Design and Development of Automatic Solar Panel Cleaning System

Major Project Report **Submitted in Partial Fulfillment of the**

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In

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(Embedded System)

By

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Certificate

This is to certify that the Major Project entitled **"Design and Development of an Automated Guided Vehicle"** submitted by **Pinal Patel(16MECE16)**, towards the partial fulfillment of the requirements for the degree of Master of Technology in Embedded Systems, Nirma University, Ahmedabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination.

Mr. Deepak Sharma
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Certificate

This is to certify that the Major Project entitled **" Design and Development of Automatic Solar Panel Cleaning System "** submitted by **PinalPatel**(16MECE16), towards the partial fulfillment of the requirements for the degree of Master of Technology in Embedded Systems, Nirma University, Ahmedabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination.The results embodied in this major project, to the best of our knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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- Pinal Patel

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Abstract

In today's scenario renewable sources are widely used to generate electricity in that solar energy plays a vital role. Efficiency of Solar Panel decrease tremendously when dust particle get deposited on it. In Order to maintain efficiency in power generation through solar panel, regularly cleaning of solar panel is necessary.There are various methods of cleaning,out of this method most of them are manual only. This methods are not so efficient and require more amount of labour work so this very hectic. In this dissertation, method that we are developing is fully automatic in which we are using moving brush which rotates on its own axis which is found to be most preferable as per our constraints and situation, and that will be controlled by micro controller. This seems in increasing efficiency of solar panel by regular cleaning at regular interval of time.

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Chapter 1

Introduction

1.1 Company Profile

JK Lakshmi Cement Limited (JKLCL); a flagship company of the renowned JK Organization (EZ) is engaged in Cement Business since 1982. The capacity of maufacturing cement is 5 Million Ton Per Annum (MTPA) The mother plant is at Jaykaypuram in Sirohi District, Rajasthan. The plant has ISO-9001,ISO-14001, and OHSAS 18001 certified and maintains very high level standards in Quality, Environment and Safety fields. The plant has won number of National and International awards in Green Energy Efficiency and was Awarded in 2008 conferred by the Ministry of Power, GOI and Three Leaves Award by Centre for Science Environment (CSE) for State of Art Pollution Control Technology.

A research was conducted at Indian Institute of Management, Ahmedabad on carbon footprints. IIM-A selected the top 20 cement companies in the country to calculate and compare their carbon footprints per rupee of revenue generated. The research, based on the data for the year 2008-09, has ranked JK Lakshmi Cements Ltd as the top performer as the company emits the least amount of carbon dioxide equivalent (CO2e) per rupee of revenue generated at 0.15 kilogram (kg).

The company is believening in sustainablity development and working with thi

s idea they had installed and commissioned a cement grinding unit of 0.5 Million Ton per Annum capacity at Kalol, Gandhinagar District in Gujarat in the year 2009. They are meaningfully utilizing the fly ash, a solid waste that generated from Thermal Power Station and Torrent Thermal Power Station, Ahmedabad. This unit consumes fly ash of about 500-600 Metric tons per day conserving equivalent quantity of natural resources, and also saves on account of logistic cost due to proximity of the unit (with in 30 km.) with the thermal power stations. The Green initiative that has been taken by the JKLCL has helped in reduction of about 1, 80,000 tons of Green House Gas Emissions by Gujarat Plant's environmental contribution, JKLCL had completed work and successfully constructed a similar type project at Jhajjar district in Haryana to utilize solid waste i.e. generated from the adjacent thermal power plants namely Aravali Power.

1.2 Cement Manufacturing Process

There are not much variation in the cement manufacturing process if we narrow it down the specific Indian standard strength for cement. Normally the method for manufacturing cement goes like Quarrying, Dredging and digging, grinding, blending, Fine grinding, burning and finally finish grinding. All these process had been taken out for cement manufacturing at Jaykaypuram plant. But, in Kalol plant only finish grinding has been taken place. And which have proven to be the best environmental friendly plant in entire cement manufacturing of J. K. Lakshmi organisation

1.3 Grinding Unit,Kalol

Firstly, the Clinker is brought from the mother plant Jaykaypuram, Rajasthan by means of truck transportation, the other materials like gypsum, (they are purchasing from near industries waste) and fly ash has been brought from the thermal power plant.

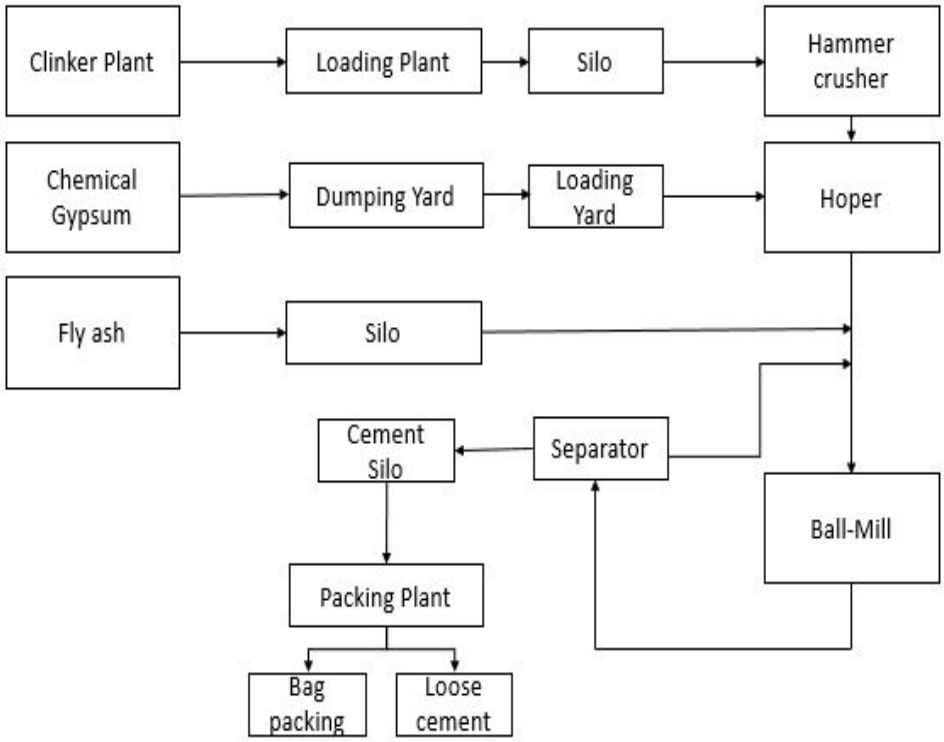

Figure 1.1: Grinding Unit Material Handling

The clinker that is brought usually comes in size between 3 to 4 inch, after that it goes to the clinker silo via clinker hopper by truck Tripler arrangement. The gypsum which is quite wet in the nature when imported from other industries, it is stored in open area where it get solar heat and after one or two days of period when it is ready it can be use as production raw material. Fly ash which brought to the plant is stored in the fly ash bin and the material is handled with the help of pressure created by pumps.

The main thing of the Kalol grinding unit is the most of the process of material handling, process, packaging and dispatch are all done with the help of automation and the main production process of the is done with computer only.

1.4 Solar Power

Solar power is a chief renewable power source with the potential to meet many of the challenges facing the world today. There are many motivations to move on its rate in the energy commercial centre. This energy supply is expanding in notoriety because of the reality it's far adaptable with many favourable circumstances to individuals and the environment. As anyone can see the worldwide growth scenario the solar panel varies strongly by the countries. There are around 24 countries in the world which have capacity to produce more than 1 gigawatt power. Out of this China, USA, and India are the top most leading countries in producing energy using solar panels. If we see the recent scenario of India till October 2017 India has produced 15.6 gigawatt and further planning of producing 100gigawatt till 2022. Now, there many leading solar developed states in India out of these Gujarat is one of the most leading state will reach photovoltaic capacity of 1262 megawatt till end of the 2017. The moderate infrastructure companies namely J. K. Lakshmi Cement Ltd. commissioned 6 MW capacity solar power plant in 2014 for reducing greenhouse gases of 7000 Tons/annum by generating more then 1,00,00,000 KWh/Annum by solar power for clean energy initiative. A photovoltaic (PV) module is a bundled, associated get together of normally 6x10 photovoltaic sun oriented cells, the cells are made of semiconductor material(silicon) .When Sun rays strikes these cells these panel produce electric current, Single cells are not able to produce require amount of current therefore multiple cells are connected together to produce current . Every module is appraised by its DC yield control under standard test conditions (STC), and ordinarily runs from 100 to 365 Watts (W). A solitary sun based module can deliver just a restricted measure of energy; most establishments contain various modules. A photovoltaic framework normally incorporates a variety of photovoltaic modules, an inverter, a battery pack for capacity, interconnection wiring, and alternatively a sun tracking device.

1.5 Existing Sub-System

1.5.1 Technical specification

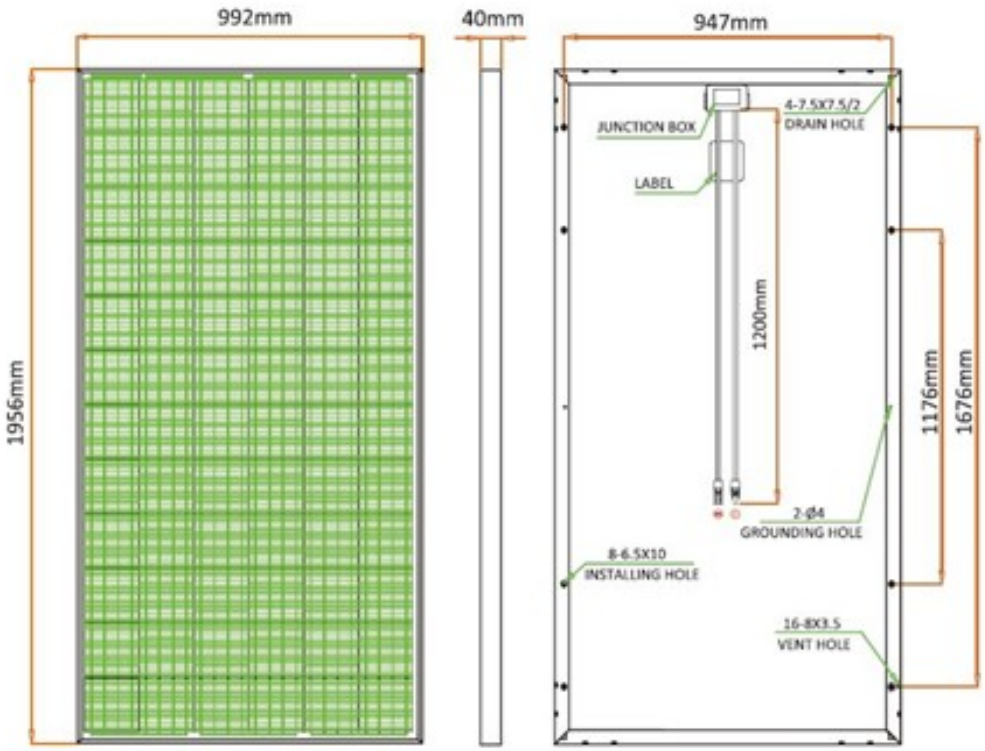

Figure 1.2: Solar Frame Descrpition

1.5.2 Mechanical Specification

Table 1.1: Specification of Solar Panel

Mechnical Characterstics	
Cell type	Virtus 2 (Polycrystalline) 156x156(+/-1)mm 72(6x12)pcs in Series
Glass	High Transmission, Low iron,Tepered Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP65/IP67 Rated with Bypass Diodes
Dimension	*1956x992x40mm
Output Cable	4mmˆ2/(EU)/12 AWG(US) 1200mm
Weight	27 Kg

But, the main problem created over the period of time that it does not give that much efficient power output that it should have. And the reason lies behind that is as it is the cement industry the dust particles are pretty much in the air and it settled on the solar plate surface. Another main reason is as the company's whole production to dispatch system is automated, the cleaning has to be done manually. For that reason they have to occupy workers which can cost much and other than that it have its working efficiency and water wastes. The major reason efficiency of Solar panel affected is humidity, panel tilt, Dust particles, Corrosion, Delimitation, Discoloration, moisture Thermal cycling, Ultra-violate radiation, Breakage and cracking of cell.

