Original Article

Design of Advanced Solar Tracking System for Mobile Laboratory

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ABSTRACT

Solar tracking system is power generating method from sunlight. Solar tracking device ensures the optimization of conversion of solar energy into electricity by properly orienting the photo-voltaic panels in accordance with the real position of the sun. This paper reveals with the design and execution of a solar tracking system to be used for photovoltaic panels. The design is based on the power requirement of fans and tubes of the mobile laboratory consisting of physics, chemistry and computer apparatus. The working of solar tracking system is based on manually controlled hydraulic direction unit that is operated with a circuit and further this circuit is controlled by micro controller circuit. Directional control unit consists of three jacks in triangular shape are fitted at 120 degree from centre and 60 degree to each other. Two photovoltaic modules of 75 Watt each are used and these panels are connected in series in this fabricated tracking system. This present solar tracking system can enhance the efficiency by 25% as compared to static module.

Keywords: Solar tracker, Solar panel, Hydraulic jacks, Height control switches and Microcontroller circuit.

INTRODUCTION

Solar energy is an important, clean, cheap and abundantly available renewable energy. Solar energy refers to the conversion of the sun's rays into useful forms of energy, such as electricity or heat. The solar energy received on earth is in the form of radiation and is used for heating and producing electrical energy. The direction of solar rays changes during the day and with season. Solar energy received on ground level is affected by atmospheric clarity, degree of latitude etc. The solar energy is converted into electrical energy by photo-voltaic (PV) cells. Solar photo-voltaic technology is the most significant renewable energy technology for remote and stand-alone consumers away from electrical distribution networks of few watts to few kilowatts. Solar PV systems have become commercially successful during 1980s. The solar Photo-Voltaic cells convert the incident sun's energy directly to electrical energy in direct current

(DC) form. A single cell has a rated voltage of about 0.5 V and rated power of about 0.3W. A solar cell is a small semiconductor device which has a light-sensitive negative-positive (N-P) junction. When solar light rays strike the N-P junction, DC electromagnetic force is generated with P-terminal as positive and N-terminal as negative. Normal ratings of a typical single PV-cell when exposed to full sun light are 0.45 V voltage, 0.75 A current and 0.33 W power.

Actual power delivered varies with intensity of sun light and the load resistance. When exposed to sun light, the solar cell acts like a tiny DC cell. Several solar cells are connected in series, parallel to get desired voltage, current and power. The several solar cells are installed on the structure to form a solar PV collector.

A Solar PV panel delivers certain DC voltage for certain intensity of incident solar energy. The DC output power depends upon total number of cells and power per cell. The current and voltage are influenced by circuit connections and external resistance. Solar PV-panels are installed outdoors in a position to receive maximum sun light during the day, and an year. Solar PV panels may be fixed type or tracking type; without focusing or with line focusing or with point focusing etc. Fixed type Flat plate fixed panels without focusing are commonly used as they are simple, cheap and maintenance free. The Solar PV panels deliver DC electrical power only during favorable conditions of sun light. To obtain electrical power during nights the energy storage batteries are necessary. During the favorable sunlight hours and low load the storage batteries get changed. During nights and cloudy weather, the storage batteries supply the electrical energy to the load. It is generally uneconomical to install storage batteries for supplying the energy requirement of the load beyond few hours. Some of the electrical loads require 50 Hz AC supply. 50 hertz (Hz), alternating current(AC) power, DC to AC inversion is achieved by means of static invertors[1]. Many of researchers and companies working in the area of crystalline silicon, feeding their capabilities into the manufacture of crystalline silicon materials, cells and modules. The main motivation for developing higher cell efficiency is reduction in area- related cost[2]. As the earth keeps revolving around the sun as well as on its own axis, the intensity of solar radiation varies throughout the day and year. So in order to collect maximum solar energy it is important to determine the correct orientation and slope of the solar photovoltaic panel. This problem can be solved by tracking the sun daily throughout the year. The output of PV system can be increased by using monthly and seasonal tracking manually[3]. According to International Energy Agency (IEA) report, the global efforts in capacity building of photovoltaic technology have been increased with the growth rate of 40 % per year. A conversion of sunlight into electrical energy is not a difficult task for engineers, but the efficiency improvement of photovoltaic cells is still a challenging one. The sun orientation is changing continuously as a result of this the incident radiation on solar panel is continuously changing. This is the main cause of failure in terms of solar panel efficiency rate. A single axis tracker can increased the annual power output energy by 30 %, by using the applications of two axis, it may be achieved up to 36 – 50 % [4,6]. Ankit N. Parmar studied the maximum production of solar energy with the help of solar tracking system working on the Zomework principle. During calculations in this project, he studied that output of panels increases by 23.33% [5]. The experimental study carried by Raj Paul Guleria and NandLal Sharma shows that using solar tracker, the power generation has been increased by 45 % when compared to fixed PV modules. The result obtained is 53.8 % gain in energy production, which reveals that solar tracking system is able to deliver high power and better efficiency compared to fixed module inclined 45^o at the same latitude[6].

