Performance Improvement of Air Conditioning System using Applications of Evaporative Cooling: A Review Paper

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Abstract

In present situation, reduction of energy consumption is necessary due to continuous increase in energy demand and reduction in global energy supply. Coefficient of performance of air conditioning system can be increased with evaporative cooled condenser in place of air cooled condenser. This paper presents a broad review of evaporative cooled condenser used in residential and commercial cooling systems. Evaporative cooled condenser increases the heat rejection process with the cooling effect of evaporation and therefore improve coefficient of performance. It is found by using evaporative cooling condenser, the power consumption can be decreased upto 20 % and coefficient of performance can be increased around 50%.

Keywords - *Vapour compression refrigeration system, Evaporative cooling, Coefficient of performance (COP), Energy saving.*

I. INTRODUCTION

Energy demand worldwide for buildings cooling has increased sharply in the last few decades, which has raised concerns over depletion of energy resources and contributing to global warming. Air condenser is generally used in small size residential air conditioners like window or split type, for heat rejection process in the cycle. The reason is to make the system as simple as possible without any need to the water connection line and other equipments. This idea seems reasonable as far as the air temperature in summer is moderate and not too high (about 40 °C). But when the air temperature increase and approach 50°C or higher, as it happens in many Middle East countries, the performance of the air condenser drops down and the air conditioner works improperly since the temperature and the pressure of the condenser increase and the compressor is forced to work under the greater pressure ratio, which results in more power consumption [4]. To do this, it is required to decrease the temperature of the ambient air before it passes over the condenser coil, in order to decrease temperature and pressure of the condenser. The simple and cheapest way for cooling the ambient air temperature is employing the evaporative cooling system. This could result in significant energy and demand savings overall since there are millions of air conditioners in the residential sector and any small reduction in power consumption of an air conditioner could save huge amount of megawatt in the network.

II. REVIEW OF LITERATURE

In order to increase the performance of air conditioner, one of the best solutions is decreasing the condenser temperature. Reducing the condenser temperature reduces the pressure ratio across the compressor which results power consumption reduction. It also decreases the refrigerant quality after the capillary tube and more liquid refrigerant would be available in the evaporator, therefore mass flow rate of refrigerant and the cooling capacity of the refrigerant are increased. To reduce the condenser temperature, one of the easiest ways is the application of direct evaporative cooler in front of the condenser to cool down the air temperature before it passes over the condenser. Using evaporative cooler in front of the air condenser can be considered as energy efficient, environment friendly and cost-effective method to enhance the performance of air conditioners. Since huge numbers of air conditioners are used in the residential sector, therefore, any considerable improvement in the performance of the cycle will have huge effect on the power consumption of the whole network [8].

S.S. Hu and B.J. Huang [1] investigated of a high-efficiency split residential water cooled air conditioner that utilizes cellulose pad as the filling material of the cooling tower. The cooling tower performance is improved due to good water wet ability of the cellulose pad that causes a uniform water film over the entire surface of the pads and a perfect contact between water and cooling air. The cooling tower is integrated with the condensing unit of the Rankine cycle in structure design to form an integral-type outdoor unit. The heat and mass transfer characteristics of the cellulose pads is first studied and the results are used for the design of the cooling tower. A prototype with 3.52 kW cooling capacity was constructed and tested in the present study. The experimental results show the coefficient of performance (COP) reaches 3.45 at wet-bulb temperature 27 °C, dry-bulb temperature 35 °C, air velocity 1.7 m/s, water flow rate 5.1 l/min, and that is higher than the standard value (2.96) of those conventional residential split air conditioners.

Vrachopoulos *et al*. [2] investigated a water evaporation system to an air-cooled condenser by spraying water mist into the air flow upstream to the condenser. They concluded a COP enhancement of 211% and it also maximizes the life duration of the cooling unit and brings energy saving up to 58% because of the necessary temperature difference reduction.

Youbi-Idrissi *et al.* [3] worked on simulation of a spray evaporative condenser reported an 11% increase in capacity and also revealed an upper theoretical limit of the spray rate to assure efficiency.

Hajidavalloo *et al*. [4] performed a test on an application of evaporative cooling on the condenser of window-air-conditioner. In this article, a new design with high commercialization potential for incorporating of evaporative cooling in the condenser of window-air-conditioner is introduced and experimentally investigated. A real air conditioner is used to test the innovation by putting two cooling pads in both sides of the air conditioner and injecting water on them in order to cool down the air before it passing over the condenser. The experimental results show that thermodynamic characteristics of new system are considerably improved and power consumption decreases by about 16% and the coefficient of performance increases by about 55%.

Nasr *et al*. [5] investigated on experimental and theoretical investigation of an innovative evaporative condenser for residential refrigerator. A theoretical model for the evaporative condenser was developed, and validated by experimental results. The theoretical model showed that the evaporative condenser can operate at a condensing temperature of 20 ^{0}C lower than that of the air-cooled condenser for heat flux of 150 W/m^2, and at air velocity 3 m/s. The effect of the different parameters on the condenser temperature was studied too.

