Chapter 1

Introduction.

- **Over view**
- **General Block Diagram .**
- **Time table .**
- **Elements and cost table .**

1.1 Over view

The solar energy is a very promising source since it supports delocalized power generation, it requires regular maintenance after installation. Accumulated dust on the surface of photovoltaic solar panel can reduce the system's efficiency up to 50% . This emphasizes the need to keep the surface of the solar panel as clean as possible. Most of the present cleaning methods employ water based techniques (e.g., washing directly from a water pump, a soap solution, etc.) . One could not afford to waste copious amounts of water on cleaning solar panels since it cannot be recycled very easily for practical uses. Also standalone panels installed in different areas do not always have a nearby water source which further adds to the problem. Another efficient method of cleaning solar panels is using Electrostatic cleaning method. Though it is very effective, there is a decrease in power performance . Also every solar panel requires an individual electrostatic cleaner for permanent installations which makes cleaning laborious and expensive [1] .

Photovoltaic panels are generally installed in relatively inaccessible areas like roofs or arid deserts which make manual cleaning operations difficult and expensive. Most solar panels are normally cleaned early in the morning or late at night since cleaning during its principal operation leads to non-uniform power outage and decrease in efficiency. Thus the lack of automation capabilities in most cleaning solutions proves costlier in terms of water and energy-use. Thus, by implementing the proposed design the need for water based cleaning methods, manual intervention and cleaning difficulties in remote places is eliminated [2] .

1.2 General Block Diagram:

The proposed design contains the power supply unit which consist of battery , PV panels , charge control , and control part which consist of Microcontroller, sensor , motor driver , and the mechanical part which consist of the main structure which carry all the parts ,more details will be described in chapter 3 .

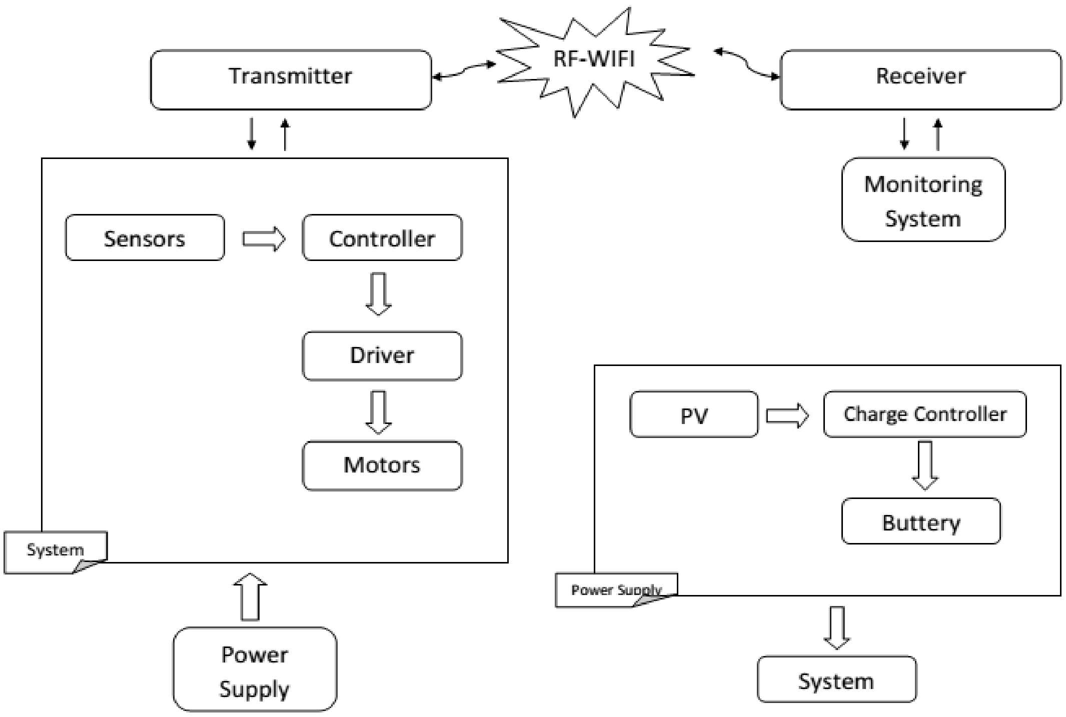

Figure1-1: General Block Diagram

1.3 Time Table:

This project is divided into 11 tasks with time duration of 16 weak .

Task1: Equipment purchase.
Task2: Aluminum structure design
Task3: Installation of horizontal movement motor and testing.
Task4: Installing brushes and it's motor on the aluminum structure and testing it.
Task5: Installing the lift with other part and testing it .
Task6: Printing the Electronic circuit on PCB, and Programming the Microcontroller.
Task7: Preparation of Power Supply.
Task8: Connecting the Electrical element with the mechanical parts.
Task9: Doing first test
Task10: Doing final test.
Task11: Writing the graduation project document.

week / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Task 1	■	■														
Task 2			■	■	■											
Task 3					■	■										
Task 4							■									
Task 5							■	■								
Task 6									■	■	■					
Task 7												■				
Task 8												■	■			
Task 9														■		
Task 10															■	
Task 11																■

Table 1-1 Time table

1.4 Elements and cost table:

#	Element	number	Cost for unit $	Total cost $
1	Structure aluminum and mechanic work	1	550	550
2	Dc motor	7	15	105
3	Brush	2	25	50
4	steel wire	10M	2	20
5	Microcontroller	1	10	10
6	Motor Driver	3	3	9
7	PV Panels 30W	1	50	50
8	Regulator	1	20	20
9	Buttery 12V	1	30	30
10	Xbee	1	50	50
11	PCB board	1	30	30
12	Power Connection cables	1	15	15
13	Proximity sensor	1	15	15
14	Limit switch	5	3	15
14	Other work	1	1	50
Total Cost				1029

Table 1-2: Element and cost table

Chapter 2

Photovoltaic Systems

- **Photovoltaic energy.**
- **Components Of Photovoltaic System**
- **Loss in PV system.**
- **Environmental factors effecting efficiency of PV panels.**
- **Effects of dust on solar panel efficiency.**
- **Methods used to clean PV panels.**

2.1 Photovoltaic energy

Photovoltaic's (PV) is the name of a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon commonly studied in physics, photochemistry and electrochemistry. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. The process is both physical and chemical in nature, as the first step involves the photoelectric effect from which a second electrochemical process takes place involving crystallized atoms being ionized in a series, generating an electric current. Power generation from solar PV has long been seen as a clean sustainable energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source – the sun. The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation. It is well proven, as photovoltaic systems have now been used for fifty years in specialized applications of a number of solar cells to supply usable solar power. This can be achieved with the aid of inverters which convert Direct Current (DC) into Alternating current (AC) .

2.2 Components Of Photovoltaic System

2.2.1 Solar Panels

Solar panel form a group of solar cells that convert sunlight into a continuous stream composed , it is divided into two main type:

- Monocrystalline cells : which are cut from a single crystal of silicon- they are effectively a slice from a crystal . In appearance, it will have a smooth texture; they are considered as most efficient and most expensive solar cell .

- Polycrystalline (or Multicrystalline) cells are effectively a slice cut from a block of silicon, consisting of a large number of crystals, They have a speckled reflective appearance, These cells are slightly less efficient and less expensive than Monocrystalline.

  As shown in fig 2-1.

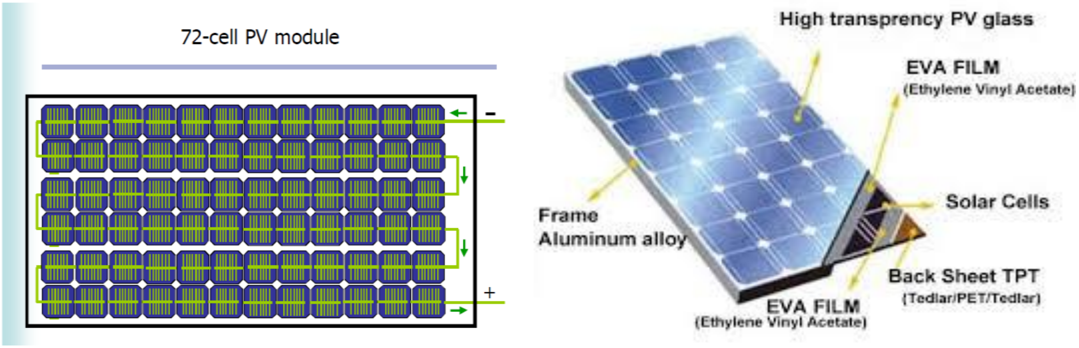

Figure 2-1 : Installation of the solar cell and internal conductivity

2.2.2 Inverter

A device that converts direct current electricity to alternating current either for stand-alone systems or to supply power to an electricity grid. There are many types of inverters depending on the solar power system needed , connected with other component such as DC Disconnecter , AC Disconnecter , Charge controller and communication System .

2.3 Losses in PV systems

As sunlight gets converted in usable electricity there are different losses lowering the system output power. To quantify the performance of a PV system, a performance ratio is introduced. This ratio represents the final yield (*YF*) divided by the reference Yield (*YR*). In essence it compares the AC output power with the DC power coming out of the module, thus calculating the losses due to the conversion [3]. These losses can be linked to:

- panel degradation(η_{deg})
- temperature (η_{tem})
- soiling (η_{soil})
- internal network (η_{net})
- inverter (η_{inv})
- transformer (η_{tran})
- system availability and grid connection network (η_{ppc})

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

$$PR = \frac{YF}{YR} = \eta_{deg} \times \eta_{tem} \times \eta_{soil} \times \eta_{net} \times \eta_{inv} \times \eta_{tran} \times \eta_{ppc} \quad (2\text{-}1)$$

2.4 Environmental factors affecting efficiency of PV panels.

Solar power generation can be influenced by many factors. The major factors that reduce or impede the generation power of the PV panels are; shadows, snow, high temperatures, dust, dirt, bird droppings, pollen and sea salt and discussed below:

2.4.1 Shadow

When installing PV panels, it is important to consider where the shadows fall .If PV panels are not installed correctly, their output will be reduced. To avoid reducing the efficiency of the PV panel, the following should be considered:

- The dimensions of any shadow at different times of the year.
- The structure and angle of the PV panel.
- Tracking how the shadow influences the panel.

2.4.2 Snow

PV panels can still generate electricity under a light snowfall, but once the snow completely blocks out the sun radiation, the PV panels will stop generating electricity. Further, if one area of a solar panel is completely covered by snow, the rest of the panel can stop functioning because of the way the solar cells are wired together. In this project snow was not considered because it has rarely snowed in Palestine and especially in Jericho.