Design of a solar tracking system

A setup has been designed and fabricated for generating electricity through solar panels. These panels are installed on the top of the mobile laboratory consisting Physics. Chemistry and Computer equipment.

The apparatus used for this setup is as follows

- 150 Watt solar panels
- 24 V charge controller
- 32 ampere batteries
- Direction control mechanism

Two solar photovoltaic modules having rated power 75 Watt each are used. These panels are connected in series. Single panel when working on load gives 17.5 V and 4.3 A current. Two 32 A batteries are used for storage of electrical energy produced by panels and these batteries are connected in series for making the system 24 V. To prevent against over charging, complete discharging and over voltage, a 12 V/24 V solar 30 charge controllor is connected between solar panel, battery and load. A direction control mechanism is used to give easy

Orientation to the panels according to direction of the sun. This mechanism is combination of mechanical and electrical devices.

Mechanical and Electrical Devices

Three hydraulic jacks of 2 Ton capacity are fitted on 2 x 2 feet iron plate at an angle of 120 degree from centre and 60 degree from each other such that set up form triangular shape. Distance between centre axis of one jack to another is 11 inches. The height to which each jack lift is kept 21 cm. The whole platform is welded on the top of the bus. The panels are riveted to stand made of iron angle with dimensions 35 x 56 inches. Stand is attached to the jacks through springs. Two solenoid valves are connected to inlet and outlet port of each jack. Solenoid valve is an electromechanically operated valve controlled by an electric current through a solenoid. A double plunger pump is coupled with 24 V DC motor. The motor runs the pump and whole unit is enclosed in the box. A resevior is attached to the box for the storage of oil. Oil used is dot 4 mobil oil. A three way distributor system is used to supply oil from pump to all the jacks. Pressure pipe of pump is attached to three way distributor to which all three input solenoid valves are attached. In same way outlet valves of three jacks are attached another three way distributor which drain the oil back from jacks to reservoir. On/ Off type switches are used to control the height of hydraulic jacks. These switches are used to switch off pump and motor, when jack attained this height. A washer is welded to the collar of jacks which touches these height control switches when jack attains the height of 21 cm. The whole mechanism is controlled by two mechanisms.

1. Micro controller circuit
2. Hydraulic direction control circuit.

The microcontroller circuit is placed in driver's cabin and enclosed in indicator box. The signal to direction control circuit is controlled by this circuit. The signal is send through CAD 5 E ethernet cable. The indicator box has six indicator led bulb which indicates the direction of panels orientation. The orientation of panels is controlled by single switch. NE 555 timer I.C is used which gives output pulseto counter I.C. Two capacitors of 1 micro faraday and 0.01 micro faraday and two resistances of 100 k are attached to this timer I.C circuit.

A switch is attached to circuit to control the pulse sent from timer I.C to counter I.C. The counter I.C used is CD 4017. Further this I.C contains configuration of pins to which IN 4148 Diodes are attached. The output pulse of timer I.C is the input pulse of counter I.C.

Supply to the micro controller is 12 V. When the system is switched on the panels will be at intial stage that is pin number 3 of counter I.C. CD 4017 is activated and the panels will be at neutral level. By pressing the switch for one time, positive pulse will be send by timer I.C. as output and is received at pin number 14 of counter I.C as input signal due to which pin number 3 will get deactivated and it will activate pin number 2, which further will operate single relay S_1 and jack 1 will get lifted. Here S_1, S_2 and S_3 are three different relays used in the circuit which further operated Jack1, Jack2 and Jack3. Now again pressing the switch for second time, pin number 2 gets deactivated and pin number 4 will receive pulse and gets activated. This will operate both the relays S_1 and S_2 and both the jacks 1 and 2 will get lifted. Pressing the switch again will deactivate pin no 4 and pin no 7 receives the pulse and get activated. This will operate single relay S_2 and only Jack 2 gets lifted up. Pressing switch for fourth time will deactivate pin no 7 and pulse will be received at pin no 10, which will operate both relays S_2 and S_3 and jack 2 and 3 gets lifted up. Further press on switch will deactivate pin no 10 and activate pin no 1 which will operate relay S_3 and only single Jack 3 will get lifted. Again pressing the switch will deactivate pin no 1 and pin no 5 gets activated which will operate relay S_3 and S_1 and jack 1 will get lifted. Next click on switch will reset the timer and the panels will be at neutral level and initial stage is achieved.

