ISSN (Online) : 2455 - 3662
SJIF Impact Factor :5.148

EPRA International Journal of

Multidisciplinary Research

Monthly Peer Reviewed & Indexed
International Online Journal

Volume: 4 Issue:11 November 2018

Published By :
EPRA Journals

Volume: 4 | Issue: 11 | November 2018 SJIF Impact Factor: 5.148 ISSN (Online): 2455-3662

EPRA International Journal of
Multidisciplinary Research (IJMR)

WATER SPRINKLER BASED SOLAR PANEL CLEANING SYSTEM OPERATED BY MICROCONTROLLER INTERFACED ROBOTIC ARM

Poonam Chand Sharma[1]
[1]MTech Scholar
RKDF College of Engineering
RGPV University
Bhopal, MP
India

Dr. A. K. Jhala[2]
[2]Principal and Professor
RKDF College of Engineering
RGPV University
Bhopal, MP
India

Pramod Kumar Rathore[3]
[3]Assistant Professor
RKDF College of Engineering
RGPV University
Bhopal, MP
India

ABSTRACT

In the proposed system, solar energy is used to charge the battery during day time and during night, this stored energy is then utilized to clean the dust formation on the panel with the help of sensor based robotic arm controlled by a microcontroller unit. An increase in the irradiance absorption without overheating the PV panel can be achieved by a proposed system which observes the infrared light for the position of each solar panel with the help of optical sensor. The system is also incorporated with the robotic arm for surface cleaning purposes which cleans the surface with the help of water sprinkler when sensor based positioning of solar panel is detected. The use of water also decreases the overheating of the panel. The sensors are also utilized for the heat detection up to a certain range. The overheating detected by these sensors is then used for warning purposes which then automatically stops the robotic arm. The cleaning robotic arm works on the signal received by optical sensor which is related to the position of solar panel and signal generated by this sensor is used by the microcontroller unit in the form of digital data which is further used to decide the activation of robotic arm.

KEYWORDS: *Solar PV, Sprinkler, infrared sensor, motor, robotic arm, microcontroller.*

1. INTRODUCTION

In solar energy based supply systems, energy losses are reported during the reception of solar radiation on the surface of PV panels. The energy drop by the dirty or dusty surface can be bypassed by the cleaning system of solar panels. A system is designed and developed in which power supplies from solar is used in such a way that power from solar supply is used to charge the battery during night and this stored energy is then utilized for cleaning system in the night. A natural solar radiation helps to charge the battery through the charge controller. The charged battery is then used for cleaning the PV panel by a water sprinkler attached robotic arm working with the help of control unit interfaced by microcontroller. Mains supply can also be used for battery charging during night. The increased solar supply after cleaning can be used to vary the amount of electrical load. The amount of supply used for controlling the robotic arm on solar panel is obtained by the connection of solar supply to battery through a microcontroller based charge controller. The amount of solar power is also supplied which is affected by the depositions of dust and droppings. In this way, power supplied by solar energy during its availability helps to maximize the energy saving.

Various cleaning systems have been come to front to fulfil the energy demand which integrates the renewable energy sources of varying nature. Also, different techniques of cooling and cleaning have also been implemented to meet the gap between demand and supply. But, the energy shortages can be overcome when the cleaning is performed in such a way that it should not affect the radiation fall on the panel. In this regard, a system is presented which controls the robotic arm based cleaning system by using solar supply in such a way that maximum extraction of solar supply is resulted which then maximizes energy saving. The control strategy used in this cooling and cleaning system uses natural solar supply for controlling the entire robotic arm interfaced with other control unit.

The most important reason for undertaking this project is to improve the life standard of human beings. Also, the study is motivated by the global trends of designing robots with human appearance, think creatively concept, reduction of greenhouse gas emissions and ever-growing increase in energy cost, need to improve work conditions, and negative human impact on the environment.

One of the promising low-water-based cleaning processes is to apply a transparent super hydrophobic (SH) coating with nanostructured surface on the optical collectors for reducing adhesion of dust particles to improve cleaning efficiency with low water use described by Cohen et al [1]. Application of transparent electrodynamic screens (EDS) said by Pavan et al [2] is an emerging method for cleaning solar collectors by the electrostatic removal of the deposited dust layer. Piezoelectric actuators have been successfully used in optical adjustment, biomedical manipulation said by Anderson et al [3]. Renewable energy is the energy obtained from natural resources that can be replenished, such as solar energy, wind energy, biomass, geothermal and ocean energy said by Mondal et al [4]. PV system is claimed to have a problem in its energy conversion efficiency that is reducing in time due to increasing temperature by 4-17% during its operational period said by GEKKO Solar Farm [5]. One of the methods found from previous study is using light reflection method. The solar panel is attached with multiple fixed directed mirrors that act as reflectors said by Heliotex [6].

2. TECHNICAL BACKGROUND

Solar energy is first converted into electrical energy in the form of dc supply with the help of solar PV panels. The electrical energy of dc supply is then stepped down by 11% because of temperature losses. Further dirt and dust losses deducts 7% from the remaining energy. Other losses are module mismatch losses, wiring losses which are 2% and 3% respectively.

Electrical energy in batteries in the form of chemical energy is applied from solar panel by using charge controllers. These controllers consumes electrical energy for its own operation. The energy transformation of electrical to chemical in batteries produces conversion loss. Now, when sun radiation is not available on solar panels, the stored chemical energy again converted into electrical energy for the use of inverter and converter. This transformation of energy again affect the conversion loss. Furthermore, the dc supply is stepped down or stepped up by using converter which consumes electricity and therefore, electrical loss again occurred. Moreover, the conversion loss of 10% is again produced when the dc supply is converted into ac supply by using inverter. The ac supply is then stepped up or down with the help of transformers and other associated circuits. This conversion again leads to energy loss of 2%. In this way, to operate an electrical load from solar energy, there are consumption and conversion losses in the process of electrical supply from source to load. The proposed system rectifies these intermediate losses generated due to the dirt and dust accumulation and offers a clean utilization of solar energy in electrical supply systems.

