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MICROCONTROLLER BASED SPRINKLER ATTACHED CLEANING SYSTEM FOR SOLAR PANEL OPERATED BY ROBOTIC ARM

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ABSTRACT

The efficiency and performance of solar panel is strictly affected by the surrounding dust particles which affect the radiation absorption of the solar PV panel. This system aims at increasing the efficiency of solar power plants by solving the problem of accumulation of dust on the surface of solar panel which leads to reduction in plant output and overall plant efficiency. The system proposes a design and development of sensor based solar panel cleaning system which can remove the accumulated dust on the panel surface on a regular basis with the help of water sprinkler based robotic arm and improves the solar power plant efficiency. The main advantage of the system is the improvement of power output generated by PV panel with the help of simple cleaning robot construction to clean depositions of impurities on the panel's surface. On the other hand, this system aims to reduce the human involvement in the process of solar panel cleaning as it is a very hazardous environment for them in scorching sun. The improvements in the power output generated by PV panel is reported with the cleaning robotic arm which is used to clean depositions of impurities on the panel's surface.

KEYWORDS: *Solar panel, infrared sensor, motor, robotic arm, charge controller, microcontroller.*

1. INTRODUCTION

Solar energy in electrical supply systems requires improvements in energy efficiency through its utilization by rectifying the portion of lost energy in the process of dustless conversion on SPV panel. In this regard, a system is proposed which is a design and development of optical sensor based cleaning system for solar PV plants. The solar PV panel is automatically cleaned with the help of microcontroller based robotic arm, water sprinkler and its associated circuits in such a way that when supply from solar is available during daytime, all the power from solar is utilized to store in the battery, while during night, the complete stored power is then released in the cleaning process of solar panels. Solar supply increased in this way finally utilized for larger output of its electrical load. The system is a kind of cleaning and cooling system where the supply from solar is utilized in such a way that maximum extraction of solar energy can be achieved during sunlight since the panels are cleaned and cooled during night with the help of water sprinkler based cleaning system.

Under the Indian weather conditions, solar panels must be cleaned numerous times a week because even a very little quantity of dust has the potential of reducing the overall efficiency of a PV system. As a result, the proposed solar panel cleaning robot is suggested to be mounted on the PV array in such a way that it frequently cleans the solar panels if any dust or dirt is spontaneously detected. Hence, this paper investigates the best way to maintaining the

effectiveness of solar PVs through efficient cleaning schemes when they are exposed to various weather factors, including humidity and dust.

The most important reason for undertaking this project is to improve the life standard of human beings. Also, the study is motivated by the:

(1) Global trends of designing robots with human appearance,
(2) Think creatively concept,
(3) Reduction of greenhouse gas emissions and ever-growing increase in energy cost,
(4) Need to improve work conditions, and
(5) Negative human impact on the environment.

A work proposes two solar photovoltaic (PV) systems; a PV system integrated with multiple fixed concentrating mirrors and cooling system, and a PV system embedded with an improved panel robot cleaning system described by Zhu et al [1]. Arrays with less number of panels are cleaned with the help of a mop and soap water solution which has less speed of less than 2m2 / minute described by Landis et al [2]. Currently small residential and office space use small size solar panel which does not hinder the instalment and hence to clean those small panel arrays Solar Wash mentioned by Hayden et al [3] is residing in market. NASA has researched the decreased efficiency due to dust and build-up in relation to number of days on Mars described by NASA Jet Propulsion Laboratory [4]. Washing solar collectors with water and detergent is the most commonly practiced method for cleaning quoted by Sheratte et al [5]. Robotic brush cleaning is also used for smaller solar plants, which uses less water and detergent said by Morris et al [6].

2. TECHNICAL BACKGROUND

Solar energy in electrical systems is utilized with the help of solar panels, charge controllers, inverters, converters and batteries. Involvement of these different electrical utilities yields conversion losses because most of the energy loss is due to the conversion loss within the components of these utilities. Further losses are also reported due to the dust accumulation on the solar panel. Energy is reduced with every process of conversion while transferring from one component to other. The energy loss from renewable energy source (solar) to load during energy conversion is shown in figure 1.

