Performance Analysis of Personal Air-Conditioning System Using Evapolar as Heat Waste Management

by Nor Azazi Ngatiman

Submission date: 20-Oct-2021 09:27PM (UTC+0800)
Submission ID: 1679064503
File name: -Conditioning_System_Using_Evapolar_As_Heat_Waste_Management.pdf (427.45K)
Word count: 5511
Character count: 28751

Bulletin of Electrical Engineering and Informatics
Vol. 99, No. 1, Month 2099, pp. 1~1x
ISSN: 2302-9285, DOI: 10.11591/eei.v99i1.paperID

Performance Analysis of Personal Air-Conditioning System Using Evapolar as Heat Waste Management

Nor Azazi Ngatiman[1], Muhammad Nur Othman[1], Tole Sutikno[3], Suparje Wardiyono[4], Mustafa Manap[5], Mohd Hatta Jopri[6]

[1,2]Department of Mechanical Engineering Technology, Faculty of Mechanical & Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka, Malaysia
[3]Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[4]State-Owned Enterprise Power Company (PLN), North Kalimantan Province, Indonesia
[5,6]Faculty of Electrical and Electronic Engineering Technology, Universiti Teknikal Malaysia Melaka, Malaysia

Article Info

Article history:

Received month dd, yyyy
Revised month dd, yyyy
Accepted month dd, yyyy

Keywords:

Personal air conditioner
Performance analysis
Heat waste management
Peltier impact module
Evapolar

ABSTRACT

In a tropical country particularly Malaysia, generally human heat feeling in compact office has a low cooling load. Air-conditioning system that uses compressor-based initiate more energy and affects bill rate which became expenditure for small room-scale. As a result, an application of the Peltier impact module, a portable air-conditioning system is introduced to compensate user convenience by lowering sensible and latent heat inside the office area. Thermoelectric Peltier module is a thermoelectric semiconductor that offers cooling and hot plate once the plate is supplied by electric, where Peltier has significant performance and the study demonstrates that with a series circuit, performance of Peltier greater compared to the earlier researcher. The result also reduces the cost, power consumption, and give thermal comfort in a dedicated space. The advantage of the study is the ability to cost deduction due to low power consumption and green technology devices factor because without refrigerant that harms the environment. Redesign the product with Evapolar as heat waste management will affect the performance and need to be validated. The development stage of this product is better compared to a previous product which offers small scale, light, and portable. This product focuses on the office room, which gives a good feeling to users. This product uses air to remove the heat waste and the result indicates Evapolar is fit enough in dissipating heat. Finally, the performance of this system developed demonstrated that it can attain thermal comfort level.

Corresponding Author:

Nor Azazi Ngatiman
Department of Mechanical Engineering Technology, Faculty of Mechanical & Manufacturing Engineering Technology, Universiti Teknikal Malaysia, Melaka, Malaysia
Email: azazi@utem.edu.my

1. INTRODUCTION

The cooling unit to cool a room usually uses a split unit which has a larger amount of cool air to distribute. For example, a standard office with an area 12'x12' will be a waste to cool the whole room since the space needed is a small area. In-office buildings, occupants will have a restricted space to move and have to control their movements. It will give an uncomfortable zone due to unbalanced comfort ventilation [1]–[5]. This proves that a portable air conditioner can cool with a range of 1 meter around a person will be more suitable than split units since it conserves less energy. Hot temperatures in a space must be removed to achieve a thermal comfort zone [6]–[8]. The previous researcher found that the Peltier module can cool down temperature and develop it as a portable air conditioner [9], [10]. It is proven to overcome waste energy consumption in portable air conditioning, Peltier Module was used. Hot effects on the hot side of the Peltier Module cannot fully be utilized while vice versa on the cold sides [11], [12]. The problem with the hot sides that not be used in Peltier Module must be utilized because Portable Air Conditioning using Peltier Module have a great achievement in transferring cool air to surroundings [13], [14]. Peltier Module will be affected due to a lot of heat waste in the surroundings. The latest researcher [15]–[17] found that heat waste from portable air conditioning using a Peltier module can be used as heat energy. This study also showed that thermal efficiency in the heat recovery process proves that higher thermal conductivity produces higher heat transfer to the surface. Less amount of heat loss occurred during the study [10], [18]–[20].

From the latest product of portable air conditioning system design [13], [21], the heat waste is released to the surrounding in large amounts due to unorganized energy [22]. The thermal comfort zone standardized by The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is around 22^{o}C to 24^{o}C for most buildings in Malaysia [23]–[25]. Heat waste from the Peltier module spread to the air and cause uncomfortable to users. Due to limited space in a room, users feel hotter because of Peltier Module generates the same capacity of hot and cold energy. Adding external energy such as electrical equipment and body, the temperature increase and hot temperature will overwhelm cold temperature [26]–[28]. So in favour of producing thermal comfort zones, this research will design new ways on how to recover the heat waste from release to surroundings [29]–[31]. In terms of ergonomics to users, this product needs to be upgraded for a better purpose. The heat waste from the product needs to be recovered to ensure the product will be convenient and increase efficiency [32]–[34]. This method also is a new idea in managing heat waste using Evapolar and finding ways to increase the effectiveness of the system.

