Development of a Multi - Split Solar-Assisted Cooling System for Residential Application

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Abstract: The Philippines is one of the countries in the world with generally high electricity rate and consumption. In this regard, engineers continuously develop new technologies to lessen electricity consumption and they are more inclined to renewable energy sources. A lot of establishments and residences are likely to use air - conditioning units since it can be very hot and humid in the country. The aim of this study was to design a solar – assisted air – conditioning system and compare it with that of a conventional one in terms of power consumption and performance. The multi-split system was also tested in terms of its effectiveness in cooling the three rooms. Both systems were operated continuously for eight hours which is the usual average operating time of air – conditioning units in a household setting. Results showed that the conventional air – conditioning systems used in the three rooms accumulated an average total power consumption of 33.53 kW-h for 8 hours while the use of the solar – assisted, multi-split system which was tested for 5 straight days accumulated an average total power consumption of 27.19 kW-h for 8 hours. Thus, the solar – assisted, multi - split system produced better results with 18.91% savings in power consumption while producing and maintaining a cool temperature. The coefficient of performance (COP) of the solar – assisted system was 2.84 compared to that of the conventional system which was 1.57. Further studies to improve the performance of the system are recommended.

I. INTRODUCTION

Due to the El Niño and global warming phenomenon being experienced in our country, energy is becoming scarce and the use of renewable energies is becoming the new interest in the industry. From this situation, harvesting natural energies is evidently needed, hence an air-conditioning system that minimize the consumption of electricity is a must. With the aid of the solar energy it could help the people to save and cut costs on electrical bills. Air-conditioning is the process of treating the air so as to control simultaneously its temperature, humidity, cleanliness and distribution in order to satisfy human comfort.

The objective of this study is to design a multi-split, solar assisted air-conditioning system that will be suitable for residential application. This includes determining the appropriate specifications of its components through cooling load calculations. In this study, the conventional air – conditioning system and the solar – assisted multi – split system were compared in terms of its performance and energy consumption.

The solar collector is one of the main components in a solar assisted-air conditioning system that converts solar energy to thermal energy that drives the chiller or cold production component. Evacuated tubes solar collector is preferred rather than the conventional flat plate solar collector due to its efficiency and ability to produce high temperature, as a requirement to drive the chiller. The average driving temperature for absorption chiller is between 80°C to 90°C depending on the type of models by different manufacturers. Currently, there are two types of evacuated tubes solar collector, namely the heat pipe and the direct flow.

Figure 1: Evacuated tubes solar collector

I. METHODOLOGY

The multi-split solar-assisted cooling system, using refrigerant R410A, was designed to cool three rooms in a residential setting. The parameters needed for the design, such as the area of the room, heat loads, outside air temperature and relative humidity were measured to be able to identify the specifications of the system components. The system was then designed, assembled and installed in the residential unit. Figure 2 shows the schematic diagram of the multi – split air - conditioning system.

The system went through a series of leak tests to ensure that the system is leak free. Leakage will not only cause the system to be error free but to be potentially safe because refrigerant is still a chemical substance that may cause hazardous problems if not properly handled. The system was then operated to determine its performance. Both systems were operated continuously for eight hours which is the usual average operating time of air – conditioning units in a household setting. The power consumption of the systems was recorded and its coefficient of performance were calculated. Note that a separate electric meter was used for each unit to determine its electricity consumption.

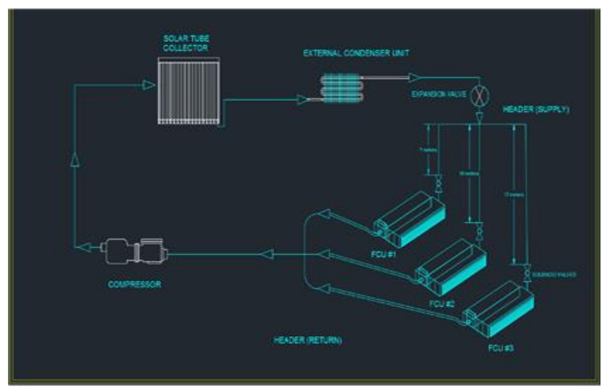

Figure 2: Schematic diagram of the multi – split air- conditioning system

Actual room temperature was measured using a digital thermometer at different points within the room. Power consumption for both the existing and multi – split, solar assisted systems were measured using a multi – meter. The voltage was measured from the socket of each stand – alone unit while the current was measured using the clamp ammeter feature.

