وزارة التعليـــم العالـــي والبحـــث العلمـــــــي
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

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Theme

Real-time Data Acquisition of Solar Panel

Defended on 14/06/2022 before the examination committee composed of:

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بسم الله الرحمن الرحيم

Dedication

We are honoured to dedicate this modest work:

To ***our parents*** *for their love, sacrifice, constant encouragement and support for us. May God prolong their life and grant them happiness. To* ***our dear brothers****, to* ***our families****, to all* ***our friends*** *and* ***colleagues****, to all those who helped us through difficult times while studying and during this work.*

Acknowledgements

*Firs of all, we would like to **praise ALLAH**, the most merciful for making the realization of our project possible and also for making our wishes come true and achieving our goals.*

In these few lines, we would like to thank all the people who, in one way or another, have contributed to the smooth running of our work, both on human and scientific matters.

*We would also like to show gratitude to the members of the jury (**Mr.SETTOU Belkhir** and **Mr.ROUABAH Boubaker**), for being attentive to our work and for having also agreed to participate in the examination committee.*

*Our thanks as well go to our supervisor **Dr.MAHBOUB Mohamed Abdelbaset**, whose extreme patience allowed us in return to accomplish our work,*

*We thank each of the co-supervisors, **Mr.REHOUMA Yousef**, whom we were able to benefit from his scientific skills to solve the difficulties we encountered during our investigation and answer our questions, also **Mr.FAZZANI Amar**, researcher in the Applied Research Unit in Renewable Energies.*

*We express our gratitude to all the **professors of the Applied Engineering Department** who have contributed to our training, we ask them to believe in our capacities in the hope that this humble work will give credibility to their efforts.*

*Big thank you to all **our friends**.*

***Abstract*:**

We created a real time acquisition system to track the voltage, current and temperature changes of the solar panel as we installed it in a charging regulator with battery.

The system consists of an Arduino Uno board, the controller ship, which is programmed by the Arduino IDE application, based on the C language, and sensors to capture the variables, we put the SD card to save the data and the LCD to see it currently, and can be monitoring the data by connecting the Arduino Uno board to the computer and processing it with the Excel application.

Keywords: Solar Panel, Data Acquisition, solar charge controller, arduino, sensors.

ملخص:

في هذا المشروع قمنا بإنشاء نظام لمتابعة تغيرات خصائص اللوح الشمسي في الوقت الفعلي، يتكون النظام من لوحة اردوينو التي تبرمج بواسطة برنامج اردوينوIDE المبني على لغة البرمجة C ومستشعرات لالتقاط المتغيرات (التوتر و التيار و الحرارة) و قارئ بطاقة الذاكرة لحفظ البيانات بالإضافة الى شاشة LCD لعرض البيانات آنيا و يمكن متابعة البيانات عن طريق ربط لوحة Arduino Uno بالحاسوب و تعريفها في برنامج

الكلمات المفتاحية : اللوح الشمسي , استحواذ على البيانات، منظم الشحن ، ، اردوينو ، أجهزة الاستشعار.

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GENERAL INTRODUCTION

Real-time data refers to data that is presented as it is acquired. The idea of real-time data handling is now popular in new technologies such as tracking changes progress and knowing the problems as they occur, and by collecting quantitative data, we were able to improve the quality of processing. [1]

In the world of machinery, this allows a technician to intervene quickly when there is a problem, allowing their machinery to function at peak performance. Automated data entry was once carried out by hand.

TABLE 1: COMPARATION BETWEEN STANDARD AND REAL TIME DATA ACQUISITION

	Standard Data Acquisition	**Real time Data Acquisition**
Goal	Strategic Decision-Marking (Long-term planning)	Tactical Decision-Making (Daily decisions)
Data Acquisition	Request Oriented (Nightly background job)	Data Availability Oriented (Permanently active background job)
Load Cycle	1/Day……...1/Week	1/Minute……1/Hour
Resource Consumption	Processing normally nights (load balancing)	Permanent Resource Consumption

Data acquisition systems employ automation, which minimizes human error and misplacement. Additionally, storing information gathered digitally is cheaper, takes up less space than physical paper, and can be retrieved almost instantaneously.

The data is also entered faster. These things don't happen when humans are manually doing the job.

This project purpose real-time monitoring changes of current, voltage and temperature of the solar panel and the battery through using the Arduino board, which stores the data obtained in the SD Card and piloted it instantaneously in Excel spreadsheet or MATLAB programs.

Chapter I

THE ELEMENTS OF DATA ACQUISITION SYSTEM

I.1 Introduction:

In this chapter, we will present the mechanism of the solar panel and the hardware components definition of our project, which aims to create a low-cost system for real-time monitoring of the characteristics of the photovoltaic panel such as voltage, current and power. This is based on the Arduino Uno board equipped with various sensors that we will present below**.**

I.2 Components:

I.2.1 Solar Panels:

I.2.1.1Definition*:*

A solar panel is defined as a device that converts solar radiation into electrical energy through photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels.

FIGURE I. 1: SOLAR PANEL

I.2.1.2 Solar Panel Component:

a- Aluminum Frame: The outer frame is usually manufactured from aluminum and its role is to ensure the mechanical durability of the solar panels.

b- Tempered cover glass: In addition to the high transmittance and low reflective properties, the upper surface material is impermeable to water and has low thermal resistance, as its primary role is to protect the photovoltaic cells from harsh weather, dirt and dust. Usually made of toughened glass.

C- Solar Cells: Solar cells are the basic building blocks of solar panels as they convert the solar radiation falling on them into a direct current DC. These cells are connected on the sequence to form a solar panel.

d- Encapsulation (EVA- Ethylene vinyl acetate): The EVA is the most common material as a coating material in the manufacture of solar panels. It is highly transparent, durable, and withstands extreme temperatures and humidity. It ensures the insulation and fixation of photovoltaic cells together.

e- Back Sheet: This layer is made of a group of polymer materials, usually white on one-sided panels and transparent on two-sided panels, provides both mechanical protection and electrical insulation.

f- Junction Box: The Junction boxes are the central point where the cables connect to the panels. It contains on diodes, whose main function is to prevent the excitation of hot-spots that can damage the PV cells.[2]

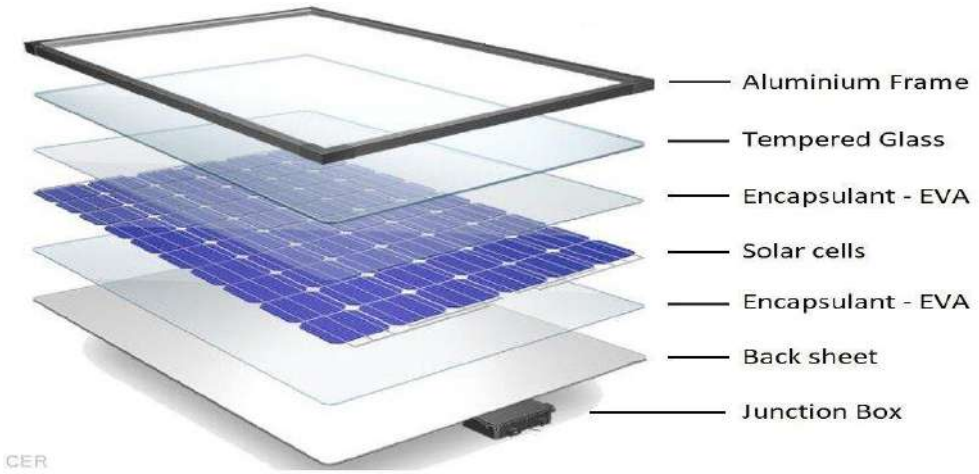

FIGURE I. 2:SOLAR PANEL COMPONENT

I.2.1.3 The principle of work of solar cells:

Solar panels are made up of smaller unit called solar cells, the most common solar cells are made from silicon, a semiconductor that is the second most abundant element on earth. In a solar cell, crystalline silicon is sandwich between conductive layers. Each silicon atom is connected to its neighbors by four strong bonds, which keep the electrons in place so no current can flow. Here is the key;

A silicon solar cell uses two different layers of silicon. An N-type silicon has extra electrons, and P-type silicon has extra spaces for electrons, called holes.

Where the two types of silicon meet, Electrons can wander the P/N junction, leaving a positive charge on one side, and creating negative charge on the other. we can think of light as the flow of tiny particles, called photons, shooting out from the sun. When one of these photons strikes the silicon cell with enough, it can knock an electron from its bond, leaving a hole. The negatively charged electron and location of the positively charged hole, are now free to move around.

