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PRINCE MOHAMMAD BIN FAHD UNIVERSITY

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Senior Design Project Report

Utilizing Al_2O_3 nonsolid particles to enhance the efficiency of hybrid photovoltaic/thermal (PVT) system

Team 16

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Abstract

This project will address the enhancement of the overall efficiency of the hybrid photovoltaic thermal (PVT) system by utilizing nanosolid particles of Al_2O_3 that will be dispersed in the base fluid of water. The study will be conducted experimentally and important measurements of the irradiance, inlet and exit nanofluid temperatures and the output power of the PV system will be shown and analyzed. Moreover, the impact of the nanosolid particles volume fraction on the performance of the hybrid system will be discussed and analyzed.

Acknowledgments

We would like to thank our advisor Dr. Wael Al-Kouz and the Co advisor Eng. Faizan Ahmed For feeding us their knowledge, comments, also providing suggestions when we need them anytime a day through the project. A special thank for Dr. Faramarz Djavanroodi for contacting the suppliers and providing information about some devices that we need.

List of symbols:

Symbol	Definition
T	Temperature
P	Density
K	Thermal conductivity
Cp	Heat capacitance
Ø	Volume fraction
$\dot{m}$	Mass flow rate
G	Irradiation
A	Area (collector)
I	Current
V	Voltage
η_0	Overall efficiency
η_T	Thermal efficiency
η_E	Electrical efficiency
M	Mass

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Chapter one: introduction

1.1 Definition

Solar energy becomes one of the most important renewable energy resources in the last few decades, due to its wide applications; one of these applications is the Photovoltaic / Thermal (PVT) hybrid system in which a combination of electric energy and thermal energy of such a system are gained. The extra heat that will affect the PV panel efficiency will dissipated to the fluid that is moving in the heat exchanger integrated at the back of the PV panel, so the fluid is heated and the PV panel is cooled and consequently better performance is achieved. The goal of this project is to enhance the overall efficiency of the hybrid PVT system by utilizing nanosolid particles, namely Al_2O_3 dispersing them in the water base fluid. Effects of irradiance, ambient temperature, nanosolid particles, and volume fracture on the PVT overall efficiency will be analyzed by conducting experiments. The experimental setup is to include the following:

1- PV panel

2- Batteries

3-Steel structure

4- Nanosolid particles

5- Measurement devices

A. thermocouple

B. Flow meter

C. Irradiance meter

1.2 Objectives

The main objective of this project is to enhance the overall efficiency of the hybrid system that combines both of the electric and thermal efficiency. In order to achieve the objective of this project, experimental setup is needed such that the stand-alone PVT hybrid system is going to be built in the house with all the measuring devices built and installed. Accurate measurements of important data such as irradiance, nanosolid temperature in, nanosloid temperature out, surface temperature of the PV panel are going to be recorded. Finally, a detailed analysis of the data will be provided and discussed thoroughly.

Chapter two: Literature Review

2.1 Project Background

Renewable energy harnessing is one of promising methods for meeting the increasing demands of energy. Conventional sources of energy such as fossil fuels (oil, gas, petrol) are very expensive and they are limited. Poor countries which do not afford these conventional energy resources can rely on renewable energy resources. Energy from sunlight, water waves in ocean, wind, geothermal heat, biomass are few sources which can be used to fulfill demands of energy necessary for daily needs. Sunlight is the most abundant energy resource available. It can be used for heating purposes.

It can also be converted directly into electricity using photovoltaic cells. But photovoltaic system has some inefficiency. Increase in cell temperature reduces cell efficiency. In hotter areas and in summer season, this can cause a significant loss of energy which could be obtained if temperature does not rise. Due to this, Photovoltaic cells are combined with a thermal system to make a hybrid photovoltaic/thermal solar system. Different types of PVT collectors are used in this system. Based on the fluid such as water or air for cooling of cells, these systems differ in efficiency. In this project, use of nano-fluid is shown to improve the efficiency of a hybrid photovoltaic/thermal solar system.

2.2 Previous work

Solar cells can only convert light coming from the sun into electricity. It does not use the heat coming from the sun. This heat energy is wasted. So only half of sun's energy is being converted, the rest is wasted. This heat when falls on solar cell, increases the temperature of cell. One drawback of photovoltaic cells is that there efficiency decreases with increase in temperature and it will not produce the actual output, it should produce. The efficiency decreases up to 25% due to rise in temperature.

To reduce such inefficiency, use of nanotechnology can remove the excess heat from the system and this extracted heat can be used for other purposes. Nano-fluid is a fluid which can be used to remove heat from photovoltaic cells. These nano-particles when used with base fluids can increase the thermal conductivity of fluid and in turn increases heat transfer coefficient. This can improve efficiency of such system. Nano-fluid contains particles of size ranging from 1 to 100nm. These nano-particles are mixed into base fluids.

Nano-particles usually used are made of metals, oxides, carbides or carbon nano-tubes. Base fluids can be water, ethylene glycol, oil etc. Nano-particles of metal oxide Al_2O_3 is dispersed in base fluid of water for this project. Dispersing nano-fluid into PVT systems is a very good way of improving the overall efficiency of such systems. For example, Al-Waeli et al.[1] inquired using experiment that the use of nano-fluid Silicon Carbide as a base fluid for a PVT system. It concluded that dislocating these particles which are actually nano-solids into the system would better the value of overall efficiency. Albeit, they formulated that the PVT system performs very better than the PV stand-alone system. Another researcher, Tzivanidis et al.[2] inquired about the yearly performance of a hybrid PV operating with Copper or water as nano-fluid. It was found out that using nano-fluid will enhance the overall efficiency compared with using only water as a working fluid. Moreover, Radwan et al.[3] researched the productivity upgrade of low focused PVT frameworks utilizing Al2O3/water and SiC/water nano-liquids in a miniaturized scale channel. Their outcomes demonstrate that utilizing nano-liquids will diminish the board cell temperature all the more productively contrasted and utilizing just water as the working liquid. It was additionally presumed that utilizing SiC/water nano-liquid is better the extent that the cell temperature is concerned.

Stand-alone system for this project includes solar panels and batteries with a solar charge controller. Behind the panel, copper tubes are integrated which are connected to a tank having a mixture of water and Al_2O_3. The fluid flows in the tubes by a pump. Cold nano-fluid enters at the inlet of tube behind the panel and absorbs heat and hot nano-fluid comes out the tube at the outlet. It then enters a cold storage tank and the cycle is repeated. The serious issue in PV is the aggregation of warmth, which diminishes the electrical presentation clearly; in this way, heat must be scattered. In Iraq, the issue turns out to be much genuine, due to a sweltering climate in the vast majority of the year; this makes the electrical effectiveness of PV cells to diminish with the expansion of the warmth inside the PV cells. The dynamic answer for this issue can be utilizing a water-cooling procedure to diminish the warmth impacts by moving the warmth to the water which can be utilized in numerous applications as a boiling water. Warm conductivity improvement can be accomplished by utilizing nano-fluid applications, for example, Zn-H_2O. The creativity of their work is the utilization of another structure of a cooling system including copper channels set on PV back surface to ingest the warmth aggregated inside the PV cells. This point was accomplished through assessment of the presentation of photovoltaic boards under various working conditions, upgrade of the electrical and warm execution for the photovoltaic/warm framework with water siphoning framework at various water mass stream rates, and contemplating the impact of utilizing nano-fluid (Zn) as a working liquid in water-circling channels at various fixation proportions (0.1, 0.2, 0.3, 0.4, and 0.5).

2.3 Comparative studies

In this section we will show different studies

- **Improving the Hybrid Photovoltaic/Thermal System Performance Using Water-Cooling Technique and Zn-H_2O Nanofluid.** Hashim et al[4].

This paper introduced the improvement of the presentation of the photovoltaic boards under Iraqi climate conditions. The most serious issue is the warmth put away inside the PV cells during activity in summer season. The photovoltaic/warm framework was worked under dynamic water cooling method. The temperature dropped from 76 to 70°C.

The varieties in sun oriented radiation for the most part impact the yield current, while the adjustments in temperature basically influence the yield voltage. Mixture PV/T frameworks are one of the strategies used to upgrade the electrical effectiveness of board at that point improve the photovoltaic water siphoning framework execution.

The electrical and warm efficiencies of the cross breed framework will increment with expanding mass stream pace of water. At ideal stream pace of 2 L/min, electrical proficiency was 6.5% and warm productivity was 60%. The outcomes showed that when nanofluid (Zn) is utilized at different focus proportions (0.1, 0.2, 0.3, 0.4, and 0.5%) at 2 L/min stream rate, the cell temperature dropped all the more fundamentally from 76°C to 58°C at an ideal fixation proportion of 0.3% nanofluid; this prompted an expansion in the electrical productivity of PV board to 7.8%.

Performance of a hybrid photovoltaic/thermal system utilizing water-Al2O3 nanofluid and fins. Montasir et al. [5]

Creative half breed sun powered boards consolidating photovoltaic cells alongside an effective warmth exchanger with connected balances to the parallel plates and water-Al2O3 nanofluid as a working liquid is introduced in this work. Numerical limited component examination utilizing COMSOL programming is used to research stream and warm qualities also the general productivity of the half and half framework.

Results demonstrate that as the Reynolds number, the length of the balance, and the volume division of the nanosolid particles increment, the general proficiency increments. Besides, expanding nanoparticle volume part and the balance length was found to build the erosion coefficient.

- **Photovoltaic Thermal /Solar (PVT) Collector (PVT) System Based on Fluid Absorber Design: A Review.** Tamaldin et al.[6]

This paper means to survey the headway and progress in the field of PVT gatherer dependent on water liquid. The survey explored different research articles by examining their proposed structures of PVT authority and safeguard. Diverse PVT authorities and safeguards setups are introduced and talked about. The examination reasons that water-based PVT are broadly utilized and produce improved productivity when contrasted with the air-based PVT.

url: In this project, a study is performed experimentally to improve the heat transfer through the system and to use the clean energy for protection of environment. Measurements of irradiance, inlet and exit nanofluid temperatures and the ouput power of system is shown. The impact of nano solid partcles volume fraction on the performance of system is analyzed.

