

PV Solar Charger Optimization Based Maximum Power Point With Real Time Tracking Information

Deeman M. Najat ¹, Sarmad Nozad Mahmood ², Omar Faruk Refaat ²

Sameer Algburi ^{2,*}, and Sinan Kivrak ¹

¹*Department of Electric and Electronic Engineering, Yildirim Beyazit University, Turkey*

²*Department of Computer Technical Engineering, Al – Kitab University College, Iraq*

*Corresponding Author Email: sameer.al-juboori@gis.lu.se

ABSTRACT

The paper focuses on power system modeling that gives priorities to realize and store the maximum power radiated out of the sun to feed a definite primary load. The power of the sun can be stored in different ways based on PV modules employed by renewable solar systems. The infinite abundance of the natural environmental resources classifies the solar system as the major sustainable energy resources. The challenge starts by reducing the cost via converting the sunlight into energy based on photovoltaic cells. Consequently, the sun tracking system shows endless interaction and support to improve the efficiency of the systems. The main challenge of this proposed idea is realizing the maximum sun power denoted as MPP (maximum power point) which is considered the most effective and energetic spot overpower storage curves. MPPT indicates the maximum power point realized during a specific time. In accordance, a tracking system is employed in order to follow the sun trajectory, direction, and the way of power radiation. Moreover, another point should be taken into consideration that is the sun can feed the proposed load at day periods. However, the batteries are considered a most suitable solution for providing power at night periods. Hereby, the primary load gets the power from the sun directly at the day and indirectly at night based employed batteries. In addition, the temperature over the panel, the real-time sun tracking information, the charge ratio in the employed batteries, and the strength of the wind are demonstrated over an LCD display. Finally, a GSM module based notification request is employed to direct the situation of the power system as an SMS through a specific phone number.

Keywords: Sun Tracking, Real Time Systems, Solar Panel Physical Conditions, Power System Modules

1. INTRODUCTION

Energy is the basic need for development and existence of human life. Fossil fuels (Coal, oil and natural gas), hydroelectric power and nuclear power are the commercial sources of energy. Total world consumption of energy is increasing at an alarming rate year after year. Total world final consumption of energy has increased from 4672Mtoe (million ton of oil equivalent) in 1973, to 8677Mtoe in 2010. On the contrary, the fossil fuels are rapidly depleting and reserves of the fossil fuels are gradually coming to an end. Because of the increased world total consumption of energy and depletion of resources the cost of the commercial resources has achieved

high excess. Because of these problems, the focus is now shifting towards renewable energy sources. Solar energy is a renewable energy source that can lead us away from our commercial energy sources. Solar energy is clean, renewable and sustainable unlike fossil fuels such as coal, oil and natural gas and is also sustainable. Photo voltaic systems have two major problems; the conversion efficiency of electric power generation is very low about 10-24%, and get reduced under low irradiation conditions.

PV panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation. In order to continuously harvest maximum power from the solar panels, they have to operate at their MPP despite the inevitable changes in the environment. MPPT maximum power point tracker strongly tracks this operating point to generate maximum power from PV panel. To generate the maximum power from solar panel, solar panel must be aligned perfectly towards the sun with respect to transfer and demonstrate system information based specific GSM network (Hardeep Saini, Abhishek Thakur, etc, 2016). Hereby, MPPT is used in conjunction with a mechanical sun tracking in the proposed system (Falinirina F. Rakotomananandro, 2011). The most optimum way to solve energy disasters and the ecological contaminations is the solar system. The efficiency of the solar system can be elevated by maximizing the output power with respect to align the panel model along sun radiation. Hereby, sun tracking methodology with a sensitive exactitude is proposed. The main objective of sun tracking system establishment is to move the panel in synchronous with sun movement starting from sunrise in order to expose the panel to the sun in the whole sunny periods to obtain the maximum power (Ashraf Balabel, Ahmad A. Mahfouz, etc, 2013). It is worth mentioning that electricity demand increases considerably nowadays. However, the limitation of the resources and the unsociability effect of the non-renewable energy sources such as oil, fossil fuel, coal, etc. leads to defeat their attractiveness.

The solar system is considered one the most efficient, friendly, and reliable aspects among renewable system components. The Photovoltaic (PV) cells transform the energy of the sun into electrical energy. Conversely, the Competence of the solar system depends mainly on the efficiency of the solar cell particularly by using sun tracking approach (Fazlur Rahman Bin Karim, Md. Mamunor Rashed, etc, 2014).

2. OVERVIEW ON PROJECT COMPONENTS

The main system components are constructed of:

- Arduino Uno microcontroller.
- DHT11 sensor module.
- LCD display unit.
- Photocell sensor.
- Anemometer / wind speed meter.
- Arduino GSM shield module.
- Limit switch.
- Linear actuator motor.
- Solar panel.

2.1. Arduino Microcontroller

Arduino microcontroller is an open source electronic board fabricated in several forms identified by Arduino mini, Uno, Mega, Nano ...etc. Arduino supports both the hardware and software (N. Sabharwal, R. Kumar, etc, 2014; Sarmad Nozad Mahmood, Forat Falih Hasan, 2017) and considered the most typical microcontroller that deals with the input modules such as the sensors that transfers the realized data into the

Arduino in order to take the suitable decision. Moreover, Arduino microcontroller deals with output modules and devices such as controlling the lights, motors, and the other actuators. The part responsible for controlling modules is equipped regularly on the board called (ATMEGA) (Arduino Uno, 2017; Atmel USA, 2017) that can be programmed by using Arduino IDE programming language. Arduino program is written by interfacing the real board shown in Fig.1 with computer in order to create programming user interface area to startup controlling tasks properly.