2. RESEARCH METHOD

A strategy to develop a portable air conditioning system using Evapolar from several previous research is discussed. Different criteria and mechanical engineering concepts are used as a significant strategy [35]–[38]. This chapter includes the examination, evaluation, preparation, production, improvement, and testing.

Figure 1 depicts the process of developing portable air conditioning and also identifies the performance of the product. It starts from defining the standard condition until analysis of the developed product. Design is a process of designing a system to fulfil the outcome for this study, which provides a thermal comfort zone with the help of an Evapolar. A good design is defined to achieve the objective by the product's engineering characteristics. The great design of this device can be created by following a standard conventional method which is the Morphological method and Pugh method.

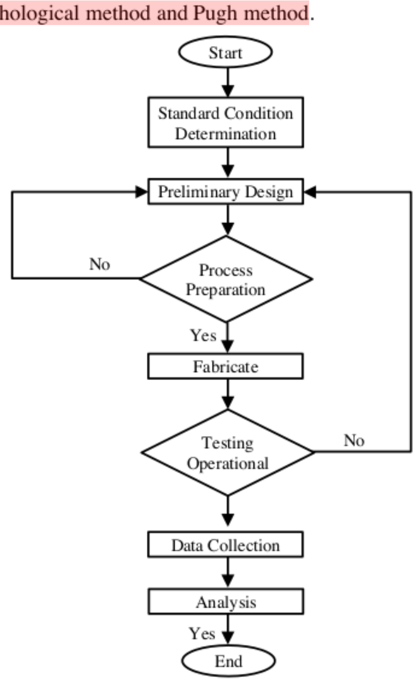

Figure 1. Process phase of energy saving personal air-conditioning development

2.2. Morphological chart

The morphological technique is the study of shape as well as forms before the product is being developed [39]–[42]. The basic idea of the morphological technique is to elaborate the overall design issue into few variables to generate a solution for each criterion. It also systematically mixes up criteria solutions into multiple effective solutions and evaluate all combinations. It is a visual aid that comes with several ideas for selecting the suitable element throughout the design technique. Table 1 shows the Morphological chart attributes for portable air conditioning system.

Table 1. Morphological chart of portable air conditioner

Characteristics	Option 1	Option 2	Option 3
Heat Sink	Fin	Flare	Flare
Size	Medium	Small	Big
Blower	Draw Through Fan	Centrifugal	Axial
Sensing Element	Thermocouple	RTD	Bimetallic Strip
Power Source	Electrical	Solar	Mechanical
Casing Material	Metal Sheet	Plastic	Aluminum Sheet
Supply Connection	Direct	Wireless	USB

2.2. Pugh method

The Pugh method was introduced by Stuart Pugh, a plan division head at the University of Strathclyde in Glasgow [43]. Pugh is used to assess different alternatives by calculating the overall score between the choices [44]–[46]. The selections derive from the morphological method in which three concepts have produced the character of the product. Pugh method evaluates three concepts in terms of choosing a good concept based on the total raw score. The weightage describes the crucial feature, which should be carefully measured before selecting the best idea as shown in Table 2.

Table 2. Pugh method of portable air conditioner

Characteristics	Weightage	Option 1	Option 2	Option 3
Heat Sink	0.2	1	-1	-1
Size	0.2	1	-1	0
Blower	0.2	1	-1	0
Sensing Element	0.2	1	0	-1
Power Source	0.1	0	-1	1
Casing Material	0.1	1	-1	0
Supply Connection	0.1	1	0	1
	Total	1.3	-0.6	0

Table 2 shows option 1 is the best concept among other concepts due to the highest total raw score. Option 1 from the morphological method applies an electrical power supply, medium device, draw through fan, Arduino controller, thermocouple sensing element, metal sheet casing, finned heat sink, and connect directly. By using these methods, the design of the product is made and the results are shown as in Figure 2.

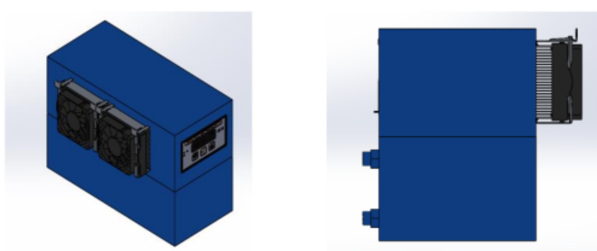

Figure 2. Conceptual of personal air-conditioning development

2.3. Testing Condition

A field measurement is carried out in this research to investigate the performance of a product in an office room [47]–[49]. This room size is measured and it is situated in Ayer Keroh, Melaka. It used a VRF (variable refrigerant flow) fan system where it is efficient and reliable. The ceiling measurement height from floor to ceiling is 2.5 meters. The collected data will be summarized. This equipment will be placed on the table at 1-meter height from the ground.

