Utilization of Solar Energy as an Energy Source in DC Freezer Machines for Mobile Ice Cream Sellers

I Dewa Made Susila[a], I Wayan Adi Subagia[b], Daud Simon Anakottapary[c], Putu Wijaya Sunu[d] and I Nengah Ardita[e]
Bali State Polytechnic, Indonesia

Keywords: DC Freezer, Solar Energy, Performance, Energy Consumption.

Abstract: Currently, refrigeration machines have a very important role in domestic, commercial, industrial, and transportation needs. One type of refrigeration machine is a freezer machine that is used for mobile ice cream sellers. A prototype freezer machine for mobile ice cream sellers has been made. The DC compressors and solar PVs will be used on these mobile ice cream sellers. Solar energy is the largest renewable energy on earth that can be converted into electrical energy. The electrical energy produced by solar PVs will be stored first with batteries before use in the DC freezer system. The components of the solar PV system include solar PVs, solar charge controllers, and batteries. The DC compressor used is a hermetic type with a power of 100W, while the condenser is equipped with a fan motor with a power of 12W. By considering the operation of the DC freezer machine for 8 hours a day, the solar PVs used to have a capacity of 300WP, monocrystalline type. While the size of the solar charge controller is 20A and the battery used is 12V and 200Ah. From the test, the COP value is 4.97 and the energy consumption is 13.61kJ.

1 INTRODUCTION

In this modern era and with the large purchasing power of the people, ice cream entrepreneurs among small communities flocked to make mobile ice cream businesses. They make uniqueness from the process of making ice cream to the choice of flavors. Making this ice cream utilizes the science of refrigeration so people try to make breakthroughs by making a portable ice cream machine where this machine uses a battery as its power source. Because the compressor of this ice cream freezer machine uses AC and it is not possible to carry it around, it requires a DC power source, so that the ice cream freezer machine can be carried.

For this reason, the solution is to use solar PVs that produce DC, so that they can be used directly on the ice cream freezer machine.

Indonesia has a large enough solar energy potential. Indonesia's average solar radiation potential is around 4.8 kWh/m2/day with a monthly variation of around 9% (Widyana Gede, 2012). The solar PV system is very suitable to be developed in Indonesia because it gets sunlight all year round, and in remote areas that are difficult to reach by PLN. Solar PVs are also an environmentally friendly alternative energy. Converting solar energy into electrical energy requires solar cells which are semi-conducting materials using the photovoltaic effect. Solar cells or PV cells rely on the photovoltaic effect to absorb solar energy and cause current to flow between two oppositely charged layers. To get a large electrical voltage as desired, several solar cells are arranged in series.

A study on evaluation analysis of the development of a solar cooling machine using conventional refrigerant HFC134a for use in rural and medical areas where there is no access to a modern power source has been carried out. From the results of the study, it was found that the COP of the system

[a] https://orcid.org/0000-0002-2567-9932
[b] https://orcid.org/0000-0001-9261-3549
[c] https://orcid.org/0000-0001-7856-6512
[d] https://orcid.org/0000-0002-6915-0475
[e] https://orcid.org/0000-0003-3391-2404

Susila, I., Subagia, I., Anakottapary, D., Sunu, P. and Ardita, I.
Utilization of Solar Energy as an Energy Source in DC Freezer Machines for Mobile Ice Cream Sellers.
DOI: 10.5220/0011860500003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 638-642
ISBN: 978-989-758-619-4; ISSN: 2975-8246

increased by 8.67% when working with solar energy and reduced energy by 2.38% respectively (Banjo S.O. et al, 2021).

Chaitanya G et al (2021) conducted a study to develop a Solar PV system that can run a cooling engine with a vapor compression refrigeration cycle. From his research, it was found that the use of electricity generated from the Solar PV system saves monthly costs incurred on electricity bills. Solar PV systems help in eliminating CO2 emissions when compared to electricity generated from coal-based power.