3. PROPOSED SYSTEM

The system as shown in figure 1 is a combination of cleaning and cooling which is utilized with the help of solar energy. The system is developed to work in night after absorbing the solar radiation in daylight. Solar power is received by means of radiation on the solar panel. This solar power is used to charge the battery with the help of charge controller. The battery status is continuously checked by the relay and upon getting the battery status, charge controller connects solar or mains power to the battery for the purpose of charging it. When the battery is fully charged, it is then used for its stored power in the night for cooling and cleaning purposes.

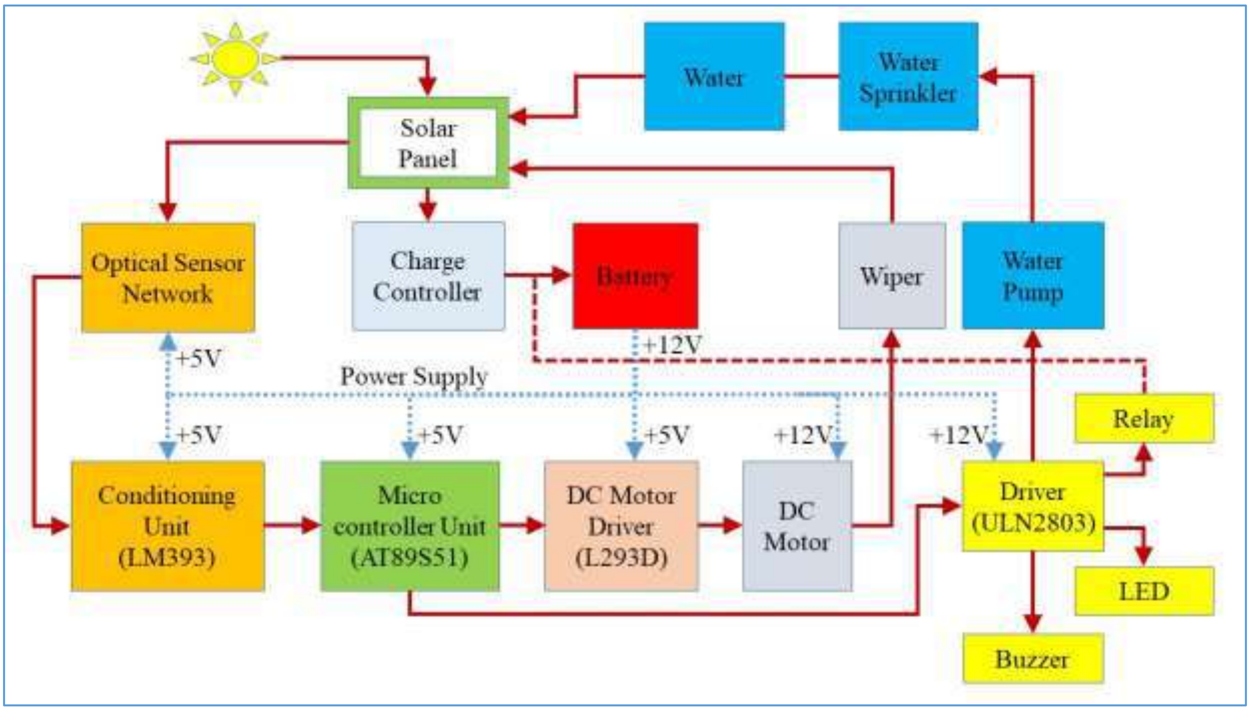

Figure 1. Water sprinkler based solar panel cleaning system

In the night time, solar panels are cleaned and cooled by the water sprinkler based robotic arm operated by a microcontroller based control unit. A four infrared optical sensor network is used to initialise this task. These sensors check the position of robotic arm on the solar panel. Upon getting the correct position, the left-right movement of robotic arm is stopped immediately and water sprinkler comes in action. After getting the water on panel, the robotic arm cleans the surface of panel from top to bottom and the process continues for remaining panels. The signal generated from optical sensors are sent to microcontroller unit (AT89S51) through the conditioning unit which is op-amp (LM393) based amplifier.

The movement of robotic arm is controlled by two DC motors. Each motor is responsible for left-right and top-down motion. Both motors are operated with the help of L293D based motor driver. Another driver (ULN2803) is used for the operation of water pump motor, relay activation, LED indication and buzzer alarm. All the components work together for proper operation of the system.

In this way, solar supply is always maximized during the availability of solar energy. In the system, relays is used as a switching device in the charge controller network. This relay is activated by microcontroller. Hence, the control devices are not involved in intermediate consumption when the energy source is used for supply to load and therefore, the load consumes energy directly from the source with maximised power.

4. DESIGN AND DEVELOPMENT OF HARDWARE

Solar power based panel cleaning hardware consists of all the physical components for the system with a common control unit which provides a new technique over conventional technique.

Common order of magnitude for losses due to soiling can be estimated between 3-8% but can go up to 30-40% in dry and sandy climates. Seeing that precipitation plays a considerable role in the cleaning capability it must be said that rainfall often does not suffice because some types of soil cement and stick. The same counts for bird droppings which don't flush away either.

However cleaning solar panels is not always as straightforward. To begin with, there is the issue of accessibility. Due to the fact that PV panels often are situated on dangerous and difficult to reach places, it might be hard to clean them manually and it takes time to do it safely. Secondly, cleaning a panel only once a year might not have a significant impact on the yearly energy yield for the simple reason that dirt stacks up again in a short period of time making the difference negligible. Especially if we need to contract someone to clean the panel for you, it might just not be economical. However, leaving panels uncleaned might not be wise either since soiling can lead to permanent damage of the glass limiting the lifespan of the installation.