2.4. Peltier Performance

The efficiency of both generators and coolers conclude the greater the value of this term, the greater the efficiency [50]–[52]. The heat flux gives the value of the thermoelectric of merit between hot and cold sides due to conduction is:

$$Q_m = SIT_c - 0.5I^2R - k\,(T_H - T_c\,)\ \text{KJ} \tag{1}$$

Where S is Seeback coefficient = 0.053 V/K, *K* is Lattice thermal conductivity = 0.3 w/m.K, *R* is electrical resistance = 0.45 Ω, and *I* is current. Electrical power consumed by the module is calculated based on the heat flux difference of the two sides of the module as, where *I* is current, *V* is voltage, and *t* is time.

$$E_m = IVt\ \text{(KJ)}$$
$$\text{COP} = Q_m/E_m \tag{2}$$

2.5. Performance Coefficient of Device

A previous thermoelectric air-conditioner (heat pump) typically contains a large number of n-type and p-type bulk semiconductor thermoelements linked electrically in series by copper strips and sandwiched between two electrically insulating, but thermally conducting ceramic plates. In the cooling mode, the cooling capacity performance of the cooling effect is expressed as below:

$$\text{COP}_c = \frac{1}{\frac{Thout - Thin}{Tcin - Tcout}Cr - 1} \tag{3}$$

Where C_r is heat capacity ratio:

$$C_r = \frac{mcpc}{mcph} \tag{4}$$

The arithmetical average temperature of the thermocouple is:

$$T_m = \frac{1}{2}(T_H + Tc) \tag{5}$$

V is an electrical voltage:

$$V = \frac{\alpha \Delta T}{\sqrt{1 + ZTm} - 1} \tag{6}$$

Hence, the power can be obtained by using the volt calculated;

$$P = v\ x\ I \tag{7}$$

3. RESULTS AND DISCUSSION

The newly developed product is considering design parameters defined from the morphological chart where the combination of specific conditions for the creation of a product is shown in Figure 3. The system features use Peltier as a cooling source, a heat sink with aluminium finned to increase the heat transfer rate of a wood case to guard the internal component, Evapolar as a medium to cool down condenser and the fan to blow the cool air.

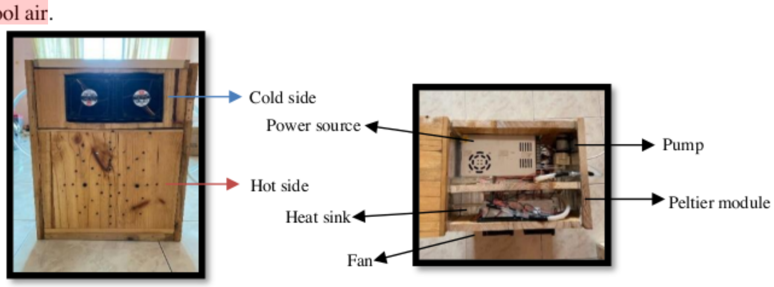

Figure 3. Final product assembled

3.1. Thermoelectric performance

This measurement repeated three times to prove whether the product achieve efficiency at different times. Table 3 shows the time taken to the temperature of Peltier becomes hot and cold. The temperature is measured every 5 minutes and COP for Peltier performance is calculated.

Table 3. Summary of data for all test

No	Time (sec)	Tc (K)	Th (K)	ΔT (°C)	Current (A)	Volt (V)	Q_m	E_m	COP_m
Test 1	1800	296.90	324.70	27.8	3.50	12	43.978	75.600	0.581
Test 2	1800	296.10	324.40	28.3	3.50	12	43.680	75.600	0.577
Test 3	1800	296.90	324.90	28.0	3.50	12	43.918	75.600	0.580
Average	1800	296.63	324.66	28.0	3.50	12	43.858	75.600	0.579

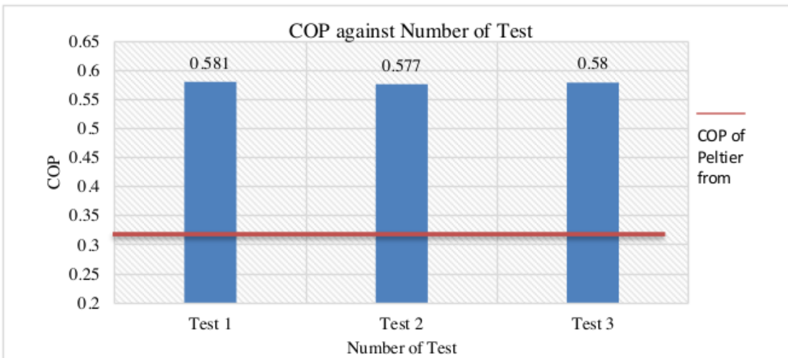

Figure 4. COP against the number of tests compared to the previous researcher [53]

Figure 4 shows the relationship between the Cop of Peltier performance after several tests. The trend of the chart is almost similar. Based on the previous research, the highest COP for Peltier reach 0.3205, which had different conditions that need to be counted. For this experiment, it shows COP for Peltier can reach 0.58 with proper conditions which show that for series connection and condition inside a room can affect the performance of Peltier. Thermal paste was used in this Peltier to lessen heat transfer losses that occur and increase the efficiency of Peltier.

