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Microcontroller Based Smart Solar Tracking System

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Abstract: Main motivation of this project is to design microcontroller based solar intensity collection system. In this system, parabola dish mounts to follow the path of the sun during the day to maximize the solar radiation that the parabola receive. There are two types of solar panel mount in tracking system that is directly using photovoltaic (PV) or indirectly using concentrated solar power (CSP). CSP systems use lenses, mirror or parabola dish and tracking systems to focus a large area of sunlight into a small beam. The microcontroller will control the whole tracking system. The parabola dish and light dependent resistor (LDR) are used as a sunlight sensor.

Keywords: Microcontroller, CSP, Parabola Dish, Solar Intensity, Sunlight Sensor.

I. INTRODUCTION

Solar energy is used as renewable energy source and is most unlikely to vanish. These days electrical generation is typically provided by fossil fuels such as coal, natural gas, and oil and also as nuclear power [1]. Some of today's most serious environmental problems can be linked to world electricity production based primarily on the use of non-renewable resources. One solution for these problems are renewable energy in the form of photovoltaic (PV) systems. Concepts related to the solar energy have constantly been under heavy research and development. The basic objective is to optimize the energy produced from photovoltaic cells, by making the overall systems more efficient and cost effective. Most solar panels are statically aligned; they have a fixed position at a certain angle towards the sky.

Therefore, the time and intensity of direct sunlight falling upon the solar panel is greatly reduced, resulting in low power output from the photovoltaic (PV) cells. Solar tracking system is the solution to this issue as it plays a major role in overall solar energy optimization. In order to ensure maximum power output from PV cells, the sunlight's angle of incidence needs to be constantly perpendicular to the solar panel. This requires constant tracking of the sun's apparent daytime motion, and hence develops an automated sun tracking system which carries the solar panel and positions it in such a way that direct is always focused on the PV cells [2].

This paper is about moving a solar panel along with the direction of sunlight; it uses a gear motor to control the position of the solar panel, which obtains its data from a PIC16F877A microcontroller. The objective is to design and implement an automated, double–axis solar-tracking mechanism using embedded system design in order to optimize the efficiency of overall solar energy output [3]. Light dependent resistor (LDR) is used to know the actual sun position as sensor. LDR is basically photocells that are sensitive to light. Software will be developed which would allow the PIC to detect and obtain its data from the LDR and then compare its resistance at each position. The MCU will detect the difference in resistance and thus actuate the motor to move the solar panel at a position where the light upon LDR is the most.

Figure1. Photo of dual axis maximum solar intensity solar tracker.

Section II provides system block diagram of solar tracking system; section III includes the design of solar tracker. Section IV describes main components of tracking system. Section V is software implementation of the tracking system. Section VI contains algorithm of solar intensity tracking system. Finally, circuit design of solar tracker is shown in section VII and conclusions and future work conclude in section VIII.

II. SYSTEM BLOCK DIAGRAM OF SOLAR TRACKING SYSTEM

The overall block diagram of the system is shown in Figure2.There are two main parts: maximum solar intensity tracking section and solar panel positioning section. The PIC microcontroller is a very common component in modern electronic systems. Not only is the cost of modern microcontroller based system decreasing but also the performance is raising daily. The four Permanent Magnet stepper motors will be used as actuators in this system. Two stepper motors are used to set the vertical and horizontal axis of the maximum solar intensity tracking section and other two motors are used in solar panel positioning section. Nowadays, a control system will be necessary for all electronics devices. Solar tracking control system is necessary for domestic and rural areas. In this research as a sensor is used because it is suitable for the proposed system and it has low cost. Especially in this paper, maximum solar intensity tracking section is shown.

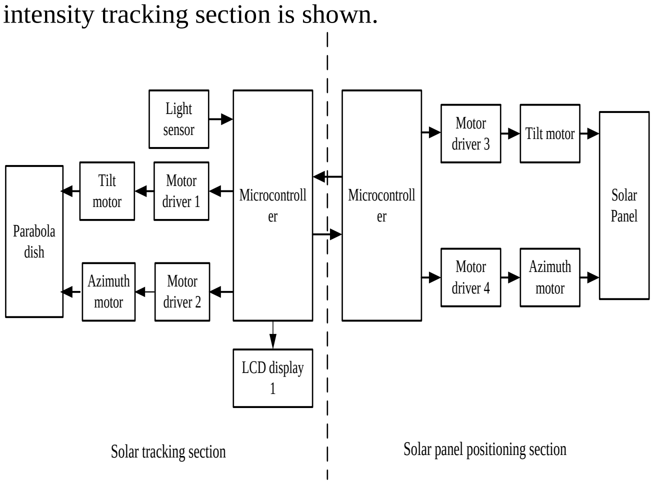


Figure2. The overall block diagram of solar tracking system.