2.4.3 Externally high temperature

When panels reach high temperatures, power efficiency drops. The efficiency of energy output drops by 1.1% for every extra degree in Celsius once the PV panel temperature reaches 42 .

2.4.4 Dust, dirt, bird droppings, pollen and sea salt

Accumulated dust on the surfaces of PV panels can come from many different sources; it has a big impact on electricity production. The efficiency of the solar panel can be reduced by up to 50% in a dusty environment, as this interferes with the amount of direct sunlight received to the PV array. The rate of dust in Jericho is high,. Pollen from flowering trees, bird droppings and salt spray from the salty soil are particular problems for this area [4].

2.5 Effects of dust on solar panel efficiency :

The output power generated by PV panels is decreased over time due to accumulation of dust and other dirt. In the Middle East, India and Australia, PV power output is significantly affected by the accumulation of dust on the surfaces of PV arrays. In Saudi Arabia, the accumulation of dust decreases the power production up to 50%.

As the growth of PV panel use increases, so does the need for monitoring and cleaning the panels' surfaces. The frequency of cleaning the PV panels depends on the environment of the solar installation.

In Palestine the effect is about 20%-25% and depends according to the region , for example Jericho had dry dust , Jerusalem had a moisture dust which is difficult to remove in comparison to dry dust , in this case water must be used to clean the panels [4] .

2.6 Methods used to clean PV panels :

PV panels can be cleaned manually and automatically. Over time, manual cleaning is more costly compared to automatic cleaning. This project considered some different cleaning technologies available on the market today, such as; the Heliotex rinse, electrostatic cleaning, the V1 cleaning robot system and the Sun Brush robot system. These cleaning methods were chosen to review, so as to determine whether the development of the i7 house-cleaning robot will work on a PV panel's surface. Furthermore, the use of PV panels cleaning robotics has been expanding over the last few years to reduce the need for manual cleaning . The cleaning methods are explained below:

2.6.1 Heliotex technology

Heliotex is an automatic cleaning system that washes and rinses solar panel surfaces. The cleaning system can be programmed whenever it is necessary, depending on the environment. It does not require any further attention except the replacement of the water filters and the occasional refilling of the soap concentrate. It contains a five-gallon reservoir for soap, which does not cause any damage to the solar panels and roofing materials. The Heliotex system sources the water from the residence via a hose or pipe connected to the pump and attached to nozzles on the solar panel surface without causing rubbing. See Fig 2-2.

Figure 2-2: Heliotex cleaning technology using water and soap to clean the surface of PV panels

The advantages and disadvantages of using the Heliotex cleaning system are listed below:

Advantages:
- Good for areas with ready access to water.
- Improves the effectiveness of the PV panels after being washed by almost 100%.
- The Heliotex cleaning system is reliable (warranted for 10 years).

Disadvantages:
- Expensive equipment such as the soap, hoses and pumps which are required.
- Requires ready access to plenty of water.
- Needs regular checking for the water and soap residue build up.
- The soap may affect the environment of plants.

2.6.2 Electrostatics cleaning

Electrostatics cleaning technology is named “Harvesting electricity”. This cleaning technology was first developed by scientists to solve the problem of dust deposits on the surfaces of PVs located on Mars. This technology can also be used in dry dusty areas on Earth. Electrostatic charge material is used on a transparent plastic sheet or glass that covers the solar panels. Sensors monitor dust levels and activate the system into cleaning mode .

The dust is shaken off the solar panels when an electrically charged wave breaks over the surface material. This is not a safe way for homeowners who are using solar panels because the panel shakes which may loosen its connection to the roof and it could fall down and cause injury. However, it is an effective solution for larger systems elsewhere. The structure of the panels is strong and flexible to avoid breakage that may be caused by shaking, as shown in Fig 2-3.

Figure 2-3: Structure of PVs system that uses electrostatic

In two minutes this system can remove up to 90% of dust from the surfaces of the PV panels by sending an electrical dust deterring wave which causes the dust to fall off onto the ground . However, this system is not going to remove dust when it gets wet, or if it is in a moist environment. The movement of the wave mechanism requires only a small amount of electricity which makes it a power efficient system however at present; the worldwide usage of the harvesting system is only 4% .

2.6.3 Robotic cleaning solutions

The section below discusses and analyses cleaning robots, such as the V1 cleaning fixed robot and the SunBrush cleaner robot, to develop a better solution for using the vacuum-cleaning robot on PV panels.

2.6.3.1 The PV cleaner V1 robot

The robotized V1 system was designed for cleaning the surface of the PV panels automatically to maximize the output of energy. The V1 robot is composed of a cleaning head and a drive system. The cleaning head has two cylindrical brushes traveling upward and downward along the panel surface edges by a pair of motorized trolleys to generate a clean PV panel as shown in Fig 1-4.

A guide cable is connected to each drive trolley to control the movement of the cleaning head and prevent unwanted rotation.

Figure 2-4: Traveling system of robot V1.0 head along of the panel arrays

The drive system consists of three main components of motion: the top and bottom trolleys and the cleaning head. The top and bottom trolleys use a 12V DC motor, to provide motion to the cleaning system. The top and bottom can be controlled independently along the panel rows.

Contrinex 500 M30 sensors located on the trolley frame detect the edges of the panel, giving a command to the control system to slow or stop the motion when the trolley reaches the end of the panel array. The drive wheels of each trolley are composed of two pairs. Each pair is linked via a chain as shown in Fig1-5. The wheels were designed in pairs to avoid falling down when it is crossing gaps between two panels [4] .

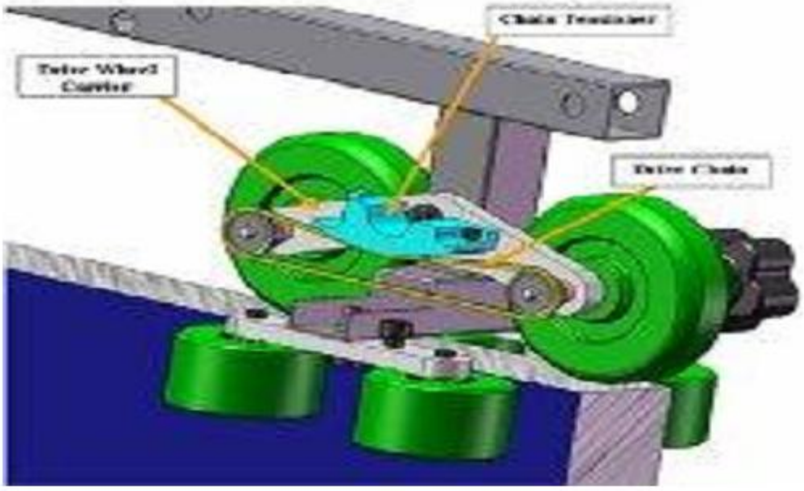

Figure 2-5: Drive Wheel Paired Via a Chain

2.6.3.2 The SunBrush robot

The SunBrush is a similar fixed cleaning robot primarily designed for cleaning snow from PV panels. It is a fully automated cleaning system for the PV panels. This cleaning robot was produced in Germany to remove snow from the solar power surfaces as shown in Figure 1-6. The main use was in solar heating systems, as Removal of the accumulated snow reduced the amount of sunlight going into the panels, which impacted on the amount of hot water produced. Use of this system has led to a 15-18% increase in solar panel efficiency and up to a 20% increase in hot water production. The structure of the SunBrush is simple. It is fixed to the roof and is composed of a brush that is driven by a small motor through a roller.

Figure 2-6: Sun Brush full automatic cleaning over solar panels

The disadvantages of using these fixed robotic systems are that they are expensive, and difficult to install over a large PV area [4] .

Chapter 3

Mechanical Design

- **Overview.**
- **Complete design .**
- **Main structure.**
- **Stand of brush .**
- **Y-axis pulley .**

3.1 Overview

Since the target group of stations with high capacity and open spaces located in the exposed dry dust areas, and there are no sufficient water to clean the panels, using waste accumulated technique for dust removal force to add extra infrastructure.

The goal of the project is to design a robust, commercially viable product which provides a simple, cost-effective solution to clean solar panels, this will be achieved by using manufactured brush material Micro fiber, controlled by a special robot Designed for this task without changing the PV station infrastructure.

The robot uses one stage cleaning process to remove dust effectively from the solar panels; A rolling brush is placed in front to disperse the dust towards the brush. A high speed motor capable of creating suitable suction is used for removing dust from the panels. It moves on the edges of solar panels by the wheels of robot in a special speed and detect the motion by the sensors. The proposed design can detect the end easily, and works on inclined planes which automatically charge itself at the docking station.

3.2 Complete design :

All the component described above are assembled using masterCAM software which is used widely for mechanical design with scale of 1:1 as shown in fig (3.1) .

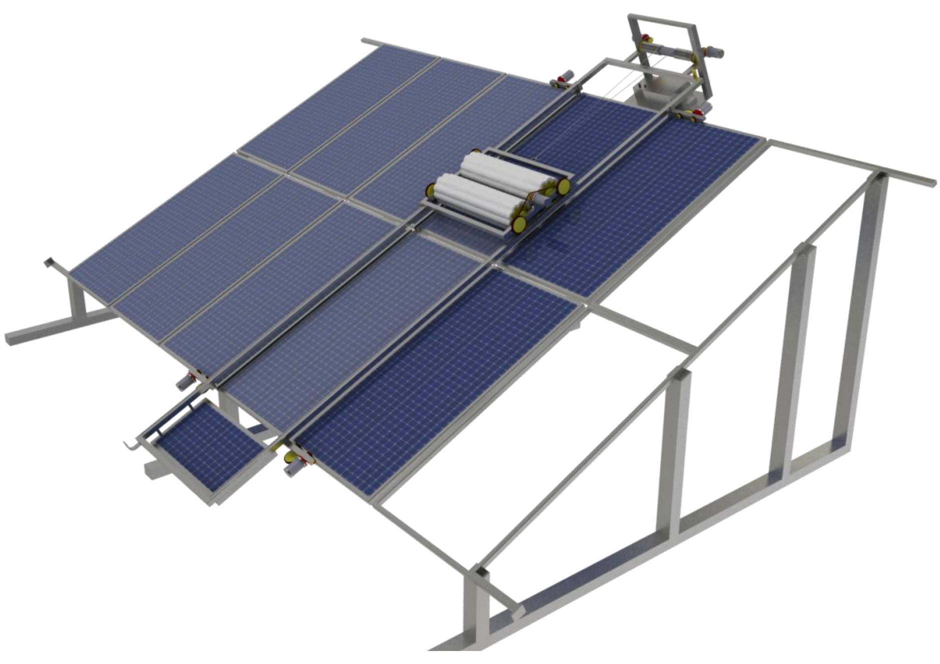

Figure 3-1: Complete design

3.3 Main structure:

In this project all the structure are aluminum. One of the best known properties of aluminum is that it is light, with a density one third that of steel, 2,700 kg/m3. The low density of aluminum accounts for it being lightweight but this does not affect its strength.