Figure 1.3: Installed panel onsite

1.6 Challenges for Design

[1] Weight Constrains: Weight should be less than 5400 Pa which equals to 55.054 grams/cm2

[2] Cleaning Water Constrains: Temperature difference between water and PV module should be -5 to +10 degree and pressure should be less than 1000 Pa.

[3] Cautions for glass surface: Use of only soft sponges and cloths to clean the glass surface.

[4] Alignment for device: Some of the plates are not equally spaced, So it can affect the movement of the device.

[5] Compatible material: The material used for the making of device should not damage the solar device.

[6] Robust design: As the solar plates are always out in the open environment it should not be delicate design, it should be of strong material.

[7] Reduce human effort: Some of the solar panels are place on roof-top and not usual reachable areas.

Chapter 2

Background Study &Literature Survey

2.1 Review Papers

2.1.1 Influence of Dirt Accumulation on Performance of PV Panels

Sulaiman, Shaharin Anwar, et al.,[1] their research work shows that accumulation of cement particle at 73 g/m2 would decrease the short circuit voltage of the PV panels Surprisingly, the report shows that little the size of fixed deposition density, the greater would be the reduction in solar intensity received by the solar PV panels. 4 g/m2 of a tidy layer on the PV panel decreased the output of solar panel by 40percentage. Previously, an experiment, it is seen that if glass plate is tilted towards 45 degree, sunlight diminish by 8 in 10days. The analysis indicates that power output of the solar plate decreased toward the middle of 25 to 31 percenatge because of those impacts of talcum, between 65 and 74 percentage because of sand, the middle of 65 percentage to 74 percentage because of dust, the middle of 15percentage with 86percentage because of moisture, . The analysis finds out that cleaning PV plates is very important in order to maximize its output.

Dust Type	grain size [micro meter]	Ref.
Soil	100-300	Kaldellis and Kapsali (2011)
Sand	250	Appels et al. (2013)
Salt (NaCl)	>210	Appels et al. (2013)
Gypsum	<60	Kaldellis and Kapsali (2011)
Cement	10	Appels et al. (2013)
Ash	<10	Kaldellis and Kapsali (2011)

Table 2.1: Grain Size of Dust

2.1.2 Experimental study of the dust effect on photovoltaic panels energy yield

Abderrezek, Mahfoud, and Mohamed Fathi,[2] in research found that incoming solar rays decreases linearly with increase in dust concentration. In terms of power output, It decrease by 50percentage which is 15.43W to 7.2W when dust density becomes 8 g/m2.This is an outdoor experimental study record of degradation in solar spectrum with the increase in the weight of dust, this is due to absorption, scattering and the reflection of light due to dust deposition. In this papers researchers have shown that "Ash" and "Soil" particles are one of those material that overheats the module more than another particles as show in table 2.1

2.1.3 The contribution of due to performance degradation of PV modules in a temperate climate zone

Tanesab, Julius, et al.,[3] In this it is found that about time, the electrical strength yield will decrease, usually (humidity, thermal cycling, ultra-violet radiation and moisture) that causes permanent degradation namely corrosion, discoloration, delamination and breakage and cracking cell (Munoz et al., 2011). The output of the experiment was, very long term performance degradation of seven PV modules

deployed at ROTA for almost 18 years without any cleaning. The Analyses shows that performance of PV panel is degraded and output Power losses is mostly due to non-dust related factors such as corrosion, discoloration and delamination which is about 71-84percent, although the contribution of dust still near the vicinity of 16-29percent.

2.1.4 Experimental study on the effect of dust deposition on solar photovoltaic panels in desert envoirment

Saidan, Motasem, et al.,[4] this experiment was carried out in desert and utilized extensively real-world measurements, the output is like that the normal energy yield of solar plant is heavily impacted by the gathering of dust, particularly for the long period of time. If impact will be ignored, it will be cause great reduction in output.

2.1.5 Different types of method for cleaning solar panel

Gaofa He, Chuande, et al.,[5] in this research they had shown different cleaning methods t 1)natural, 2) mechanical, 3)self-cleaning nano-film and 4)electrostatic means. The natural way was the obvious way like the clean of the rain water, gravitation and wingpower. Mechanical way include brushing, blowing, vibrating and ultrasonic driving type of device In self-cleaning nano-films there are two types super-hydrophilic film and super-hydrophobic film is present. Electrostatic removal of dust is one another method in which triboelectric charge and photoemission of electron from the surface of particles by UV radiation includes.

2.1.6 Robotic Device for Cleaning Photovoltaic Panel Array

Anderson, Mark, et al.,[6] have found that a solar plant in Arizona uses over 280 liters of water to clean 5 square meter array and it required 10 teams of two people to clean 10,000 panels in 8 hours. It include two trolley that are installed on the upper

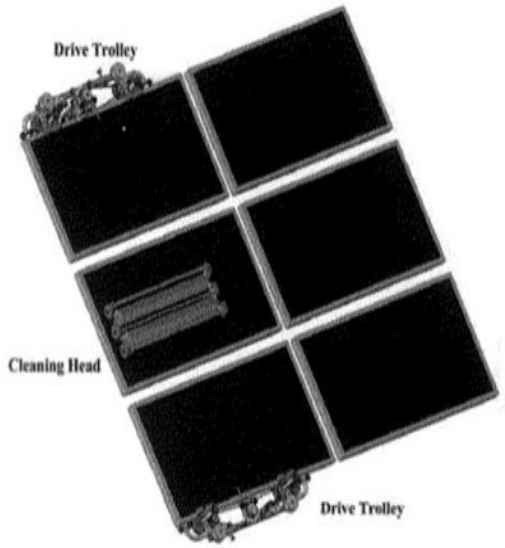

Figure 2.1: Schematic of PV Cleaner Robot V1.0

and lower side of the panel which are motorized with a 12V DC motor. It has lifting mechanism for the cleaning head which is motor type Leeson 90V DC which drives the belt-pulley arrangement. For the horizontal operation, four inductive proximity sensors are used to detect the gap and edge of the panel to know when to stop. It uses solenoid valve (Omega SV3100) for water supply which are spreading through sprayer which located to position to create minimize scratches. One of the thought selection of the material can be counted as the selection of frame and brush material, in this they have selected Acrylonitrile Butadiene Styrene (ABS) plastic to reduce weight for frame and .006" Nylon for brush bristle.In the further improvement paper named ''Robotic Device for Cleaning Photovoltaic Arrays V2", had been done. In this the main difference is that, it uses oscillating sponge instead of using rotating brush.The another secondary change is carried out that the component vertically aligned to meet the requirement of cleaning in one horizantal pass.For overcoming the major slipage problem custom made wheel has been designed to provide high coefficient of friction and load on single drive as you seen in Figure.

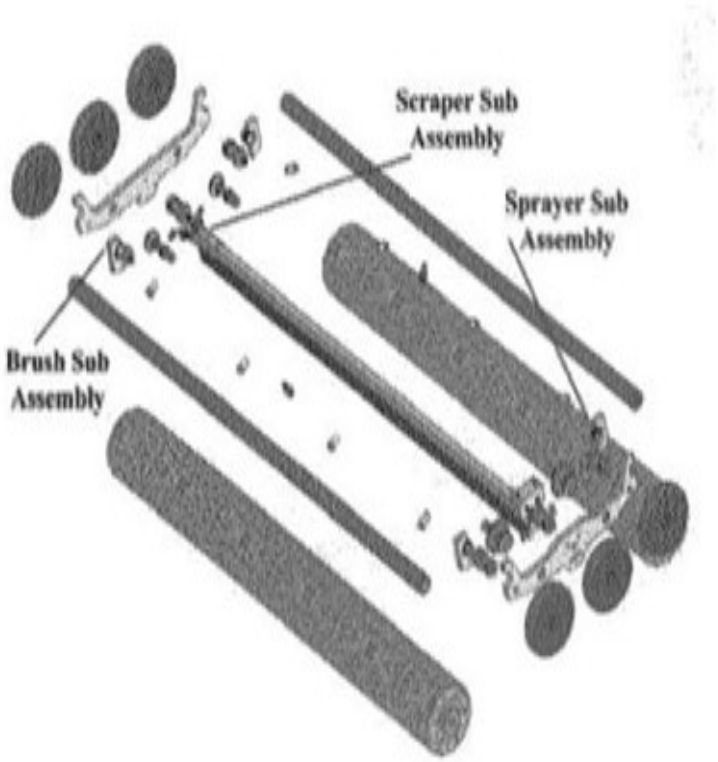

Figure 2.2: Exploded View of Cleaning Head

2.1.7 An effective P-V cleaning Robot to Alleviate partial shading problems

Angeline Sreeja S1, Balakumar N2,[7] have found the method to reduce shading problems for PV plates. They have created prototype model for the experiment with the help of PIC cotroller, Relay driver circuit, power supply and IR driver unit.