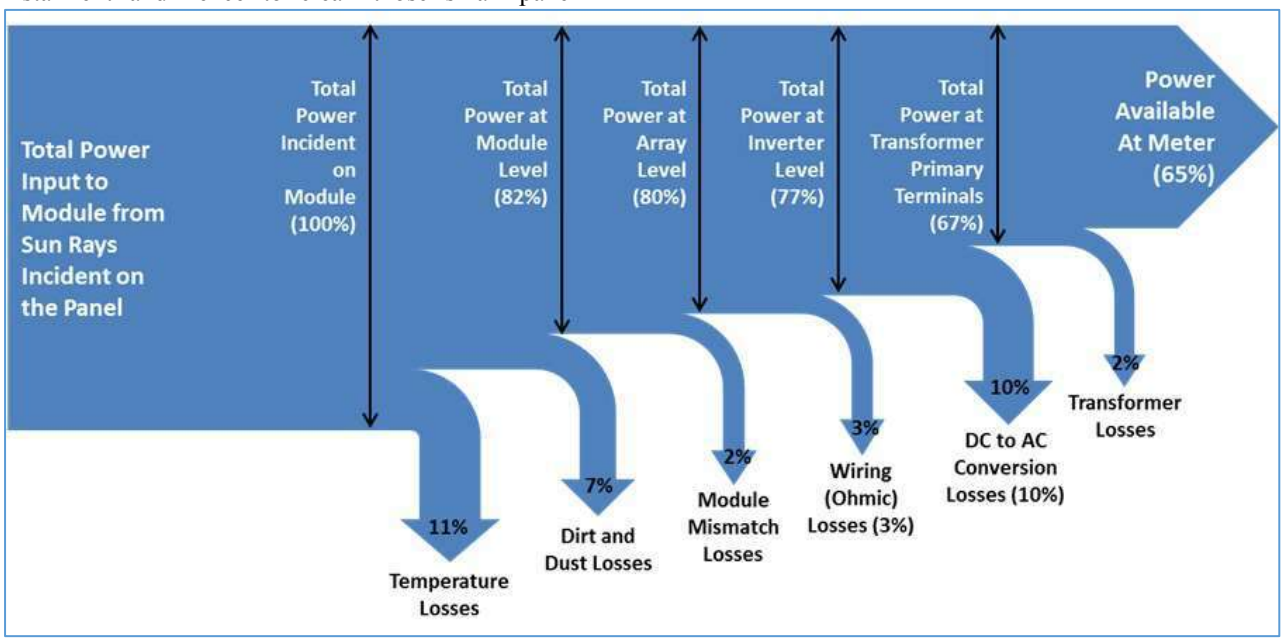

Figure 1. Electrical losses from solar energy to load

3. PROPOSED SYSTEM

The water sprinkler based solar panel cleaning system is based on the maximum utilization of solar energy which is changed according to the dust accumulation subjected to the atmospheric conditions throughout the day. Solar energy received in the form of non-uniform solar radiation changes the output voltage of solar panel in accordance with the droppings, dust and dirt. This fluctuating voltage is used to charge the battery with the help of charge controller during daytime. This stored energy is then released for the movement of water sprinkler based robotic arm in the night time. The robotic arm is actuated with the help of microcontroller based control unit interfaced with the optical sensor network. The sensors are arranged in such a way that upon getting the position of each panel, a particular sensor activates and sends a signal to the microcontroller. This signal is then used to start and stop the robotic arm.

An arrangement of microcontroller dependent water sprinkler based robotic arm in the proposed system is shown in figure 2.

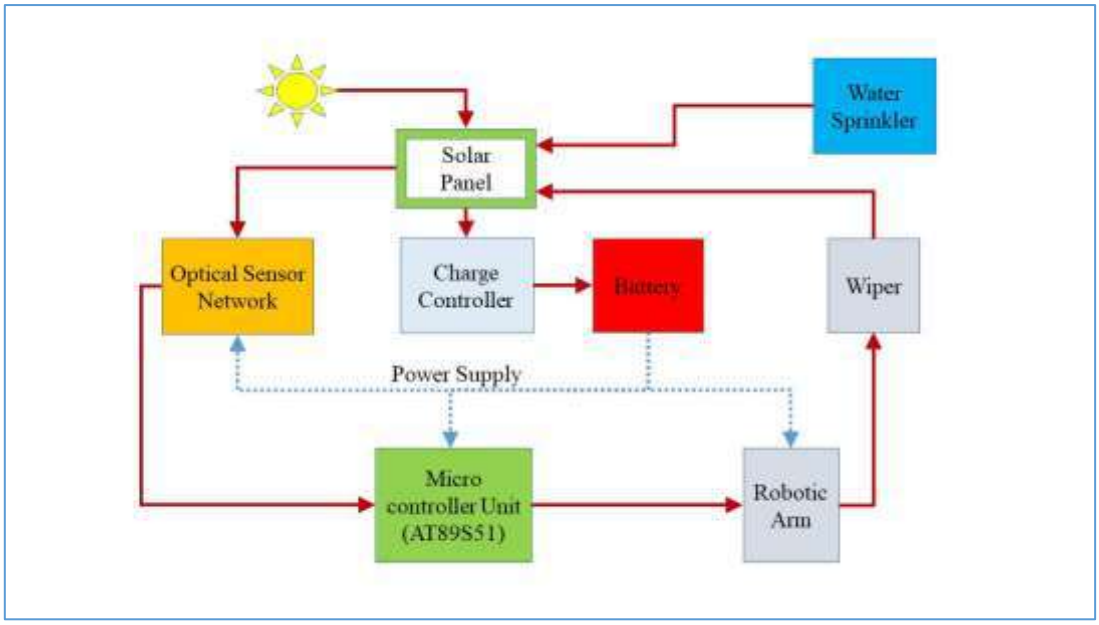

Figure 2. Water sprinkler based solar panel cleaning system

Total power of the system is always maximised as compared to that of non-cleaning systems. In this way, the power from solar is maximised and this maximised power is added to the load from solar in order to keep the maximum output of the system. A microcontroller and its supporting components are used for the implementation of this control logic. In this system, optical positioning parameter depended sensor based data is used to uplift the solar power in the output. Hence, it is also a power or energy maximisation control system. The control logic of this system manages both cleaning and cooling of the solar PV system.

