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Design and Implementation of Robotic Tracking System for the Solar Power Generation

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ABSTRACT

World's desire for technical innovations is progressing regularly with high aims to achieve a tremendous amount of power generation and to facilitate instant needs of electricity. As the sources of coal are extinguishing, there is a need to use renewable resources. Solar energy is the best alternative among all the renewable energy sources; it is clean, abundant and eco-friendly. Solar power plants have up to hundreds or thousands of arrays, each with its own tracking motors which are used to orient the panel towards the sun and other mechanical parts. With this existing setup, it is unable to achieve the desired level of efficiency. In addition, maintenance of this equipment is difficult and expensive. The disadvantages of the traditional tracking system can be overcome by eliminating individual trackers and letting an artificially intelligent robot to do that work. This optimized, dual axis, the robotic tracking system improves power generating capabilities of solar power plants. The crucial parts of this robotic tracking system are Solbot and Tracker. Solbot is an autonomous, rugged and mobile robot. Solbot is capable to serve and control a 340 KW PV array. These robots are also capable of working in extreme environmental conditions. The trackers are preassembled, reliable, easy to install and compatible with all modules. In this proposed method an increment of 30-40% of power generation is obtained.

Index terms: Solbot, The Robotic tracking system, Tracker, Micro Controller (ATMEGA-328), Servo Motor, Ultrasonic sensor (HC-SR04), BO Motors, L293DMotor driver IC, Light dependent resistor (LDR).

1. INTRODUCTION

Conventional tracking systems use two to three times more metal and concrete than standard fixed solar systems, making conventional tracking systems significantly more expensive to install and to maintain then fixed systems, while also introducing performance and reliability issues from the significant number of motors used. RTS is installed to resolve these issues and designed around a more efficient use of materials and a focus on reliability. The angle of inclination, tilt and orientation of individual solar arrays can be rectified by implementing artificially intelligent, robust, auto-charging, mobile robots throughout the day and year. The working of these robots plays an important role in the success of RTS. It mainly provides two efficient and crucial advantages: Increase in solar project profit gains (e.g. IRR and NPV), and easy erection.

In general, RTS utilizes a set of two mobile and autonomous robots for handling up to 340kW (As per design) of solar modules with the greater amount of efficiency, reliability, and 100% redundancy. Solar panels are erected on the RTS developed trackers without separate motors for every panel, which gives optimization in price, potency, endurance, and simple installation. Solbot is made to run on a track to rectify every tracker for optimal facing of the sun periodically. Each rugged robot substitutes several individual motors and controllers used in traditional tracking systems. The usage of a pair of robots per block improves built in system redundancy if one of the robots breaks down, improving system accuracy and establishing high scope for developing tracking capability.

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2. COMPONENTS OF THE ROBOTIC TRACKING SYSTEM

The crucial components of the robotic tracking system are

- Solbot
- Tracker

Solbot is a solar tracking robot implemented in solar power generating stations for rectifying an array of solar panels for optimum tracking of the sun. Solbot moves on a track and modifies every photovoltaic cell for optimal facing of the sun and returns in every 40-minute intervals to make accurate adjustments as the sun travels across the sky. It is an autonomous, rugged and mobile robot. It contains motors and controllers needed to adjust the panels and move from unit to unit on the track, rectifying every photovoltaic cell as they go. Solbot is robust, weatherproof, serviceable and safe. The tracks can be established on the ground without extensive grading needed and the system is modular, so the tracks can be developed if more panels are added.

A tracker is a machine that aligns a solar panel along with the Sun. Payloads are usually solar panels, parabolic troughs, Fresnel reflectors, mirrors or lenses. Trackers come preassembled for fast installation and engineered to withstand for high wind loads. Providing complete design flexibility, RTS trackers are universally compatible with all types of PV panels, inverters, and foundations. These trackers can be of mainly two types, namely, Single Axis Trackers and Dual Axis Trackers.