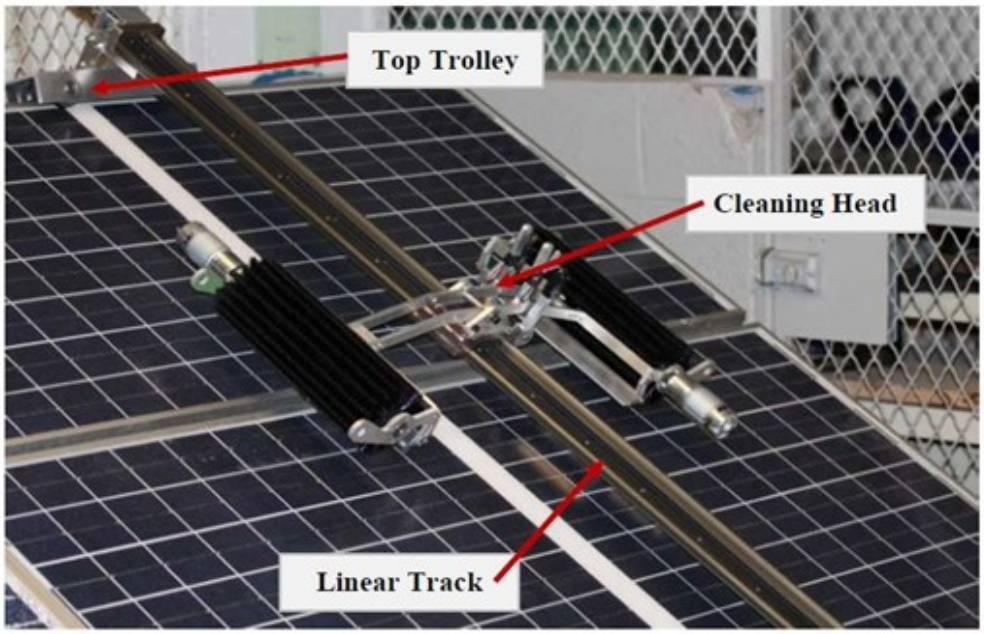

Figure 2.3: V2 Robot

Figure 2.4: Prototype Model

2.2 Effect of Dust Accumulation on Solar panels and Mechanism for Alleviation: Design for street Lighting Purpose

Paudyal, Basant Raj, et al.,[8] In this research they had invent design for cleaning the solar plates for the street light. The main objective is to create system with locally available component so it could made as cheap as possible, with good attaching equipment so it can automatically clean panel with scheduled time without any human intervation.

Figure 2.5: Top Module of Design

2.2.1 Self-Cleaning and Tracking Solar Photovoltaic Panel for improving Efficiency

Abhilash, Bandam, and Ashish K. Panchal,[9] In this they have found method for cleaning and as well as for improving the efficiency of the solar panel. The method include things like microcontroller, light dependent resistor that had been used during implementation.

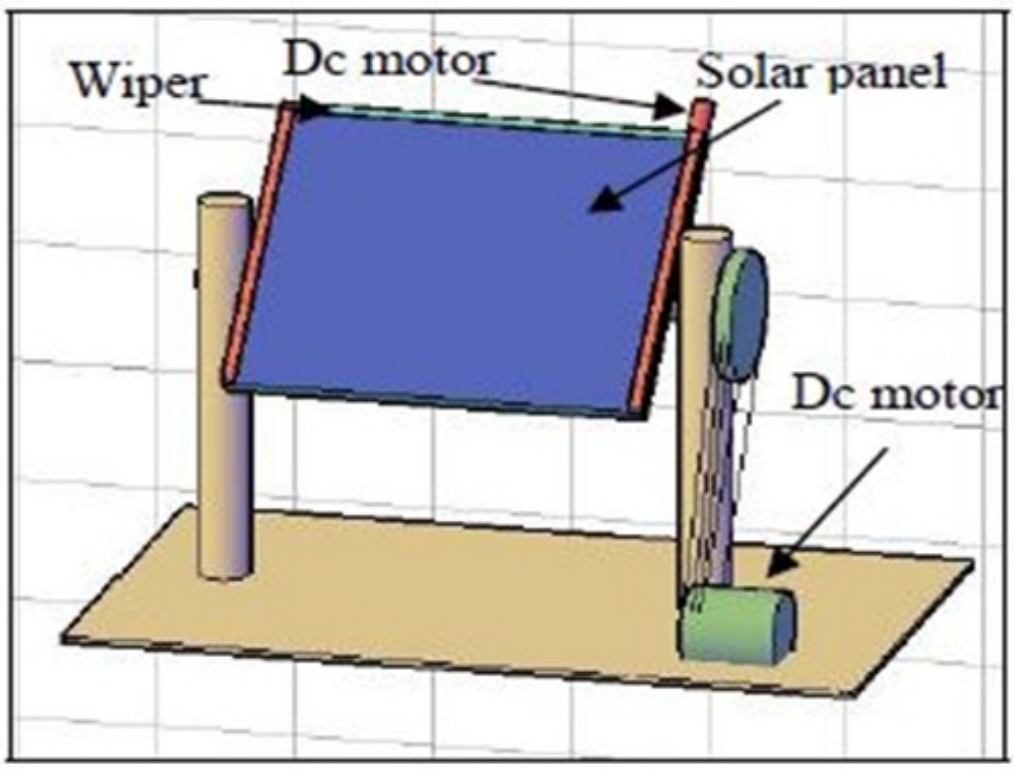

Figure 2.6: Prototype for proposed model

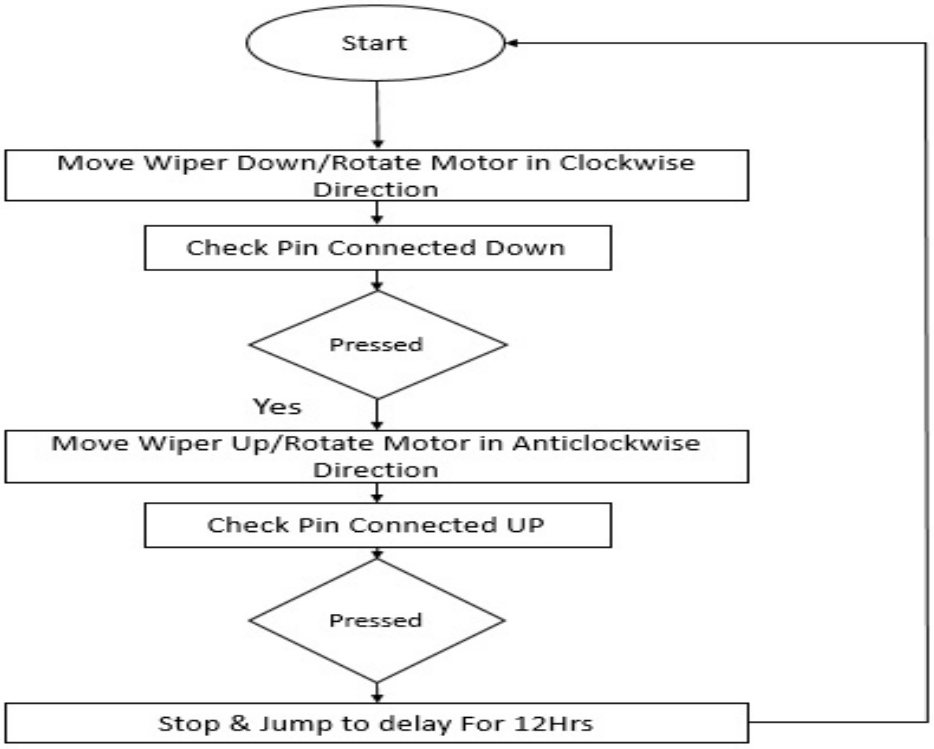

Figure 2.7: Flowchart for Cleaning

2.2.2 A Fully Portable Robot System For Cleaning Solar Panels

Jaradat, Mohammad A., et al.,[10] have developed and tested the full portable robot for cleaning the solar panel.The things that used for making system are brush, wheels, motors, connecting rods, side panels, Wheel driving system, brush driving system.

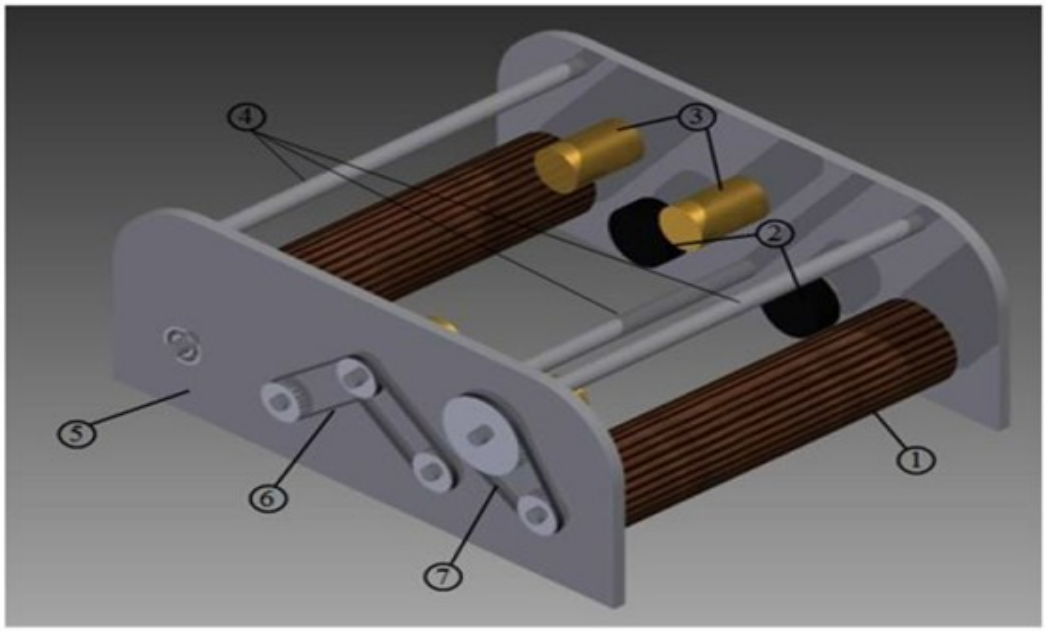

Figure 2.8: Cleaning Robot System

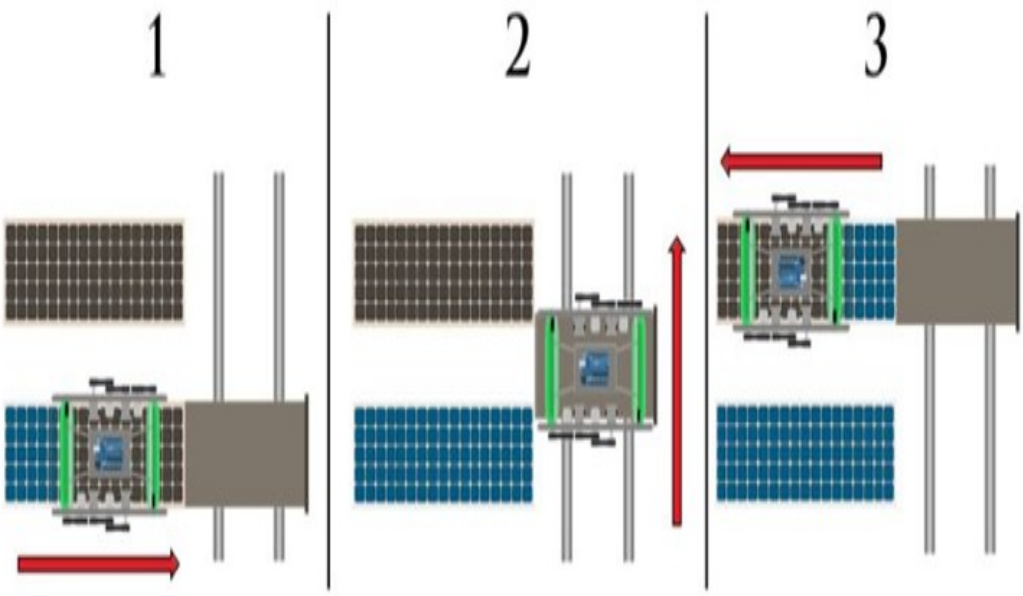

Figure 2.9: The proposed System for performance

2.3 Patterns

2.3.1 Transparent Self-Cleaning Dust Shield

US 6,911593 B2- Mazumdar, Sims and Wilson,[12] In this pattern they invented the method for cleaning the dust with use of electromagnetic shield that does not require more mechanical parts but requires maintenance in one or other way. The material that is used for making electromagnetic field are nonconductive transparent consist series of linear parallel electrical thin wires. A single phase AC signal current are passes through the shield and due to electricity it creates flux eventually dust particles fall down due to gravity.