4. DESIGN AND DEVELOPMENT OF HARDWARE

Growing interest in renewable energy has led the solar photovoltaic (PV) industry to expand notably in the last decade. Because Photovoltaic energy is 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 laboratories all over the globe to work hard on making the technology both more efficient and cost effective.

Regardless of the effort of the industry to shorten the payback time, a preventable loss namely soiling is often overlooked. As a result a layer of dirt piles up on 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 etc.

The description of each section of the system is described in following paragraphs.

4.1 Solar Panel

Solar photovoltaic panel is a renewable energy source in this system. It works on the basis of photovoltaic effect according to which it generates electricity when solar radiation in the form of light falls on it [49]. This can be seen with the help of figure 3. The solar panel generates electrical energy without going through thermal process as in case of conventional energy. Solar panels used in this work are meant to charge the battery in daytime for the purpose of power supply to whole system during night. Solar panels or dc generators without having any rotating parts as in case of conventional ac generators are maintenance free and don't emit greenhouse gases to environment [50].

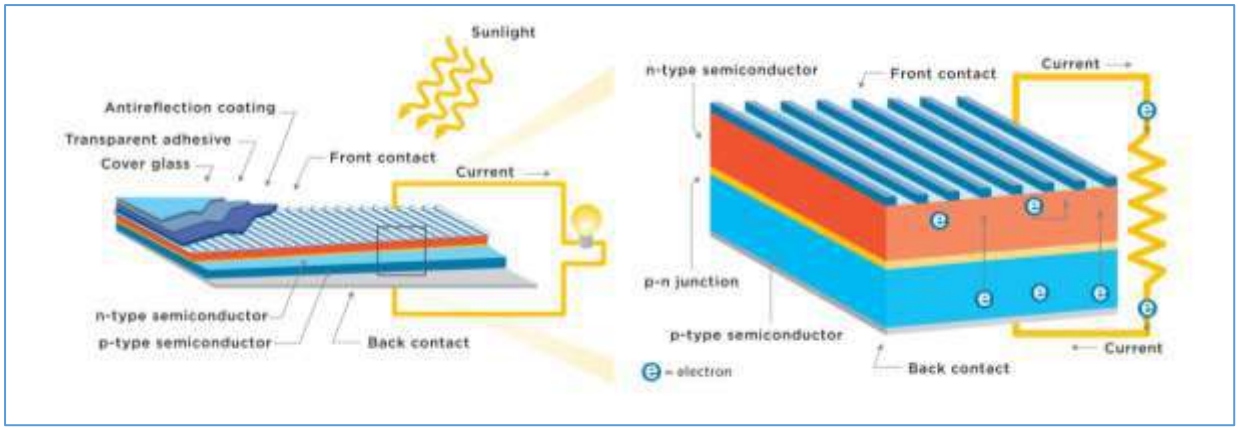

Figure 3. Basic working of a solar cell

4.2 Charge Controller

A solar charge controller or regulator is a small box placed between a solar panel and a battery consisting of solid state circuits PCB. They are used to regulate the amount of charge coming from the solar panel in order to protect the battery from getting overcharged. Adding to this, it can also be used to allow different dc loads and supply appropriate voltage. A functional block diagram of charge controller is shown in figure 4.