The dimension of main structure 500 cm length and 85 cm width without wheels , 120 cm width with wheels .

Aluminum alloys commonly have tensile strengths of between 70 and 700 MPa. Unlike most steel grades, aluminum does not become brittle at low temperatures. Instead, its strength increases. At high temperatures, aluminum's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account. Aluminum is now the second most widely used metal in the world after iron .

The object of the main structure is to holds all the parts of the robot ,it moves horizontally over the panels .

The movement relies on four motors for load distribution and to ensure the stability of the movement on track as shown in fig(3.2) and fig(3.3)

Figure 3-2 : Main structure Design

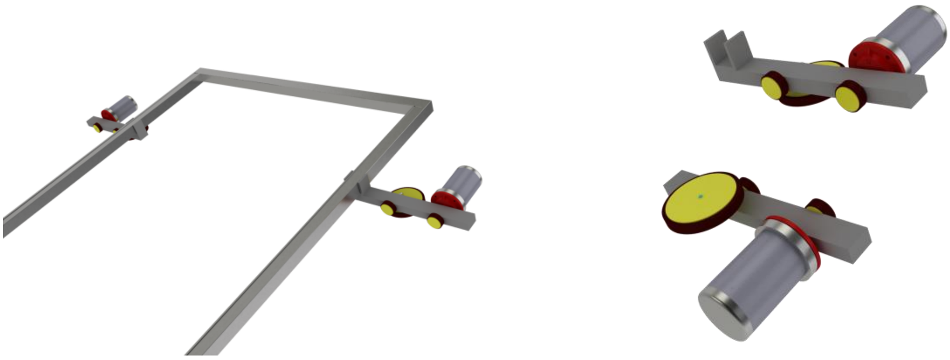

Figure 3-3 : Part of main structure design

Figure 3-4: wheels and motor of structure

3.4 Stand of brush:

The stand is connected with two microfiber brushes via bearing for high efficiency cleaning and lowering the friction .

The motor is connected with two pulleys by special belt to rotate the brush in high speed , it contain four wheels to move on the track as shown in fig(3.4) and fig(3.5).

The dimension of the stand equal 75 cm width and 60 cm length .

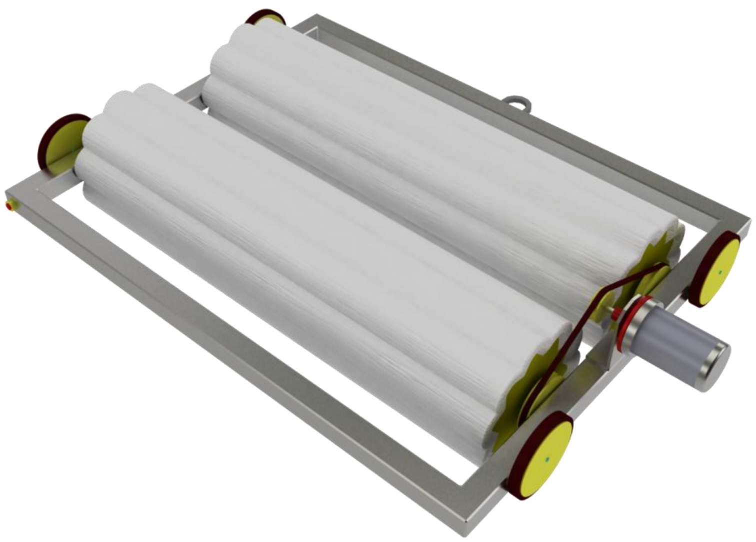

Figure 3-5: Stand of brush Design

Figure 3-6 : Stand of brush

3.5 Y-axis pulley :

The main operation of the pulley is moving the stand of brush in vertical motion on the main structure using two motors, to move in two deferent speeds as shown in fig(3.6) and fig(3.7) .

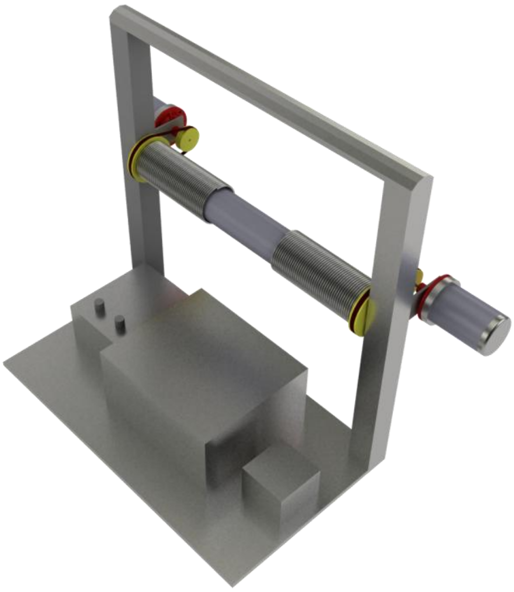

Figure 3-7 : Y-axis pulley Design

Figure 3-8 : Y-axis pulley

This system is assembled and tested practically on JDECO dead sea PV plant in Jericho as shown in fig 3.9

Figure 3-9 : Test of project in JDECO dead sea station

Chapter 4

Electrical Design .

- Overview.
- Motor
- Choosing power supply .
- Control circuit design.
- Power circuit design.
- Main block diagram.
- Schematic circuit and PCB board.

4.1 Overview

The electrical system interact with the mechanical system , with automated control process using microcontroller which interfaces with all parts of the system , electrical system consist of different parts as described in this section .

4.2 Motors

A **Direct Current Motor**, it is named according to the connection of the field winding with the armature. Mainly there are two types of DC Motors. First one is **Separately Excited** DC Motor and **Self-excited** DC Motor. The self-excited motors are further classified as shunt motor, series motor ,compound motor . permanent magnetic field motor ,as shown in fig (4-1) , the parts of DC motor stator , Rotor and winding

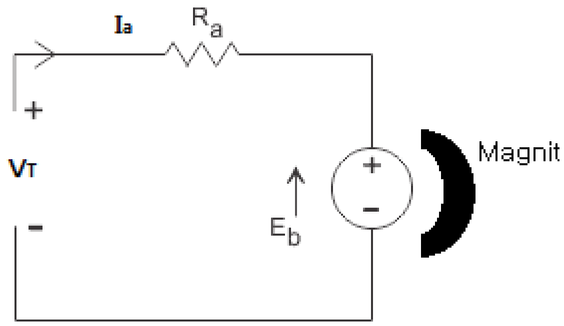

Figure 4-1 : Permanent magnetic motor circuit

Permanent magnet motor has a constant magnetic field .

The use of permanent magnets in construction of electrical machines had the following benefits:

- No electrical energy is absorbed by the field excitation system and thus there are no excitation losses which means substantial increase in efficiency.
- Higher power density and/or torque density than when using electromagnetic excitation.
- Better dynamic performance than motors with electromagnetic excitation (higher magnetic flux density in the air gap).
- Simplification of construction and maintenance.
- Reduction of prices for some types of machines.

The speed control in this type can by controlled by changing the voltage of armature , while the stator flux is constant because it is generated by permanent magnet field .

The relation between voltage and speed is described according to eq4-1

$E_b = C\omega_m = VT - I_a R_a$ (4-1)

A permanent magnets DC motor equivalent circuit is shown in Figure (3.1).

The torque developed in the rotor (armature) is given by:

$T_{dev} = C\, I_a$ (4-2)

From equation (3-2), the current in the armature winding can be found as:

$I_a = \frac{T_{dev}}{C}$ (4-3)

Substituting for Ia in equation (3-1) and rearranging the terms:

$V_T - C\,\omega_m = R_a \frac{T_{dev}}{C}$

Therefore, the torque developed in the rotor can be expressed as:

$T_{dev} = \frac{C}{R_a}(V_T - C\,\omega_m)$ (4-4)

This equation shows the relationship between the torque and speed of a permanent magnet DC motor. If the flux is constant, the torque-speed relationship is a straight drooping line. Terminal voltage VT and constant flux C .as shown in fig (4-2) [5] .

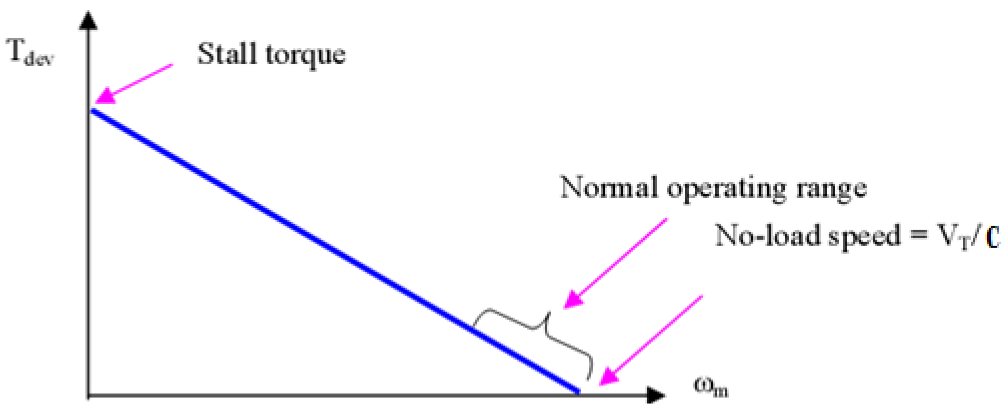

Figure4-2: Relationship between the speed and the torque

4.2.1 DC Motor Speed Control.

Many applications require the speed of a motor to be varied over a wide range. One of the most attractive features of DC motors in comparison with AC motors is the ease with which their speed can be varied.