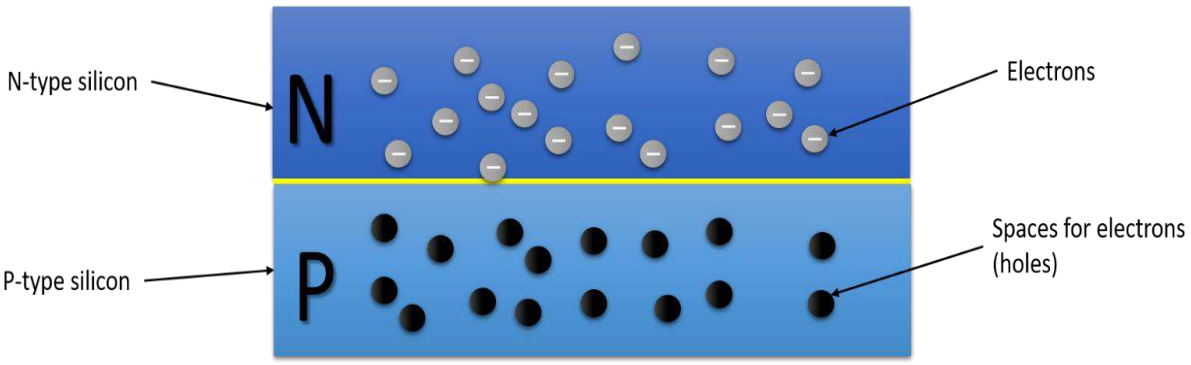

FIGURE I. 3: N/P TYPES SILICON

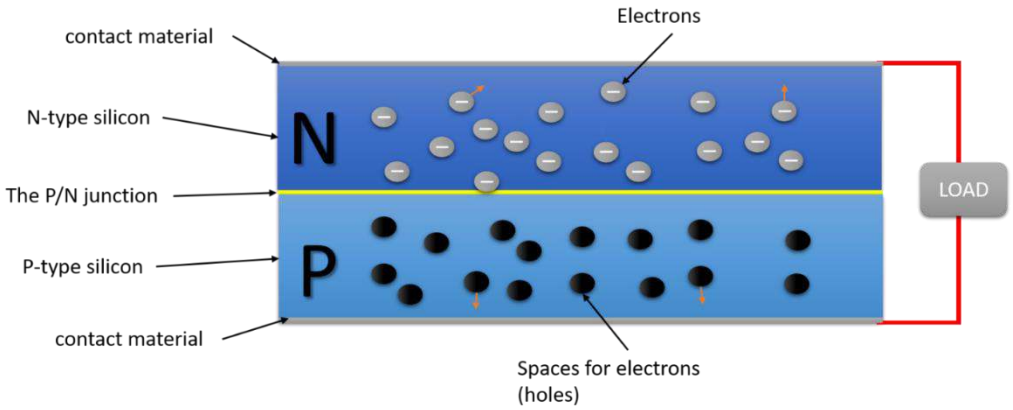

FIGURE I. 4: SOLAR CELL WORKING PRINCIPLE

But because of the electric field at the P/N junction, they will only go one way. The electron is drawn to the N side, while the hole is drawn to the P side. The mobile electrons are collected by thin metal fingers at the top of the cell. From there, they flow through an external circuit, doing electrical work, like powering a lightbulb, before returning through conductive aluminum sheet on the back.

Each silicon cell only puts out half a volt, but you can string them together in modules to get more power. Twelve photovoltaic cells are enough to charge a cellphone, while it takes many

modules to power an entire house. Electrons are the only moving parts in a solar cell, and they all go back where they came from. There is nothing to get worn out or used up, so solar cells can last for decades. [3]

We used a solar panel from AEG Company

TABLE I. 1:SOLAR PANEL CHARACTERISTIC

Puissance	38.4W
Voltage	17.2V
type	Polycrystalline (Multi-Crystalline)

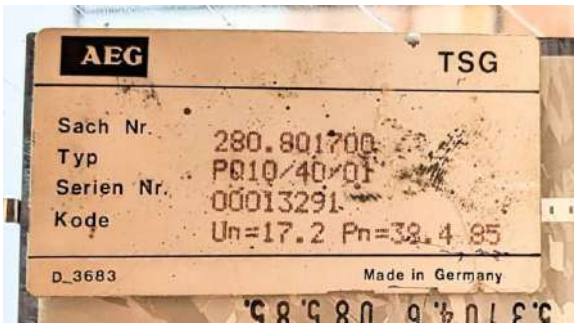

FIGURE I. 5: SOLAR PANEL CHARACTERISTIC

I.2.2 Arduino Uno:

I.2.2.1 Definition:

Arduino is an electric board open-source hardware and software, which can be programmed by software called Arduino IDE (Integrated Development Environment) based on C++ a programming language, which is used to write and upload the computer code to the physical board. [4]

FIGURE I. 6: ARDUINO UNO

I.2.2.2 Arduino Uno Properties:

TABLE I. 2: ARDUINO CHARACTERISTIC

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V

Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32KB(ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

I.2.1.3 Arduino Uno Component:

1-Digital pins 6-GND and 5V pins

2-Pin 13 LED 7-Power connector

3-Power LED 8-TX and RX LEDs

4-ATmega Microcontroller 9- USB port

5-Analog Pins 10- Reset button

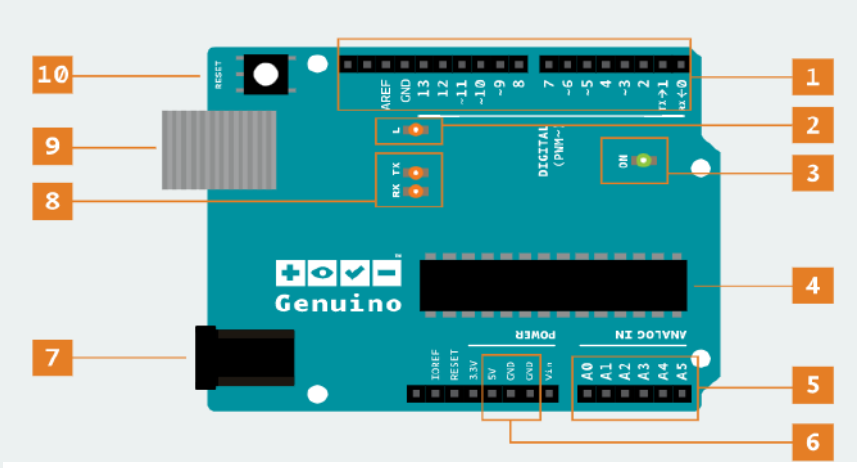

FIGURE I. 7: ARDUINO ELEMENT

I.2.3 Sensors:

I.2.3.1 Voltage Sensor B25:

The Arduino analog input is limited to a 5saV DC input, The sensor B25 is based on electric resistances to divider de voltage. It is capable of reducing five times of the voltage of the input terminal connection. You can use a maximum voltage of 5V on the ADC side so that it allows a maximum of 25V on the input side, when used 3.3V, the input voltage must not exceed 16.5V, but it is used only on direct current. [5]

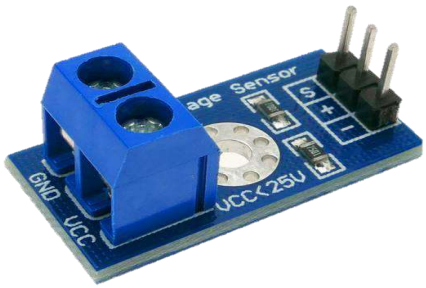

FIGURE I. 8: VOLTAGE SENSOR B25

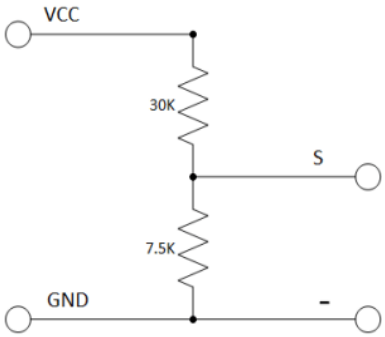

FIGURE I. 9: B25 SCHEMATIC

Properties of B25:

TABLE I. 3: B25 CHARACTERISTIC

Input voltage range	DC 0-25V
Voltage detection range	0.02445V - 25V
Resolutions:	0.00489V
Output interface	“+” 5 / 3.3V “- “ GND “s” to analog input
Size	27*14*12mm

I.2.3.1 Current Sensor ACS712:

ACS712 sensor read the input current and covert it to voltage output by a hall effect, the Hall Effect, electrons from an electric current flow through a magnetic field plate. The field then causes the electrons to "push" to one side of the plate and produce a voltage difference between the two sides. The difference in voltage from the side of the plate is the output of the sensor, the ACS712, it allows work on DC or AC sources. [6]

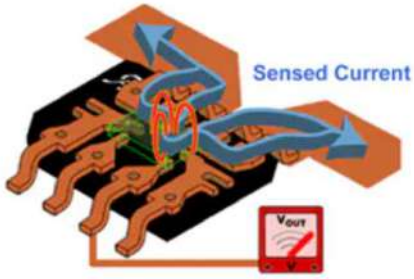

FIGURE I. 10: HALL EFFECT

FIGURE I. 11: CURRENT SENSOR ACS712

Properties of ACS712:

TABLE I. 4: ACS712 CHARACTERISTIC

Measuring Range	30 A
Response Time	<5 us
Power consumption	10 mA
Bandwidth	80 kHz
Sensitivity	185 m V / A
Internal conductor resistance	1.2 mΩ
Linearity	1.5% at TA = 25 C
Accuracy at - 40 to 25 .C	0.054 mV/A/C
Accuracy at 25 to 150 .C	-0.008 mV/A/C
Size	27*14*12mm
Interface	VCC to 5V GND to Ground
	Out: Analog pin
	Wire In: Inlet for the current to be measured Wire Out: Outlet for current to be measured

I.2.2.3Temperature Sensor (Thermocouple):

Thermocouple is type of temperature sensors, it is consisting of two wires made from deferent metal, The wires are welded together at one end, every kind of metals have coefficient of heat transfer or electrons movement speed because when the electrons gain energy (heat) it diverges from each other, So it creates a voltage in the beginning of the wire, that a voltage is construe of a temperature degree.

There are many types of thermocouples J, K, T, & E each with its own unique characteristics, we used K type.