Chen *et al*. [6] conducted a realistic prediction of the potential energy saving for using water cooled air conditioners in residential buildings in Hong Kong. A split type air conditioner with air cooled (AAC) and water cooled (WAC) options was set up for experimental study at different indoor and outdoor conditions. The cooling output, power consumption and coefficient of performance (COP) of the two options were measured and calculated for comparison. The experimental results showed that the COP of the WAC is, on average, 17.4% higher than that of the AAC. The overall energy savings were estimated to be around 8.7% of the total electricity consumption for residential buildings in Hong Kong.

Yu *et al*. [7] investigated how their coefficient of performance (COP) can be improved by using mist to pre-cool ambient air entering the condensers. The benefit of this application rests on the decrease of compressor power resulting from the reduced condenser air temperature with insignificant consumption of water and pump power associated with the mist generation. Based on a simulation analysis of an air-cooled screw chiller operating under head pressure control, applying such mist pre-cooling enables the COP to increase by up to 7.7%. Precise control of mist generation rate and integration with floating condensing temperature control are the major challenges of using a mist system to maximize electricity savings. The results of this study will prompt low-energy operation of existing air-cooled chillers working for various climatic conditions.

Hajidavalloo *et al.* [8] has been done his work on Performance improvement of air-cooled refrigeration system by using evaporative cooled air condenser. It is also found that by using evaporative cooled air condenser in hot weather conditions, the power consumption can be reduced up to 20% and the coefficient of performance can be improved around 50%.

Delfani *et al.* [9] used indirect evaporative cooling system (IEC) to pre-cool air for a conventional mechanical cooling system has been investigated The results indicate IEC can reduce cooling load up to 75% during cooling seasons. Also, 55% reduction in electrical energy consumption of packaged unit air conditioner can be obtained.

Chaktranonda *et al.* [10] investigated of Energy Saving in a Split type Air Conditioner with Evaporative Cooling Systems. This research aims to experimentally evaluate the energy saving in a split type air conditioner, which is using various types of evaporative cooling systems. The condensing unit is retrofitted with a cellulose corrugated pad, water sprayers, a water source and a pump. The power consumption and refrigeration capacity obtained from various cooling types are monitored and compared. The results show that the electrical consumption and coefficient of performance (COP) significantly depend on the ambient conditions. Due to effects of condensing pressure, when the ambient temperature rises, the electrical consumption becomes higher, while the COP becomes lower. Utilizing the indirect evaporative cooling system decreases the temperature of air entering the condensing unit, and this causes the system performance to be enhanced considerably. Among the investigated cases, the maximum energy saving occurs when the water spray cooperates with cellulose cooling pad. By using the evaporative cooling systems, COP is improved by around 45%, and electrical consumption is approximately reduced by 15%.

Khandelwal et al. [11] performed to reduce the annual energy consumption of a central air-conditioned building through advanced evaporative cooling systems. The building considered is a typical three floor library building of a University. The regenerative evaporative cooling technology is coupled with the liquid cooled water chiller system to accomplish the energy conservation objective. Comparisons of the regenerative evaporative cooling are made with simple evaporative cooling to bring out the importance such a system. The well-known building simulation software, TRNSYS is used to carry out the heat load the indoor temperature, the relative humidity and the thermal comfort index ‘PMV’ are compared for all the three different air-conditioning systems. The coupling of direct and regenerative evaporative cooling technologies with water chiller system has shown, respectively, 12.09% and 15.69% savings in annual energy consumption of the building.

J.K. Jain et al. [12] have performed of new evaporative cooling pad materials. This paper presents performance analysis of two new evaporative cooling pad materials. Now-a-days evaporative cooling pads are commonly made from aspen and khus fibers. These two materials along with new materials namely coconut fibers and palash fibers have been tested in a laboratory using suitably fabricated test set up. Air flow rate was kept constant. Evaporative cooling effectiveness was obtained and compared with that of aspen and khus pads. The effectiveness of pad with palash fibers was found to be 13.2% and 26.31% more than that of aspen and khus pads respectively. Where as effectiveness of coconut fibers was found to be 8.15% more than that of khus and comparable with that of aspen pad. Khus pad offers lowest pressure drop where as aspen pad (most commonly used) offers highest pressure drop among the four materials tested. The proposed new material (palash) offers pressure drop lower than that of the aspen pad. Because of better performance, lower costs and easy availability of coconut and palash fibers, their use as wetted media may enhance the scope of using these materials in domestic.

