A REVIEW OF THE ENERGY FLOW THROUGH A CENTRIFUGAL WATER-COOLED CHILLER AIR CONDITIONING SYSTEM

AMINA ISMAIL & FREDDIE INAMBAO

Department of Mechanical Engineering, University of KwaZulu-Natal, Durban, South Africa

ABSTRACT

Heating, ventilation, and air conditioning systems consume a significant amount of electrical energy to transfer heat energy from the space into the atmosphere. This paper aims to analyze the flow of heat energy to provide space cooling and the losses involved. Energy losses from complex energy consuming equipment will be discussed to further understand how systems can become more energy efficient.

KEYWORDS: Centrifugal Water-Cooled Chiller, Energy Efficiency, Thermal Energy & Energy Losses

Received: Mar 03, 2021; **Accepted:** Mar 23, 2021; **Published:** May 11, 2021; **Paper Id.:** IJMPERDJUN202127

1. INTRODUCTION

Heating, ventilation, and air conditioning (HVAC) systems consume a significant amount of energy and there is a growing demand for HVAC systems. To restrain the amount of energy consumed by HVAC systems, it is important to understand how energy is transferred, used and lost in the system. This paper primarily analyses the flow of energy from the space being cooled to the atmosphere and the electrical energy used by complex heat transfer equipment used in the process. The flow of heat energy and electrical energy is discussed to highlight and surface opportunities to reduce energy consumption and improve the energy efficiency of the system. This article will use centrifugal water-cooled chiller system as the basis for discussion.

2. ENERGY CONSUMING CHILLER EQUIPMENT AND ENERGY LOSSES

Water cooled chillers, known for their high efficiency, use the vapour compression cycle to chill water which is used to absorb heat from the air-conditioned space [11], [12],[13]. The chiller uses a working fluid, the refrigerant, to cool the chilled water returning from the space, and the heat absorbed by the refrigerant is then compressed to increase the pressure and the corresponding saturation temperature. The refrigerant then enters the condenser, the cool condenser water absorbs the energy from the refrigerant which returns to the evaporator. The heat absorbed from the refrigerant by the condenser water is then expelled into the atmosphere through a cooling tower. Figure 1 shows the main energy consuming components of a chiller air conditioning system [13].

Figure 1: Schematic Diagram of a Chiller Air Conditioning System [14].

There are five heat energy loops within the air conditioning process involved in transferring the heat absorbed from the building and expelling it into the atmosphere. Understanding the relationship between electrical energy consumption and heat energy transfer will assist in understanding the flow of energy and the losses and how this process can be improved. In each link of the chain, heat is absorbed by the subsequent link until the energy is rejected into the environment. Figure 2 shows the heat transfer flow with the associated electrical equipment used to transfer heat from one loop to the next, thereafter each link will be discussed[8].

Figure 2: Thermal Chain for an HVAC System in Cooling Mode (Adapted from [8]).