It is most popular and inexpensive, accurate, reliable and has a wide temperature range -200 to 1260ºC. [7]

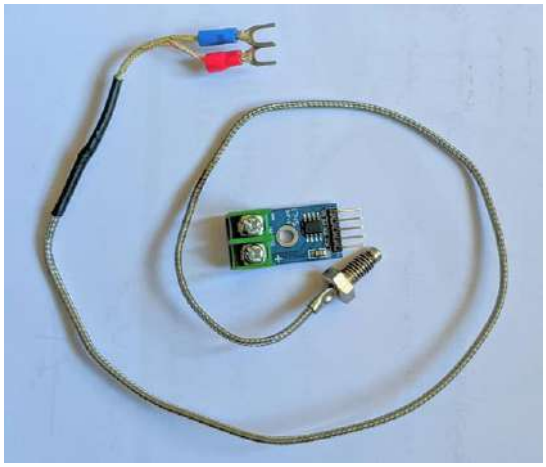

FIGURE I. 12: TEMPERATURE SENSOR

a) Characteristic of K Type:

TABLE I. 5: CHARACTERISTIC OF K TYPE

Used material	K (Nickel-Chromel / Nickel-Alumel)
Temperature Range	–270 to 1260 Cº
Limits of Error	+/- 1.1C or 0.4%
Max Error Tolerance	+/- 2.2C or 0.75%

b) Amplifier MAX6675:

The MAX6675 performs cold-junction compensation and digitizing the voltage signal from a K type thermocouple, SPI-compatible, read-only format. [8]

➢ Pin Function of Amplifier MAX6675*:*

TABLE I. 6: PIN FUNCTION OF AMPLIFIER MAX6675

Pin	Function
T+	Chromel Lead of Type-K Thermocouple
T-	Alumel Lead of Type-K Thermocouple. Should be connected to ground externally.
Vcc	Positive Supply. Bypass with a 0.1µF capacitor to GND. +3.0V to +5.5V
GND	Ground
SCK	Serial Clock Input
CS	Chip Select. Set CS low to enable the serial Interface
SO	Serial Data Output

I.2.4 Display LCD:
I.2.4.1 Definition:

LCD (Liquid Crystal Display) is type of screens that uses Liquid Crystal for display the text, Output of the sketch on a 16x2 LCD (16 Column & 2 Row). The LCD 1602A content on a shipset called Hitachi HD44780, it is found in most pupilar LCD that are based on text, and it is has a parallel interface. It means that the microcontroller operates several pins at once to control the LCD display. [9]

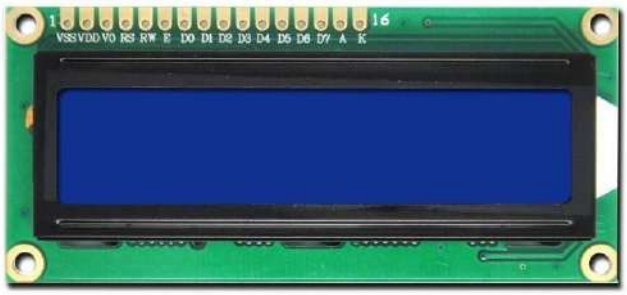

FIGURE I. 13: LCD DISPLAY

I.2.4.2 Pins functions:

we will explain below the pin function of LCD Display:

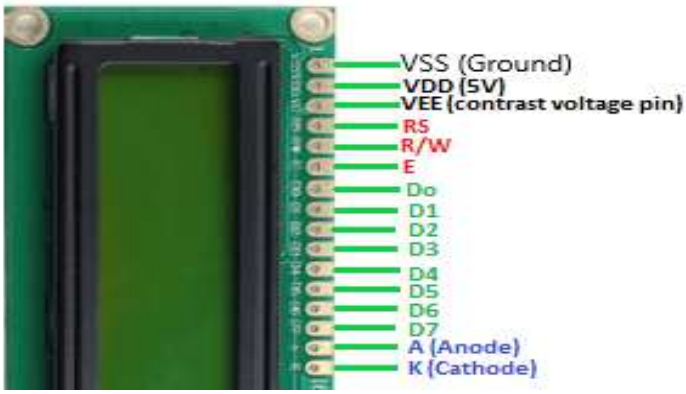

FIGURE I. 14: LCD DISPLAY PINS

TABLE I. 7:PINS FUNCTIONS OF LCD DISPLAY

Pin	Function
VSS	connected to ground.
VDD	connected to a +5V power supply.
VO	to adjust the contrast.
RS	A register select pin that controls where in the LCD's memory you are writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.
R/W	A Read/Write pin to select between reading and writing mode.
E	An enabling pin that reads the information when High level (1) is received. The instructions are run when the signal changes from High level to Low level.
DO-D7	to read and write data.
A	Pins that control the LCD backlight. Connect A to 3.3v.
K	Pins that control the LCD backlight. Connect K to GND.

I.2.5 SD card adapter:

The Arduino Uno can read and write files to the SD card. This module will be useful in projects where you need to save information periodically. [10]

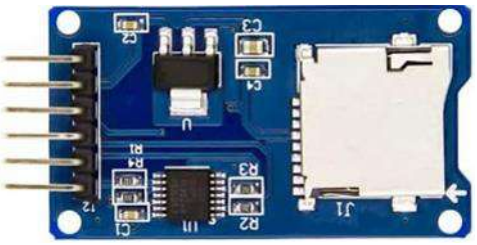

FIGURE I. 15: MICRO SD CARD ADAPTER

I.2.6 Solar Charge Controller:

It is a voltage regulator DC/DC or DC-DC power converter is an electrical system which convert a direct current source form one voltage level input to another Voltage level output.

we used "20A Solar Charger Controller" PWM (Pulse width modulation) model, is great option for those needing support for charging phones in the USB port and the car batteries. With LCD Display adjustable parameter for easy readability and usage. Features short-circuit open-circuit protection, reverse and over-load protection to improve controller that can automatically handle the workings of both the solar panel and the battery in the solar system. [11]

FIGURE I. 16: SOLAR PANEL CONTROLLER

I.2.7 Battery:

The battery must be available in the installation of the solar energy system in order to regulate the load alimentation and ensuring its continuity in the presence and absence of the sun or the supply of the solar panel. We used ProPower battery 12V100Ah model.

FIGURE I. 17: BATTERY OF SOLAR PANEL

TABLE I. 8: BATTERY CHARACTERISTIC

voltage	12V
Capacity	100Ah
wight	12kg
size	340*182*265mm

Chapter II

SOLAR PANEL SYSTEM AND DATA ACQUISITION

II.1. Introduction:

In this chapter, we will present how to connect the hardware components to the Arduino uno and the solar panel charging regulator, in addition to the programming code and how to work on it. We will also present how to extract and display the information obtained in real time using the Excel program.

II.2 Code and program:

We need install the Arduino IDE application with following the steps from site official “Scan QR code”

FIGURE II. 1: ARDUINO IDE LOGO

FIGURE II. 2: QR CODE FOR IDE SITE

The program code embedded in the Arduino UNO board, which allows to acquire the measured data of solar panel from sensors and send it to an Excel Spreadsheet, is presented as follows:

```
/*
 * ************************************************************
 * Written by:
 * Ghorma Djafer                E-mail: djaferghorma@gmail.com
 * Nadejmi Ahmed Abdelouarith   E-mail: na.abdelouarith@gmail.com
 * ************************************************************
 * Function : Real-time data acquisition of solar panel using
 *            Arduino and Excel.
 * Date :     Mai 2022
 * ************************************************************
*/

// include the library code of LCD Display
#include <LiquidCrystal.h>
// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int
rs = 7,
en = 6,
d4 = 5,
d5 = 4,
d6 = 3,
d7 = 2;
// create instance object of LCD
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);


// include the library code of max6675 "temperature sensor"
#include <max6675.h>
int soPin = 0;// SO=Serial Out
int csPin = 1;// CS = chip select CS pin
int sckPin = 9;// SCK = Serial Clock pin
// create instance object of MAX6675
MAX6675 Module(sckPin, csPin, soPin);


// include the libraries code of SD Card Adapter
#include <SPI.h>
#include <SD.h>
File myFile;
// MOSI - pin 11 on Arduino Uno/Duemilanove/Diecimila
// MISO - pin 12 on Arduino Uno/Duemilanove/Diecimila
// CLK - pin 13 on Arduino Uno/Duemilanove/Diecimila
//you can't replace them
//CS - is chipSelect value
const int chipSelect = 8;


//Create a variables
float R0, R2;
float pv_Volt; // for the Solar Panel Voltage
float pv_Curr; // for the Solar Panel Current
float Puissance; // for the Solar Panel Puissance
float batt_Volt; // for the Battery Voltage
float batt_Curr;  // for the Battery Current
float Temperature;// for the Temperature