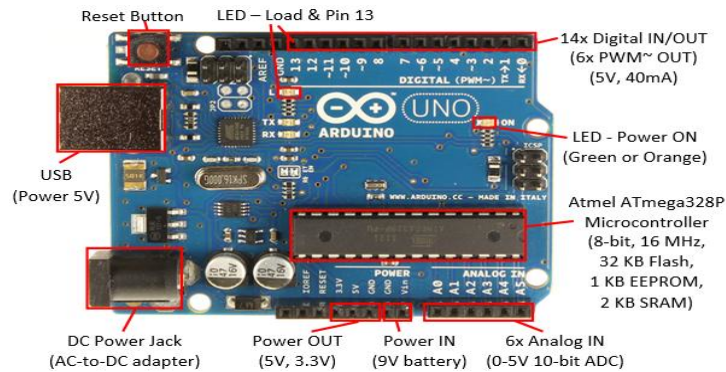


Figure1: Arduino UNO Board schematically

2.2. Dht11 Sensor Module

The Temperature and Humidity sensor is denoted as DHT11, measures both the temperature and humidity in an individual distinctive model. Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output (D-Robotics, 2010). By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connected to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost effectiveness (Sarmad Nozad Mahmood, Forat Falihi Hasan, 2017). DHT sensor measures both temperature (T) and humidity (H) which hands the readings over the LCD display. The sensor consists of 3 terminals (VCC, DATA, GND) knowing that the data pin of the sensor acts well when mapped with digital Arduino Uno pins. The connection scheme of the sensor is followed as shown in the Fig.2 such that, the VCC terminal of the sensor is connected to the 5V of Arduino board, the data is chosen to be connected to the digital pin 5 of Arduino Uno, and the GND terminal of the sensor is connected to the GND pin of Arduino Uno board as shown in schematic diagram in Fig.2.

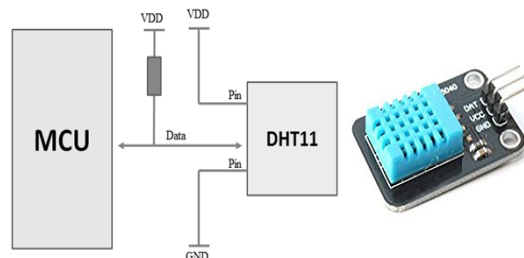


Figure 2: Temperature – Humidity DHT11 module

2.3. Lcd Display Unit

A liquid crystal display, or LCD, is a video display that utilizes the light modulating properties of liquid crystals to display pictures or text on a screen. Since their invention in 1964, LCD screens have grown to be used in a very wide variety of applications, including computer monitors, televisions, and instrument panels. One way to utilize an LCD is with an Arduino microcontroller (Arduino LiquidCrystal, 2017). By wiring an Arduino microcontroller to the pins of an LCD display it is possible to program the microcontroller to display a desired text string or image on the screen. The display is considered the spotlight of this project that demonstrates several data synchronously over 16 columns and 2 rows. LCD display has 16 pins illustrated as shown in Table.1.

Table 1: LCD pins interface configuration

PIN NO	FUNCTION	NAME
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7 V – 5.3 V)	VCC
3	Contrast adjustment; through a variable resistor	VEE
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read / write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V _{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

The interface processes of Arduino microcontroller with LCD display was performed in *Fritizing* software and demonstrated as revealed in Fig.3.

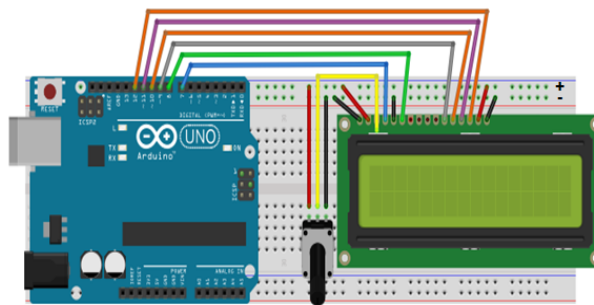


Figure 3: LCD display interfacing with Arduino

2.4. Photocell Sensor

The photocell or photoresistor or light dependent resistor denoted as LDR is a sensor directly excited by the amount of incident light intensity. In the other word, it is the sensor that can be controlled based on the photoconductivity. The photoresistor part that equipped over the module is made of high resistivity semiconductor. Once the light beam radiates on the semiconductive part, the photons is absorbed in the

semiconductor in order to create a bound of energetic electrons. The created electrons move towards conduction band that is the region which collects larger number of free electrons resulting what is called electrons – holes creation phenomenon. In accordance, more free electrons in the conduction band leads to create low resistivity and high current (Karthik K, Suraj T, etc, 2015). For more clarity, the module shown in Fig.4 is constructed of four pins identified by VCC, GND, Analog pin A0 and Digital pin D0 (Sarmad Nozad Mahmood, Forat Falih Hasan, 2017).

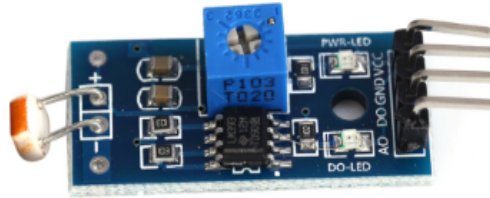


Figure 4: Photocell Sensor Module

2.5. Anemometer – The Wind Speed Module

An anemometer is a device used for measuring wind speed, and is a common weather station instrument. This well-made anemometer is designed to sit outside and measure wind speed with ease. To use, connect the black wire to a common ground between anemometer and Arduino microcontroller, the red wire to 7-24 Vdc and measure the analog voltage on the yellow wire as shown in Fig.5 (Kiwi Electronics, 2017; Nitant S, Rajesh K, etc, 2014).