2.1 Air Loop

With reference to Figure 2, heat is extracted from the air that occupies the conditioned space in the air loop. A fan is used to pass the warm air through a cooling coil where heat energy is absorbed by the chilled water, thus reducing the temperature of the air within the space. The air loop can be considered as an open process because realistically, the air loop is subject to ventilation, air exhaustion and air leaks that occur in ducts and conditioned spaces [8]. Supply air fans are used to provide fresh air to the ventilated space, while return air fans extract the warm air from the cooled space. As much as these fans are not cooling or heating the air, they are the source of transportation for the air, with an electrical energy source. Static pressure drop and volumetric flow rate determine the fans capacity and energy consumption and a considerable amount of energy can be allocated to the ventilation fans in an HVAC system [15]. [15] indicates that there are various issues that can affect a fan's performance, such as dirty fan blades, mechanical wear and poor maintenance to aging fans [15]. Over time these factors increase the fans energy consumption. There are two main factors that affect electrical energy consumption of ventilation fans: 1) fan selection by the system design engineer, and 2) poor maintenance. Design engineers tend to "over specify" to compensate for being responsible for inadequate system performance [16]. However, over specifying reduces the efficiency of the fan operation, reduces the life span and increases operation cost [16]. HVAC filters, dampers, duct lengths (including bends, tees and expansion/reduction pieces), and the cooling coil, affect the static pressure and energy consumption of the fan which needs to be considered by the design engineer. Dampers and HVAC filter selection contribute to the fans' static pressure. As energy efficiency is an important aspect in HVAC design, engineers should ensure that dampers and filters specified for the system conserve energy and provide thermal comfort and air quality. According to research conducted by [17] the difference in energy consumption and indoor air quality (IAQ) depend less on the filter and more on the system design, the building operation and the operation time of the fans [17]. However, [17] indicates that their study found a difference in the fan energy consumption when filters were added to the system, but different types of fans were affected in different ways. The permanent split capacitor (PSC) motor fans used more power than electronically commutated motor (ECM) fans under normal conditions; when filters with a pressure drop of 150 Pa were used, PSC fans used less power than ECM fans [17]. The research conducted by [18] indicates that when dampers are not functioning properly a high pressure drop is created across the dampers which adds to the fans' static pressure load, but adding a control system to the dampers

can reduce the fan energy by a maximum of 30%, depending on the numbers of hours the system operates [18].

2.2 Chilled Water Loop

The chilled water loop is a closed system, and a pump is used to circulate the water to and from the conditioned space, refer to Figure 2. The chilled water absorbs the heat energy from the air in the cooling coil, thus increasing the temperature of the chilled water. As the warmer chilled water passes through tubes in the chiller evaporator, the heat energy is transferred to the refrigerant[8]. When heat is absorbed by the refrigerant from the chilled water it becomes vapour and the chilled water temperature drops. The chilled water is then recirculated to the cooling coils in the AHU, the process repeats itself. The cooling coil and the chiller evaporator are both heat transfer components of the system and the circulating pump converts electrical energy to kinetic energy in the chilled water[19]. The chilled water circulating pumps are used to provide chilled water at the calculated flow rate and static head of the HVAC system. Pump designers manipulate the vane design to achieve optimum output velocity for an impeller [19]. Centrifugal pumps have reached the peak of design, however, VSDs are commonly used to improve energy efficiency and it is the responsibility of the design engineer to select the right pump to create optimal operating conditions.

2.2.1 Cooling Coil

The performance of the cooling coil plays an important role in improving thermal energy transfer between the chilled water and air to be conditioned. Ambient temperatures affect the sensible (Q_s) and latent heat gains (Q_L) of the space, rising the dry bulb and wet bulb temperatures and affecting IAQ. Figure 3 shows the common change in air properties during the cooling process across the cooling coil. Outside air (at ambient temperature and humidity) enters the cooling coil then if the cooling coil is 100% effective, the air will be cooled to apparatus dew point (ADP) or dew point temperature which is located at point C on the saturation curve in Figure 2. Realistically, a limited surface is never 100% effective, therefore the final temperature of the cooled and dehumidified air will be somewhere along the line between entering coil conditions (point A in Figure 2) and ADP (point C in Figure 2). The amount of condensed vapour will be the difference in specific humidity between the specific humidity of air entering the coil and the specific humidity of air leaving the coil; this process decreases the specific humidity and increases the relative humidity[20], [21].

Figure 3: Psychrometric Chart with the Properties of Air Entering and Leaving the Coil[20].