```

```
58 //Create a variables for current Equation
59 int adcValue= 0;
60 double adcVoltage = 0;
61 double currentValue = 0;
62
63 void setup()
64 {
65   // Open serial communications and wait for port to open
66   Serial.begin (9600);
67
68   lcd.begin(16, 2);// set up the LCD's number of columns and rows
69
70   while (!Serial) {
71     ; // wait for serial port to connect.
72       // Needed for native USB port only
73   }
74
75   // set the cursor to column 0, line 0
76   // (note: line 1 is the second row, since counting begins with 0):
77   lcd.setCursor(0,0);
78   // print "Initializing SD card..." to Serial monitor
79   Serial.print("Initializing SD card...");
80   // print "Initializing SD card..." to LCD Display
81   lcd.print("Initializing SD card...");
82   // set the cursor to column 0, line 1
83   lcd.setCursor(0,1);
84
85   //  chick the SD card if is work and
86   //  print it in the monitor and lcd card
87   if (!SD.begin(chipSelect)) {
88     lcd.print("SD Card failed ");
89     Serial.println("SD Card failed ");
90   }
91   else{
92     lcd.print("SD Card working ");
93     Serial.println("initialization done.");
94   }
95
96   // open the file. note that only one file can be open at a time,
97   // so you have to close this one before opening another
98   myFile = SD.open("test.txt", FILE_WRITE);
99   // if the file opened okay, write to it:
100  if (myFile) {
101  //print line for  differentiation between
102  // past and next Data in the SD card
103    myFile.println("########################################");
104    // close the file:
105    myFile.close();
106  }
107  delay(4000);
108 }
109
110 void loop()
111 {
112 //  Voltage Equations
113   R0= analogRead(A0);
114   R2= analogRead(A2);
```

```
115   pv_Volt=(R0 * 25.0) / 1023 - 1.8;
116   batt_Volt= (R2 * 25.0 ) / 1023 - 1.9;
117
118   // Current Equations
119   adcValue = analogRead(A1);
120   adcVoltage = (adcValue / 1024.0) * 5000;
121   pv_Curr = ((adcVoltage - 2500) / 66);
122   adcValue = analogRead(A3);
123   adcVoltage = (adcValue / 1024.0) * 5000;
124   batt_Curr = ((adcVoltage - 2500) / 66);
125
126   //  Temperature Equation
127   Temperature = Module.readCelsius();
128
129    //print the Data in the SD Card
130   myFile = SD.open("test.txt", FILE_WRITE);
131   // if the file opened okay, write to it
132   if (myFile) {
133     myFile.println(String(pv_Volt) + "," + String(pv_Curr) + ","
134       + String(Puissance) + "," + String( batt_Curr)+","+
135       String(batt_Volt)+ "," + String(Temperature));
136     // close the file:
137     myFile.close();
138   }
139
140 //  print the SD card in LCD Display
141   // set the cursor to column 0, line 0
142   lcd.setCursor(0,0);
143   lcd.print("V:" + String(pv_Volt) + " C:" + String(pv_Curr));
144   // set the cursor to column 0, line 1
145   lcd.setCursor(0,1);
146   lcd.print("T:"+String( Temperature)+ " BC:" + String(batt_Curr));
147
148 //  print code in the Monitor and Excel
149   Serial.println(String(pv_Volt) + "," + String(pv_Curr) + ","
150                  + String( batt_Curr)+","+ String(batt_Volt)+
151                  "," + String(Temperature));
152
153 //  300000 mS = 5 min cycle time
154   delay(300000);
155 }
```

2.1 Voltage sensor equation is:

- Vpv: panel voltage value
- analogRead (A0) : the Arduino reading the input voltage as percent value from 1023.
- α: sensor coefficient
- 25V: the maximum voltage the sensor can read it.

$$Vpv = \frac{analogRead(\ A0\ )}{1023} \times \alpha \times 25V$$

TABLE II. 1: VOLTAGE SENSOR PIN CONNECT

Sensor pin	Arduino pin
Vcc	//
Out	Panel Voltage Pin A0
	Battery Voltage Pin A1
GND	Ground

2.2 Current sensor equation is:

Read the voltage from the sensor: $Vin = \frac{analogRead(\ A1)}{1023} \times 5000\ mV$

Function of the convert the voltage signal to the current value $C = \frac{(\ Vin - 2500\ mV)}{66\ mV/A}$

TABLE II. 2: CURRENT SENSOR PIN CONNECT

Sensor pin	Arduino pin
Vcc	5V pin
Out	Panel current Pin A1
	Battery current Pin A3
GND	Ground

C: the current value

- 2500mV: $2500mV \equiv 0A$

V*in* < 2500mV for the negative value

V*in* > 2500mV for the positive value

- $66\ mV/A$: Sensitivity of current sensor 30A

2.3 Max6675 Thermocouple:

TABLE II. 3: MAX6675 THERMOCOUPLE PIN CONNECT

Include the library "**max6675**.h", which defined the sensor instance object, put the

Sensor pin	Arduino pin
GND	Ground
Vcc	5V pin
SCK	Pin 9
CS	Pin 1
SD	Pin 0

TABLE II. 4: LCD DISPLAY PIN CONNECT

2.4 LCD Display:

Include the library "LiquidCrystal.h", which defined the sensor instance object.

Note: the LCD must be come with variable resistance for the display clarity.

LCD pin	Arduino pin
VSS	Ground
VDD	5V pin
V0	Resistance Variable
RS	Digital pin 7
R/W	Digital pin 6
E	Ground
D4	Digital pin 5
D5	Digital pin 4
D6	Digital pin 3
D7	Digital pin 2
A	3.3V pin
K	Ground

2.5 SD card Adapter:

The module is connected to the Arduino via the SPI interface and for this we will need the SCK, MISO, MOSI and CS pins. Arduino Uno boards have dedicated pins for the SPI. We can use any free microcontroller pin for the CS pin and specify this change in code.

Adapter pins	Arduino pin
GND	Ground
Vcc	5V pin
MOSI	Pin 11
MISO	Pin 12
CLK	Pin 13
CS	Pin 8

Table II. 5: SD card Adapter Pin Connect

II.3 Schematic:

The pictures below present element wiring arduino and the solar panel controller:

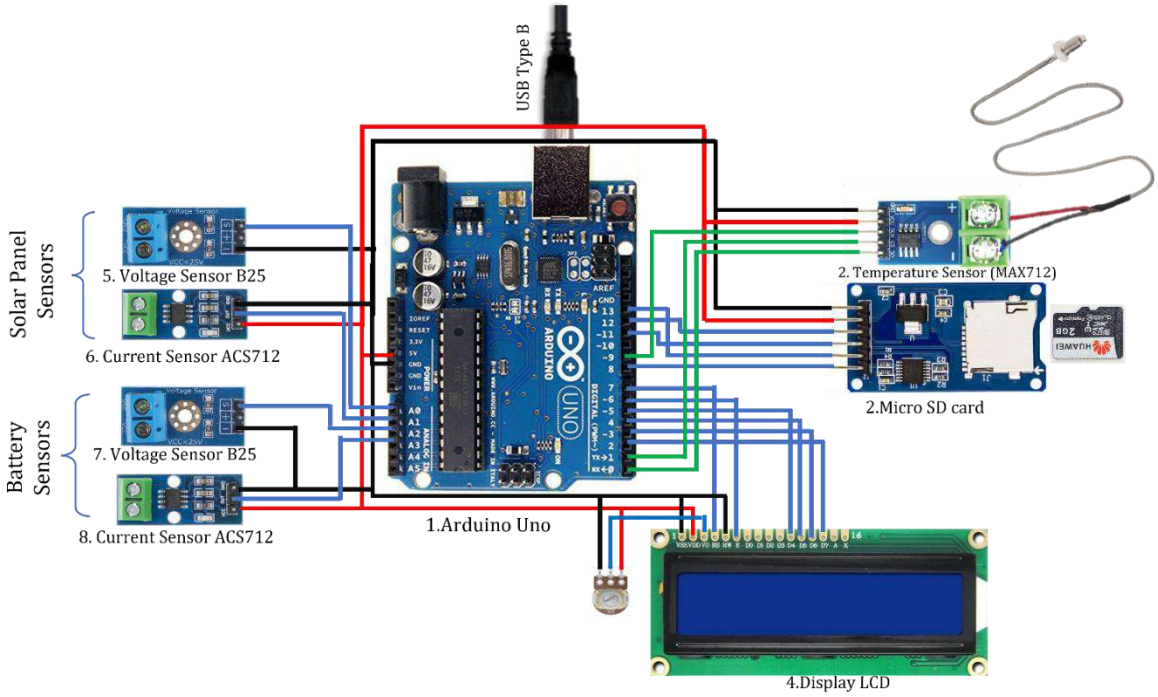

FIGURE II. 3 :SCHEMATIC VIEW OF THE HARDWARE COMPONENTS CONNECTED TO THE ARDUINO

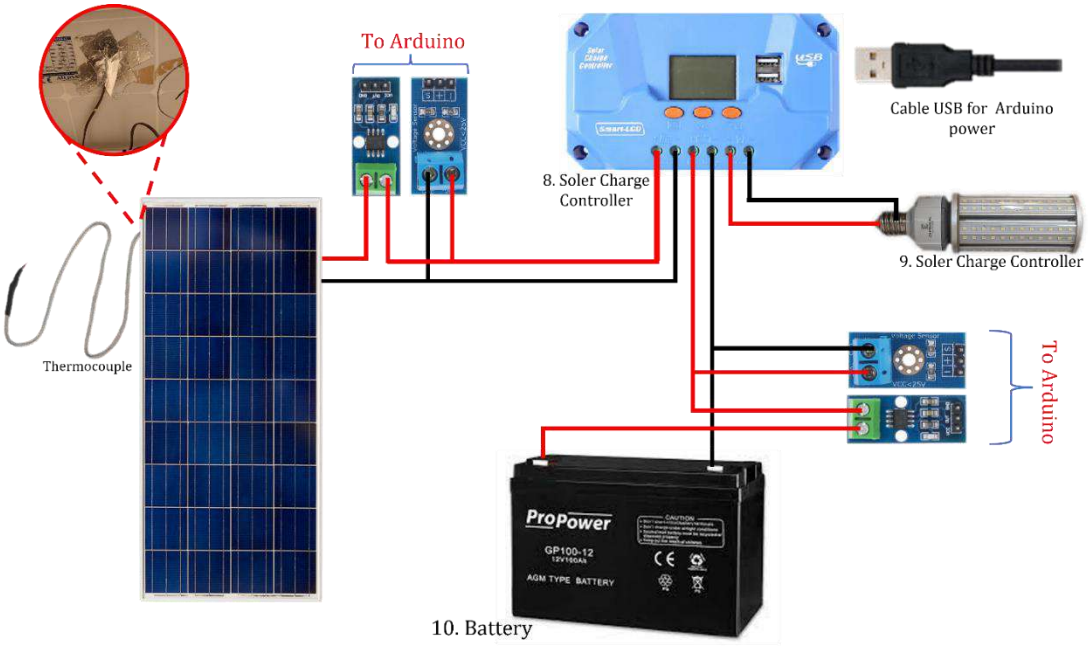

FIGURE II. 5: SCHEMATIC VIEW OF THE HARDWARE COMPONENTS CONNECTED TO THE PANEL CONTROLLER

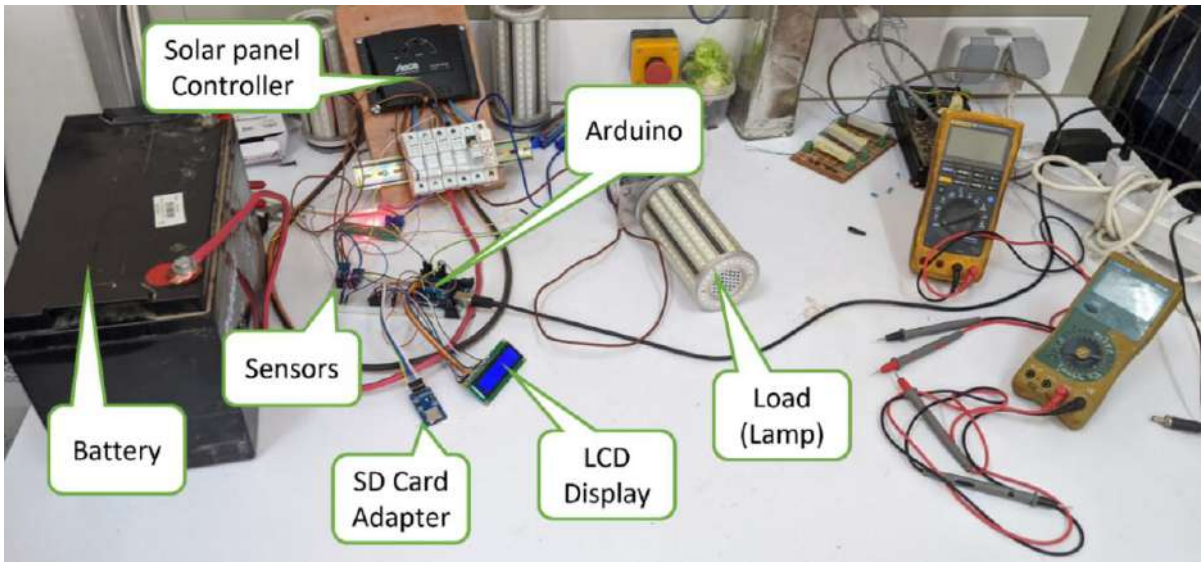

FIGURE II. 4: PRESENTATION OF MANIPULATION

II.4 View and extract data from the system

Data can be extracted and displayed in three different ways, which we will present as follows:

II.4.1 The LCD display:

The LCD displays is taking the Data from the Arduino board in real time, and display it in that order: The Panel voltage and current in the first line and temperature and battery current to know if it was charging or discharging in the second line.

FIGURE II. 6: : PARAMETER ORDER IN LCD DISPLAY

II.4.2 The Excel program:

We can also get the data in real time by connecting the Arduino to the computer via a USB cable and defining it in the Excel 2021 program as shown below:

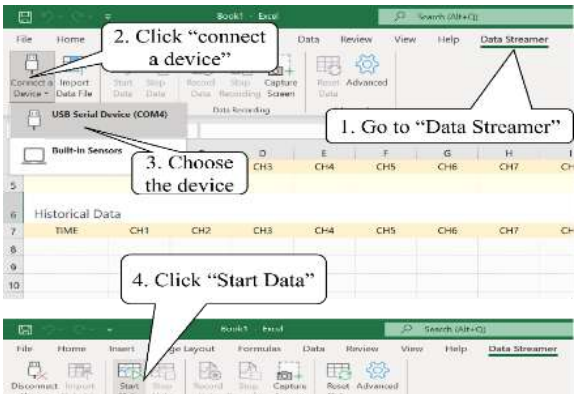

FIGURE II. 7: HOW TO STREAMING DATA IN EXCEL

II.4.3 The SD card:

The Micro SD card records the data taken from the Arduino board in real time according to the code that was programmed and presented above in the following order: panel voltage, Panel current, Battery voltage, battery current, temperature. Into a file in the form of text document ".txt", Must be placed comma between the parameter or escape to be able excel application Differentiate between them, set a dividing line ”###” whenever restart the Arduino board.

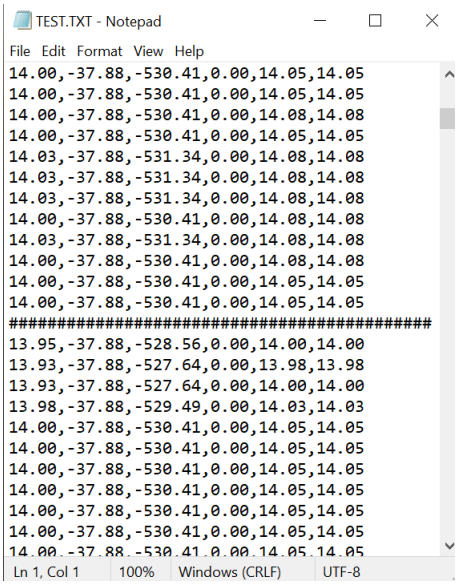

FIGURE II. 8: TEXT DATA FILE

which we extract by insert it into the computer and follow steps:

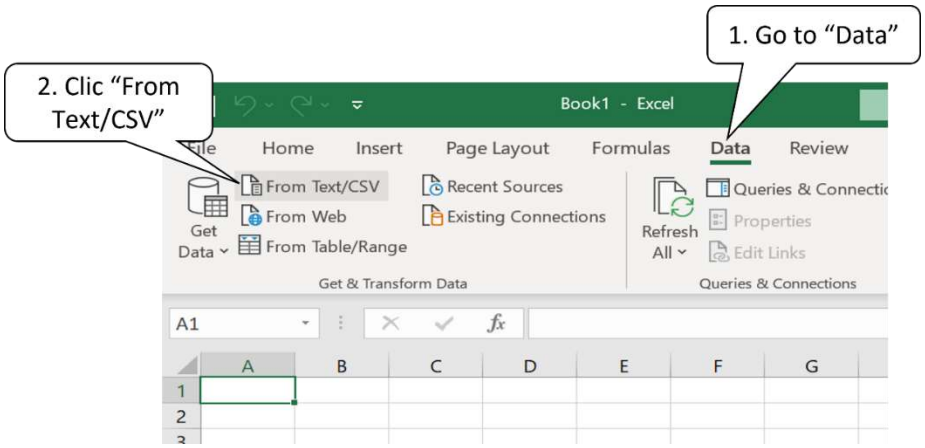

FIGURE II. 9: HOW TO INSERT “.TXT” FILE

III.3 Conclusion:

In this chapter, we explained how to wiring the hardware components of the system and write the code program and upload it into Arduino board, in addition to how to extract and display the data obtained.

Chapter III

RESULTS AND DISCUSSION

III.1 Introduction:

In this chapter we will present the results of tests performed by a real-time solar panel data monitoring system, as previously described. The various results obtained and their scientific interpretation are presented in the following.

III.2 The Experiment:

We did this experiment in Applied Research Unit in Renewable Energies Ghardaia (URAER) in Wednesday 01/06/2022.

