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Energy saving of cooling tower replacement by a mathematical model

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Abstract

The cooling tower replacement of chiller system is effected to energy saving of chiller because of condenser's heat transferring was improved. The evaluation of energy saving from replacement the new cooling tower could be low accuracy because the old cooling tower has been rejected. This research was study the relativity between old 1,250 ton of cooling tower and 1,000 Ton of chiller by mathematic model to use as base line. When replace new cooling tower could be measuring the energy saving because the base line of old system in mathematic model so that would be more accuracy in energy saving evaluation. The result of mathematic model creation for old system found accurate 2.7 of CVRMS. The mathematic model equation could be predicted the energy saving when replace new cooling tower, the potential energy saving was 693,863 kWh/year.

Keywords: Cooling tower, Chiller, Mathematic model, Cooling tower base line, Energy saving

1. Introduction

Air conditioning system use a lot of energy even in industrial factories or buildings account 40-60% of total energy consumption [1] thus energy saving is significantly. The chiller system is one component of air-condition commonly use, cooling tower is part of chiller system that receive heat from condenser and transfer to the ambient [2] if heat transferring inefficient its will effect to pressure in discard side of compressor to higher and caused increase demand of electric power [3]. The consideration of cooling tower is comparing welt bulb temperature and water temperature (T_{CDS}) after cooling. The decision to replace new cooling tower will considering in addition to effective are investment, energy saving, and payback period. The relation of cooling tower and chiller in mathematic model could be predict the energy consumption, energy saving and can use as base line to calculate when replace new cooling tower.

2. Materials and methods

2.1 Chiller system

This research was study chiller in Yarn industries by 1,000 ton of chiller and 1,250 ton of cooling tower. The cooling tower was used for 17 years thus the industry was planned to replacement new cooling tower because of long term using and high rate of maintenance but lacked the information of energy saving and others investment.

2.2 Experimentation

According to Figure 1 the experiment was not installing new system thus the concept ended in that step.

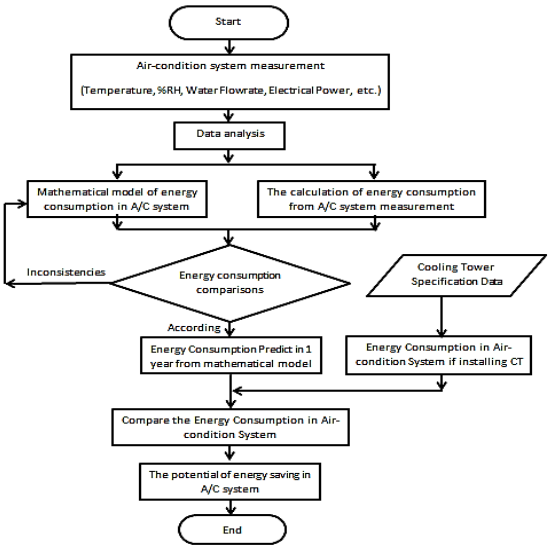

Figure 1 experimentation diagram of old system

In case of remodel in the future will use the old system's mathematic model to compare with veritable measurement of new system (This research was not remodel the system).

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2.3 Measurement and analysis

The studying chiller size is 1,000 ton consist the 1,250 ton of cooling tower and condenser water pump size is 45 kW, the measure position of study as Figure 2.

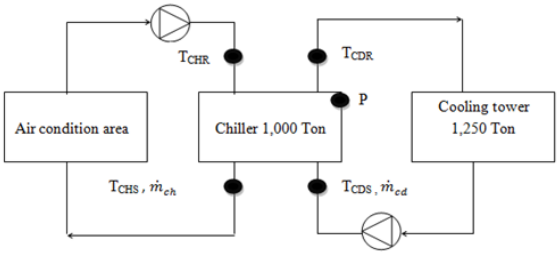

Figure 2 measure position [4]

T_{CDS}, T_{CDR}	is condenser water temperature supply/return (^oF)
T_{CHS}, T_{CHR}	is chill water temperature supply/return (^oF)
$\dot{m}_{ch}$, $\dot{m}_{cd}$	is flow rates of cool water and condenser water (GPM)
P, P_e	is electrical power of chiller using in old system/calculate by the model (kW)
T_{db}, T_{wb}	is dry/wet bulb temperature of air around cooling tower
%RH	is air relative humidity

The calculation of chiller's air-conditioning load as Equation 1

$$Load = \frac{\dot{m}_{ch}(T_{CHR}-T_{CHS})}{24} \quad (1)$$

When; Load is chiller's air-conditioning load (Ton)
The calculation of chiller performance (Chp) as Equation 2

$$\text{Chp} = \frac{\text{P}}{\text{Load}} \quad (2)$$

When; Chp is chiller performance (kW/Ton)
The calculation of coefficient of performance or COP by converting method as Equation 3 [5]

$$\text{COP} = \frac{3.517}{\text{Chp}} \quad (3)$$

The cooling tower's performance calculation in approach temperature form as Equation 4 [6]

$$\text{Appr.} = (T_{CDS} - T_{wb}) \quad (4)$$

Appr. is approach temperature of cooling tower that the approach temperature must lower than 3-5 ^{o}C [7]

