MATEC Web of Conferences **225**, 06016 (2018) https://doi.org/10.1051/matecconf/201822506016
UTP-UMP-VIT SES 2018

Environmental Assessment on Hybrid Solar Air Conditioning System in Tropical Region

D. N. Noor[1], *H.* Ibrahim[1, *], and *F.* Basrawi[1],

[1]Energy Sustainability Focus Group (ESFG), Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

Abstract. Vapour compression systems are widely used in large scale of cooling application in industrial, commercial and institutional buildings. This conventional system did contribute to environmental problem; thus to overcome this issue nowadays, exploitation of solar energy for cooling purpose been studied. This paper presents a hybrid solar air conditioning system through appropriate solution for current problem of vapour compression system. However, solar air conditioning have major issue regarding an intermittence input due to unstable of daily solar radiation. Thus, introduction of thermal energy storage (TES) such as chilled water storage (CWS) foreseen to be the best solution and more economical compared to other types of storage. Through appropriate practicality in design and application, variation on solar collector area was analysed to determine optimum sizing which best suit with environmental factor. Surprisingly, the smallest collector area (150 m2) did shown highest saving on greenhouse gasses emission to environment.

1 Introduction

In renewable energy field, solar energy becomes popular for last decade and its contribution to world energy efforts. Harvested solar energy can be categorized into two system; thermal energy system which convert solar energy into thermal energy form and photovoltaic system which convert solar energy to electric energy. Thus, solar energy gets more attention from world point of view because of its independent and sustainability characteristic and giving almost zero impact to the environment. Solar energy resources are abundant and clean; therefore has important role to play as substitute to electricity in building energy system and affordable to meet common household demand over a year. Unfortunately, its intermittency of output is variable with local climate condition, thus lead to mismatch of heating demand and supply system of solar energy. Tropical climate experiencing hot and raining season throughout the year and availability of solar energy can be promising in positive manners.

Regarding to environmental issue, solar air conditioning is proven more clean and significantly contribute to operational cost saving. Technically, solar air conditioning have a problem on non-steady daily solar radiation behaviour and require to actively control the system as studied by [1] thus its necessary to have support from thermal energy storage (TES). Thermal energy storage is an economical energy management resource and can

* Corresponding author: drhassan@ump.edu.my

support any of the systems; either vapour-compression system or solar air conditioning. Solar cooling has progressed considerably over the past years as a result of efforts toward environmental protection and new developments in components and systems, and significant experience has been gained from previous projects by [2] and its proven have potential of energy saving up to 40-50% as mention by [3]. Combination of solar air conditioning with thermal energy storage is a relatively new development to increase its efficiency by dynamic modelling and control strategies which had been determined by [4] and supported by [5, 6]. The system will operate day and night and use various type of thermal energy storage such as aquifer and chilled water tank. Results have shown that chilled water or cold storage improve comfort level and this storage energy is able to be used for both cooling and heating; therefore suitable to be used in winter and summer season as studied by [7-9].

The concept of thermal energy storage (TES) involves the process of energy charging and discharging. Charging process is energy been stored in specific medium use such as chilled water, ice or phase change material (euthentic salt) while discharging process is energy that is released for system usage. Thermal storage technology is economical in office buildings since they have short occupancy periods and narrow cooling loads as studied previously by [10]. Furthermore, from economical point of view, it's proven thermal energy storage (TES) can reduce annual cost of operation [11, 12] and give the same result while some research shown that reduction on environmental point of view which is greenhouse gasses emission [13-16]. However, very less studies on solar air conditioning in tropical region due to high installation cost during commissioning and long return rate of investment. Thus, theoretical study of hybrid solar air conditioning is needed to fulfil abstract knowledge of community about solar technology and later on to be a motivation to government as a baseline for any development in future.

2 System Description

In general solar thermal cooling system consists of solar collector (flat plate, evacuated tube collector and concentrating collector), hot storage tank, auxiliary heater and heat exchanger system as shown in Figure 1. The temperatures needed to operate this solar water heater system range from 60 to 100 ^{0}C. In this case, evacuated tube collector was chosen since its efficiency is much higher than common flat plate collector and can be classified in medium temperature range of collectors.

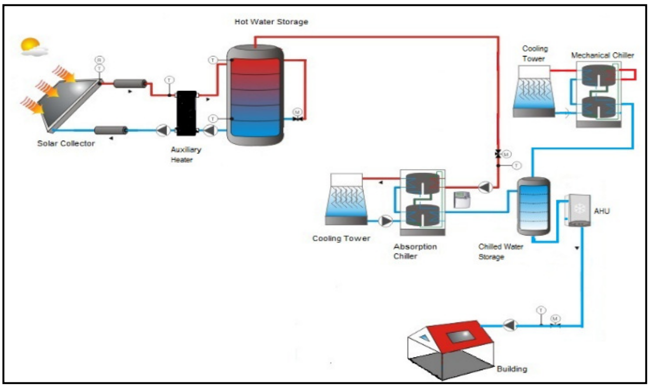

Fig. 1. Schematic diagram of hybrid air conditioning.