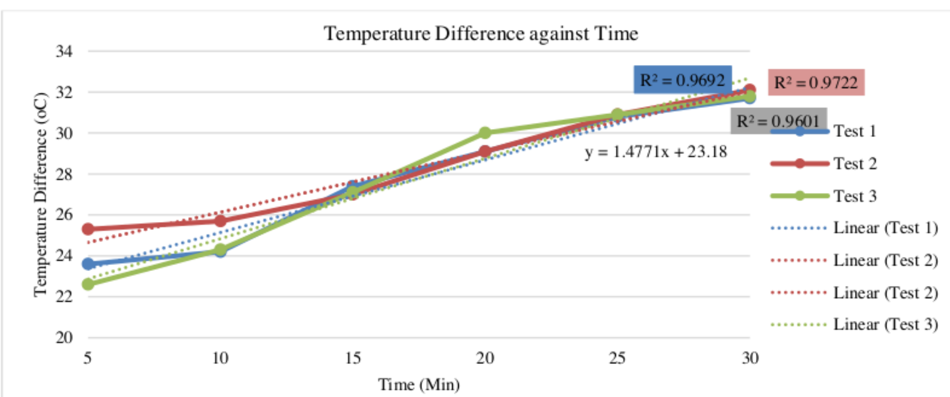

Figure 5. Temperature difference against time

From Figure 5, the temperature difference is increasing and the longer time is taken, the higher the temperature difference will occur. The efficiency of the Peltier can be seen due to the series connection to the wiring for all Peltier. When the current is in series connection it increases the voltage to the maximum while parallel connection increases the current to maximum [54]. For this experiment, R^2 values that are near to 1 are shown and R^2 data for each analysis reaches a suitable determinant coefficient. The data obtained is acceptable for the overall result of testing because it is higher than the set value where y = 1.4771x + 23.18 can be used to calculate the difference in temperature at any point for this product.

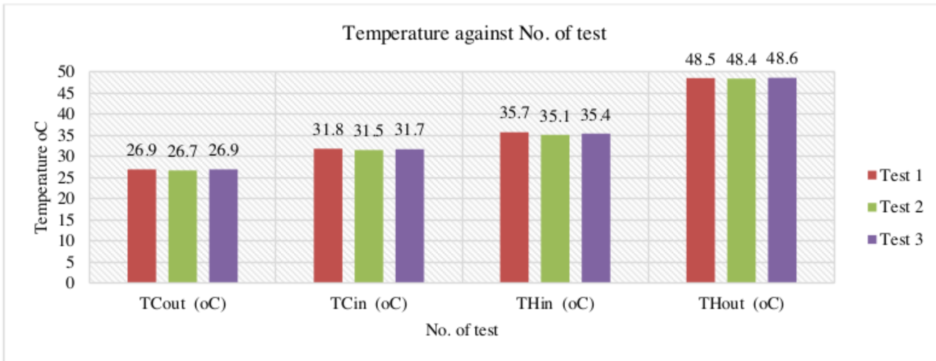

Figure 6. Different in temperature hot and cold with the number of tests

Figure 6 shows the different numbers of tests in the same conditions of the product. All of the temperatures have a minimal difference, which shows that the limit of the product that can be reached. Test 1 shows that for TCout, the temperature that blows to occupants can reach 26.9 °C when ambient temperature which TCin, at 31.8 °C. Next, THin which temperature of the air outside shows 35.7 °C while the temperature inside can reach 48.5 °C. This data showed that with the Evapolar mechanism, the amount of heat waste that could be removed is high and more productive.

3.2. Coefficient of performance on product

Table 4.9 shows the summarize of data for all testing.

Table 4. Summary of data for all test

No	TC_{out} (°C)	TC_{in} (°C)	TH_{in} (°C)	TH_{out} (°C)
Test 1	26.9	31.8	35.7	48.5
Test 2	26.7	31.5	35.1	48.4
Test 3	26.9	31.7	35.4	48.6
Average	26.8	31.6	35.4	48.5

3.3. Tariff of the device

A number of tests with the temperature of Peltier.

Table 5. Number of tests with the temperature of Peltier

No	Tc (K)	Th (K)	ΔT	Current (A)	Volt (V)
Test 1	296.90	324.70	27.8	3.50	12
Test 2	296.10	324.40	28.3	3.50	12
Test 3	296.90	324.90	28.0	3.50	12
Average	296.63	324.66	28.0	3.50	12

Table 6. Tariff of the device for product

No	Time operates	kWh	Price
Day	8 am to 5 am = 9 hours	9 x 320.83 = 2.88	RM 1.12
Week	Monday to Friday = 5days 5days x 9hours = 45hours	45 x 320.83 = 14.43	RM 5.62
Month	One month = 4weeks 4 weeks x 45hours = 180hours	180 x 320.83 = 57.74	RM 22.51
year	January to December = 12month 52 weeks x 45hours = 2340hours	2340 x 320.83 = 750.74	RM 292.78

Referring to Table 6, the estimation of the bill depends on the Malaysian tariff [55]. Compared to the previous researcher [53], 2.88 kWh power per day was used instead of 6.894 kWh. The monthly energy consumed is 137.88 kWh, while this product consumes only 57.74 kWh, which can save almost 58% of its electricity.