III. RESULTS AND DISCUSSION

The computed COP of the multi-split, solar assisted air – conditioning system was 2.84 which is higher than that of the conventional system which was 1.57 and this is due to the number of compressors operating. It is evident that the use of a single compressor will help lower the power used in running the air-conditioning system. The higher the COP, the higher the savings for the operating cost. A saving of 18.91% in terms of power consumption was achieved using the multi – split, solar assisted air-conditioning system.

Table 1: COP and Percent Savings of Existing vs Multi-Split Cooling System

	Existing System	Multi – Split, Solar Assisted System
Actual Capacity, hp	8.82	8.30
Power, Kw	4.19	3.4
Consumption, Kw-h	33.53	27.19
COP	1.57	2.84
Percent Savings	18.91%	

Table 2 shows the power consumption of both the existing and the multi – split, solar assisted systems while Table 3 provides the cooling capacity of both systems. These data are also illustrated in Figure 3. The existing system produced 1.87 TR (6.58 Kw) of cooling while the multi-split system produced an average of 1.76 TR (6.19 Kw) cooling. The existing system consumed 4.19 Kw of power while the multi-split system consumed 3.40 Kw of power. This shows the competitiveness of the multi-split system in terms of cooling capacity produced to its marginal reduction in power used.

Table 2: Power Consumption of the Existing and Multi – Split, Solar Assisted Air-conditioning System

	Power (Kw)	Consumption (Kw-h)
Existing	4.19	33.53
MS (Day 1)	3.39	27.09
MS (Day 2)	3.40	27.22
MS (Day 3)	3.41	27.27
MS (Day 4)	3.41	27.28
MS (Day 5)	3.38	27.07
Ave. for MS	3.40	27.19

Table 3: Cooling Capacity of the Existing and Multi – split, solar Assisted Air – conditioning System

	Capacity (TR)	
	Design	Actual
Existing	1.87	1.87
MS (Day 1)	2.74	1.81
MS (Day 2)	2.74	1.76
MS (Day 3)	2.74	1.75
MS (Day 4)	2.74	1.69
MS (Day 5)	2.74	1.78
Ave. for MS	2.74	1.76

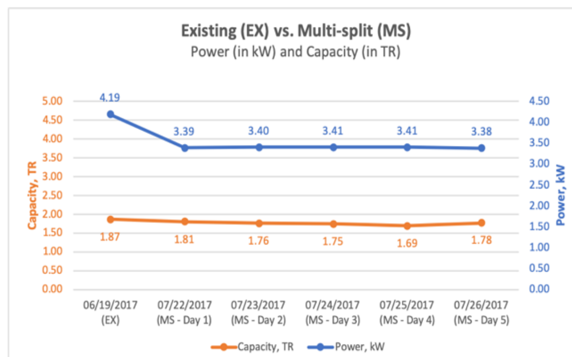

Figure 3: Cooling Capacity and Power Input of the Existing and Multi – Split Air – conditioning Systems

Table 4 shows the COP of both the existing and the multi – split, solar assisted air – conditioning systems. The same is illustrated in Figure 4. The computed COP of the existing system was 1.57 while that of the multi-split, solar assisted system was 2.84. This shows that the performance of the multi – split system is better than that of the existing system.

Table 4: COP of the Existing and the Multi – Split, Solar Assisted Air – conditioning System

	COP
Existing	1.57
MS (Day 1)	2.85
MS (Day 2)	2.83
MS (Day 3)	2.83
MS (Day 4)	2.83
MS (Day 5)	2.85
Ave. for MS	2.84

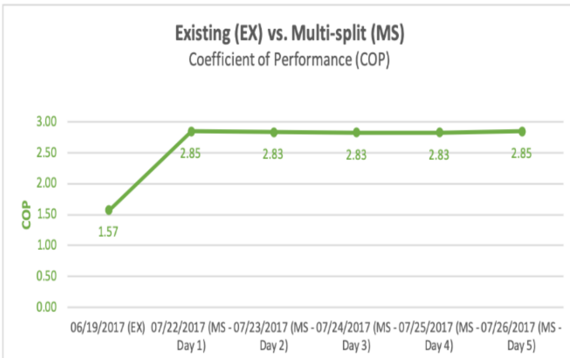

Figure 4: COP of the Existing and Multi – Split, Solar Assisted, Air – Conditioning Systems