➢ Technical sheet of URAER:

Name or Social reason: Applied Research Unit in Renewable Energies

Email: admin@uraer.dz

Activity: The Applied Research Unit has contributed to renewable energies through research programs in the management and development of these technologies: The human potential within the unit can contribute to this national research and training efforts on the one hand, in cooperation with universities and other research centres, and on the other hand, through the possibility of providing quality training High within the unit in the field of renewable energies from the level of control and control until after graduation. [11]

FIGURE III. 2: APPLIED RESEARCH UNIT IN RENEWABLE ENERGIES

FIGURE III. 1 : SOLAR PANEL OF (URAER)

pictures in intitute of Technology KASDI MERBAH UNIVERSITY OUARGLA

FIGURE III. 3: INSTALLING PROJECT

FIGURE III. 4: INSTITUTE OF TECHNOLOGY

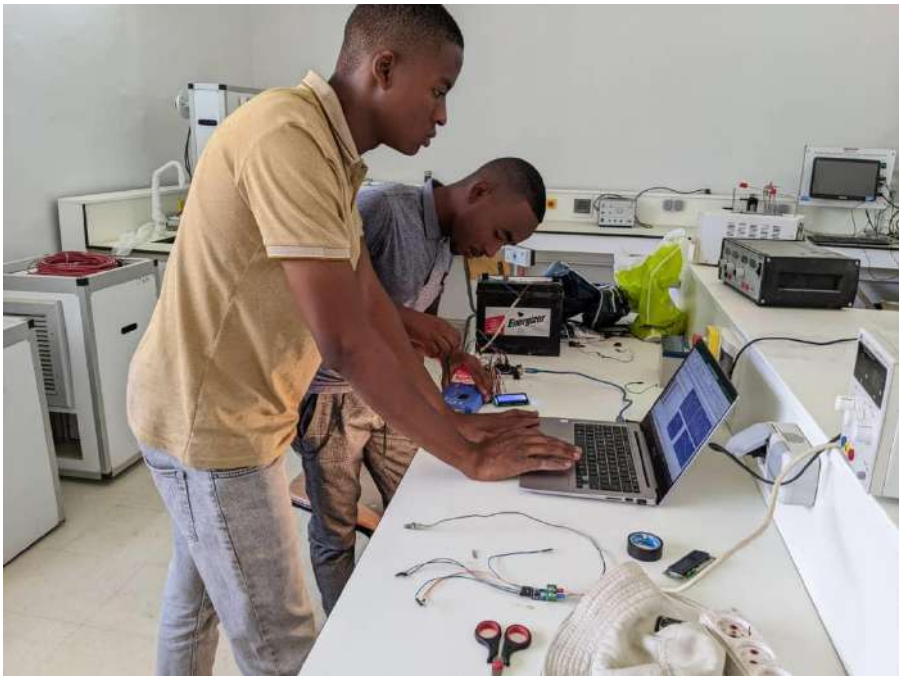

FIGURE III. 5: RENEWABLE ENERGY LAB (INSTITUTE)

III.3 Result:

Show some of data we obtained from tracking the solar panel

TABLE III. 1: RESULT DATA

Time	PV_Volt	PV_Curr	PV_Power	Batt_volt	Batt_Curr	Batt_Power	Radiation	Temp
07:00	12.25	0.37	13.94	12.18	0.37	4.51	231.63	26.37
07:05	12.18	0.37	13.16	12.13	0.37	4.49	246.20	26.73
07:10	12.23	0.44	13.11	12.15	0.44	5.35	257.88	27.29
07:15	12.23	0.44	13.14	12.18	0.37	4.51	275.02	28.09
07:20	12.18	0.44	12.28	12.15	0.52	6.32	287.70	28.70
07:25	12.2	0.44	10.42	12.13	0.44	5.34	304.84	29.14
07:30	12.2	0.44	8.65	12.15	0.44	5.35	320.50	29.86
07:35	12.15	0.44	8.67	12.1	0.44	5.32	335.57	30.36
07:40	12.25	0.52	9.27	12.2	0.37	4.51	351.42	31.54
07:45	12.23	0.44	8.18	12.15	0.44	5.35	366.49	32.80
07:50	12.18	0.52	6.36	12.13	0.44	5.34	381.38	33.25
07:55	12.25	0.59	7.20	12.25	0.52	6.37	397.58	34.47
08:00	12.23	0.52	6.54	12.15	0.44	5.35	408.94	34.83
08:05	12.25	0.52	6.19	12.23	0.52	6.36	424.55	35.26
08:10	12.35	0.59	6.33	12.27	0.59	7.24	437.82	35.50
08:15	12.3	0.59	7.75	12.3	0.52	6.40	453.39	34.56
08:20	12.37	0.59	6.36	12.35	0.59	7.29	469.13	35.23
08:25	12.47	0.67	7.06	12.45	0.59	7.35	484.17	35.11
08:30	12.42	0.67	7.20	12.37	0.59	7.30	497.72	35.34
08:35	12.47	0.67	6.97	12.47	0.67	8.35	511.11	35.69
08:40	12.59	0.67	6.36	12.54	0.74	9.28	527.40	36.12
08:45	12.52	0.74	5.39	12.49	0.59	7.37	541.27	36.45
08:50	12.5	0.67	5.50	12.49	0.67	8.37	555.14	37.14
08:55	12.57	0.81	6.34	12.54	0.74	9.28	569.55	37.88
09:00	12.67	0.96	6.22	12.64	0.67	8.47	583.96	39.81
09:05	12.62	0.89	6.27	12.59	0.81	10.20	597.15	41.93
09:10	12.59	1.04	5.34	12.59	0.81	10.20	610.79	43.71
09:15	12.64	0.96	4.26	12.64	0.96	12.13	625.90	43.13
09:20	12.64	1.11	4.95	12.59	0.96	12.09	638.58	42.66
09:25	12.64	1.11	5.24	12.62	0.96	12.12	650.70	41.78
09:30	12.69	1.11	6.19	12.67	1.11	14.06	658.15	40.88
09:35	12.72	1.04	5.21	12.67	1.04	13.18	669.59	40.82
09:40	12.69	1.04	6.20	12.69	1.18	14.97	683.81	42.37
09:45	12.74	1.33	4.00	12.74	1.18	15.03	697.07	42.25
09:50	12.67	1.11	5.22	12.67	1.18	14.95	704.07	42.32
09:55	12.74	1.26	4.41	12.71	1.18	15.00	714.66	44.00
10:00	12.72	1.18	3.58	12.74	1.04	13.25	723.87	45.20
10:05	12.72	1.26	3.33	12.71	1.26	16.01	738.61	45.91
10:10	12.74	1.18	4.45	12.74	1.26	16.05	740.82	43.72

10:15	12.84	1.18	5.22	12.84	1.26	16.18	751.29	45.45
10:20	12.86	1.41	4.33	12.84	1.33	17.08	765.88	45.14
10:25	12.81	1.33	4.41	12.84	1.26	16.18	782.23	44.10
10:30	12.89	1.41	3.33	12.86	1.26	16.20	787.42	44.53
10:35	12.84	1.55	4.06	12.81	1.33	17.04	799.39	45.06
10:40	13.01	1.48	1.62	12.91	1.41	18.20	805.94	45.60
10:45	12.91	1.33	4.33	12.91	1.41	18.20	800.65	44.72
10:50	12.91	1.41	4.35	12.91	1.41	18.20	818.11	45.88
10:55	12.94	1.48	4.39	12.93	1.41	18.23	829.59	45.93
11:00	12.91	1.41	4.36	12.88	1.48	19.06	827.61	47.29
11:05	12.89	1.48	4.38	12.88	1.33	17.13	822.48	46.18
11:10	12.94	1.48	3.31	12.93	1.48	19.14	847.47	45.73
11:15	12.96	1.55	5.29	12.93	1.55	20.04	867.94	46.89
11:20	12.91	1.63	5.20	12.91	1.55	20.01	859.39	47.94
11:25	12.94	1.7	4.33	12.91	1.7	21.95	864.14	47.23
11:30	13.01	1.63	4.43	12.96	1.48	19.18	879.55	46.52
11:35	12.94	1.7	5.27	12.91	1.55	20.01	882.35	48.88
11:40	13.01	1.7	4.46	13.01	1.63	21.21	877.67	47.66
11:45	12.96	1.78	0.00	12.96	1.7	22.03	890.07	47.98
11:50	13.03	1.48	4.45	13.01	1.7	22.12	892.34	48.58
11:55	13.01	1.78	2.54	12.96	1.63	21.12	898.64	47.09
12:00	13.01	1.33	3.60	12.91	1.33	17.17	893.12	47.60
12:05	13.2	1.41	3.60	13.18	1.48	19.51	904.54	47.35
12:10	13.16	1.18	3.60	13.15	1.11	14.60	908.92	48.42
12:15	13.2	1.55	5.29	13.2	1.48	19.54	920.51	48.44
12:20	13.28	1.63	3.57	13.3	1.55	20.62	910.42	48.59
12:25	13.25	1.48	3.24	13.23	1.41	18.65	921.63	49.66
12:30	13.52	1.85	3.62	13.5	1.92	25.92	918.43	48.40
12:35	13.45	1.85	3.92	13.45	1.63	21.92	930.85	48.28
12:40	13.2	1.33	3.60	13.23	1.26	16.67	933.17	49.25
12:45	13.16	1.04	3.62	13.13	0.96	12.60	936.28	50.59
12:50	13.23	1.26	6.09	13.23	1.11	14.69	945.41	49.93
12:55	13.38	1.63	3.29	13.37	1.48	19.79	944.63	51.05
13:00	13.35	1.78	3.89	13.35	1.7	22.70	963.26	51.58
13:05	13.45	1.63	5.34	13.45	1.78	23.94	943.84	50.32
13:10	13.45	1.7	3.57	13.42	1.78	23.89	955.66	48.64
13:15	13.38	1.78	4.24	13.37	1.63	21.79	853.16	46.83
13:20	13.45	1.78	5.24	13.4	1.7	22.78	874.97	47.40
13:25	13.3	1.41	4.50	13.28	1.33	17.66	873.97	48.16
13:30	13.16	1.41	5.23	13.18	1.26	16.61	736.59	48.50
13:35	13.18	0.96	4.40	13.27	-3.03	-37.18	855.60	45.87
13:40	13.25	1.18	4.43	13.42	-2.74	-34.03	926.77	47.33
13:45	13.23	1.18	3.18	13.35	-2.74	-33.84	873.02	47.91
13:50	13.23	1.26	3.49	13.32	-2.74	-33.76	851.22	48.30
13:55	13.59	1.7	4.47	12.71	-2	-25.42	878.45	47.63
14:00	12.74	1.92	5.22	12.81	-1.92	-24.60	810.37	46.93