The back emf for a permanent magnetic DC motor is described in eq3.5 :

$$E_b = C\,\omega_m = V_T - I_a\ R_a \qquad (4\text{-}5)$$

Rearranging the terms,

Speed $$\omega_m = \frac{V_T}{c^2} - \frac{R_a}{c^2} T \qquad (4\text{-}6)$$

From this equation, it is evident that the speed can be varied by using any of the following methods :

- Armature voltage control (By varying V_T).
- Armature resistance control (By varying R_a).

4.2.2 Armature voltage control

This method is usually applicable to separately excited DC motors. In this method of speed control, Ra and ϕ are kept constant.

In normal operation, the drop across the armature resistance is small compared to Eb and therefore:

$$E_b \cong V_T$$

Since , $E_b = C\ \omega_m$

Angular speed can be expressed as:

$$\omega_m \cong \frac{V_T}{C} \qquad (4\text{-}7)$$

From this equation,

- If flux is kept constant, the speed changes linearly with V_T.
- As the terminal voltage is increased, the speed increases and vice versa.

The relationship between speed and applied voltage is shown in figure 4-3. This method provides smooth variation of speed control.

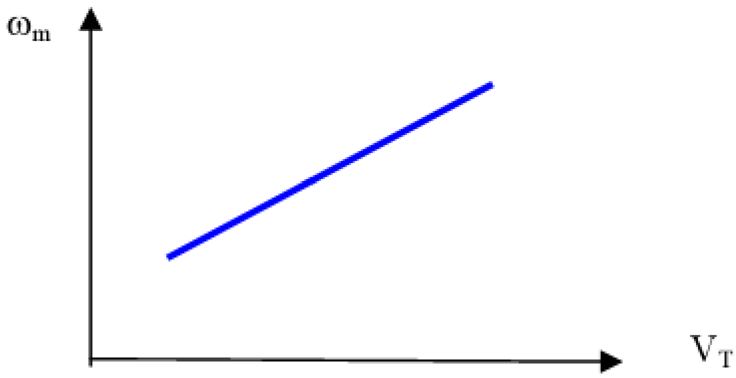

Figure 4-3: Variation of speed with applied voltage

In this project permanent magnetic dc motors are chosen because they have simple speed control by armature voltage and the relationship between torque and speed is linear ,and it had low price compared to other types of motors [5] .

4.3 Choosing suitable motors

The weight of main structure and stand brush and all parts equal 20 Kg , dividing the load on 4 motors , each motor well be loaded by 5Kg which is equal to 0.49 NM .The motor with model# JGB37-3530 is chosen in this project, because it had several speeds with gearbox and it had constant current for any load. From data sheet of motor ,the speed of motor is 60 RPM and the diameter of the shaft is 6 mm ,with a wheel of 10.6 cm diameter and Circumference equal 33.28 cm .

The width of step is 100 cm and The Revolution for a step R

$$R = \frac{The\ distance}{Circumference} \quad (4\text{-}8)$$

$$R = \frac{65}{33.28} = 1.95\ Revolution$$

And The Time of step

$$T = \frac{60\ second}{motor\ speed} \times R \quad (4\text{-}9)$$

$$T = \frac{60\ Sec}{25rpm} \times 1.95\ Rev. = 4.68\ Second$$

The calculated speed must be adjusted by the H-Bridge circuit , this means for a 60 pannel of total width 59.7m the robot moves continuously on array of 91.8 step, it needs $4.68\, Sec \times 91.8\, Step = 430\,\text{sec} = 7.2\, minutes$ to reach the final panel in the array , while in backward movement on 91.8 step it moves with nominal speed (53 rpm) and needs 2.2minutes.

Referring to motor datasheet. The current of each motor is $400mA$

The power of each motor $P = I.V$

$P = 400m\,A \times 12\,V = 4.8\,Watt$.

For 4 motors $P = 4.8 \times 4 = 19.2\,Watt$.

The consumed Energy for a motion equals the power multiplied by the time

$$E = P \times T \qquad (4\text{-}10)$$

E= $9.4 \times 19.2\,W = 288\,W.min = 3Wh$

For a stand brush the track length is $500\,cm$, this motion in Y-axis (vertical) and the weight of the stand and the brush is $6\,Kg$,the load distribution on two motor moves the roller by a diameter 10.6 cm and the circumference $C = 33.28\,cm$, each motor is loaded with $3\,Kg$ and equal to $0.196\,NM$.

The time of downward movement to finish the step at speed equals to 30 RPM

$$T = \frac{60\,sec}{30\,RPM} \times 15\,Rev = 30\,Second$$

While the time of upward movement is at speed 76 RPM

$$n = \frac{60\,sec}{76\,sec} \times 15\,Rev = 12.32\,Second$$

This time adjusted by H-Bride control circuit and pulse width modulation .

Referring to motor datasheet, the current of the motor equals 400mA .

The power of motor $P = 0.4\,A \times 12\,V = 4.8\,Watt$

For 2 motors P = 9.6 Watt

The consumed Energy for a motion from equation (4-10)

Total time = 42.36*91.8=64min

E= $64 \times 9.6\,W = 614.4\,W.min = 10.24Wh$

The brush run at continuous speed equals to 300 RPM with downward motion , the current equal 7A and 84 Watt.

The consumed Energy for a motion of each step with 40second period
$E = P \times T$

$$E = 40 \times 84\,W = 3360Wsec = 0.93Whot$$

$$\text{For 90 step } E = 0.93 \times 90 = 84WH$$

Total consumed energy = 100WH

$$The\ current\ Consumption\ for\ multi\ steps\ = \frac{Ec}{12\,V} \qquad (4\text{-}11)$$

$$= \frac{100\,Wh}{12\,V} = 8.3Ah$$

4.4 Choosing power supply

The power is supplied to the system using Off- Grid unit with solar panel 20 Watt power and 9 AH ,12V battery , which can work continuously for 100 step and clean 130 panel .

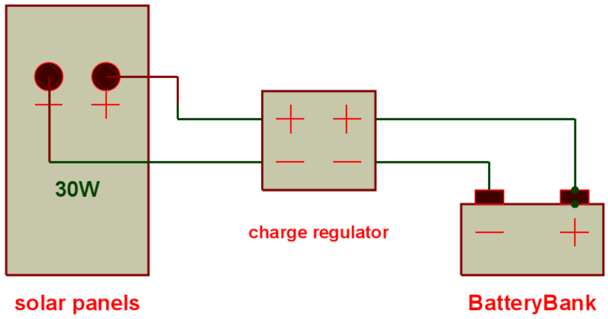

Figure 4-4: off grid dc power supply

4.4.1 Battery

Lead Acid Battery are chosen in this project ,it is one type of rechargeable batteries ,despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, it has ability to supply high surge currents which means that the cells has a relatively large power-to-weight ratio. it is low cost compared to other types of batteries .

Figure 4-5: Battery

4.4.2 Charge controller

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining (deep discharging) a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery charger.

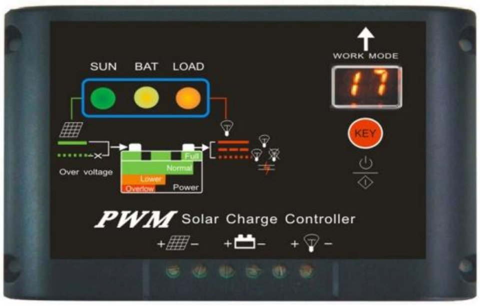

Figure 4-6: charge controller

4.4.3 PV Panel

A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. The first step is the photoelectric effect followed by an electrochemical process where crystallized atoms, ionized in a series, generate an electric current. PV installations may be ground-mounted , rooftop mounted or wall mounted . They may be mounted in a permanent orientation to maximize production and value or they may be mounted on trackers that follow the sun across the sky.

In this case the PV panel supply and charge the battery from the produced energy, and controlled by charge controller device .

Figure 4-7: 20 watt solar panel used in project

4.5 Control circuit design

This section show elements of control circuit such as a micro controller , XBee , limit switch and the Real time clock , and define the operation for each elements .

4.5.1 Arduino microcontroller

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.

Arduino can be used to develop stand-alone interactive objects or can be connected to software on using computer.

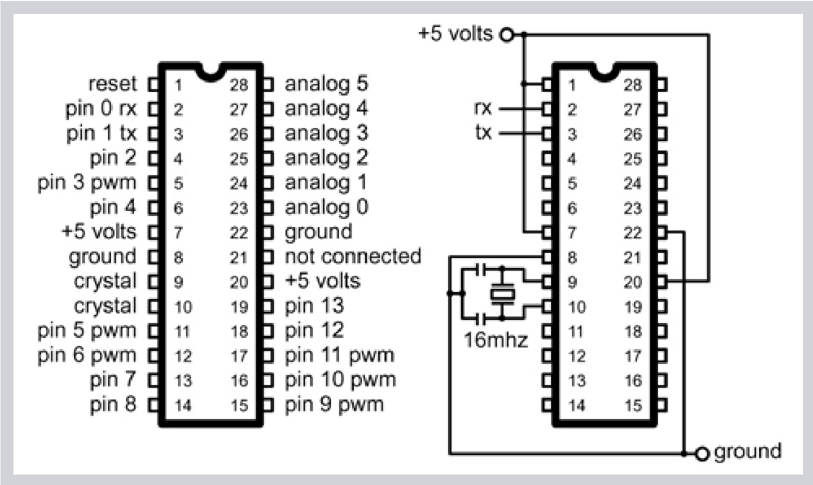

Figure 4-8: Arduino microcontroller chip

4.5.2 XBee

The Xbee shield is a board which allow to communicate wirelessly using Zigbee. It is based on the Xbee module from MaxStream. The module can communicate up to 30 meter indoors or 1600 meter outdoors (with line-of-sight). It can be used as a serial/usb replacement or it can be adjusted to command mode and configured for a variety of broadcast and mesh networking options. The shields breaks out each of the Xbee's pins to a through-hole solder pad. It also provides female pin headers for use of digital pins 2 to 7 and the analog inputs, which are covered by the shield .

Figure 4-9 : XBee

The main purpose for xbee in this project is to send and resave data between control room and microcontroller as shown fig (4-10) in order to be in the required operation furthermore it allows the user to know the state of the robot .