3. THE WORKING OF RTS

When power supply was given to the motion circuit and it comes to action, the solbot starts travelling on the track. When it detects the presence of solar panel with reference to signals given by the ultrasonic sensor, it stops the motion of DC Motors i.e. the robot stops at that panel giving a signal to the control circuit and making it to come into the picture. The control circuit takes the data or signal from the light dependent resistor and compares it with the given reference value. The output of the micro controller is obtained by comparing the output of the light dependent resistor (LDR) with the preset value or reference value in programming and it is called as error signal. Depending on the output of the program that is dumped in the micro controller, Servo motor was given the signal to rotate the panel in that particular direction until that particular angle of inclination was achieved. When the difference between the output of LDR and the preset value (error signal) was zero, it indicates that the inclination of the panel was exactly matching the sun's position and thus control circuit passes a signal to the motion circuit. The signal from the control circuit makes the motion circuit to come in to action. There by making the DC motor ON and advancing the robot to the next panel. The same procedure continues for all the panels.

After the completion of the first panel, the counter which was used to count the total number of panels was increased. When adjustment or correction of all panels are completed then counter reaches the total number of panels. If the number of panels counted through the counter becomes equal to the given number of the panels then the robot is made to come for the first position and start the next cycle. In this way RTS improves the performance of solar power plants by accurate orientation of the solar panel towards the sun. This reduces the maintenance of tracking motors, several rotating parts and gears. This also reduces the installation and maintenance cost of the solar tracking system.

4. DESIGN OF ROBOTIC TRACKING SYSTEM

The design and implementation of Robotic Tracking System involves functioning of two circuits. They are:

- Motion Circuit
- Control Circuit

Motion Circuit: The main aim of the motion circuit is to make the robot to move from one panel to the other panel. The motion circuit consists of Ultra Sonic Sensor (HC-SR04), Aurdino Board, BO Motors, L293D Motor Driver IC and DC Supply for Aurdino and Motor Driver. Ultra Sonic Sensor is used to detect the presence of the solar panel and emits a signal which is taken by the micro controller (Aurdino Board of ATMEGA328) with both analog and digital pins. The BO motor is a DC motor of 12V, which runs with speed 60 rpm. It is a DC motor with gears which gives good torque and rpm with low voltages. This DC Motor can be driven in both clockwise and anti clockwise directions by using a motor driver integrated circuit named as L293D. L293D has 16 pins that can control a pair of DC motors in both clockwise and anti clockwise directions. For carrying out this operation, it is equipped with two H-Bridge circuits. These run by an external DC power supply through a battery of 4.5V and 9A.

Design of Motion Circuit:

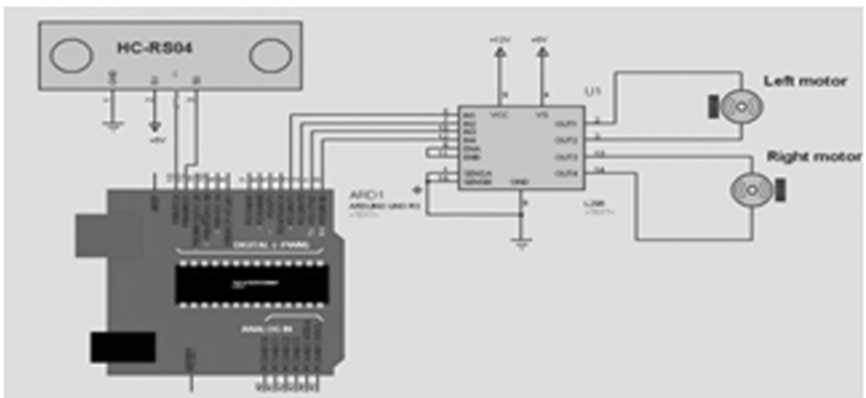

Figure 1: The circuit diagram of Motion Circuit

Implementation of the motion circuit:

