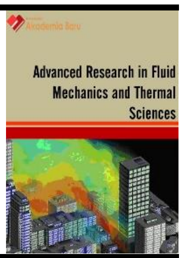
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Efficiency of Electricity Production from Installed Generator on a Condensing Unit of an Air Conditioner

Open Access

Chanita Mano[1], Atthakorn Thongtha[1,*]

[1] Department of Physics, Faculty of Science, Naresuan University, Phitsanulok, Thailand

ARTICLE INFO

Article history:
Received 3 February 2019
Received in revised form 12 May 2019
Accepted 2 June 2019
Available online 15 August 2019

ABSTRACT

This research investigated the efficiency of a generator installed on a condensing unit to produce electricity on a split air conditioner. A rectangle-shaped or a circular-shaped hood was set up to increase the wind speed coming out of the condensing unit. A DC generator with a capacity of 24 Volts and 300 Watts was operated at the end of each hood to produce electricity. All experiments were performed using a split-typed air conditioner within a 3.0 m X 3.0 m X 2.6 m room. The air conditioner was set to 25 °C in the cool mode with the fan speed set to level 5. The results showed that the average air ventilation speed of the condensing unit, the end of rectangle-shaped hood and the end of circle-shaped hood is at approximately 7.6, 12.4 and 12.5 m/s, respectively. The electrical generator operated just outside of the normal condensing unit, the end of rectangle-shaped hood and the end of circle-shaped hood had a voltage of 7.9, 15.6 and 16.1 V, and daily average electricity of 491.8, 1951.9 and 2071.6 W·hr was produced, respectively. To investigate the COP and EER, 4 cases were used: the normal condensing unit, installation of the electrical generator, installation of rectangle-shaped hood and the electrical generator, and installation of circle-shaped hood and the electrical generator. Coefficient of performance in each case was 4.1, 4.1, 4.1 and 4.1, and the energy efficiency ratio of the 4 cases was 14.0, 14.0, 14.0 and 14.0 BTU/W·hr, respectively. The installation of the rectangle-shaped and circle-shaped hoods can increase the potential of the electrical energy production with no impact on the efficiency of the air conditioner.

Keywords:
condensing unit; air conditioner; COP; electrical generator; air hood

1. Introduction

In recent decades, the demand for energy has increased due to extreme population growth and industrialization [1-3]. Among various forms of energy, electrical energy is the most popular energy and widely used as a basic necessity for life [4-6]. Historically, electricity was produced from the conversion process of fossil fuels such as coal, petroleum and natural gas [7-9]. This process causes the emissions of carbon dioxide, a greenhouse gas that contributes to global warming [10-14]. For these reasons, renewable energy sources are being investigated to move towards a sustainable

* *Corresponding author.*
E-mail address: atthakornt@nu.ac.th (Atthakorn Thongtha)

energy system such as hydroelectric power, solar energy, geothermal energy and wind energy [15-17].

In tropical areas, the weather is hot all year round with a high level of solar radiation and limited cloud cover [18,19]. These conditions caused a significant accumulation of heat and moisture in buildings [20-24]. Ventilating fans and air conditioners are used to cool the air in buildings. Presently, the use of air conditioners in modern society has become the norm for most buildings [25,26]. As the air conditioner works, the motor with a fixed propeller on the compressor rotates to ventilate the higher temperature of the coils [27]. From the literature reviews, the exhausted air from the compressor fan cannot sufficiently induce the rotation of blades that was installed by the generator [28,29]. Furthermore, the investigation of electricity generation from the exhausted wind of the condensing unit on the energy efficiency ratio has rarely been studied in the previous works. To increase the exhaust wind levels from the compressor and the potential of electricity generation, rectangle-shaped and circular-shaped hoods were installed at the condensing unit to connect to the fan of electrical generator. Importantly, the effects of hood and generator installation on efficiency of air conditioner were also investigated and compared.

2. Experimental Theory

The theory of this study is divided into 2 parts, the performance of the air conditioner, and the ventilation hood.

2.1 Performance of Air Conditioner

The performance of an air conditioner is calculated from the cooling capacity (Q) which is the capability measurement of a cooling system for removing heat. It depends on the enthalpy of the supplied and returned air from the fan coil unit by Eq. (1).

$$Q = 3.968V' \ (h_r - h_s) / 4.187v \tag{1}$$

Where Q is the cooling capacity (BTU/hr). h_r is the enthalpy of the return air and h_s is the enthalpy of the supply air from the fan coil unit (kJ/kg), V is the volume of air flow through the fan coil unit (m^3/hr), and v is the specific volume of humid air (m^3/kg).

Performance of the air conditioning unit is measured by the coefficient of performance or COP. It is the ratio of the desired output over the required input of the system which is a ratio of the heat that is removed from the cooled space over the input work or consumed electrical energy, by the following Eq. (2).

$$COP = Q / 3.413 \times P_e \tag{2}$$

Energy Efficiency Ratio (EER) is the ratio of output cooling energy (Q ; BTU/hr) to input electrical energy as the following Eq. (3) (P_e ; W), EER units are therefore BTU/W•hr.

$$EER = Q / P_e \tag{3}$$

2.2 Ventilation Hood Theory

In particular fluid dynamics, the volumetric flow rate (also known as volume flow rate, rate of fluid flow or volume velocity) is the volume of fluid which passes per unit of time. The volume flow rate calculation is shown in Eq. (4).

$$V_{air} = u_{hood} \times A_{hood} \tag{4}$$

where V_{air} is the flowing volume through the hood (m^3/s). u_{hood} is the flow velocity through the hood (m/s), and A_{hood} is the cross-sectional area of the hood (m^2).

