# Controlling of Cooling Tower Return Temperature and Energy Saving

**A. Mandal, J. Nataraj and T.K. Bera**

Rare materials Project, Bhabha Research Centre, P.O. Yelwala, Dist. Mysore, Pin – 571130.

## Introduction

Fans, Pumps, blowers, cooling towers and many other applications are subject to varying loads. The variation may occur due to various factors e.g. in cooling tower applications the load variation occurs may be due to utilization of the installed capacity, variation of process conditions etc.

Conventionally, control valve throttling, pump discharge bypass recirculation control etc. are used in order to match the requirements of varying loads in cooling tower outlet temperature control.

In this paper it has been shown that apart from conventional mode of controlling varying load can also be significantly reduced by the use of variable frequency drive – device.

## Background

The importance of maintaining optimum cooling tower cold water return temperature need not be over emphasized. It is very important for the economic reasons i.e. from the point of view of desired product yield & quality.

Cooling towers are designed to tale care of maximum adverse conditions. But normally both of these conditions do not occur simultaneously. Hence, there is lots of scope to improve the performance of operating cooling towers.

In our case, we are in use of cooling towers, the technical details of which is given below:

Cooling Tower Details:
Type – Induced draft type.
Capacity – 570 kW.
Water flow rate-115 $m^3$/HR.
Design Wet Bulb Temp. (WBT) – 25.6 ºC.
Design cooling tower water outlet temp. 28-29 ºC.
Fan Speed – 700 RPM.
Fan Power Rating – 15 HP.
Airflow rate – 17800 (513 $m^3$)/min).

The above cooling tower is installed to cater to the requirement of heat removal from six different systems having constant heat load of 110 kW each for the first two systems, 130 kW each for the next two system and for the fifth and sixth system the corresponding heat load of about 80 & 15 kW respectively. Therefore the maximum heat load expected from all the six system is approx. 575 kW.

However, at the time of carrying out this study only four systems out of sic systems were in operating conditions viz. System 1 & 2 having a heat load of 80 kW and 15 kW respectively. Hence, the cooling tower was being operated on partial load only i.e. total heat load was approx. about 315 kW.

Moreover, on studying the meteorological data of Mysore, it was observed that the variation of weather conditions between day & night & also seasonal variation was quite substantial. A rough idea about the same can be made from table – 1.

The design cold water inlet temperature in the secondary circuit of the cooling system, to various systems is approx. between 31-32 ºC and the maintenance of this design temperature was very important from the point of view of process performance.