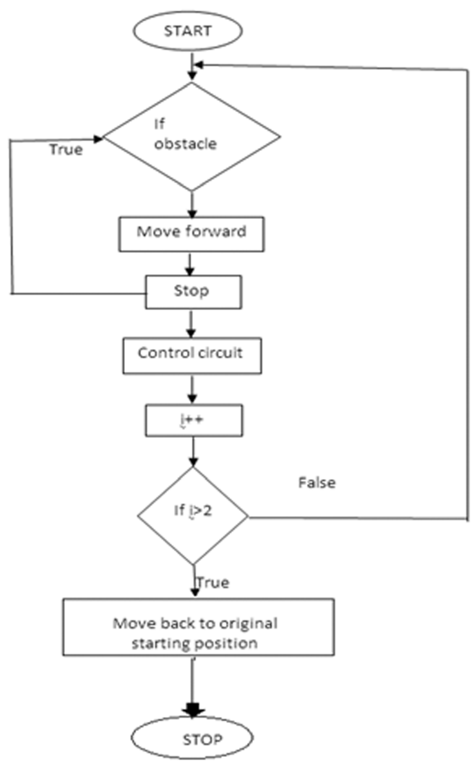

Figure 2: Flowchart of the motion circuit

Control Circuit: The function of the control circuit performs an important role in the operation of the robot. This controls the angle of the inclination of the solar panel. This generates the command signal which gives data about the angle of inclination to be rotated and also the direction of rotation. This mainly consists of Light dependent resistor (LDR), L293D motor driver IC, Aurdino Board and servo motor. Light dependent resistor senses the position of the sun according to the intensity that falls on it. The output from the LDR is given to the micro controller (Aurdino Board of ATMEGA328) where comparison between reference value and obtained value is done and an error signal is generated.

Design of Control Circuit:

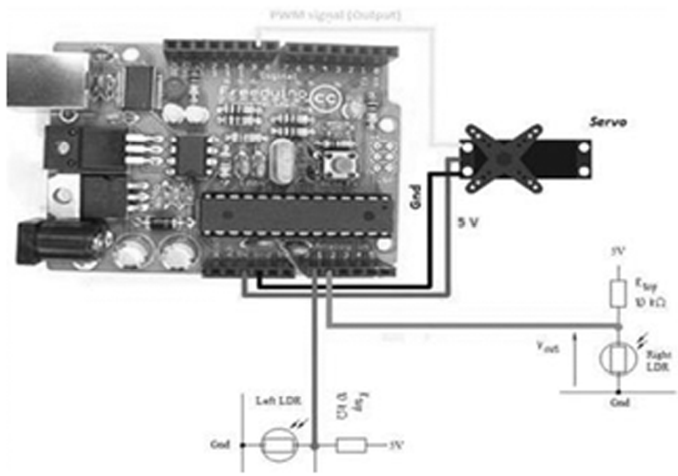

Figure 3: The circuit diagram of the control circuit

Implementation of Control Circuit:

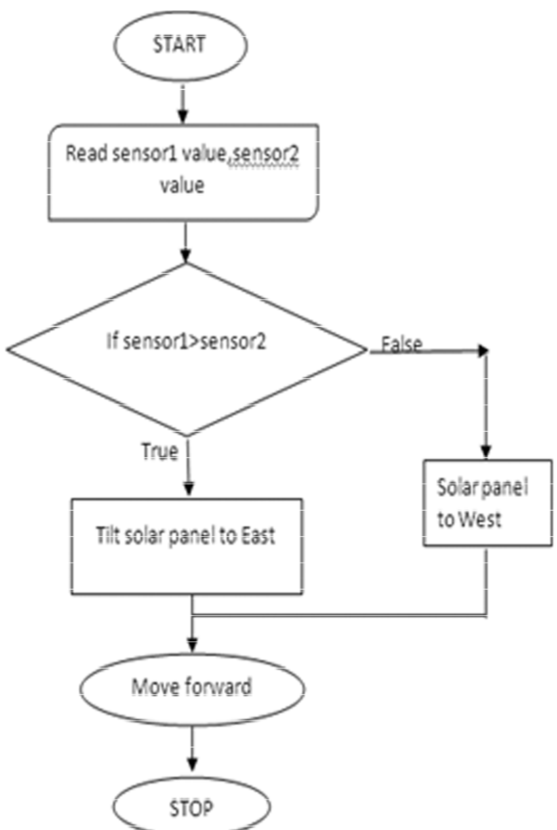

Figure 4: The flowchart of the control circuit

5. HARDWARE IMPLEMENTATION OF RTS

Experimental hardware implementation of RTS was shown in Fig5 and Fig6. In this experimental model, the body of the robot was constructed using pieces of wood and circuits of the robot was built using ultrasonic sensor (HC-SR04), BO Motors with rating as 12V and 60 rpm, L293D Motor Driver IC for BO Motor control, Light dependent resistor and DC Servo Motor with size, weight, speed, torque, voltage and connector type as 38×11.5×24mm (with tabs) 28×12.7×27mm (without tabs), 17g (without cable and connectors) 18g (with cable and connectors), 0.14sec/60degrees (4.8V) 0.12sec/60degrees (6.0V), 2.5kgf-cm (4.8V) 3.0kgf-cm (6.0V), 4.8V-6.0V, JR type (Yellow: Signal, Red: VCC, Brown: GND) respectively. The compilation of the program in AURDINO ATMEGA328 operates the function of motion and control circuits. The rechargeable battery of 6V and 4.5A supplies DC power for AURDINO ATMEGA 328, Motor driver IC L293D, servo motors and BO motors.

This experimental model can be developed to make compatible with wide capacities of solar power plants.

Figure 5: Represents Solbot of Robotic tracking system

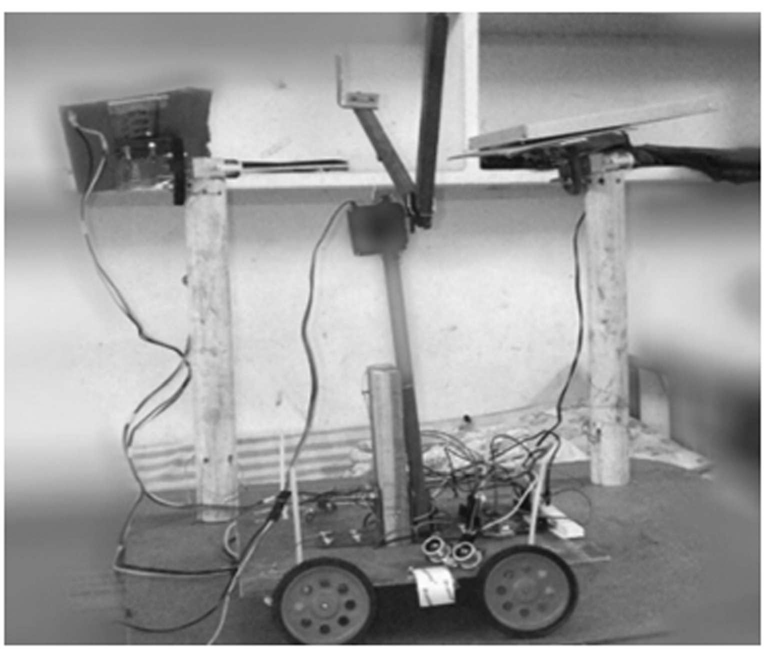

Figure 6: Represents the front view of the robotic tracking system

6. EXPERIMENTAL RESULTS

6.1. Output of the motion circuit

The output of the motion circuit is to stop the solbot when it reaches the panel detected in the range of 10 centimeters and to the start the functioning of the control circuit by giving a signal. Below is the outputof ultrasonic sensors at different ranges.

