

**PERFORMANCE ENHANCEMENT OF SINGLE SLOPE SOLAR STILL
WITH THE USE OF FINS****¹Shruti Pardeshi, ²Pranjali Shejul, ³Vivek Rukme, ⁴Sarvesh Patil**U. G Student Mechanical Department, JSPM's Imperial College of Engineering & Research, Pune, India^{1,2,3,4}
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sarveshpatil39@gmail.com⁴**ABSTRACT-**

The purpose of this project is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on Renewable solar energy. The motivation for this project is the limited availability of clean water resources the abundance of impure water available for potential conversion into potable water, in addition there are many coastal locations where seawater is abundant but Portable water is not available. Our project goal is to efficiently produce clean drinkable Water from solar energy conversion. Distillation is one of many processes that can be used for water purification. This requires an energy input as heat, and solar radiation can be the source of energy. When Solar energy is used for this purpose, it is known as Solar water Distillation. Solar Distillation is an attractive process to produce portable water using free of cost solar energy. This energy is used directly for evaporating water inside a Device usually termed a 'Solar Still'. Solar stills are used in cases where rain, piped, or well water is impractical, such as in remote homes or during power outages. Different Versions of a still are used to desalinate sea water, in desert survival kits and for home Water Purification. For people concerned about the quality of their municipally supplied Drinking water and unhappy with other methods of additional purification available to them, solar distillation of tap water or brackish groundwater can be a pleasant, energy our project goal is to efficiently produce clean drinkable water from solar energy conversion When solar energy is used for this purpose, it is known as solar water Distillation.

Keywords: *Solar still, aluminium composite material, aluminium fins, solar energy*

INTRODUCTION**Desalination processes:**

The use of solar energy for desalination can be categorized into direct, where the solar energy is absorbed directly by the saline water (solar pond and solar still), or indirect where the solar energy is absorbed by a solar collector and then transferred to the saline water. Solar energy is well suited for arid regions and rural areas where the solar intensity is high.

Desalination of seawater or brackish water is generally accomplished using water evaporation (phase change), or by using a semi-permeable membrane to separate fresh water from concentrated saline water, or by a combination of the two as in membrane distillation. Most conventional desalination plants are large scale centralized units that typically serve urban populations. In recent years, there is considerable interest in developing decentralized desalination technologies. An environmental advantage of decentralized desalination is that the brine discharge is spread out over a large area, and thus the environmental impact is considerably less than that associated with large scale centralized desalination plants. In rural arid regions, populations are distributed over a large land surface area. For such cases, it is more economical to install and operate decentralized water production units that serve the local population in view of large centralized water production where water must be transported long distances. The rural arid regions typically have excellent solar

resources, and thus solar driven desalination is appealing. Solar energy, harvested in electrical or thermal form can be used to distil water. Solar thermal energy systems, such as lath plate solar collectors, evacuated tubes, concentrating solar troughs, and solar ponds absorb the solar energy and convert it to thermal energy that drive thermal desalination processes. Solar thermal energy utilization for desalination can be categorized into direct, where the solar thermal energy is collected directly by the saline water, such as in solar stills and solar ponds, or indirect where the solar thermal energy is absorbed by a solar collector and then transferred to the saline water, such as in solar powered humidification-dehumidification (HDH) and diffusion driven desalination. Technical simplicity, low maintenance requirements, and ease of operation are very important to enable successful application of distributed solar powered desalination systems. The distillation performance can be examined in terms of characteristic parameters which are related to the method of distillations, which include:

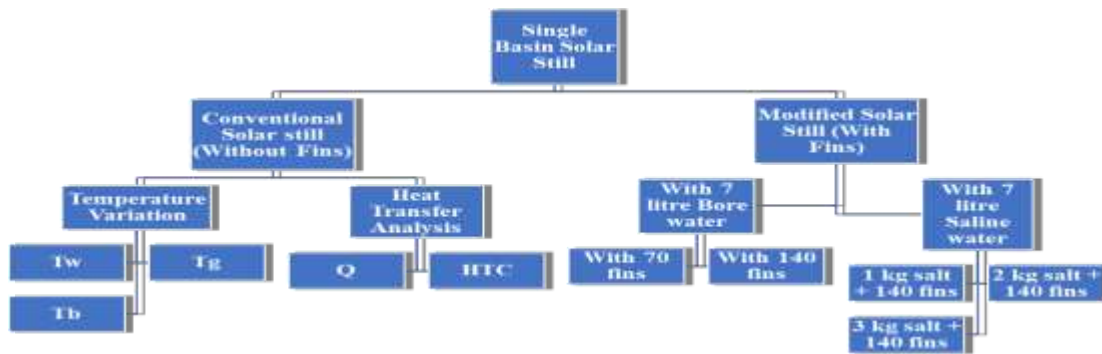
1. Special daily water production which is defined as the amount of water produced using 1 m² of solar collector area per day. This parameter describes daily water production normalized by the solar collector area. This parameter is important for all solar powered desalination systems since solar collector area is indicative of the amount of energy that is flowing into the system and is also a proxy for cost. The solar collector cost typically accounts for about 40–45% of the capital cost of air-heated HDH systems and 20–35% of the capital cost of water-heated HDH systems.
2. Gained output ratio (GOR) which is defined as the ratio of the latent heat of evaporation of the distillate produced to the total heat input to the distillation process. It is a measure of how efficiently thermal energy is used in a desalination process. In the case of solar powered Desalination systems, GOR is equal to the ratio of latent heat of evaporation of the distillate produced to the heat absorbed by the solar collectors.
3. Recovery ratio (RR) is defined as the ratio of the total fresh water produced to the saline feed water input. RR for small scale solar powered HDH desalination systems is much smaller than RR for conventional desalination processes, such as MSF, MED, VC and RO due to the low production efficiency of small-scale systems.

AIM & OBJECTIVES

Due to growing population, agriculture, industries, etc. the need for fresh and drinkable water is increasing.

1. The current processes are expensive, energy-intensive, and involve large-scale facilities so to fulfil the growing needs this project will help to fulfil the needs in less cost using solar energy.
2. As it is based on solar energy which is renewable resource there will be no scarcity of resources for the desalination process to achieve fresh water. The cost for this project is low.
3. To explore the factors like the intensity of solar radiation and ambient temperature.

METHODOLOGY



LITERATURE REVIEW

1. **Hitesh N Panchal, Sanjay Patel:** - proposed that **An extensive review on different design and climatic parameters to increase distillate output of solar still** Most of the part of the land is covered by saline water where fresh water is available in less proportion and also the demand of fresh water for drinking use is increasing rapidly day after day due to increase in the population. Hence, solar desalination is a feasible alternative to sweep over this massive difficulty. The process by which impure water is converted into clean water is called solar desalination and instrument which is used for it is known as solar still. A lot of investigation has been done by various researchers to inspect the parameters which affect the efficiency of solar still and thereby to improve its performance. In this review paper different design and climate parameters are reviewed which affects the yield of a solar still.

2. **Hitesh N Panchal, Manish Doshi, Anup Patel, and Keyursinh Thakor:** - **A comprehensive review of solar cooker with sensible and latent heat storage materials** Solar still is very important device to convert the available brackish water into drinkable water. Here work is carried out to know the effect of coupling an Evacuated Heat Pipe Collector on the solar still. Other different parameters like Water depth, Sun direction and solar radiation to enhance the productivity. It has found that coupling an Evacuated Heat pipe collector with a solar still has increased the productivity by 32%. Also, it has found that the productivity is reduced while using higher water depth and solar insolation is directly proportional to the Productivity.

