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Automatic Solar Tracker with Pre-Installed Panel Cleaner

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Abstract: With the forthcoming drought of Non-renewable resources, people are considering to use alternate sources of energy. Solar energy is one such form, it is swiftly attaining center stage as an important means of amplifying renewable energy resources. So it vital to those in the engineering field to understand the technologies associated with this area & design new ideas. The proposed system tracks the sun's movement and tries to maintain the solar panel perpendicular to sun rays, ensuring that the maximum amount of sunlight is incident on the panel. This is better than the fixed solar panel, where the panel is fixed and can't track the transition of the sun from east to west, hence generating optimum energy. This proposed system solves the problem by arranging for the solar panel to track the sun. The idea in which this paper is unique is that with the solar tracker, the system also includes an automated solar panel cleaning robot. A big issue which is often overlooked too easily is keeping the panel clean. After installation of the panel, it is often difficult & dangerous to reach the panels. Also if done manually, it is a time taking process & also requires more money. Hence to remove this limited use of technology is a good choice. This opens up the new field to build an automatic solar tracker which comes with the automatic panel cleaning robot. The project uses a dummy solar panel which is coupled to a DC stepper motor for tracking the sun rays such that maximum sunlight is incident on the solar panel at any given time of the day. The tracking movement of the solar panel is achieved by teaming a DC stepper motor with the solar panel such that the face of the panel is always perpendicular to the sun, so as to generate maximum energy. This is attained by utilizing a programmed 8051 microcontroller to furnish stepped pulses in specific time intervals for the DC stepper motor to rotate the solar panel as appropriate. The cleaning mechanism can be achieved by a DC servo motor which is coupled to the solar panel with wiper & brushes. The DC servo motor is also connected to the microcontroller which is programmed to send signals for cleaning mechanism to operate at different time intervals. Therefore this paper presents a novel method of finding a more economical and efficient system that not only ensures maximum amount of sunlight but also helps in the maintenance of solar panel.

Keywords: Solar Energy, Solar Tracker, Stepper Motor, DC Servo Motor, Microcontroller.

I. INTRODUCTION

Renewable energy resources supply almost 14% of the total world energy demand. It includes biomass, hydropower, geothermal, solar, wind & tidal energy. In all of this our concentration is solar energy which is available in both forms direct as well as indirect form. The sun emits energy at a rate of 3.8x10^23 KW of which approximately 1.8x10^14 kW is intercepted by Earth. Solar energy can be converted into electricity using photovoltaic panels. Electrical energy is the pivot of all development efforts in both developed & the developing nations. Therefore converting this abundant amount of solar energy into electrical energy would do much good because conventional energy sources are finite & fast depleting.

Solar power is used interchangeably with solar energy but refers more specifically to the conversion of sunlight into electricity by photovoltaic. Photovoltaic energy is now an accessible technology, it has become a popular investment for companies as well as for residential users. Consequently, this demand has stimulated the research for increasing the overall output power of PV systems, causing people all over the globe to work hard on making the technology more efficient as well as cost-effective .Solar panels are photovoltaic cells which gives voltage directly if you place them in sunlight. These panels' works by allowing photons, all particles

of light, knock electrons free from atoms, generating a flow of electricity. The proposed system uses a solar panel coupled to a stepper motor to track the sun so that maximum sunlight is incident upon the panel at any given time of the day. This movement is achieved by interfacing a stepper motor to the solar panel that changes its direction according to the position of the sun. This is better than the light sensing method that may not be accurate always for example for example during cloudy days.

Regardless of the effort of the industry to increase electricity production, a preventable loss namely soiling is often overlooked. As a result, a layer of dirt piles up on the top of the glass reducing its transmittance and therefore decreasing the power output of the entire system. The rate at which the power reduces over time is rather unpredictable as it depends on various environmental factors such as the type of soil, agricultural activity precipitation, wind, bird droppings. Common order of magnitude for losses due to soiling can be estimated between 3-8% but can go up to 30-40% in dry & sandy climates. However cleaning solar panels is not always straightforward. To begin with, there is the issue of accessibility, due to the fact that PV panels often are situated in dangerous places, it might be hard to clean them manually & it takes time to do safely. Secondly cleaning a panel once a month or year might not have a significant impact on the energy yield for the simple reason that dirt stacks up again on the solar panel in a very short period of time which makes the effort negligible.
Therefore this paper is aiming at working out a concept design for an autonomous cleaning robot that is pre-furnished with the automatic solar tracker. Hence the idea is that the proposed system should be able to utilize the maximum power from the sun keeping in mind that system is flexible as well as cost-effective.