Chapter 3: system design

3.1 Design constraints and methodology

Geometric Constraints

Photovoltaic cells are very small in size and generate very low power. To obtain a useable amount of energy from such cells, it is important to combine many such cells so their collective energy can be harnessed. There are a few configurations by which PV cells can be combined.

Engineering standards

There are three standard testing conditions to check the performance of a photovoltaic cell whether it generates the estimated amount of power. Their output significantly depends on two parameters.

First is temperature, second is irradiance.

Voltage decreases with an increase in temperature. This means that these cells have a negative temperature coefficient. Most solar cells are designed for a 25-degree centigrade temperature.

Current produced by the incidence of light on the solar cell is dependant upon the amount of irradiance. Voltage variation does not depend upon irradiance. Solar irradiance for design purposes is taken to be 1000 watts per square meter.

Sustainability

For solar cells to work for a longer time, the cleaning of panels should be done so power output does not get affected much.

Environmental

These systems are environmentally friendly. The only chemical used is in the fluid, having solid nanoparticles in it. This system is enclosed and does not cause any harm to the environment.

Economic

The operating cost for such systems is not much. But when these are compared with electricity generated by coal or other fuels, it is not economic at larger scales. But for smaller scales, these systems are economically feasible.

Manufacturability

From a manufacturing point of view, solar cells are costly and are not very attractive for large scale energy demands.

3.2 Engineering Design Standards

There are various standards available for installation and safety-related aspects of photovoltaic systems. Few international standards are shown below.

ASTM E44, ISO TC180, IEEE SCC21, SEMI etc.

SEMI standards are very useful when manufacturing of either semiconductor or photovoltaic systems needs to be considered.

Building codes can be used for consideration of structures and buildings while installing solar systems so that the public in the surroundings does not get affected in any adverse manner. Sometimes, wind can become a problem and it is important to consider that the

PV system is safe from damaging effects of wind. The danger of fire due to heat up or due to electric sparking needs to be considered to ensure the safety of people around.

NEC (National Electric Code) gives information regarding the handling of conductors and wires for such systems.

3.3 Components

The selection of components of this photovoltaic system is given as

Solar panel

A solar panel consists of an arrangement of arrays of solar cells in a certain configuration. Both the solid works model of the solar panel and the plate we are going to use in the figure below:

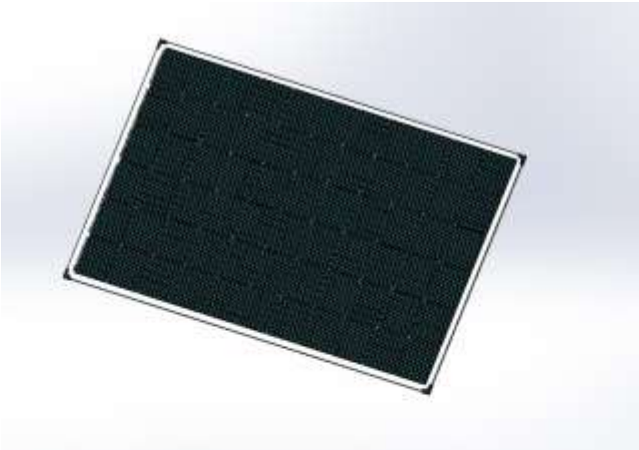

Figure 3.1

Figure 3.2

Stand

For the mounting of the panel, a steel structure for one panel is used. Stand will be sued to mount the copper wires and then the Photo-Voltaic cell on it. The model of stand and the copper wire mounted on it can be shown form the solid works model given below.

Figure 3.3

Copper tubes

Tubes of metallic copper are used for the flow of fluid which will take heat away from the panel. Copper tubes are shown in the figure below:

Figure 3.4

Cooling tank

The purpose of the cooling tank is to take the heat of hot fluid coming from the panel side. This will make the fluid to be able to take heat again during the next cycle. Copper tube in the form of a coil passes through the cooling tank. Cooling tank in which copper wires are swirled is shown below:

Figure 3.5

Solar Charge Controller

It is a type of controller or regulator used to control the flow of electricity from solar panels to the battery. It regulates the amount of voltage and current. Solar charge controller ((Phocos 10 Amp) is used.

Figure3.6

Battery

The purpose of the battery is to store electrical energy generated by a solar panel. 12 volt, 100 Ah battery is used.

Figure 3.7

MC4 connector

These are commonly used for connecting solar panels. These are single-contact electrical connectors. MC stands for multi-contact and 4 means 4 mm diameter contact pin.

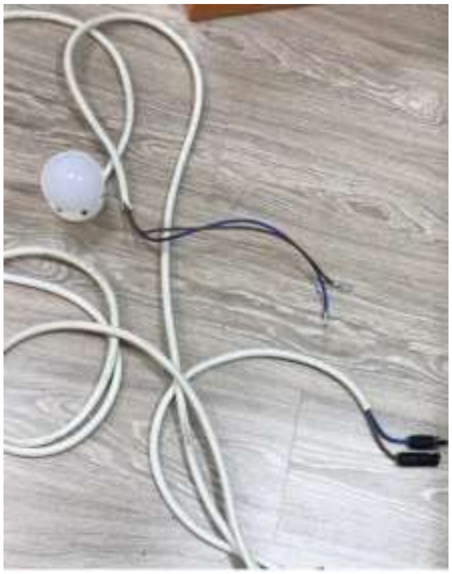

Figure 3.8

Nanoparticles

Solid nanoparticles of aluminum oxide are mixed with water. Water acts as a base fluid. This mixing is done to increase the thermal conductivity of water so more heat could be extracted from the panel. It is the main element in increasing the efficiency of this system.

Figure 3.9

Pump

The function of the pump is to move the water from the tank to the whole cycle through the tube.

Figure 3.10

3.4 Manufacturing and assembly

Safety factors need to be considered during the assembly of components. A solar panel is mounted on the steel frame which holds the panel. Before attaching a panel with stand, copper tube in a zig-zag manner is attached to the frame. The panel must be at an angle with the horizontal surface. It must not be placed in a flat manner because this can affect the amount of light incident on the panel. Upon copper tubes, the panel is attached and is in direct contact with tubes so that heat from the panel is transferred to the tube. The copper tubes are passed through a cooling tank in the form of a coil. The fluid flows into the copper tube with the help of a small pump. The steel frame has to be fixed with the surface on which it stands so it must hold the panel firmly in one place.

The solid works model for the assembly is shown below. It comprises of all the parts explained above in detail:

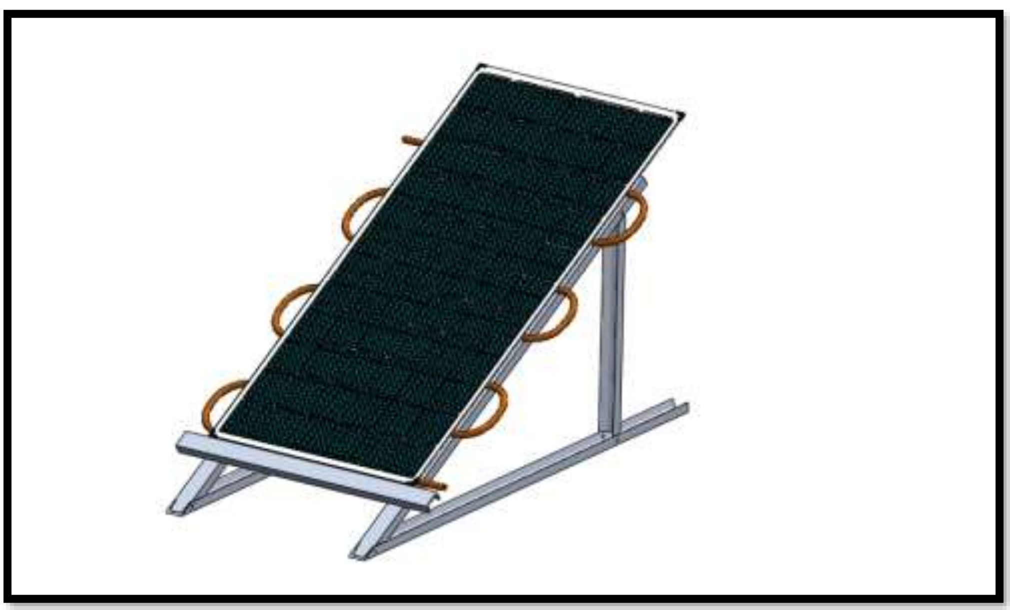

Figure 3.11

The introduction of fluid containing nanoparticles is to be done carefully. The fluid must not leak from the tube at any location along the pipe. The pressure in the pipe should be monitored and the flow of fluid in the pipe must not be too high that it might affect the heat extraction and lower the efficiency.

The solar panel is connected with the battery and solar charge controller. All the electrical components must be properly connected. Care has to be taken during connecting wires to avoid any kind of short circuit or sparking.

The assembly of real-time model is shown below:

Figure 3.12

3.5 Theoretical calculation:

- Density: $\rho_{nf} = (1 - \emptyset)\rho_f + \emptyset\rho_s$
- Heat capacitance: $Cp_{nf} = (1 - \emptyset)(Cp)_f + \emptyset(Cp)_s$
- Thermal conductivity: $k_{nf} = k_s \frac{k_s + 2k_f - 2\emptyset(k_f - k_s)}{k_s + 2k_f + \emptyset(k_f - k_s)}$
- Electric efficiency: $\eta_E = \frac{P_{E\,out}}{P_{in}} = \frac{I * V}{G * A_{collector}}$
- Thermal efficiency: $\eta_T = \frac{\dot{m} * C_P(T_0 - T_i)}{G * A_{collector}}$
- The overall efficiency of hybrid solar PVT system: $\eta_0 = \eta_E + \eta_T$
- Volume fraction $\emptyset = \frac{\frac{m_n}{\rho_n}}{\frac{m_n}{\rho_n} + \frac{m_f}{\rho_f}}$

Chapter 4: System Testing and Analysis

4.1 Experimental Setup and data acquisition system

In this section I will explain the instrument that I used in order to conduct the measurement:

1. **V-Resourcing Non-Contact LCD Laser Infrared Digital Temperature Gun**

In this part, we measured the temperature in three different parts of the system using this device.First, measure the inlet temperature to the system by placing the device at the inlet of copper tube heat exchanger. Second, measure the outlet temperature from the system by placing the device at the outlet of copper tube heat exchanger. Finally, measure the solar panel surface temperature that by placing it on the surface of the solar panel. In addition, sometimes the water temperature is measured in the tank.