The contact factor (β) and the bypass factor (BPF) are both used to express the efficiency of the cooling coil, the

BPF describes the percentage of air that is not cooled to ADP whereas the β is used to describe the percentage of air that has been cooled to ADP, as described in equations (1) [20], [21], [22].

$$\beta = \frac{\omega_A - \omega_B}{\omega_A - \omega_C} = \frac{h_A - h_B}{h_A - h_C} \approx \frac{T_A - T_B}{T_A - T_C} \quad (1)$$

Where:

β = Contact factor

ω = Humidity ratio or specific humidity relative to dry air (kg/kg)

h = Enthalpy (kJ/kg)

T = Temperature ($^{\circ}\text{C}$)

The following equation (2) calculates the bypass factor:

$$BPF = \frac{h_B - h_C}{h_A - h_C} = \frac{T_B - T_C}{T_A - T_C} = \frac{\omega_B - \omega_C}{\omega_A - \omega_C} \quad (2)$$

Where:

BPF = Bypass factor

In summer, the outdoor ambient temperatures are much higher than the conditioned space, therefore the latent and sensible heat gains will be transferred to the interior, increasing the temperature and relative humidity of the interior [23]. The total heat flow in a cooling coil can be analysed using the equation (4). The difference in enthalpy between points A (entering the cooling coil) and B (leaving the cooling coil) provides an overall analysis of the energy requirements of the total cooling process [21], [22]. Equation (3) is used to calculate the total heat flow in the cooling coil.

$$\dot{q}_T = \dot{m}(h_A - h_B) \quad (3)$$

Where: $\dot{q}_T$ = Total heat flow rate (kJ/s) and $\dot{m}$ = Mass flow rate of air in (kg/s)

At any given point on the psychometric chart, the mass flow rate can be determined by using the volumetric flow rate and the density of air. The total heat flow rate is the sum of the latent heat and the sensible heat. The sensible heat flow rate is a function of temperature change and can be calculated using the equation (4) [21], [22]:

$$\dot{q}_s = \dot{m}C_p(T_A - T_B) \quad (4)$$

Where: $\dot{q}_s$ = Sensible heat flow rate (kJ/s); $C_p = 1.01$ Specific heat capacity of air (kJ/kg $^{\circ}\text{C}$)

The latent heat flow rate is a function of the specific humidity relative to dry air and can be calculated with the equation (5) [21], [22]:

$$\dot{q}_L = \dot{m}h_{we}(\omega_A - \omega_B) \quad (5)$$

Where: $\dot{q}_L$ = Latent heat flow rate (kJ/s) and h_{we} = Water evaporation enthalpy (2502 kJ/kg)

With reference to Figure 3, the following mass and energy equations can be used to analyse the heat and mass transfer across the cooling coil for cooling with dehumidification [24]. According to the conservation of mass principle, the mass at point A must be the same as the mass at point B in a controlled volume, as mathematically described by

equation. (6)[24].

$$\dot{m}_{airA} = \dot{m}_{airB} \quad (6)$$

A and B refer to state points A and B in Figure 3. During the cooling and dehumidification process, the moisture in the air condenses, reducing the amount of moisture to dry air. The psychometric chart provides the kg of humidity per kg of dry air at a specific condition on the chart, therefore with equation (7) the amount of condensate formed can be calculated.

$$\dot{m}_{wA} = \dot{m}_{wB} + \dot{m}_{cond} \rightarrow \dot{m}_{airA}\omega_A = \dot{m}_{airB}\omega_B + \dot{m}_{cond} \quad (7)$$

Where the subscript “Cond” refers to the amount of condensate formed.

The conservation of energy is applied to the amount of energy entering and leaving the cooling coil to analyse the flow of energy across the cooling coil, as mathematically described in equation (8) [24]. The total mass flow rate of air and its enthalpy is the sum of the heat flow rate at point A on entering the cooling coil, the mass flow rate of air at point B and its enthalpy at point B, and the mass flow rate of the condensate formed and the enthalpy of the condensate.

$$\dot{m}_{airA}h_A = \dot{Q}_A + \dot{m}_{airB}h_B + \dot{m}_{cond}h_{cond} \quad (8)$$