III. DESIGN OF SOLAR TRACKER

The tracker control system contains a control board, a control program, a power supply board, three motor interface board and a pair of light sensor. The main idea of design of the solar-tracking system is to sense the sun light by using a parabola dish and LDR .LDR is fixed at the focus point of parabola dish. While sensing, when the parabola will be directed towards the sun, parallel sunrays (as they are coming from infinite source) will incident on it, and converge into the focus where the LDR sensor is located. The resistance of LDR will change according to the light intensities. So the voltage drop across the LDR will also be changed. This voltage drop is fed to an ADC, and hence corresponding digital values are stored in the microcontroller memory. After sensing is completed, it will check all the intensity values and decide which one is the maximum and hence the co-ordinates, as well as it will also send the direction information to move according to that position to all the solar devices connected to it where the movement arrangement is also present. It will start scanning again and thus the solar devices will direct towards next location of the sun. Hence maximum amount of energy is obtained. Moreover this gives a nearly constant amount power.

A microcontroller system with PIC16F877A used as the controller of the position control scheme offers up to 20MHz clock frequency, eight ADC channels with10-bit, 256x 8 bytes EEPROM memory and 40 I/O pins [3]. Since the apparent speed of the sun is very slow, the panel will also move very slowly. Therefore, a crystal with a frequency of 4MHz is used as a clock signal generator for MCU. The signals, taken from LDR are applied to I/O port lines of MCU (RA3). These analog signals are converted to digital signals. The biggest signal all of the sensing signal will generate driving signals for stepper motors .MCU is responsible this function. MCU generates no signal; which means that the solar panel is facing the sun and the light intensities do not change from the previous condition. Schematic representation of the solar-tracking system is given in Figure3.

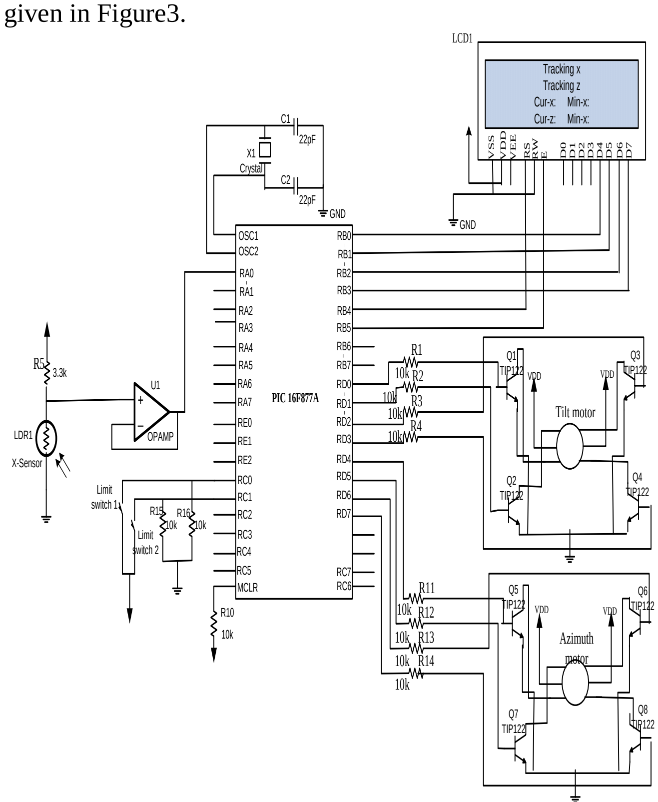


Figure3. Schematic representation of solar tracking system.

In order to drive two stepper motors, RD0 to RD7 (pin 19-26) of microcontroller are used. Four output signals (RD0-RD3) drive the first motor (tilt motor) and the rest of the signals (RD4-RD7) drive the second stepper motor (azimuth motor). In this system, eight Darlington pair transistors (TIP122) are used to drive the stepper motors. The control commands generated by MCU for driving of stepper motors and positioning of the parabola dish are given in Table 1. As can be seen from the Table 1, when stepper motor 2 is driven, four- driving signals for stepper motor 1 is set (1111XXXX).