3. **Laxmikant D Jathar, S Ganesan, Kiran Shahapurkar, Manzoore Elahi M Soudagar, MA Mujtaba, Ali E Anqi, Muhammad Farooq, Abdulqahdar Khidmatgar, Marjan Goodarzi, Mohammad Reza Safaei:** - **Effect of various factors and diverse approaches to enhance the performance of solar stills: a comprehensive review.** This article mainly focuses on the climatic, design, and operational parameters affecting the performance of solar stills. Results reveal that a combination of the incredible intensity of solar radiations, solar still type, and regions with optimum temperature can provide higher daily distillate output. Further, high productivity can be achieved with inclined solar stills by making an inclination angle equivalent to the location's latitude.

4. **Hitesh Panchal, Jay Patel, Sudhir Chaudhary:** - **experimented on a comprehensive review of solar cooker with sensible and latent heat storage materials** solar energy is available freely and does not create any pollution to the environment. Hence, researchers from all around the world are always working on solar energy applications with enhancement technologies. The solar cooker is one of the largest solar energy applications, which is used to cook the food. However, because the solar energy is available only during the daytime, it is not widely used for industry as well as household application. To store the heat during the day,

energy storage materials are used. Hence, this study presents a review of sensible and latent heat storage materials used to store the heat during daytime and use for other than daytime hours.

5. **BadawiTleimat MaherTleimat:- Developments in saline water distillation technology this paper reviews the basic** distillation processes in the distillation of saline water and then gives an overview of different types of evaporators presently in use in saline water distillation plants as well as discussing the effects of their construction on performance. The paper then reviews the development of the wiped-film rotating-disk evaporator and shows performance data in the recovery of distilled water from sea water, agricultural waste water, gray water, and brackish waste water resulting from the injection of steam in the recovery of oil from old oil wells in Southern California.

6. **Hamed, O.A.: - Desalination Technologies Research Institute, Saline Water Conversion Corporation, Jubail, Saudi Arabia.** This chapter provides a brief description on these processes, their performances and challenges. The operational and design developments which have been associated with the thermal desalination processes are explained. Salient features of conventional power water cogeneration cycles in which the MSF/MED-TVC distillation plant operates are highlighted. Challenges that have to be addressed to enhance developments of thermal desalination processes such as introduction of innovative methods to reduce specific energy consumption are also discussed.

7. **Pankaj Kumar Pandey, Renu Upadhyay: - Desalination of Brackish Water using Solar Energy** Experimental study was carried out and report the effect of temperature, time and flow rate on permeates flux. Results show that permeates flux increases with increase in temperature. Also, the analysis of the well water has been performed by various techniques and reported.

8. **Mahmoud Shatat Mark Worall Saffa Riffat :- Opportunities for solar water desalination worldwide: Review** This paper explores the challenges and opportunities of solar water desalination worldwide. It presents an extensive review of water desalination and solar desalination technologies that have been developed in recent years and the state-of-the-art for most important efforts in the field of desalination by using solar energy, including the economic and environmental aspects.

9. **Dr. Parimal Bhambare:- Solar Thermal Desalination: Sustainable Alternative for Sultanate of Oman** Desalination plays critical role in filling the gap between fresh water demand and availability in water scarce Sultanate of Oman since 1976. Installed desalination capacity in the country has almost increased by 60 times that in 1976 with increasing fresh water demand. Even though desalination share in meeting the fresh water demand is increasing, 80-85% of fresh water demand today is still satisfied with ground water.

10. **Pascale Compain: - Solar Energy for Water desalination** this paper presents the different solutions to the most commonly used desalination process (RO, MSF, MED), and solar energy production technology compatible with desalination. The goal is to assess the feasibility and profitability of the substitution of fuel energy used for desalination plants with renewable energy. A review of various technologies will define broadly features associated to each technology and range of cost that are expected. Finally, a review of various projects will detail the practical aspects of floor space and actual production costs of fresh water.