Specification

- Measures in Celsius or Fahrenheit mode with temperature range: -50 C° to 380 C° /-58 °F to 716°F with (± 1.5 C°) instrumental error.
- Easily handle: simply point at what you want temperature recording for and pull the trigger, temperature data show on the LCD screen immediately.
- Distance Spot Ratio: 12:1, and Response Time with 500ms for instant Result Readout.
- Power Type: AAA Battery (not included)
- Display Type: Digital
- Model Number: Infrared Thermometer
- Built-in red laser for precisely aiming.
- Auto Power Shut Off in 7 seconds without any operation; Low electricity consumption.

- Suit for the temperature measuring and monitoring of hot water pipes, hot engine parts, cooking surfaces, hot tubes insulation, juice coolers hot asphalt, swimming pools, air conditioning

Figure 4.1 laser thermometer

2- TES solar power meter

In the second part of the experiment, the reflected sunlight on the solar panel was measured by placing the device perpendicular to a certain angle above the solar panel. Solar energy is measured by a sensor located at the top of the device, which is very sensitive to light. In addition, It gives many readings in less than a second, and also if the required solar meter is selected just click on the hold button and the purpose of that is to saves the required reading on the device screen. The device readings depend on the angle at which the device is placed above the panel.

Specification:

- Display: 3-1/2 digits.Max.indication1999
- Range:2000W/m 2,634Btu/(ft 2 * h)
- Resolution:1W/m2.1Btu/(ft2*h)
- Spectral response: 400-1100nm.

- Accuracy: Typically within ± 10W/m2 [±3 Btu / (ft2*h)] or ±5%, whichever is greater in sunlight; Additional temperature induced error ±0.38W/m2 / C [±0.12 Btu / (ft2*h)/ c] from 25 C°
- Angular accuracy: Cosine corrected: 5% for angles <60 Calibration “User recalibration available Over-input: Display shows"

Figure 4.2 solar power meter

3- Fluke 325 Clamp Multimeter AC-DC TRMS

In this part, this device is used to measure the electric current produced by the solar radiation falling on the solar panel by converting solar energy into electrical energy. The electrical current goes through positive and negative wires are connected to the battery. The current is measured by placing the device around the wire that connected to the battery without touching the wire. The electrical current is measured by the electrical frequencies coming out of the wire and is read by sensitive sensors designed in the red ring of the device. In addition, the current is converted to DC while taking measurements

<u>Specification</u>

- Digital clamp meter measures AC current to 400 amp, AC and DC voltage to 600V, and resistance to 4 kilo ohms
- True RMS sensing meter provides accurate readings when measuring linear or non-linear loads, regardless of waveform
- Jaw opening measures current in a conductor up to 30mm without touching or interrupting the circuit
- Audible continuity sensor confirms that the circuit conducts electricity
- Meets IEC safety standard 61010-1, and is rated for CAT IV installations to 300V and CAT III installations to 600V
- 400 A AC and DC current measurement
- Resistance measurement up to 40
- Ac voltage make for the most accurate measurements on non-linear signals
- Temperature and capacitance measurement
- Frequency measurement

Figure 4.3 Clamp Multimeter

4-solar charge controller

This device was used to control the electrical charges entering the system so that if the battery is low this device allows the entry of electrical charges to the battery to be charged. Also, it does not allow charges to enter the battery in case of fullness.added to that, this device is connected to MC4 connecters that is connected to the behind of the solar panel and connected to the battery as mentioned earlier. Further, the function of this device is to measure the voltage produced by the conversion of solar energy into electricity and shows the measurement through the digital screen and it also shows the battery charge percentage.

Specification

- Rated working current:20A
- Rated working voltage:12V/24V
- Solar input voltage:<55V
- Over voltage protection:17V; *2/24V
- Float charging voltage (adjustable):13.8V;*2/24V
- Over-discharge recovery voltage:12.6V*2/24V
- Charging recovery voltage: 13.2V;*2/24V
- Max. Voltage at the battery end:<35V

Figure 4.4 solar charge controller

5- Ambient temperature measurements:

The ambient temperature was measured during the project by an application called Weather Link .The application was relied on throughout the project, and the reason for relying on this application because the university has a weather station and the station is located in the roof of the faculty of engineering, and was linked the mobile to the PMU weather station via the application. This station is accurate in measurements and better because it is located in the same place of taking measurements.

Figure 4.5 Ambient temperature station

Table 4.1 measurements devices objectives

Testing devices	Objective
V-Resourcing Non-Contact LCD Laser Infrared Digital Temperature Gun	To measure the inlet , outlet and surface temperature
TES solar power meter	To measure sun light radiation
Fluke 325 Clamp Multimeter AC-DC TRMS	To measure the current in the system
Solar charge controller	To measure the voltage in the system
Weather Link application	To measure the ambient temperature

Measurement procedures were taken from early morning to evening, meaning that they are taken from sunrise to sunset. There are two types of measurements that were taken for the system, first type which is adding water only and the second type is adding a water with aluminum oxide (Al_2O_3) nanoparticles together and also each had a certain time to take measurements. Further, water measurements were taken from 10 AM to 3:30 PM and it is taken every ten minutes from the beginning of the scheduled time to the end. Several measurements of the system were taken it is the sun radiation measurement (I_{rr}) that is falling on the solar panel and the voltage measurement (V) that is resulting from the conversion of solar energy to electrical Also, the electric current (I) was measured and the water temperature entering (T_{in}) and leaving (T_{out}) the system was as well measured . In addition, solar panel surface temperature (T_{sur}) measurements and ambient temperature (T_{amb}) measurements were taken. This process was repeated for two days using the mentioned measuring parameters. As well after was moved to the next stage that aluminum oxide (Al_2O_3) nanoparticles has been added to the water in the tank, and it forming a chemical compound and this is the main focus and important factor in the project. Moreover, Aluminum oxide has been added in different quantities in each day, starting with the volume fraction Ø=0.1% and Increase the quantity up to Ø =0.2% volume fraction in next day and that was the upper limit. Therefore, these measurements took two more days and the total days were four days of taking all measurements needed in this project .Next, the purpose of this is to compare its effect on efficiency raising in the system and how efficiency is raised depending on which factor that used in the system. All measurements has been taken in the system are important and have not been developed without any reason and It was used to determine efficiencies in the system thermal system, electrical efficiency and overall efficiency that is a combination of electrical and thermal efficiency together.

4.2 Results, Analysis and Discussion

4.2.1 Thermal efficiency

In this section we will analyses the thermal efficiency and we get that thermal efficiency is increased after adding the (Al_2O_3) nanoparticles by 0.1% and0.2%:

Table 4.2 thermal efficiency

Time	Thermal efficiency φ=0%	Thermal efficiency φ=0.1%	Thermal efficiency φ=0.2%
10:00	18.78764216	10.89642074	14.7507112
10:10	6.145347714	17.08958526	68.23433101
10:20	8.215406132	18.78573252	35.43293536
10:30	7.916528443	34.09933327	53.86532682
10:40	11.77580094	17.68480556	29.27358558
10:50	7.685050297	13.44886326	39.68346641
11:00	8.339285739	13.75160401	33.83706979
11:10	6.405797038	19.10138322	32.59231132
11:20	7.825895964	12.45349799	38.92055577
11:30	12.90772498	17.35405714	21.33247109
11:40	9.298931792	20.73299528	44.82340498
11:50	13.12223459	38.15040741	28.72863915
12:00	22.01077426	35.6976	37.1002085
12:10	16.49552796	29.2703755	35.1135367
12:20	11.42693847	28.34735037	36.58640679
12:30	10.23373835	34.58112838	28.77172274
12:40	18.75912229	31.60413659	50.14195409
12:50	15.73581658	25.01967297	28.83697053
13:00	21.55020329	22.1561959	41.3305466
13:10	18.27508408	26.26830103	30.16890203
13:20	13.0740493	37.57300057	32.26056185
13:30	17.79773691	33.14846375	76.42357988
13:40	17.09467371	50.83377876	42.39406411
13:50	18.99120539	33.27213578	64.3448197
14:00	15.1946008	26.13277508	36.27452068
14:10	18.93413008	24.85514638	45.8699977
14:20	22.05623772	20.70303409	27.44404989
14:30	8.975230525	21.06450466	62.39748825
14:40	8.614526292	19.45977956	47.91172551
14:50	18.58619705	13.93143309	62.14738767
15:00	12.66862613	28.13221884	29.07917069

15:10	8.691389424	38.32289435	31.11221574
15:20	25.14329714	14.7589207	12.59194451
15:30	15.13529865	18.73833933	23.92511361