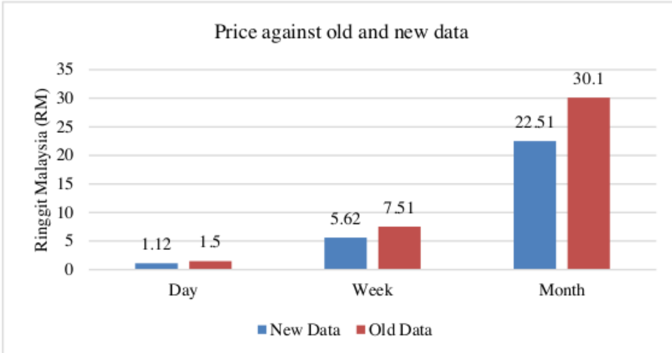

Figure 7. Price comparison with the previous researcher [53]

Figure 7 shows the amount of the bill per day to be paid for this product is RM1.12, which the previous shown RM1.50, which can save 25% of the bills per day. Besides, the margins are increasing as compared in the month that this new product can save 26 %. Based on the above information, this product provides consumers with fewer electricity bills while providing an individual with comfort.

4. CONCLUSION

The performance study of an office scale portable Peltier air conditioner is demonstrated. The product can reduce the temperature inside the room. The objective of the study has achieved which design is made based on the Pugh method and Morphological chart. The design process has also been done using Solid Work Software. The performance of the product using Evapolar as heat waste management has been discussed. It reaches the purpose to remove heat from the inside of the product to the outside using Evapolar as heat removal. The coefficient of performance is similar to the level of the previous product, which means it can provide higher efficiency despite no controller temperature. Tariff for electricity shows this product can save energy approximately by 25% compared to previous one.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Ministry of Higher Education Malaysia (MOHE) for funding for this research. We would like to also express gratitude to Universiti Kebangsaan Malaysia (UKM) and Universiti Teknikal Malaysia Melaka (UTeM) for the support given by providing hardware for experiments and simulations.

REFERENCES

[1] X. Deng and Z. Tan, “Numerical analysis of local thermal comfort in a plan office under natural ventilation,” *Indoor Built Environ.*, 2020, doi: 10.1177/1420326X19866497.

[2] A. Staveckis and A. Borodinecs, “Impact of impinging jet ventilation on thermal comfort and indoor air quality in office buildings,” *Energy Build.*, 2021, doi: 10.1016/j.enbuild.2021.110738.

[3] D. Y. Park and S. Chang, “Effects of combined central air conditioning diffusers and window-integrated ventilation system on indoor air quality and thermal comfort in an office,” *Sustain. Cities Soc.*, 2020, doi: 10.1016/j.scs.2020.102292.

[4] A. R. R. Abdullah, N. S. S. Ahmad, N. Bahari, M. Manap, A. Jidin, and M. H. Jopri, “Short-circuit switches fault analysis of voltage source inverter using spectrogram,” *Electr. Mach. Syst. (ICEMS), 2013 Int. Conf.*, pp. 1808–1813, 2013, doi: 10.1109/icems.2013.6713294.

[5] L. R. L. V. Raj, A. Jidin, K. Abdul Karim, T. Sutikno, R. Sundram, and M. H. Jopri, “Improved torque control performance of direct torque control for 5-phase induction machine,” *Int. J. Power Electron. Drive Syst.*, vol. 3, no. 4, 2013, doi: 10.11591/ijpeds.v3i4.5249.

[6] A. F. Noor Azam *et al.*, “Current control of BLDC drives for EV application,” 2013, doi: 10.1109/PEOCO.2013.6564583.

[7] M. Z. R. Zuber Ahmadi, A. Jidin, K. B. Jaffar, M. N. Othman, R. N. P. Nagarajan, and M. H. Jopri, “Minimization of torque ripple utilizing by 3-L CHMI in DTC,” *Proc. 2013 IEEE 7th Int. Power Eng. Optim. Conf. PEOCO 2013*, no. June, pp. 636–640, 2013, doi: 10.1109/PEOCO.2013.6564625.

[8] R. Nair, A. Jidin, M. N. Othman, M. H. Jopri, and M. Manap, “Comparison performance of 3-Level and 5-Level Cascaded H-Bridge multilevel inverter of DTC of Induction Machine,” 2013, doi: 10.1109/ICEMS.2013.6713181.

[9] A. N. P. & B. P. BENZIGER B, “Review Paper on Thermoelectric Air-Conditioner Using Peltier Modules,” *Int. J. Mech. Eng.*, 2015.

[10] M. A. Singh, “Air Conditioner using Peltier Module,” *Int. J. Res. Appl. Sci. Eng. Technol.*, 2019, doi: 10.22214/ijraset.2019.2047.