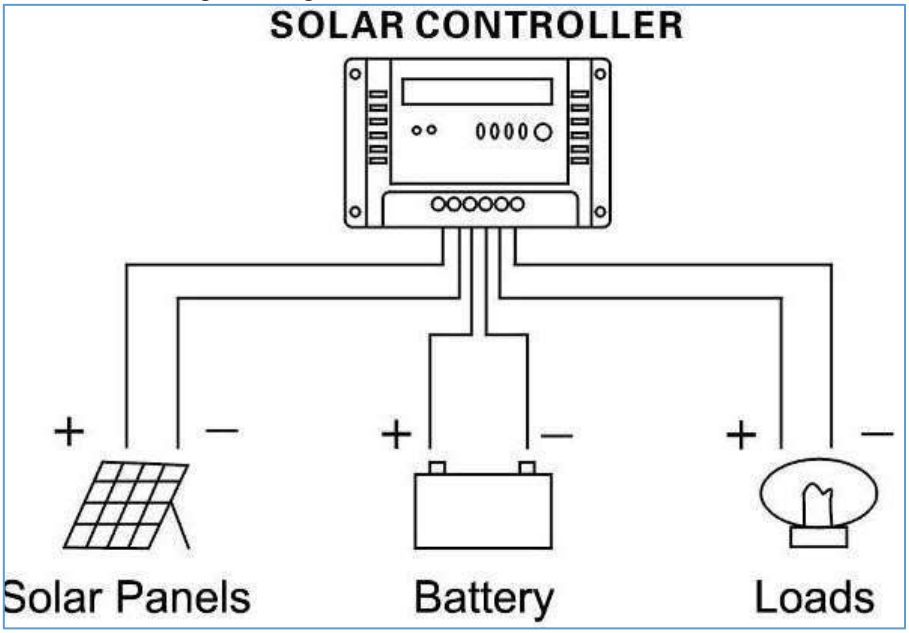

Figure 4. Functional block diagram of charge controller

4.3 Battery

Renewable energy sources, such as photovoltaic (PV) energy, are widely used as stand-alone power systems supplying different electrical loads in rural and remote areas. These sources are of intermittent nature and, therefore, the stand alone power systems should include storage battery banks. The storage battery banks improve the reliability of these systems because the excess energy is stored in the battery bank, and this energy is delivered to the load when the solar energy is not available or not sufficient.

With respect to reliability and cost of standalone PV power systems, storage batteries represent main and important components. Even a battery block represents only 8% of the initial cost of a new PV system; it represents 23% of the total system cost when considering the replacement of batteries during the total life time of the system (20 years). Storage batteries provide the PV system with advantages such as ability of providing energy during night time and sunless periods, ability to meet momentary peak power demands and stabilizing the system voltage.

4.4 Optical Infrared Sensor

An infrared sensor is an electronic device that emits infrared in order to sense some aspects of the surroundings. An IR sensor can also measure the heat of an object as well as detects the motion. The emitter is an IR LED and the detector is an IR photodiode. The IR phototdiode is sensitive to the IR light emitted by an IR LED. The photo-diode's resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor which can be shown by figure. Signal generated by IR sensor is then fed to conditioning unit. Figure 5 shows the principle of IR sensor.

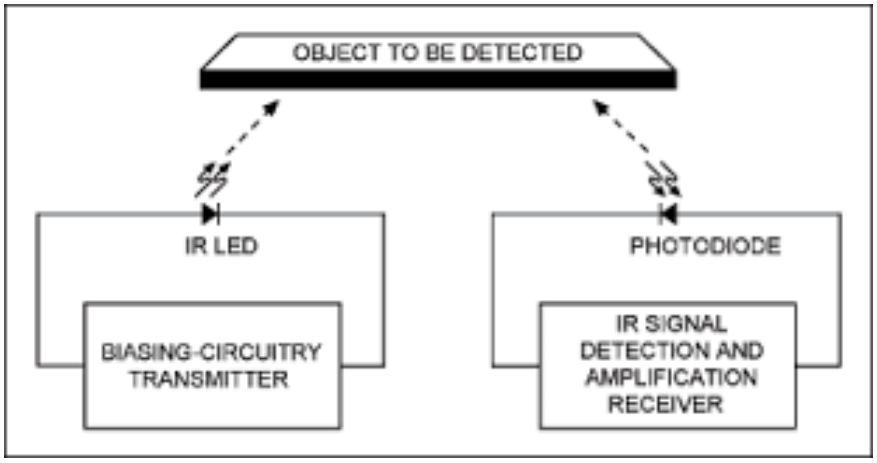

Figure 5. Principle of IR sensor

4.5 Conditioning Unit

In this unit, the transmitter section includes an IR sensor, which transmits continuous IR rays to be received by an IR receiver module. An IR output terminal of the receiver varies depending upon its receiving of IR rays. Since this variation cannot be analyzed as such, therefore this output can be fed to a comparator circuit. Here, an operational amplifier (op-amp) of LM 393 is used as comparator circuit. A basic building block of conditioning unit is shown in figure 6.