Table1. The control Commands for stepper motors

Stepper motor 1 (Tilt motor)		Stepper motor 2 (Azimuth motor)	
RD0-RD1-RD2-RD3-RD4-RD5-RD6-RD7			
Foward	Reverse	Foward	Reverse
0001-1111	1000-1111	1111-0001	1111-1000
0010-1111	0100-1111	1111-0010	1111-0100
0100-1111	0010-1111	1111-0100	1111-0010
1000-1111	0001-1111	1111-1000	1111-0001

IV. MAIN COMPONENTS OF TRACKING SYSTEM

In this design, the following main components are mainly used for tracking the sun intensity.

A. Light Dependent Resistor (LDR)

Many different methods have been proposed and used to track the position of the sun. The simplest of all uses Light Dependent Resistor (LDR) to detect light intensity changes on the surface of the resistor. The proper and efficient use of LDR with a parabola dish reduces the overall cost as well. The resistivity of LDR decreases significantly with increasing illumination.Fig.3 shows the general resistivity versus illumination plot of an LDR.

The electronic circuit is a simple, robust, low-cost voltage divider circuit. Circuit variant is illustrated in fig.3:

- The output voltage increases when the illumination decreases.
- The output voltage decreases when the illumination increases.

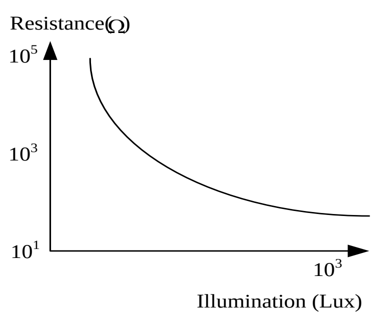
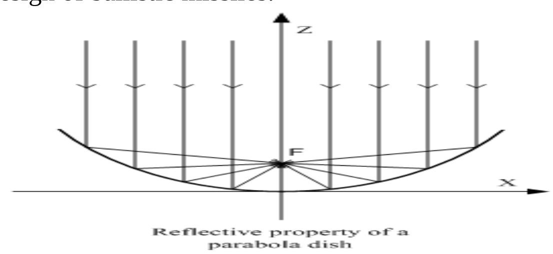


Figure4. Resistivity versus illumination plot of an LDR.

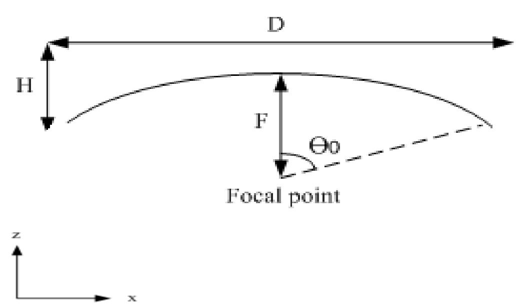
The efficiency of LDR increases with directed rays. Concentrated and directed incident light rays can be achieved by using parabola dish. When parallel rays incident on parabolic dish, they reflected back and converge in the focal plane. If the incident parallel rays are essentially perpendicular to the focal plane, they meet at the principle focus. This phenomenon is used in this design. The LDR is kept at the principal focus. The solar rays are assumed to be parallel to each other as the source (i.e. the sun) is at about infinite (essentially large) distance from the mirror. So they are expected to be converging into the principal focus when they are perpendicular to the focal plane as shown in Figure5(a). So if we scan the total upper hemisphere i.e. the day-sky, at some single point only, the solar rays are expected to incident on the principal focus i.e. detected by the LDR, in other positions, they will meet at focal plane and are not detected by the LDR sensor. Thus the accurate position of the sun can be tracked.

B. Parabola dish

Parabolas have the property that, if they are made of material that reflects light, then light which enters a parabola travelling parallel to its axis of symmetry is reflected to its focus; regardless of where on the parabola the reflection occurs. Conversely, light that originates from a point source at the focus is reflected into a parallel beam, leaving the parabola parallel to the axis of symmetry. The parabola has many important applications, from a parabolic antenna or parabolic microphone to automobile headlight reflectors to the design of ballistic missiles.