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

4.1 Solar Panel

Solar panel is one of the supply source in the system. The supply from solar panel is extracted for the load. Higher-wattage up to 40W panels can be used with some modifications to the controller unit. PV systems can reduce or eliminate the amount of electricity purchased from the utility provider. Solar panels are dc generators which don't require any rotating parts as in case of conventional generators and hence these are maintenance free. Solar radiation

strictly affect the output of solar panel. Any changes in radiation further vary its output power. Panels can save money by acting as a hedge for increasing energy prices. Energy is clean, renewable, and reliable. It helps the community by staying off the grid.
A performance of solar panel is shown in figure 2.

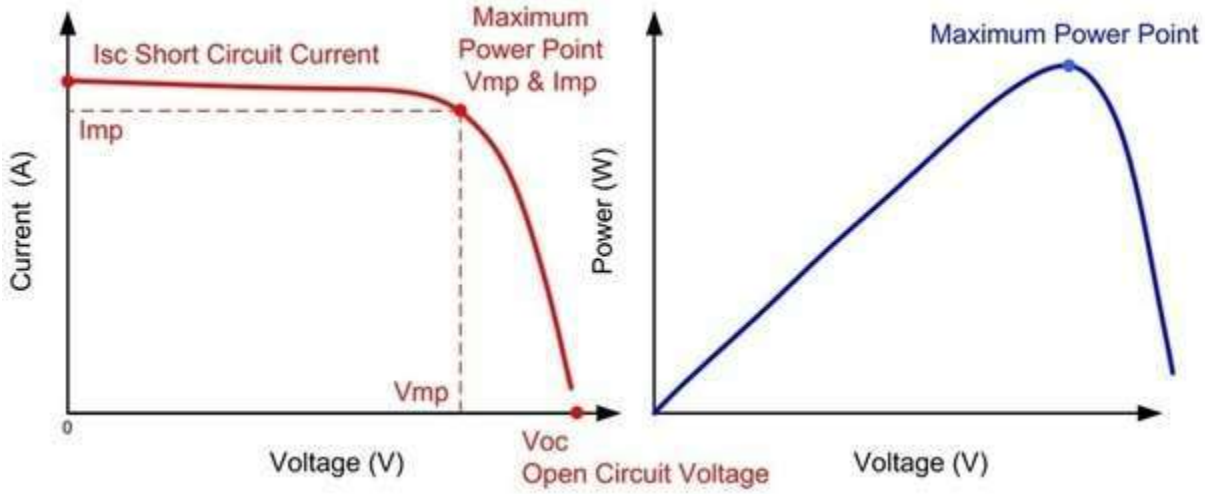

Figure 2. Basic performance of a solar cell

4.2 Charge Controller

A charge controller is an essential part of nearly all power systems that charge batteries, whether the power source is PV, wind, hydro etc. A PV system consists of a PV array which converts sunlight to DC power, a control system which regulates the battery charging and operation of the load, energy storage in the form of secondary batteries and loads is referred to as charge controller. A charge controller is one of the functional and reliable components of PV system. The main function of a charge controller in a PV system is to keep batteries properly charged and safe for the long term, and to protect it from deep discharging, without a charge controller, the battery will overcharge. Absence of charge controller in PV system results in high maintenance cost including frequent battery replacement. Hence, a charge controller is important to prevent battery overcharging excessively. A schematic of charge controller is shown in figure 3.

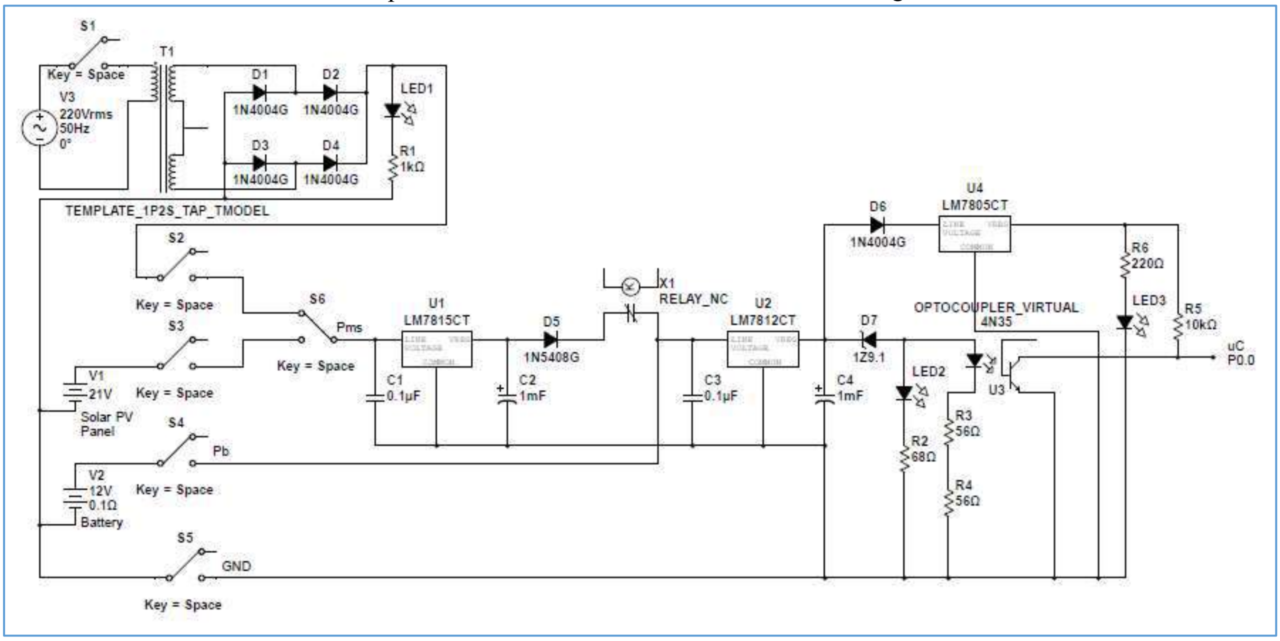

Figure 3. Schematic of charge controller

4.3 Battery

A rechargeable battery or storage battery is a group of one or more electrochemical cells. They are known as secondary cells because their electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging anything from a button cell to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of chemicals are commonly used, including: lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion) [20]. A basic structure of a lead-acid battery is shown in figure 4.