[11] J. Ding, W. Zhao, W. Jin, C. an Di, and D. Zhu, "Advanced Thermoelectric Materials for Flexible Cooling Application," *Advanced Functional Materials*. 2021, doi: 10.1002/adfm.202010695.
[12] C. N. Kim and J. Kim, "Numerical Examination of the Performance of a Thermoelectric Cooler with Peltier Heating and Cooling," *J. Electron. Mater.*, 2015, doi: 10.1007/s11664-015-3845-y.
[13] A. A. Adeyanju and K. Manohar, "Design and Analysis of a Thermoelectric Air-conditioning System," *J. Sci. Res. Reports*, 2020, doi: 10.9734/jsrr/2020/v26i430243.
[14] L. R. L. V. Raj, A. Jidin, C. W. M. F. Che Wan Mohd Zalani, K. Abdul Karim, G. Wee Yen, and M. . Jopri, "Improved performance of DTC of five-phase induction machines," 2013, doi: 10.1109/PEOCO.2013.6564621.
[15] A. Anthony Ademola, "Theoretical and Experimental Analysis of a Thermoelectric Air-conditioning System," in *Low-temperature Technologies*, 2020.
[16] "A Report on Design & Setup of Peltier Module Based Air Cooler," *Int. J. Recent Technol. Eng.*, 2020, doi: 10.35940/ijrte.a3010.059120.
[17] M. M. M. Al-Khalidy and A. M. Isa Ahmed, "Internet of things and intelligent peltier cold/hot air conditioning system," 2019, doi: 10.1049/cp.2019.0175.
[18] A. Youssef, N. Caballero, and J. M. Aerts, "Model-based monitoring of occupant's thermal state for adaptive HVAC predictive controlling," *Processes*, 2019, doi: 10.3390/pr7100720.
[19] Y. Zhang *et al.*, "Analysis of thermal comfort during movement in a semi-open transition space," *Energy Build.*, 2020, doi: 10.1016/j.enbuild.2020.110312.
[20] M. R. Ab. Ghani, M. H. Jopri, and M. R. Yusoff, "A critical review of time-frequency distribution analysis for detection and classification of harmonic signal in power distribution system," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 6, pp. 4603–4618, 2018, doi: 10.11591/ijece.v8i6.pp.4603-4618.
[21] G. D. Ramady *et al.*, "Development of a Cooling System Simulation Model using Thermoelectric Peltier based on Microcontroller," 2021, doi: 10.1088/1742-6596/1933/1/012088.
[22] L. R. L. V. Raj, A. Jidin, Z. Ibrahim, K. A. Karim, M. A. Said, and M. H. Jopri, "Optimal torque control performance of DTC of 5-phase induction machine," 2013, doi: 10.1109/ICEMS.2013.6713180.
[23] N. Aqilah Hisham, S. Ahmad Zaki, A. Hagishima, and N. Md Yusoff, "Load and Household Profiles Analysis for Air-Conditioning and Total Electricity in Malaysia," *KnE Soc. Sci.*, 2019, doi: 10.18502/kss.v3i21.5010.
[24] S. A. Damiati, S. A. Zaki, H. B. Rijal, and S. Wonorahardjo, "Field study on adaptive thermal comfort in office buildings in Malaysia, Indonesia, Singapore, and Japan during hot and humid season," *Build. Environ.*, 2016, doi: 10.1016/j.buildenv.2016.09.024.
[25] M. A. C. Munaaim, K. M. Al-Obaidi, and M. Azizul Abd Rahim, "Performance comparison of solar assisted and inverter air conditioning systems in Malaysia," *J. Des. Built Environ.*, 2017, doi: 10.22452/jdbe.sp2017no1.5.
[26] M. Manap *et al.*, "A verification of periodogram technique for harmonic source diagnostic analytic by using logistic regression," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 1, pp. 497–507, 2019, doi: 10.12928/TELKOMNIKA.v17i1.10390.
[27] M. H. Jopri, A. R. Abdullah, M. Manap, T. Sutikno, and M. R. A. Ghani, "An identification of multiple harmonic sources in a distribution system by using spectrogram," *Bull. Electr. Eng. Informatics*, vol. 7, no. 2, pp. 244–256, 2018, doi: 10.11591/eei.v7i2.1188.
[28] M. R. Yusoff, M. H. Jopri, A. R. Abdullah, T. Sutikno, M. Manap, and A. S. Hussin, "An Analysis of Harmonic and Interharmonic Contribution of Electric Arc Furnace by Using Periodogram," *Int. J. Electr. Comput. Eng.*, vol. 7, no. 6, p. 3753, 2017, doi: 10.11591/ijece.v7i6.pp3753-3760.
[29] S. K. Sansaniwal, J. Mathur, V. Garg, and R. Gupta, "Review of studies on thermal comfort in Indian residential buildings," *Sci. Technol. Built Environ.*, 2020, doi: 10.1080/23744731.2020.1724734.
[30] R. F. Rupp, N. G. Vásquez, and R. Lamberts, "A review of human thermal comfort in the built environment," *Energy and Buildings*. 2015, doi: 10.1016/j.enbuild.2015.07.047.
[31] M. H. Jopri, A. R. Abdullah, M. Manap, M. R. Yusoff, and T. Sutikno, "A fast localization of multiple harmonic sources for rectifier loads by utilizing periodogram," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 15, no. 1, 2017, doi: 10.12928/TELKOMNIKA.v15i1.3120.
[32] A. Baroutaji *et al.*, "Advancements and prospects of thermal management and waste heat recovery of PEMFC," *Int. J. Thermofluids*, 2021, doi: 10.1016/j.ijft.2021.100064.
[33] C. W. R. Lin, Y. J. M. Parng, and Y. L. Chen, "Profit optimization of sustainable low-to-medium temperature waste heat recovering management," *Ind. Manag. Data Syst.*, 2018, doi: 10.1108/IMDS-04-2017-0148.
[34] A. S. Hussin, A. R. Abdullah, M. H. Jopri, T. Sutikno, N. M. Saad, and W. Tee, "Harmonic load diagnostic techniques and methodologies: A review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 9, no. 3. Institute of Advanced Engineering and Science, pp. 690–695, Mar. 01, 2018, doi: 10.11591/ijeecs.v9.i3.pp690-695.
[35] N. Shafiei, M. H. Harun, K. A. M. Annuar, M. F. A. Halim, M. S. M. Aras, and A. H. Azahar, "Development of portable air conditioning system using peltier and seebeck effect," *J. Telecommun. Electron. Comput. Eng.*, 2016.
[36] Z. Abbas *et al.*, "Performance evaluation of novel solar-powered domestic air cooler with Peltier modules," *J. Mech. Sci. Technol.*, 2020, doi: 10.1007/s12206-020-1036-0.
[37] J. Nemade, "Portable Air Conditioner based on Hybrid Method of Peltier Effect Cooling and Liquid Based Cooling," *Int. J. Res. Appl. Sci. Eng. Technol.*, 2021, doi: 10.22214/ijraset.2021.34446.
[38] Z. S. Zomorodian, M. Tahsildoost, and M. Hafezi, "Thermal comfort in educational buildings: A review article," *Renewable and Sustainable Energy Reviews*. 2016, doi: 10.1016/j.rser.2016.01.033.
[39] D. Rakov, "Advantages and disadvantages of morphological methods in engineering," *MATEC Web Conf.*, 2020, doi: 10.1051/matecconf/202032903028.
[40] A. M. Hassan, A. A. Fatah El Mokadem, N. A. Megahed, and O. M. Abo Eleinen, "Improving outdoor air quality based on building morphology: Numerical investigation," *Front. Archit. Res.*, 2020, doi: 10.1016/j.foar.2020.01.001.
[41] M. Mozuni and W. Jonas, "An Introduction to the Morphological Delphi Method for Design: A Tool for Future-Oriented Design Research," *She Ji*, 2017, doi: 10.1016/j.sheji.2018.02.004.
[42] D. Rakov, "Morphological methods of searching for new engineering solutions and their use in Industry 4.0," 2020, doi: 10.1088/1742-6596/1679/4/042083.
[43] A. Marina Reis de, V. L. da Silva, and V. E. Beala, "APPLICATION OF THE PUGH METHOD FOR THE SELECTION OF STRUCTURAL ADHESIVES IN PRECISION INSTRUMENTS: A CASE STUDY," 2020, doi: 10.5151/siintec2020-applicationofthe.

