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PERFORMANCE ANALYSIS OF NATURAL AND INDUCED DRAFT COOLING TOWER IN SUMMER AND MONSOON SEASONS

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Abstract— In India 68% of total electricity generate by coal based thermal power plant. Now a day's thermal power plant is very efficient and gradually increasing the generation of electricity. Where water is the most usable part in the thermal power plant, it is used for the generation of the steam. Water resources are easily available in plenty amount, but usage of water has to be done very carefully to from the environment point of view. In the thermal power plant large amount of water is used for the steam generation and it also recirculated. For the continuous recirculation of water, it is necessary to cool it. For this purpose, cooling tower is used in the thermal power plant. Cooling tower is an essential part of the thermal power plant. It cools the hot water and releases heat in the environment. A cooling tower cools water by a combination of heat and mass transfer. Water to be cooled is distributed in the tower by spray nozzles, splash bars, or film-type fill, which exposes a very large water surface area to atmospheric air. So here i'm analyzing the performance of natural and Induced draft cooling tower in different seasons. And here we have used the analytical method for the analysis of cooling tower. This method of analysis is quite popular and have been referred by most of the researchers working in this field. The result coming through this method is quite comparable with practical scenarios. With the use of these formulas one can easily produce and compare the effectiveness of cooling towers, range, approach and other such parameters at different working conditions. This is the mathematical methodology of analysing the performance and hence efficiency of cooling towers. Where i found the result that in the monsoon season cooling tower is more efficient as compared to summer season. The effectiveness of natural draft cooling tower in summer season is 57.37 % and the same in monsoon season is 66.21%, where as In the induced draft cooling tower, effectiveness is more in the monsoon season by 52.23 %. Where in summer season its effectiveness is 49.37 %.

Keywords— Thermal power, Cooling tower, Natural Draft, Performance Analysis, Effectiveness, Efficiency

I. INTRODUCTION

Cooling towers are thermal power plant's essential parts. It cools the hot water and releases heat in the environment. Through combining the transfer of mass and heat, the water is colled down with the use of this cooling tower. Film type fill, splash bar or spray nozzle is used for distributing the water which needs to be cooled. A Water portion absorbs the heat to change from a liquid to vapour at persistent pressures. At atmospheric pressures, this vaporization's heat is transmitted from the water remaining in the liquid state into the air streams. In the thermal power plant out coming steam from the turbine section condensed in the condenser with the surface contact of water, the condenser water take heat of the steam and temperature rise itself. These water continuously recirculation in the condenser tube, so that hot water goes to cooling tower for cooling and again recirculating in the condenser tube. During the recirculation of cooling water some amount of water will be lost, the losses will be fulfilled by the adding of makeup water.

A. Function of cooling tower

Cooling towers are devices used for transferring the heat. It facilitates the direct contact of water and air for heat transferring process. Within it, hot water sprays from the nozzle on to the large surface area called 'fill'. Fill is made up of PVC (Poly Vinyl Chloride); it is more durable and efficient for the temperature distribution. Fill area is a heat transfer zone and direct contacting zone of cold air and hot water. The heat transfer rate depends on the contact time of water & air in the fill area. A cooling tower consist drift eliminators, fill area, nozzle, fan as design demand procedure. The hot water comes from the condenser; by the help of pump it sprays on the large surface area of fill.

Here, the cold air will be taken from atmosphere and it will be allowed to contact with the fill area for heat transfer. Cold air takes heat from hot water and gets heated. Then the hot air transfers its heat to the environment. Hot air may carry some liquid particles along, which will get separated by through the drift eliminator.

B. Losses in cooling tower

1) Evaporation loss

Losses of water due to evaporation process. When hot water and cold air transferring heat with each other some amount of water evaporated. These losses are calculated as follow:

E = (0.00085) x (R) x (1.8) x (C)

E = Evaporation Loss (m3/hr) R= Range

C = Circulating Cooling Water (m3/hr)

(Reference: Perry's Chemical Engineers Hand Book)

2) Blow down

In the cooling tower water is evaporated dissolve solid particles are increases and cycle of concentration increases. To maintain the cycle of concentration blow down of water done and make up water mixed. Blow down is the function of cycle of concentration.