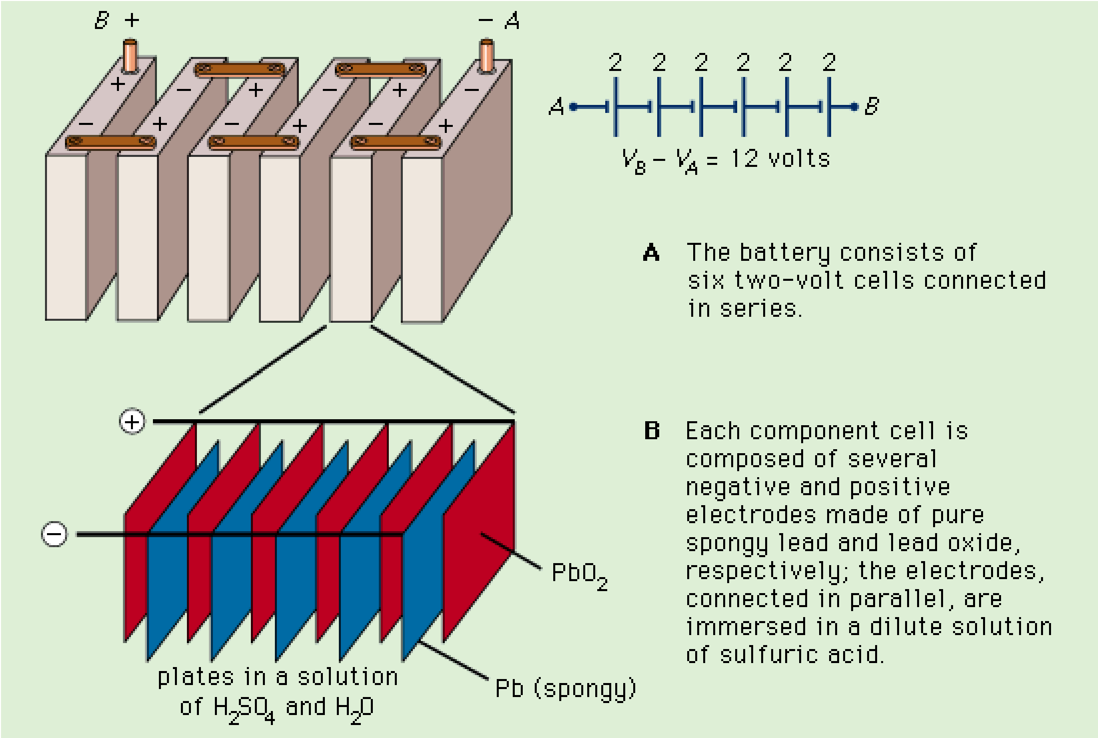

Figure 4. Structure of lead-acid battery

Storage batteries are indispensable in all standalone solar electric systems (PV power systems). Their efficiency and life time affects significantly the overall PV system performance and economics. Batteries specified especially for use in PV systems have to be distinguished with standing of a very deep discharge rate and high cycling stability. The most proper types of storage batteries (rechargeable batteries) are lead acid batteries which are necessarily evaluated for their performance. Selecting the optimum conditions of lead acid battery to obtain the maximum efficiency and maximum ampere hour and watt hour capacities by implemented measurements on a lead acid battery are presented in this work. The internal resistance of the battery is a reliable key for determination of its state of charge. The value of this resistance increases almost linearly with increasing of the stored energy. The experiments have shown that the battery internal temperature doesn't change significantly from the ambient temperature during charge and discharge process. The implemented experimental tests have proved that a regular battery cell will be not more rechargeable if it is fully discharged. This issue requires using always a controllable battery charge controller within the PV power systems to protect the storage batteries against deep discharge and extremely over charge. Such equipment will extend the life time of the battery and consequently improve the economic feasibility and reliability of the PV power systems.

4.4 Optical Sensor Network

The IR transmitter sends an infrared signal that, in case of a reflecting surface (e.g. white color), bounces off in some directions including that of the IR receiver that captures the signal detecting the object. When the surface is absorbent (e.g. black color) the IR signal isn't reflected and the object cannot be detected by the sensor. This result would occur even if the object is absent. In this way, according to the working principle of the IR sensor, when the Infrared (IR) light leaves an IR LED, it reflects on an object. This reflected light travels back to an IR receiver. The IR receiver detects the presence of an object. This is illustrated in Fig 5.