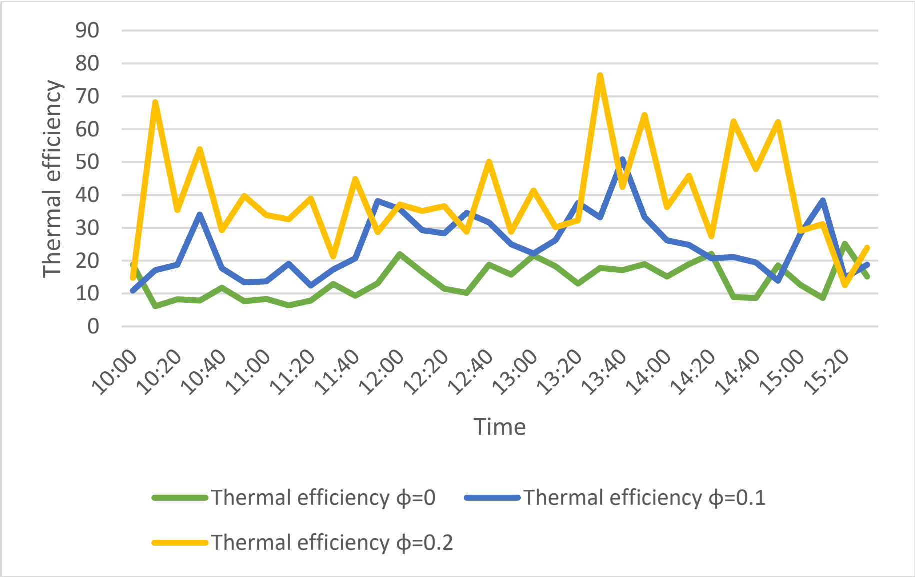

Figure4.6 Thermal efficiency

In this graph the slopes raising and falling is shown are the comparison of thermal efficiency in the three cases first, by adding water only Ø =0 % volume fraction means no (Al_2O_3) nanoparticles added and after that also is adding (Al_2O_3) nanoparticles by Ø = 0.1% volume fraction and adding Ø=0.2 % volume fraction in the last stage.further, It is evident at the beginning of the test that the efficiency is not high enough and when start in adding of aluminum oxide (Al_2O_3) to water efficiency start rises smoothly depending on the amount of aluminum oxide (Al_2O_3) that is placed and also the factors affecting the surrounding, for example, the ambient temperature and solar radiation is the most important factors because when ambient raises above 35 C° it may decreases efficiency of the solar panel and in that temperature it reach the maximum cells efficiency .And these are the specifications on which solar panels are made in most of the world international standard but in our project the maximum temperature we reach is 28 C° that's mean the result it will be in a good shape. However, the results reached the maximum thermal efficiency in water measurements Ø =0 % and percentage was 25.2% at 15:20 PM and the ambient temperature (T_{amb}) =24.5 C° and we get this temperature depend on the average ambient temperature between the two days. Also it was in the first day 23 C° and 26 C° in the second day added to that, surface temperature (T_{sur}) it was 30.7 C°. On the other side, (Al_2O_3) nanoparticles was added by Ø = 0.1% volume fraction and the maximum percentage reached was 50.8% at 13:40 PM and the percentage was raise by 25.6% than the previous percentage and also the (T_{amb}) =27C° and the surface temperature (T_{sur}) =45.4C° the percentage is raising about 14.7% the percentage increase is good. As a result of this, when we added (Al_2O_3) in water it increases the efficiency and this is a function of this element. Finally, (Al_2O_3) nanoparticles was added by Ø = 0.2% volume fraction and the maximum percentage reached was 76.4% at 13:30 PM and the percentage was raised by 25.6% this percentage is considerably increased from the previous .in addition this is the goal that we aspired to reach. also it was the (T_{amb}) =28 C° and the surface temperature (T_{sur}) =64.4 C° and it was raise about 19% comparing with the previous one. In conclusion, when adding or increasing the amount of (Al_2O_3) nanoparticles it results in an increase in thermal efficiency of the system. Proof of this is that the slopes in the graph started from low to high level after adding nanoparticles.

4.2.2 Overall efficiency

In this section we will analyses the overall efficiency and we get that overall efficiency increased after adding the (Al_2O_3) nanoparticles by 0.1% and0.2%:

Table 4.3 overall efficiency

Time	Overall efficiency φ=0%	Overall efficiency φ=0.1%	Overall efficiency φ=0.2%
10:00	26.04444547	13.57273461	16.33271399
10:10	13.98277849	18.58786573	69.39993872
10:20	14.54253522	20.12233922	36.2058938
10:30	14.15401988	35.34069345	54.87925674
10:40	19.02515683	18.94357368	29.95029927
10:50	13.38273525	14.69849772	40.65417563
11:00	15.11344036	14.9828426	34.98908414
11:10	11.96112405	20.64355677	33.6689284
11:20	12.81200485	14.012433	40.0425427
11:30	17.81823761	18.98851128	22.50053082
11:40	14.19492751	22.36629633	46.0280888
11:50	18.78713254	39.85505826	30.03745898
12:00	26.18122638	36.53330936	38.11705632
12:10	20.42208085	32.77214993	35.94953178
12:20	15.31666405	29.20712727	37.55762538
12:30	15.06910057	35.76758428	29.59246846
12:40	23.53329019	32.92290081	51.15631679
12:50	19.61129897	26.48554891	29.79410964
13:00	25.4609705	23.50762441	42.39301778
13:10	22.80636932	27.81575426	31.12072016
13:20	18.2652738	39.1099161	33.22877026
13:30	21.93550356	34.7714246	77.50453285
13:40	21.27708492	52.47415078	43.44494962
13:50	23.18230118	35.19215517	65.44810837
14:00	20.53865296	27.85569799	37.45045387
14:10	23.75325914	26.59151033	47.52467736
14:20	31.88487396	22.59206824	29.03522199
14:30	14.54715594	23.03793602	63.92748832
14:40	16.82381572	21.51687045	49.54129513
14:50	29.05410965	17.88444329	63.82754933
15:00	21.37214546	30.43975019	30.99343842
15:10	15.84061114	40.63781345	33.41103379
15:20	35.82765077	17.25518259	14.99029105
15:30	21.22116345	21.49800618	25.64300699

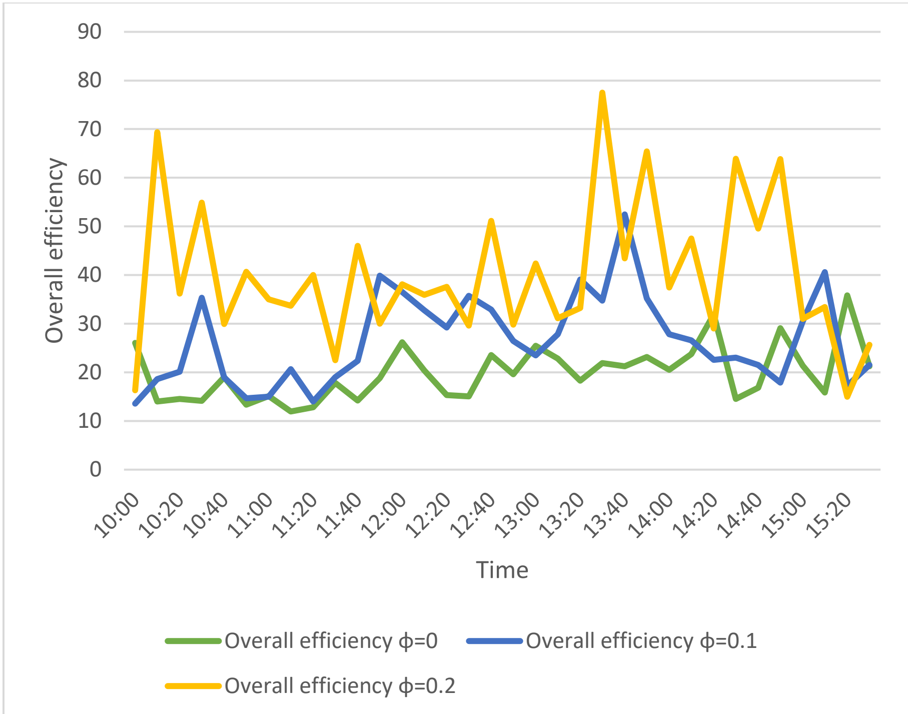

Figure4.7 Overall efficiency

As shown in the diagram there is a comparison between the results reached is a combination of the overall efficiency which combines electrical efficiency with thermal efficiency together. The calculations show that the overall efficiency of water Ø =0 % is maximum reached 35.8% at 14:50 PM further, the surface temperature is reach (T_{sur}) = 30.7 C° and the ambient temperature (T_{amb}) =24.5 C° and we get this temperature depend on the average ambient temperature between the two days. Also it was in the first day 23 C° and 26 C° in the other day. Moreover, in the second scale (Al_2O_3) nanoparticles was added by Ø = 0.1% volume fraction the maximum percentage reached 52.5% at 13:40 PM and it raise about 16.7% than the previous percentage. Likewise, the ambient temperature it was (T_{amb}) =27 C° andefficiency naturally gives positive indications because the ambient temperature is in the reasonable range and as for the surface temperature it was (T_{sur}) =45.4 C° the percentage is raising about 14.7% the percentage increase is good as was discussed in the previous part. Lastly, (Al_2O_3) nanoparticles was added by Ø = 0.2% volume fraction and the maximum percentage reached was 77.5% at 13:30 PM and the percentage was raised by 25% this percentage is considerably increased from the previous. in addition this is the goal that we aspired to reach. also it was the (T_{amb}) =28 °C and the surface temperature (T_{sur}) =64.4 C° and it was raise about 19% comparing with the previous one also as discussed in the previous part. When adding aluminum oxide increases efficiency even if not by much but does not decrease and increase it depends on the application on which the experiment is working on it.

Chapter 5: Project Management

5.1 Project Plan

There are many takes in our project, so we distributed the tasks between our team. Table 5.1 and 5.2 shows the task distribution and duration for each task.

Table 5.1

#	Tasks	Start	End	Duration
1	Chapter 1: Introduction	25 / 9 / 2019	27 /9 / 2019	2
2	Chapter 2: Literature Review	27 / 9 / 2019	2 / 10 / 2019	7
3	Chapter 3: System Design	5 / 10/ 2019	29 / 10 / 2019	24
4	Chapter 4: System Testing & Analysis	15 / 11 / 2019	26 / 11 / 2019	14
5	Chapter 5: Project Management	26 / 11 / 2019	30 / 12 /2019	4
6	Chapter 6: Project Analysis	30 / 12 /2019	4 / 12 /2019	4
7	Design of Prototype	18/09/2019	22 / 9 / 2019	4
8	Parts Purchase	22/09/2019	09/10/2019	19
9	Testing	15 / 11 / 2019	26 / 11 / 2019	14

5.2 Tasks distribution table

#	Tasks	Assigned Members
1	Chapter 1: Introduction	All team
2	Chapter 2: Literature Review	Amer
		abdulaziz
3	Chapter 3: System Design	Nawaf
		Amer
4	Chapter 4: System Testing & Analysis	Abdulaziz
		Nawaf
5	Chapter 5: Project Management	Amer
		Abdulaziz
6	Chapter 6: Project Analysis	All team
7	Design of Prototype	All team
8	Parts Purchase	All team
9	Testing	All team

5.2 Contribution of Team Members

In this project the tasks was disrupted equally between team members. Most of the tasks was completed by all the team working together. However, the other tasks was assigned for one or two of the team members. Table 5.3 shows the tasks assigned to the team members.