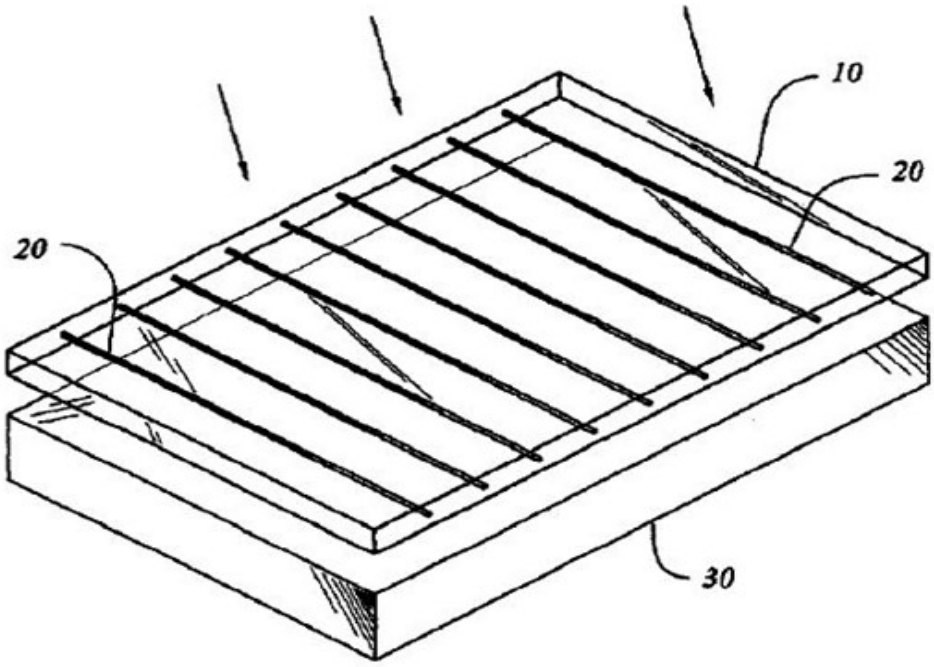

Figure 2.10: Perspective view of dust shield of the present invention

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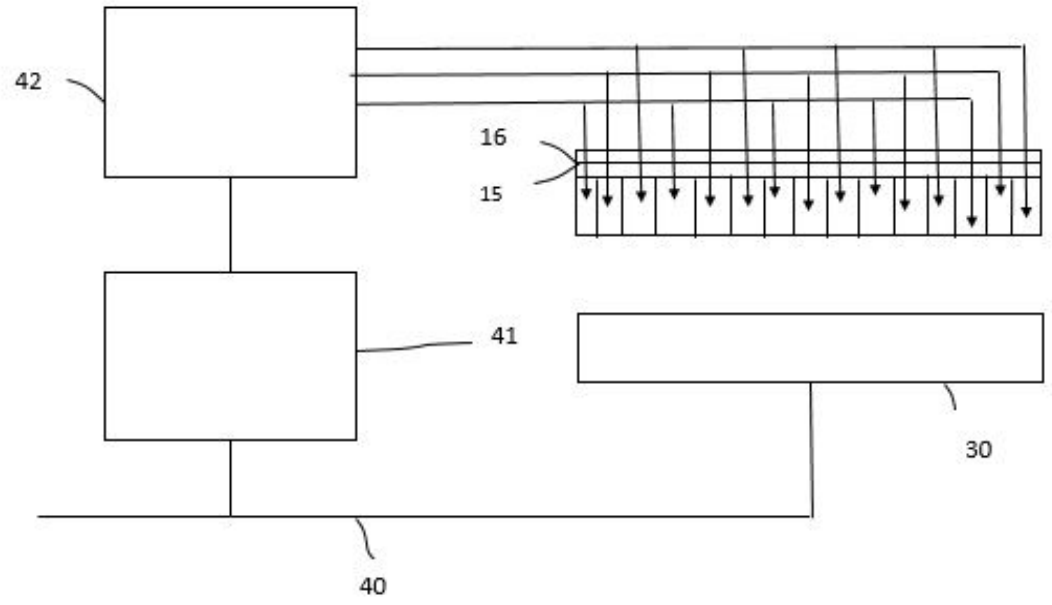

Figure 2.11: Block diagram of the dust shield showing a multi-phase AC source.

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2.3.2 Automatic Cleaning System For Solar Panels and Methods Thereof

Pub No.: US 2009/0266353 A1-Han-Lung lee, Tu-Cheng (TW),[13] has invented the method for automatic solar panel cleaning. In this method basically they take difference between the sun intensity that is detected by light sensor and transmitted light sensor that is derived and the comparison and analysis is done in the detection device. Other devices like per fusion device, driving device and cleaning device are worked with the help of different sensors like clock signal generator, time setting module, communication sensor etc.

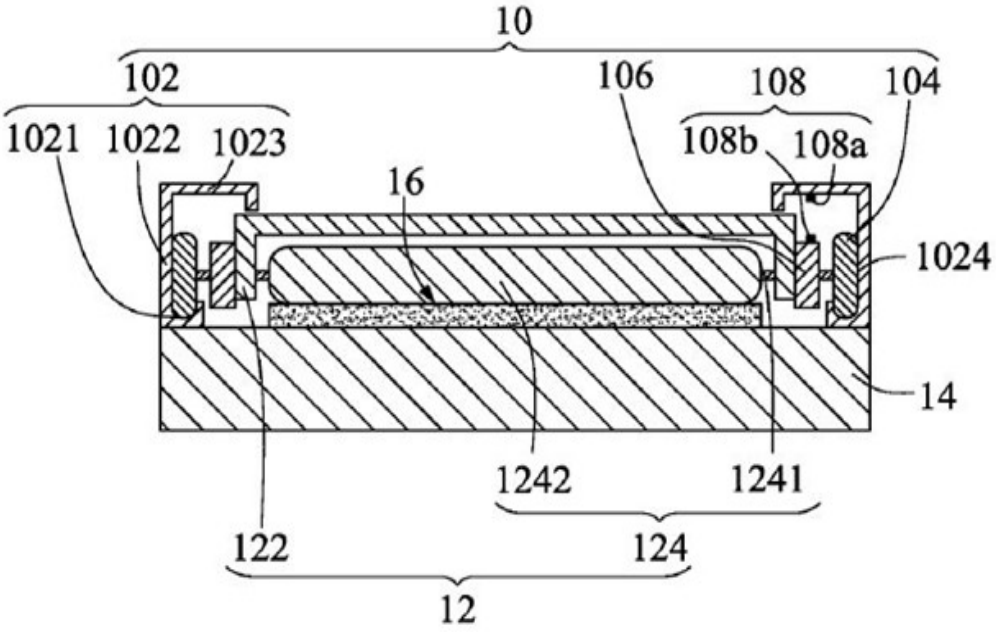

Figure 2.12: : Side View

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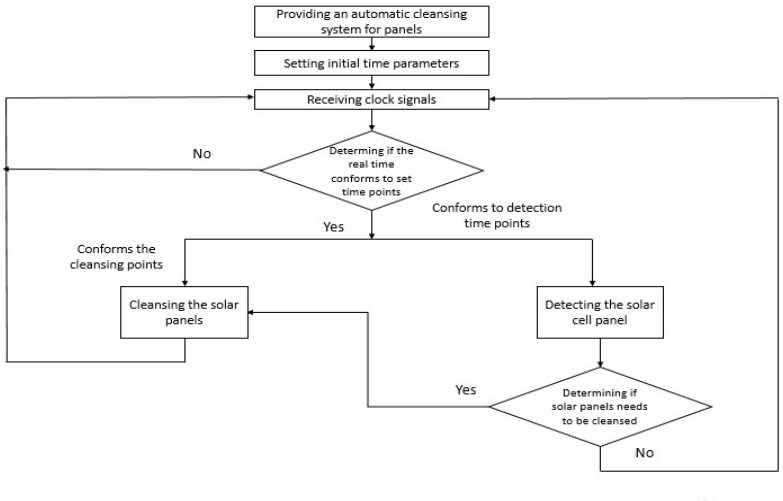

Figure 2.13: Flow chart of Cleaning Device

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Chapter 3

Proposed concept and Designs

3.1 Proposed Concept

There are too many type of mechanism referred and picked the best possible method with most of the positive interested outcomes.Method for the system decided was to the make the device mobile and as automated as possible. Currently decided concept system work with the help of mechanical and electronics equipment.The method works without any type of super structure and mounted directly on the panel. The working power supply for the system is externally provided. The below shown diagram is the placement of the cleaning device on the installed solar panels.

The movement of the cleaning system will be in horizontal direction along the length of the panels. The other work of automation i.e. to give signal to clean, to start the water sprinkler, to start the motor etc. all the signals will be given by controller with the help of sensors and programming.The main attraction of this device to work without human intervention. It will work with the help of pre-defined programing and timing. It starts from the one end of the solar panels to the other end, which are arranged in array. And after reaching the other end of the panels it reverses its direction of movement and comes right at its original assigned place. The clean-

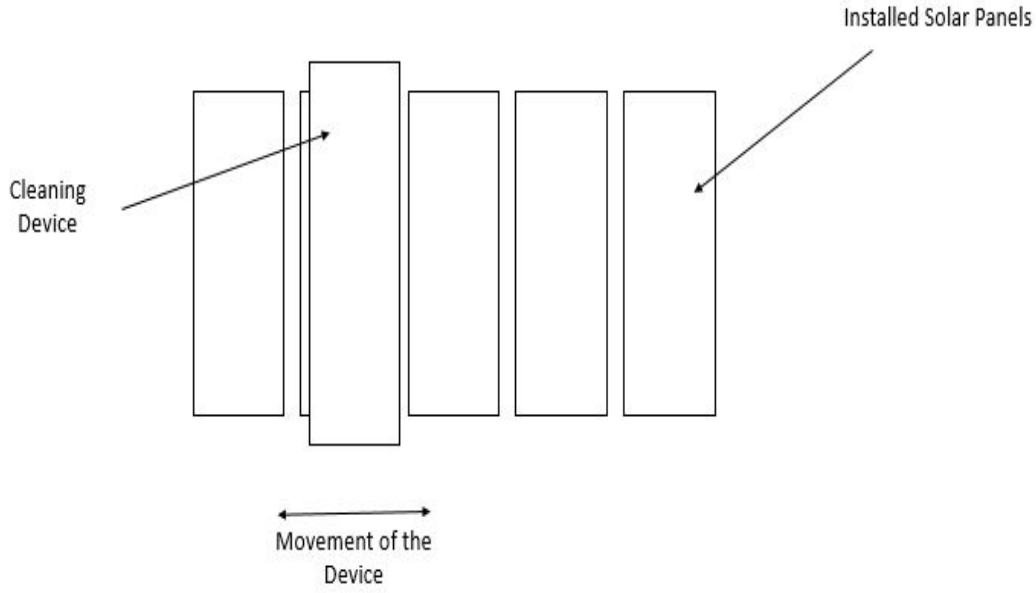

Figure 3.1: Conceptual design

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ing rod itself attached with the device which fulfil its cleaning objective. Another countable object of maintaining the system which is its daily power consumption and for that optimization of material selection has been done and on that tried to reduce the components of the device. Other possible operation can be done is to maintain the temperature of the solar panels which can be done with the help of water/cooling fluid sprayed on the surface of the panel which help to increase its efficiency in hot temperature climate.