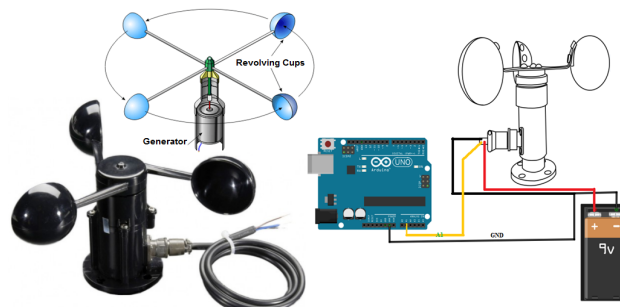


Figure 5: Wind speed meter connection scheme

The interior structure of the device is constructed of a DC motor that works in synchronous with the revolving cups rotation. The rotation of the revolving cups gives a synchronous moving to the DC motor due the pole combination between the motor and the Hub which carries the cups. The interior motor can generate can work as a voltage generator if the rotor excited by mechanical motion. Hereby, the wind speed sensor attached to the analog pin of employed Arduino board. For more clarity, the specification of the anemometer is specified in Table 2.

Table 2: Anemometer module specifications

Output (V)	Range	Start Speed	Resolution	Accuracy	Max Speed
	m / s				

2.6. Arduino Gsm Shield Module

The specified weather station and power system information are ordered and managed in order to be sent via Arduino GSM shield module. The employed GSM in the proposed module is identified by SIM900 Arduino GSM shield, which is also called Quad – Band GSM/ GPRS unit. It is worth mentioning that the proposed SIM900 GSM module shown in Fig.6 can work over four frequencies specified by (850 MHz, 900 MHz, 1800 MHz, 1900 MHz) in order to provide (Voice, SMS, Data, Fax) services respectively with inconsiderable power consumption (Satyashil Nagrale, Poonam Khetmalis, etc, 2016). The standard proposed system uses SMS service; hence, 900 MHz frequency is put in charge. The GSM modem is modeled to be worked normally when provided with 3 – 5 Volt external power, which makes the modem to be interfaced competently with several friendly microcontrollers such as (Raspberry Pi, PIC, and Arduino). In addition, Tx / Rx symbol rate of SIM900 GSM modem is specified between 9600 – 115200 bit / second, which makes SMS or Data acknowledgment broadcasting through the mobile phone more applicable.



Figure 6: Arduino GSM shield module

2.7. Limit Switch

The term limit is given to such switches in order to cut power when tripped to prevent over-run. The limit switch type that is used in the project is called snap action limit switch. The switch is designed to satisfy wide industrial applications due to its availability in heavy duty metal. The limit switch is suitable for the work based separated contacts application to switch high current and potential necessities with galvanic ally for switching based different polarities in a given circuit. The contacts of the switch can be treated independently with respect to mechanism connectivity that is excited by EN confirmation. Finally, the switch shown in Fig.7 can sense the action from different areas based 360o so that a tiny contact can cut the power accordingly (SCHALTBAU, 2017).

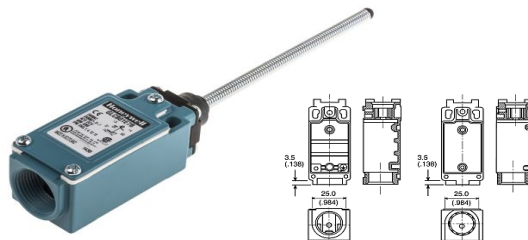


Figure 7: Snap action limit switch

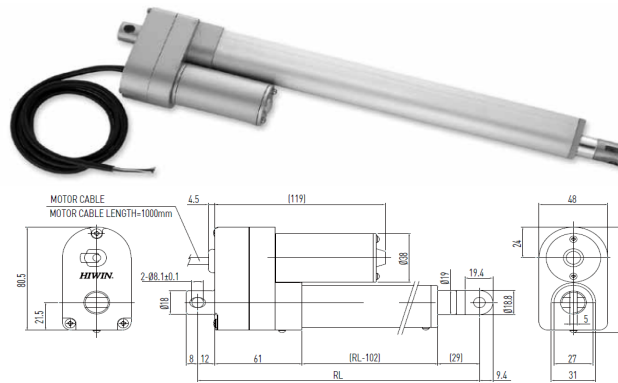
The specification of the proposed snap action limit switch is exposed for more details as shown in Table 3.

Table 3: Snap action limit switch specifications

Actuator Type	Coil Spring
Maximum Current	10 A
Housing Material	Die Cast Zinc
Maximum AC Voltage	300 V
Maximum DC Voltage	300 V
Contact Type	Snap Action
Length	68.5 mm
Width	30.5 mm
Minimum Life	10 000 000 Cycles
Max Operating Temp	+ 85°C
Depth	26.35 mm
Dimensions	184 × 30.5 × 30 mm
Min Operating Temp	-40°C

2.8. Linear Actuator Motor

The actuator type that is employed in this project is called super duty linear actuator. These actuators can be used in place of pneumatics or hydraulics. The super duty linear actuators are driven by high torque brushed DC gear motors coupled to a ball-screw to create a low friction linear drive. The ball-screw provides efficient linear thrust that can handle loads in both the pushing and pulling orientation. The linear actuators can handle an incredible amount of static load and will hold position even when power is removed. Each actuator has a built-in potentiometer which can be used for positioning feedback if your application requires. Fig.8 shows the aluminum and steel construction with full metal drive gears that ensures tremendous durability and reliability.

