EFFICIENCY ENHANCING BY CONVERTING FROM AN AIR-COOLED CONDENSER TO A WATER-COOLED CONDENSER USING A SHELL AND TUBE HEAT EXCHANGER

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Abstract
Cooling is one of the major concern in commercial building all over the world. The use of energy for space cooling is growing faster than for any other end use in buildings, more than tripling between 1990 and 2016. Space cooling – typically by means of an air conditioning (AC) system- is contributing increasingly to global energy demand. The currently installed air-conditioning system was inefficient and to replace it with the latest currently available system will not be economical. The aim of this paper is to present energy savings obtained by using different energy saving techniques on the currently installed air-conditioning system in commercial and industrial buildings to enhance the approachability of energy conservation around the world. The energy saving techniques used are: Evaporative cooling through pads, Heat load reduction through the reflective coating, Improving chiller performance using automatic tube cleaning system, and Retrofitting of air-cooled condenser to water-cooled condenser by using shell and tube heat exchanger. This paper presents case studies of these energy saving techniques used in commercial and industrial buildings, based on energy audit carried out in different buildings. The most power consuming area was the air conditioning system. The audit discloses that the buildings in which these four energy saving techniques were adopted, has achieved a total of 75,190 kWh annual saving of energy, and in terms of money; it would be Rs. 7.98 Lacs. So as to achieve these savings, we need an investment of Rs. 9.7 Lacs, following in the payback period of 1.02 years. This effort plays a major role in arriving better utilization of energy in commercial and industrial buildings through these four energy-saving techniques.

Keywords: *Energy audit methodology, Evaporative cooling, Retrofitting, Shell and tube heat exchanger, Reflective coating, and Automatic tube cleaning system*

Introduction

Energy conservation is a limitless field of research and improvement as energy is everywhere just we have used it efficiently so that everyone needs to be fulfilled with current energy generation technology. Global sales of ACs have been growing steadily and significantly. Those ACs vary enormously in energy efficiency, and keeping them running consumes over 2000 terawatt hours (TWh) of electricity every year, which is two and a half times the total electricity use of Africa. Almost a fifth of all the electricity used in buildings is for cooling. Energy saving techniques have become extremely important because there are already installed air conditioning systems which are inefficient and consuming more power for the same amount of cooling effect. Commercial building such as hotels, hospitals, and industries are consuming a large amount of energy in the form of air conditioning and because of improper management of energy in this sector, a considerable amount of energy is wasting. Most of the techniques are focused on heat transfer enhancement of condenser as condenser pressure plays a major role in compressor power consumption. As condenser of the air conditioning system previously uses only air to heat transfer from the refrigerant.

Methodology

The research study provides four energy saving techniques that have been successfully implemented and can be used further. Predominantly, this study comprises of energy audit carried out in different commercial and industrial buildings. Digital energy meter and digital temperature meter is used for power consumption and indoor air temperature measurement respectively. Data were collected from the air conditioning system before and after the implementation of energy-saving techniques. The overview of the methodology is shown in fig. 1