3.2 Design of Device

The below shown figure3.2, is the CAD model of proposed system which use for the cleaning of the solar panels

Figure 3.2: Perspective view of design without motor

.

The design consists of a frame as a major part of device. On the both side of the frame there are attachments which are plates with self-aligned ball bearing which can handle the cleaning shaft and other supporting shaft. In the middle part of the device there is another plate that is attached to frame which helps structure to increase its strength and with the help of the wheels that are mounted on the plates it can distribute the whole load of device and gives better support in running condition. The plate that is attached in the middle upper side is the place where

DC motor and electronics equipment are going to mounted. The main objective of putting motor on the middle of the assembly is to create drive the hole assembly by only one driving device without any synchronization problems to be occurred in future. And one of the major solution of not having any kind of super structure is done with the help of guiding wheels mounted on the upper bottom side of the structure. These wheels are helping the system to move from one plate to another plate with ease.

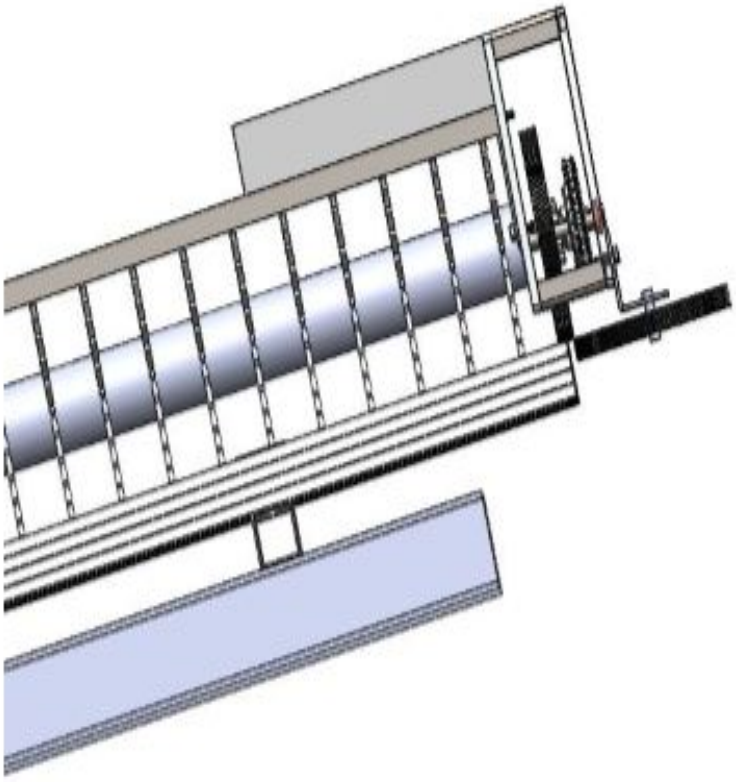

Figure 3.3: CAD model of guiding wheel assembly

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As seen from the figure 28, the guiding wheels are placed on the upper side of the

solar plates and helps to guide device on the incline plane.

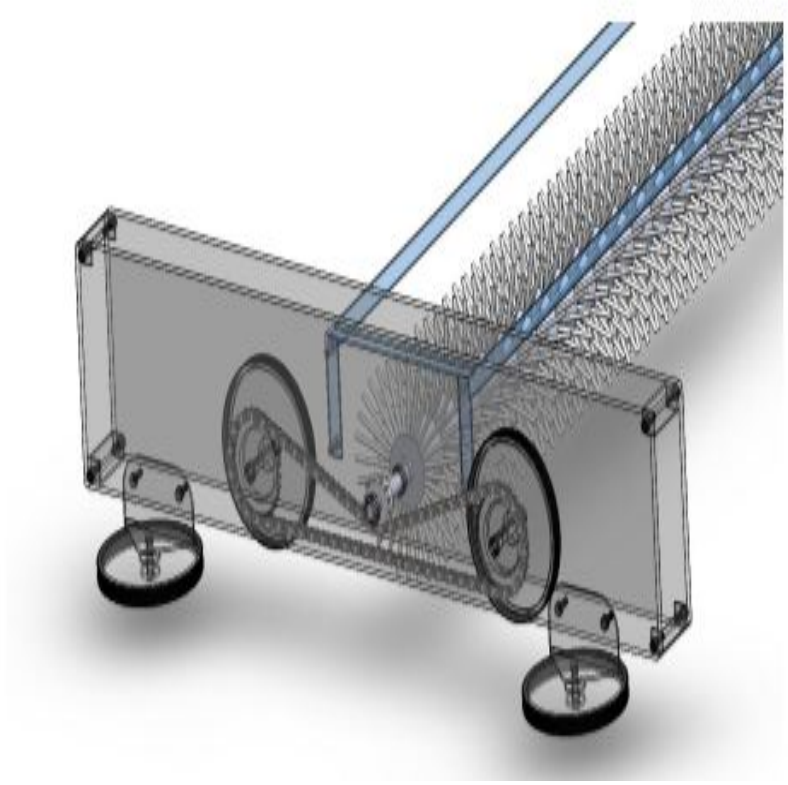

Figure 3.4: Transmission assembly

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3.3 Calculation of mass and weight of whole system

The main constraint in this device is weight because it has to do movement on the solar panel itself and for the ease of understanding the system has been divided into four main parts for calculation purpose.

$$\text{Total Weight} = 44.474 \times 9.81 \tag{3.1}$$

$$= 432.4\text{N}$$

$$\text{Weight on each wheel} = \text{Total Weight} \div \text{Number of wheels} \tag{3.2}$$

$$= 432.69 \div 4$$

$$= 109.27\text{N}$$

3.3.1 Calculation of Torque

This calculation has been carried out asper maximum amount torque required for movement of the device by each wheel.

$$\text{F} = \mu \times W \tag{3.3}$$

$$= 0.3 \times 109.07$$

$$= 32.72\text{N}$$

(The co-efficient of static friction between Aluminium and rubber is 0.3)

$$\text{T} = F \times r \tag{3.4}$$

$$= 3.75 \times 0.075$$

$$= 2.454$$

Torque require on wheels

$$\text{Torque require on wheels} = \text{Required Torque} \times \text{No of Wheels} \tag{3.5}$$

$$= 1.21 \times 4$$

$$= 4.854$$

Calculation for Safety

$$\text{Total required torque} = \text{Required Torque} \times \text{ Factor of safety} \tag{3.6}$$

$$= 4.85 \times 1.5$$

$$= 7.26 \text{ Nm}$$

Factor of safety had been taken of various miscellaneousreasons for example bearing friction, Ideal wheel friction, cleaning brush friction.

Table 3.1: Specification of System

Section	**Material**	**Mass (kg)**	**Nos.**	**Mass (kg)**	**Total mass(kg)**
Brush Assembly	Brush	5.75	1	5.75	**11.874**
	Rod	5.15	1	5.15	
	Small sprocket	0.15	3	0.45	
	Big keys	0.5	1	0.5	
	Small key	0.012	2	0.024	
Transmission box	Small shaft	0.25	4	1	**25.1**
	Big sprocket	0.7	4	2.8	
	Wheel	0.15	8	1.2	
	Top plates	3	2	6	
	Bottom plates	5.5	2	11	
	Angle plates	0.3	4	1.2	
	Support joint	0.075	8	0.6	
	Bearings	0.05	6	0.3	
	Chain			1	
Support Frame	Main structure	2.4	1	2.3	**2.5**
	Electronics box	0.2	1	0.2	
Drive	Motor (approx.)	5	1	5	**5**
Total mass (kg)					**44.474**

3.4 Selection of Motor

One of the most important selection in any automation device has been selection of motor. In context of the device the precision of motor affects the device's movements. The first selection for high precision motor has always been servo motor but as it is not economical in this project it's narrowed down the selection to DC motors. There are four major types of DC motors:

1) PMDC(Permanent Magnet DC motor)

2) Series DC Motor

3) Shunt DC Motor

4) Compound DC Motor

Above stated motor, the PMDC motor has been selected because of the its advantages over other and as well as it fulfils our requirement as it is simple, economical and will provide the higher starting torque. In the PMDC motor there is also sub type i.e. PMDC motor with brush and without brush. In comparison of these two motors BLDC (Brush less DC motor) has more advantage then with brush motor which are high efficiency, more reliable, more acceleration and high power and speed to size ration. But, as per availability at company facility of PMDC motor has been better choice. And for better efficiency, PMDC motor is normally available with gear arrangement for better starting toque and lower power consumption.

3.4.1 Current motor in Specification

Power: 0.25HP

Voltage :24 volts

Amp : 8A

KW : 0.18

This motor works at 180 rpm at inner core and reduce to 30 rpm by the worm wheel and gear by the ratio of 6:1.

3.4.2 Selection of Brush

There is wide range of variety for the selection of the brush available at market. And many of the factors which has to be considered while selecting i.e. bristle size, minimum inner diameter of the brush, mounting methods.

The main consideration of the selection that bristle size selection and it varies from

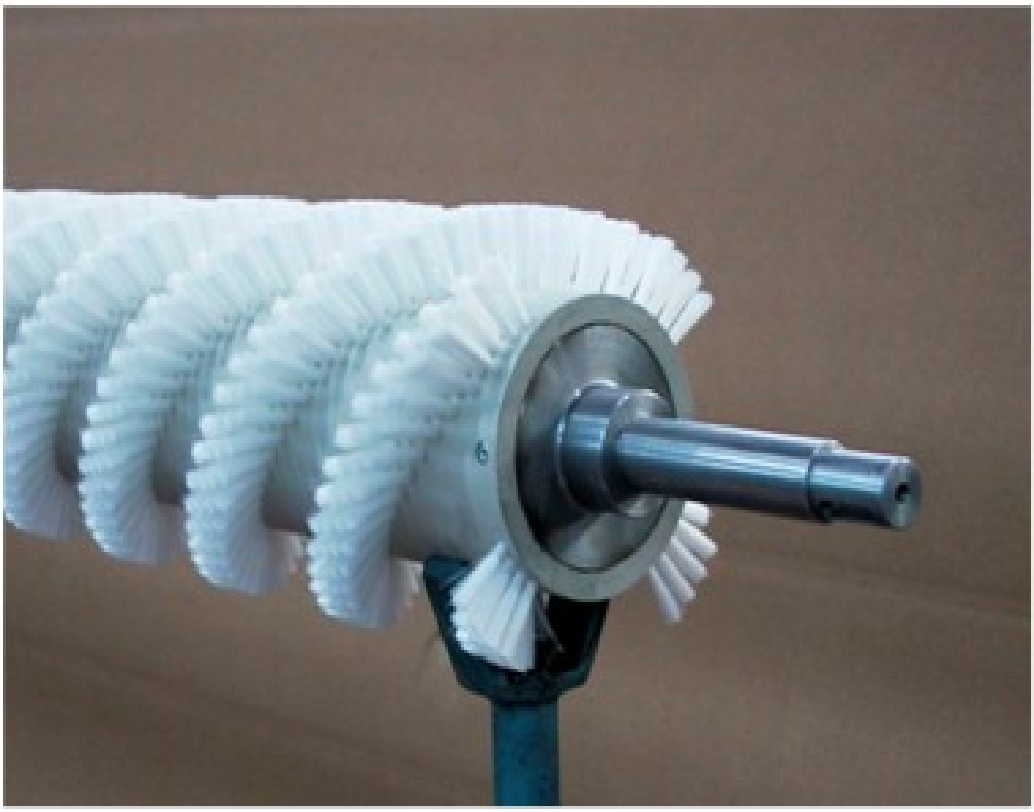

Figure 3.5: Cleaning Brush assembly

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0.15 microns to 0.65 microns and 0.20 micron spherical brush was selected which provides the sweeping effect by testing with the help of the prototype made at plant facility.