**Figure 8:** Super duty linear actuator

For more details, the specifications of the proposed linear actuator motor (HIWIN GmbH, 2015) are demonstrated as shown in Table 4.

Table 4: Linear actuator specifications

Screw Type	ACME		
Weight	1.27 kg		
Protection	IP54		
Working Temp	+5°C ~ 40°C		
Supply Voltage	24 VDC	12 VDC	5 VDC
The Output	High level 24 VDC	High level 12 VDC	TTL
	Low level0.2V/40mA PNP*	Low level0.2V/40mA PNP*	
	PS. Open collector		

2.9. Solar Panel

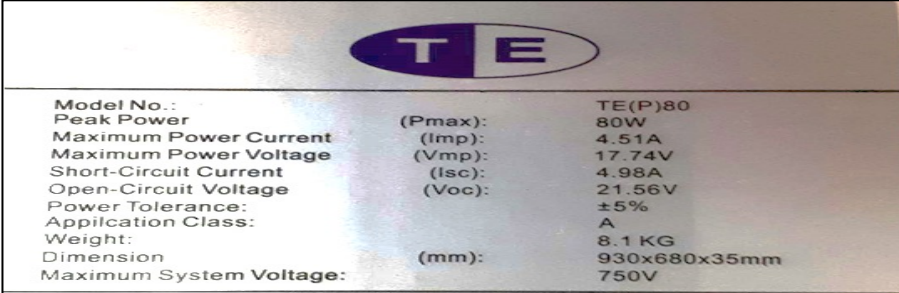
The performance of PV modules and arrays is generally rated according to the maximum DC power output and current (to produce watts) under Standard Test Conditions (STC). Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 % of the STC rating.

2.9.1 Standard Test Conditions are defined by a module (cell)

- Operating temperature of 25o C,
- Incident solar irradiance level of 1000 W/m
- Under Air Mass 1.5 spectral distributions (SNV organization, 2012).

2.9.2. Reading a Solar Panel Name Plate

Fig. 9 shows an extract of a nameplate of a solar panel used in our work.



Model No.:		TE(P)80
Peak Power	(Pmax):	80W
Maximum Power Current	(Imp):	4.51A
Maximum Power Voltage	(Vmp):	17.74V
Short-Circuit Current	(Isc):	4.98A
Open-Circuit Voltage	(Voc):	21.56V
Power Tolerance:		±5%
Appilcation Class:		A
Weight:		8.1 KG
Dimension	(mm):	930x680x35mm
Maximum System Voltage:		750V

Figure 9: An extract of a name plate of a solar panel used

- Maximum Power: means it can deliver maximum 80 Watts electricity.
- Maximum Voltage: means its maximum output voltage = 17.74V.
- Open Circuit Voltage: means the voltage without load= 21.56V
- Maximum Current: means the maximum output current = 4.51A
- Short Circuit Current: means the current of short circuit of solar panel= 4.98A
- Maximum System Voltage: means that, when we connect solar panel in series then Maximum Voltage Limit is 1000V.

3. METHODOLOGY

The connection methodology was implemented based on two independent microcontrollers identified by MCU1 and MCU2, which they are dominated by a main Modular supervisor denoted by (S) as exposed in Fig.10.

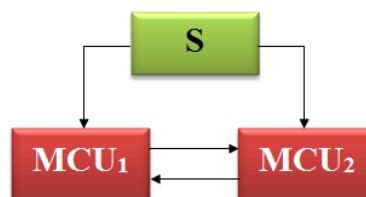


Figure 10: Modular supervisor concept

This independency based the microcontrollers was proposed due to the need for larger number of pins and in order to specify the programing code that govern sun tracking mechanism and the meteorological conditions over solar panel separately. The first Arduino microcontroller denoted as MCU1 is put in charge to control two linear actuators identified by M1 and M2 as shown in Fig.11.

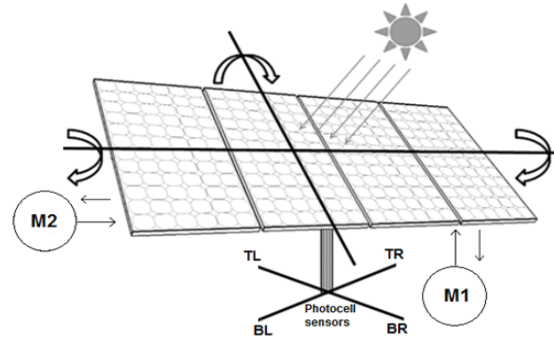


Figure 11: Solar panel combination with LDR sensors and motors

The location of the photocell sensors in the real module was equipped on the upper side of the panel but the genuine place omitted in Fig.7 for clarity. Generally, the proposed photocell sensors are equipped over the solar panel in order to face sun light radiations from top left *TL*, top right *TR*, bottom left *BL*, and bottom right *BR*. The motors *M1* & *M2* are controlled by MCU1 based the photocell sensors with respect to sun radiation strength. Moreover, the motors are responsible of moving the panel horizontally based *M1* or vertically based *M2* to specify the highest $h1$, $h2$, and $h3$ as shown in Fig.12.