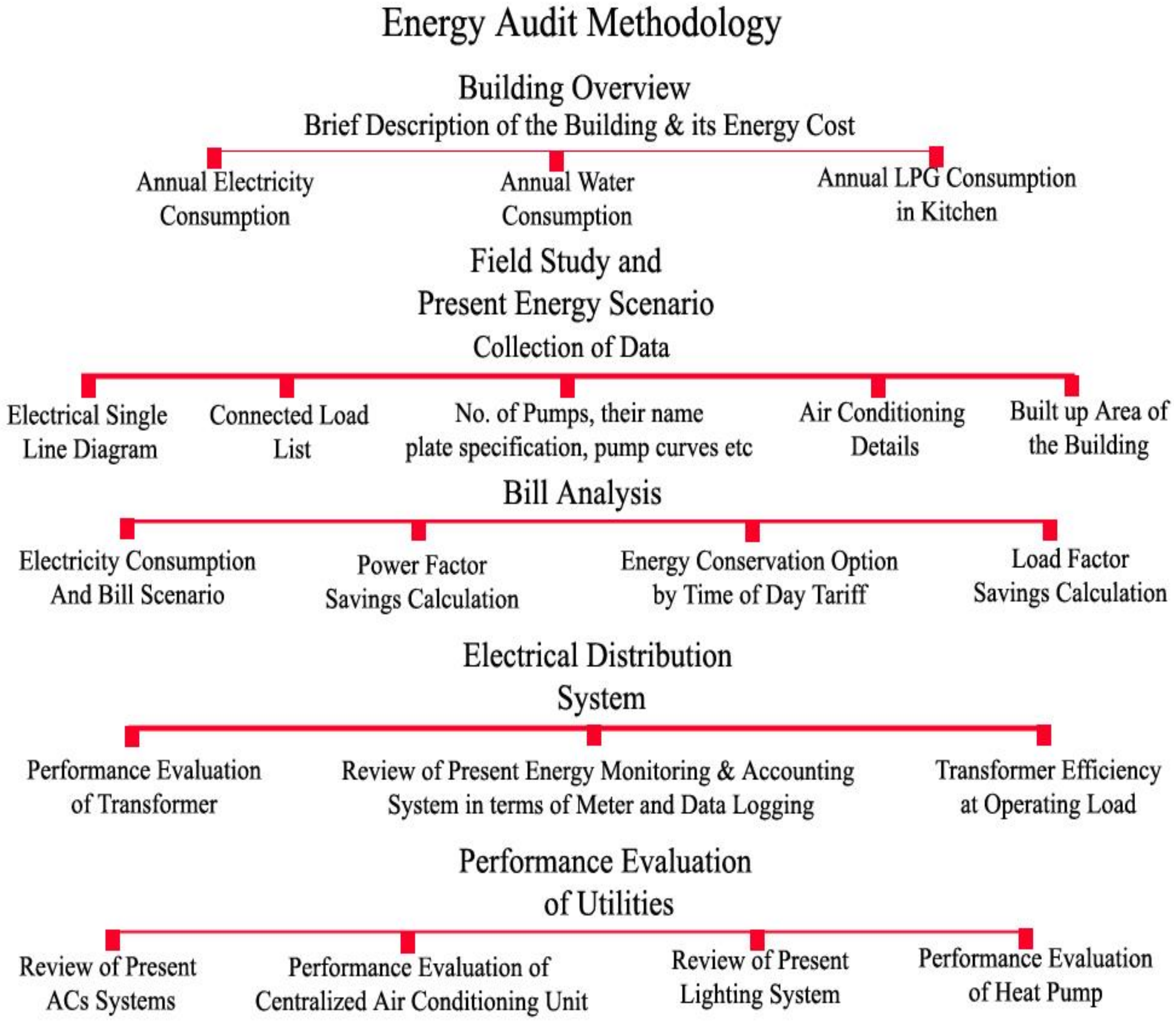

Figure 1 Overview of Methodology

ENERGY Saving techniques USED IN the present STUDY**EVAPORATIVE COOLING THROUGH PAD**Evaporative cooling is used to lower the temperature and increase the humidity of air by using latent heat of evaporation, changing liquid water to water vapor. In this process, the energy in the air does not change. Warm dry air is changed to cool moist air. The heat of the outside air is used to evaporate water.A mechanical direct evaporative cooler unit uses a fan to draw air through a wetted membrane, or pad, which provides a large surface area for the evaporation of water into the air. Water is sprayed at the top of the pad so it can drip down into the membrane and continually keep the membrane saturated. Any excess water that drips out from the bottom of the membrane is collected in a pan and recirculated to the top.

Figure 2 Evaporative Cooling Through Pad

Single-stage direct evaporative coolers are typically small in size as they only consist of the membrane, water pump, and centrifugal fan. The mineral content of the municipal water supply will cause scaling on the membrane, which will lead to clogging over the life of the membrane. Depending on this mineral content and the evaporation rate, regular cleaning and maintenance are required to ensure optimal performance. Generally, supply air from the single-stage evaporative cooler will need to be exhausted directly (one-through flow) because of the high humidity of the supply air. As shown in fig. 2 several pads are installed surrounding the condenser and a separate water tank with a pump is fitted in a corporate building split air conditioning system.