Brush outer diameter: 180 mm

Bristle size: .20 micron

Nylon density: 1150 kg/m3

3.4.3 Wheel Design

Most of the parameters which were selected as per the standards and availability but on the other hand the wheel requirements for this device has been tricky. It is because as per the solar panel design the panels corners have metallic part only up to 10mm on its top periphery which has been the problem for the selection of the standard size wheel thickness. In the contrarily, the wheel diameter has to be selected on the basis of ease of movement for the device as well as it should satisfy the brush standard dimensions. It implies that out of three parameter of the wheel which is outer diameter thickness, and inner diameter first two parameters would not satisfy even one standard scenario.So wheels have dimensions that are stated below. In addition, tracking belt was used to give better friction between wheels and metal of solar panel.

Inner diameter of wheel = 150 mm

Outer diameter of wheel = 10 mm

Material: Nylon

Width: 15 mm

For the calculation of linear travel in one revolution of the wheel

$$\text{Diameter of wheel } = 150mm\text{Distance wheel travel in one revolution} \tag{3.7}$$

$$= 2 \times \pi \times r$$

$$= 2 \times 3.14 \times 0.075$$

$$= 0.471\text{m}$$

For this revolution, if cleaning device move with this speed the cleaning will be difficult or if we maintain cleaning speed then device will move very fast. So, Solution for this device has to be maintain the ratio between wheel and cleaning rod revolution.

3.4.4 Prototype of System

Figure 3.6: Prototype Design

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Chapter 4

Electronics Design

4.1 Block diagram of System and its component

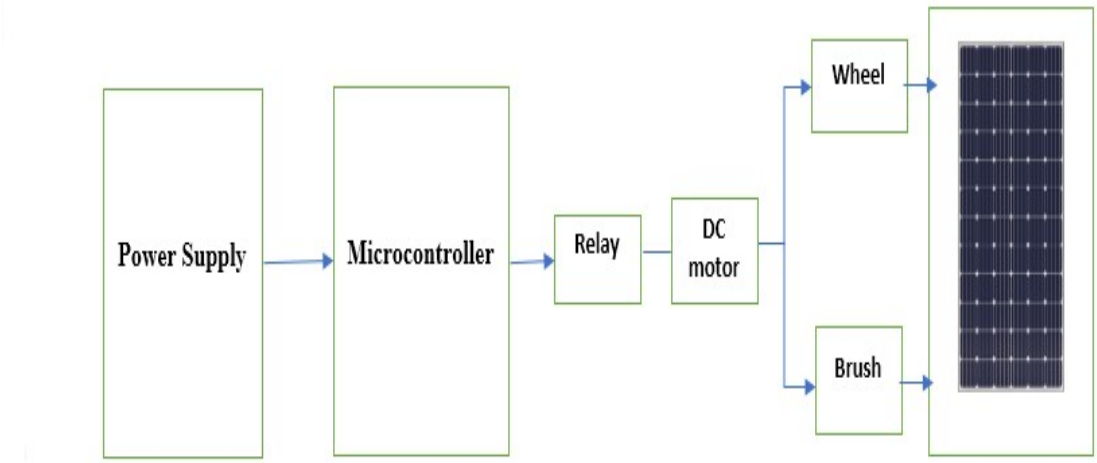

Figure 4.1: Block Diagram of System

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1) Power Supply:-From power supply line, we get 230v ac, but our system in

which we are using component that all work on DC, so we have to convert 230v ac into DC, according to their needs. Basically we use AC to DC converter for that. So basically we are using 12v SMPS (Switch mode Power Supply).As microcontroller we are using is Arduino Uno which needs 5v Dc supply, we will convert 12v DC into 5v Dc using LM7805 IC. This IC has high power dissipation capability and has output current up to 1.5A which is suitable for Arduino Uno.

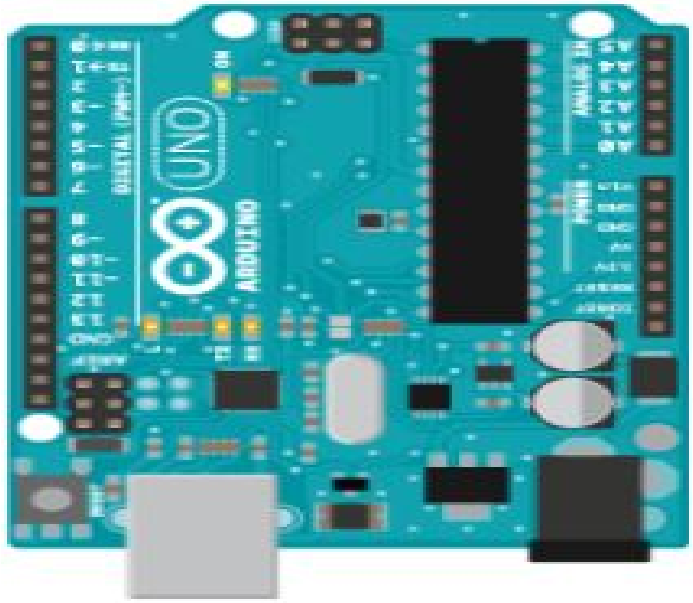

Figure 4.2: Arduino controller

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2) Microcontroller: - We are using Arduino Uno as microcontroller for controlling mechanism.

Arduino Uno: - The Arduino Uno is a microcontroller board consists of ATmega328P chip. It has 14 computerized input/output yield pins (of which 6 can be utilized as PWM yields), 6 simple data sources and also consists of 16 MHz precious stone oscillator, with a USB attached, a power jack, an ICSP header, and a reset button. We can easily interface this microcontroller with PC via USB link or we

can power it with a DC adapters or battery. It varies from every single board, let say that in Uno it does not have FTDI USB-to-serial driver chip but it includes the Atmega8U2 customized as a USB-to-serial converter.

- **Importance of using Microcontroller**

1 It is open source platform, based on hardware as well as software

2 It gives us platform for testing purpose

3 As our system works on 12V, this board has inbuilt voltage regulator IC that easily support 6v to 20v input voltage.

4 The IDE of arduino software support on various platform such as windows, Linux, Mac operating system.

5 The arduino boards comparatively cheap as compared to other microcontrollers

3) Relay : Relay are switch that are normally open (NO) and normally closed (NC) electronically or electromechanically. Relay is generally used where several routes has to be controlled by one single signal. When the relay is not energized there is normally open (NO) for open contact and normally closed for closed contact (NC), by applying a small amount current to this contact we can their state. Relay are generally classified in two categories 1) solid state relay 2) Electromechanical relay, Out of which we have used solid state relay.

Solid State Relay: It is electronic relay only and is function is similar to electromechanically relay but it will not include any heavy components to move. It will use TRIAC, Thyristor, or other solid state device as Switch to load. Less voltage is required to turn on solid state relay The solid state relay commonly comes in range of 3vDC to 32Vdc (minimum input voltage required). It is activated by DC controlled signal that is come from logic controller microprocessor, and microcontrollers.In this

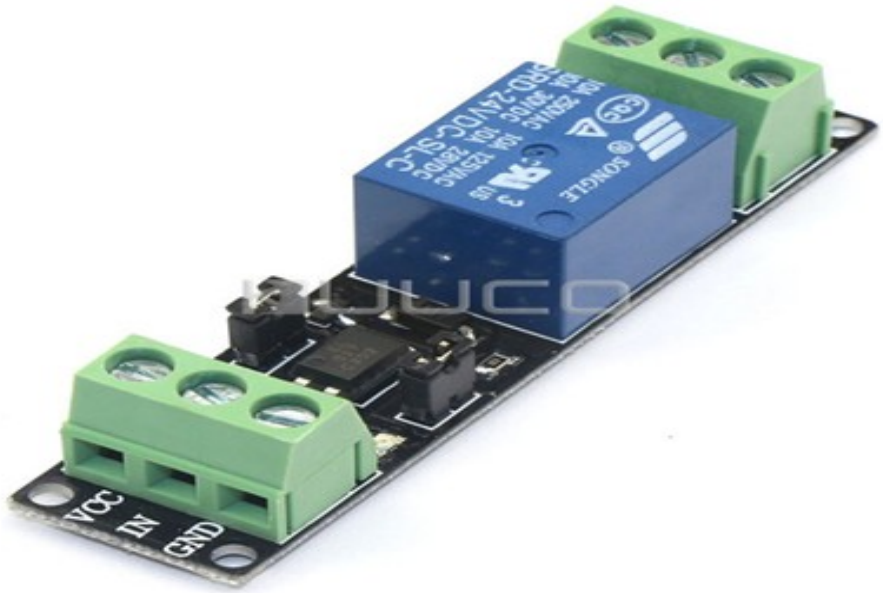

Figure 4.3: Solid State Relay

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solar panel cleaning system we are using solid state relay of two channel 12v Dc to switch the direction of DC motor. Now this is circuit diagram of DC motor control using relay and arduino microcontroller.

3) **DC Motor (RMCS-2102Rhino Motion Control Servo Motor)**: It is a high torque encoder DC servo motor wit driver installed. It is basically designed for ease of operation and, we can do multiple operation using different interfaces that is supported by this motor. This motor is available with 18000RPM base motor with metal gear box. Gear box for 10RPM, 60RPM, 100RPM, 900RPM are also available. It also include 0.2 degree resolution optical encoder on its output shaft, using this we can control the speed and position of motor shaft with zero backslash output. We can also allow the speed and position control via UART, I2C, and PPM input signal and analog voltage input. In this we have use project we have

Figure 4.4: RMCS-2102 DC Motor

use these two 10rpm motor attached with wheel and one 60rpm motor for rotation of shaft.The direction of motor can be changed by '+' and '-'characters before the speed value. For example -255 will rotate the motor in anticlockwise direction and +255 will rotate the motor in clockwise direction. The motor will remain its position at '0'. The speed of RMCS-2102 can be controlled using PPM signal generator like a wireless PPM receiver, Servo-controller, or a micro-controller I/O pin. To enable this PPM signal the UART Txd and UART of Rxd should have to be short. The speed will change based on its current value, by using this it will remove the jerk from the system.