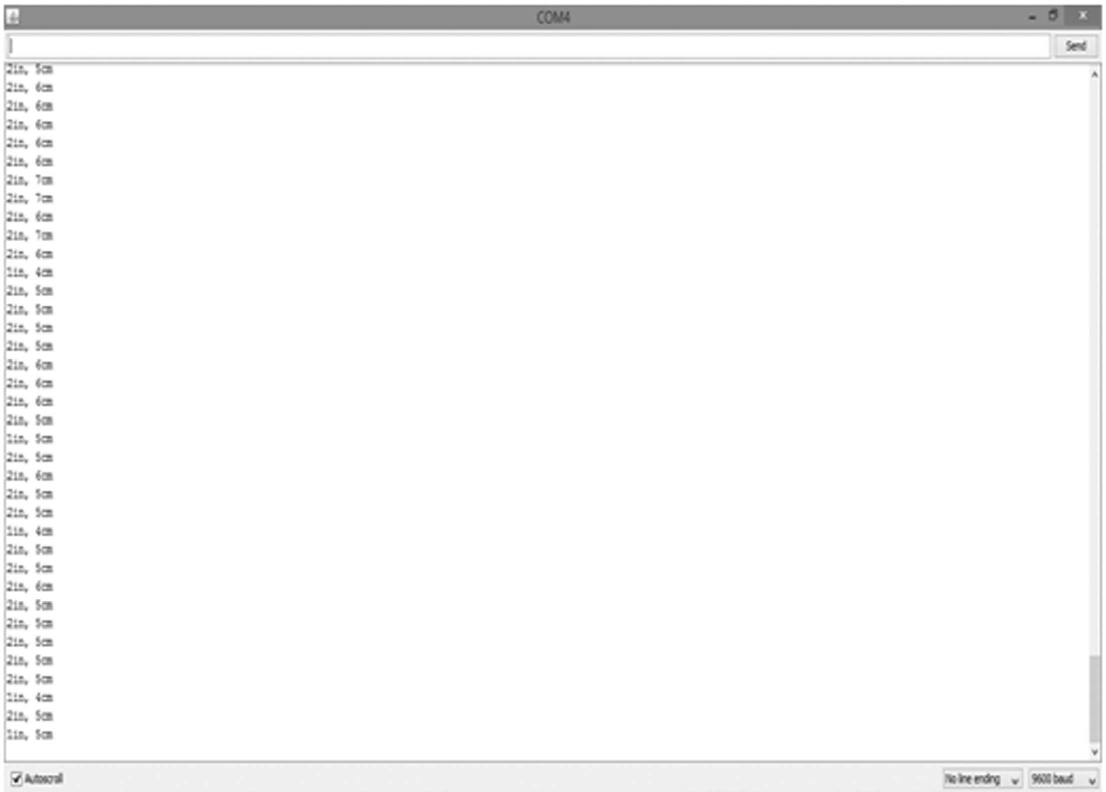

Figure 7: Represents the output of ultrasonic sensor at a range of 5cm

Figure 8: Represents the output of ultrasonic sensor at a range of 8cm

Results of the control circuit:

The output of the control circuit was depended on the signal from the light dependent resistor. The output of the AURDINO ATMEGA 328 makes the panel to incline in the orthogonal position to the sun. There by giving an increment in the output power efficiency of 30-40%.

The tabular form given below describes about DC output voltages and currents obtained for both fixed mount and robotic tracking systems. On comparisons of the results at various time intervals we observe that there is an increase in the levels of voltages and currents than the fixed mount system. This increment in output values can be expressed as efficiency values. This method causes an increment in the efficiency from 30-40%. This increment is obtained because of the excellent performance of light dependent resistors and accurate output of the control circuit that control the inclination of the solar panel.