Table 5.3

#	Tasks	Assigned Members	Cont. %
1	Chapter 1: Introduction	All team	100%
2	Chapter 2: Literature Review	Amer	50%
		abdulaziz	50%
3	Chapter 3: System Design	Nawaf	50%
		Amer	50%
4	Chapter 4: System Testing & Analysis	Abdulaziz	50%
		Nawaf	50%
5	Chapter 5: Project Management	Amer	50%
		Abdulaziz	50%
6	Chapter 6: Project Analysis	All team	100%
7	Design of Prototype	All team	100%
8	Parts Purchase	All team	100%
9	Testing	All team	100%

5.3 Challenges and Decision Making

In our project we face a few problems that has affected the progress of the project. There are two problems that we had which is mixing nanoparticles, and the pump.

There are two ways to mix the nanoparticle in the water but the best way is by using ultrasonic vibration. But this device was very costly and we couldn't afford to purchase it. The other option was mixing the nanoparticles manually by a steel mixer. But before we start testing the system one the groups was facing the same problem and they found a way to mix it by using connecting the steel mixer to a drill machine. So we barrowed it from them during our system testing.

At the beginning we struggled finding the pump that our system required but after a while we found one. However, the pump was DC and we didn’t know so when we plugged the electrical wires directly to the power source it's ruined the pump and we had to buy a new one with adapter that convert the DC system to AC.

5.4 Project Bill of Materials and Budget

Table 5.4 shows each part of our system and how much it cost.

Table 5.4 Project Bill of Materials and Budget

Parts	Costs(SR)
PV panel	2800
Charge controller	
Battery	
MC4 connector	
Aluminum structure	
Water tank	100
Copper tubes	90
Pump	110
Flowmeter	70
Irradiation meter	450
Nanoparticles	1065
Total cost	4685

Chapter 6: Project Analysis

6.1 Life-long Learning

When we start working on our project, we look forward to acquiring the skills that matter to us and which are essentially required for us to complete the tasks in every aspect of the project. And also by working as a team in terms of cooperation between team members to distribute tasks in order to shorten the time to take advantage of other times are in our scientific and practical interest. One of the benefits of this experience is that we have successfully improved our time management skills.in addition, effective communication between the group members. We also briefed in mutual respect and exchange of opinions among the group members. In this section we will discuss the skills and gained experience since we worked on the project.

6.1.1: Software Skills

We learned many skills from some of the programs that already we used in the project, Such as: SolidWorks, Excel and Word documents .moreover, Excel and word documents are look familiar to us because we have used them in our live during a college. As for SolidWorks, one of the advanced skills in our engineering field is also a scientific requirement in the study plan. We used the skills of this program to design project pieces and we used other tools to assemble and simulate them.

6.1.2: Hardware Skills

Through our project, we have used some measuring instruments that aim to collect the required data. We used four different devices and it was the first is laser thermometer the function of this device is to measure the temperature of liquid and solid objects without contact and through the laser that is designed in the device We learned how to use it and put it on objects. Regarding to the second device was solar power meter we used it to calculate the sun's rays on the solar panel and place the device at the appropriate angle to take the data correctly. And also as for the third device it was a multi-meter and the benefit of this device is the calculation of the current. And we learned how to put it properly during the test. Finally, the fourth device is was a charge controller and the function of this device is to calculate the voltage and the battery power percentage the readings are clear through the digital screen.

6.1.3: Time Management Skills

in our project, we acquire important skills in our time management and from this standpoint we are able to reach our goals And we have to manage our time appropriately and properly and also to suit with the tasks .We are divided in terms of handing out tasks while we are submit it on the time. One of the important things that will help us in the task management is the Gantt chart and it keeps them informed about our tasks and times of submission.

6.1.4: Project Management

We have divided the work and tasks among the group members, there are individual tasks that the member to accomplish and we meet every two days to discuss the tasks done by the member, but mostly we work collectively, whether in the work of research and writing reports or installation of the project and the purchase of pieces.

6.2 Impact of Engineering Solutions

6.2.1: Society

Our project has an advantage to the community, which is through the use of solar panels and Nano-solids particles is to heat water quickly and produce electricity can be utilized when few sources of energy It can be used during road trips and camping. In addition, It is also easy to install and easy to use.

6.2.2: Economy

Our project going to helps people to produce thermal and electrical energy sources that are less expensive than other sources and over the long term it is an economical method. The project was expected to cost 6,000 Saudi riyals, but in the end it cost only 4,685 riyals and this can save you a lot of money that can be spent on the family's energy needs.

6.2.3: Environmentally

Our project is that it produces clean energy and helps people to produce it in the future energy demand and also it is unlike the traditional sources such as factories and gas plants that is produced power.

6.2.4 Contemporary Issues Addressed

We in Saudi Arabia face the problem of air pollution resulting from the large number of factories and gas plants spread throughout the Kingdom Resulting from the production and export of various kinds of energy There are many of the most common diseases of these factories are allergies, pneumonia, respiratory diseases and irritation of the eyes and skin .finally, We in the Gulf region, especially in Saudi Arabia, have weather that we can produce very large solar energy that we can use to produce energy in all forms in the future and reduce consumption on the main sources.

Chapter 7: Conclusion and recommendation

7.1 conclusion

In this project we gained a lot of experience that feeds our knowledge by using the Photovoltaic thermal system for heating purposes and producing electric energy from the green energy. Moreover, we learned how to manage time among the semester to start the project from A to Z within four month and distribute the tasks between group members and following up each other to finish it before the due date and checking up with our advisor. The goal of this project is to enhance the overall efficiency of the hybrid system and we achieved this goal by utilizing nanoparticles (Al_2O_3) with volume fraction range $0\% < Ø < 0.2\%$ and the overall efficiency increased by 41.7%. During the experiment we faced a problem with distributing the (Al_2O_3) in water, the nanoparticles settled in the bottom of the tanks, we used a drill as a mixer to distribute the nano-particles in water. Another problem we struggled with, the pump used in the system was DC so we plugged directly to the power source which is ruined the pump and we had to buy a new pump and adapter to convert the DC system to AC.

7.2 Future recommendations

For this project there is a lot of ideas that will enhance the overall efficiency, such as integrate fins to the system where the fins located between the panel and heat exchanger to increase the rate of heat transfer. To avoid the sun damages while doing the experiment outdoor, use artificial sunlight bulb and the advantages of testing the system indoor to avoid the affective of wind speed.

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Appendix A

Chapter 4: Experimental data

Table A.1 (Reference data for surface temperature, electrical efficiency)

Time	T(surface)φ=0	T(surface)φ=0.1	T(surface) φ=0.2	Electrical efficiency φ=0	Electrical efficiency φ=0.1	Electrical efficiency φ=0.2
10:00	33.85	49.9	52.5	7.256803304	2.676313867	1.58200279
10:10	38.65	51.8	56.3	7.837430774	1.498280466	1.165607708
10:20	38.05	53.3	56.1	6.327129085	1.3366067	0.772958447
10:30	39.6	56.6	56.5	6.237491439	1.24136018	1.013929924
10:40	39.3	58.7	56.1	7.249355895	1.258768115	0.676713685
10:50	41.95	58	57.5	5.697684953	1.249634468	0.970709217
11:00	42.05	55.7	50.6	6.774154622	1.231238592	1.152014344
11:10	42.45	58.4	61.1	5.555327012	1.542173555	1.076617078
11:20	42.95	60	61.4	4.986108887	1.558935011	1.121986931
11:30	43.85	60.1	66.7	4.910512631	1.634454135	1.168059727
11:40	44.7	61.5	61.2	4.895995718	1.633301052	1.204683822
11:50	44.3	60.8	61.2	5.66489795	1.704650844	1.30881983
12:00	45.05	65	61.3	4.170452117	0.835709364	1.01684782
12:10	45.7	65.2	60.8	3.926552892	3.501774432	0.835995077
12:20	40.4	65	60.3	3.889725575	0.859776907	0.971218588
12:30	47.8	63	58.6	4.835362227	1.186455895	0.820745719
12:40	45.3	61	60	4.774167907	1.318764228	1.014362697
12:50	45.9	60.6	56.8	3.875482396	1.465875935	0.957139109
13:00	41.5	60.6	55.7	3.910767202	1.351428514	1.062471183
13:10	46.35	58.6	56	4.531285231	1.547453234	0.951818128
13:20	45.35	51.1	59	5.191224503	1.536915527	0.96820841
13:30	45.4	52.8	64.4	4.13776665	1.622960847	1.080952967
13:40	47.4	45.4	56.7	4.182411208	1.640372019	1.050885503
13:50	40.35	49	61.1	4.191095794	1.920019397	1.10328867
14:00	39.05	49.8	50.5	5.344052168	1.722922909	1.175933191
14:10	36.6	47.9	50.3	4.819129055	1.736363948	1.654679659
14:20	37.65	47.6	45.2	9.828636243	1.889034153	1.591172093
14:30	38.65	44.8	49.1	5.571925412	1.973431357	1.530000073
14:40	35.45	43.1	47.5	8.209289433	2.057090895	1.629569612
14:50	30.7	44.2	46.1	10.4679126	3.953010194	1.68016166
15:00	27.85	44	40.5	8.703519323	2.307531345	1.914267731
15:10	28.55	43.5	42.5	7.149221713	2.314919103	2.29881805
15:20	26.25	38	36.1	10.68435363	2.496261896	2.398346532
15:30	25	37.8	37.2	6.085864807	2.759666847	1.717893378

Table A.2 (Reference data for thermal efficiency, overall efficiency and temperature inlet and outlet)