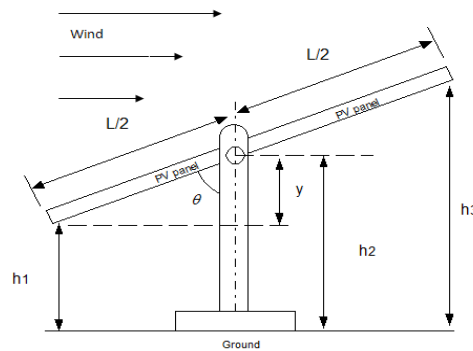


Figure 12: Solar panel motion possibilities

There exist several motors compatible with Arduino microcontroller such as Servo motor and DC motor, etc. However, the suitable choice based motor modules will be the servo motors due to their abilities to be rotating in degrees. On the other hand, such a motor is not that tough to hold and move the heavy solar panel that is employed in the project. Accordingly, linear actuators are employed in order to move the panel up, down or left, right and the limit switches are used to specify the maximum rotation range of the motors *M1* & *M2* instead of dealing with motor rotation based degrees as the servo motors. Hereby, four limit switches denoted as Lm1, Lm2, Lm3 and Lm4, were connected as shown in Fig.13 to specify the four directions accurately.

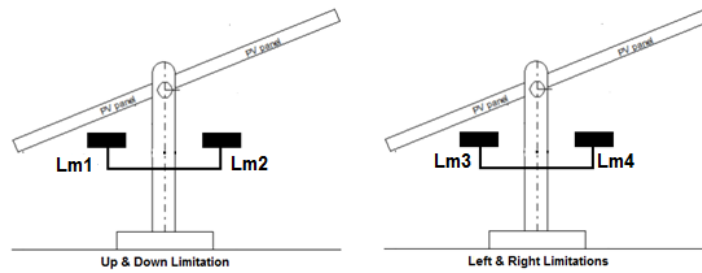


Figure 13: Panel based Lm structure from two side views

For more simplifications, the connection methodology of the power elements based MCU1 is converted into blocks and demonstrated as shown in Fig.14.

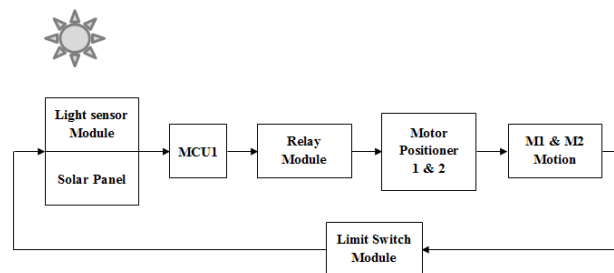


Figure 14: Components connection based MCU1

3.1. Working Principle Based Mcu1

The working principle based MCU1 starts from the light sensors that are synchronized directly with solar panel motion. It is worth mentioning that the sensor that gets more light intensity with respect to *TL*, *TR*, *BL*, *BR* will be the ultimate coordinator to report a given situation to MCU1 in order to take the right decision to move the actuators either vertically or horizontally. The motion mechanism of the actuators is synchronized with motor controller called positioner. There exist two positioners denoted by *pos1* *pos2* to control M1 and M2 respectively. The high voltage requirement of $18V_{dc}$ that the actuators need and the microcontroller cannot supply led to use relay modules in order to deal with higher voltages supplied by the Ac source of the positioners. For more clarity, the connection module is demonstrated in Fig.15.

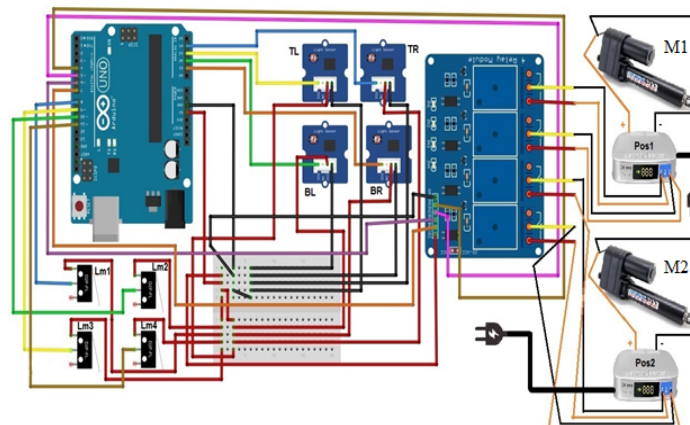


Figure 15: MCU1 components connection

3.2. Working Principle Based Mcu2

The second microcontroller unit MCU2 is employed to show the information regarding physical situation over the solar panel. The physical situation attributes are chosen to be concentrated on demonstrating the temperature T , humidity H and the speed of the wind W in the proposed power system established location. Hereby, DHT sensor and wind speed meter modules are put in charge to perform the tasks ordered by MCU2 in synchronous with MCU1 under the domination of the coordinating supervisor (S). It is worth mentioning that the proposed system module can provide real time information about the system status based on the SIM900 GSM module employed in the system as the hierarchical connection of the components based MCU2 shown in Fig.16.