14:05	13.25	2.66	4.43	13.35	-1.04	-13.88	891.02	47.67
14:10	12.79	1.85	4.36	12.88	-1.85	-23.83	513.29	47.14
14:15	13.06	2.29	5.28	13.18	-1.63	-21.48	597.30	42.78
14:20	13.5	2.44	6.18	13.62	-1.18	-16.07	585.62	42.23
14:25	13.35	2.15	3.59	13.45	-1.55	-20.85	831.12	44.41
14:30	13.38	2.15	4.31	13.47	-1.41	-18.99	953.61	47.20
14:35	13.23	2.22	4.40	13.32	-1.33	-17.72	914.75	51.72
14:40	13.77	1.7	4.18	13.84	-1.92	-24.65	939.09	55.83
14:45	13.23	1.7	4.40	12.99	-1.92	-23.65	927.26	55.50
14:50	13.96	1.55	4.36	13.5	-2.07	-24.94	895.96	56.01
14:55	13.42	1.55	4.29	13.4	1.7	22.78	911.98	53.06
15:00	13.33	1.41	3.59	13.28	1.63	21.65	777.85	49.52
15:05	13.4	1.18	3.54	13.37	1.55	20.72	685.96	47.33
15:10	13.42	1.41	4.39	13.35	1.63	21.76	761.47	47.85
15:15	13.79	1.92	3.03	13.74	2.22	30.50	854.90	46.50
15:20	13.52	1.55	4.81	13.47	1.7	22.90	687.90	48.84
15:25	13.47	1.33	4.36	13.45	1.55	20.85	640.45	47.80
15:30	13.5	1.41	3.57	13.47	1.63	21.96	641.97	47.36
15:35	13.5	1.48	5.24	13.45	1.63	21.92	539.00	48.12
15:40	13.96	2.29	5.24	13.91	2.37	32.97	801.58	45.56
15:45	14.16	2.44	4.39	14.08	2.66	37.45	762.58	46.15
15:50	14.01	2.22	5.25	13.98	2.44	34.11	574.14	48.52
15:55	14.21	2.52	7.04	14.16	2.74	38.80	389.86	44.93
16:00	14.04	2.15	5.17	13.96	2.37	33.09	619.19	40.70
16:05	14.18	2.29	0.81	14.08	2.66	37.45	744.07	42.30
16:10	13.96	2.15	3.89	13.91	2.37	32.97	434.81	42.43
16:15	13.91	2.15	4.24	13.89	2.22	30.84	473.72	40.89
16:20	13.96	2	3.57	13.91	2.22	30.88	396.06	40.87
16:25	13.94	2	3.46	13.86	2.22	30.77	342.63	39.17
16:30	13.79	1.7	4.40	13.72	2	27.44	346.88	38.38
16:35	13.74	1.7	4.34	13.69	1.92	26.28	401.43	37.11
16:40	13.84	1.7	3.18	13.76	1.92	26.42	522.66	37.94
16:45	13.79	1.78	4.38	13.74	2.07	28.44	669.69	40.21
16:50	14.01	2.07	4.40	13.94	2.15	29.97	694.76	43.46
16:55	13.64	1.48	4.41	13.59	1.63	22.15	369.62	42.44
17:00	13.64	1.63	5.21	13.59	1.7	23.10	372.59	40.42
17:05	13.86	1.48	2.62	13.62	1.63	22.20	419.94	39.34
17:10	13.79	1.63	4.39	13.74	1.92	26.38	578.48	39.76
17:15	13.69	1.48	4.40	13.64	1.7	23.19	584.75	42.83
17:20	13.74	1.48	4.26	13.67	1.7	23.24	485.45	43.12
17:25	13.79	1.55	4.76	13.74	1.78	24.46	303.70	39.42
17:30	13.74	1.48	3.89	13.64	1.78	24.28	300.50	37.32
17:35	13.72	1.41	1.31	13.67	1.7	23.24	311.79	36.04
17:40	13.74	1.55	4.31	13.81	1.78	24.58	291.28	34.87
17:45	13.77	1.48	4.10	13.72	1.78	24.42	262.62	34.59
17:50	13.84	1.55	4.23	13.76	1.7	23.39	287.42	34.16

17:55	13.79	1.41	4.35	13.72	1.7	23.32	284.29	34.52
18:00	13.74	1.41	3.38	13.72	1.7	23.32	279.97	35.29
18:05	13.77	1.41	4.43	13.69	1.63	22.31	285.34	35.43
18:10	13.69	1.48	3.58	13.72	1.92	26.34	279.38	35.29
18:15	13.79	1.55	3.02	13.74	1.78	24.46	285.39	36.07
18:20	13.74	1.33	4.97	13.69	1.7	23.27	289.03	36.68
18:25	14.23	2.15	3.55	14.18	2.44	34.60	273.98	37.21
18:30	14.01	2	3.54	13.98	2.22	31.04	254.15	36.83
18:35	13.89	1.7	3.16	13.84	1.92	26.57	275.32	37.07
18:40	13.79	1.55	4.40	13.74	1.92	26.38	231.51	36.27
18:45	13.84	1.7	4.26	13.79	1.78	24.55	279.10	35.82
18:50	13.86	1.85	5.17	13.81	2	27.62	327.32	35.51
18:55	13.94	1.85	3.56	13.86	2.07	28.69	286.99	35.85
19:00	13.99	1.92	4.19	13.91	2.15	29.91	252.88	35.87

Notes:

1. All measurements were taken with the same angle of inclination of the panel.

2. We take the radiation as a reference by the pyranometer.

2.1 Voltage Curve:

In the voltage curve, we notice that the battery is increasing from 12v to 13.8v, as the battery is charging, as is the PV voltage, while the Soler Charge Controller sets the battery the appropriate voltage for charging.

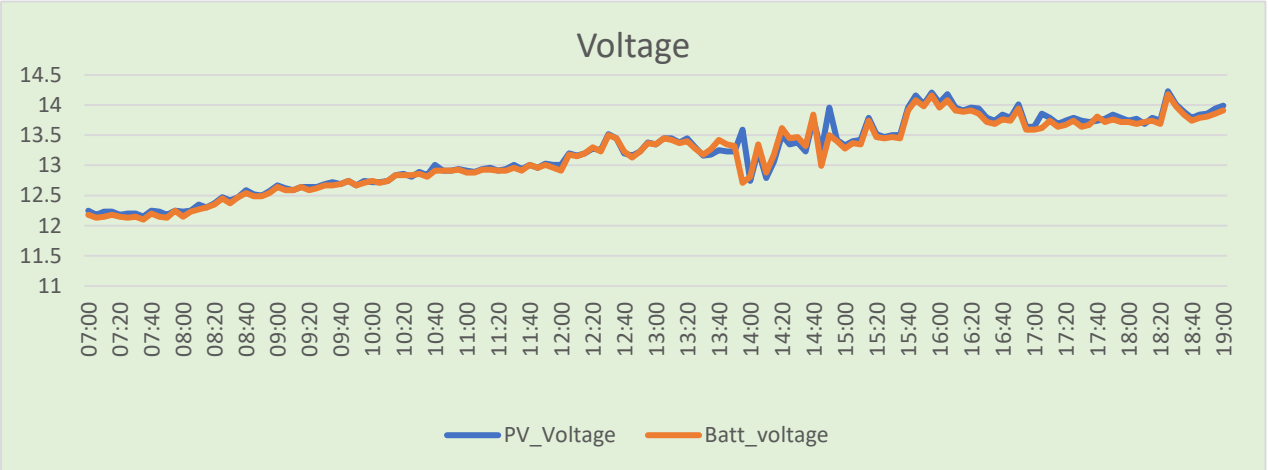

FIGURE III. 6: VOLTAGE CURVE

2.2 Current Curve:

We notice that the PV current increasing from 0.37A at 7:00 to 1.6A at 12:00 , with increasing the radiation, then it becomes almost stable after 12:00.