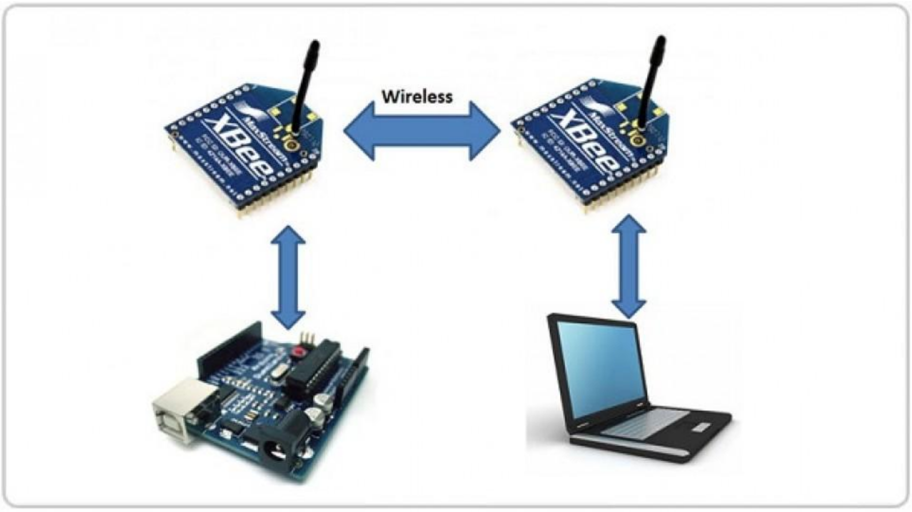

Figure 4-10: communication between Pc and microcontroller by xbee

4.5.3 Limit switch

A limit switch is a switch operated by the motion of a machine part They are used for controlling machinery as part of a control system, as a safety interlocks, or to count objects passing a point. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

Figure 4-11: Limit switch

4.5.4 Real time clock

A real-time clock (RTC) is a battery-powered clock , This microchip is usually separate from the microprocessor and other chips and is often referred to simply as a small memory on the microchip which stores system description or setup values - including current time values stored by the real-time clock. The time values are for the year, month, date, hours, minutes, and seconds. When the processors is turned on, the Basic Input-Output Operating System (BIOS) that is stored in read-only memory (ROM) microchip reads the current time from the memory in the chip with the real-time clock.

Figure 4-12: Real time clock circuit

4.6 Power circuit design

This section show the elements of power circuit such as MOSFET , MOSFET driver and the design of main block diagram, Schematic circuit and PCB board

4.6.1 MOSFET Transistor

The power MOSFET offers high switching frequency and simple gate drive requirements. They can achieve fast switching speeds because they store no charge in their drain-to-source area. The MOSFETs gate is voltage controlled and requires a low average current. MOSFETs are available in a wide range of voltages (20V to 1000V) and currents (1 to 1000A). Typically, MOSFETs are used in motor drives rated less than 200V, otherwise the device has to become large to achieve a low on resistance, MOSFETs are quite inexpensive and are a popular choice for many switch-mode applications.

Application	**Power Device Technology**	**Attributes**
High current Moderate Voltage	MOSFET	• Very low on resistance • Very high speed (500KHz) • Gate easily controlled
High Voltage High Current	IGBT	• Lower on losses than MOSFET • Average speed (20KHz) • Gate easily controlled
High Voltage Low Current	BJT	• Low on losses • High speed (100KHz) • Complex, expensive drive required
High Current Low Voltage	SCR	• Need transient suppression • Complex, expensive drive required • Hard to drive with PWM signal

Table 4-1: Power Device Attributes

4.6.2 L298 Dual Full Bridge Driver

The L298 is an integrated monolithic circuit in a 15 lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver de- signed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

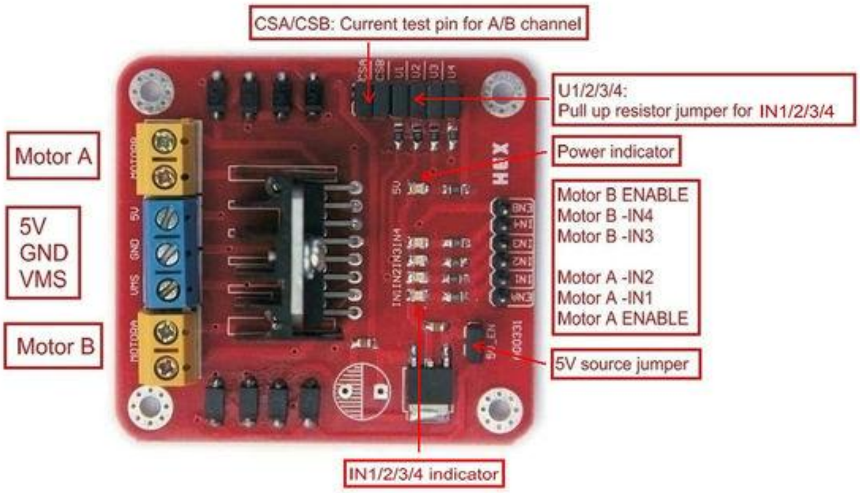

Figure 4-13: L298 Dual Full Bridge Driver Kit.

4.6.3 Isolated MOSFET driver TLP250

MOSFET driver TL250 like other MOSFET drivers have input stage and output stage. It also have power supply configuration. TLP250 is more suitable for MOSFET and IGBT. The main difference between TLP250 and other MOSFET drivers is that TLP250 MOSFET driver is optically isolated. Its mean input and output of TLP250 MOSFET driver is isolated from each other. Its works like a optocoupler. Input stage have a light emitting diode and output stage have photo diode. Whenever input stage LED light falls on output stage photo detector diode, output becomes high.

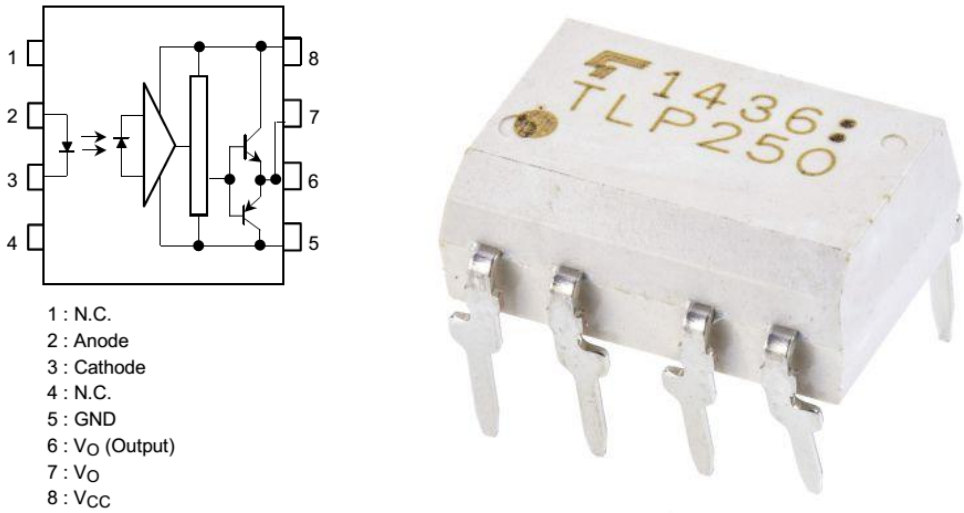

Figure 4-14: Pin mode configuration of insulation MOSFET driver TLP250

4.6.4 TLP781 optocoupler

The TOSHIBA TLP781 consists of a silicone photo transistor optically coupled to a gallium arsenide infrared emitting diode in a four lead plastic DIP (DIP4) with having high isolation voltage (AC: 5kV RMS (min)). The main function optocoupler isolated control circuit on the power circuit for protection control circuit from any fault .

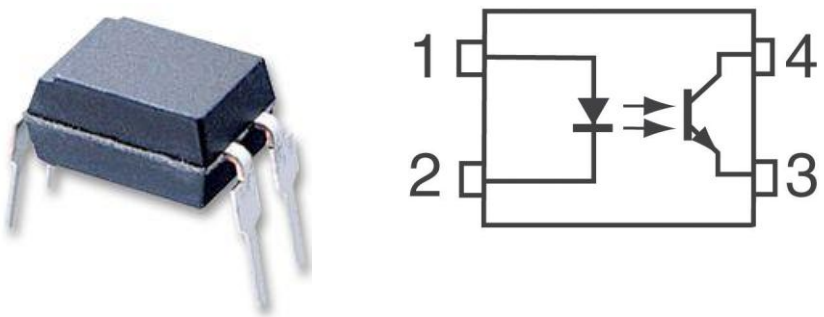

Figure 4-15: TLP781 optocoupler

4.7 Main block diagram

Figure 4.16 shows the overall system components , including the design of control and power circuitry, and the interface between them . This robot can be controlled and monitored using computerized system .