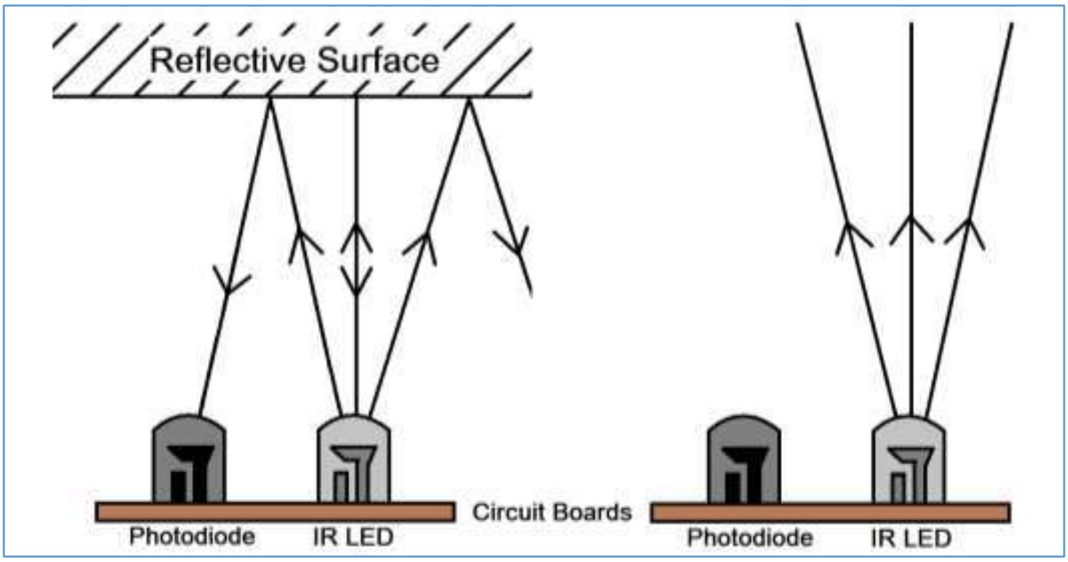

Figure 5. Operation of IR sensor

4.5 Conditioning Unit

Here the LM393 IC do the voltage comparing here, a reference voltage is set by the adjustable potentiometer, when the analog output value over this value, the LM393 will output a digital value to indicate this sensor is triggered by reaching this setup threshold. This unit is shown in figure 6.

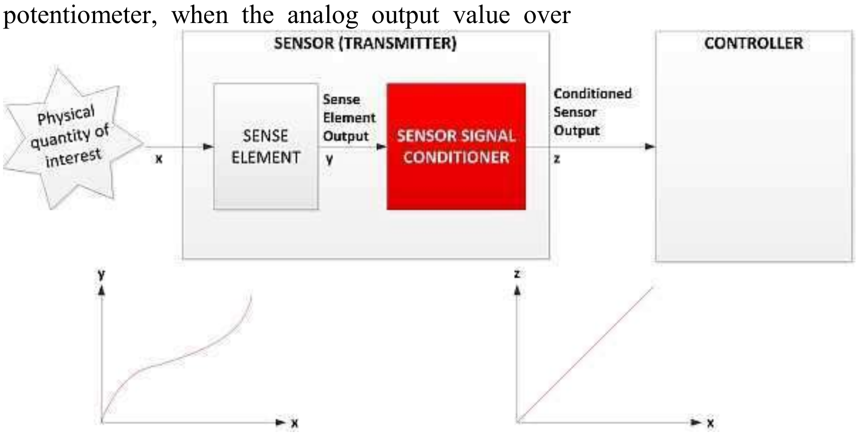

Figure 6. Workflow of conditioning unit

4.6 Microcontroller Unit

In 89s51 microcontroller, 11.0592 MHz crystal is used for providing the basic clock frequency. All I/O pins are reset to '1' as soon as RST pin goes high. Holding RST pin high for two machine cycles, while the oscillator is running, resets the device [48]. Microcontroller works as a digital section for processing the digital data. A functional diagram of microcontroller is shown in figure 7.

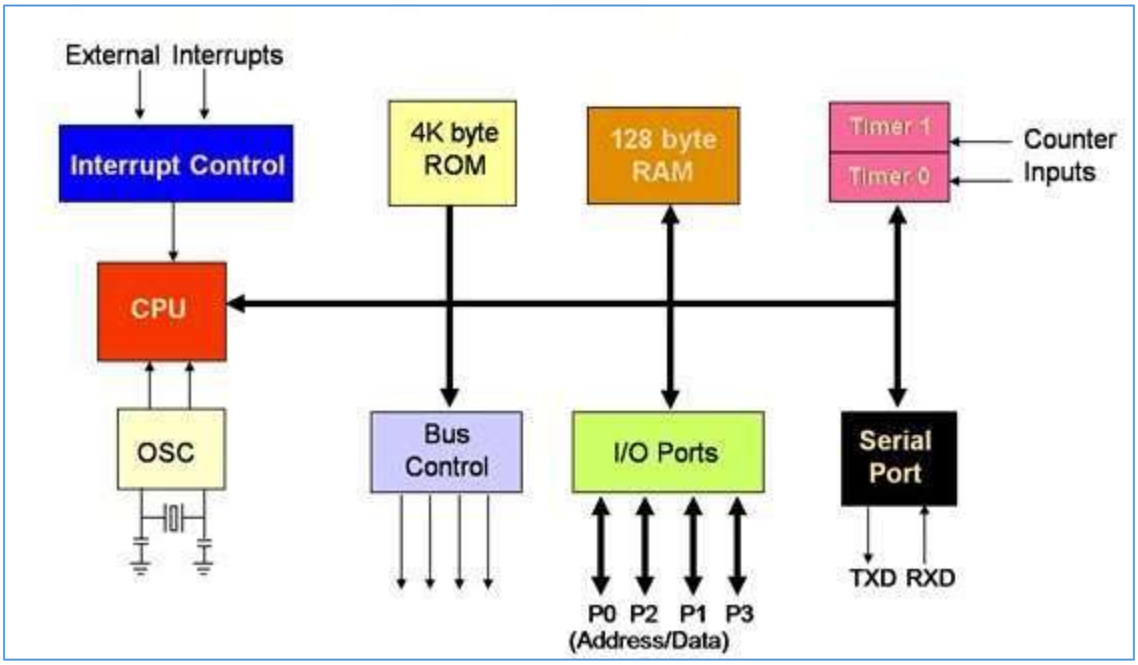

Figure 7. Functional diagram of microcontroller

4.7 Motor and its Driver

A gear motor is a specific type of electrical motor that is designed to produce high torque while maintaining a low horsepower, or low speed, motor output. Gear motors are driven by a motor driver L293D in this system. L293D is a dual H-bridge motor driver integrated circuit (IC) which is shown in figure 8. Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors.