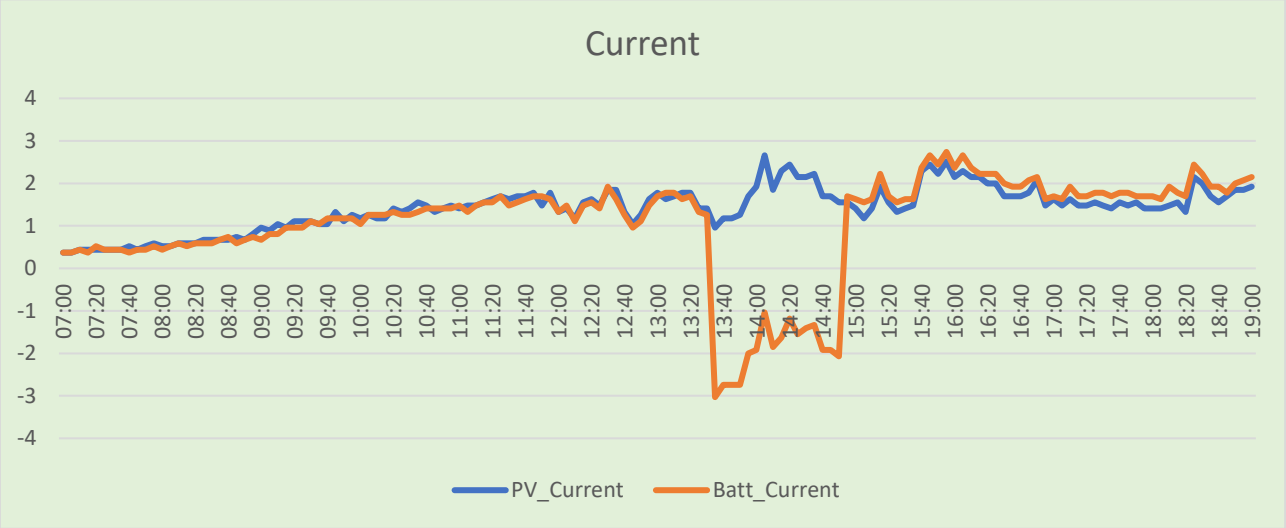

FIGURE III. 7 : CURRENT CURVE

We turned on the 48W lamp from 10:45 to 12:25. We notice that the current of the battery has become negative -2.74A as it is discharging, and there is also an increase in the PV current to 1.18A.

$$12V \times (1.18A - (-2.74A)) = 47.04W$$

2.3 Power Curves:

We notice that the PV Power is the same curve of current . It was 5W at 07:00 then becomes stable at 30W from 12:00 to 19:00

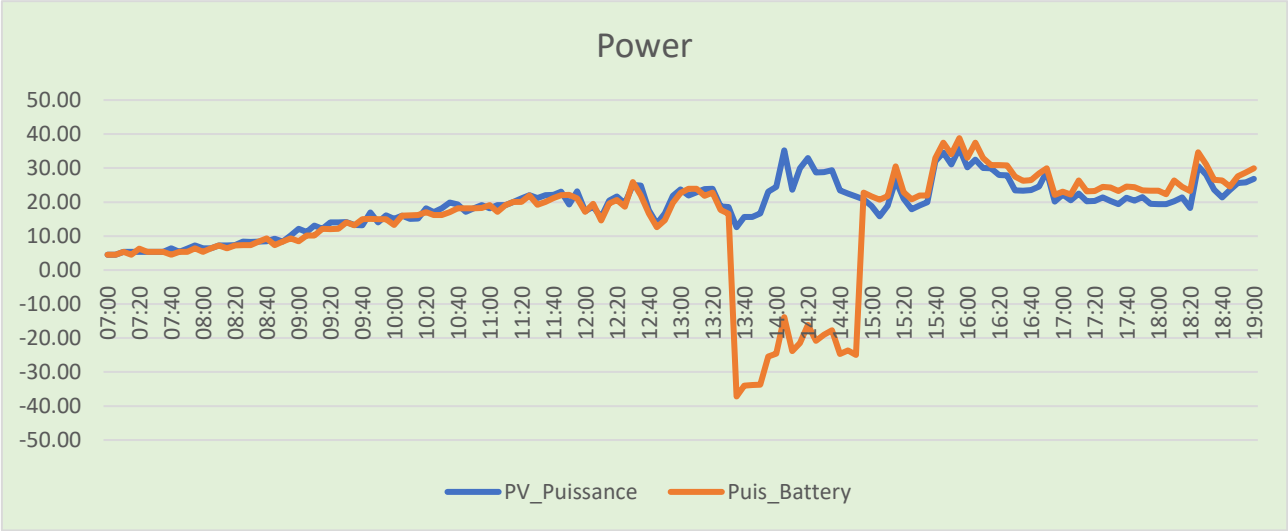

FIGURE III. 8: POWER CURVE

2.4 Temperatue and Radiation Curves:

We note that the temperature and radiation are the same as the curve at the beginning of the day was 26° at 7:00 AM, corresponding to 232w/m², the temperature reached a maximum value of 14:48 57°, and the light intensity also reached 963W/m² at 13:00.

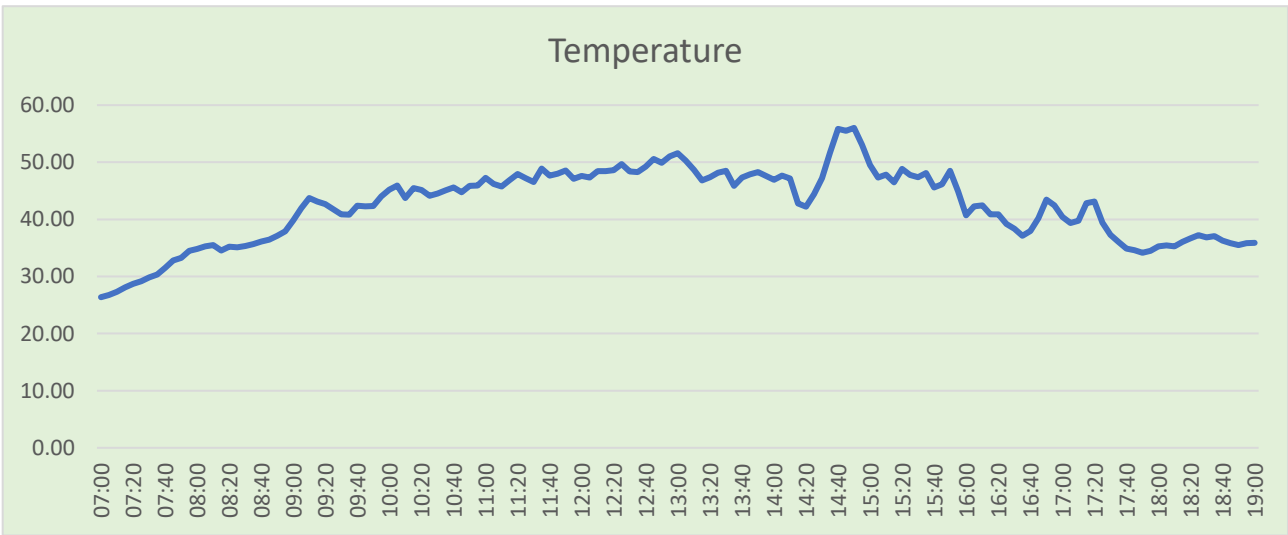

FIGURE III. 9: TEMPERATURE CURVE

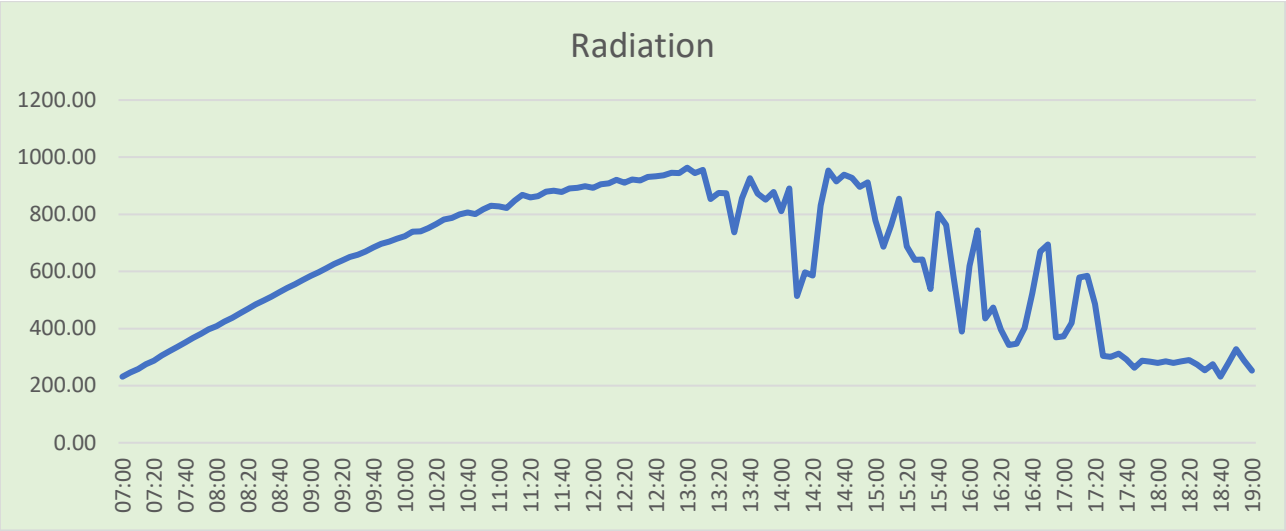

FIGURE III. 10: RADIATION CURVE

III.3 Conclusion:

In this chapter, we explained the curves of the Parameter voltage, current, and temperature of the Solar Panel and voltage, current of the Battery. We obtained them through the memory card, and we created the curves in Excel.

General Conclusion:

Through this cheap cost project, we designed a system to monitoring the data of the solar system (solar panel + battery), we took into account the characteristics of the solar panel and the characteristics of the UNO Arduino board. We have provided the Arduino Uno board with the following: a MAX6675 temperature sensor, two B25 voltage sensors, two ACS712 current sensors, a MICRO SD card adapter, and an LCD screen. Through this installation, we aim to measure (the temperature of the solar panel, the voltage of the solar panel, the battery voltage, the current strength of the solar panel, the strength of the battery current) and present it by the LCD screen and the Excel program. In order to monitor the performance of the solar panel, the results we get are excellent, the system works well and it is scalable.

It was part of our work plan to improve this system by equipping the Arduino board with a Wi-Fi adapter, and programming a web page in html so that we connect it to the Arduino via Wi-Fi, this enables us to access the web page from anywhere and see the data in real time, we hope that we can develop this system in the future.

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