3. Methodology

3.1 The Operation of the Condensing Unit

An experimental setup was done to investigate the potential of electricity generation from mechanical energy of a condensing unit of air conditioner. The split-typed Mitsubishi air conditioner model GL09VF size 9,212 BTU was considered to operate within a 3.0 m x 3.0 m x 2.6 m room dimension. The working temperature of the air conditioner was set to 25 °C in the cool mode and the fan speed set to level 5. In this study, the working period of the fan motor in condensing unit was studied. This process was tested throughout the day to measure the number and average time of motor rotation every hour in each day.

3.2 The Potential of Electricity Generation from Exhausted Ventilation of the Air Condensing Unit

The investigation of the potential for electricity generation from the condensing unit of an air conditioner is divided into 3 parts: i) the potential of electricity generation from the air ventilation of a normal condensing unit, ii) the potential of electricity generation from the air ventilation of the condensing unit with a rectangle-shaped hood and iii) the potential of electricity generation from the air ventilation of the condensing unit with a circle-shaped hood. In all cases, electricity was produced from a 24 V 300 W DC generator.

3.2.1 The potential of electricity generation from an air ventilation of the normal condensing unit.

Figure 1 shows the experimental setup to measure the wind speed, voltage (V) and current (I) values. The output power (P) and electricity work (W) are as follows in Eq. (5) and Eq. (6), respectively.

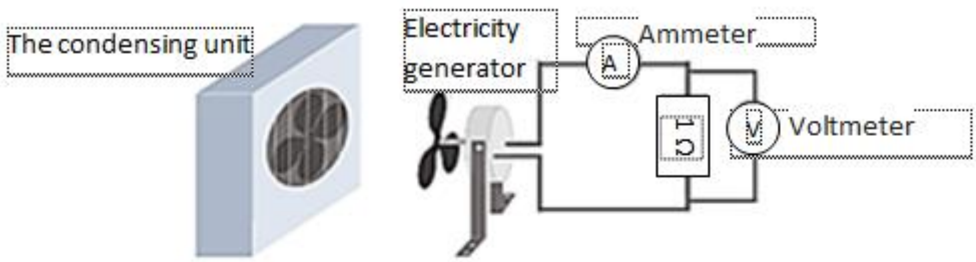


Fig. 1. The electricity generation of the normal condensing unit

$$Electrical\ power\ (W) = I\ x\ V \quad (5)$$

$$Electrical\ work\ (W{\bullet}hr) = I\ x\ V\ x\ T \quad (6)$$

3.2.2 The potential of electricity generation from air ventilation of the condensing unit with the hood

In this experiment, the rectangle-shaped hood (as shown in Figure 2) and the circle-shaped hood (as shown in Figure 3) were set up to increase the wind speed by the following Eq. (4). One side of the hood was connected to the air ventilation fan of the condensing unit and another side of the hood was designed with the half cross-sectional area as illustrated in Figure 2 and 3.

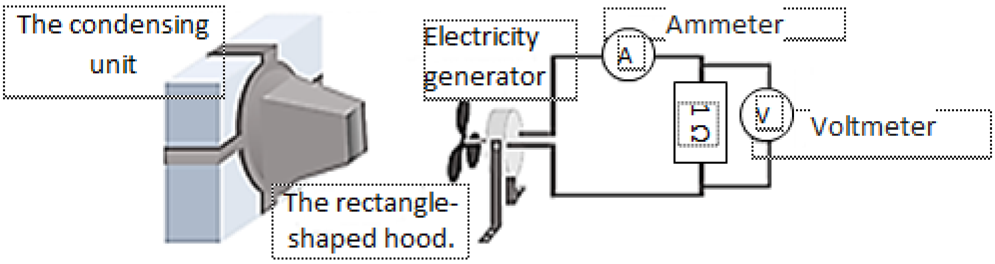


Fig. 2. Electricity generation of the condensing unit with the rectangle-shaped hood

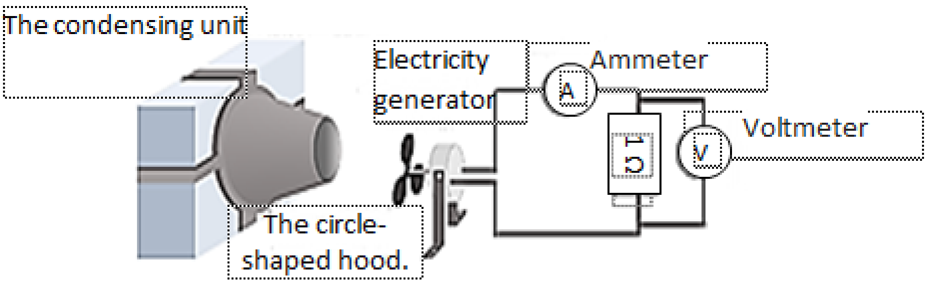


Fig. 3. Electricity generation of the condensing unit with the circle-shaped hood

The voltage (*V*) and current (*I*) produced by the electrical generator were measured. And the power (*P*) and electricity work (*W*) were calculated by following Eq. (5) and Eq. (6).

3.3 Performance of the Air Conditioner by the Operation of the Fan Coil Unit

K-type thermocouples with an accuracy of ±0.5 °C were employed to measure the ambient and room temperatures throughout the duration of the experiments. All data were recorded at 10 min intervals using a data logger. Data was recorded continuously throughout the duration of experiments in real ambient conditions. Humidity data recorders were also set both inside and outside the rooms to measure the humidity, as shown in Figure 4.