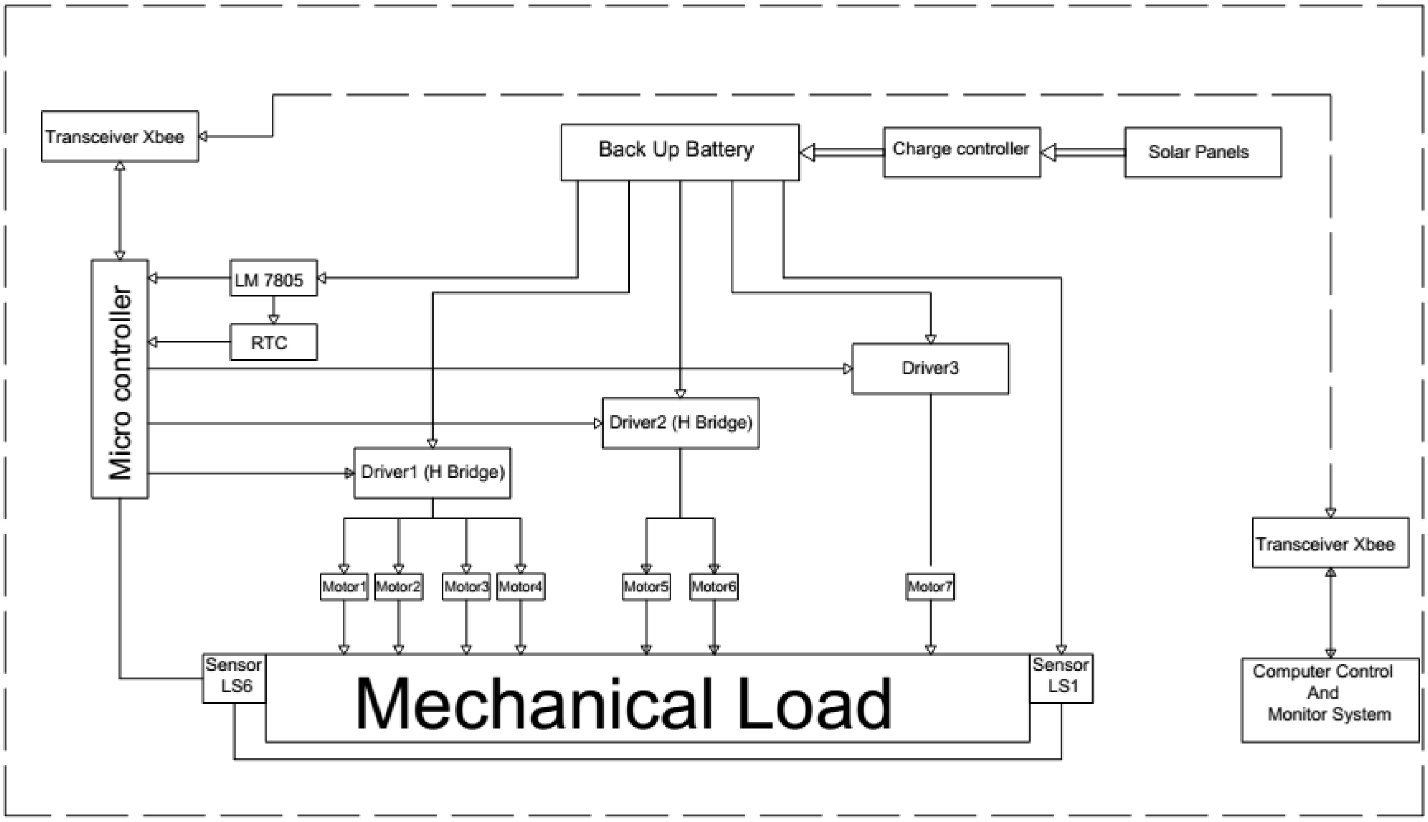

Figure 4-16: Main block diagram

4.8 Schematic circuit and PCB board

All the component described above are assembled using prouteus 8 professional software which is used widely for electrical design with scale of 1:1 as shown in fig(4-17) , fig(4-18) , fig(4-19) and fig(4-20) .

4.8.1 Control circuit

The robot is controlled using atmega328p-pu microcontroller , it contains a group of inputs and outputs ,six of them are used as inputs connected with limit switches , and five outputs used to trigger the MOSFET , using Pulse Width Modulation (PWM) and two analog ports connected with Real Time Clock (RTC) , for controlling the time of starting the cleaning operation, and all scheduled operations , two ports are connected with the XBEE using RS232 communication protocol for sending and receiving serial data .

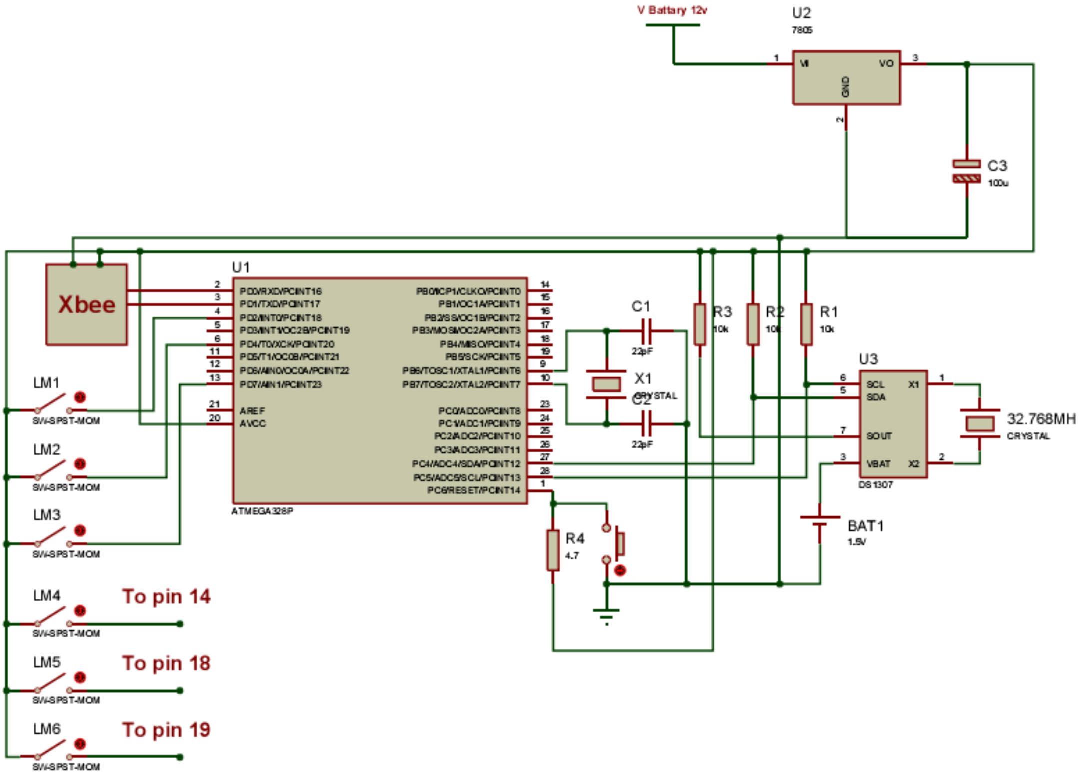

Figure 4-17: control circuit

4.8.2 Power circuit

The overall load is connected with power circuit , which is divided into three parts , each part had separate circuit ,and used for moving the motors in different speeds , and reversing the direction of rotation , an OptoCoupler had been used to separate the power circuit from the control circuit , in order to protect the control circuit from any defect in the power circuit ,and for consuming low current from the ports of the microcontroller , the loads is connected via diodes to protect them from reverse current .

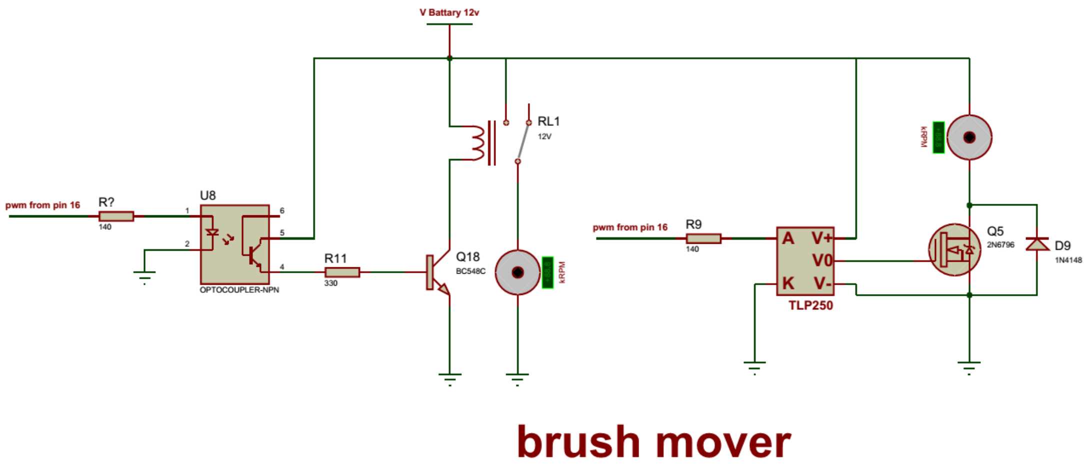

Figure 4-18: power circuit of brush motor

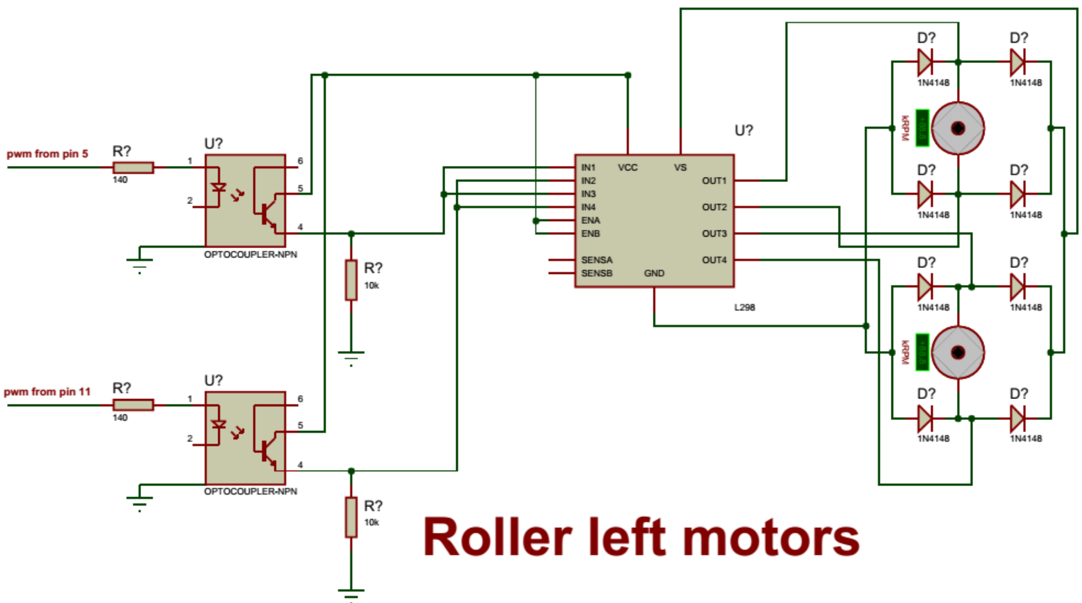

Figure 4-19: Power circuit of roller left motors

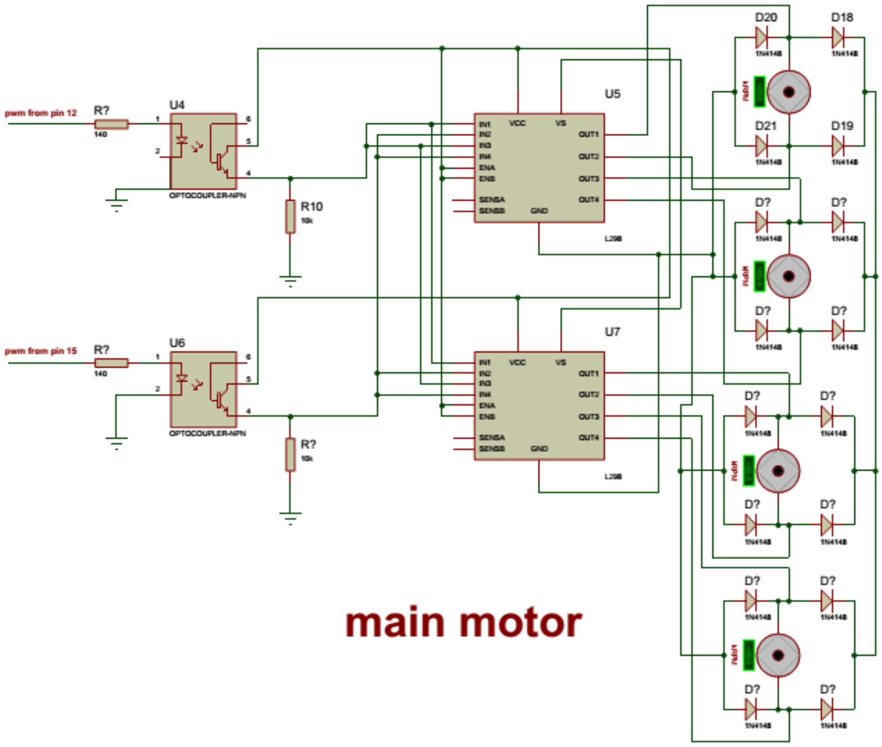

Figure 4-20: Power circuit of main motors

4.8.3 PCB Board

Proteus had the ability to produce PCB board with 1:1 scale as a Gerber file, ready to be printed using PCB machine as shown in fig 4.21 and 4.22 .
The board had been printed using CNCPCB printer with the AID of JDECO electronic lab as shown in fig (4.22)