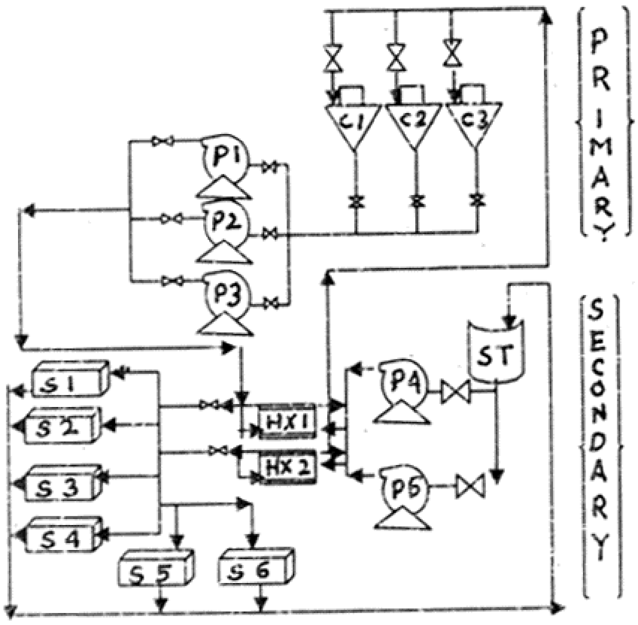


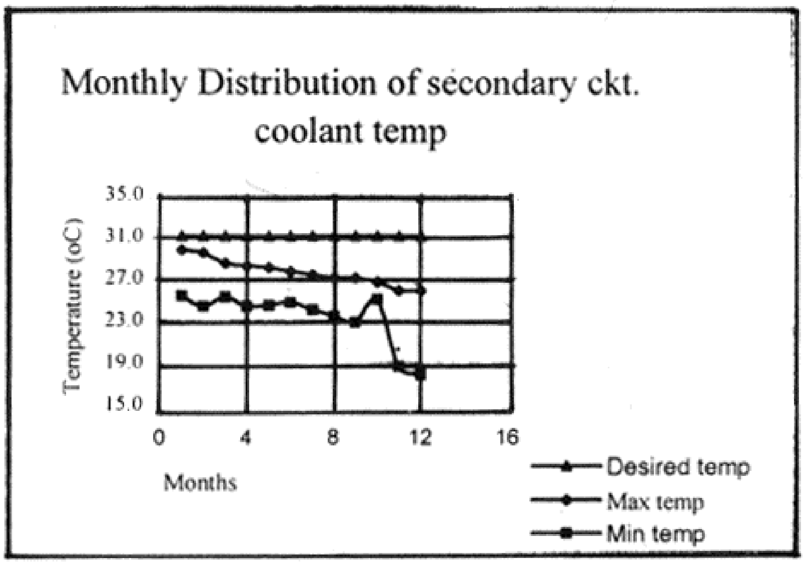

Fig.-1: Block diagram of cooling system.

However, due to the wide, fluctuation of weather conditions & also due to the partial loading of cooling tower, it had virtually become impossible to maintain optimum cooling tower cold water return temperature i.e. 28-29 ºC and operating cold water inlet temperature to various system i.e. 31-32 ºC. A rough idea about the extent of variations that has been taking place can be made from the following table – 1 below:

**Table – 1**

| Month | Wet Bulb Temp (in ºC) | | CTW-Cold water return temp (ºC) | | Secondary Coolant cold Water return temp (ºC) | | |
|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Desired Temp |
| Jan | 24.5 | 21.5 | 26.5 | 22.2 | 29.7 | 25.3 | 31.0 |
| Jul | 24.0 | 21.0 | 29.3 | 22.3 | 29.4 | 24.3 | 31.0 |
| May | 24.5 | 19.5 | 24.6 | 21.8 | 28.4 | 25.2 | 31.0 |
| Oct | 22.5 | 20.5 | 25.5 | 21.8 | 28.2 | 24.3 | 31.0 |
| Apr | 25.5 | 21.0 | 30.6 | 22.2 | 28.0 | 24.4 | 31.0 |
| Sep | 22.5 | 19.5 | 21.8 | 21.8 | 27.6 | 24.7 | 31.0 |
| Mar | 21.0 | 17.0 | 26.8 | 20.5 | 27.3 | 24.0 | 31.0 |
| Aug | 23.5 | 21.0 | 21.8 | 21.2 | 27.0 | 23.4 | 31.0 |
| Feb | 20.0 | 18.5 | 23.2 | 19.2 | 27.0 | 22.8 | 31.0 |
| Nov | 21.0 | 16.5 | 24.0 | 23.0 | 26.6 | 25.0 | 31.0 |
| Dec | 21.5 | 16.0 | 23.6 | 19.3 | 25.8 | 18.6 | 31.0 |
| Jan | 21.5 | 16.0 | 22.6 | 17.4 | 25.8 | 17.8 | 31.0 |

Meteorological data of Mysore city & temp. Distribution in Primary and Secondary circuit of cooling system.




From table-1 & the graph shown above, it can be due to the partial loading of the cooling tower and also due to seasonal fluctuation of weather conditions frequently, we are not able to maintain the optimum cooling tower cold water return temperature.

So, our main objective of this study was to take some measures in order to achieve optimum cooling tower cold water return temperature.

## Options Available

Regulation of water loading in cooling tower

In order to see the extent of temperature control possible by varying the flow rates of both primary and secondary circuit coolant, both the flow rates were varied & the result of the same is presented in Table–2.

