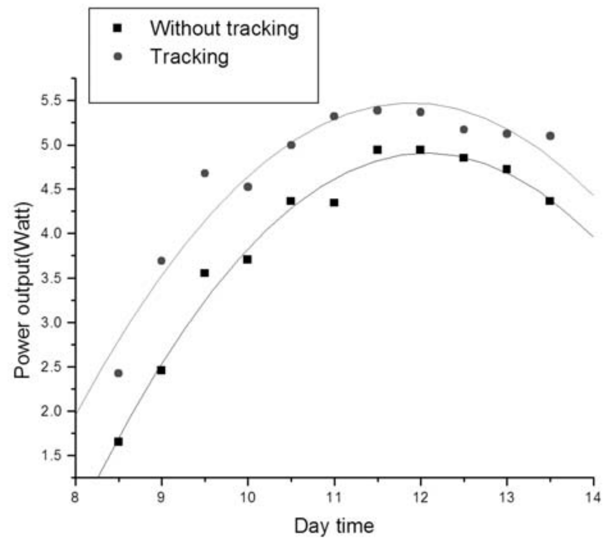

Fig. 7. Power output of tracked and stationary PV panel at different day time

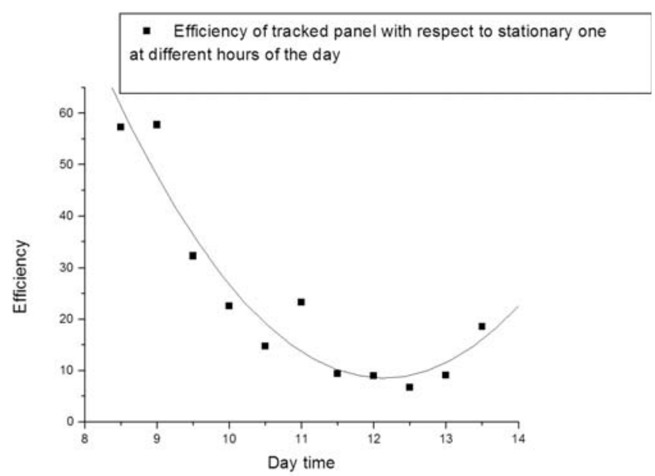

Fig. 8. Efficiency of tracked panel with respect to stationary one at different hours of the day

Conclusion

The output of the tracked panel was higher than the stationary panel all over the day time. The efficiency was higher during early and late hours. The overall efficiency of the tracked panel was 25.9%. This is a significant improvement of power output gained by modification of setup only. This tracking may however still be improved by two axes tracking which would allow adjustment for annual variation of incident angle.

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