Yang *et al*. [13] investigated the effect of water mist evaporative pre-cooling on air cooled chillers by on-site experimental studies in a subtropical climate to improve the chiller efficiency. The pre-cooled condenser air enabled a drop of the condensing temperature by up to 7.2 K, and the chiller coefficient of performance (COP) could be improved in varying degrees by up to 18.6%. This study demonstrates that the water mist system coupled to air-cooled chillers is an energy efficient and environment friendly technique, which has significant potential to improve the efficiency of air cooled chillers and reduce the electricity demand for the commercial and industrial sector.

Hao et al. [14] performed a test on a optimizing the pad thickness of evaporative air-cooled chiller for maximum energy saving. To maximize the energy saving potential of an evaporative air-cooled chiller (EACC), which composes of an evaporative air cooler and a conventional air-cooled chiller, a mathematical model was developed and a new index, increase of seasonal energy efficiency ratio (ISEER), was proposed to evaluate the energy saving potential of the evaporative air-cooled chiller. The energy saving potential of EACC was simulated by using the hourly weather data for four typical cities in China. The impacts of various factors on the energy saving potential were analysed and it was found that there exists an optimal pad thickness which maximizes the energy saving. The optimal pad thickness varies with climatic condition and face velocity. Optimization results of the pad thickness in 31 main cities in China are presented. The maximum energy saving potential of EACC in China is between 2.4% and 14.0% depending on the climatic condition.

Pongsakorn et al. [15] studied an inverter air conditioner with an evaporative cooled condenser. They tested the system under multiple water spray rates and frequencies with three different temperature scales in fixed ambient temperature. As a result, up to 35% increase of COP was achieved at a lower water spray rate of 100 L/h and a higher frequency of 80–90 Hz.

Tianwei Wang et al. [16] investigated of air conditioning system using evaporative cooling condenser, this paper presents an experimental investigation of the Coefficient of Performance (COP)’s augmentation of an air conditioning system utilizing an evaporative cooling condenser. The results indicated an inverse relation between the condenser inlet dry bulb temperature and the COP. By using the evaporative cooling condenser to pre-cool the air, the saturation temperature drop through the condenser increased from 2.4^0C to 6.6^0C. It also resulted in an increase of the mass flow rate of refrigerant that went into the evaporator. This mass increase of liquid entering the evaporator consequently resulted in the increase of COP from 6.1% to 18%. A power reduction up to 14.3% on the compressor was also achieved. The result reveals the relation between water consumption and compressor energy saving regarding to their costs.

Sreejith et al. [17] investigated of a Household Refrigerator using Air-cooled and Water-cooled Condenser. The objective of this paper was to investigate experimentally the effect of water-cooled condenser in a household refrigerator. The experiment was done using HFC134a as the refrigerant and Poly-ester oil (POE) as the lubricant. The performance of the household refrigerator with air-cooled and water-cooled condenser was compared for different load conditions. The results indicate that the refrigerator performance had improved when water-cooled condenser was used instead of air-cooled condenser on all load conditions. Water-cooled condenser reduced the energy consumption when compared with the air-cooled condenser between 8% and 11% for various load conditions

Alotaibi, et al. [18] investigated of air conditioning system using air cooled condenser with water atomization. In this research, a design of evaporative cooling in the air-cooled condenser air-conditioning system is introduced and experimentally investigated. A real air conditioner is used to test the innovation by using a mist system (water atomization) in order to cool down the ambient air before it passing over the condenser. To meet the aim of the study, two rooms were constructed with same material and same size each equipped with brand new mini split air conditioning units having the same size and same brand name. The experiment was repeated nine times in different weather conditions. All results show that thermodynamic characteristics of the proposed system are considerably improved. The power consumption decreases in average by about 11% and the coefficient of performance increases in average by about 13%.

Islam et al. [19] studied experimentally and numerically an air-conditioning unit with evaporative cooled condenser coil. Experimental results show that the COP increases by about 28% compared to the conventional air-conditioning unit.

Martinez et al. [20] performed a test on a experimental study on energy performance of a split air-conditioner by using variable thickness evaporative cooling pads coupled to the condenser .In this work experiments are conducted in a split air-conditioning system where the condensing unit is modified by coupling different evaporative cooling pads with variable thickness. The impact of the different cooling pads on the overall performance of the air-conditioning system is experimentally determined by measuring the airflow conditions and the energy consumption of the overall air conditioning system, including both the condenser fan and the feed water recirculation pump of the cooling pads. Experimental results indicate that the best overall COP is obtained by adding a cooling pad thickness of about 100 mm. At that point the compressor power consumption is reduced by 11.4%, the cooling capacity is increased by 1.8% and finally the overall COP is increased by 10.6%.

III.SUMMARY

A review of the above reference has shown encouraging results in the direction of improving Coefficient of Performance by using evaporative cooling condenser. Evaporative cooler retrofitted to condenser is a reliable, cost effective and efficient method to increase the performance of any air cooled condenser such as window air conditioning systems, split type air conditioning systems, domestic refrigerator systems and commercial refrigeration systems. It is expected that more efficient evaporative cooling condenser will further increase the COP of air conditioning unit by a significant degree.

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