Time	Thermal efficiency φ=0	Thermal efficiency φ=0.1	Thermal efficiency φ=0.2	Overall efficiency φ=0	Overall efficiency φ=0.1	Overall efficiency φ=0.2	ΔT φ=0	ΔT φ=0.1	ΔT φ=0.2
10:00	18.78764216	10.89642074	14.7507112	26.04444547	13.57273461	16.33271399	2.95	1.9	2.7
10:10	6.145347714	17.08958526	68.23433101	13.98277849	18.58786573	69.39993872	1.05	3.1	12.5
10:20	8.215406132	18.78573252	35.43293536	14.54253522	20.12233922	36.2058938	1.45	3.5	6.9
10:30	7.916528443	34.09933327	53.86532682	14.15401988	35.34069345	54.87925674	1.4	6.7	10.6
10:40	11.77580094	17.68480556	29.27358558	19.02515683	18.94357368	29.95029927	2.15	3.5	6.1
10:50	7.685050297	13.44886326	39.68346641	13.38273525	14.69849772	40.65417563	1.45	2.7	8.3
11:00	8.339285739	13.75160401	33.83706979	15.11344036	14.9828426	34.98908414	1.6	2.9	7.3
11:10	6.405797038	19.10138322	32.59231132	11.96112405	20.64355677	33.6689284	1.25	4.1	7.1
11:20	7.825895964	12.45349799	38.92055577	12.81200485	14.012433	40.0425427	1.55	2.7	8.5
11:30	12.90772498	17.35405714	21.33247109	17.81823761	18.98851128	22.50053082	2.6	3.8	4.7
11:40	9.298931792	20.73299528	44.82340498	14.19492751	22.36629633	46.0280888	1.9	4.6	10.1
11:50	13.12223459	38.15040741	28.72863915	18.78713254	39.85505826	30.03745898	2.65	8.5	6.5
12:00	22.01077426	35.6976	37.1002085	26.18122638	36.53330936	38.11705632	4.5	7.7	8.5
12:10	16.49552796	29.2703755	35.1135367	20.42208085	32.77214993	35.94953178	3.35	6.2	8
12:20	11.42693847	28.34735037	36.58640679	15.31666405	29.20712727	37.55762538	2.35	5.9	8.2
12:30	10.23373835	34.58112838	28.77172274	15.06910057	35.76758428	29.59246846	2.1	7.2	6.2
12:40	18.75912229	31.60413659	50.14195409	23.53329019	32.92290081	51.15631679	3.6	6.4	10.5
12:50	15.73581658	25.01967297	28.83697053	19.61129897	26.48554891	29.79410964	3.25	4.9	5.9
13:00	21.55020329	22.1561959	41.3305466	25.4609705	23.50762441	42.39301778	4.15	4.3	8.6
13:10	18.27508408	26.26830103	30.16890203	22.80636932	27.81575426	31.12072016	3.35	5.1	6.1
13:20	13.0740493	37.57300057	32.26056185	18.2652738	39.1099161	33.22877026	2.35	7.1	6.3
13:30	17.79773691	33.14846375	76.42357988	21.93550356	34.7714246	77.50453285	3.15	6	14.8
13:40	17.09467371	50.83377876	42.39406411	21.27708492	52.47415078	43.44494962	2.9	9	7.9
13:50	18.99120539	33.27213578	64.3448197	23.18230118	35.19215517	65.44810837	2.9	5.8	12.1
14:00	15.1946008	26.13277508	36.27452068	20.53865296	27.85569799	37.45045387	2.3	4	6.4
14:10	18.93413008	24.85514638	45.8699977	23.75325914	26.59151033	47.52467736	2.75	3.7	6.6
14:20	22.05623772	20.70303409	27.44404989	31.88487396	22.59206824	29.03522199	1.65	3	3.9
14:30	8.975230525	21.06450466	62.39748825	14.54715594	23.03793602	63.92748832	1.3	3.1	8.6
14:40	8.614526292	19.45977956	47.91172551	16.82381572	21.51687045	49.54129513	2.8	2.4	6.3
14:50	18.58619705	13.93143309	62.14738767	29.05410965	17.88444329	63.82754933	2.5	1.8	7.8
15:00	12.66862613	28.13221884	29.07917069	21.37214546	30.43975019	30.99343842	3	3.5	3.1
15:10	8.691389424	38.32289435	31.11221574	15.84061114	40.63781345	33.41103379	3	4.2	2.9
15:20	25.14329714	14.7589207	12.59194451	35.82765077	17.25518259	14.99029105	1.4	1.5	1
15:30	15.13529865	18.73833933	23.92511361	21.22116345	21.49800618	25.64300699	1.2	1.7	1.8

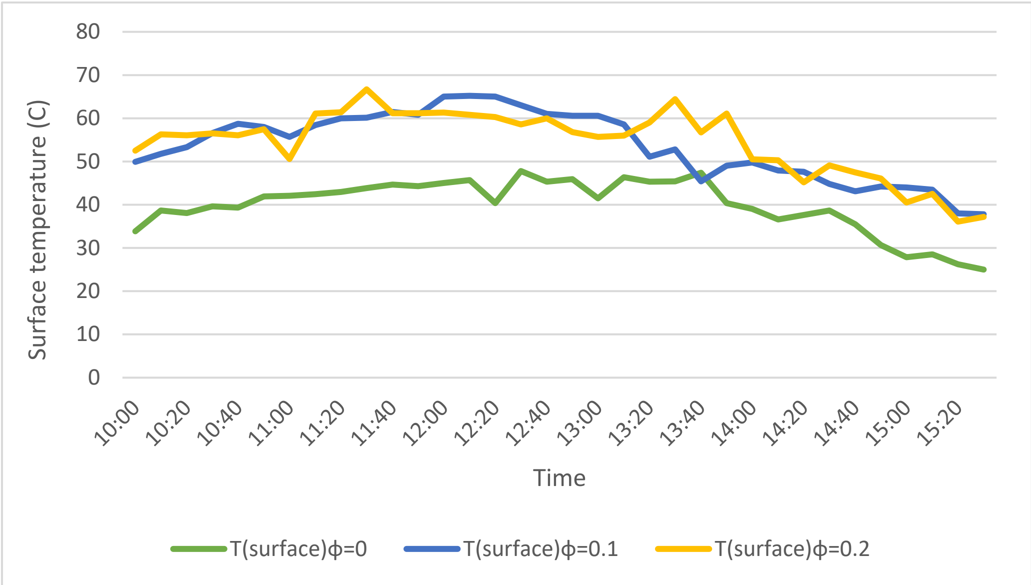

Figure A.1 (Surface tempruture)

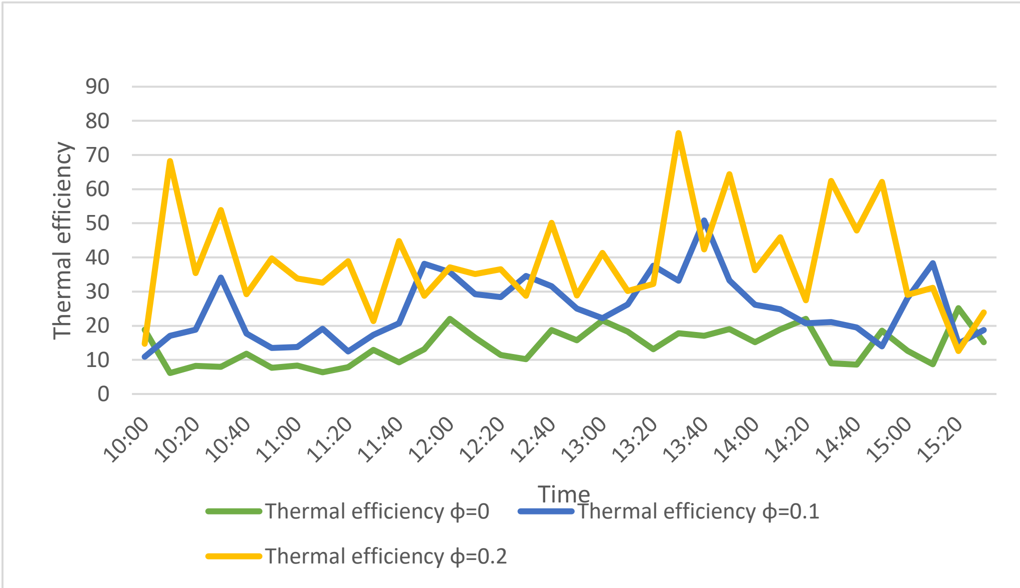

Figure A.2 (Thermal efficincey)

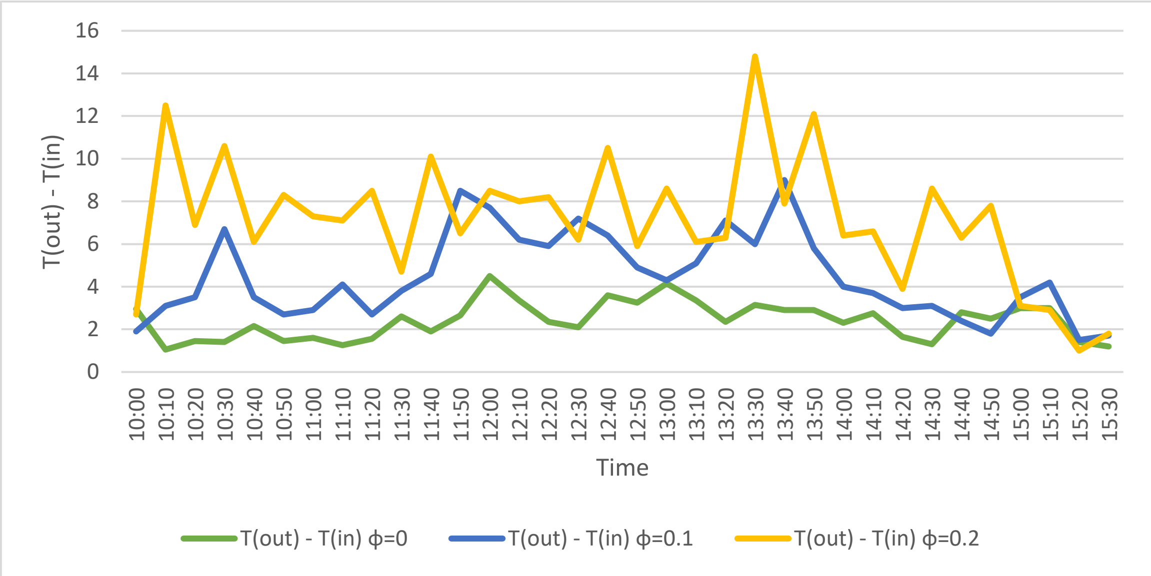

Figure A.3(ΔT)