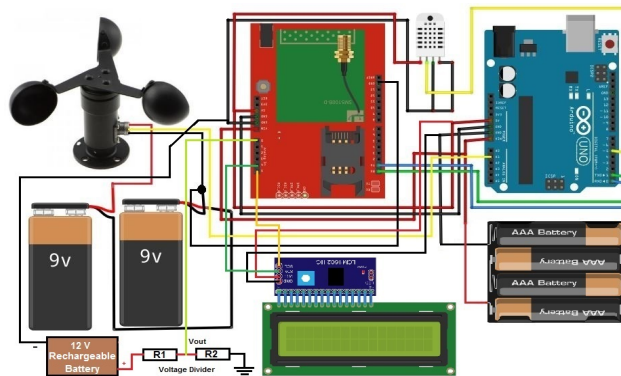


Figure 16: Hierarchical connection based MCU2

As shown in Fig.16, the display module was interfaced with I2C connector module in order to shrink the pins that are connected to microcontroller. As a background, Arduino microcontroller generally deals with 0 – 5 V for both inputs and outputs that is the reason which effects on the compatibility between the 12 V rechargeable battery and Arduino board. Hereby, the compatibility issues will be solved by applying voltage divider rule depending on the connection shown in Fig.17.

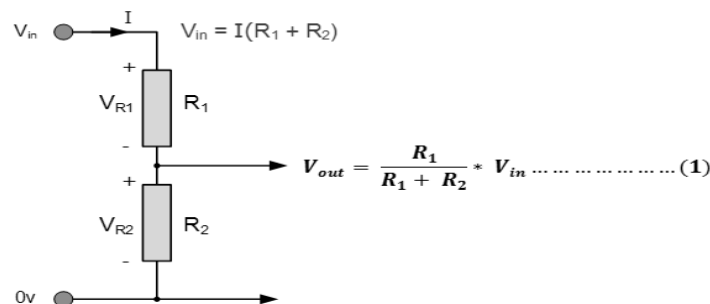


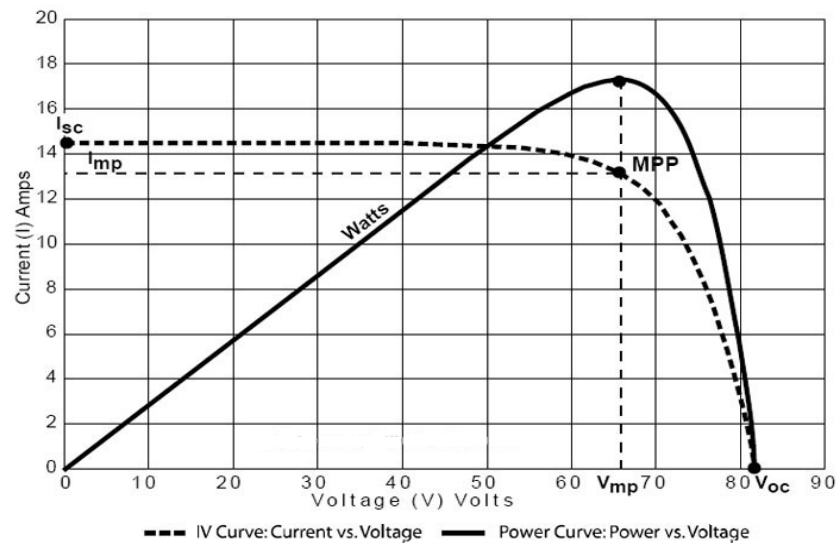
Figure 17: Voltage divider operation

The formula in equation (1) sets the voltage down in order to map the 12 V of the rechargeable unit to 5 V. As mentioned before, there exists a relational connection between MCU1 and MCU2 based on the presence of the common rechargeable unit. The term common is given to the storage unit for being the parallel connector between sun tracking system and its physical circumstances with respect to MCU1 and MCU2 respectively. However, the whole connection based the coordinating supervisor principle is omitted for more clarity. It is worth mentioning that the mapping methodology applied to convert the 12 – 5 V was processed nominally based on the programming code by formally linking each specific voltage to its corresponding charge ratio in percentage (Chin. CG, 2012) as shown in Table 5.