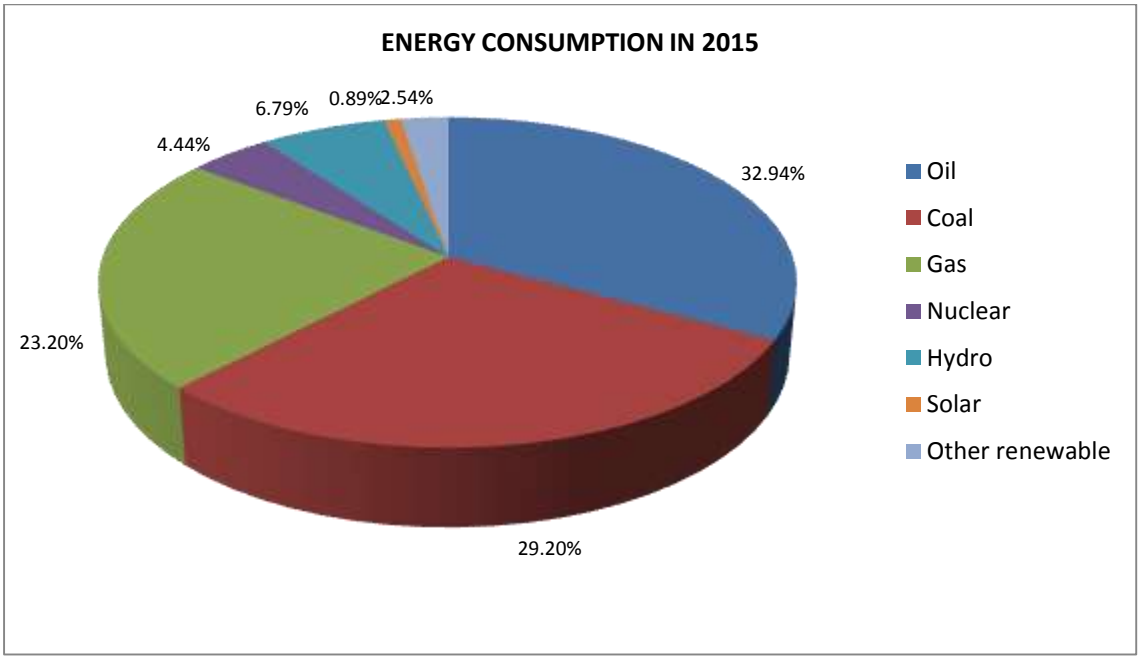


Fig 1: Energy consumption in 2015

As it is quite clear from the above-depicted diagram that thermal energy which includes coal, oil, and gas were consumed the most. But the problem is that they are all non-renewable energy resources. Also, we can see that our subject of interest, Solar energy was used the least, hence there is an urgent need in the present system to utilize solar energy on a large scale as it completely available for free. Our proposed idea applies the same, it promotes the use of solar panels to convert the sun's energy to electrical energy in a more economical and efficient way.

II. LIMITATIONS OF PRESENT TECHNOLOGY

Disadvantages of fixed solar panels

- The biggest disadvantage of fixed solar panels is that they are non-functional on cloudy days.
- Fixed solar panels are functional only until the time when the sun rays are incident at the same angle as that of the solar panel at which they are fixed, therefore they are generally non-functional for rest of the day
- It requires time to time maintenance as dirt always pile up on the panels, hence making the maintenance costly

Disadvantages of solar trackers

Some ongoing maintenance is generally required, though the quality of the solar trackers can play a role in how much and how often this maintenance is needed

- Solar trackers are generally designed for climates with little or no snow. Hence they would not work properly in colder climates.
- Solar trackers with light sensing method are generally non-functional on cloudy days.