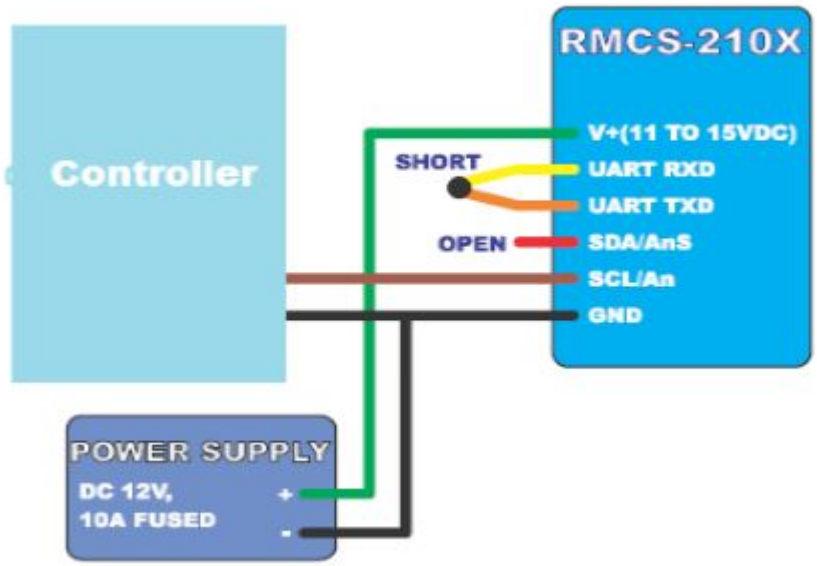

Figure 4.5: Interface of RMCS motor

Table 4.1: Specification of Motor

Specification	**Min**	**Max**	**Units**	**Comments**
Supply voltage	11	15	Volts DC	BetweenV+and Gnd
Current	0.5	7	Amps	No load to stalled condition
Input signal High voltage	4	6	Volts DC	With respect to Gnd
Input signal Low voltage	0	1	Volts DC	With respect to Gnd
Baud Rate	-	9600	Bps	For UART interface
Clock Frequency	10	200	kHz	For I2C interface
Analog input voltage	0	5	Volts DC	For Analog Voltage interface
PPM pulse width	600	2400	Usec	For PPM signal interface

Mechanical Specification :

Dimension (L×$W \times H$) = $120mm \times 60mm \times 65mm$

Weight = $350gms$

Encoder Specification :

Counts per rotation = 1800counts

$$\text{Degree per counts on shaft} = 0.2^\circ \times 1800 \quad (4.1)$$
$$= 360^\circ$$

Speed :

$$\text{Speed} = \text{Speed value} \times \text{max speed value} \times \text{motor rated rpm} \div 65000 \quad (4.2)$$
$$= (100 \times 255 \times 10) \div 65000$$
$$= 3.923\text{rpm.}$$

Linear velocity :

$$\text{Linear velocity} = 2 \times \pi \times r \quad (4.3)$$
$$= 2 \times 3.14 \times 50mm$$
$$= 314\text{mm.}$$

4.1.1 Advantages of Motor

1)The very first advantages is that there is Better speed versus torque characteristics

2)The speed of motor can also change by changing in its input voltage

3) High efficiency

4)Long operating life due to a less amount of electrical and friction losses.

5)Noiseless operation

6) For Higher speed ranges

4.2 Sensors

Sensor : Sensor is device or module whose work is to identify events or any adjustments in the environment and send their data to CPU or controller. The change in environmental physical parameter (for instance: temperature, circulatory strain, moistness, speed, and so on.) can be measured electrically using sensor. There are many sensors which are used according to their application as shown fig, we are using Proximity Sensor in our system.

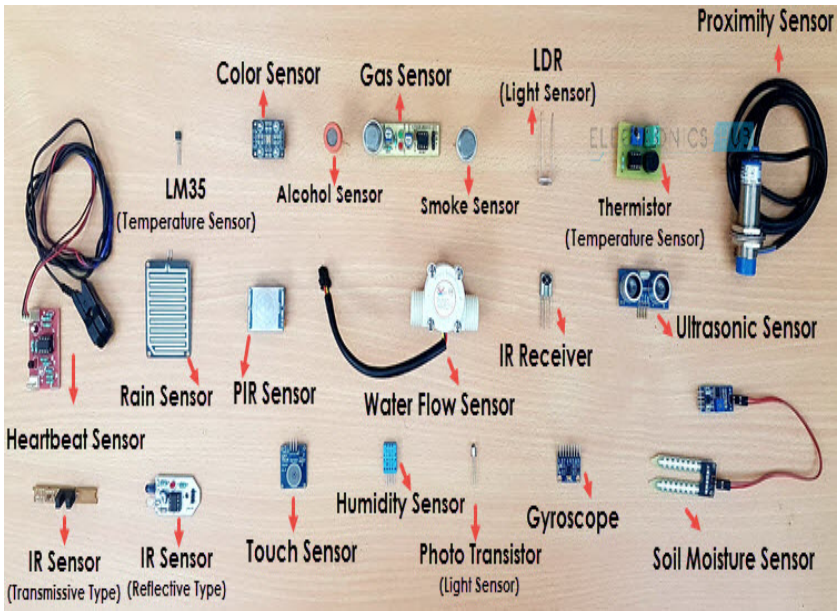

Figure 4.6: Sensors

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4.2.1 Different types of Proximity Sensor

Table 4.2: Different types of Proximity Sensor

Name	Characteristics	Application
Capacitive Sensor	Capacitive Sensor used electric field to sense object it detect both metal and non-metal things	"It is used to detect plastic
Inductive Sensor	Inductive sensor uses electromagnetic field to sense it use non-contact metal for detection metallic objects	For detection of metal.
Ultrsonic Sensor	It is transmit and receive sound waves it will generate high frequency sound waves receive back by reflecting from object	For measuring distance from the targeted object.
Optical Sensor	It will convert light rays into an electronic signal	In remote sensing place

4.2.2 Proximity Sensor:

- A proximity sensor is instrument that will detect the close objects without making any physical contact. It emits electromagnetic radiation and if there is change in the field or radiation that object is often called as proximity target. A inductive sensor will requires a metal for detection. The industrial proximity sensor is referred to as

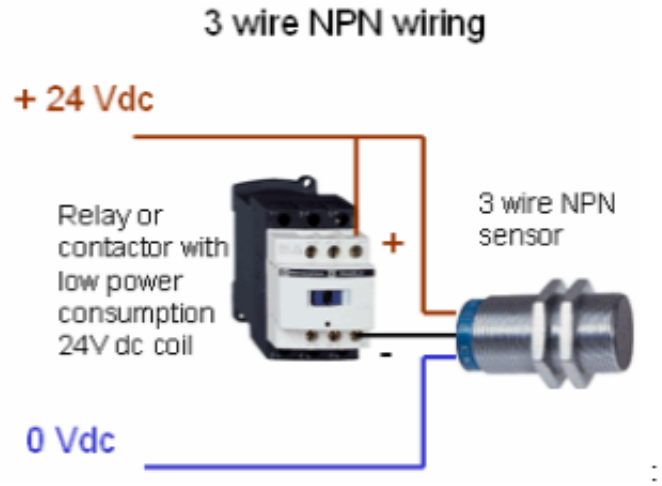

Figure 4.7: Proximity Sensor

solid state device.

Inductive proximity Sensor : - In this Sensor it use ferrite core,oscillator detector and switch inside it.As soon as sensor comes close to metal, the oscillation diminished and detector will turn the solid state switch off.Again when the object-metal moves away from the range of sensor it turns on its again. Solid state device like transistor are used as sensor material for detection of object. There are two types of proximity sensor available PNP and NPN.

The main feature of this sensors is that both PNP and NPN have a same function for open (N/O) or typically closed (N/C). The determination of a PNP sensor versus an NPN sensor is controlled by the idea of the circuit the gadget is to be utilized as a part of. At the point when utilized as a part of a conventional hand-off sort control circuit, it is regularly conceivable to utilize either the PNP or the NPN kind of sensor demonstrated as follows

Table 4.3: Difference between NPN PNP

NPN Sensor	PNP sensor
NPN sensors are at some point called ”sinking sensors” since they sink ground energy to the yield	PNP sensors are in some cases called ”sourcing sensors” since they source positive energy to the yield
In NPN transistor p-sort material sandwiched between two n-sort materials.	In PNP transistor n-sort material is sandwiched between two p-sort materials
In NPN transistor electrons are lion’s share charge bearers and gaps are minority charge transporters	In PNP transistor openings are the lion’s share charges bearers and electrons are minority transporters
In NPN sensor we use pull up resistor	In PNP sensor we will use pull down resistor
The NPN gadget, the lead from the heap must be connected with the positive shaft of the power supply.	The PNP gadget has 2 control drives, one associated with positive, and the other to negative.

4.3 RF module

RF module : It is It is electronic module that is used to transfer or accept radio signals between two components. In an embedded system it is necessary to connect with a different device wireless.Various kind of RF module are available depend on its range and frequency. This module with operate on radio frequency that is between 30KHz to 300 GHz

This module consists of transmitter and receiver,both will operate at same frequency(ie 433 MHz).The TX transmitter module is known as ASK(amplitude shift keying), in this the digital data will be characterized as deviation in amplitude of carrier wave. The receiver module will receives the modulated signal demodulated

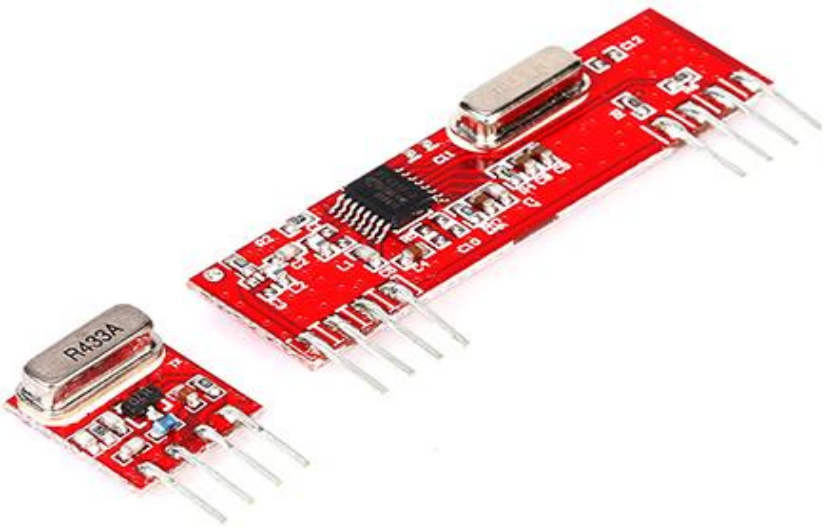

Figure 4.8: RF module

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the digital signal for next decocder stage. RF transmitter will receive serial data and transfer the data wirelessly using its antenna which is connected to pin 4 of module. This transmission will occur at data rate 10kbps.