A review on the development and application of Solar PV in refrigeration machines operated with AC and DC electric current has been carried out by Gangadhar V, Umesh V. Hambire (2021). With the change of the AC compressor motor to a DC compressor, no inverter is needed and the load on Solar PV will be less. For AC refrigerators, the power surge is 250-425W during the cycle, while for refrigerators with DC power, the power surge is less than 75 W.

Ganorkar S. V. et al (2017) conducted research on refrigeration systems with solar power. A solar refrigerator is a cooling system that uses solar energy. The solar refrigerator consists of a compressor, condenser, expansion valve, and evaporator. During the normal operation of the solar refrigerator, the power is supplied directly by the solar panel, but when the output power of the solar panel is less, the additional power is supplied by the battery. It was concluded that implementing a cooling system with solar energy is one of the best ways to achieve efficiency and ensure that environmental conservation can be carried out.

Kalbande S. R. and Sneha Deshmukh (2015) conducted research on a refrigeration system with a vapor compression refrigeration cycle using solar PV for vaccine preservation. The output power of the photovoltaic system is determined at no-load and full-load conditions. The average photovoltaic efficiency was found to be 8.4 and 8.2% for no-load and full-load conditions while the energy efficiency was 11.4 and 11.2%, respectively.

Simson Pinto, A. Madhusudhan (2016) conducted a study on a refrigeration system with Solar PV equipped with a cold thermal bank for use at night. The refrigerator system is designed for a capacity of 150 liters. The power supply to run the AC compressor is provided by solar panels via an inverter. When the refrigerator is powered by Solar PV, the solution takes 3½ hours to reach -100oC at full load. The 10liter aqueous solution can provide nearly 17 hours of cooling at full load without running the refrigerator.

Suamir IN et al (2020) conducted an experimental study on the use of PV panels on chest freezers in hot climates. This study investigates the potential use of PV power supply systems for freezers in Indonesia a hot climate area. A PV solar-powered chest freezer has been created to experimentally investigate its daily operating performance. The results of the study show that PV panels applied to freezers and in hot climate areas are highly prospective.

2 STUDY OF LITERATURE

2.1 Vapour Compression Refrigeration Cycle

The freezer machine used for this ice cream seller uses a vapor compression refrigeration cycle. The main components of the vapor compression refrigeration cycle are the compressor, condenser, expansion device, and evaporator. The important performance parameters of the vapor compression refrigeration cycle are the coefficient of performance and energy consumption.

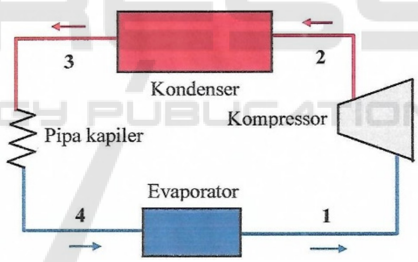

Figure 1: Diagram of ideal vapor compression refrigeration cycle process. (Susila I Dewa Made et al (2021).

Currently, refrigeration machines have a very important role in the household, commercial, industrial, and transportation needs. Refrigeration machines are used both for convenience and for preserving food products. One type of refrigeration machine that is used to cool and simultaneously freeze food products is a freezer. Ice in everyday life also has an important role, both for preservation and for serving as well as ice cream (Widiyatmoko, 2015).

2.2 Solar PV System

Solar panels, also known as Solar Photovoltaic (Solar PV) are devices consisting of solar cells that function to convert sunlight into electrical energy.

Photovoltaic (PV) cells are solid-state semiconductor devices that directly convert light energy (solar radiation) into direct current (DC) electrical energy. The voltage and electric current produced by solar cells is influenced by two variables, namely the intensity of solar radiation and ambient temperature. The intensity of solar radiation received by solar cells is proportional to the voltage and electric current produced by solar cells, while the ambient temperature is higher with a constant intensity of solar radiation, the voltage of the solar PVs will decrease and the electric current generated will increase. Solar photovoltaic panels generate DC power which can be used to operate DC motors.