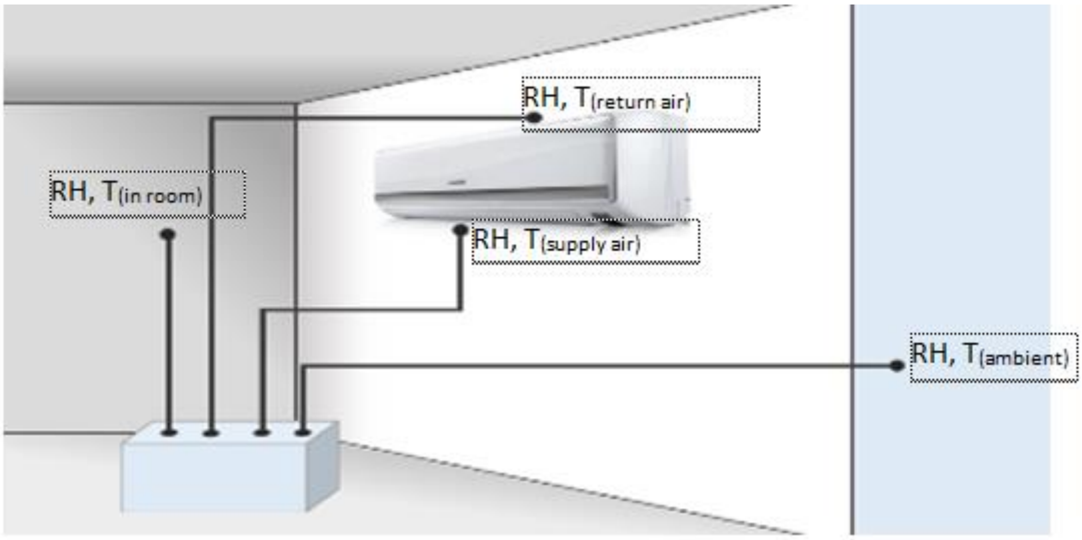


Fig. 4. The positions of temperature and humidity measurements

4. Results and Discussion

The study is divided into 3 parts including of the operation of the normal condensing unit, the electricity generation from the condensing unit and the performance of the air conditioner.

4.1 The Operation of the Normal Condensing Unit.

The time period, counts and average time of the rotation of the motor in a condensing unit of air conditioner was observed every hour from midnight of day to midnight of the following day, giving a 24 h test cycle. The rotation of the motor in a condensing unit of air conditioner was approximately 6 times per hour throughout three days. For the three days tested, the average rotation time of the motor was from 174 s to 299 s, and the total time of work was 30,961 s/day or 8.60 hours per day as shown in Figure 5.

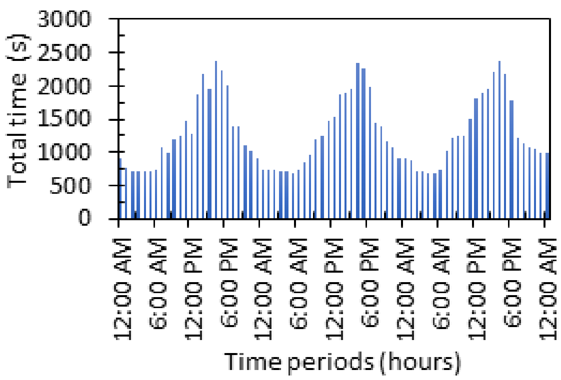


Fig. 5. The working period of the motor rotation in a condensing unit

4.2 The Electricity Generation from the Condensing Unit of Air Conditioner

Figure 6-8 show the potential of electricity generation of the normal condensing unit, that of a condensing unit with a rectangle-shaped and that of a circle-shaped hood. The average exhaust air speed in the case of the normal condensing unit, the condensing unit with the rectangle-shaped hood, and the condensing unit with the circular-shaped hood was 7.6 m/s 12.4 m/s and 12.5 m/s, respectively.

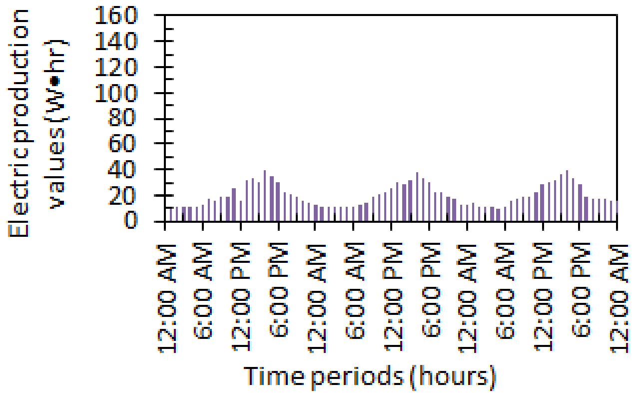


Fig. 6. Electricity production values in the case of a normal condensing unit

This demonstrated that a hood installed on the condensing unit can increase the exhausted air speed from the condensing unit. When the electrical energy generator was installed, the average voltage produced of the normal condensing unit, condensing unit with a rectangle-shaped hood and condensing unit with a circular-shaped hood was 7.9 V, 15.6 V and 16.1 V, respectively. The daily average electrical production values of the normal condensing unit, condensing unit with a rectangle-shaped hood and a condensing unit with a circular-shaped hood were 491.8 W·hr, 1951.9 W·hr and 2071.6 W·hr, as shown in Figure 6-8, respectively. This indicated that the installation of a hood can improve the electricity production.