Losses in PV systems

As sunlight gets converted to usable electricity there are different losses lowering the systems output power. To quantify the performance of a PV system, a performance ratio is introduced. This ratio represents the final yield divided by the reference yield. These losses can be linked to:

- Panel degradation(η_{deg})
- Temperature(η_{tem})
- Soiling(η_{soil})
- Transformer(η_{tran})
- Inverter(η_{inv})

Therefore, the performance ratio (PR) can be expressed as follows:

$$\textbf{PR= final yield} \div \textbf{reference yield} = \eta_{deg} * \eta_{tem} * \eta_{soil} * \eta_{tran} * \eta_{inv}$$

Now our area of concern in these losses are mainly soiling and degradation of solar panels:

Soiling: When time passes, operational PV panels get covered with a thin layer of dirt, hence decreasing the amount of light hitting the cells. It decreases the efficiency of the solar panels and also requires time to time maintenance. The amount of power loss due to soiling is dependent on several factors.

First of all, it depends on the type of dirt deposited on the panel. Possible polluters are sea salt, pollen or matter from air pollution, agricultural activity, construction and other natural sources.

Secondly, there is the influence of precipitation. Both the amount of rainfall and the time between rain events change the layered pileup. At last important factor is the angle at which the panel is tilted. The lower the angle, the faster the dirt accumulates having a maximal effect when panels are installed horizontally.

Panel degradation: Over time, PV cells lose some of their efficiency due to a various amount of nonreversible damage. A couple of reasons for this phenomenon are oxidation, cell cracks, irreversible soiling, and hotspots. Keeping the panels clean can certainly help in slowing down the degradation of the modules. Hence an improved system is required such that these modules can be maintained from time to time.

III. SOLUTIONS TO ALL THESE LIMITATIONS

AUTOMATIC SOLAR TRACKER WITH INSTALLED PANEL CLEANER SYSTEM ANALYSIS:

- **BLOCK DIAGRAM**

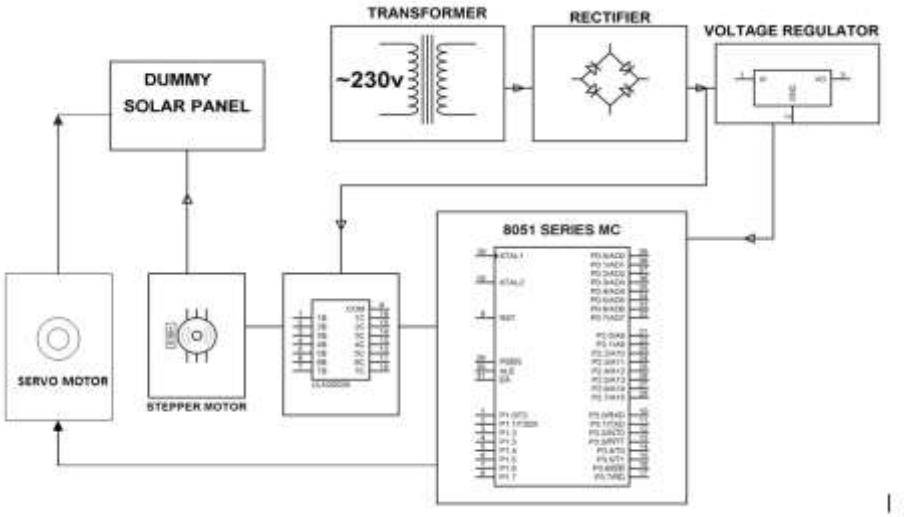


Fig 2: Block diagram

CIRCUIT OPERATION

The circuit uses a standard power supply comprising of a step-down transformer from 230V to 12V and 4 diodes forming a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470micro farad to 100 microfarads. The filtered dc being fed to IC LM7805 which is used to get 5V constant at its pin no. 3 irrespective of input dc varying from 9V to 14V. The power from the voltage regulator powers the microcontroller as well as the relay driver which is used for interfacing. The motors are being supplied by the microcontroller (AT89S52) itself. Also, the time signals are provided by the timers of the microcontroller.