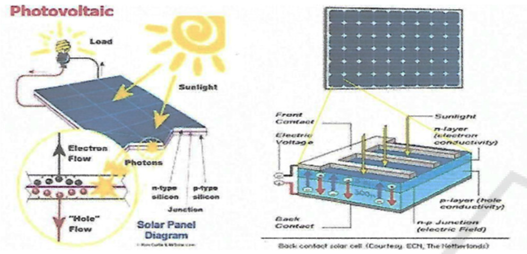

Figure 2: PV solar system schematic (Widayana Gede, 2012).

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. A Solar panel refers either to a photovoltaic module, a solar thermal energy panel, or a set of solar photovoltaic (PV) modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity for commercial and residential applications. A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and/or solar tracker and interconnection wiring (Manabhanjan Sahoo, Ivan Sunit Rout, 2016).

3 RESEARCH METHODS

This research was conducted through research and development (R & D). The AC compressor on the freezer machine prototype was replaced by using a DC compressor. Similarly, the fan motor for the condenser, which was originally an AC type, was replaced with a DC fan motor.

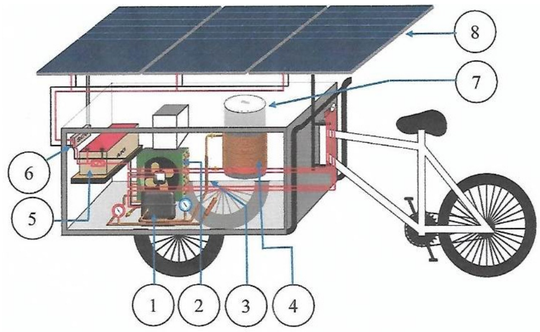

Figure 3: DC freezer machine design drawing for traveling ice cream sellers.

Table 1.

No	Parts
1	DC Compressor
2	Condensor
3	Capillary tube
4	Evaporator
5	Battery
6	Solar charge controller
7	Ice-cream box
8	Solar PV

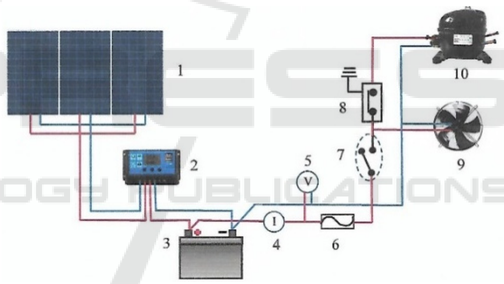

Figure 4: Wiring diagram on DC freezer for mobile ice cream seller.

Table 2.

No	Parts
1	Solar PV
2	Solar charge controller
3	Battery
4	Ampere meter
5	Volt meter
6	Fuse
7	Switch ON-OFF
8	Thermostat
9	DC fan motor
10	DC compressor

The DC compressor used has 12V and 100W technical specifications, while the fan motor has 12W power, so the total power of this freezer is 112W. With this total power, by using the formulas to calculate the capacity of the solar panels, the capacity and number of solar panels to be used will be obtained, as well as the size of the solar charge controller (SCC) and battery capacity. The capillary tube will also be replaced and its size determined using the CapSel application program version 1.0, database 2.2. The refrigerant used is HFC-134a with a design temperature of -20oC and a condensation temperature of -20oC, respectively. The sub-cooled (SC) and super-heated (SH) degrees are designed for 3K and 8K, respectively. Its isentropic efficiency is considered to be 100%.

After the components of the solar panel system are assembled, the refrigerant is filled into the system with the optimum mass according to its working pressure. After the system works normally, it will be tested to determine its performance and energy consumption. The test is carried out by measuring the refrigerant temperature at 6 set-points using a type K thermocouple and temperature display while measuring DC voltage and current are measured at the input cable to the system.