[44] M. S. F. Hussin *et al.*, "Conceptual design and structure analysis of savonius vertical axis wind turbine under low wind speed," *J. Adv. Res. Fluid Mech. Therm. Sci.*, 2020, doi: 10.37934/arfmts.71.2.178187.
[45] C. Y. Von Teh, M. N. S. Bin Shahrol Aman, W. A. Mustafa, and S. A. Bin Ahmad, "Conceptual Design for Ankle Rehabilitation Robot by Using Morphological Chart and Pugh Method," 2020, doi: 10.1088/1757-899X/932/1/012062.
[46] P. M. Villanueva, R. Lostado Lorza, and M. Corral Bobadilla, "Pugh's Total Design: The design of an electromagnetic servo brake with ABS function - A case study," *Concurr. Eng. Res. Appl.*, 2016, doi: 10.1177/1063293X16638710.
[47] A. S. Rahimi, A. Subki, W. N. A. Rashid, N. A. A. Hadi, A. Z. Jidin, and T. S. Ying, "Development of Portable Air Conditioning Using Peltier Effect for Small Area Uses," *J. Telecommun. Electron. Comput. Eng.*, 2018.
[48] Y. Qiao *et al.*, "Experimental Study on Portable Air-Conditioning System with Enhanced PCM Condenser," 2018.
[49] M. Sahoo and I. S. Rout, "Design, fabrication and performance analysis of solar PV air conditioning system," *Int. J. Sci. Res. Publ.*, 2016.
[50] A. Singha and B. Muralidharan, "Performance analysis of nanostructured Peltier coolers," *J. Appl. Phys.*, 2018, doi: 10.1063/1.5044254.
[51] F. AFSHARİ, "Experimental Study for Comparing Heating and Cooling Performance of Thermoelectric Peltier," *J. Polytech.*, 2020, doi: 10.2339/politeknik.713600.
[52] H. Sadighi Dizaji, S. Jafarmadar, S. Khalilarya, and S. Pourhedayat, "A comprehensive exergy analysis of a prototype Peltier air-cooler; experimental investigation," *Renew. Energy*, 2019, doi: 10.1016/j.renene.2018.07.056.
[53] W. N. Fakhira and M. K. Fadzly, "Smart portable air cooler using thermoelectric peltier," 2019, doi: 10.1063/1.5118158.
[54] W. Jin *et al.*, "Exploring Peltier effect in organic thermoelectric films," *Nat. Commun.*, 2018, doi: 10.1038/s41467-018-05999-4.
[55] A. H. Razali, M. Pauzi Abdullah, M. Y. Hassan, D. M. Said, and F. Hussin, "Net energy metering scheme based on time of use pricing for residents in Malaysia," *Indones. J. Electr. Eng. Comput. Sci.*, 2020, doi: 10.11591/ijeecs.v19.i3.pp1140-1146.