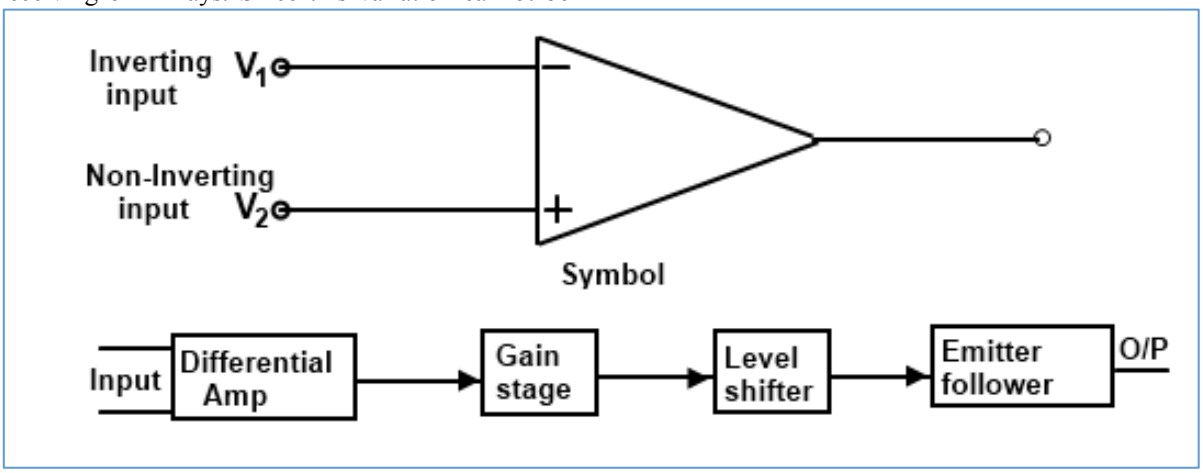

Figure 6. Block diagram of conditioning unit

4.6 Microcontroller Unit

Microcontroller unit with industry standard MCS-51 based AT89S51 controller is the heart of the circuit. It is a low-voltage, high-performance, 8-bit microcontroller that features 4 kB of Flash, 128 bytes of RAM, 15 input/output (I/O) lines, two 16-bit timers/counters, a five-vector two-level interrupt architecture, a full-duplex serial port, a precision analogue comparator, on-chip oscillator and clock circuitry. A schematic is shown in figure 7.

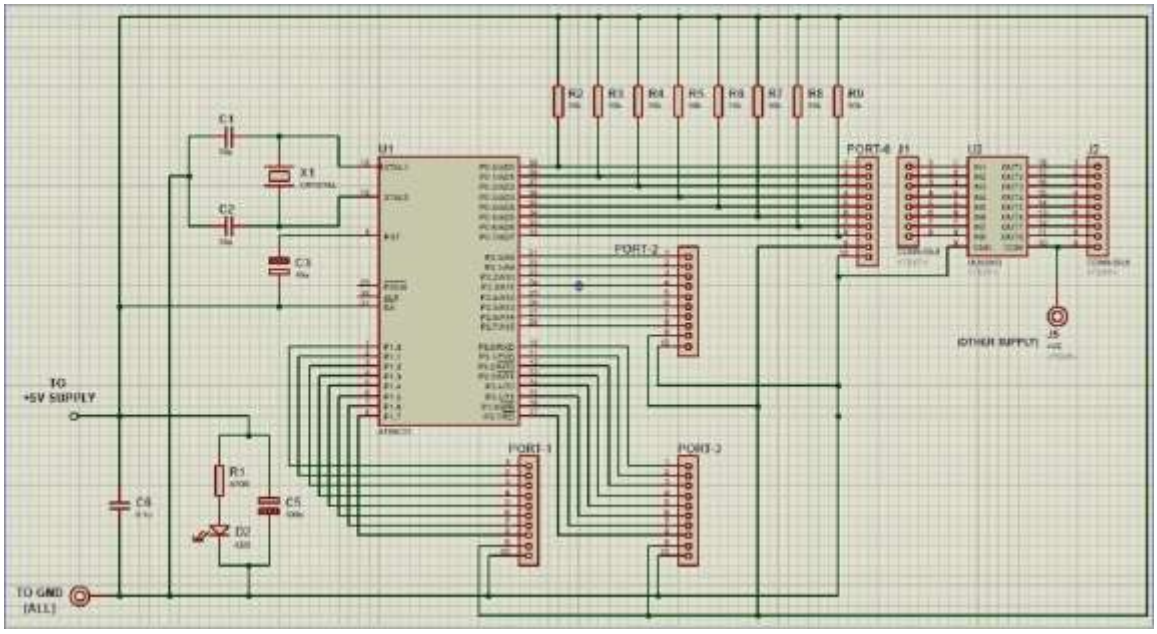

Figure 7. Schematic of microcontroller

4.7 Motor and Motor Driver

Geared DC motors can be defined as an extension of DC motor which already had its Insight details demystified here. A geared DC Motor has a gear assembly attached to the motor. The speed of motor is counted in terms of rotations of the shaft per minute and is termed as RPM. The gear assembly helps in increasing the torque and reducing the speed. Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. This concept where gears reduce the speed of the vehicle but increase its torque is known as gear reduction. A basic block of geared motor is shown in figure 8.