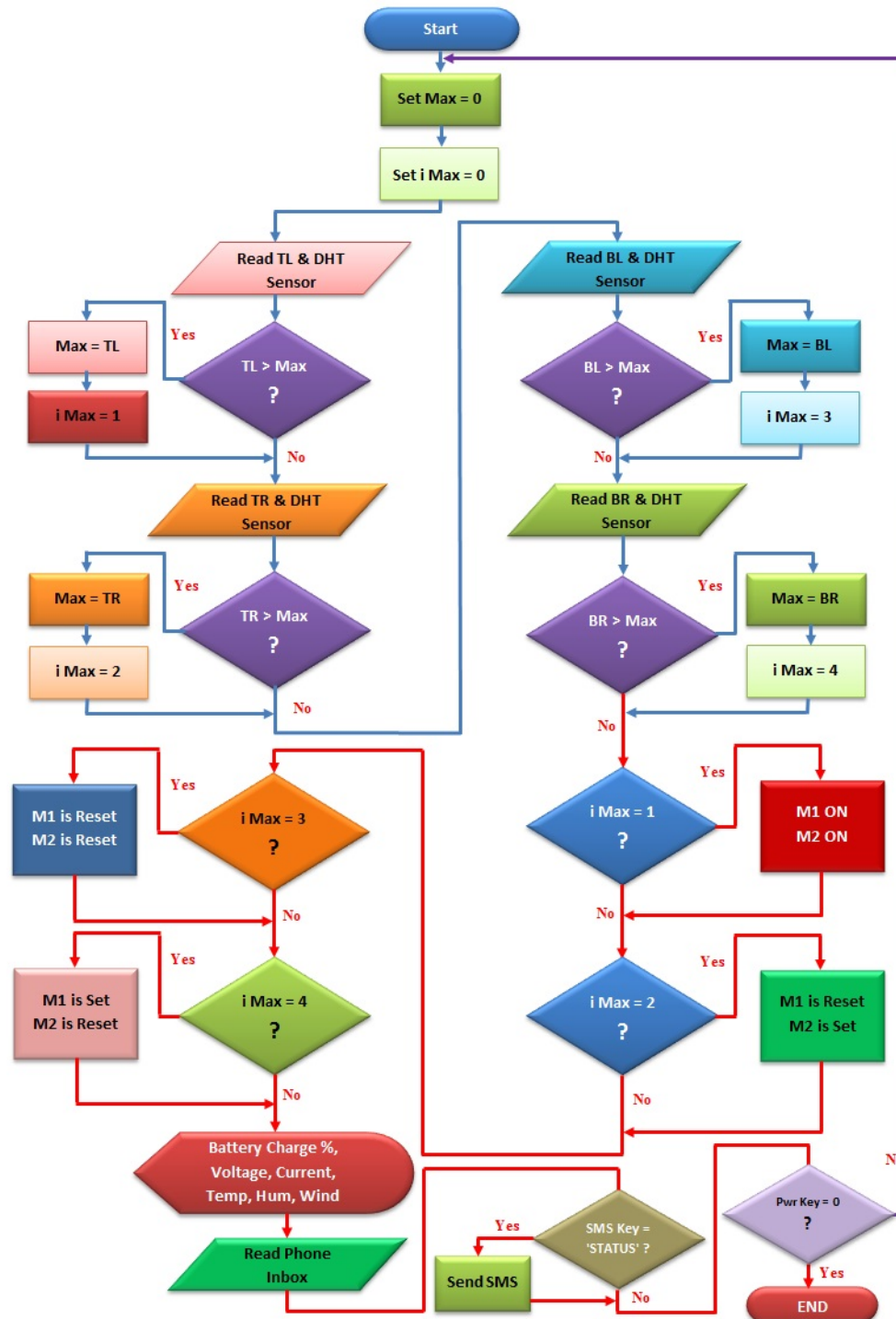
Table 5: State of charge with respect to the voltage

Voltage (V)	State of charge (%)
12.63	100
12.54	90
12.45	80
12.39	75
12.27	60
12.18	50
11.97	25
11.76	No charge

It has to be mentioned that the proposed project tracks the motion of the sun in order to obtain MPPT spot that increases the maximum efficiency of a given system that realizes the knee of power realization curve between the current I_{mp} and the voltage V_{mp} as shown in Fig.18.

**Figure 18:** Maximum power point MPPT relational curve

For more clarity, the programming code is demonstrated as a flow chart in Fig.19 to activate the direct awareness and understand the code easily.



Finally, the information of the system such as the temperature – humidity on the panel, the wind speed in the proposed location and the charging ratio of the storage unit can be transferred remotely to any specific phone number by notification SMS request included with "*STATUS*" word as the diagram unveiled in Fig.20.

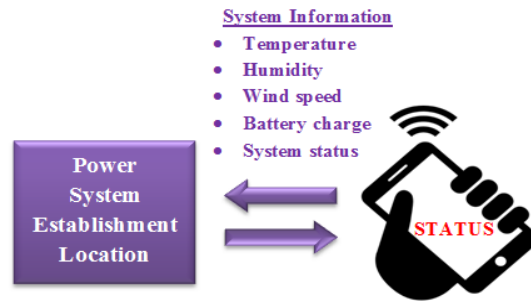


Figure 20: Data transfer center diagram

4. RESULTS

The project's installations were completed inside the university laboratories as shown in Fig. 21 and Fig. 22. Before establishing our system on the roof of Al-Kitab university, the following main parts were checked inside the university labs:

The projects four optical sensors were checked in the labs using ordinary lamp instead of the sun light. The movement of the linear actuator motors depending on Light intensity on each sensor was observed and the two motors movements to the four directions were limited by limit switches. Finally, the information of the system such as the temperature – humidity on the panel, the wind speed in the proposed location and the charging ratio of the storage unit were transferred remotely to any specific phone number by notification SMS request included with "STATUS".



Figure 21: System installation in the laboratory

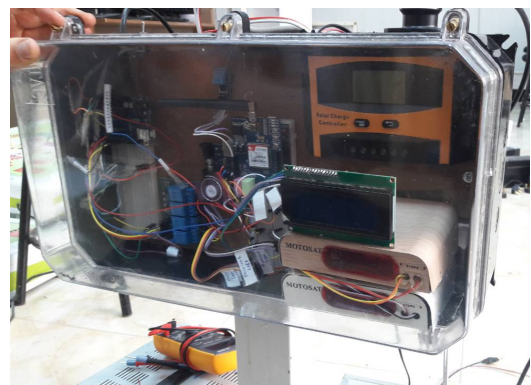


Figure 22: Project equipment's box

The system equipment was installed on the university roof as shown in Fig.23. Data transferred (temperature, humidity, wind speed and chagrin batteries) were recorded in 1/1/2018 for 24 hours as exposed in Table 6 and Fig.24.