**Table-2**

| Primary (Cooling tower) Loop | | | Secondary Loop | | |
|---|---|---|---|---|---|
| Flow | HX inlet temp (ºC) | HX outlet temp (ºC) | Flow | HX inlet temp (ºC) | HX outlet temp (ºC) |
| Full | 23.5 | 27.8 | Full | 26.8 | 25.8 |
| 75 % | 23.4 | 26.7-28.3 | 50-55 % | 25.3-27.3 | 24.6-27.1 |
| 50 % | 23-23.5 | 26.8-28.8 | 50-51 % | 27.6 | 26.6 |
| 25 % | 22, 8-24.8 | 28-29.9 | 50-51 % | 27.7-29.2 | 26.9-28 |

Effect of water loading regulation on Cooling Tower primary & secondary circuit Temperature.

From table-2, it can be seen that in spite of varying both the primary & secondary circuit cooling water flow rates to extent of 100-25 % & 100-50 % of the design flow rates, the change in temperature, in both the circuit, could be achieved only upto 3-3.4 ºC. Whereas, we are expecting to manage the temperature variation upto 11-12 ºC which is not achievable by this method.

Regulation of Air loading in cooling tower

Regulation of air loading in cooling tower can be done by the following method as described below:

(i) By changing the length of the fan Blade: To reduce the cooling capacity if fan blade length is reduced then its cooling capacity gets fixed to a lower value & it can not work under varying load.

Alternatively, to meet the requirements of variable load at least 2-3 different size blades are to be stocked & and blades of operating cooling towers are to be changed as & when load conditions vary. Practically, it is a difficult proposition. Hence, this method was not adopted.

(ii) Changing the pitch of the fan blade: In order to vary the cooling capacity, according to this method, the pitch of the blades are usually rotated to + or – 3 degree from the mean.
In summer, the blades shall be in, +3° position & in winter -3 ° position. In winter, -3° position delivers about 80 % of +3° air quantity, the power saving is about 40.

However, the limitation in this method is that the regulation of air loading can be done only for two fixed values. Regulation of air loading for a wide range of values is not possible. Hence, this method also was not adopted.

(iii) Regulating the speed of the fan: Regulating the supply frequency of the power to the fan motor can regulate the speed of the cooling tower fan. By this method, the fan speed & the quantity of air being supplied to the cooling tower can be varied in the entire range from zero speed to maximum fan speed & from zero air supply to maximum air supply as per the requirement of the process. The speed regulation of the fan is possible with the help of advice viz. Variable Frequency Drive (VDF) System.

By varying the frequency of the supply power with the help of VDF, the speed of industrial motors (used fro running fans, bowlers, pumps, compressors etc.) can be varied. This device, VDF, consists of a frequency converter, which varies from frequency and voltage of the supply fed to the AC induction motor.

Before buying and installing a VDF for achieving the optimum CTW return temperature, it was decided to operate the cooling tower at zero fan speed & at full fan speed in order to see the extent the temperature control possible with the installation of a VFD. The result of the experiment is described in the Table-3 below:

**Table - 3**

| Fan speed | Cooling Tower return temp (°C) | Secondary Ckt Temp (°C) | |
|---|---|---|---|
| | | Inlet | Outlet |
| FULL | 23.5 | 26 | 28 |
| ZERO | 32 | 35.5 | 37 |

Variation cooling system temp with respect full speed & zero speed of cooling tower fan.

So, from table-3, it can be seen that the extent temperature control possible, by varying the speed of the fan full speed to zero speed is approx, 9-10°C & the same fulfills our requirements.

On the basis of the above results, it was decided to install a common VDF for all the three cooling towers.