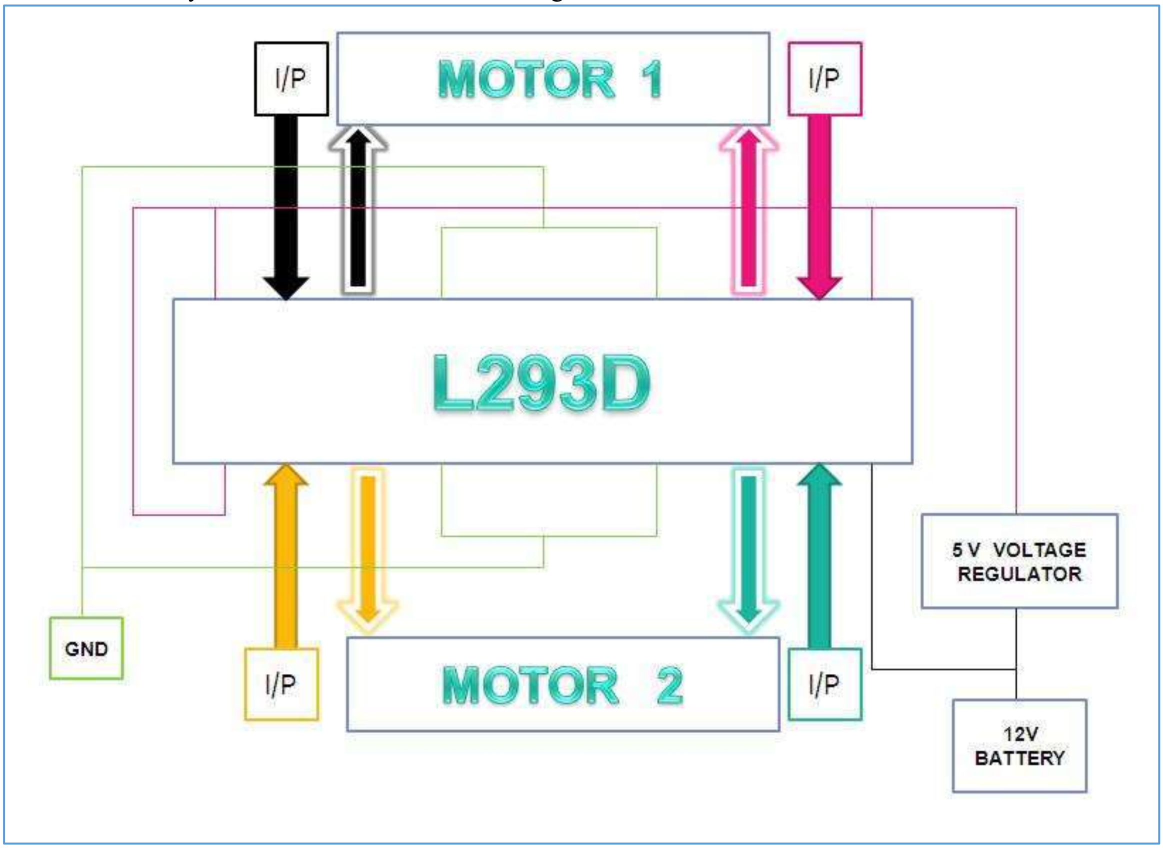

Figure 8. Block diagram of motor driver L293D

Enable pins of the motor driver must be high for motors to start operating. When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state.

4.8 Darlington Transistor Driver

The Darlington transistor (commonly called a Darlington pair) is a compound structure of a particular design made by two bipolar transistors connected in such a way that the current amplified by the first transistor is amplified further by the second one. A basic circuit of Darlington driver is shown in figure 9.

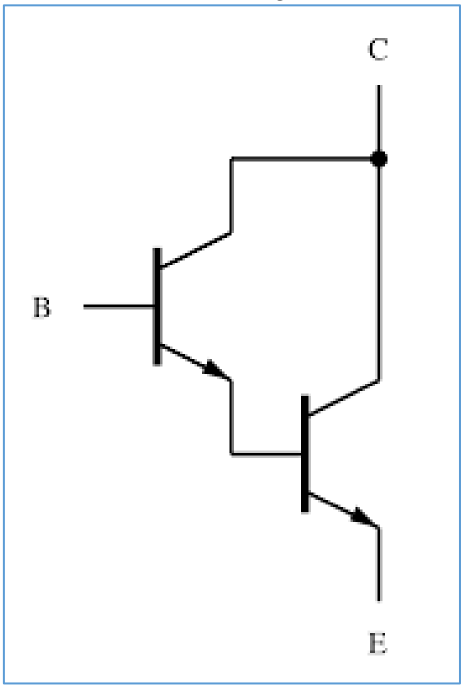

Figure 9. Schematic of Darlington transistor driver

4.9 Relay

An 8-Channel relay is a way to interface the battery and charge controller for switching applications. The relays decide that at which time, battery is to be connected with power supply and when it has to be fed to the load.

4.10 Indicators

In a buzzer, a piezo electric element is a crystal or ceramic that deforms slightly when a voltage is applied to it. So if we supply a DC pulsating voltage at a few kilohertz, it deforms back and forth at the same speed as the DC signal, and produces an audible sound. The same effect works in reverse. A diagram of the buzzer working is shown in figure 10.