SCOPE OF PROJECT

India is expected to witness a high demand for desalination systems during the forecast period, owing to factors, like growing population, rapid urbanization, and increase in the demand for water in drought affected areas,

coupled with an increase in government investment in water desalination. As it is based on solar energy which is renewable resource there will be no scarcity of resources for the desalination process to achieve fresh water.

The cost for this project is low.

EXPERIMENTAL SETUP

Solar still:

A solar still distils water with substances dissolved in it by using the heat of the Sun to evaporate water so that it may be cooled and collected, thereby purifying it. They are used in areas where drinking water is unavailable, so that clean water is obtained from dirty water or from plants by exposing them to sunlight. The solar still is one of the oldest and by far the simplest water desalination method.

Principle of solar still:

Solar still works on the principle of solar distillation. A solar still duplicates the way as rainwater i.e. Evaporation and condensation. Saline water is filled in the black painted basin of the solar still. This is enclosed in a completely air tight surface. A sloping transparent cover is provided at the top. Then solar radiations are allowed to fall on it. Solar radiation is transmitted through the cover and is absorbed in the black lining. The distillation is designed so that an efficient amount of solar radiations gets trapped inside it. This increases the internal temperature of distillation causing the saline water to evaporate leaving behind all the salt contents, insecticides, herbicides, bacteria, viruses etc.

DESIGN AND SPECIFICATIONS

1. Outer Box:

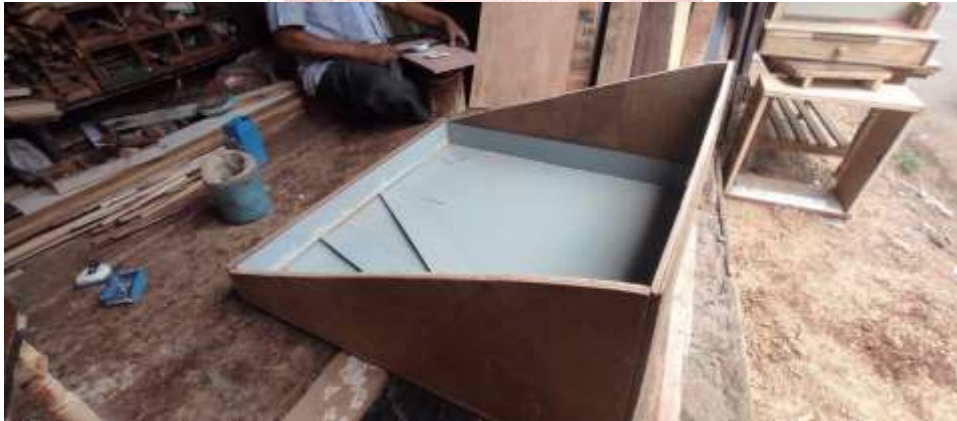


Fig no 3.4.1(1) outer box

The wooden box is the outer casing of the solar still, which acts as a thermal insulator helps in retaining the heat generated inside the acrylic box which leads to the increase in the rate of evaporation of the water which is poured into the solar still in the form of salt water or brackish water.

2. Aluminium composite material sheet:



Fig no 3.4.1(2) ACP Sheet

Fig no 3.4.1(3) Composition of aluminium sheet

ACP aluminium composite panel (ACP), made of aluminium composite material (ACM), are flat panels consisting of two thin coil-coated aluminium sheets bonded to a non-aluminium core. The thickness of aluminium wall panels is usually in the range of 3-6 mm, and the aluminium skins are in the range of 0.2- 0.8 mm. The insulated core is made of different materials

3. Aluminium fins:



Fig no 3.4.1(4)

Aluminium fins placed in basin



Fig no 3.4.1(5)

Aluminium fins 20mm height

Aluminium fins are used as a heat storage material as it has thermal conductivity (160 W/m·K) and also good corrosion resistance. Its high thermal conductivity helps in conducting more heat to the salt water or brackish water and its corrosion resistance helps in preventing it from corroding when placed in the salt water or brackish water.