The calculation of the blow down is expressed below:

B = E / (COC-1)

B = Blow Down (m^3/hr)

E = Evaporation Loss (m^3/hr)

COC = Cycle of Concentration. Varies from 3.0 to 7.0 depending upon Manufactures Guidelines

3) Windage loss or Drift loss

The en-trained small droplets are gathered with the help of the air stream which is flowing in the upward direction inside the mist eliminators. Further, these droplets get accumulated for forming large size droplets which will at the end return towards the fills. Generally, in droplets forms, a very small amount of water is carried with the air. However, because of these droplets, water loss takes place. This loss is either termed as wind age loss or drift loss.

If it is not available it may be assumed as :

For Natural Draft Cooling Tower D = {(0.3 to 1.0) * C }/100

For Induced Draft Cooling Tower D = {(0.1 to 0.3) * C} /100

For Cooling Tower with Drift Eliminator D = {(0.01) * C} /100

(Where C = Cycle of concentration)

II. Literature Review

Ajeet kumar et al in "analysis of performance of natural draft cooling tower at optimized injection height" the effectiveness of cooling tower generally depend on the distribution, initial water droplet diameters, humidity with the temperatures of the ambient air, flow rate of the water, height of the tower's inlet, depth of the fill and operating parameters in the rain zone. Author designed a natural cooling tower in modelling software and analyses in CFD technique above parameters taking constant and Different injection height has been taken for optimizing the height of the injection and analysing its effect over the natural draft cooling tower's performance. [1]

Pushkar R. Chitale,, et al made a novel design for the cooling tower's counter flow. This is made on the basis of the parameters of the input process with keeping various kinds of probable losses in consideration. After that, the researcher modelled the presented design which the help of the software known as Solidworks 2012. The performance and efficiency of the model is observed with the help of the CFD software. The observance of the variance in the angle of the inlet of the air is made with the cooling tower efficiency with the help of the ANSYS. The researcher then concluded that when the angle of the inlet of the air increases, there will be an increase in the temperature of the outlet water. There the efficiency of cooling will get reduced. [2]

Vishnu s kumar et al had perform analysis and optimized on cooling tower with water mass' different rate of flow inlet water temperature, air influences on the counter flow induced draft cooling tower. Design is created in SOLIDWORKS and analyses in CFD technique and it found that enhancement in the cooling tower performance can be made by increasing the air's mass flow rate. All the parameters (like characteristic ratio of the tower, efficiency, range of water cooling) established for calculating the performances have hiked. A hike of 20% can be made in the cooling tower's efficiency through L/G ratio optimization. The effect of water mass flow rate also seen that through optimization of the mass flow rate of both air and water the efficiency can be hiked. 3]

Umakanta et al study on IDCT performances and analysis in captive power plant, Taken consideration flow rate of water, fill area material, atmospheric condition and analytically calculate losses, range, approach, heat losses. He elaborated types of cooling tower, needs, and functions. They concluded that an efficient prediction by the model is made when a stack of cooling tower shaped rectangular is considered. This prediction is related to the temperature of water and air outlet, perquisites of fan control, stream rates of water mass as well as gulf air and requirements of water. [4]

Rahul et al Effectiveness of cooling tower mostly depends on the WBT, DBT, humidity of atmosphere. He works on the mechanical draft cooling tower (Forced draft cooling tower) and also computed material balanced and packed height of column. He conclude that efficiency of the cooling tower tends to 65% and observe that leakage of water and blow down of water reasons for the lower efficient. [5]