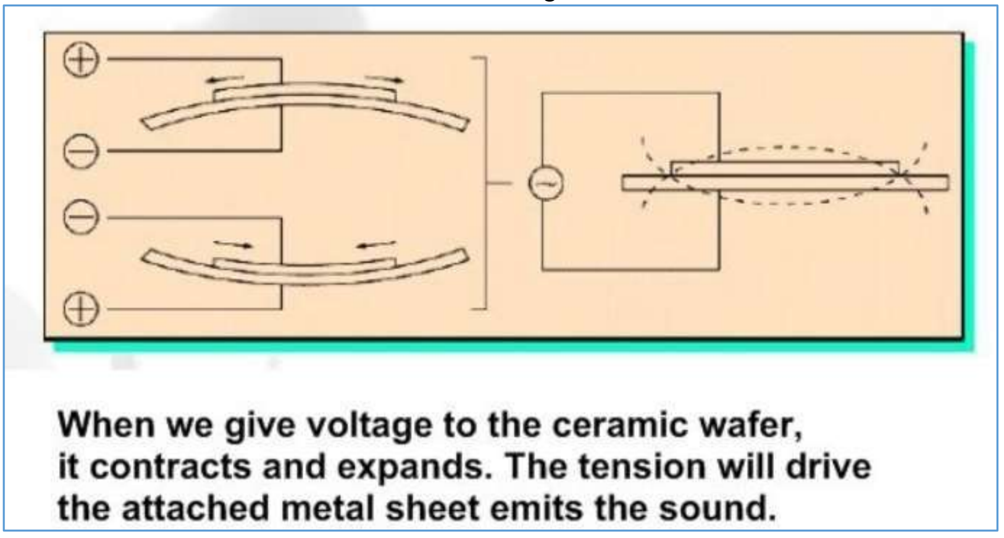

Figure 10. Working of the buzzer

A light-emitting diode is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

4.11 Robotic Arm

The proposed solar panel cleaning system falls in the category of cleaning robots for industrial cleaning application in large scale solar power plants. It is an autonomous robot that moves on the slanted surface of the solar panels with the help of rotating pulleys and cleans the surface of the panels with the help of a wiper. In each cycle the robot first moves a certain distance in the direction parallel to the base of the solar panel and then the wiper moves in the direction perpendicular to the base from top to bottom. Depending upon the latitudinal location of the solar power plants, the solar panels are fixed at an angle to the ground, so as to receive maximum solar irradiance.

4.12 Water Sprinkler

Water sprinklers are also used for cooling and for the control of airborne dust. Figure 11 shows cleaning of dust by using water sprinkler.

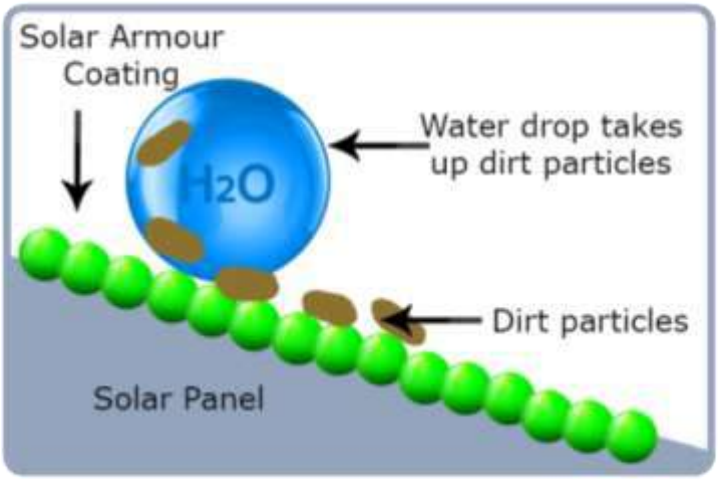

Figure 11. Basic operation of water sprinkler system

4.13 Supply Unit

The mains power supply unit is developed for providing the supply to the complete developed hardware. This unit comprises of rectifier and filter circuit. The power unit takes the step down AC supply from the transformer at its input and provides 24V DC supply at its output for other units. The rectifier circuit is used to provide 5V for microcontroller, whereas 12V for relay, buzzer, LED and water pump. A working flow of supply from AC to DC is shown in figure 12.

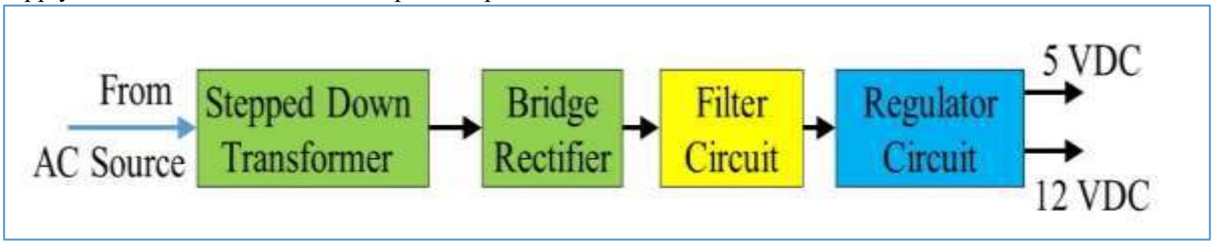

Figure 12. Block representation of supply unit

5. DEVELOPMENT OF SOFTWARE PROGRAM

The algorithm can be viewed graphically in the form of flow-chart which is divided into two parts. First part consists of port decision, battery check-up and faulty start-up conditions. This is shown in figure 13.