In order to control the orientation of panels a circuit is designed, which is named direction control circuit and this circuit is placed under the panel frame in a box fixed below. It controls the working of hydraulic jacks, motor and pump, solenoid valves and height control switches. The output signal from the micro controller circuit is the input signal to this circuit. The resistance used in this circuit is 2.2 k. The solenoid valves of jacks are operated by the relays and these relays futher are controlled by BC 148 N-P-N transistor. This transistor also controls the height control sensors. When S_1 is active or signal is received at S_1, current flows through transistor Q_1 to relay R_1. A magnetic field will be created in R_1 and switch of relay will become active. When this switch gets active the solenoid valve connected in the delivery inlet of jack gets activated and oil will flow from pump through the jack.

Thus raising Jack 1, when the jack will attain its required position or required height that is 21cm, the height control sensor gets activated and will stop the pump from overrunning. This sensor is also controlled by transistor. The relay R_4 that is the relay of pump will operate in OR gate operation that is $S_1+S_2+S_3=S_4$. S_4 is the resultant here. Similarly when S_2 is active current flows in relay R_2 through transistor Q_2 and magnetic field will be created in R_2. The switch of this relay becomes active. This will activate the delivery solenoid valve of jack 2 which is connected in delivery inlet of jack and the oil flows through this jack thus raising it. Again when signal is received at S_3, current flows through transistor Q_3 to relay R_3. Magnetic field will be created in R_3 and the switch of relay becomes active. When this switch gets active the solenoid valve connected in the delivery inlet of jack gets activated and the oil will flow from pump through the jack, thus raising Jack 3. The outlet or suction solenoid valve of all the jacks remain active all the times and get deactivated only when current flows through delivery valve of that jack that is delivery valves get active only when jack has to work. When all jacks work independently the oil flows through each jack thus raising it according to the orientation needed. When two jacks work in collaboration then oil flows through inlet valves of both jacks. Like S_1 and S_2 ports are in operation oil will flow through inlet valves of both jacks. When next position is to be achieved that is only S_2 port is in operation, the suction valve of Jack 1 gets active and oil from Jack 1 flows back to reservoir thus lowering the jack and single position of panel through S_2 port is achieved. The suction valves work when the magnetic field in relays gets destroyed and oil is sent back from hydraulic jack to the reservoir. These valves open when the adjusted position of jacks is achieved and height adjusting sensor activates.

DISCUSSION

Solar tracking systems help in maximization of power output. Many researchers have made their contribution in design and development of different types of solar tracking systems. Sanzidur Rahman and Rashid Ahammed Ferdaus had designed and implemented dual-axis solar tracking system and during their research they had studied power gain of 52.78% by using their own designed tracker when compared with a fixed one [8]. Dual-axis trackers perfectly aligns with sun direction and tracks the sun movement in more efficient way and has a tremendous performance improvement. Study done by Aashir Waleed and DR. K.M Hassan reveals that by using dual-axis solar tracker, energy can be increased by 40% as compared to fixed arrays[9]. Shyngys Almakhanovich Sadyrbayev and Amangeldi Bekbaevich Bekbayev also worked on dual-axis solar tracking system and studied that 31.3% more power is produced as compared with stationary photo-voltaic modules[10].

CONCLUSION

The solar tracking system for photovoltaic panels is a great concern especially in morning and evening hours of a day and the panels get back to their initial position during night so this system saves energy by keeping motor and pump off during night. If one time investment of tracking module in addition to panel, batteries and convertor is considered then positive amount of money can be saved. The design of present solar tracking system is based on manually controlled hydraulic direction unit operated by circuit and further controlled by micro controller circuit. This present solar tracking system can enhance the efficiency by 25% as compared to static module.