2.3 Refrigerant Loop

In the evaporator, the refrigerant absorbs the heat from the chilled water by means of a vapour compression cycle. The refrigeration process then undergoes a change of thermodynamic properties, transferring heat energy to the condensing water in the condenser [8]. With reference to Figure 4, the refrigerant leaves the evaporator as a low pressure and low temperature gas [25]. It then becomes a high pressure and high temperature gas before being used again, thus the refrigerant flows from the evaporator to the compressor where pressure and temperature is increased (see state point 2 in Figure 4) before entering the condenser [25]. In a water cooled chiller, the condenser uses water to absorb heat energy from the refrigerant, thus the refrigerant condenses to a liquid once again [25]. The liquid refrigerant leaves the condenser at a high pressure and temperature and flows through the expansion valve. The expansion valve separates the high-pressure side of the refrigerant from the low-pressure side, acting as a pressure reducing valve. Only a small amount of refrigerant is allowed to pass through the valve into the evaporator as a cooled liquid [25].

Figure 4: Refrigerant Cycle in a Water Cooled Centrifugal Chiller [12].

2.3.1 Centrifugal Compressors

The centrifugal compressor converts electrical energy to mechanical energy to increase the pressure and temperature of the refrigerant. Centrifugal compressors are of a turbine type, moving gas by converting kinetic energy to pressure energy. Refrigerant, in vapour phase, enters the compressor through a suction vane and passes through the impeller. Centrifugal compressors are more energy efficient and robust when compared to other compressors for use in water cooled chillers [26], [27]. In general, the energy consumption costs of compressors are higher than the typical investment and maintenance costs [28]. Electric motors account for a considerable proportion of energy consumption. In the European Union alone, 70 % of the total electrical demand can be allocated to motors and electric motor driven compressors account for 18 % to 25 % of the energy consumption [27]. As a result, electric motor driven compressors have potential for energy efficiency improvements [27]. The energy efficiency of a centrifugal compressor design has been improved to such a high level that the potential for further improvements lie in the diffuser development [27]. There are three main types of diffuser designs: vaneless diffuser, low solidity vaned diffuser and vaned diffuser, all of which influence the compressor performance and operating range differently [27]. [27] focuses on energy improvement in centrifugal compressor component design and the energy efficiency benefits of each diffuser type and the results show that improvements in compressor energy efficiency have a significant effect on the total energy usage of the system, with energy savings of between 2.5% and 4.9% [27]. Clearly component design is an important aspect when considering energy efficiency of the entire system. In the case of refrigeration compression, a change in operating conditions or a change in the medium viscosity decreases the Reynolds number [30]. A decrease in the Reynolds number increases the boundary layer thickness and the frictional losses which then leads to lower efficiency and pressure ratio [30]. According to a study by [31], the shape of the diffuser and a low Reynolds number contribute to the deterioration in the performance of centrifugal compressors [31]. To improve the performance of a centrifugal compressor the growth in the impeller hub and the diffuser boundary layer should be reduced [31]. The manufacturer's data and tests conducted on the centrifugal compressor do not always favour the real operating conditions of the compressor. In some cases, the efficiency of the system is compromised. In chilled water air conditioning systems, it is essential to select an energy efficient compressor that will also improve the energy efficiency of the system as a whole.

2.3.2 Expansion Valve

An expansion valve is a small orifice which controls the flow of liquid refrigerant pumped from the high pressure condensing side to the low pressure evaporator [32], [33]. The refrigerant exiting the orifice will be rapidly expanding, it will be at a low pressure in the form of liquid vapor [32], [33]. The expansion valve regulates the refrigerant flow keeping the pressure difference between the high and low pressure side of the refrigeration system [32], [33]. The expansion valve works in conjunction with the compressor to achieve the desired results at the evaporator. There are various types of expansion valves depending on the type of refrigerant, the evaporator capacity, liquid refrigerant temperature and the pressure drop requirements. Thermostatic expansion valves are commonly used in air conditioning; however, electronic expansion valves are becoming popular as they reduce energy consumption on start-up of the HVAC system. [34] found that the energy efficiency ratio (EER) was low after each start up in all tests conducted. This is a result of the refrigerant leaving the evaporator in liquid phase, thus entering the compressor in a liquid phase and endangering the operation because the thermal expansion valve cannot differentiate between the different cooling demands [34]. When the compressor stops, liquid refrigerant migrates through all parts of the evaporator and there is an imperfect control of the expansion valve which causes swings in the system when in operation [34]. The compressor will have to replace a larger volume of refrigerant, thus leading to energy wastage. The use of thermostatic expansion valves may lead to energy increases as great as 23% during start up. [34] also found that electronic expansion valves always had a higher EER as the electronic expansion valve has the ability to