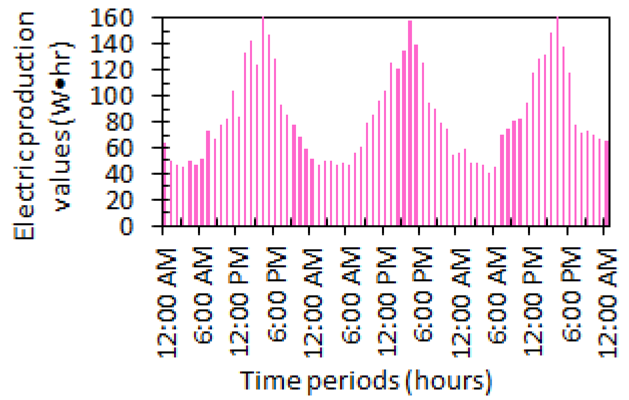


Fig. 7. Electricity production values of the condensing unit with a rectangle-shaped hood

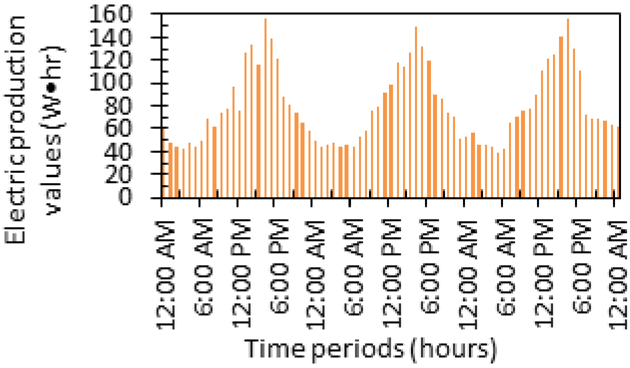


Fig. 8. Electricity production values of the condensing unit with a circular-shaped hood

4.3 The Coefficient of Performance of the Air Conditioner

The performance of the air conditioner based on the Coefficient of Performance (COP) and the Energy Efficiency Ratio (EER), which are calculated from the cooling capacity (Q) and the actual electrical power consumption (P).

4.3.1 Temperatures and relative humidity in case of the normal condensing unit

Temperature and relative humidity in case of the normal condensing unit are displayed in Figure 9. For 3 days, the ambient temperature (T_{am}) varies between 31.0 °C and 40.0 °C while, the relative humidity (RH_{am}) of the surroundings varies between 57.6 % and 96.9 %. This is inversely related to the ambient temperature. The relative humidity (RH_{sup}) of the supply air from the fan coil air unit varies between 88.3 % and 98.9 % and the temperature (T_{sup}) swing of the supply air from the fan coil air unit is between 10.2 °C and 22.4 °C. The stable room temperature was controlled by the air conditioner. The average room temperature (T_{in}) was approximately 25 °C and the relative humidity (RH_{in}) varied between 39.4 % and 91.1 %. At the same time, the average temperature (T_{re}) of the return air to fan coil air unit was approximately 25 °C and the relative humidity (RH_{re}) varied between 36.6 % and 83.8 %.

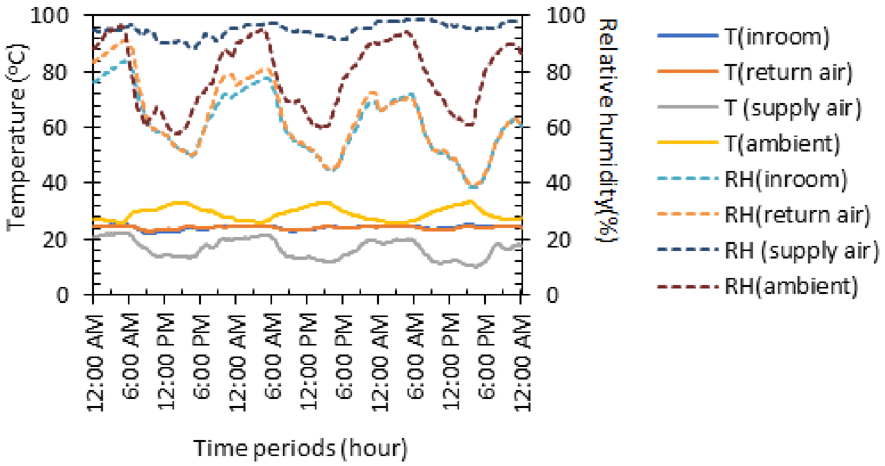


Fig. 9. Temperature and relative humidity in case of the normal condensing unit

Next, the cooling capacity (Q), that is the measurement of a cooling system's ability to remove heat, was studied [30]. The temperature and relative humidity of the supply air from the fan coil unit and the return air to the fan coil unit were used to calculate the cooling capacity. The fluctuation of the cooling capacity is between 5490.3 BTU/hr and 23062.7 BTU/hr, the range of maximum values occurs in the afternoon of each day. The average cooling capacity for 3 days was approximately 14989.7 BTU/ hr. For actual AC electrical power consumption (P_e), the turn is similar to the cooling capacity. The fluctuation of P_e varies between 1021.0 W and 1110.8 W. The average P_e for 3 days was 1067.7 W, as illustrated in Figure 10.

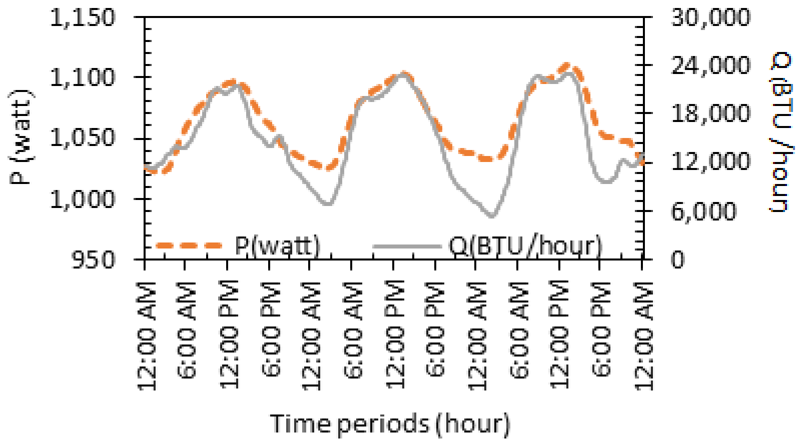


Fig. 10. The cooling capacity (Q) and AC power consumption (P) in case of the normal condensing unit

4.3.2 The temperature and relative humidity in case of the condensing unit and the generator

The average ambient temperature (T_{am}) varies between 26.3 °C and 33.4 °C throughout 3 days. The relative humidity (RH_{am}) of the environment varies between 43.4 % and 97.3 %. This correlation is inverse with the ambient temperature. The relative humidity (RH_{sup}) of supply air from fan coil air unit varies between 87.1 % and 97.8 % and the temperature (T_{sup}) swing of supply air from fan coil air unit is between 10. 1 °C and 21. 5 °C. The average room temperature (T_{in}) was fixed at approximately 25 °C. The relative humidity (RH_{in}) within the testing room varies between 38.5 % and 95.2 %. At the same time, the average temperature (T_{re}) of the return air to fan coil air unit is approximately 24 °C and the relative humidity (RH_{re}) of the return air to fan coil air unit varies between 37.6 % and 87.4 %, as illustrated in Figure 11.