Yagnesh S. Anchan et al works on the different literature survey and determine the new type of cooling tower which is more durable, less noisy, less water polluted. He observed that the characteristics along with the various kinds of generation of losses and designs of the cooling towers are in close relations with each other.Two very significant parameters for assessing the cooling tower's performances are efficiency and evaporation loss. Its performances rise when the rate of flow of the air rises and the characteristics reduces. It also depends over the rise of the ratio of the water to air. In comparison to the "Horizontal Orientation Wire-Mesh", a better performance is attained with using "Vertical Orientation Wire-Mesh Packing". [6]

Pooja Rai et al works on the cooling tower, it's main focused on the different area like as Fill Area Performance, Heat and Mass Transfer (hmt) Analysis, Evaporation Loss, Scaling and Fouling Phenomenon in CT, Climate Condition performance. She conclude that Scaling and fouling deposited in condenser tube and fill area can be prevented by using Chemical dosing, CIO2 generator, side stream filter.[7]

Ajit Prasad Dash et al works on mechanical draft cooling tower and calculates thermal efficiency. He taken a standard data and specification and according to these data using psychometric chart calculate effectiveness. The author made an analysis over the distributions of water through the plane area and made an adjustment of the water quantity for suiting the conditions of the air flow. This remains uninfluenced from the "natural draft cooling towers". When the water was distributed optimally, a static temperature for water outlet was attained. This decreased the exergy loss and the generation of the entropy from the cooling towers.[8]

Sunil J. Kulkarni et al conducted a study to increase the power saving and effectiveness of the cooling towers for making it better on the basis of efficiency and economy. He finds out the losses in cooling tower which is main crucial role for efficiency. He observed that a hike in the efficiency can be attained if the tower is provided with appropriated distribution of water. One of the most important issues is the degradation of the materials used for filling. When efficient strategies for shut down are applied, it will reduce the manpower. One more observation was made according to which temperature of water as well as air inlet, rate of flow of water at inlet and performances increase with packing's vertical orientation. With the help of this study, a conclusion can be made that appropriate distribution of water, strategies related to the shut down and packing are significant for optimizing the cooling tower. [9]

Jasem H. ALsuwaidi et al researched on natural draft cooling tower by two different method. First Merkel and then the approach for analysing "e-number-of-transfer-units" (e-NTU) is used over various ambient and operating conditions. The author first made an observation and then made a prediction according to which the rates of evaporation of water is always comparatively higher in accordance of the approach of e-NTU in comparison to the approach of Merkel. [10]

Priyank V.Dave et al performed analysis on NDCT using CFD by varying throat height of cooling tower. He taken some different height and various thermal operating parameters consider constant and the author concluded that when the range of the cooling hikes and there is a reduction in the approaches, these 2 parameters comes in direct relation with the effectiveness of cooling as cooling range increases and approach decreases this two parameters are directly related with cooling efficiencypresent at the throat height at specific effectiveness of cooling which is higher by 10-20% in comparison the real throat heights.This validated the fact that enhancement in the parameters for operation of the cooling towers for evaluating the performances. [11]

Shashank Tiwari et al analysis of counter flow induced draft cooling tower byTaguchi Method. It is a logetharim method analysis. The outlet water temperature optimized by the different method i.e. Prediction by Taguchi method and by MATLAB regression modelling and relate with actual experiment values.[12]

Syed Amjad et al had performed an analysis to increase the cooling tower with using aluminium in fill area instead of plastic wood and PVC. They conclude that being an elemental of aluminium solids are free from corrosions and in addition they are highly capable of carrying it i.e. they are good conductors of heat. Aluminium's specific heat is of 900J/kg°C. This permits the air for removing the heat of the water when brought in touch with plates made up of aluminium. The author concluded one fact which states that the performance of the cooling tower becomes more efficient at the time of winter in comparison to the summer because of the drop in the level of the humidity. This increases the performance of the cooling tower. [13]