2.4 Creating mathematic model

Analysis the measured data in Figure 2 by mathematic model [8] got value as Equation 5

$$\frac{1}{cop} = 1 + \left(\frac{T_{CDS}+273.15}{T_{CHS}+273.15}\right) + \frac{\left[A_o + A_1 T_{CDS} - A_2\left(\frac{T_{CDS}+273.15}{T_{CHS}+273.15}\right)\right]}{Load} \quad (5)$$

When; A_0, A_1, A_2 is value to analysis

2.5 Energy saving evaluation method (If install new cooling tower)

In Equation 5 is stead equation of old system, the change variable in this equation is T_{CDS} and load while T_{CHS} is generally stable thus even old and new system will be the same to using Equation 5 but different in T_{CDS}. The experiment will be use T_{CDS} from Equation 6, 7 in Equation 5 T_{CDS} value of old system from

$$T_{cds\ before} = T_{wb} + \text{Appr.}_{before} \quad (6)$$

$T_{CDSbefore}$, Appr._{before} is value before remodel
$T_{CDSafter}$ value of remodel system calculate from

$$T_{cds_{after}} = T_{wb} + \text{Appr}_{after} \quad (7)$$

Use $T_{CDSbefore}$ value in Equation 6 stead in Equation 5 to find COP_{before} value in old system and use $T_{CDSafter}$ in Equation 7 stead in Equation 5 to find COP_{after} of new system. Then could be calculate the electric power by

$$P_e = \frac{\text{COP}}{\text{Loadx3.517}} \quad (8)$$

3. Results

3.1 Result from measurement and analysis

The measurement from Figure 2 the result is air-condition load is 902 Ton, average electric power is 515.7 kW , average COP value is 6.152, condenser and chill water flow rate is 2,377 and 3,123 GPM respectively and average cooling tower approach temperature is 6.3 ^{0}C

3.2 The creation of mathematic model

From Equation 5 and measurement result, analysis to find A0, A1, A2 value and replace the value into Equation 5 as Equation 9

$$\frac{1}{cop} = -1 + \left(\frac{T_{CDS}+273.15}{T_{CHS}+273.15}\right) + \frac{\left[-2157 - 4.9458T_{CDS} - (-2232.3)\left(\frac{T_{CDS}+273.15}{T_{CHS}+273.15}\right)\right]}{Load} \quad (9)$$

3.3 Precisions analysis between veritable measurement and mathematic equation

Comparing veritable measurement and mathematic equation to find precisions value in CVRMS, the result of creating model found CVRMS value is 2.7%, shown the equation model is high precision value and can be use this equation to calculate the system before remodel from Equation 8 and 9 could be calculate to find electric power from prediction equation, by with veritable measurement. The value as Table 1.

Table 1 Chiller electric energy consumption

Energy consumption by	Measurement (kWh/day)	Prediction (kWh/day)	Different (%)
Chiller	20,112	20,107	0.02

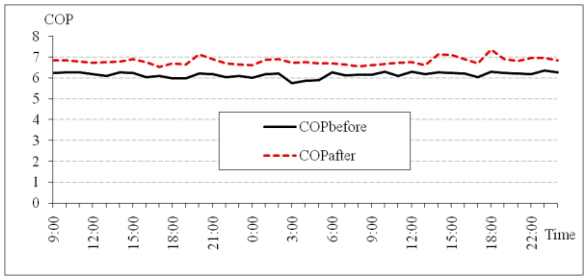

Figure 3 Comparative before and after COP value

3.4 Evaluate energy use after system remodel and energy conservation potentiality

The evaluation of energy using after remodel if replace new cooling tower. Information of one cooling tower manufacturing has Approach Temperature value as 4 ^{0}C then comparing COP value before and after replacement as Figure 3, the evaluation of energy saving when replacement new cooling tower show as Table 2.

Table 2 Potential energy saving in chiller

Electrical energy	Before (kWh/day)	After (kWh/day)	Saving (kWh/day)
Energy consumption in Chiller	20,107	18,206	1901

4. Discussion

The study found mathematic model can be accurately estimated the energy consumption, the solution is difficult to measure A0, A1, A2. The equation would be more accuracy if air-conditioning load is stable, if air-conditioning load is vary the method would more appropriate than calculate the average. In case of energy saving is more precisely, by use the new measure values to comparing with simulate value to find the energy saving in real time.

5. Conclusions

The research to find mathematic model and potentiality of energy saving if replace new cooling tower size 1,250 Ton using in 1,000 Ton of chiller found the value of model is CVRMS 2.7 % with high accuracy can be used as stead equation in process of old system. The old and new system Approach Temperature value is 6.3 and 4 ^{0}C respectively, energy save is 693,863 kWh/year or amount 2,636,687 baht/year or 9.45 % of energy using before remodel. This research is appropriate with large system and need high accuracy result to be supplementary information for investment decision.

6. Acknowledgements

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