The fluctuation of the cooling capacity (Q) varies between 53780.7 BTU/hr and 22895.8 BTU/hr, the range of maximum values occurs in the afternoon of each day. The average cooling capacity for 3 days was approximately 15132.4 BTU/ hr. For the actual AC electrical power consumption (P_e), the fluctuation varies between 1008.5 and 1123.6 W. The average P_e for 3 days was approximately 1059.3 W. that is corresponded to the cooling capacity, as shown in Figure 12.

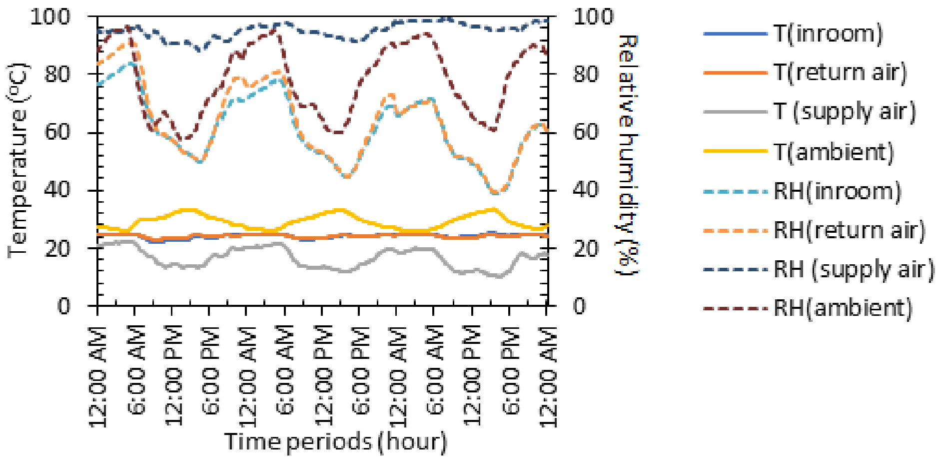


Fig. 11. Temperature and relative humidity in case of the condensing unit with installing generator

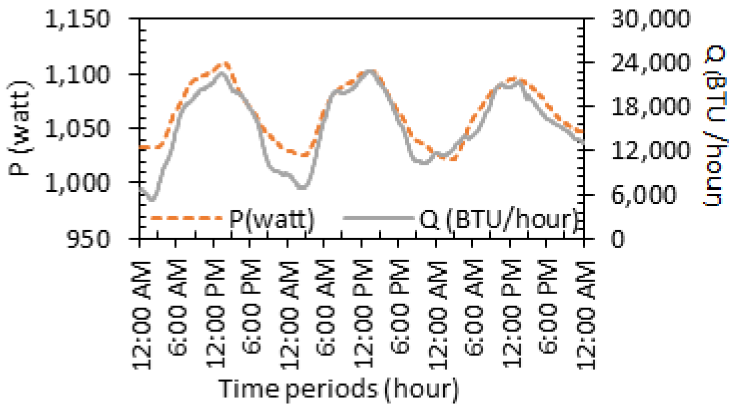


Fig. 12. The cooling capacity (Q) and AC power consumption (P) in the case of the condensing unit with a circular-shaped hood

4.3.3 The temperature and relative humidity in case of the condensing unit with a circular-shaped hood

The ambient temperature (T_{am}) for 3 days varies between 26.4 °C and 33.3 °C while the relative humidity (RH_{am}) in the ambient space varies between 56.4 % and 96.2 %, This relative humidity (RH_{am}) is inverse with the ambient temperature. The relative humidity (RH_{sup}) of the supply air from fan coil air unit, varies between 88.3 % and 98.9 % and the temperature (T_{sup}) swing is between 10.4 °C and 22.4 °C. The average room temperature (T_{in}) is controlled at approximately 24 °C and the relative humidity (RH_{in}) in the room varies between 38.6 % and 84.2 %. At the same time, the average temperature (T_{re}) of the return air to fan coil air unit was approximately 24 °C and the relative humidity (RH_{re}) varies between 39.0 % and 92.3 %, as illustrated in Figure 13.

In this case, the fluctuation of the cooling capacity (Q) is between 6387.9 BTU/hr and 23589.9 BTU/hr, the range of maximum values occurs in the afternoon of each day. The average cooling capacity for 3 days was approximately 15211.8 BTU/hr. For the actual AC electrical power consumption (P_e), the curve is similar to the cooling capacity. The fluctuation varies between 1009.9 W and 1112.2 W. The average P_e for 3 days was approximately 1112.5 W, as shown in Figure 14.