4. Glass Cover:



Fig no 3.4.1(6) glass cover of 5mm thickness

The top cover of the wooden box is taken as glass as it allows more amount of solar radiations to pass inside the solar still as it increases the absorption of solar radiations by the aluminium fins.

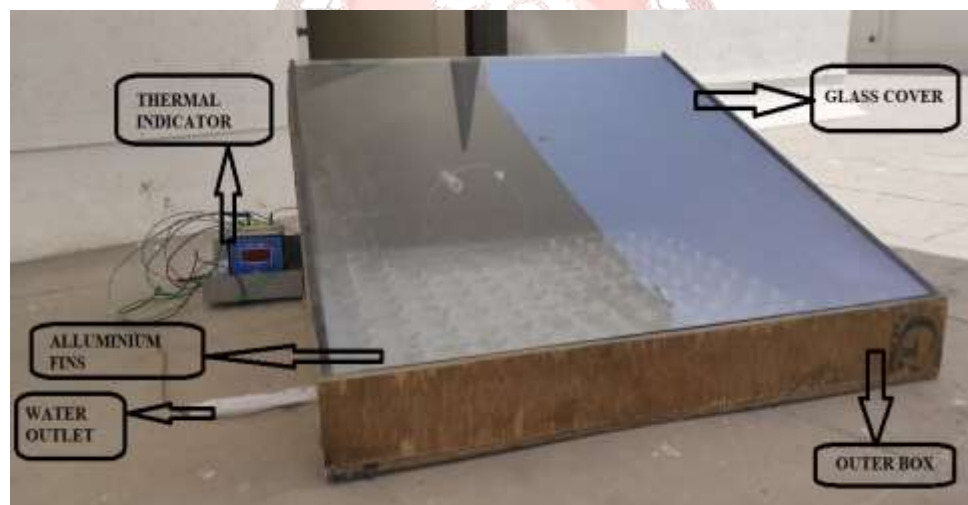
5. Thermocouples:



Fig no 3.4.1(7) K type thermocouple

The thermocouples are used to measure the variation of temperature of the aluminium fins, water, water vapor, glass bottom surface and ambient temperature on hourly basis. In this project K Type thermocouples are used.

WORKING PRINCIPLE OF SOLAR STILL



Solar stills are called stills because they distil, or purify water. A solar still operates on the same principle as rainwater: evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills mimic this natural process. A solar still has a top cover made of glass, with an interior surface made of a waterproof membrane. This interior surface uses a blackened material to improve absorption of the sun's rays. Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation to pass into the still.

This solar still experiment is performed under the different climatic conditions of pune India with latitude of (18.5808° N, 73.9787° E) which is being experimented at jspm's imperial college of engineering and research pune.

In basin 3mm Aluminium composite panel sheet is used as heat storage material since it has high good thermal conductivity and is made up with combination of protective film, PVDF coating, primer, aluminium coil (top) Adhesive film, polyethylene core, Adhesive film, Aluminium coil(bottom), Services coating which helps to conduct more heat to brackish water. Which also helps to improve performance and productivity of solar still.

On aluminium composite panel sheet fins of aluminium which are 10mm in diameter and 20mm in height are fabricated with 60mm distance apart from each other to avoid the shadow effect. As this brackish water gets heated up the moisture content of air get trapped between the water surface and glass cover increases. The heated water then evaporates from basin and condenses on inner surface of glass. Hence evaporation of water takes place.

This evaporated water vapor gets condensed and Trickle down to incline glass Cover which is inclined up to 20° Hence method of condensation comes into picture. This water is then collected with help of interior collectors and collected in storage tank. The only energy required for operation of solar still is solar energy and total water production is collected at one time. Water which is collected on inner glass surface is collected with help of inlet provide at the end of basin which is made up of PVC pipes with 10 mm diameter. 6 kg of salt is dissolved to 6 litres of water to check the efficiency of the still will continue to produce distillate and desalinate after sundown until water temperature cools down. Water should be continuously feeded to still each day to exceed still production to provide flushing of basin water to clean out excess salt left behind during evaporation. Leads to total purification of sea water and Output of fresh water is obtained with purification methods.