4 RESULTS AND DISCUSSION

By using the total 112W power required by the DC freezer machine for mobile ice cream sellers, it can be determined the total capacity of the solar panels needed, which is 300WP. Because the solar panels are selected with a capacity of 100WP, 3 solar panels are needed. For the solar charge controller, a size of 20A is used, while the battery with a capacity of 12V and 200Ah is used. By inputting the design data into the CapSel application program version 1.0, database 2.2, the size of the capillary tube is 0.031 inches in diameter and 2.39 meters long. The evaporator used is a bar tube type that is wrapped around an ice cream box. The evaporator is made of copper pipe with an outer diameter of 3/8 inch and a length of 15.8 meters, with a heat transfer area of 0.47m^2. While the condenser used is a finned tube type with a heat transfer area of 0.64 m^2. The optimum mass of refrigerant HFC-134a filled into the system is 0.510 grams. Tests were carried out by load at a low pressure of 4.5 PSIG and high pressure of 130 PSIG. In the load test, the lowest evaporator temperature up to -18^{o}C takes 270 minutes. The load used is 5 liters of water which is put into 5 plastic bottles with a capacity of 1 liter each.

To determine the COP of a DC freezer machine for this mobile ice cream seller, the CoolPack application program is used. The input test data includes refrigerant type, evaporation temperature, condensation temperature, super-heat degree, sub-cooled degree, and isentropic efficiency. Meanwhile, to determine energy consumption, the existing formulas are used.

Figure 5: DC freezer machine for mobile ice cream sellers.

4.1 Variation of COP, Evaporating Temperature, Energy Consumption and Cooling Time

From Figure 6 below, it can be seen that the curve for energy consumption from the 20th minute appears to have a downward trend, although not too much. This decrease in energy consumption is proportional to the decrease in temperature that occurs. The average energy consumption is 13.61kJ. The energy consumption of the same device using an AC compressor is much higher (67.8kJ) (Susila I Dewa Made, et al, 2021) when compared to using a DC compressor.

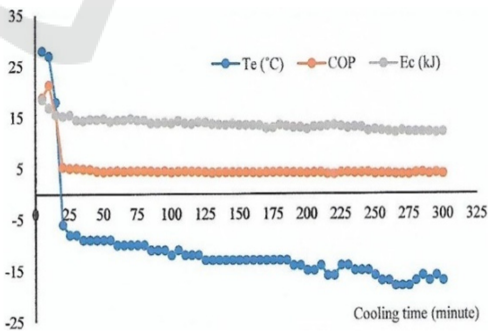

Figure 6: Variation of COP, evaporating temperature, energy consumption, and cooling time.

Likewise, the curve for COP starting at minute 20, tends to decrease and is very small until minute 300. The average COP during the test is 4.97. Compared to the same test carried out in the previous year but using an AC compressor, the freezer machine for itinerant ice cream vendors using a DC compressor has a higher COP.

This is in line with research conducted by Gangadhar V, and Umesh V.Hambire (2021). On the one hand, the evaporation temperature curve decreases steadily from the 25th minute and the lowest temperature of -18°C is reached at 265 to 275 minutes. When compared with the design evaporation temperature, there is a difference of 2°C. The evaporator is used to cool the ice cream box which is designed to work at a temperature of -17°C.

5 CONCLUSION

This DC freezer machine for mobile ice cream sellers is designed using a solar panel system. With a total power required by the system of 112W, the required solar panel capacity is 300WP with a 20A solar charge controller (SCC) and 12V, 200Ah batteries used. After testing, the COP of the DC freezer machine for this mobile ice cream seller is 4.97 and the energy consumption is 13.61kJ.

ACKNOWLEDGEMENTS

The authors would like to thank the government of the Republic of Indonesia, especially the Bali State Polytechnic has funded this research. The author also thanks the head of P3M PNB who has helped facilitate the writing, implementation, and reporting of the research.