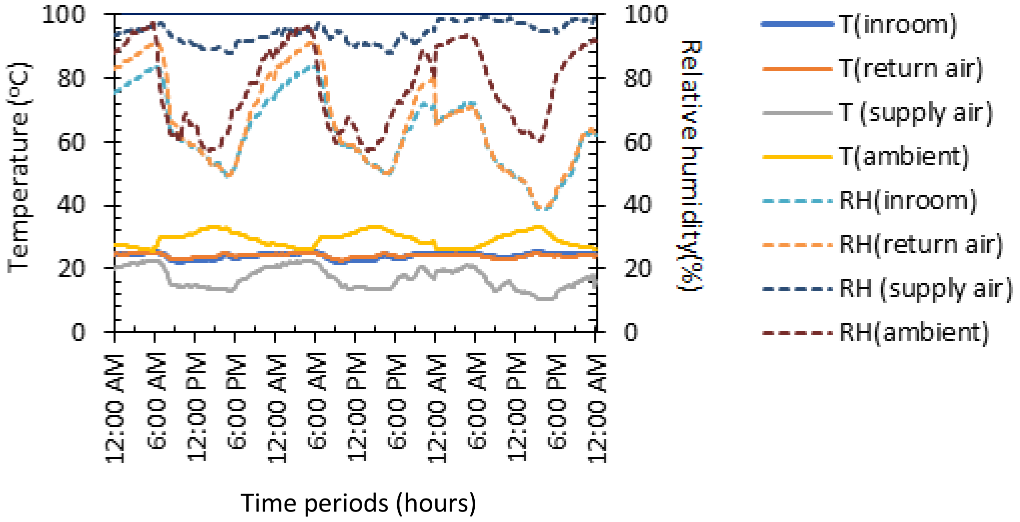


Fig. 13. Temperature and relative humidity in the case of the condensing unit with a rectangle-shaped hood

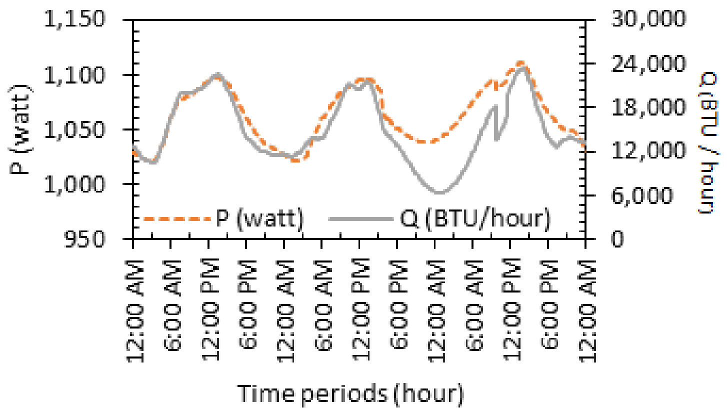


Fig. 14. The cooling capacity (Q) and AC power consumption (P) in the case of the condensing unit with a rectangle-shaped hood

4.3.4 The temperature and relative humidity of the condensing unit with circle-shaped hood

The ambient temperature (T_{am}) for 3 days varied between 25.1 °C and 33.0 °C while the relative humidity (RH_{am}) in the surrounding varied between 56.8 % and 97.1 %. The relative humidity is inverse with the ambient temperature. The relative humidity (RH_{sup}) of the supply air from the fan coil air unit varies between 90.1 % and 98.0 % and the temperature (T_{sup}) swing is between 10.3 °C and 22.9 °C. The average room temperature (T_{in}) was approximately 24 °C, the relative humidity (RH_{in}) varies between 38.5 % and 91.1 %. At the same time, the average temperature (T_{re}) of the return air to fan coil air unit was at approximately 24 °C and the relative humidity (RH_{re}) varies between 36.6 % and 84.2 %, as shown in Figure 15.

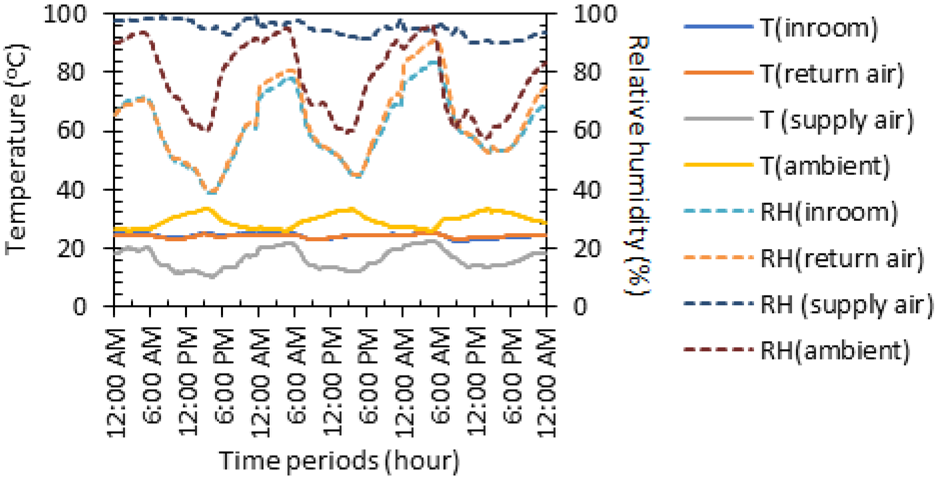


Fig. 15. The temperature and relative humidity in the case of the condensing unit with a circular-shaped hood

In this case, the fluctuation of the cooling capacity (Q) is between 5139.3 BTU/hr and 21698.3 BTU/hr, the range of maximum values occurs in the afternoon of each day. The average cooling capacity for 3 days was approximately 14998.2 BTU/hr. For the actual AC electrical power consumption (P_e), the curve is similar the cooling capacity. The fluctuation varies between 1016.2 W to 1245.5 W. The average P_e for 3 days was approximately 1100.8 W, as shown in Figure 16.