Krishna et al study a case the comparison of some calculations regarding the cooling tower. He observed that several things to improve efficiency of cooling tower. The author also optimized the angles of the fan blade of the cooling towers based upon the load or/and season.In addition, the author replaced the splash bars with the cellular film fills capable of self-extinguishing. Balanced flows are provided for the hot water basin of the cooling towers. Occasionally, cleaned plugged cooling tower distribution nozzles. Replaced slat type drift eliminators with low pressure drop, self-extinguishing, PVCcellular unit. Monitor approach, effectiveness and cooling capacity for continuous optimisation efforts, as per seasonal variations as well as load side variations.[5]

Pushpa B. S et al studied a case of thermal power plant and observed the rate of heat loss is affected by the atmospheric parameters such as air temperature, water temperature, relative humidity and rate of heat loss. The supply of fresh air, the size of droplets and the temperature of warm water will be governing the efficiency of the natural draft cooling tower.[14]

Randhire Mayur research for improvement of cooling tower efficiency by several points and determine that, The result is lower outlet water temperature from the cooling tower and, thus, from the condenser, which results in greater efficiency of the power plant.[15]

T.Jagadeesh et al research on the efficiency evaluation of the cooling tower at different season, as summer season and winter season. He taking all the thermal parameter regarding cooling tower that is WBT, DBT, Relative humidity, COC and soon. Author observed that in the winter season efficiency of cooling tower is more comparatively summer season. [16]

B Bhavani Sai et al designed cooling tower and calculate its losses, effectiveness, heat losses and many parameters analytically. In this paper presents detailed methodology of a Induced draft cooling tower of counter flow type in which its efficiency, effectiveness, characteristics are calculated. The technical data has been taken from a mechanical draft cooling tower.[17]

III. METHODOLOGY

Markel theory, Taguchi Method, NTU method all are numerical methods. These techniques are very lengthy and massive, but it shows very accurate results. These methods assist to calculate range, approach, and effectiveness of cooling towers. Also with the help of these methods one can find and analyse different types of losses in the cooling tower, how much air is required for the given hot water volume, heat energy losses by water, energy received by cold atmospheric air and the electric power consumption by the pump and motor set. Again after attaining these values by analytical methods in the given work comparison of performance of cooling towers have been done for the different season conditions for 250MW and 600MW. Also analysis of electric power consumptions in different seasons has been attempted in this work for both 250MW & 600MW units. The below mentioned relations have been used in this work along with the reference of steam table and psychometric chart.

- Range = (Hot water temp – Cold water temp)
- Approach = (Cold water temp - Wet bulb temp)
- Effectiveness = (Range) / (Range + Approach)
- Drift losses are generally taken as 0.002% to 0.005%.
  Drift losses = (0.005%) × (Mass flow rate of water)
- Evaporation losses(E) = (0.00085) x (Range) x (1.8) x (mass flow rate of water)
- Blow down losses = (Evaporation Losses) / (COC-1)
- Heat loss by water
  $HL = Mw_1 \times Cp_w \times (T_1 – T_2)$
- Volume of air required (v)
  $V = (HL \times Vs_1) / ((Ha_2 - Ha_1) - (W_2 – W_1) \times Cp_w \times T_2)$
- Heat gain by air (HG)
  $HG = V \times ((Ha_2 - Ha_1) - (W_2 - W_1) \times Cpw \times T_2) / Vs_1$
- Mass of air required (Mair)
  Mair = volume of air required/specific volume of air at inlet temperature
  $Mair = V / Vs_1$
- Liquid gas ratio (L/G)
  $L (T_1 - T_2) = G (h_2 - h_1)$
- Power = (voltage) x (current) x (time) x (power factor) x 1.73 (For 3- phase motor)

A. Parameters of natural draft cooling tower

Specifications of Natural Draft Counter Flow Cooling Tower

TABLE 1
Construction details of NDCT

Tower height	155 m
Air inlet height	9.05 m
Fill depth	1.5 m
Tower basin diameter	111 m