REFERENCES

Widayana Gede. 2012. Pemanfaatan Energi Surya. *JPTK Undiksha*, Vol. 9 No. 1, ISSN 0216-3241, hal. 37-46.

Bambang Hari Purwoto, Jatmiko, Muhamad Alimul F, Ilham Fahmi Huda. Efisiensi Penggunaan Panel Surya Sebagai Sumber Energi Alternatif. *Emitor: Jurnal Teknik Elektro* Vol.18 No. 01 ISSN 1411-8890, hal. 10-14.

Banjo S.O., O.O. Ajayi, B.O. Bolaji M.E. Emetere, O.S.I. Fayomi, N.E. Udoye, A.O. Olatunde, K. Akinlabu. Evaluation analysis of a developed solar refrigerator using conventional refrigerant for rural and medical applications. 2021. *International Conference on Energy and Sustainable Environment*. IOP Conf. Series: Earth and Environmental Science 665 (2021) 012028. Page: 1-9

Chaitanya G. Balinavar, Rohan N. Bhairavkar, Stanzin Lotos, Shubham G. Bhumkar, Dr.Vijay W. Bhatkar. 2021. Design and Simulation of Solar Powered Vapour Compression Refrigeration System. *International Journal of Engineering Research in Mechanical and Civil Engineering*, Vol 6, Issue 8, ISSN (Online) 2456-1290, pages: 44-50.

Gangadhar V. Amratwar, Umesh V. Hambire. 2021. A Review of Development and Application of Solar Photovoltaic Powered Refrigeration System. *International Journal of Energy and Power Engineering*; 10(3): 57-61.

Ganorkar S. V., Kadam Yogesh Yuvraj, Kuchekar Gaurav Babasaheb, Shende Kiran Subhash. 2017. Solar Assisted Refrigeration System. *Journal oF Information, Knowledge, and Research in Mechanical Engineering*. ISSN 0975 – 668X| Nov 16 to Oct 17, Volume –04, Issue – 02. Page: 786-790.

Kalbande S. R., Sneha Deshmukh. 2015. Photovoltaic Based Vapour Compression Refrigeration System for Vaccine Preservation. *Universal Journal of Engineering Science* 3(2):17-23, DOI:10.13189/ujes.2015.030202. Page: 17-23.

Simson Pinto, A. Madhusudhan. 2016. Solar Powered Refrigeration System with Cold Bank. *Indian Journal of Science and Technology*, Vol 9(42), DOI: 10.17485/IJST/2016/v9i42/104688, ISSN (Print): 0974-6846 ISSN (Online): 0974-5645. Page: 1-5.

Suamir IN, IGAB Wirajati, IDMC Santosa, IDM Susila and IDGA Tri Putra. 2020. Experimental Study on the Prospective Use of PV Panels for Chest Freezers in Hot Climate Regions. *Journal of Physics: Conference Series* 1569, 032042, doi:10.1088/1742-6596/1569/3/032042, Page:1-8.

Susila I Dewa Made, Daud Simon Anakottapry, Adi Subagia I Wayan, Wijaya Sunu Putu, Ardita I Nengah.. (2021). Performance and Energy Consumption Analysis of Freezer Machines for Mobile Ice Cream Sellers Using Eco-Friendly Refrigerant MC134. *International Conference on Applied Science and Technology*. October 23rd at Politeknik Negeri Samarinda

Widiyatmoko. 2015. Perancangan, Perakitan, Dan Pengujian Performa Mesin Pembuat Es Krim manual Kapasitas 5 Liter. *Jurnal Teknologi Pendingin dan Tata Udara Politeknik Sekayu (PETRA)*, Volume 1, No.1, pp. 55-72.

Manabhanjan Sahoo, Ivan Sunit Rout. 2016. Design, fabrication, and performance analysis of solar PV air conditioning system. International Journal of Scientific and Research Publications, Volume 6, Issue 10. Page: 277-282.