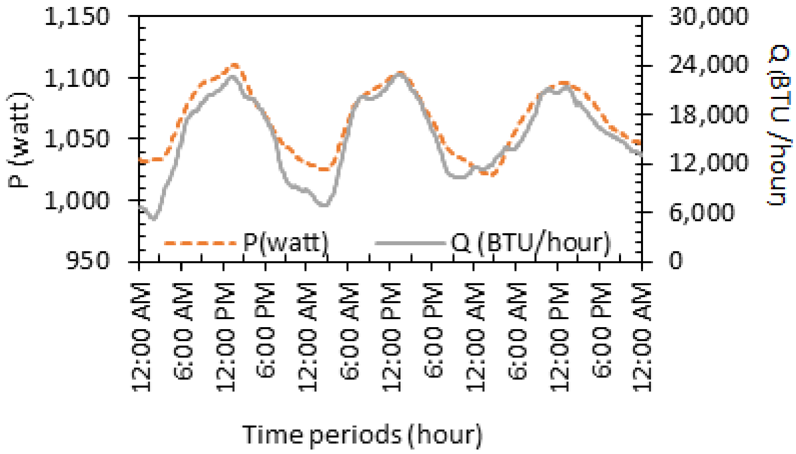


Fig. 16. The cooling capacity (Q) and AC power consumption (P) in the case of the condensing unit with the installation of circle-shaped hood

4.3.5 The performance of the air conditioner

From the previous data, the average values of the Coefficient of Performance (COP) in the case of the normal condensing unit (case 1), that of installing only an electrical generator (case 2), that of installing a rectangle-shaped hood and an electrical generator (case 3), and that of installing a circular-shaped hood and a generator (case 4) are approximately 4.1, 4.1, 4.1 and 4.1 and the average Energy Efficiency Ratio (EER) of all cases was around 14.0 BTU/W·hr. This demonstrated that the condensing unit that was operated with the rectangle-shaped/circle-shaped hood and generator for electricity production has no effect on the coefficient of performance of the air conditioner, as displayed in Figure 17.

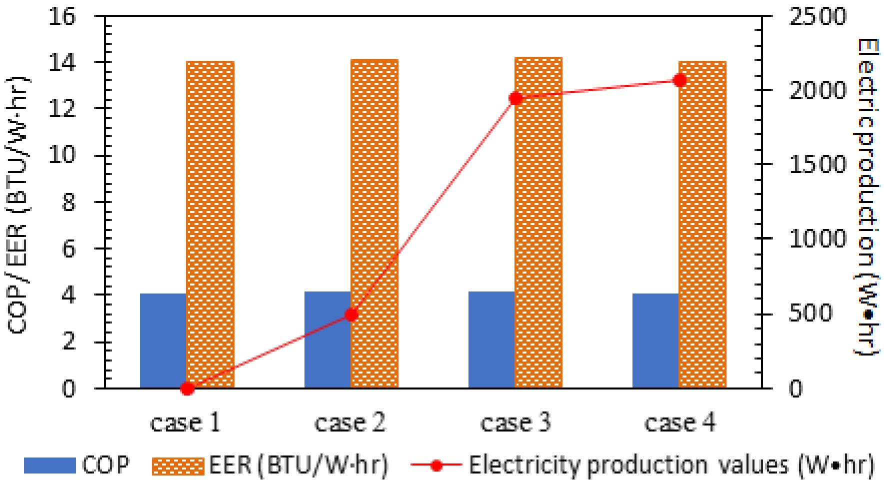


Fig. 17. The performance of the air conditioner and the electricity production values

5. Conclusions

The installation of an air hood, to funnel exhaust air, and a generator for electrical generation on a condensing unit has no impact on the coefficient of performance of the air conditioner. The addition of a rectangle-shaped or a circular-shaped hood on a condensing unit can increase the exhausted air speed. The average air speed values of the air ventilation at the end of the normal condensing unit, rectangle-shaped and circular-shaped hood was approximately 7.6 m/s, 12.4 m/s and 12.5 m/s, respectively. Higher average electricity production was produced from the installation of the rectangle-shaped and circular-shaped hoods at the exhausted air position of condensing unit. The coefficient of performance of the air conditioner in all conditions was approximately 4.1. Therefore, the use of the air ventilation of air conditioning condensing units for generating electricity is an alternative way to produce renewable energy to produce electricity for low power electronic equipment.

Acknowledgement
The authors would like to thank the Department of Physics, Faculty of Science, Naresuan University for providing facilities and financial support to this research work, and our research center. Thanks to Dr. Kyle V. Lopin for editing of this document.

References

[1] Royston, Sarah, Jan Selby, and Elizabeth Shove. "Invisible energy policies: A new agenda for energy demand reduction." *Energy Policy* 123 (2018): 127-135.

[2] Tian, Xin, Fuli Bai, Jinhu Jia, Yang Liu, and Feng Shi. "Realizing low-carbon development in a developing and industrializing region: Impacts of industrial structure change on CO2 emissions in southwest China." *Journal of environmental management* 233 (2019): 728-738.

[3] Mohsina, R., Z. A. Majid, A. H. Shihnanc, N. S. Nasrid, Z. Sharere, and R. C. Matf. "Effects of Multi-Variant Biofuel on Engine Performance and Exhaust Emission of DDF Engine System." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 6, no. 1 (2015): 1-18.

[4] De Courchelle, Inès, Tom Guérout, Georges Da Costa, Thierry Monteil, and Yann Labit. "Green energy efficient scheduling management." *Simulation Modelling Practice and Theory* 93 (2019): 208-232.

[5] Liu, Jia, Xi Chen, Sunliang Cao, and Hongxing Yang. "Overview on hybrid solar photovoltaic-electrical energy storage technologies for power supply to buildings." *Energy Conversion and Management* 187 (2019): 103-121.