control refrigerant flow in the evaporator and thus limit liquid refrigerant in the compressor [34]. With the use of a thermal expansion valve, the greatest energy loss occurs during start up because thermal valves are either opened or closed and cannot control the required amount of refrigerant for the cooling load. However, electronic expansion valves easily control the flow of refrigerant entering the evaporator and entering the compressor as vapour. To improve energy efficiency of the HVAC system, the designer should consider the use of electronic expansion valves.

2.4 Condensing Loop

Referring to Figure 2, the heat absorbed from the refrigerant in the condenser and is then transferred to the environment through the cooling towers [8]. The heat from the refrigerant is absorbed by the cooling water and is pumped to the cooling towers where the heat from the water is dissipated into the atmosphere, thus cooling the water. Thereafter the cool water from the cooling tower is pumped to the condenser, as shown in Figure 5[35]. The cooling fan in the cooling tower induces cooling of the condenser water through convection. The recirculating pumps and the cooling tower fans contribute to the total power consumption of the HVAC system. Improving the efficiency of the cooling tower fan and the recirculating pumps will improve the overall efficiency of the HVAC system.

Figure 5: Schematic of a Condenser Water Loop[35].

Regular maintenance on a condenser can easily improve overall efficiency of the condenser [36]. Annual brushing of the condenser water pipes will remove any scale build up and maintain the efficiency of the heat transfer surface. Water treatment of the condenser water is critical to prevent fouling as untreated water damages the tubes and piping. Cooling tower blowdown is the most effective way to remove solids and contaminants [36]. Reducing the water temperature before it enters the condenser can improve the chiller's efficiency[36]. A condenser is rated according to the amount of heat it rejects into the atmosphere. The total heat rejected from the refrigerant in the condenser refers to the de-superheating, the condensation and the subcooling of the refrigerant and is mathematically expressed using equation (10)[26]:

$$Q_{rejected} = \dot{m}_{refrigerant} (h_{leaving} - h_{entering}) \quad (10)$$

The temperature of the condenser water leaving and entering the shell-tube condenser has an impact on the condensed refrigerant temperature, the compressor input power, the condenser water pump power and the cooling tower fan input [26].

2.5 Heat Rejection to the Atmosphere Loop

The main mechanical equipment that uses energy or distributes or loses energy to dispel the heat energy from the cooled space to the atmosphere, are the cooling towers, cooling tower fans and the condenser water recirculating pumps.

2.5.1. Cooling Towers

Cooling towers are used to dissipate the heat energy absorbed through the air conditioning cycle into the atmosphere. Recirculated condenser water from the chiller condenser is evaporatively cooled by contact with atmospheric air [24]. Mechanical draft cooling towers are commonly used for large commercial buildings [24]. A fan is used to extract atmospheric air, passing it through the condenser water as it is sprayed downwards across the fill, thus absorbing the heat energy and reducing the temperature of the condenser water, see Figure 6 [24], [34]. About 1% of the water evaporates as it flows concurrently with and is absorbed by the upward flow of air. Drift eliminators trap the larger droplets, while those droplets that leave the tower are referred to as drift [24]. Among the different types of cooling towers, the counterflow induced draft cooling tower will be discussed here. The counterflow induced draft cooling tower allows for the driest air to contact the coldest water, thus increasing the performance of the cooling tower [24]. Another advantage of the counterflow induced draft cooling tower is that the fill creates an even distribution of air across the water spray and is discharged at a higher velocity from the fan outlet [24].