The tracking movement is achieved by coupling a stepper motor to the solar panel such that the panel maintains its face always perpendicular to the sun to generate maximum energy. This is achieved by utilizing a programmed 8051 microcontroller to furnish stepped pulses in specific time intervals for the DC stepper motor to rotate the solar panel as appropriate. The microcontroller used in this project is from 8051 families.
The DC stepper motor is operated by an interfacing IC as the microcontroller is not capable of controlling the power requirements of the stepper motor. The timer existing in the microcontroller is programmed such that it tracks the movement of the sun and accordingly sends signals to the stepper motor to operate.

Now for the cleaning mechanism, we are using a DC servo motor which is energized by the microcontroller itself. We will create a delay such that the motor rotates in one direction such that the wiper reaches one end of the panel. Now we will interchange the supply polarity of the motor and the motor starts rotating in the opposite direction and the wiper reaches the other end. This cycle continues and is simulated at certain time intervals which are programmed in the timer present in the microcontroller. The project uses a dummy solar panel which is used to demonstrate the full operation.

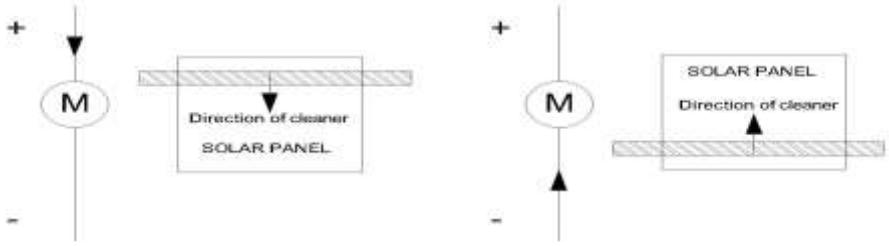


Fig 3: working of the cleaning mechanism

HARDWARE REQUIREMENTS

- TRANSFORMER (230 – 12 V AC)
- VOLTAGE REGULATOR (LM 7805)
- MICROCONTROLLER (AT89S52/AT89C51)
- PUSH BUTTONS
- ULN2003
- STEPPER MOTOR
- DC SERVO MOTOR
- 1N4007
- RESISTORS
- CAPACITORS

HARDWARE COMPONENTS DESCRIPTION

POWER SUPPLY

- The circuit uses a power supply which comprises a step-down transformer from 230v to 12v and 4 diodes which forms a Bridge Rectifier that conveys pulsating dc which is then filtered by an electrolytic capacitor of about 470microfarad to 100microfarad.
- The filtered dc is then sent to a regulated IC LM7805 which is used to get 5v constant at pin no 3 of the microcontroller irrespective of input dc varying from 9v to 14v.
- The regulated 5volts dc is moreover filtered by a small electrolytic capacitor of 10 microfarads to verify any noise produced by the circuit.
- One LED is attached to the 5v point in series with a resistor of value 330ohms to the ground i.e. negative voltage to designate 5v power supply.

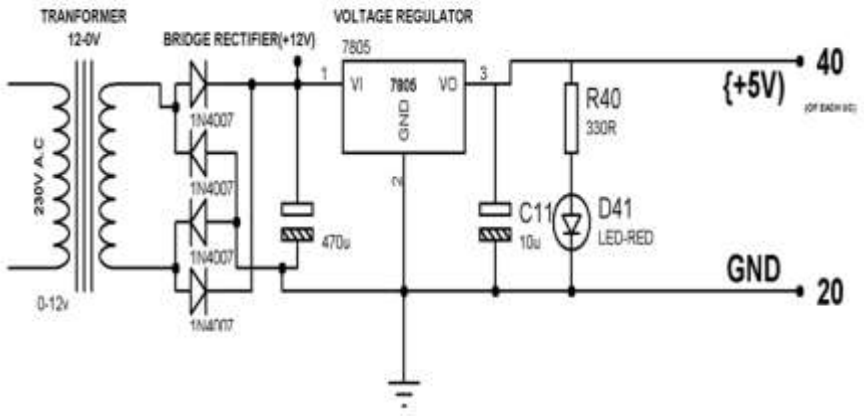


Fig 4: Power Supply

MICROCONTROLLER (AT89S52)