[6] Khattak, M.A., T.M.H.T. Yahya, M.W.M. Sallehhudin, M.I.M. Ghazali, N.A. Abdullah, and et al. "Global Energy Security and Eastern Europe: A Review." *Journal of Advanced Research Design* 45, no. 1 (2018): 19-42.
[7] Kåberger, Tomas. "Progress of renewable electricity replacing fossil fuels." *Global Energy Interconnection* 1, no. 1 (2018): 48-52.
[8] Lazkano, Itziar, Linda Nøstbakken, and Martino Pelli. "From fossil fuels to renewables: The role of electricity storage." *European Economic Review* 99 (2017): 113-129.
[9] Mohammad, R., F. Sharif, D. Sharif, Norazli Othman, and Z.A. Kadir. "Design of Heat Exchanger Network in Olefin Unit of Oil Refinery." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 12, no. 1 (2015): 21-34.
[10] Li, Shijie, Chunshan Zhou, and Shaojian Wang. "Does modernization affect carbon dioxide emissions? A panel data analysis." *Science of the Total Environment* 663 (2019): 426-435.
[11] Li, Jiazhen, Wenxu Dong, Oene Oenema, Tuo Chen, Chunsheng Hu, Haijing Yuan, and Liying Zhao. "Irrigation reduces the negative effect of global warming on winter wheat yield and greenhouse gas intensity." *Science of the Total Environment* 646 (2019): 290-299.
[12] Budiyanto, Muhammad Arif, Takeshi Shinoda, Firman Ady Nugroho, and Buddi Wibowo. "Estimated of energy saving from the application of roof shade on the refrigerated container storage yard." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 46, no. 1 (2018): 114-121.
[13] Mohammadi, Amin, and Mehdi Mehrpooya. "A comprehensive review on coupling different types of electrolyzer to renewable energy sources." *Energy* 158 (2018): 632-655.
[14] Saba, L.A., M.H. Ahmad, R.A. Majid and A. Yahaya. "Material and Assembly Selection: Comparative Analysis of Embodied Energy and Carbon as an Index for Environmental Performance." *Journal of Advanced Research in Materials Science* 44, no. 1 (2018): 1-24.
[15] Zerrahn, Alexander, Wolf-Peter Schill, and Claudia Kemfert. "On the economics of electrical storage for variable renewable energy sources." *European Economic Review* 108 (2018): 259-279.
[16] Ghaderian, J., C. N. Azwadi, and H. Mohammed. "Modelling of energy and exergy analysis for a double-pass solar air heater system." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 16, no. 1 (2015): 15-32.
[17] Doorga, Jay Rovisham Singh, Soonil DDV Rughooputh, and Ravindra Boojhawon. "High resolution spatio-temporal modelling of solar photovoltaic potential for tropical islands: Case of Mauritius." *Energy* 169 (2019): 972-987.
[18] Anis, Md Shahrukh, Basharat Jamil, Md Azeem Ansari, and Evangelos Bellos. "Generalized models for estimation of global solar radiation based on sunshine duration and detailed comparison with the existing: A case study for India." *Sustainable Energy Technologies and Assessments* 31 (2019): 179-198.
[19] Hashim, G.A. and N.A.C. Sidik. "Numerical Study of Harvesting Solar Energy from Small-Scale Asphalt Solar Collector." *Journal of Advanced Research Design* 2, no.1 (2014): 10-19.
[20] Cornejo-Bueno, L., C. Casanova-Mateo, J. Sanz-Justo, and S. Salcedo-Sanz. "Machine learning regressors for solar radiation estimation from satellite data." *Solar Energy* 183 (2019): 768-775.
[21] Ballestrín, J., M. Casanova, R. Monterreal, J. Fernández-Reche, E. Setien, J. Rodríguez, J. Galindo, F. J. Barbero, and F. J. Batlles. "Simplifying the measurement of high solar irradiance on receivers. Application to solar tower plants." *Renewable Energy* 138 (2019): 551-561.
[22] Badescu, Viorel. "How much work can be extracted from diluted solar radiation?" *Solar Energy* 170 (2018): 1095-1100.
[23] Lim, Dae Kyu, Byoung Ha Ahn, and Ji Hwan Jeong. "Method to control an air conditioner by directly measuring the relative humidity of indoor air to improve the comfort and energy efficiency." *Applied energy* 215 (2018): 290-299.
[24] Fekadu, Geleta, and Sudhakar Subudhi. "Renewable energy for liquid desiccants air conditioning system: a review." *Renewable and Sustainable Energy Reviews* 93 (2018): 364-379.
[25] Sidik, N.A.C. and O.A. Alawi. "Computational Investigations on Heat Transfer Enhancement Using Nanorefrigerants." *Journal of Advanced Research Design* 1, no. 1 (2014): 35-41.
[26] Morsy, M., M. Fahmy, H.A. Elshakour and A.M. Belal. "Effect of Thermal Insulation on Building Thermal Comfort and Energy Consumption in Egypt." *Journal of Advanced Research in Applied Mechanics* 43, no. 1 (2018): 8-19.
[27] Sidik, N.A.C., T.H. Kean, H.K. Chow, A. Rajaandra, S. Rahman and J. Kaur. "Performance Enhancement of Cold Thermal Energy Storage System Using Nanofluid Phase Change Materials: A Review." *Journal of Advanced Research in Materials Science* 43, no. 1 (2018): 1-21.
[28] Takleh, H. Rostamnejad, and V. Zare. "Employing thermoelectric generator and booster compressor for performance improvement of a geothermal driven combined power and ejector-refrigeration cycle." *Energy Conversion and Management* 186 (2019): 120-130.

[29] Shan, M. A., C. H. U. Wuli, Haoguang Zhang, L. I. Xiangjun, and Haiyang Kuang. "A combined application of micro-vortex generator and boundary layer suction in a high-load compressor cascade." *Chinese Journal of Aeronautics* 32, no. 5 (2019): 1171-1183.
[30] Shin, Mi Su, Kyu Nam Rhee, Sang Hoon Park, Myoung Souk Yeo, and Kwang Woo Kim. "Enhancement of cooling capacity through open-type installation of cooling radiant ceiling panel systems." *Building and Environment* 148 (2019): 417-432.