System operates when solar collector captured solar radiation and energy was stored in hot water storage as from Eqn. (1).The data input required are η, efficiency of solar collector used, A is solar collector area in m^2 and G is global radiation data in W/m^2. Usually temperature was set at HWS inlet and any disruption of intermittent input due to variation of daily solar radiation; auxiliary heater will start to heat the water until reach the setting temperature. Capacity and sizing of hot water storage was defined accordingly to capacity of absorption chiller used. The temperature in hot water storage will be higher than the temperature inside the evacuated tube collector due to variation of solar radiation; usually extra heat will be dissipated to environment as waste heat. There will be hot water pump functioning to circulate hot water between evacuated tube collector and hot water storage and controlled by solar pump controller. The temperature sensor should be equipped before the primary inlet of hot water storage so that operation control of solar pump could be efficient.

$$Q_{usefull} = \eta AG \tag{1}$$

This system modelling was rated accordingly to a current market specification of absorption chiller. Absorption chiller will provide cooling in sensible heat storage; chilled water storage and generally designed to provide chilled water from waste heat sources. Since this system was hybridize from current vapour compression system and heat supplied from solar energy, this system could minimize global warming effect by reducing energy consumption and eliminates the generation of greenhouse gasses to environment. Absorption chiller does not use a large motor-compressor, thus it operates in less noise mode and easy to handle due to its small size.

Chilled water storage shall maintain its cooling at the temperature range 4 to 6 ^{0}C. This chilled water later on will be distributed through air handling units in the building.

Hypothetical building chosen is Library building in Universiti Malaysia Pahang. It's a 16,000 m^2 area building and from Figure 2, maximum cooling load recorded was 2199 kW at 1pm.

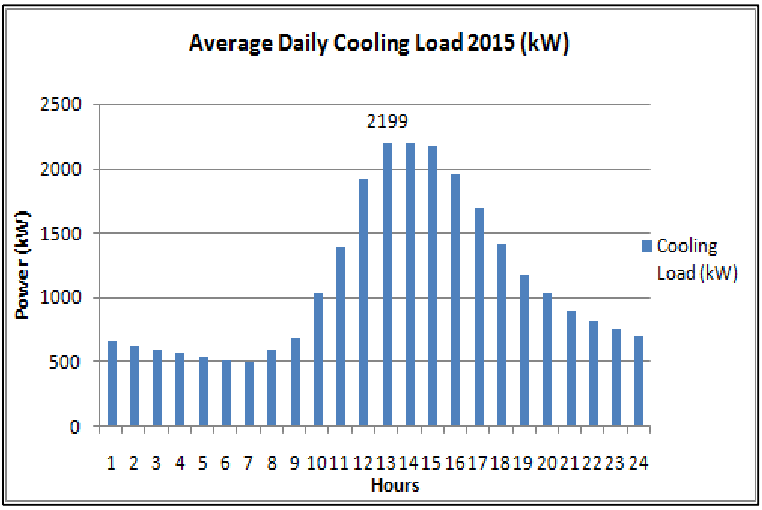

Fig. 2. Average daily cooling load for 2015.

In this assessment, impact of variation in solar collector area was studied. Since the hybrid system was introduce to the existing system, solar water heater system as a supplementary and requirement of vapour compression system still needed. Table 1 represent the configuration of different solar collector area for library building in Universiti Malaysia Pahang.

Table 1. System Configuration.

Solar Collector Area (m^2)	Hot Water Storage (Litre)	Absorption Chiller (kW)	Mechanical Chiller (kW)
150	9300	105	175
200	12300	140	140
250	15300	175	105
300	18300	210	70
350	21300	245	35

3 Environment Assessment

The environmental impact of utilizing solar energy can reduce fossil fuel consumption from power plant. Thus, reduction of greenhouse gasses such as CO_2, NO_X and CO definitely can be justified. Table 2 represent data of emission rate from three common power plants in Malaysia.

Table 2. Emission rate.

Greenhouse Gasses (g/kWh)	Coal Steam Turbine (CST)	Combined Cycle Gas Turbine (CCGT)	Boiler
CO_2	965	363	201
NO_X	1.7	0.2	0.22
CO	0.07	0.07	0.12

4 Result and Discussion

The results of environmental saving projection are shown in Figure 3-5 for CO_2, NO_X and CO. The impact of different solar collector area are reflected in the comparison of the configuration system since the largest solar collector area give results in the lowest value of CO_2, NO_X and CO impact. In addition, the indirect emission still contributed by auxiliary heater when backup energy is needed, it was found by looking through either from electric or natural gas consumption. Power plant with Coal Steam Turbine (CST) giving more impact in emission reduction compared to Combine Cycle Gas Turbine (CCGT) and Boiler. Increasing in volume of hot water storage, did increasing of backup energy from auxiliary heater in order to sustain the desired temperature for system to run smoothly.