Table 5: Ambient Air Temperature

	Ambient Temperature (°C)
Existing	31.0
MS (Day 1)	33.5
MS (Day 2)	29.0
MS (Day 3)	29.3
MS (Day 4)	29.6
MS (Day 5)	29.5
Average	30.2

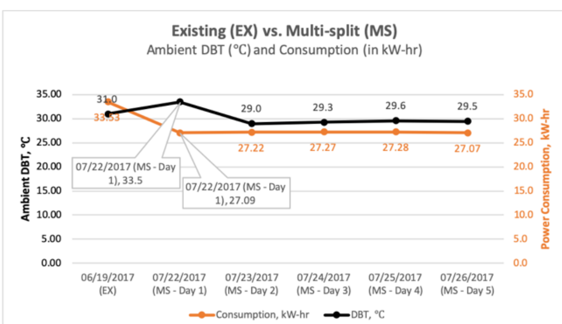

Figure 5: Ambient temperature and power consumption of the existing and multi – split, solar assisted air-conditioning systems

Table 5 shows the air ambient temperature during the actual testing of the system while Figure 5 shows the comparison of ambient temperature of air and power consumption of the existing and the multi – split, solar assisted air – conditioning system. The three rooms accumulated a total power consumption of 33.53 Kw-h using the existing system while maintaining an average room temperature of 24.64^0 C. With the use of the multi – split, solar assisted system, the average power consumption was 27.19 Kw-h while maintaining an average room temperature of 24 29°C. A savings of 18.91% in power consumption was achieved using the multi – split, solar assisted air – conditioning system.

IV. CONCLUSION AND RECOMMENDATIONS

The study showed that the performance of a multi-split cooling system is better than that of a window – type or split – type air-conditioning systems. It produced an average COP of 2.84 compared to the window type and split type systems which was 1.57. The multi – split type system also gave an average savings of 18.91% in power consumption. The computed payback period for the newly-installed multi-split solar-assisted air-conditioning system is 4 years, which is within the warranty life of five years for air – conditioning systems. Thus, instead of purchasing three or more cooling systems, the multi-split cooling system can be an alternative since it runs alone and subsequently separate its cooling capabilities into three or more different rooms.

It is recommended for future researches to have a main circuit board to run the system to minimize the errors. The use of a variable refrigerant flow (VRF) compressor is also recommended for use to run a single fan coil unit that will variate the compressor power depending on the fan coil units running.

V. REFERENCES

Andamon, M.M., (n.d.). Thermal Comfort Standards and Building Energy Use in Philippine Office Environments. School of Architecture, Landscape Architecture and Urban Design. Australia: The University of Adelaide.

Ayu, W.A., Kamaruzzaman, S., Azami, Z., Mohamad A.G. (2008). *A New Approach for Predicting Solar Radiation in Tropical*

Environment Using Satellite Images – Case Study of Malaysia. WSEAS Transaction on Environment and Development.

Henning, H.M. (2007). *Solar-Assisted Air-Conditioning in Buildings*. New York: Springer-Verlag Wien.

McQuay Air Conditioning. (n.d.). *Refrigerant Piping Design Guide.* Retreived from http://inspectapedia.com/aircond/AC_Guide_McQuay.pdf

Planning and Installing Solar Thermal Systems, A guide for installer, architects and engineers. (2007). UK: James & James Ltd.

How Sedna Aire Solar Aircon Works to Enhance Energy Savings and Cooling Comfort. (2013). *Edward Marcs Philippines Inc*. Retrieved from http://www.edwardmarcsphilinc.com/sedna-aire-solar-aircon-works-enhanceenergy-savings-cooling-comfort/

Mechanism and Principle of Air Conditioning. (2016). *Benign Blog*. Retrieved from http://benignblog.com/2012/01/how-airconditioner-works-simple-diagrammaticexplanation.html

Paratus Corporation. (2016). *How Air Conditioners Work: Components and Functions of AC Units*. Retrieved from http://www.airconditioning-andheating.com/how-acs-work/

Solar Heating and Cooling. (2013). *Solar Energy Industries Association.* Retrieved from: http://www.seia.org/sites/default/files/Solar%20Heating%20and%20Cooling%206.18.13.pdf