- Well matched with MCS®-51 Products
- 8K Bytes of In-System Programmable (ISP) Flash Memory
- 4.0V to 5.5V Range of Operation
- Fully Undeviating Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Full Duplex UART Serial Channel
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Quick Programming Time

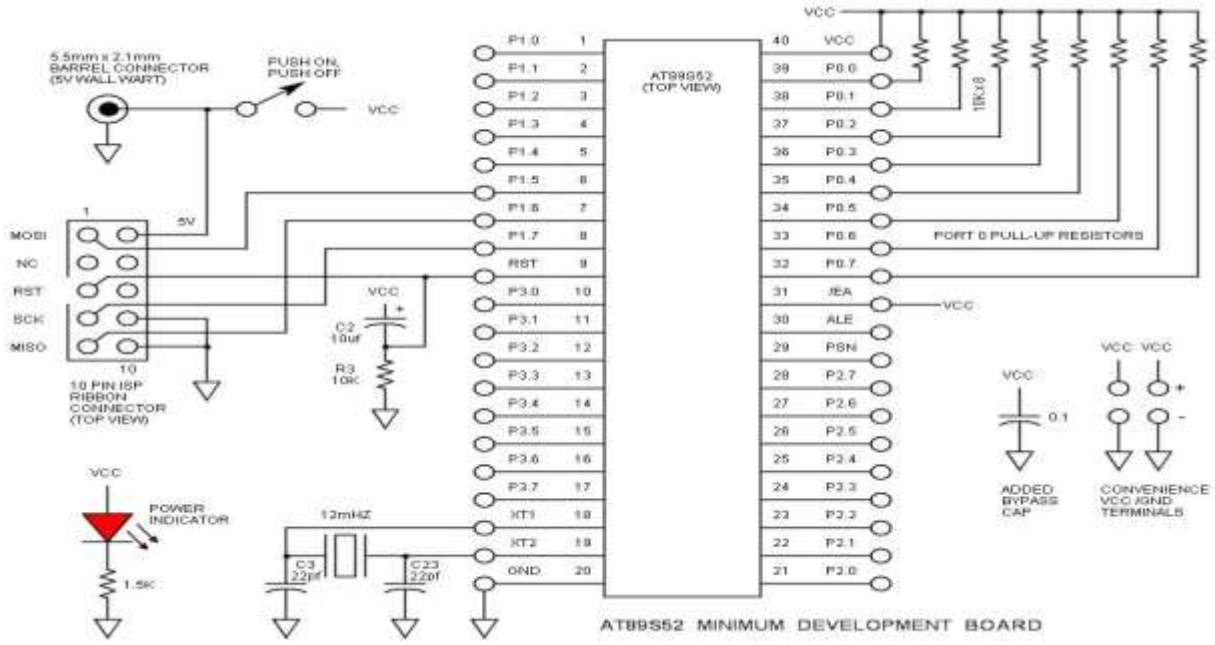


Fig 5: PIN DIAGRAM OF AT89S52

- **SOFTWARE REQUIREMENTS**

➢ Keil an ARM Company which assembles C compilers, macro assemblers, real-time kernels, debuggers, simulators, integrated environments, evaluation boards, and emulators for ARM7/ARM9/Cortex-M3, XC16x/C16x/ST10, 251, and 8051 MCU families.

➢ Compilers are programs used to transform a High-Level Language to object code. Desktop compilers produce an output object code for the unexpressed microprocessor, but not for other microprocessors**.** i.e., the programs written in one of the High-level languages like 'C' will compile the code to run on the system for a particular processor like x86 (underlying microprocessor in the computer).

➢ For example compilers for Dos platform is unlike from the Compilers for Unix platform So if one wants to describe a compiler then the compiler is a program that converts source code into object code.