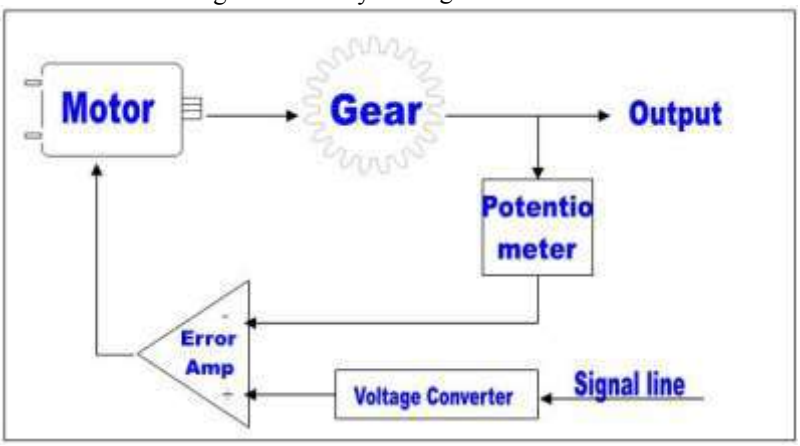

Figure 8. Basic block of DC geared motor

L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of the motor can be controlled by input logic. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

4.8 Darlington Transistor Driver

The Darlington transistor driver is meant to drive high current for relay, buzzer and and LED for the system. The ULN2003A is an array of seven NPN Darlington transistors capable of 500 mA, 50 V output. It features common-cathode flyback diodes for switching inductive loads. Outputs may be paralleled for higher current capability. A Darlington transistor driver is two transistors that act as a single transistor but with a much higher current gain. This mean that a tiny amount of current from a sensor, micro-controller or similar can be used to drive a larger load.

4.9 Relay

This relay chooses supply according to the status of battery power. The 12VDC SPDT (Single Pole Double Throw) relay is used in the system. A basic schematic of a SPDT relay is shown in figure 9.

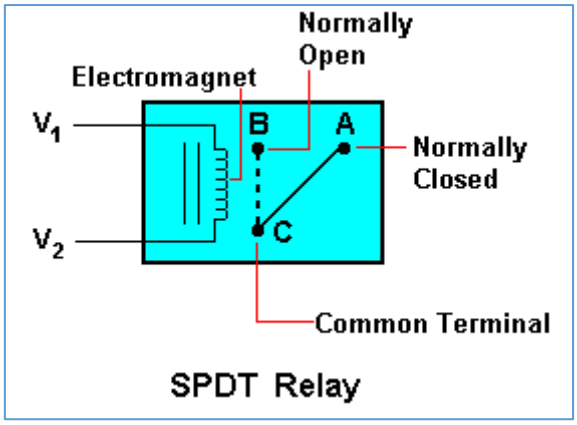

Figure 9. Schematic of SPDT relay

4.10 Indicators

Two indicators have been used in the system as buzzer and LED. Buzzer is used to sound the alarm for faulty working of the system whereas and LED is used to indicate the battery status.

An LED is also incorporated for battery status. When battery is fully charged, the LED glows, whereas it remains off when battery voltage falls below a certain value. A basic working principle of LED can be seen with the help of figure 10.

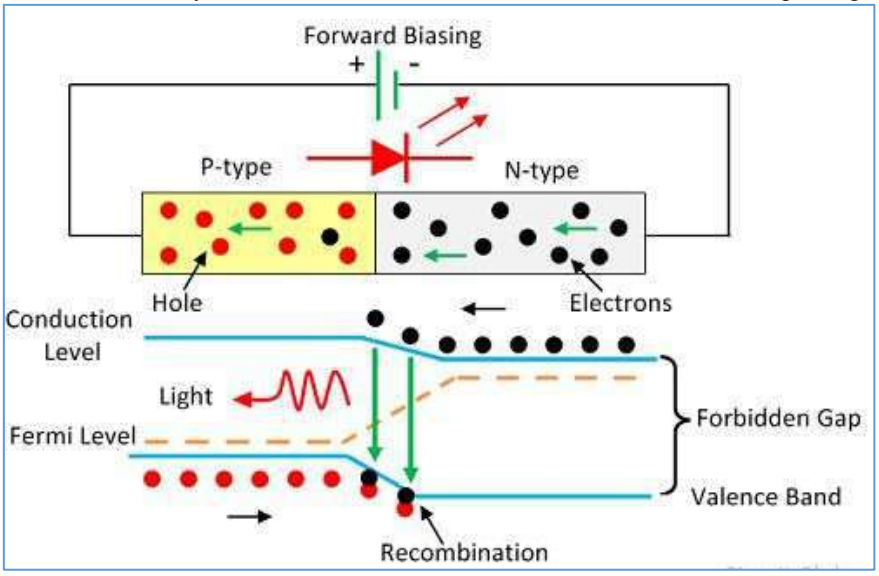

Figure 10. Working of LED

As is evident from its name, LED (Light Emitting Diode) is basically a small light emitting device that comes under "active" semiconductor electronic components. It's quite comparable to the normal general purpose diode, with the only big difference being its capability to emit light in different colors. The two terminals (anode and cathode) of a LED when connected to a voltage source in the correct polarity, may produce lights of different colors, as per the semiconductor substance used inside it.

4.11 Robotic Arm

Robotic arm is an autonomous device that can move around and clean the surface using a technique of scrubbing the surface with a wiper brush.

A basic construction of robotic arm is shown in figure 11.