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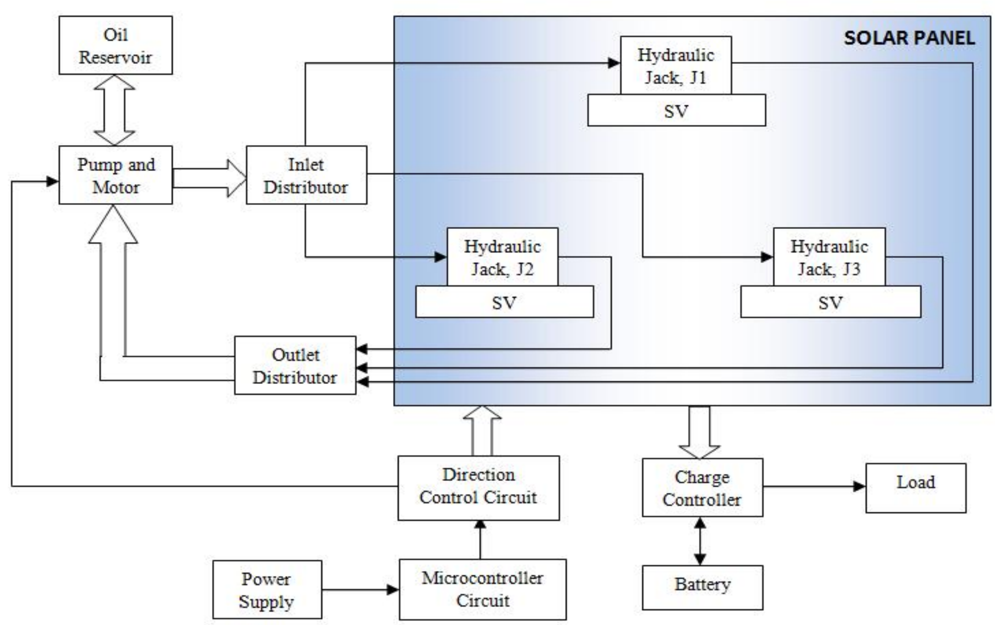