(a)



(b)

Figure5. (a) Reflective property of a parabola dish and (b) Focal point of the parabola dish.

The parabola is completely described by two parameters, the diameter D and the focal length F. The vertical height of the reflector (H) and the maximum angle between the focal point and the edge of the dish (θ0) are also defined. These parameters are related to each other by the following equations [7]:

$$\frac{F}{D} = \frac{1}{4\tan(\theta_0/2)} \qquad (1)$$

$$F = D^2/16H \qquad (2)$$

C. PIC 16F877A microcontroller

The PIC16F877A single chip RISC microcontroller is the brain of the tracking system. This microcontroller contains 8 kbytes of program memory, a 256 Bytes of temporary data RAM and 1 kbytes of EEPROM. It also contains 8 multiplexed analogue channels, a 10 bits analogue converter and a PWM generator module. These features make the PIC16f877A a useful single chip microcontroller in designing embedded systems.

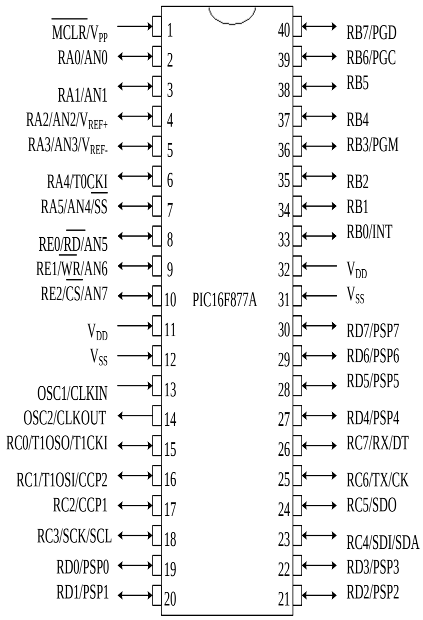


Figure6. PIN configuration of PIC16F877A

D. TIP122 Darling Pair Transistor

TIP122 Darlington pair transistor looks like normal transistors it also consists of Base, Emitter and Collector. It is designed for general purpose amplifier and low speed switching applications. In the design of the TIP 122 Darlington pair transistor, Pin 1 is Base, Pin 2 is Collector, Pin 3 is Emitter and Pin 4 is collector. TIP 122 Darlington pair transistor is shown in Figure 7.

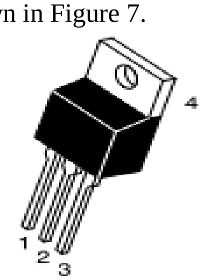


Figure7. TIP 122 Darlington pair transistor.

E. Unipolar Stepper Motor

The center tap on the unipolar motor allows a simpler driving circuit, limiting the current flow to one direction. Unipolar motors are straightforward to control. The unipolar stepper motors have the advantage of producing high torque at low speeds. DC motors do not produce high torque at low speeds, without the aid of the gearing mechanisms. This is useful for the intended application where the motor will be starting, stopping and positioning. The unipolar stepper motor has five or six wires and four coils (actually two coils divided by centre connections on each coil). Unipolar stepper motor is shown in Figure7.

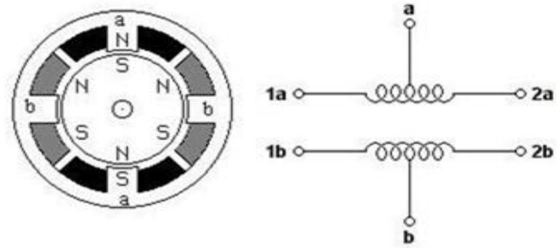


Figure8. Unipolar stepper motor.

F. 4x20 line LCD display and Limit switch

As the display device, 4x20 line LCD display is used to know the tracking condition. Limit switch is used to know the home position of solar tracker and to protect the extreme move of tracker.

V. SOFTWARE IMPLEMENTATION OF TRACKING SYSTEM

The software is developed in Micro C Pro programming language. It is compatible for PIC16F877A and is a machine level language. The software consists of a main module and a few subroutines. Simplified flowchart of the program is given in Figure 3.