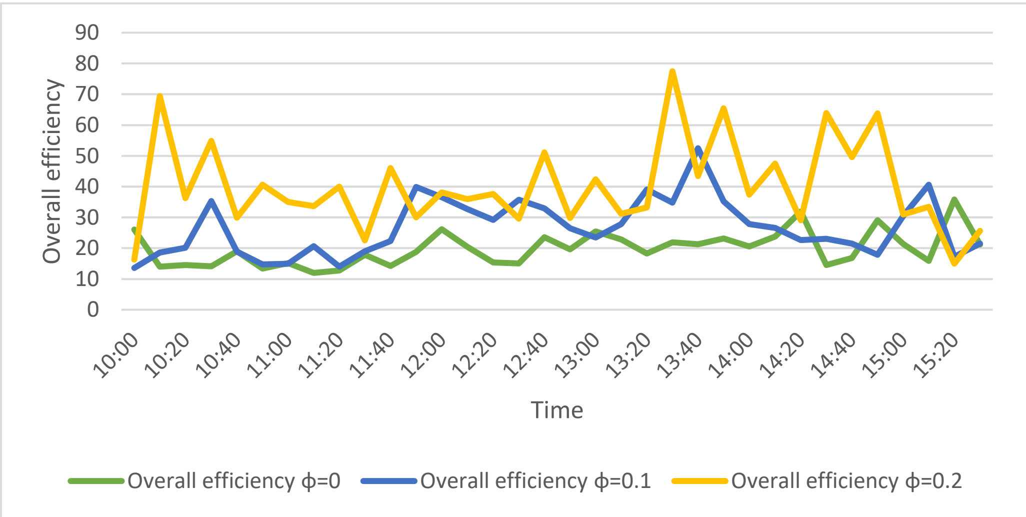

Figure A.4 (Overall efficiency)

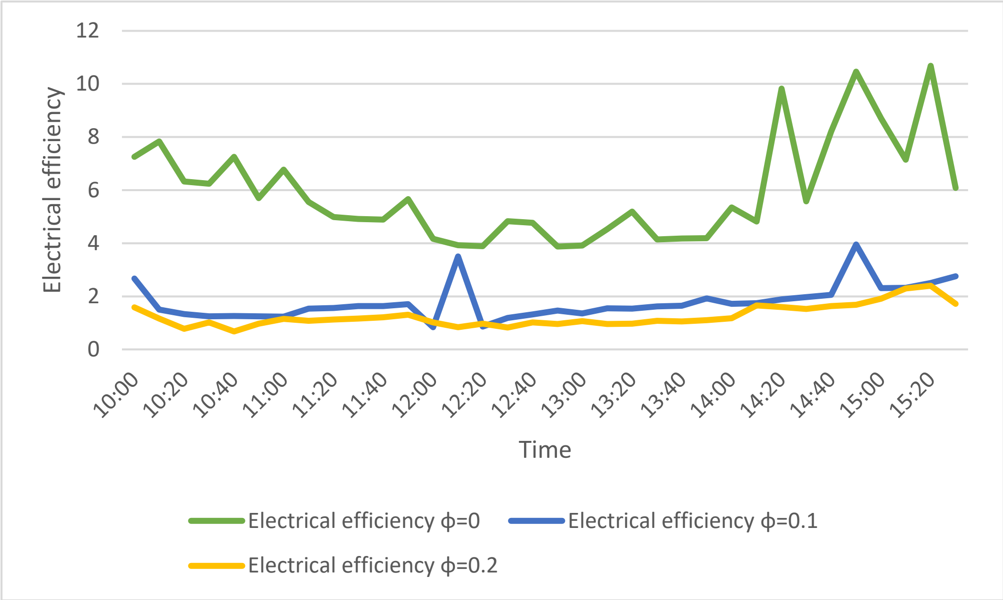

Figure A.5 (Electrical efficiency)

Appendix B

Gantt chart

Table B.1 (Tasks distribution)

Task	Start Date	Days to complete
Task 1		
Looking for adviser	01/09/19	2
Identifying the project	03/09/19	3
Seeking suppliers and avilabilities equipment	06/09/19	6
Writing the abstract	12/09/19	4
Task 2		
Disturbuting collecting material among the group	16/09/19	2
Draw the design model	18/09/19	4
Ordering stand-alone PV panel	22/09/19	12
Purchasing nanofluid particals	04/10/19	5
Prepare for the mid-term presentation	09/10/19	8
Task 3		
Start building the model	20/10/19	10
Measurment + analysing results	11/11/19	11
Task 4		
Test the project	12/11/19	3
Correction	15/11/19	5
Start writing the report	20/11/19	7
Prepare for the final presentation	27/11/19	2
Finalizing the report	29/11/19	7

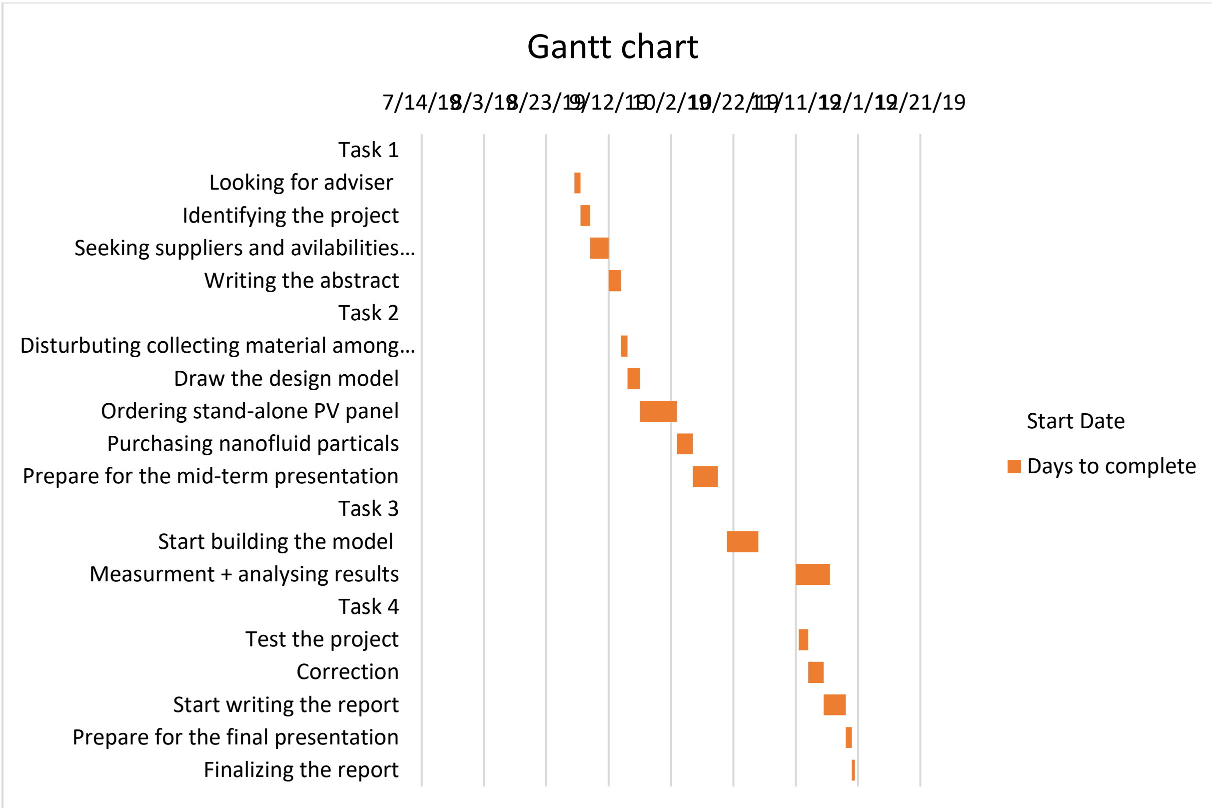

Figure B.1 (Gantt chart)