4.3.1 Feature of RF module

1)It is easy to use

2)It require 2.2v to 5v

3)The operating temperature is range between -20 to +80C.

4.3.2 Application of RF module

1) For Home Automation

2) For surveillance the objects

3) From fire protection.

4.4 PCB schematic and design

The PCB schematic has been done in Auto-desk Electronics software.

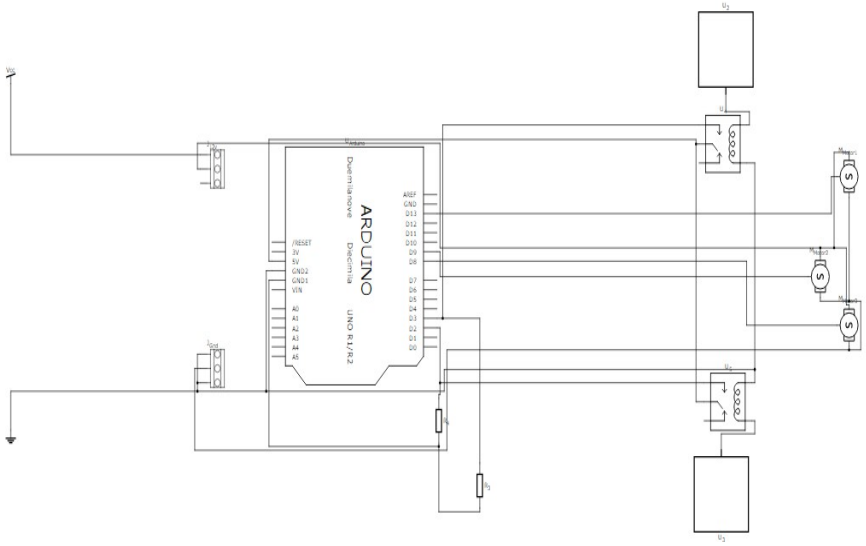

Figure 4.9: schematic design

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This is schmeatic layout system in which we have use two relay module of 12v and one arduino controller with three motor are connected.For this screw terminal has been used in which 12v DC from SMPS(switched mode power supply) has been given, through which the supply will be provided.

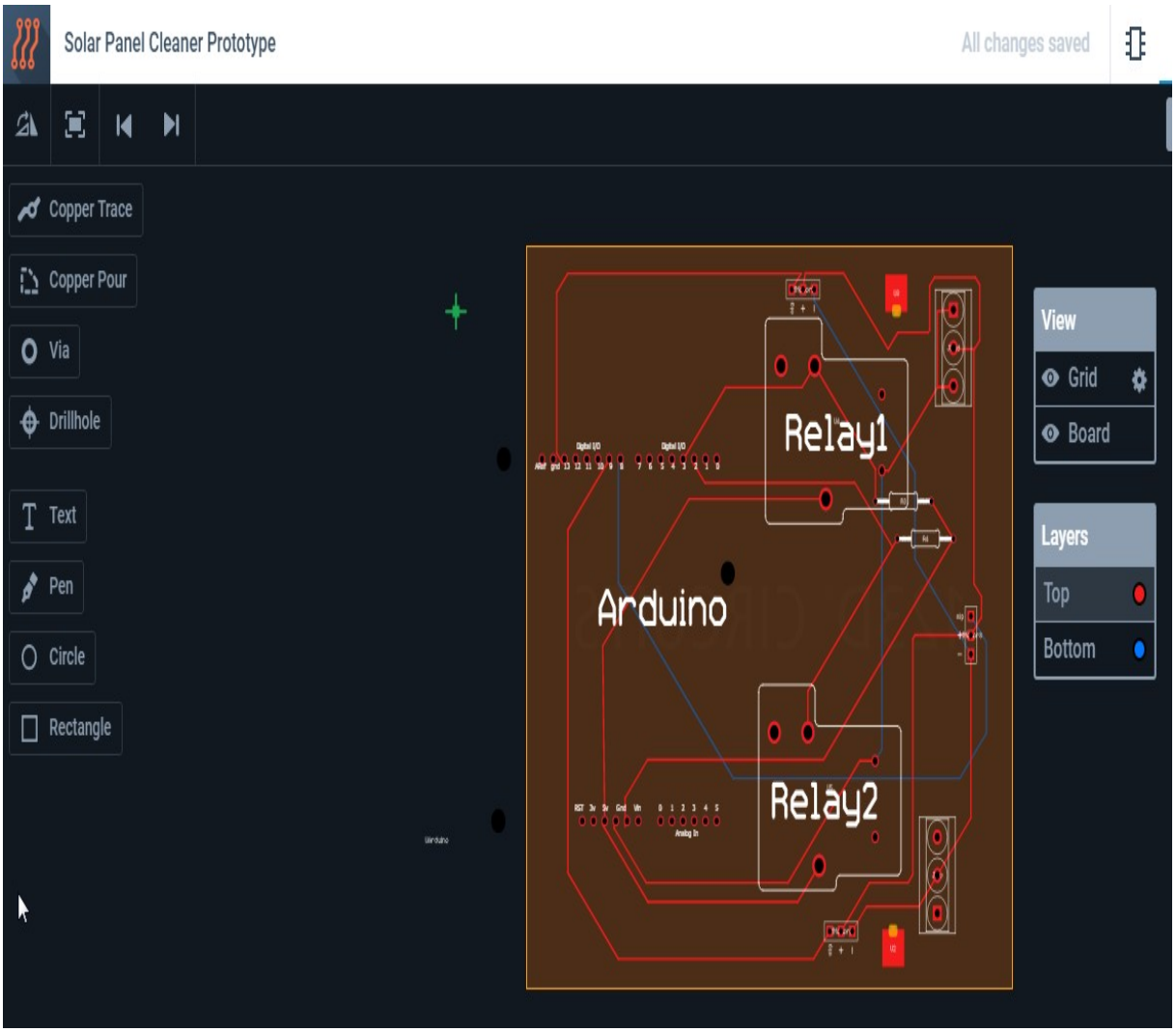

Figure 4.10: PCB layout

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4.5 Flowchart of System

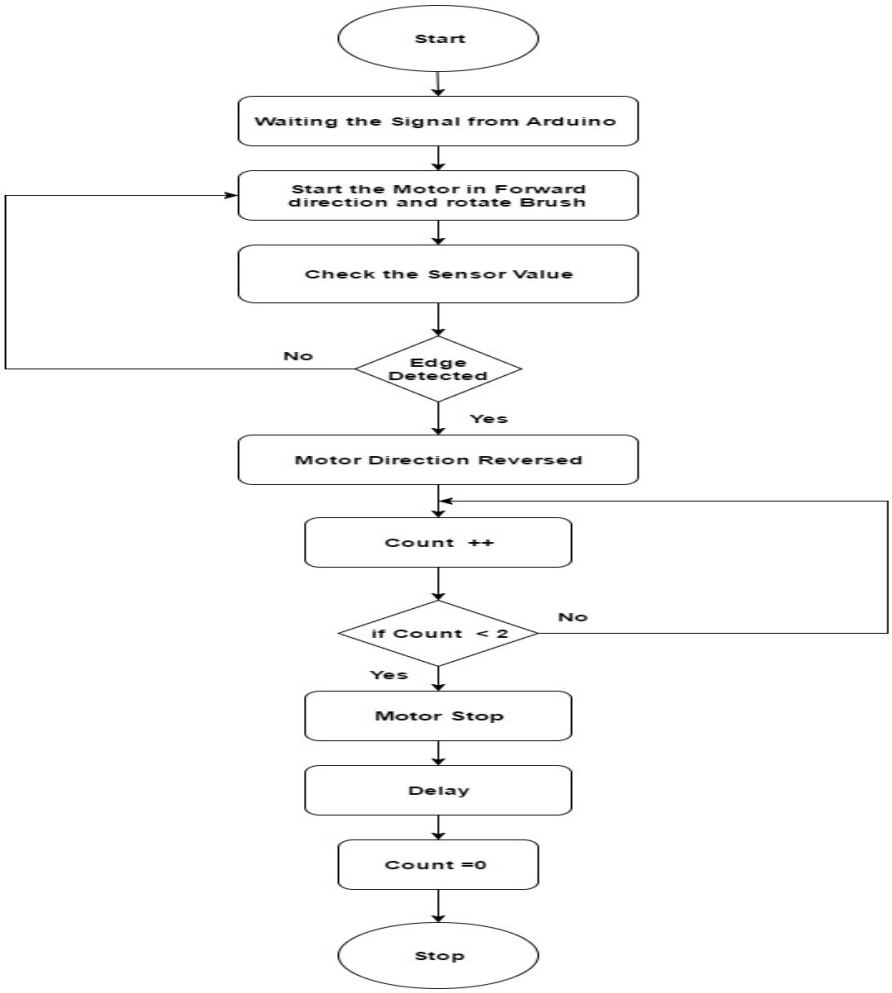

Figure 4.11: Flow Chart

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Chapter 5

Conclusion and Future Work

5.1 Conclusion

The main objective of the system is to reduce monotonous work with help this automatic device,which will eventually increase the efficiency of the panel by regular cleaning.

5.2 Future Work

1)Implementing this model on multiple array of solar panels

2)Further we can make this system more automatic by using more Real time application.

References

[1] Sulaiman, Shaharin Anwar,“ Influence of dirt accumulation on performance of PV panels ”. Energy Procedia 50 (2014): 50-56.

[2] Abderrezek, Mahfoud, and Mohamed Fathi. “ Experimental study of the dust effect on photovoltaic ‘panels’ energy yield.” Solar Energy 142 (2017): 308-320.

[3] Tanesab, Julius, “ The contribution of dust to performance degradation of PV modules in a temperate climate zone ”. Solar Energy 120 (2015): 147-157.

[4] Malay K. Mazumder, Little Rock, AR (US) Robert A. Sims, Little Rock, AR (US); James D. Wilson, Benton, AR (Us), “ Transparent self-cleaning dust shield ” U.S. Patent US6911593B2, JUNE 28, 2005.

[5] HAN-LUNG LEE, Tu-Cheng (TW), “ AUTOMATIC CLEANING SYSTEM FOR SOLAR PANELS AND METHOD THEREOF ” U.S. Patent 2009/0266353, A1 Oct. 29, 2009

[6] Anderson, Mark, “ Robotic device for cleaning photovoltaic panel arrays ”. 12th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines. 2009

[7] Abhilash, Bandam, and Ashish K. Panchal. “ Self-cleaning and tracking solar photovoltaic panel for improving efficiency ”. Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), 2016 2nd International Conference on. IEEE, 2016.

[8] Jaradat, Mohammad A " A fully portable robot system for cleaning solar panels ". Mechatronics and its Applications (ISMA), 2015 10th International Symposium on. IEEE, 2015.

[9] Paudyal, Basant Raj," Effect of Dust Accumulation on Solar Panels and Mechanism for Alleviation Design for Street Lighting Purpose ". Proceedings of IOE Graduate Conference. 2015

[10] He, Gaofa, Chuande Zhou, and Zelun Li. " Review of self-cleaning method for solar cell array ". Procedia Engineering 16 (2011): 640-645.