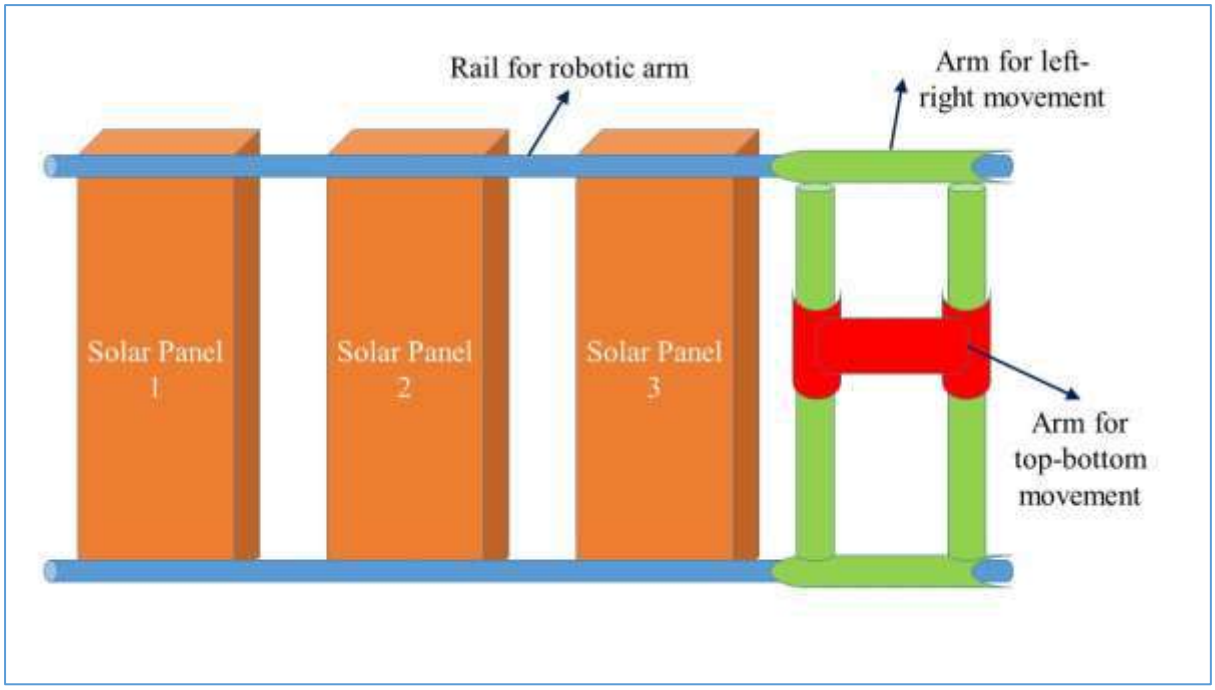

Figure 11. Basic structure of robotic arm

4.12 Water Sprinkler

Water Sprinkler is a method of applying water which is similar to natural rainfall. Water is distributed through a system of pipe by using pumping. It is then sprayed on the surface of PV panel through sprinkler so that it breaks up into small water drops.

4.13 Supply Unit

This section consists of power supplies from solar panel and mains power whereas load section consists of all the interfacing units with microcontroller.

The power unit consists of transformer, bridge rectifier, filter and regulator circuit. A 220VAC power supply is stepped down by transformer, converted into DC by bridge rectifier and then this DC supply is filtered and regulated for smooth and constant supply.

5. DEVELOPMENT OF SOFTWARE PROGRAM

Flowchart consists of main program flow which is shown in figure 12.