Tower top diameter	69.17 m

TABLE 2
Measuring performance parameter in different season of NDCT

Parameters	Summer	Monsoon
Dry bulb temperature	38 ^{O}C	32 ^{0}C
Wet bulb temperature	24 ^{O}C	26.53 ^{0}C
Hot water temperature(T1)	38.70 ^{O}C	40 ^{0}C
Cold water temperature(T2)	30.44 ^{O}C	31 ^{0}C
Relative humidity	30.4	(%)
Mass flow rate of water in cooling tower	80700 m^3/hr	80200 m^3/hr

TABLE 3
Data from psychometric chart and steam table

	Summer	Monsoon
Enthalpy of air at inlet temperature(Ha1)	70.71 kj/kg	82.23 kj/kg
Enthalpy of air at in let temperature(Ha2)	148.84 kj/kg	108.88 kj/kg
Specific humidity of air at inlet temperature(W1)	0.01250 kg/kg	0.0191 kg/kg
Specific humidity of air at outlet temperature(W2)	0.04828 kg/kg	0.02911 kg/kg
Specific volume of air at inlet temperature(VS1)	0.897 m^3/kg	0.891 m^3/kg
Specific volume of air at outlet temperature(VS2)	0.921 m^3/kg	0.91 m^3/kg
Enthalpy of water at inlet temperature(Hw1)	162.04 kj/kg	167.5 kj/kg
Enthalpy of water at inlet temperature(Hw1)	127.8 kj/kg	129.8 kj/kg

B. Parameters of Induced draft cooling tower

Specifications of Induced Draft Counter Flow Cooling Tower

TABLE 4
Construction details of IDCT

Tower type	Induced draft counter flow
No. Of cells / tower	14 (13 working + 1 standby)
Rate of flow per unit	40000 m3 (13 operating cells)
Design Cooling range	9 ^{0}C
Total fill volume	4995.09 m
Cell length/ width	12.80 m / 18.29 m
Tower length / width	179.20 m /18.29 m
Tower height (basin to fan)	10.6 m
Air inlet height	3.155 m
Hot water inlet height	5.4 m from basin

TABLE 5

Measuring data performance parameter of IDCT

Parameters	Summer	Monsoon
Dry bulb temperature	39 ^{O}C	32 ^{O}C
Wet bulb temperature	24.2 ^{O}C	26.79 ^{O}C
Hot water temperature(T_1)	42.99 ^{O}C	41.56 ^{O}C
Cold water temperature(T_2)	34.14 ^{O}C	33.76 ^{O}C
Relative humidity	28.63 (%)	66.5 (%)
Mass flow rate of water in cooling tower	30250 m^3/hr	30300 m^3/hr

TABLE 6

Data from psychometric chart and steam table

	Summer	Monsoon
Enthalpy of air at inlet temperature(Ha1)	71.43 kj/kg	83.42 kj/kg
Enthalpy of air at in let temperature(Ha2)	151.43 kj/kg	108.88 kj/kg
Specific humidity of air at inlet temperature(W1)	0.01254 kg/kg	0.01964 kg/kg
Specific humidity of air at outlet temperature(W2)	0.04182 kg/kg	0.02911 kg/kg
Specific volume of air at inlet temperature(VS1)	0.902 m^3/kg	0.894 m^3/kg
Specific volume of air at outlet temperature(VS2)	0.935 m^3/kg	0.924 m^3/kg
Enthalpy of water at inlet temperature(Hw1)	180 kj/kg	173.4 kj/kg
Enthalpy of water at inlet temperature(Hw1)	142.5 kj/kg	141.3 kj/kg

IV. Results

In the monsoon season cooling tower is more efficient as compared to summer season. The effectiveness of natural draft cooling tower in summer season is 57.37 % and the same in monsoon season is 66.21%. The humidity of air is more in monsoon season because of rain, and in this season WBT (Wet Bulb Temperature) will approach to DBT (Dry Bulb Temperature).in these conditions humidity goes high, near about 80 to 85%. Humidity is the vital factor for the cooling tower, also, it depends upon atmospheric pressure and temperature. Range is maximum in the monsoon as compared to the summer season. In the monsoon season range will appear to nearby 9°c and the same in summer season will appear as 8°c. Wet bulb temperature approaches to dry bulb temperature in monsoon season, so that the approach is minimum and in summer season approach is more as compared to the monsoon.