Appendix C

SolidWorks

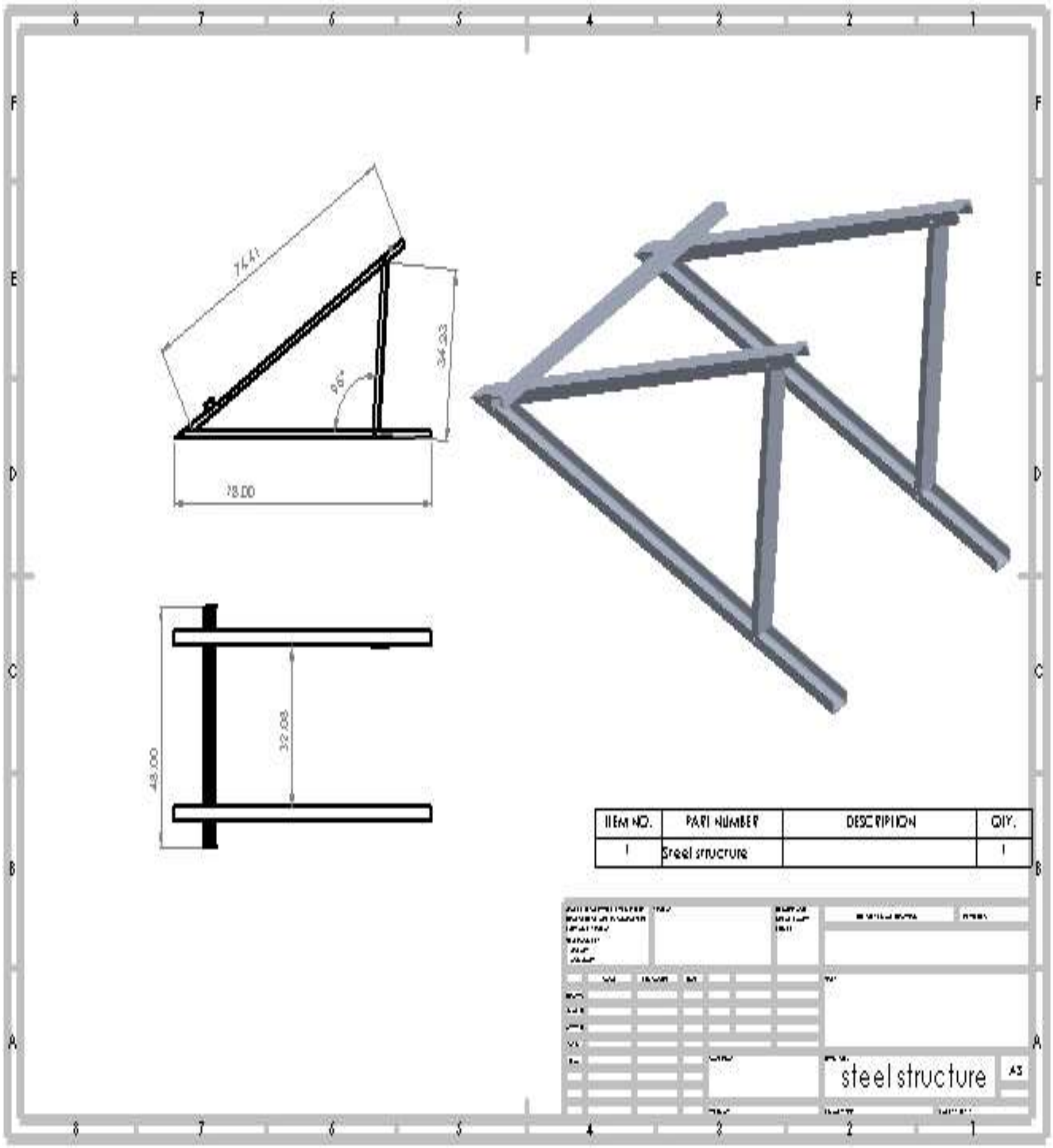

Figure C.1 (Steel structure)

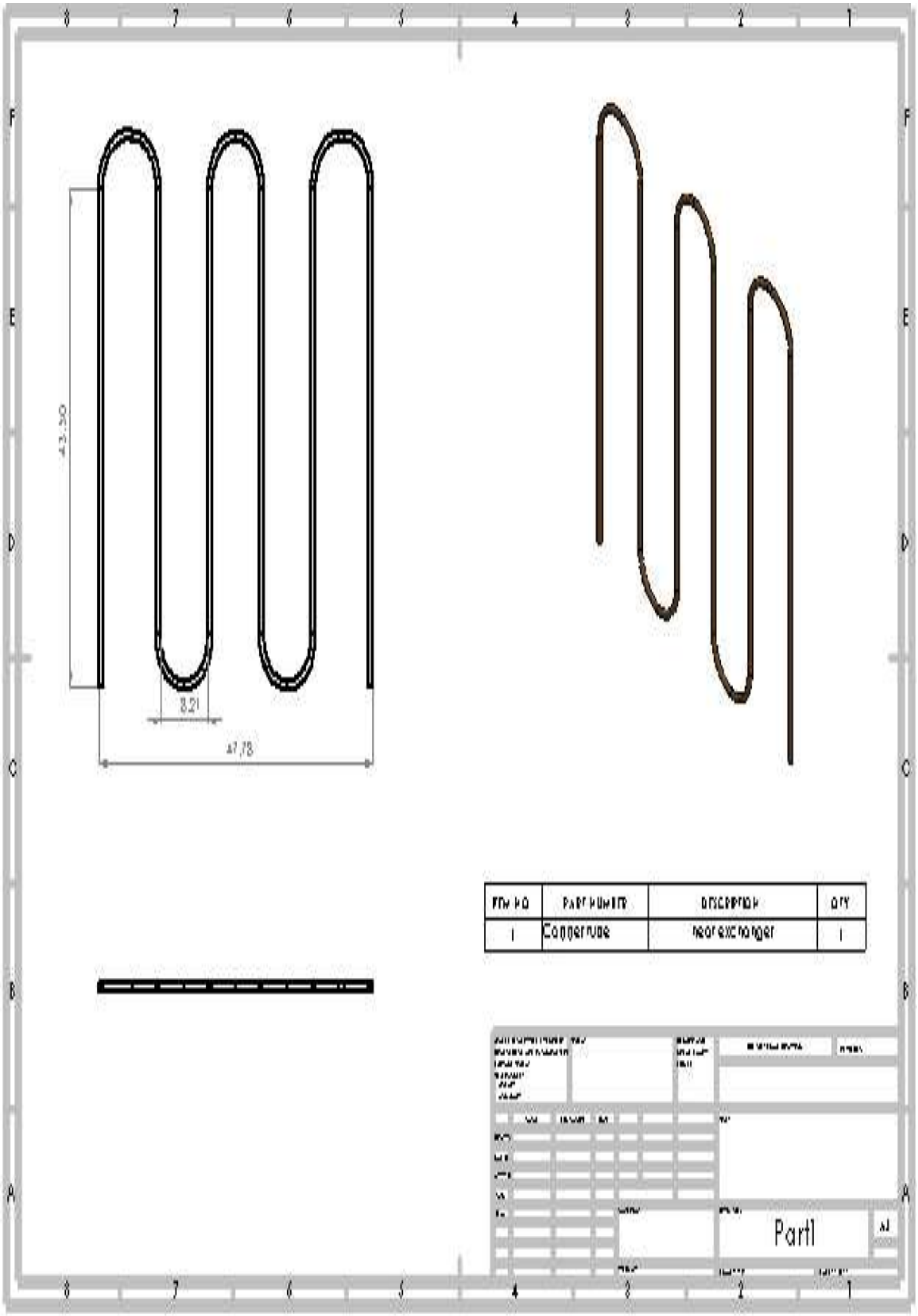

Figure C.2 (Copper tube)

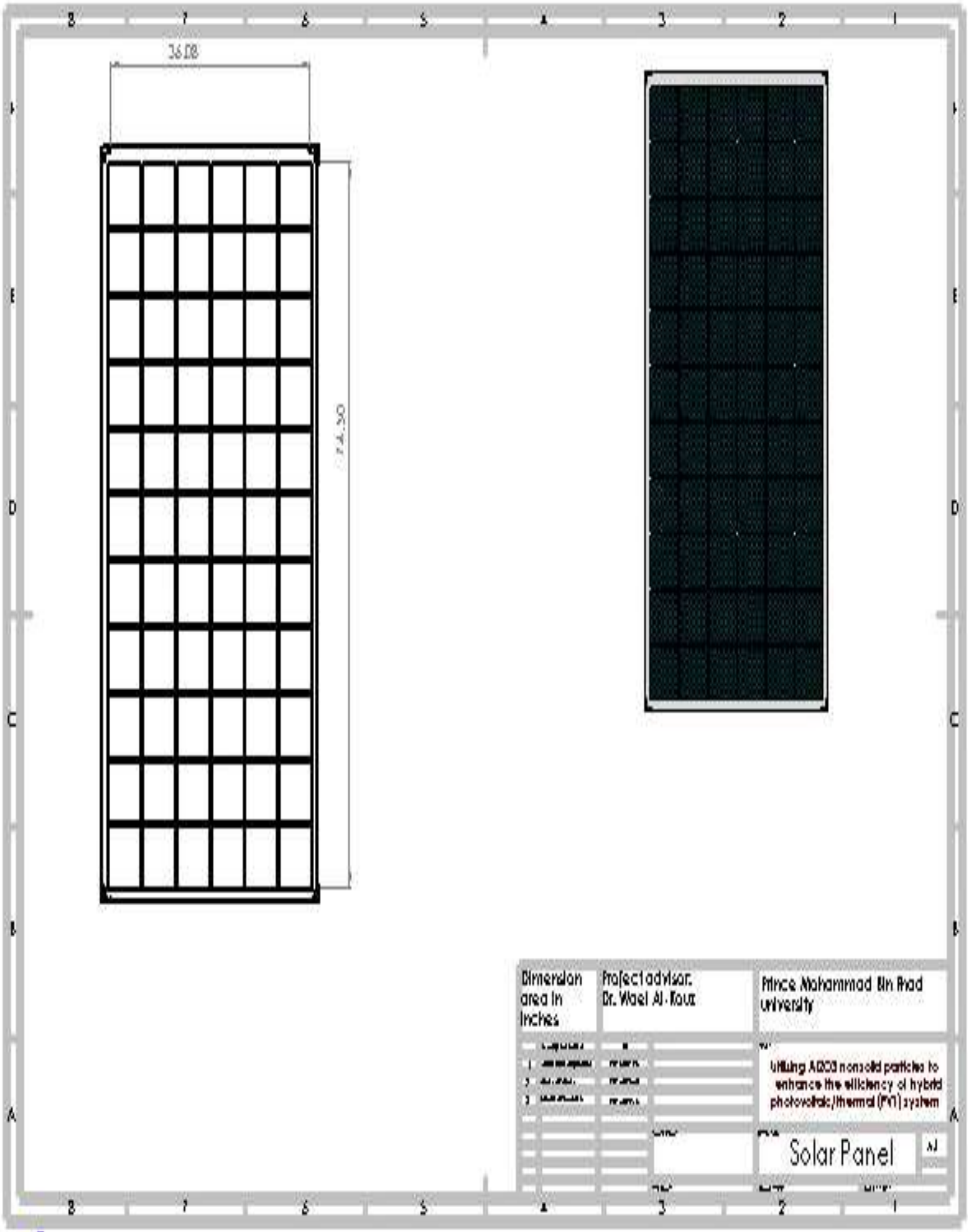

Figure C.3 (Solar panel)