Figure 6: Counterflow Induced Draft Cooling Tower [34].

2.5.1.1. Thermal Analysis of Cooling Towers

The cooling tower coefficient refers to the heat transfer unit or the size of the fill which primarily affects the efficacy of the cooling tower [24]. A higher cooling tower coefficient refers to a larger tower size or capacity for a given flow rate [24]. According to [24], if the thermal resistance of the saturated air film is neglected, the energy balance between the condenser water and the air can be calculated using equation (10), wherein the amount of heat leaving the water droplet is equal to the amount of heat absorbed by the air

$$\dot{m}_{condenser} C_p dT_{condenser} = \dot{m}_{air} dh_{air} \quad (10)$$

Where:

$\dot{m}_{condenser}, \dot{m}_{air}$ = mass flow rate of water and air (kg/s)

C_p = Specific heat of water

$T_{condenser}$ = Temperature of condenser water ($^{\circ}\text{C}$)

h_{air} = Enthalpy of air (kJ/kg)

If the saturated film of air is assumed to have no thermal resistance, then the combined heat and mass transfer from the saturated air film to the bulk air stream can be calculated using equation (11)[26]:

$$\dot{m}_{air} dh_{air} = K_m (h_s - h_{air}) dA \quad (11)$$

Where:

K_m = Mass transfer coefficient (kg/sm^2)

h_s = Enthalpy of saturated air film (kJ/kg)

A = Surface area at air-water interface (m^2)

Sensible and latent heat is transferred from the water droplets to the surrounding air which can be modelled using equation (12). The cooling tower coefficient is calculated by combining equation (10) and equation (11) to get the following equation (12)[26]:

$$\frac{K_a V}{\dot{m}_{condenser}} = \int_{T_{condenser 1}}^{T_{condenser 2}} \frac{dT_{condenser}}{h_s - h_a} \quad (12)$$

Figure 7 shows the characteristics of heat and mass transfer between the condenser water and air in a counterflow cooling tower. The condenser water enters the cooling tower at temperature w_e (29.4°C) and exits the cooling tower at w_l (23.9°C), which is the range of the cooling tower. The temperatures of the saturated air film correspond with the condenser water temperatures and can be represented by line labelled water (w_e - w_l) [26].

Figure 7: Graphical Representation of a Cooling Tower Characteristics [26].

The temperature of air entering the cooling tower is higher than the temperature of water leaving the cooling tower, therefore the air is evaporatively cooled as the air temperature approaches the condenser water temperature [26]. Thereafter, the air absorbs the heat energy and some of the water mass causing the air to become humidified and heated, as shown by

the curve *ae-al* in Figure 7. The difference between the saturated air film and the air is the driving potential of heat and mass transfer between the condenser water and the saturated air film [26].

2.5.1.2. Cooling Tower Performance Parameters

The role of a cooling tower is to effectively remove heat from the condenser water and minimise the electrical consumption of the system [24]. The performance of the cooling tower is directly affected by the tower range, water-air ratio, approach, fill configuration and water distribution system [24]. A cooling tower is rated on the following conditions; Unit of heat rejection at condenser, water circulation rate, water temperature entering the condenser, water temperature leaving the condenser, outdoor wet bulb temperature, range and approach [24].