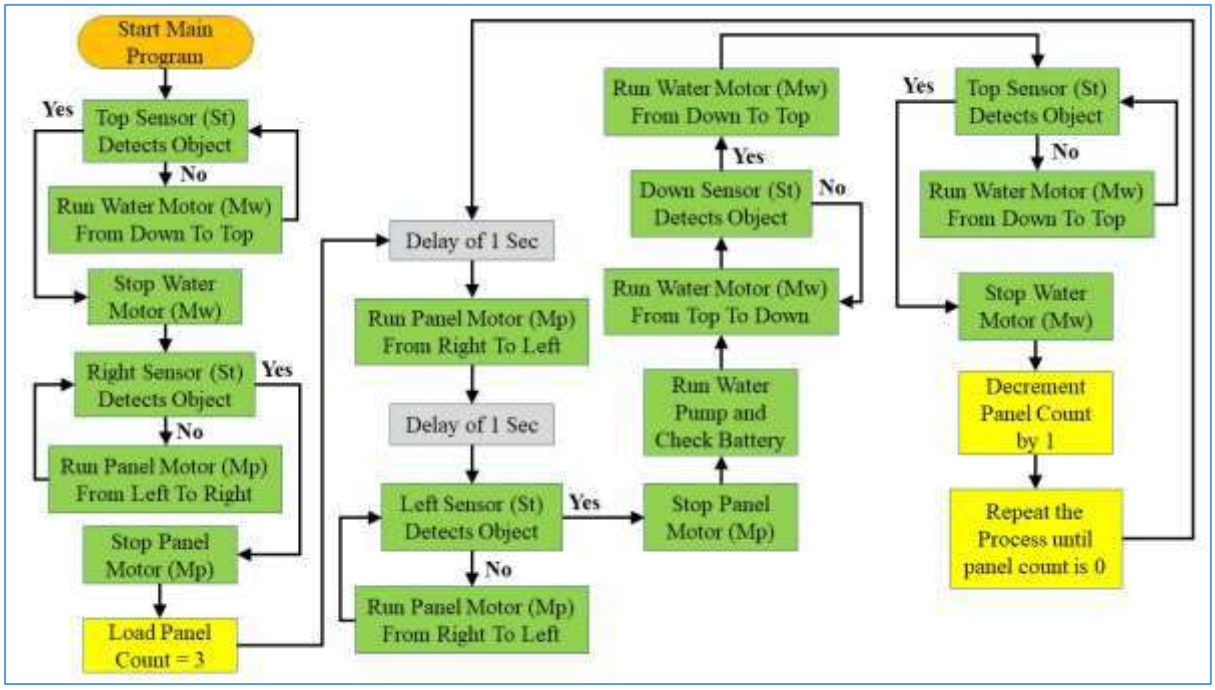

Figure 12. Flowchart of main program

6. TESTING AND RESULTS

Both motors can be operated by either mains or solar supply for their working. Solar energy can be saved for the daylight condition which can be utilized for the motor operation. Now, when the system is working on solar supply, the energy saved by the water motors can be tabulated in table 1.

Table 1. Energy saving by water motor

Sr. No.	Water Motor with Solar Supply				Water Motor with Mains Supply				Total Energy (Wh)	Energy Saving (%)
	V_{ws} (V)	I_{ws} (mA)	P_{ws} (W)	E_{ws} (Wh)	V_{wm} (V)	I_{wm} (mA)	P_{wm} (W)	E_{wm} (Wh)	$E_w = E_{ws} + E_{wm}$	$E_{ws}/ E_w \times 100\%$
1.	11.9	302.2	3.60	0.029	12.1	320.2	3.87	0.031	0.061	93%
2.	11.7	301.8	3.53	0.028	12.0	319.8	3.84	0.030	0.057	92%
3.	11.7	301.3	3.53	0.025	11.8	318.3	3.76	0.027	0.052	94%
4.	11.5	301.0	3.46	0.022	11.7	318.0	3.72	0.023	0.045	93%
5.	11.3	300.3	3.39	0.018	12.3	320.3	3.94	0.021	0.040	86%
6.	11.3	300.1	3.39	0.016	11.7	318.1	3.72	0.017	0.033	91%
7.	11.2	300.3	3.36	0.014	12.2	320.3	3.91	0.016	0.030	86%
8.	11.1	300.1	3.33	0.012	11.8	319.1	3.77	0.013	0.025	88%
9.	11.1	299.8	3.33	0.009	12.1	319.8	3.87	0.010	0.019	86%
10.	11.0	298.0	3.28	0.005	12.0	319.0	3.83	0.005	0.010	86%

In table 1, symbols used are as follows:
V_{ws} = Voltage across motor during solar supply
V_{wm} = Voltage across motor during mains supply
I_{ws} = Current through the motor during solar supply
I_{wm} = Current through the motor during mains supply
P_{ws} = Power consumed by motor during solar supply
P_{wm} = Power consumed by motor during mains supply
E_{ws} = Energy consumed by motor during solar supply
E_{wm} = Energy consumed by motor during mains supply

7. CONCLUSION

An energy efficient control mechanism is utilized for the system. According to current energy scenario, deviation in wind speed creates dust in the environment, but this dust formation is settled by the control technique of this system. Such type of control mechanism where solar energy is utilized for controlling, is very much advantageous in remote and barren areas and places of beyond human's reach. The system is able to run dc motors with the help of solar power. As a stand-alone system, it has its own supply, load and control strategy. To meet future energy demands, a utilization of solar energy for the cleaning purposes in its maximum energy extraction will be required to bridge the gap of demand and supply.

The system suggests a new approach towards the cleaning mechanism. A dustless harnessing of solar energy is one of the way towards energy saving by minimizing energy losses in droppings, snow etc involved in the formation of dusting processes. The system is now able to uplift the energy security of nation and useful for renewable energy promotion.

The system was implemented using low cost interfacing devices and a sophisticated microcontroller which are cost effective and easily upgradable. The source code for the microcontroller was written in the professional assembly language to obtain very accurate and effective connecting or disconnecting action automatically.

Solar powered system is an essential need for current energy scenario. As the current energy prices are not economical and the price of the accessories of solar system are too much high, therefore, for this purpose, we designed and developed the system in order to maximise the use of solar energy.

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