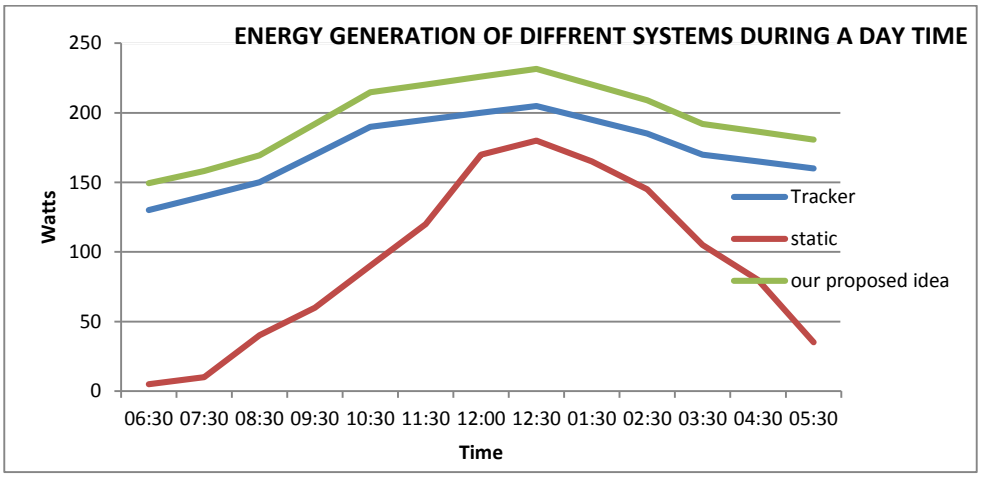
- **CLEANING MECHANISM**

✓ Sprinklers system are often used in the dry area to keep panels clean. It has the same cleaning effect as rainfall and will clean panels at a relatively low cost.

✓ Brushes- Different kind of brushes can be attached to the front of the robot in order to brush away any dust, sand, and dirt which pile up on the solar panel. The robot will clean arrays of PV panels by moving a vertical brush horizontally over the panels.

✓ Wipers- Wipers are generally used to remove rain, snow, ice, and debris from the surface of the PV panels. Hence in rainy and snowy areas where snow piles up on solar panels, wipers can be useful in removing all the snow from the surface of the panels.

COMPARISON OF THE THREE SYSTEMS



The curve for our proposed idea was calculated by knowing the fact that we would be able to save the 10-20% of energy loss which we end up losing in the solar tracker. Hence the total energy tracked by our mechanism is given by:

Energy trapped by our proposed idea= Total energy trapped by solar tracker + (10-20) % of the total energy tracked by solar tracker.

ADVANTAGES OF OUR PROPOSED SYSTEM

- ✓ As it is quite clear from the above depiction that energy production in solar tracker with pre-installed tracker is slightly more than the ordinary solar tracker at any given time of the day. Our proposed system would generate more electricity than their tracker counterparts due to increased maintenance and more exposure of the sun.
- ✓ They will generate more electricity in roughly the same amount of space needed for fixed tilted systems.
- ✓ It has provision for time to time maintenance hence problem of soiling and degradation of solar panels would be solved.
- ✓ It would very useful for installing for smaller arrays, mainly rooftops of residence and offices.

CONCLUSION

- ➢ Existing automated cleaners mainly focus on large arrays and in general are unsuitable for installing on smaller arrays namely residential roofs. For those with limited space this means that a smaller array only needs to be installed, hence our idea serves as a huge advantage for those smaller sites.
- ➢ Secondly, by installing the system energy production is at an optimum and energy output is increased year round. This is particularly noteworthy throughout the summer months with its long days of sunlight available to apprehend and no energy will be lost.
- ➢ For people who install a solar panel cleaner after setting up the solar tracker definitely add to their overall expenditure as it would combine the cost of the solar panel cleaner as well as the labor cost.
- ➢ Our proposed system is just an upgrade of an automatic solar tracker which has a pre-installed panel cleaner. The cleaning mechanism is run by the DC servo motor which is programmed and energized by the 8051 microcontroller.
- ➢ The paper promotes the use of solar panels in a more economical and efficient way.
- ➢ The implementation has a great future scope because the sun is important source of energy which is available in free of cost. As today's world needs greater amount of energy, it can be satisfied by our proposed idea in a more effective, efficient and economical way.

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