Thermocouples are connected to thermal indicator for calculating its Ambient temperature (T_a), Temperature of glass (T_g), temperature of basin (T_b), Temperature of water (T_w). This temperature is visible on thermal indicator.

RESULT & CONCLUSION

Efficiency of the System

Graphical Representation of the Efficiency with respect to cooling system

Without Cooling				
Day	Average Temperature	Average Current	Average Voltage	Average Power
	°C	A	V	Watt
15-5-22	41.1	0.17	21.1	1000
16-5-22	42.2	0.17	20.2	1110
17-5-22	40.8	0.20	18.5	1150
18-5-22	42.5	0.19	19.2	1190
19-5-22	43.5	0.16	20.3	1200
20-5-22	44.5	0.18	20.8	1225
21-5-22	44.2	0.19	18.7	1175
22-5-22	45.2	0.20	19.4	1120
23-5-22	43.8	0.17	20.5	1040
24-5-22	44.3	0.20	19.8	1020
Average	43.21	0.20	19.85	1123

Efficiency Calculation for Without Cooling

$$\text{Efficiency } (\eta) = \frac{I \times V}{G \times A}$$

$$= \frac{0.20 \times 19.85}{1123 \times 0.0368} \times 100$$

Efficiency (η) = 9.52%

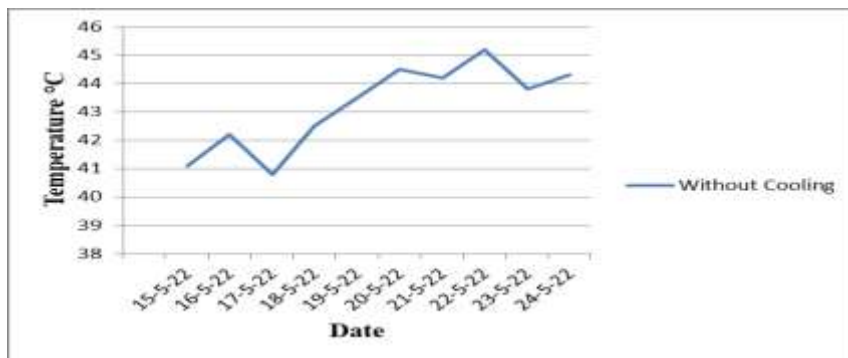


Fig 4.1.1 Graphical representation of Temperature vs. Date for without cooling

A graphical representation of fig 4.1.1 shows temperature vs. date which indicates the temperature of photovoltaic panel without cooling. It shows minimum temperature recorded is 41°C, as days are progressed the maximum temperature recorded is up to 45°C. The average temperature calculated without cooling system is 43.21°C.

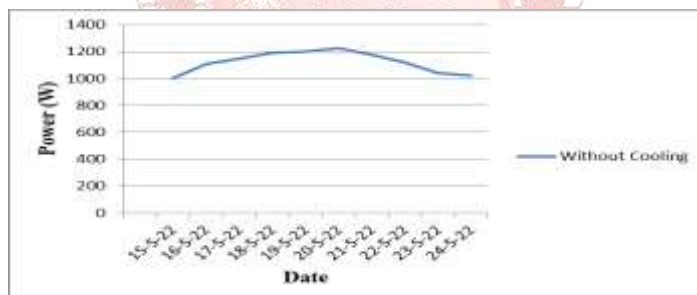


Fig 4.1.2 Graphical representation of Power vs. Date for without cooling Fig 4.1.2 Is a graphical representation of Power and date, which shows the variation of Power according to the days the maximum power recorded is 1200W and the minimum power recorded is 1000W and the average power Recorded without cooling is 1123W.