Figure 23: Project on university roof

Table 6: The main results of the Transferred data

Time	Temperature C°	Humidity %	Wind Speed (Km / Hour)	Battery Charging %
0	10	80%	15	45
1	10	80%	14	45
2	10	81%	14	45
3	10	82%	13	40
4	10	83%	13	35
5	10	85%	12	35
6	10	85%	12	35
7	9	87%	12	45
8	9	91%	13	45
9	10	86%	14	55
10	10	82%	15	70
11	11	80%	16	75
12	11	78%	17	85
13	11	75%	18	85
14	12	74%	19	95
15	12	75%	19	100
16	12	72%	17	100
17	11	72%	14	100
18	12	66%	12	95
19	11	69%	10	95
20	11	70%	14	85
21	10	68%	13	70
22	10	70%	15	55
23	10	69%	14	45

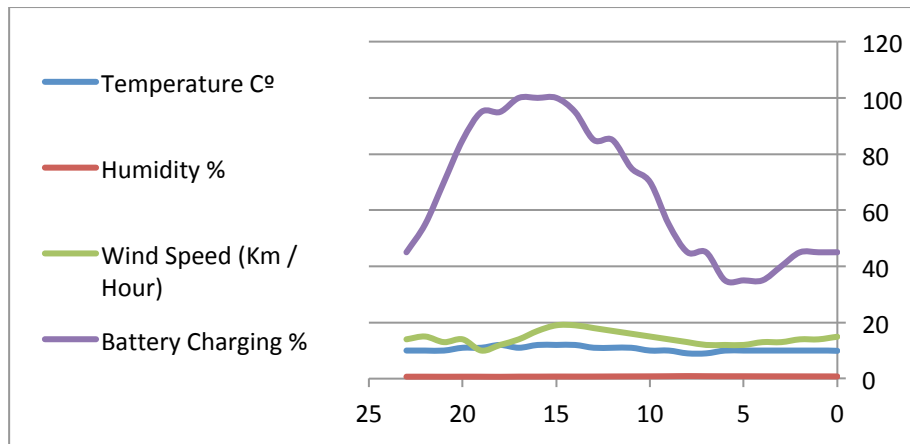


Figure 23: Realized data chart

5. CONCLUSIONS

This paper presents a robust four directional sun tracking system in order to follow the movement of the sun based on full axis coordination. For more clarity, it is intended to present the results as follows:

1. The technique realizes design novelty due to the active concentration on sun tracking from four directions so that a tiny variation in the coordination of the sun can lead the controller to change PV panel allocation correspondingly.
2. The working principle of the system depends inconstantly on sun radiation, hence power saving will be existed due to cut system operation off for the rest of night.
3. The entire system was equipped by several weather sensing modules to clarify the physical conditions of the proposed power system with respect to system establishment location.
4. The physical situation of the system is transferred remotely using the GSM module depending on notification request from any specific phone number.
5. Data handover costs are economically inexpensive due to the complete dependency on notification request.
6. The center of data transfer is managed freely so that a given specific phone number can be provided by the required information concerning system status.
7. Finally, the proposed power system realizes the maximum power point MPPT knee spot depending on the V_{mp} and I_{mp} correspondingly.

6. REFERENCES

Arduino, Uno. Accessed July 2017. The LiquidCrystal library. [online]. Available: <https://www.arduino.cc/en/Tutorial/HelloWorld>.

Ashraf Balabe, Ahmad A. Mahfouz, Farhan A. Salem, 2013. Design and Performance of Solar Tracking Photo-Voltaic System; Research and Education, International Journal Of Control, Automation And Systems, 1(2).

Atmel Corporation 1600 Technology Drive, San Jose, CA 95110 USA. Accessed July 2017. [online]. Available: <http://datasheet.octopart.com/ATMEGA328-PU-Atmel-datasheet-65729177>.

Chin, CG., 2012. Model-Based Simulation of an Intelligent Microprocessor-Based Standalone Solar Tracking System" Katsikis, V, ed. MATLAB - A Fundamental Tool for Scientific Computing and Engineering Applications. Rijeka, Croatia: InTech, pp 251-278.

D-Robotics, 2010. Humidity & Temperature Sensor datasheet. Accessed July 2017 [online]. Available: <https://www.droboticsonline.com>.

Falinirina F. Rakotomananandro, 2011. Study of Photovoltaic System, MSc. Thesis, The Ohio State University.

Fazlur Rahman Bin Karim, Md. Mamunor Rashed, Muhammad Quamruzzaman, 2014. Design and implementation of a sensorless dual axis solar tracking system based on solar sun chart algorithm using Arduino, 1st International Conference on Electrical and Communication Engineering and Renewable Energy.

Hardeep Saini, Abhishek Thakur, Satinderpar Ahuja, 2016. Arduino based automatic wireless weather station with remote graphical application and alerts", 3rd International Conference, Signal Processing and Integrated Networks (SPIN).

HIWIN GmbH, Brücklesbünd 2. D-77654 Offenburg, Catalog Linear Actuators, 2015.

Karthik K, Suraj T, Lokesh K, Arun P, 2015. Arduino Based Weather Monitoring System" International Journal of Engineering Research and General Science, 3(2).

Kiwi Electronics, Anemometer Wind Speed Sensor With Analog Voltage Output. Accessed July 2017 [online]. Available: <https://www.kiwi-electronics.nl/windmeter-windsnelheid-sensor-met-analoge-voltage-output?lang=en>.

Nitant S, Rajesh K, Abhishek T, Jitender S, 2014. A Low Cost Zigbee Based Automatic Wireless Weather Station With Gui And Web Hosting Facility" Icrtdc, 1(2).

Sarmad Nozad Mahmood, Forat Fali Hasan, 2017. Design of Weather Monitoring System Using Arduino Based Database Implementation" Journal of Multidisciplinary Engineering Science and Technology , 4(4).

Satyashil Nagrale, Poonam Khetmalis, Sanika Doke, Varsha Dherange, 2016. Real Time Data Transmission for Weather Monitoring System, International Research Journal of Engineering and Technology (IRJET), 3(2).