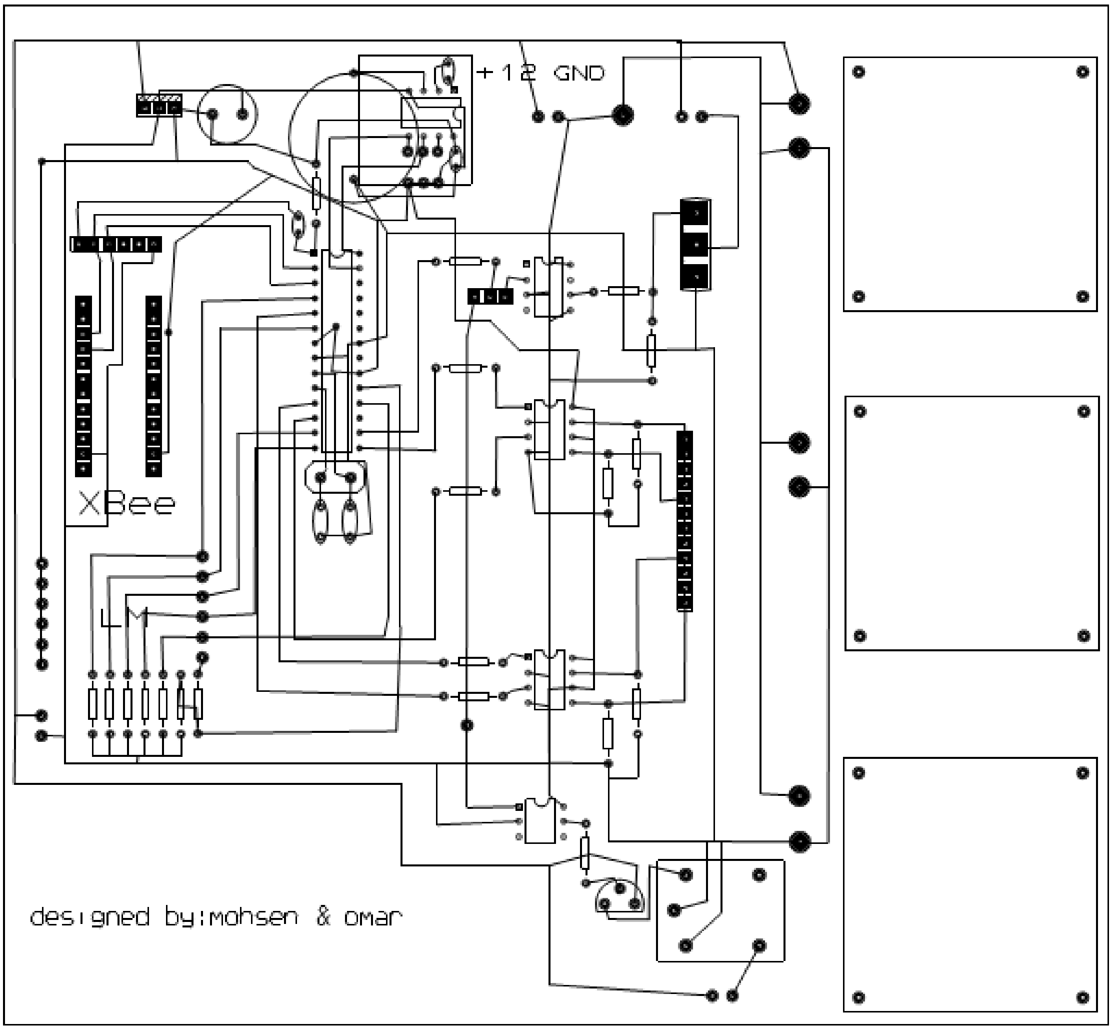

Figure 4-21 : PCB circuit

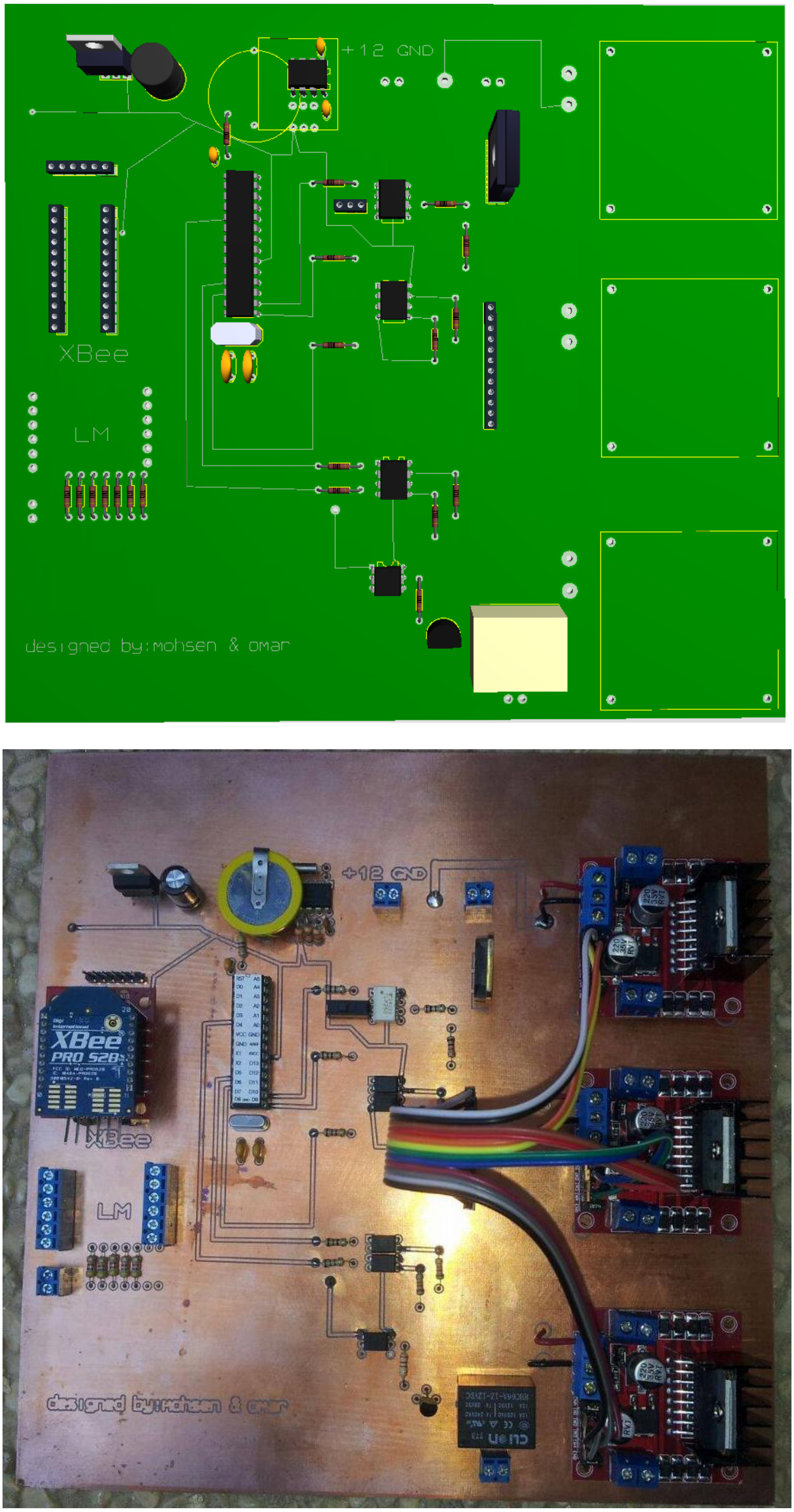

Figure 4-22: PCB board

Chapter 5

Microcontroller program

- **Overview**
- **Flow chart**
- **Software**

5.1 Overview

The main microcontroller is aurduino ATMEGA 238p , programmed with C++ code and tested practically with   availability of future modification in accordance with the desired process .

5.2 Flow chart

The flowchart explains how the robot work, step by step with control over all steps and interruption process based on sensors attached to the system .