On the basis of above study, to operate the cooling tower fans at variable speed a transistorized SPWM drive were produced & installed. The VDF device has the facility to operate both in fixed drive (FD) mode. So, depending upon the requirements, the VDF device can be operated at full speed in FD mode or at variable speed in VD mode. The performance of cooling tower was studied again thought the year and the results are shown in Table-4 below:

**Table – 4**

| Months | Period (month) | Fan Speed (C/s) | | | CTW return temp | Secondary Ckt. Inlet Temp |
|---|---|---|---|---|---|---|
| | | Day | Night | Average | ºC | ºC |
| Jun, Jul, May, Oct, Apr | 5 | 40-50 | 35-40 | 40 | 26-29 | 29-31 |
| Feb, Mar, Aug, Sep | 4 | 30-35 | 25-30 | 35 | 26-29 | 29-31 |
| Nov, Dec, Jan | 3 | 35-40 | 20-30 | 30 | 26-29 | 29-31 |

Seasonal variations of fan speed over a period of 1-year and cooling tower return temp.

[Note: Although we are able to maintain the CTW return temperature approx. equal to the design temperature, but due to severe cold climatic conditions during winter (Nov-Feb) & Monsoon (May-Aug) even after putting of the fan completely during night the CTW temp. goes below up to 19-20 ºC]

So, from the above table, it can be concluded that the regulation of cooling tower fan speed and & air flow using a VDF -device helps in maintaining optimum cooling tower return temperature even in the circumstances when cooling tower is partially loaded and also weather & climatic condition fluctuation is substantial.

However, the additional benefit which we could gain, apart from achieving the optimum CTW temperature is substantial amount of energy saving by operating the cooling tower fan at a speed lower than the design speed.

**The detailed calculation of energy saving is given below.**

**Details of fan Motor:**
440 volts 13.9 Amp, 5.5 kW, 3phase, 1440 RPM, Class-B Ip-55, S1, Fan Speed – 700 RPM through bevel helical gear arrangement.

**Details of VFD – devices:**

Manufacturer – KIRLOSKER ELECTRICALS, Mysore
Type – SPWM, Input – 415 V, 50 C/S, 3 – Phase, Output – 0-415 V, 50 C/S, 3 – Phase, 5.5 kW 11 Amp.

Assumptions:
VFD – device efficiency = 0.85
VFD – device power factor = 0.96
Motor device power factor = 0.85
Input Voltage = 405 Volt.
Power input to the motor through inverter = 1.732 X voltage X current X P.F. (VFD) X VFD device efficiency.

The data are collected from the system under various loading condition of the fan are shown in table-5 below:

**Table – 5**

| Frequency (c/s) | Current (amp) | P input (Watt) |
|---|---|---|
| 15 | 0.5 | 286 |
| 25 | 1.2 | 686 |
| 30 | 2.0 | 1144 |
| 40 | 4.3 | 2460 |
| 50 | 8.3 | 4750 |

**Current & Power input data of CT fan collected at different speed.**

Power input to motor (without inverter): 1.732* Voltage* Curr* Power factor (Motor)
50 C/S 9.15Amp 5470 watt

Therefore, amount energy saved by operating the fan through inventor at 50 C/S = 5470 – 4750 watt = 0.72 kW.

and Energy saving/Yr. (assuming elec. Charges/unit = Rs.5) = Rs. 0.72*24*30*12*5 = Rs 31,104

However, from table – 4 above, it can be seen that the cooling tower fan is being operated, for a period of one-year approx. at an average sped of 40 c/s for 9-months & 30 c/s for 3-monts.

Therefore, the actual amount energy saving per annum is:
Energy saving/Yr. = Rs {9*24*30*5*(5470- = 1,44,245.

Whereas, the additional investment for the procurement of VFD – inverter is approx. Rs. 80,000. Hence, the investment cost has been recovered within 6-months.

## Conclusion

The advantages of using VFD – device for controlling the speed of fans, blowers, compressors, pumps etc to meet the process requirements are:

- **Wide range of speed control** – Improves the performance & efficiency compared to traditional control methods viz. throttling, recalculation and damper controls.
- **Energy saving** – Saves energy substantially & reduces production cost.
- **Reliability & Availability of the system is high** – Reduces downtime of the equipment, plant.

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