1. Heat Load Reduction Through Reflective Coating

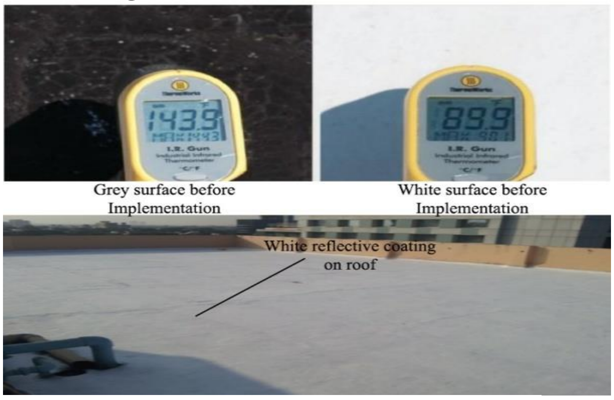

Figure 3 Heat Load Reduction Through Reflective Coating

A cool roof is one that has been designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles. Nearly any type of building can benefit from a cool roof, but consider the climate and other factors before deciding to install one. Just as wearing light-colored clothing can help keep you cool on a sunny day, cool roofs material that is designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles. Standard or dark roofs can reach temperatures of 62°C or more in the summer sun. A cool roof under the same conditions could stay more than 12°C cooler and save energy and money by using less air conditioning. As shown in fig. 3 highly reflective type of paint is applied on the rooftop and surrounding walls of industry and before and after readings were taken.

Figure 4 Automatic Tube Clealing System

3. Improving Condenser Approach Through Automatic Tube Cleaning System

Approach temperature of a condenser has a major influence on chiller system performance compared with evaporator approach temperature. A chiller system with a high condenser approach temperature would require higher condensation temperature to reject heat to the cooling water. This would increase the working pressure and energy consumption of a chiller. Automatic Tube Cleaning Systems for tube and shell heat exchangers. A revolutionary technique that automatically (programmable) cleans shell and tube heat exchanger tubes without the need for downtime, mechanical, chemical or manual cleaning. Saves on energy, maintenance, and other costs related to the old way of cleaning heat exchanger tubes. As shown in fig. 4 the automatic tube cleaning system was installed in the condenser section of the chiller in the hotel.

4. Retrofitting Of Air Cooled Condenser Through Water Cooled Condenser By Using Shell And Tube Heat Exchanger

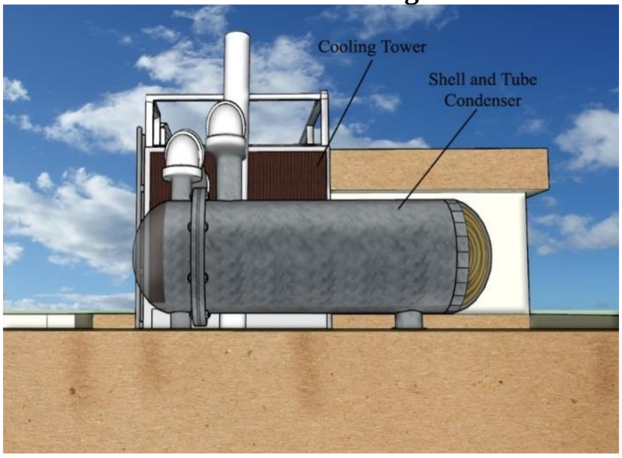

Figure 5 Retrofitting Water Cooled Condenser by using Shell and Tube Heat Exchanger

As current air conditioning systems are mostly air cooled system which is inefficient as air-cooled condensers approach less heat transfer to the environment which is not suitable for achieving desirable condenser temperature so as to reduce the condensing pressure of the refrigerating fluid leaving the compressor. As by these condensing pressure increases which increase compressor power consumption for the same amount of cooling effect. So as to deal with it we have to replace it to a water-cooled condenser which is basically a shell and tube heat exchanger which can transfer more heat from refrigerant producing the higher refrigerating effect with less power consumption. As shown in fig. 5 a conceptual image of retrofitting of air-cooled condenser to water-cooled condenser by using shell and tube heat exchanger in hospitality.

Case Study

The following case studies have been performed for Hospitality, Hotels, and Industries across India with data collected by energy audit methodology. The energy consumption of the air conditioning system for the various sector has been collected before and after implementation of energy-saving techniques. The following tables (Table 1 to 4) provide energy efficient technologies along with energy savings and payback period for the system.