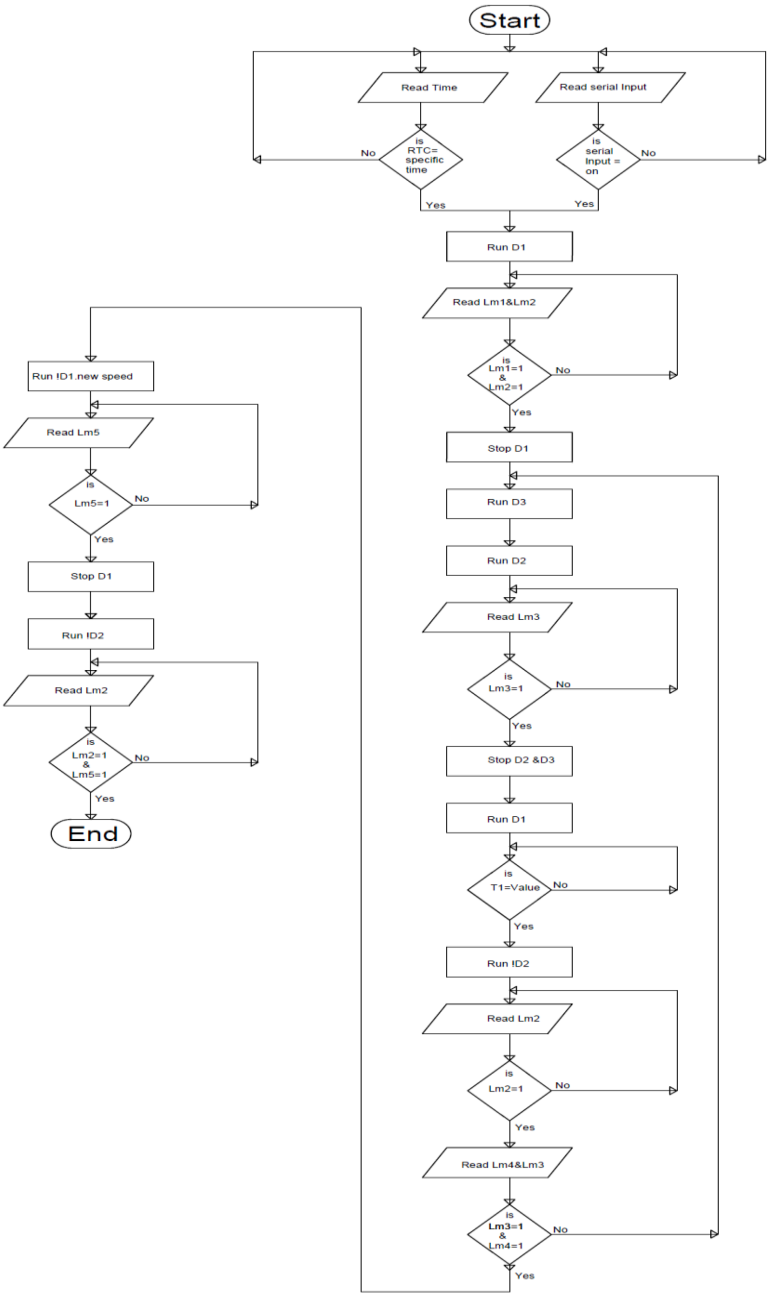

Figure 5-1: Flow chart

5.2.1 Flow chart element

Driver 1	D1	Controls the motors for Main structure
Driver 2	D2	Controls the motors for Y-axis pulley
Driver 3	D3	Controls the motors for brush
Limit switch 1	LM1	First panels on the rows
Limit switch 2	LM2	The beginning of the vertical track
Limit switch 3	LM3	The end of the vertical track
Limit switch 4	LM4	End rows
Limit switch 5	LM5	Determines location the robot when in the station
Real time clock	RTC	
Time for one step	T1	

Table 5-1 : Symbol of element in flow chart

5.3 Software code

The project has been programmed by the language C ++ using arduino program.

```
#include "Wire.h"
#define DS1307_ADDRESS 0x68
const int LML = 4;     // limit switch Determines location First panels on the rows
const int LMR = 2;     // limit switch Determines The beginning of the vertical track
const int LMUP = 8;     // limit switch Determines The end of the vertical track
const int LMDO = 7;     // limit switch Determines End rows
const int LMSTART = 13;    // limit switch Determines location the robot when in the station // limit switch Determines location First panels on the rows
const int UPMOT = 3;     // driver 1 Controls the motors for Main structure to the motion with clock wise
const int DOMOT = 5;     // driver 1 Controls the motors for Main structure to the motion with counter clock wise
const int LMOT = 6;     // driver 2 Controls the motors for  Y-axis pulley with clock wise
const int RMOT = 9;     // driver 2 Controls the motors for  Y-axis pulley with counter clock wise
const int BRUSH = 10;     // driver 3 Controls the motors  for brush
int i = 0;
int x = 0;
int y = 0;
int b = 0;
int m = 0;
int n = 0;
int o = 0;
int c = 0;
int z = 1;
int LMLstate = 0 ;
//int LMRstate =0 ;
int LMUPstate = 0 ;
int LMDOstate = 0 ;
int LMSTARTstate = 0 ;
volatile int LMRstate = 0;
char incomingByte = 0;
void setup() {
attachInterrupt(0, pin_ISR, RISING);
Wire.begin();
pinMode(LML, INPUT);    // initialize the LML pin as an input:
pinMode(LMR, INPUT);    // initialize the LMR pin as an input:
pinMode(LMUP, INPUT);    // initialize the LM3UPpin as an input:
pinMode(LMDO, INPUT);    // initialize the LMDO pin as an input:
pinMode(LMSTART, INPUT);    // initialize the LM5 pin as an input:
pinMode(UPMOT, OUTPUT);   // initialize the UPMOT as an output:
pinMode(DOMOT, OUTPUT);   // initialize the DOMOT as an output:
pinMode(LMOT, OUTPUT);   // initialize the LMOT as an output:
pinMode(RMOT, OUTPUT);   // initialize the LMOT as an output:
pinMode(BRUSH, OUTPUT);    // initialize the BRUSH as an output:
// initialize the D3 as an output:
Serial.begin(9600);
```

```
int LML = 0;
int LMR = 0;
int LMUP = 0;
int LMDO = 0;
int LMSTART = 0;
int UPMOT = 0;
int DOMOT = 0;
int LMOT = 0;
int RMOT = 0;
int BRUSH = 0;
int LMLstate = 0 ;
int LMRstate = 0 ;
int LMUPstate = 0 ;
int LMDOstate = 0 ;
int LMSTARTstate = 0 ;
}
byte bcdToDec(byte val)  {
// Convert binary coded decimal to normal decimal numbers
return ( (val / 16 * 10) + (val % 16) );
}
void loop() {
if (Serial.available() > 0) {
incomingByte = Serial.read();
}
Wire.beginTransmission(DS1307_ADDRESS);
byte zero = 0x00;
Wire.write(zero);
Wire.endTransmission();
Wire.requestFrom(DS1307_ADDRESS, 7);
int second = bcdToDec(Wire.read());
int minute = bcdToDec(Wire.read());
int hour = bcdToDec(Wire.read() & 0b111111); //24 hour time
int weekDay = bcdToDec(Wire.read()); //0-6 -> sunday - Saturday
int monthDay = bcdToDec(Wire.read());
int month = bcdToDec(Wire.read());
int year = bcdToDec(Wire.read());
//   Serial.print(hour);
//  Serial.print(":");
//  Serial.print(minute);
//  Serial.print(":");
//  Serial.println(second);
LMLstate = digitalRead(LML);
LMRstate = digitalRead(LMR) ;
LMUPstate = digitalRead(LMUP) ;
LMDOstate = digitalRead(LMDO) ;
LMSTARTstate = digitalRead(LMSTART);
if (hour == 22 && minute == 28 && second == 30 && LMLstate == HIGH && n == 0 || incomingByte == 50) {
analogWrite(LMOT, 0);
analogWrite(RMOT, 255);
n = 1;
incomingByte = 0;
Serial.print("start");
}
if (incomingByte == 49) {
```

```
analogWrite(LMOT, 0);
analogWrite(RMOT, 0);
digitalWrite(BRUSH, LOW);
digitalWrite(BRUSH, LOW);
analogWrite(DOMOT, LOW);
Serial.println("emergency stop");
incomingByte = 0;
}
if (LMSTARTstate == HIGH && n == 1 && LMUPstate == HIGH) {
analogWrite(LMOT, 0);
analogWrite(RMOT, 0);
delay(500);
analogWrite(BRUSH, 255);
delay(1000);
analogWrite(UPMOT, 0);
analogWrite(DOMOT, 100);
x = 1;
}
if (LMDOstate == HIGH && x == 1 && b == 0 && LMUPstate == LOW) {
x = 0;
y = 1;
analogWrite(UPMOT, 0);
analogWrite(DOMOT, 0);
digitalWrite(BRUSH, 0);
delay(1000);
//analogWrite(LMOT, 0);
digitalWrite(RMOT, 255);
delay(5000);
analogWrite(RMOT, 0);
analogWrite(UPMOT, 100);
i = 1;
Serial.println("step:");
Serial.print(z);
z++;
}
if (LMUPstate == HIGH && i == 1 && y == 1 && LMDOstate == LOW) {
x = 1;
y = 0;
analogWrite(UPMOT, 0);
analogWrite(DOMOT, 0 );
analogWrite(RMOT, 0);
delay(500);
digitalWrite(BRUSH, HIGH);
delay(1000);
analogWrite(UPMOT, 0);
analogWrite(DOMOT, 100);
m = 1;
}
if (LMDOstate == HIGH && LMRstate == HIGH && m == 1) {
analogWrite(UPMOT, 0);
digitalWrite(BRUSH, LOW);
analogWrite(DOMOT, 0);
delay(500);
analogWrite(LMOT, 255);
analogWrite(RMOT, 0);
```

```
= 1;
}
if (LMLstate == HIGH && o == 1) {
= 0;
analogWrite(LMOT, 0);
analogWrite(RMOT, 0);
delay(500);
analogWrite(UPMOT, 50);
c = 1;
}
if (LMUPstate == HIGH && c == 1) {
analogWrite(UPMOT, 0);
analogWrite(LMOT, 0);
digitalWrite(BRUSH, LOW);
digitalWrite(BRUSH, LOW);
analogWrite(DOMOT, LOW);
i = 0;
x = 0;
y = 0;
b = 0;
m = 0;
n = 0;
= 0;
c = 0;
}
if (incomingByte == 49) {
Serial.println("end");
analogWrite(UPMOT, 0);
analogWrite(LMOT, 0);
digitalWrite(BRUSH, LOW);
digitalWrite(BRUSH, LOW);
analogWrite(DOMOT, LOW);
i = 0;
x = 0;
y = 0;
b = 0;
m = 0;
n = 0;
= 0;
c = 0;
}
}

void pin_ISR() {
analogWrite(LMOT, 0);
analogWrite(RMOT, 0);
b = 1;
m = 0;
}
```

Conclusion:

Maintenance of PV panels is important to keep the energy production as high as possible, cleaning panels is the most important factor in increasing energy production, there are different ways of cleaning with different costs, some of them had high cost , and can decrease the overall profit even though the energy production is increased , the proposed design increase the overall profit with low cleaning cost using a robot based topology .

This system is made and tested in JDECO Dead Sea PV station in Jericho with cleaning efficiency of 95 % for array of 120 panels from 2360 panel; it can be modified to work with different stations and full automated process via internet.

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Appendix