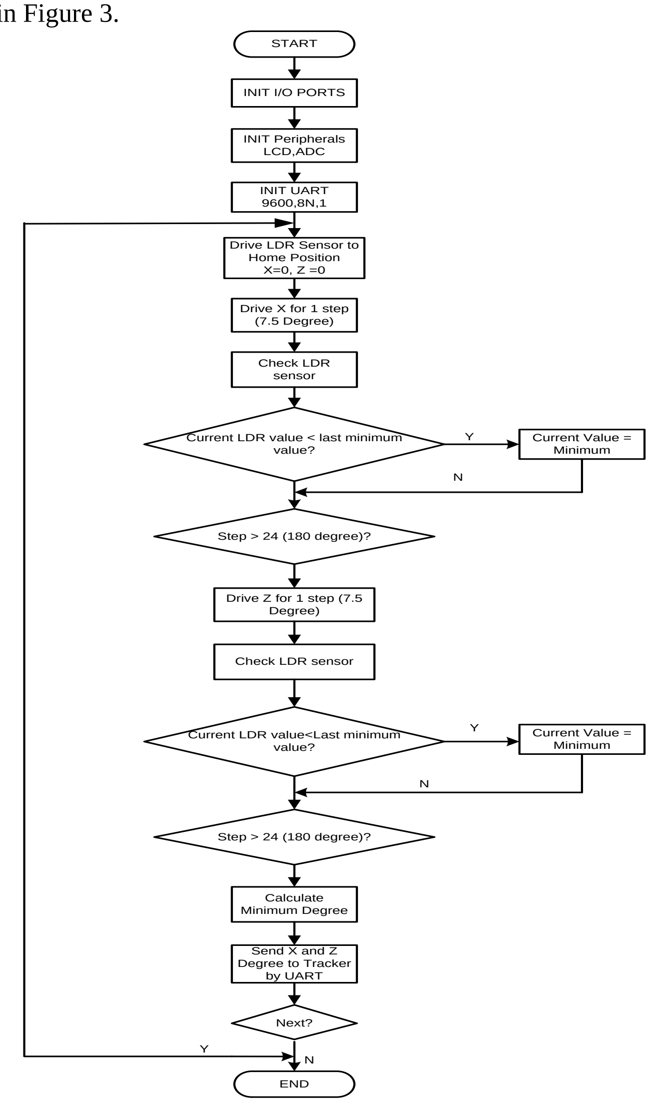


Figure9. Simplified flowchart of the solar tracking program.

In this system, PIC16F877A microcontroller is important to control the whole solar tracking system to work accurately track. In this paper, two PIC16F877A microcontrollers are used because to satisfy the memory insufficient problem. In this program, MikroC Pro programming is used to control the whole process. The maximum solar intensity tracking operation of the program flow is shown in Figure 8 and the solar panel driving procedure flow is shown in Figure3. In the above procedure flow chart, firstly, x and z motor drive to home position 0 degree, initial LDR value equal zero. Then tilt motor (z) drive 1 step (7.5) degree and check LDR output, if current LDR value is less than last LDR minimum value, the current will save as minimum value. The step drive will go until 24 steps (24x7.5=180 degree). Then, drive z motor for 1 step, read LDR, compare minimum and drive until 24 step. After finding x, z minimum degree, the degrees are sent to panel tracker by UART (Universal Asynchronous Receive/Transmit) of microcontroller.

VI. Algorithm Of Solar Tracking System

This solar tracker is simple and low cost for huge solar energy extraction project. This is basically dual axis tracker. At first it will scan all the values of light intensity in each point of the upper hemisphere where the sun actually lies. The stepping angle of both the stepper motors used here is 7.5 degree per step. Both the motor will rotate 180 degree covering all the points in the upper hemisphere, thus rotating 180/7.5 i.e. 24 times each. This scanning process will take 1-2 minutes depending on the stepper motor and program logic.

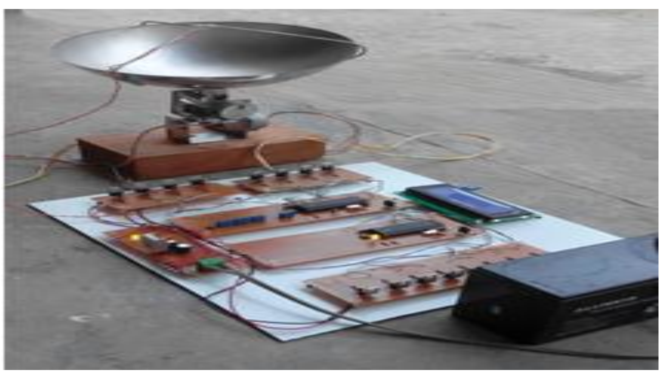


Figure10. A photograph of the proposed solar tracking-system.