1. Evaporative Cooling Through Pad

Table 1 represents the annual unit consumption of previous air conditioning system and possible energy savings with payback. The present air conditioners are operated for 6 hours a day.

Table 1. Energy savings by Evaporative Cooling Pad

Sr No.	Description	Before	After
1	Type	Split air conditioner	Split Air Conditioner
2	Rating	15*5.5 TR	15*5.5 TR
3	Average Power Consumption, kW	48	43.5
4	Annual Unit Consumption, kWh	1,03,680	93,960
5	Annual Saving, kWh	9,720	
6	% Saving	9%	
7	Payback, Years	1.05-1.2	

2. **Heat Load Reduction Through Reflective Coating**

On the basis of data recorded, savings can be estimated by applying the reflective coating on the rooftop of the corporate building. By this technique, the radiation heat load which is coming inside the building is reduced considerably. Thus, energy savings can be achieved by a reduction in unit consumption. Obtained savings for Air conditioning system on the basis of data taken are as follows:

Table 2. Energy saving using Reflective Coating

Sr No.	Description	Before	After
1	Type	Split air conditioner	Split Air Conditioner
2	Rating	20*7.5 TR	20*7.5 TR
3	Average Power Consumption, kW	90	88
4	Annual Unit Consumption, kWh	3,88,800	3,80,160
5	Annual Saving, kWh	8,640	
6	% Saving	2%	
7	Payback, Years	0.61-0.9	

3. Improving Chiller Performance By Using Automatic Tube Cleaning System

Table 3 represents annual unit consumption before and after the implementation of a water cooled system with possible energy saving and payback period. The conditioning system average operating hours per day are 22 hours.

Table 3. Energy savings by using ACTS

Sr No.	Description	Before	After
1	Type	Water Cooled Chiller	Water Cooled Chiller
2	Rating	225 TR	225 TR
3	Average Power Consumption, kW	122	116
4	Annual Unit Consumption, kWh	9,66,240	9,18,720
5	Annual Saving, kWh	47,520	
6	% Saving	5%	
7	Payback, Years	1.3-1.6	

4. Retrofitting Of Air-Cooled Condenser To Water-Cooled Condenser By Using Shell And Tube Heat Exchanger

Table 4 shows annual energy saving by retrofitting of the air-cooled condenser to the water-cooled condenser by shell and tube heat exchanger respectively.

Table 4. Energy savings using Water-Cooled Condenser

Sr No.	Description	Before	After
1	Type	Air Cooled Split air conditioner	Water Cooled Split Air Conditioner
2	Rating	17 TR	17 TR
3	Average Power Consumption, kW	16.887	11.715
4	Annual Unit Consumption, kWh	30,397	21,087
5	Annual Saving, kWh	9,310	
6	% Saving	31%	
7	Payback, Years	1.1-1.4	

Result

The observations from the experimental and numerical results imply that using energy saving techniques; savings are obtained as shown in table 5. The annual saving achieved is about 9,720 kWh, 8,640 kWh, 47,520 kWh, and 9,310 kWh by using an evaporative cooling pad, reflective coating, ATCS, and retrofitting by shell and tube heat exchanger respectively.

Table 5. Energy efficient technologies in Hospitality

Sr. No.	Energy Saving Techniques	Savings Achieved on Total Annual Bill	Payback Period
1	Evaporative Cooling Through Pad	8-10%	1-1.2 Years
2	Heat Load Reduction Through Reflective Coating	2-2.5%	5-7 Months
3	Automatic Tube Cleaning System	4-6%	1.3-2 Years
4	Retrofitting Air Cooled Condenser	29-32%	1-1.3 Years
Average Estimated Savings on Annual Bill		11-13%	

Conclusion

This case study demonstrated that energy and bill saving is achieved by using different techniques like evaporative cooling, reflective coating, ATCS, and retrofitting by shell and tube heat exchanger in the existing system of hotels, hospitality, industries, and corporate buildings. It is found that an average estimated saving achieved by applying these four energy-saving techniques are 11-13% on an annual energy bill, with a reasonable return on investment of 1.02 years. The intent of this paper is to bring out the energy saving techniques in commercial and industrial buildings depending upon the system requirement with enhancing its performance.

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