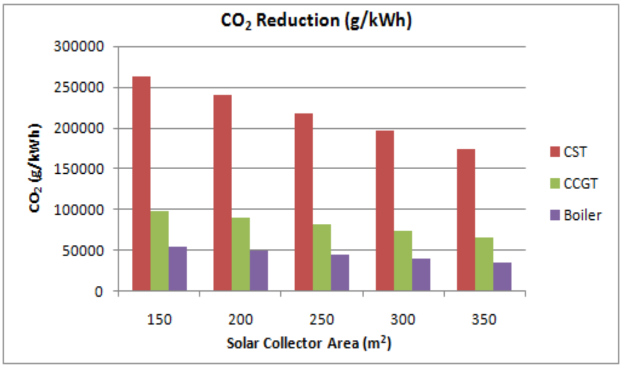

Fig. 3. Graph of CO2 Reduction.

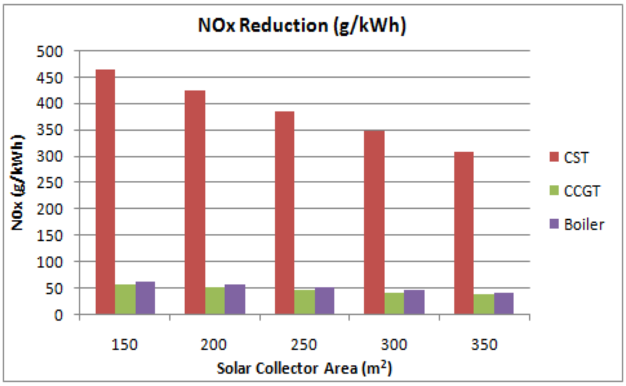

Fig. 4. Graph of NOx Reduction.

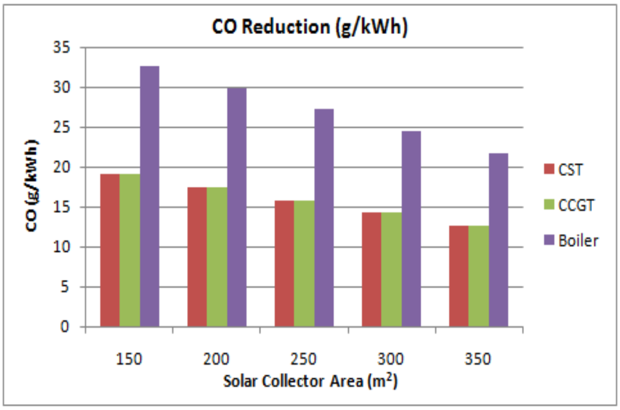

Fig. 5. Graph of CO Reduction.

5 Conclusion

The results of this assessment of variety solar collector area of solar air conditioning did portray on energy savings thus saving on greenhouse gasses emission can be achieved. The small area of solar collector which is 150 m^2 gives the highest saving on CO_2, NO_x and CO emission. The main reason for this is due to requirement of backup energy from auxiliary heater while this component did contribute to total energy consumption in overall point of view. Thus, for environment competitive point of view, small area of solar collector is good enough to serve cooling load of library building in Universiti Malaysia Pahang.

References

1. A. Lecuona, R. Ventas, C. Vereda, and R. López, Appl. Therm. Eng.,**79**, pp. 140-148, (2015)
2. C. A. Balaras, G. Grossman, H.-M. Henning, C. A. Infante Ferreira, E. Podesser, L. Wang, *et al.*, Renew. Sust. Energ. Rev., **11**, pp. 299-314,(2007)
3. X. Q. Zhai and R. Z. Wang, Appl. Therm. Eng., **29**, pp. 17-27, (2009)
4. G. Evola, N. Le Pierrès, F. Boudehenn, and P. Papillon, Int. J. Refrig., **36**, pp. 1015-1028, (2013)
5. J. Albers, Int. J. Refrig., **39**, pp. 48-56, (2014)
6. O. Marc, G. Anies, F. Lucas, and J. Castaing-Lasvignottes, Sol. Energy, **86**, pp. 2231-2239, (2012)
7. V. Čongradac, B. Prebiračević, N. Jorgovanović, and D. Stanišić, Energ. Buildings, **48**, pp. 146-154, (2012)
8. B. M. Diaconu, S. Varga, and A. C. Oliveira, Energy, **36**, pp. 1280-1291, (2011)
9. H. O. Paksoy, O. Andersson, S. Abaci, H. Evliya, and B. Turgut, Renew. Energ., **19**, pp. 117-122, (2000)
10. S. M. Hasnain, Energ. Convers. Manage., **39**, pp. 1139-1153, (1998)
11. B. A. Habeebullah, Energ. Buildings, **39**, pp. 355-363, (2007)
12. Y. Sun, S. Wang, F. Xiao, and D. Gao, Energ. Convers. Manage., **71**, pp. 101-114, (2013)
13. S. Boonnasa and P. Namprakai, Appl. Therm. Eng.,**30**, pp. 1396-1408, (2010)
14. H. Lin, X.-h. Li, P.-s. Cheng, and B.-g. Xu, Energ. Buildings, **79**, pp. 41-46, (2014)
15. B. Rismanchi, R. Saidur, H. H. Masjuki, and T. M. I. Mahlia, Energ. Buildings, **50**, pp. 347-354, (2012)
16. A. Simons and S. K. Firth, Energ. Buildings, **43**, pp. 1231-1240, (2011)