While scanning, when the mirror will be directed towards the sun, parallel sunrays (as they are coming from infinite source) will incident on it, and converge into the focus where the LDR sensor is located. The resistance of LDR will change according to the light intensities. So the voltage drop across the LDR will also be changed. This voltage drop is fed to an ADC, and hence corresponding digital values are stored in the microcontroller memory. After scanning is completed, it will check all the intensity values and decide which one is the maximum and hence the corresponding co-ordinates are located which is in turn the position of the sun. Then it will move to the calculated co-ordinates, as well as it will also send the direction information to move according to that position to all the solar devices connected to it where the movement arrangement is also present. It will wait for some time, until a noticeable change in the position of the sun occurs and then after returning to its initial position, it will start scanning again and thus the solar devices will direct towards next location of the sun. Hence maximum amount of energy is obtained. Moreover this gives a nearly constant amount power. The waiting time can be changed by the program written in the microcontroller. And then the same direction information signal will send to the solar panel photovoltaic cell to collect the solar energy.

VII. Circuit Design of solar tracker

Figure 11 is complete circuit diagram of the maximum solar intensity tracking system. The microcontroller PIC16F877A has been used as the brain of the project. It is connected to the necessary connection as shown in figure 11.

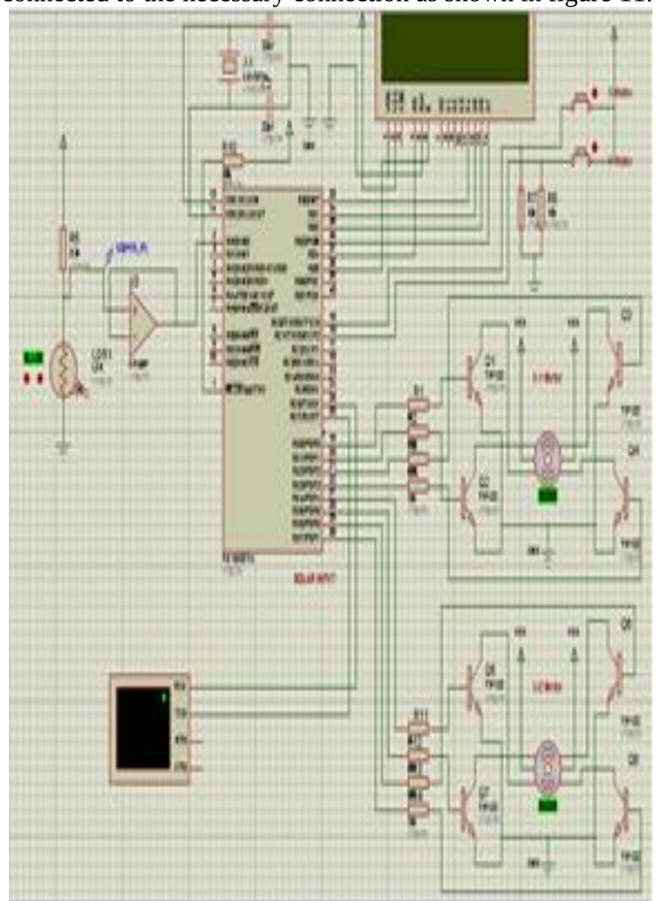
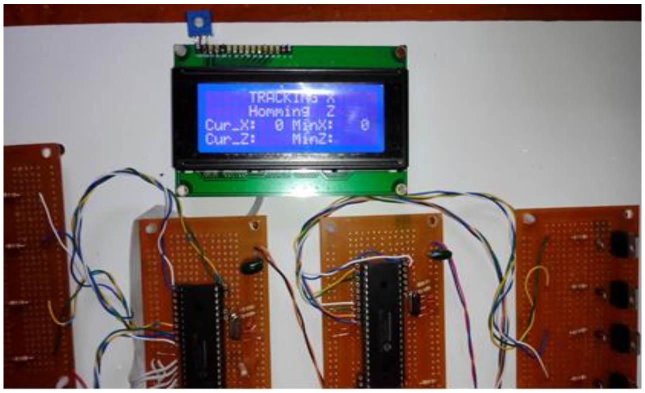
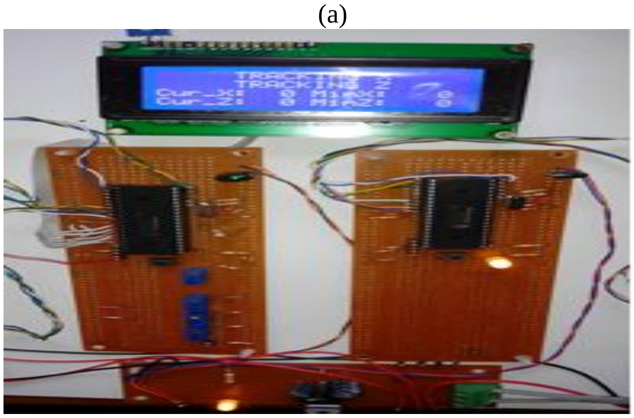