BIOGRAPHIES OF AUTHORS

	**Nor Azazi Ngatiman** received the B.Sc. degrees in Mechanical Engineering from Universiti Kebangsaan Malaysia, in 2005 and M.Sc. degrees in Manufacturing Systems Engineering from Universiti Putra Malaysia in 2010. He experienced with engineering research and development field industry for over 5 years from 2005. In 2021, he got a PhD degree in Mechanical & Material Engineering from Universiti Kebangsaan Malaysia. His current research interests include condition-based monitoring, mechanical signal analysis, vibration analysis and machine learning. He can be contacted at email: azazi@utem.edu.my
	**Muhammad Nur Othman** received the Bachelor of Engineering (Mechanical-Automotive) from International Islamic University Malaysia, in 2006 and M.Sc. degrees in Mechanical Engineering from University of Malaya in 2016. He experienced in teaching Heating, Ventilation and Air Conditioning subject since 2016 until current. His current research interests include acoustic of natural fibre, HVACR, CAE and Renewable Energy. He can be contacted at email: muhammadnur@utem.edu.my
	**Tole Sutikno** is a Lecturer in Electrical Engineering Department at the Universitad Ahmad Dahlan (UAD), Yogyakarta, Indonesia. He received his B.Eng., M.Eng. and Ph.D. degrees in Electrical Engineering from Universitas Diponegoro, Universitas Gadjah Mada and Universiti Teknologi Malaysia, in 1999, 2004 and 2016, respectively. He has been an Associate Professor in UAD, Yogyakarta, Indonesia since 2008. He is currently an Editor-in-Chief of the TELKOMNIKA since 2005, and the Head of the Embedded Systems and Power Electronics Research Group since 2016. His research interests include the field of industrial applications, industrial electronics, industrial informatics, power electronics, motor drives, renewable energy, FPGA applications, embedded system, image processing, artificial intelligence, intelligent control, digital design and digital library.
	**Suparje Wardiyono** was born in Sleman, Indonesia on 1978. He received his B.Eng in Electrical Engineering from Faculty of Engineering, Gadjah Mada University, Indonesia in 2001, M.Sc. in Electrical Power Engineering from Rheinisch-Westfälische Technische Hochschule Aachen (RWTH), Germany in 2011. He is an experienced electrical engineer and since 2002, he has been serving well-known State-Owned Enterprise Power Company in Indonesia, PLN and held various engineering, procurement, asset management, retail and customer service in various units PLN in Indonesia. His focus areas are Engineering, Management and Customer Service. Currently he is serving PLN as Customer Service Manager for North Kalimantan Province, Indonesia.

	**Mustafa Manap** was born in Kuala Lumpur, Malaysia on 1978. He received his B.Sc from Universiti Technologi Malaysia in 2000 and Msc. in Electrical Engineering from Universiti Teknikal Malaysia Melaka (UTeM) 2016. Since 2006, he has been an academia staff at Universiti Teknikal Malaysia Melaka (UTeM). He registered with Malaysia Board of Technologist (MBOT), and a member of International Association of Engineers (IAENG). His research interests are power electronics and drive, instrumentation, and DSP application.
	**Mohd Hatta Jopri** was born in Johor, Malaysia on 1978. He received his B.Eng from Universiti Teknologi Malaysia (UTM), Msc. in Electrical Power Engineering from Rheinisch-Westfälische Technische Hochschule Aachen (RWTH), Germany, and PhD from Universiti Teknikal Malaysia Melaka (UTeM), respectively. Since 2005, he is an academia and research staff at UTeM. He registered with Malaysia Board of Technologist (MBOT), and a member of International Association of Engineers (IAENG). His research interests include power electronics and drive, power quality analysis, signal processing, machine learning and data science.

Performance Analysis of Personal Air-Conditioning System Using Evapolar as Heat Waste Management

ORIGINALITY REPORT

15%	7%	6%	14%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	11%
2	Noor Iswaniza Md Siam, Tole Sutikno, Mohd Junaidi Abdul Aziz. "Lithium ferro phosphate battery state of charge estimation using particle filter", International Journal of Power Electronics and Drive Systems (IJPEDS), 2021 Publication	3%
3	Submitted to Universiti Teknologi Malaysia Student Paper	2%

Exclude quotes	Off	Exclude matches	< 2%
Exclude bibliography	On		