2.5.1.2.1 Range and Water Circulating Rate

The primary parameters that should be specified during design are the range and the corresponding water circulation rate(kg/s) [24]. The relationship between the range and rate of circulation can be expressed using equation (13) [24]:

$$T_{condenser\ E} - T_{condenser\ L} = \frac{Q_{rej}}{C_p \dot{m}_{condenser}} \quad (13)$$

Where:

$T_{condenser\ E}$ = Condenser water entering the cooling tower

$T_{condenser\ L}$ = Condenser water leaving the cooling tower

Q_{rej} = Amount of heat rejected from the condenser (W)

$\dot{m}_{condenser}$ = Rate of the condenser water circulation (kg/s)

A smaller range and greater $\dot{m}_{condenser}$ imply that the system will require a lower condensing pressure and temperature, greater pumping energy, greater tower size because of the smaller range and higher airflow rate for a fixed water to air ratio [24]. The designer of the system will need to calculate the energy efficiency and cost implications in relation to the lifespan of the system.

2.5.2 Cooling Tower Fans and Recirculating Pumps

The cooling tower fans play an important role in optimizing the chilled water system by regulating the condenser water inlet temperature. To prevent surging, centrifugal chillers require a minimum temperature for the water entering the condenser [37]. Cooling tower fan cycling may be achieved by a simple ON-OFF control, variable speed drives (VFD) and using 2 or 3 speed motors[37]. The condenser water recirculating pumps are essential to provide the condenser water with a flow rate that creates a balance for optimum heat transfer between the refrigerant and the condenser water. The cooling tower may require a second pump to supply make up water if needed. It is essential that both the cooling tower fans, and the recirculating pumps are driven by VSDs. VSDs allow the fan or pumps to run at a wide range of speeds to match the capacity of the load. When the system senses a high load, the VSDs will increase their speed in relation to the load and continue operating the system within a range set by the designers. Research conducted by [38] showed by using VSDs the energy consumption for the chillers and cooling towers was reduced by 5.8% for the same amount of cooling.

3. DISCUSSIONS

This article provides a review of a holistic approach to identifying electrical and thermal losses within the air conditioning process and how energy usage can be optimised from the component level to an operational level by using the thermal energy loop as a map, thus identifying electrical energy consuming components and thermal losses. The primary cause for energy loss in the air loop are the ventilation fans. The two primary reasons that affect electrical energy consumption of the ventilation fans is fan selection by the design engineer and poor maintenance. Regarding design of an air conditioning system, design engineers tend to over specify, thus incurring initial cost and operational costs. The design engineer must be careful not to over design the system and specify components with a greater capacity than calculated for. Ventilation fans must be sized for their application and maintained throughout their service life.

In the chilled water loop, the cooling coil and the chiller evaporator are responsible for heat transfer while the chilled water circulating pump converts electrical energy to kinetic energy. The design of the cooling coil can be improved to increase the heat transfer surface area. Another important aspect is material selection for the cooling coils. This area requires further research to ensure that the material used provides the least resistance for heat transfer between the chilled water and air flow.

The compressor and the expansion valve are the two most important components in the refrigerant loop. The systems design engineer must ensure that the compressor selected is suited for its application and that it contributes to the energy efficiency of the air conditioning system. The expansion valve has minimal impact on the energy consumption of the HVAC system – the greatest loss occurs during start up. Electronic expansion valves are more energy efficient as they easily control the flow of refrigerant entering the compressor as a vapour.

In the condensing loop, recirculating pumps are used to provide kinetic energy to the condenser water. Maintenance of the condenser is critical to ensure that the heat transfer surface provides maximum heat transfer from the refrigerant to the condenser water.

Cooling tower fans and condenser water pumps are the major energy consumers in the heat rejection to the atmosphere loop. The design and selection of the cooling tower is important to ensure that the condenser inlet water temperature is regulated according to the systems design parameters to prevent surging of the compressor. The condenser water pumps must create a balance for optimum heat transfer between the condenser water and the refrigerant. To improve energy efficiency both the fans and the pumps should use VSDs.

4. CONCLUSIONS

The five heat energy loops within the air conditioning process involved in transferring the heat absorbed from the building and expelling it into the atmosphere has been analysed and discussed. A holistic approach to understanding and identifying energy losses has been used. Heat and electrical energy lost to the environment has been identified, this can further be used when designing air conditioning systems and selecting complex energy transfer components.

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