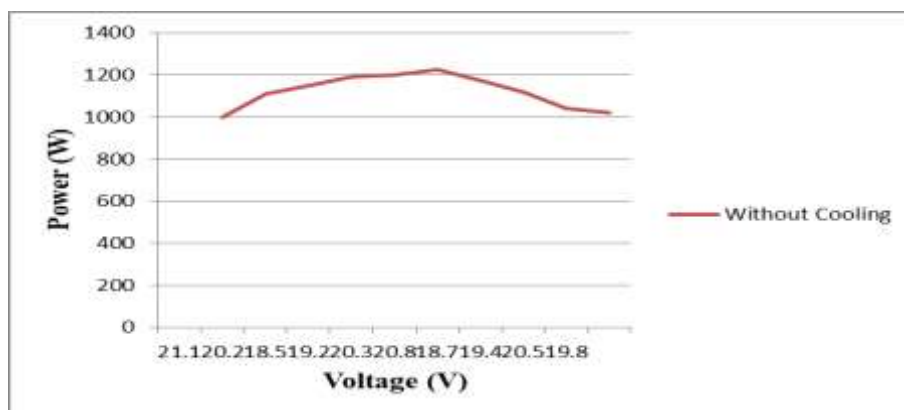


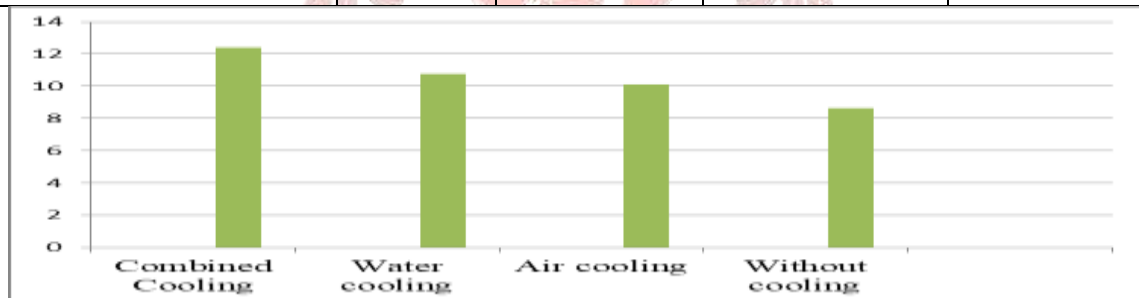
Fig 4.1.3 Graphical representation of Power vs. Voltage for without cooling

Fig 4.1.3 is graphical representation of power vs voltage for without cooling which shows the average power and average voltage recorded for 10days. the highest power recorded is 1200W and the highest voltage recorded is 22 volt and the lowest average voltage and power is 1000W and 18 volts respectively Readings taken while performing the experiment to calculate the efficiency of solar panel the reading taken with Air Cooling is provided to the system reading.

ANALYSIS OF DATA

From the calculated data above, it is seen that, without cooling system the efficiency of the solar PV cell is 9.52% and when cooling was implemented on the panel it increased to 2.88%. from these data, the efficiency was increased to 12.40% to 9.52%. Through the experiment and calculated data, it indicates that if the temperature is controlled to a certain limit, the efficiency of the PV panel increases. it has been seen that, the output power has increased with the increase if irradiation. But the amount is significantly large in case of with cooling system which is clearly visible. indicates the solar panel surface temperature. The cooling system did not allow the surface temperature to increase much. But without cooling system, the surface temperature increased significantly and it caused the output lower than solar cell with cooling system.

	Without Cooling System	Combined Cooling System	Water Cooling System	Air Cooling System
Average Power Output (Watt)	1123	1302.4	1302.4	1117.1
Average Current (A)	0.20	0.24	0.23	0.20
Average Voltage (V)	20.76	19.85	24.77	23.52
Average Temperature (°C)	43.21	36.19	33.1	27.63
Efficiency (%)	9.52%	12.40%	11.28%	10.10%



Graphical Representation of the Efficiency with respect to cooling system

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