Figure11. Complete circuit diagram of solar tracker.

Firstly, the two stepper motors go to home position (0 degree) as soon as the simulation running. The value of LDR sensor is changed to get minimum resistance value. This value is stored in microcontroller. And then the value of LDR is changed again and is stored in microcontroller. The microcontroller will compare the former value and later value. If the former value is large than the later value, the stepper motor will rotate clockwise direction. Else the stepper motor will rotate counter clockwise direction. This condition is shown in Figure 12(a) and 12(b).



(a)



(b)

Figure12. (a) A photo of tilt axis motor(z) tracking and (b) A photo of tilt (z) and azimuth(x) motor axis tracking

VIII. CONCLUSIONS AND FUTURE WORK

This paper proposes the conception and development of solar tracking system based on two axis microcontroller control system approach using 7.5 degree stepper motors. This system can be used for solar cell array tracker and is modified the normal tracking system. If the fewer stepping degree motor is used instead of 7.5 degree stepper motor, the tracker can be scanned the solar intensity more accurately. In this paper, especially, it demonstrates a working software simulation for maximizing solar intensity searching system. This method not only improves power collection efficiency by developing a system that tracks the sun to keep the solar panel at perpendicular to its rays but also decreases the overall cost of production. The electronics needed to activate the motors are simple and the system can be applied to any electromechanical configuration. As the future work, the solar panel two axes frame will be built to work with solar intensity tracker and to test the actual result. In this paper, the photo of tracker and simulation result is shown.

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X. REFERENCES

[1] Steve Heckeroth. Solar is the Solution,2008.http://www. Motherearth news.com/Renewable-Energy/2007-12-01/Solar – is the- Solution.aspx (accessed Dec20,2008).

[2] J.Rizk,and Y.Chaiko(2008).Solar Tracking System:More Efficient Use of Solar Panels Proceedings of World Academy of Science, Engineering and Technology.

[3] “Solar devices and solar tracking system,” http:// en.wikipedia.org/wiki/Solar-tracker.2011.

[4] “LDR sensors,” http://en.wikipidea.org/wiki/Photore sistor.2011.

[5] J.Arai,K.lba,T.Funabashi; Y.Nakanishi, K. Koyanagi, and R.Yokoyama,”Power electronics and its applications to renewable energy in japan,” The IEEE Circuits and Systems Magazine,Vol.8, No.3,pp.52-66,2008.

[6]S.Takemaro and Shibata Yukio,” Theoretical Concentration of Solar Radiation by Central Receiver Systems,” The International Journal of Solar energy,261-270,1983.

[7] S.Armstrong and W.G Hurley “Investigating the Effectiveness of Maximum Power Point Tracking for a solar System”, The IEEE International Conference on Power Electronics Specialists, pp.204-209,2005.

[8] C.F.Gay,J.H.Wilson and J.W.Yerkes,”Performance advantages of two-axis tracking for large flat-plate photovoltaic energy systems,” Conf.Rec.IEEE Photovoltaic Spec,1982.

[9] Wilson,Ray N.(2004).Reflecting Telescope Optics: Basic design theory and its historical development. http://www. mathwarehouse. com/ geometry/parabola/area-of-parabola .php.

[10] Anonymous: PICmicro™ Mid-Range MCU Family Reference Manual, December, (1997).

[11] http://www. Power Solutions/ product.do?id=TIP122.