Figure 1. Block diagram of solar tracking system

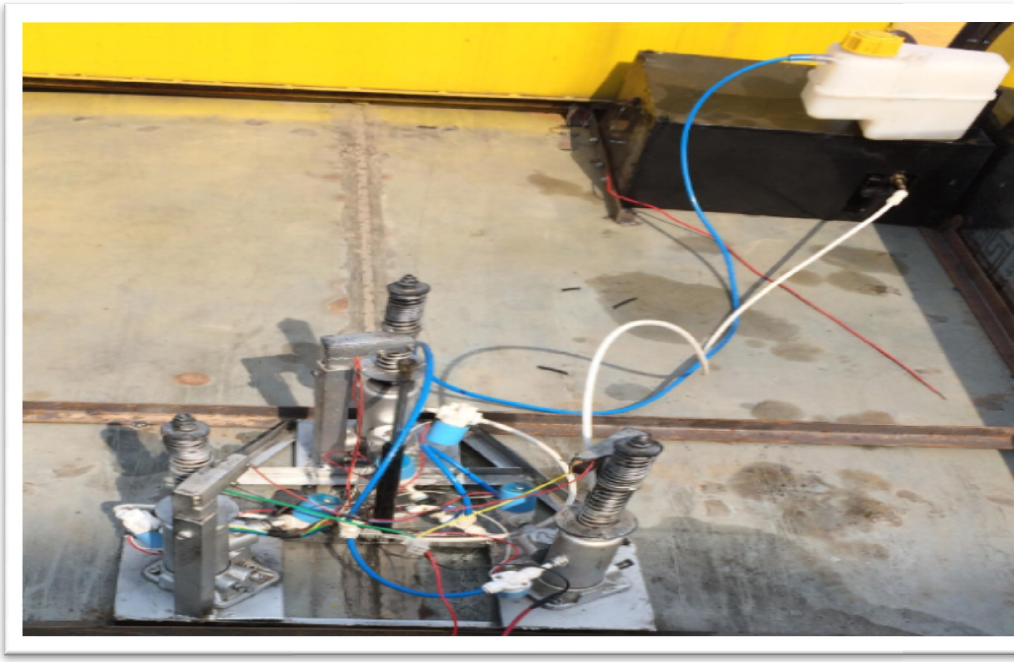

Figure 2. Actual Diagram of solar tracking system

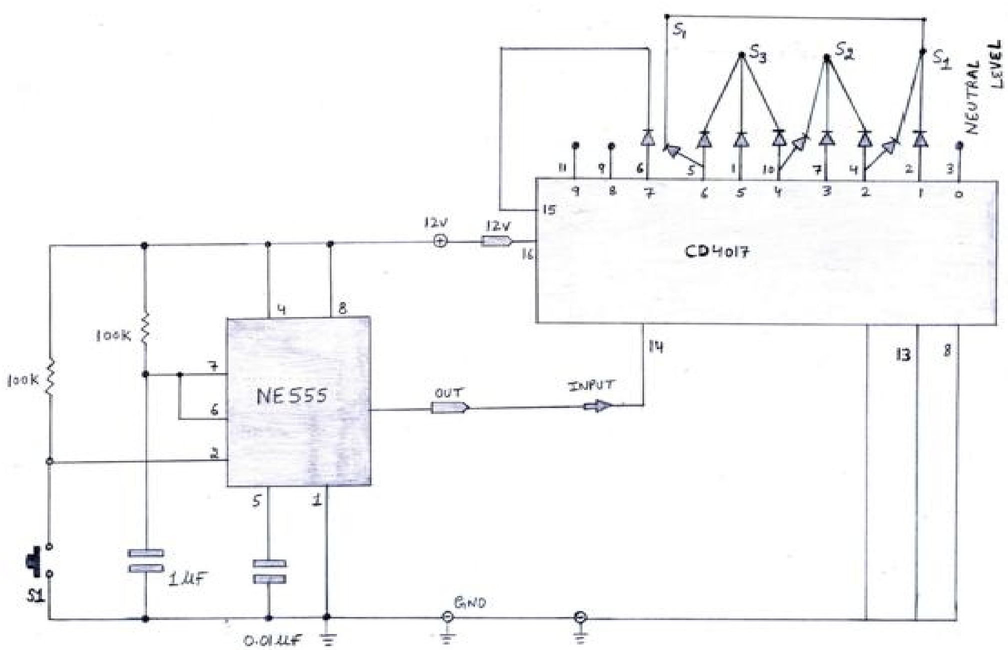

Figure 3. Microcontroller circuit

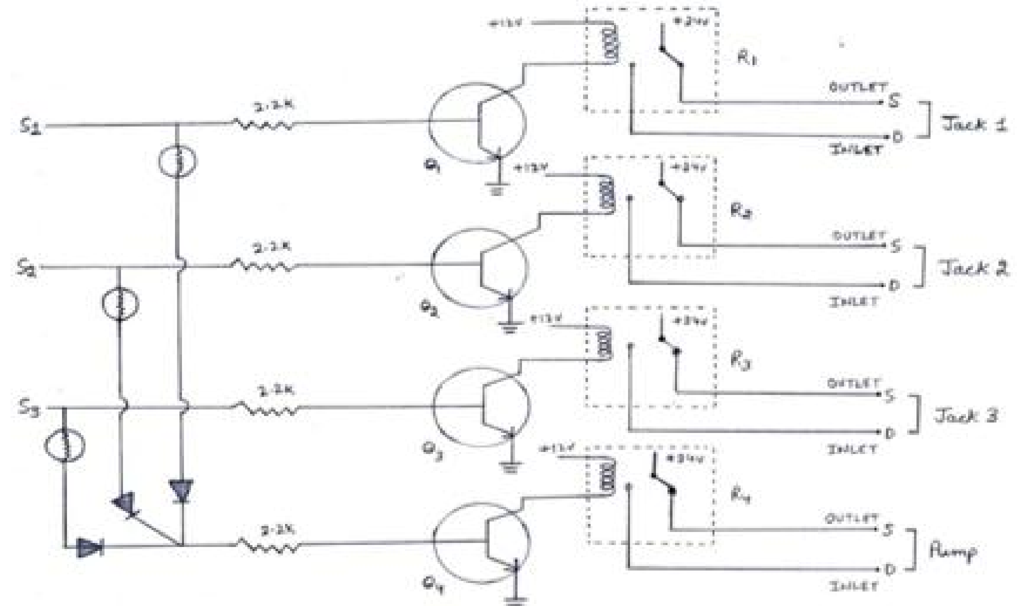

Figure 4. Hydraulic Direction Control Circuit