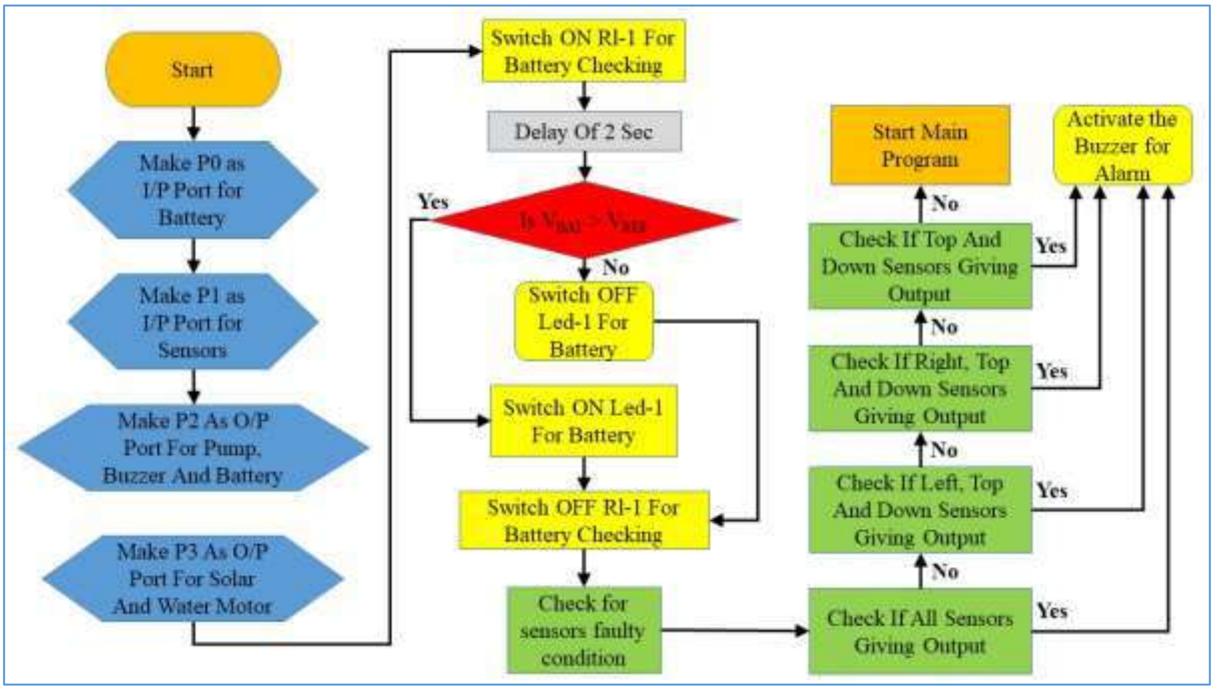

Figure 13. Flowchart for system start up

6. TESTING AND RESULTS

When solar panel motor is tested with solar supply, energy saving is reported which is shown in table 1.

Table 1. Energy saving by panel motor

Sr. No.	Panel Motor with Solar Supply				Panel Motor with Mains Supply				Total Energy (Wh)	Energy Saving (%)
	V_{ps} (V)	I_{ps} (mA)	P_{ps} (W)	E_{ps} (Wh)	V_{pm} (V)	I_{pm} (mA)	P_{pm} (W)	E_{pm} (Wh)	$E_p = E_{ps} + E_{pm}$	$E_{ps}/ E_p \times 100\%$
1.	12.1	322.2	3.90	0.032	12.1	340.2	4.12	0.034	0.067	95%
2.	11.8	321.8	3.80	0.029	12.0	339.8	4.08	0.031	0.061	93%
3.	11.7	321.3	3.76	0.026	11.8	338.3	3.99	0.028	0.054	94%
4.	11.5	321.0	3.69	0.023	11.7	338.0	3.95	0.024	0.047	93%
5.	11.5	320.9	3.69	0.022	12.3	340.3	4.19	0.025	0.046	88%
6.	11.4	320.7	3.66	0.018	11.7	338.1	3.96	0.019	0.037	92%
7.	11.3	320.5	3.62	0.015	12.2	340.3	4.15	0.017	0.032	87%
8.	11.3	320.5	3.62	0.014	11.8	339.1	4.00	0.016	0.030	91%
9.	11.1	320.3	3.56	0.010	12.1	339.8	4.11	0.012	0.021	86%
10.	11.1	320.1	3.55	0.007	12.0	339.0	4.07	0.008	0.014	87%

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

In this way, maximum energy was saved with the help of solar power based system operation and the values obtained were very close to the expected readings.

7. CONCLUSION

A cleaning of solar panel from either solar or mains supply with the help of water sprinkler based robotic arm is implemented in the system. A software program is also developed for the hardware by using assembly language which is useful for fast program execution. Developed system now has an ability to utilize solar energy for cleaning purposes and prevents energy losses generated by dust accumulation on the panel surface. This strategy is also helpful for economic point of view.

The system is now able to utilize the solar energy for cleaning purposes. Utilization of solar energy in cleaning systems prevents electrical as well as economical losses. Cleaning of dust accumulation on solar panel is a way towards the lossless power generation. The technique presented in this work replaces the conventional control methods and suggests a new digital way of instant cleaning of solar panels. This control technique is very much useful specially in rural and distant areas, where an automatic controlling without any human interruption is required.

A hardware for this scheme was developed for which a high speed assembly language program was executed on the microcontroller platform. The software written in assembly language for its fast processing time was successfully tested on this hardware. Also, the stability of microcontroller was good enough for sudden input and output reactions. The testing results were closely related to the expected values in local environmental conditions.

REFERENCES

1. *G. E. Cohen, D. W. Kearney, and G. J. Kolb, "Final report on the operation and maintenance improvement for concentrating solar power plants," Sandia Nat. Lab., Albuquerque, NM, USA, Tech. Rep. SAND99-1290, 2018.*
2. *A. M. Pavan, A. Mellit, and D. D. Pieri, "The effect of soiling on energy production for large-scale photovoltaic plants," Sol. Energy, vol. 85, no. 5, pp. 1128–1136, May 2018.*
3. *M. Anderson et al., "Robotic device for cleaning photovoltaic panel arrays," in Proc. 12th Int. Conf. Climbing Walking Robots Support Technol. Mobile Mach., Istanbul, Turkey, Sep. 9–11, 2018, pp. 1–11.*
4. *A. K. Mondal and K. Bansal, "Structural analysis of solar panel cleaning robotic arm," Current Sci., vol. 108, no. 6, pp. 1047–1052, 2018.*
5. *GEKKO Solar Farm: Automated Cleaning Solution for Large Free Field Solar Power Plants, May 22, 2018. [Online]. Available: http://bit.ly/1TVHJ3A*
6. *Heliotex: Automatic Solar Panel Cleaning Systems, May 22, 2018. [Online]. Available: http://bit.ly/1PQfZvu*