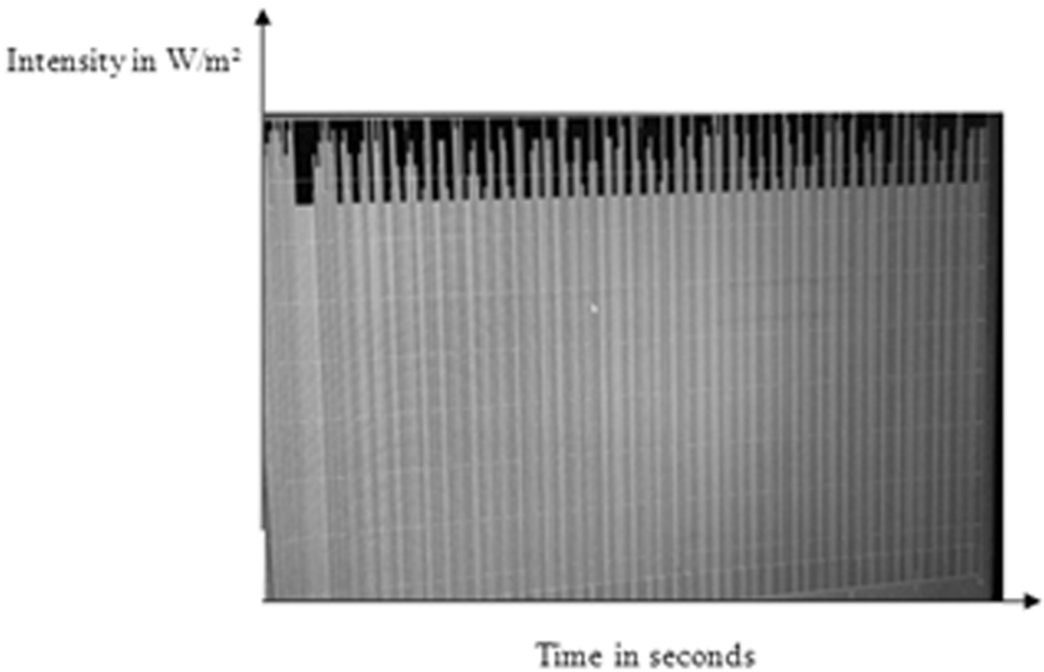

Figure 9: Representing the graphical output of the light dependent resistor at 11AM

Figure 10: Represents the output of the Light dependent resistor at 11 AM

Day 10/3/2016	9 AM	10 AM	11 AM	12 AM	1 PM	2 PM	3 PM	4 PM
Fixed mount system								
Voltage V1 (V)	**5.7**	**11.5**	**12.5**	**10.6**	**12.54**	**11.7**	**9.45**	**7.17**
Current I1(A)	**0.16**	**0.16**	**0.15**	**0.15**	**0.15**	**0.14**	**0.13**	**0.18**
Power P1(W)	**0.91**	**1.84**	**1.86**	**1.59**	**1.88**	**1.63**	**1.22**	**1.29**
Robotic Tracking System								
Voltage V2 (V)	**6.1**	**12.99**	**13.01**	**12.85**	**12.99**	**12.5**	**11.25**	**10**
Current I2(A)	**0.2**	**0.19**	**0.2**	**0.17**	**0.15**	**0.15**	**0.14**	**0.18**
Power P2(W)	**1.22**	**2.46**	**2.602**	**2.18**	**1.94**	**1.87**	**1.57**	**1.8**
Increase in efficiency (η %)	**34.06**	**33.69**	**39.89**	**37.10**	**31.19**	**14.72**	**22.29**	**39.53**

The Table 1 representing comparison between fixed mount and the robotic tracking system.

This method is more economical than the conventional solar tracking system because of the replacement of all the individual tracking motors with a single battery powered robot. As this reduces the number of moving parts of the system, this requires less maintenance and also easy installation. Because of these advantages, this system gives a saving of 15-20% of installation and maintenance costs when compared with the conventional solar tracking system.

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