TABLE 7

NDCT results

Season	Summer	Monsoon
Range (^{0}C)	8.26	9
Approach (^{0}C)	6.44	4.47
Effectiveness (%)	57.35 %	66.21 %
LOSSES		

Drift losses	4.035 m^3/hr	4.01 m^3/hr
Evaporation loss	1022.175 m^3/hr	1104.35 m^3/hr
Blow down loss	204.75 m^3/hr	220.87 m^3/hr
Heat loss by water	2790312.253 MJ/hr	3021454.8 MJ/hr
Volume of air required	34020797.7 m^3/hr	106197879 m^3/hr
Mass of air required	37927309.9 KG/hr	119189539 kg/hr
L/G ratio	2.26/1	.68/1
ELECTRIC POWER		
CW motor	5480.64 KW/day	CW motor
ACW motor	3992.040 KW/day	ACW motor

In the induced draft cooling tower, following result have been observed which indicate that the effectiveness of induced draft cooling tower is more in the monsoon season by 52.23 %. Where in summer season its effectiveness is 49.37 %. Relative humidity in monsoon highly fluctuates between 60 to 85% due to rain, but in summer season relative humidity varies between 22 to 50%. Effectiveness of cooling towers is mostly depending upon the relative humidity of the surrounding air and humidity, which is directly proportional to the wet bulb temperature. When the wet bulb temperature approaches to dry bulb temperature, then the effectiveness goes to maximum, the result would remain unaffected because in the rainy day's wet bulb temperature tends to or approach to dry bulb temperature. And since the humidity will also be high so that the effectiveness of the induced draft cooling tower is high compare to the other days. As approach increases the effectiveness decreases. So that in summer season approach is 9.94 that is the cause of less effectiveness.

TABLE 8

IDCT results

Season	**Summer**	**Monson**
Range (°C)	8.85	7.8
Approach (^{0}C)	9.94	6.97
Effectiveness (%)	47.39 %	52.23 %
Drift loss	1.5125 m^3/hr	1.515 m^3/hr
Evaporation loss	408.99 m^3/hr	361.66 m^3/hr
Blow down loss	81.79 m^3/hr	72.32 m^3/hr
Heat loss by water	1,12,064,4.525 MJ/hr	9,893,19.24 MJ/hr
Volume of air required	13333615.11 m^3/hr	28828272.5 m^3/hr
Mass of air required	14782278.39 kg/hr	32246393.2 kg/hr
L/G ratio	2.16/1	.79/1
CW motor	90781.32 KW/day	
ACW motor	15055.318 KW/day	Total power consumption 169231.8 KW/day
CT motor	49435.372 KW/day	
IDCT fan motor	13959.69	KW/day

V. Conclusion

In this dissertation after analysis of natural and induced draft cooling tower in different seasons, we conclude the below mentioned points:

- The effectiveness of cooling tower is more in monsoon season or rainy day over the summer season. As we seen that above result 8.86% efficiency increase in rainy days in NDCT where as 4.48% efficiency increase in IDCT.
- Effectiveness of cooling tower depends upon the ambient temperature and pressure of air along with the moist present in air.
- In the rainy season humidity is relatively high. It appears between 80 to 85 % so that the wet bulb temperature approaches to the dry bulb temperature and hence approach tends to becomes unity. This phenomenon signifies the effectiveness, if the approach is minimum or lesser then the effectiveness will be more or maximum.
- Initial cost of natural cooling tower is more but running cost is very less because of possessing less mechanical equipment in it. Whereas initial cost of induced draft cooling tower is quite low as compared to natural draft cooling tower, but operating cost is more as compared to induced draft cooling tower. Reason behind that would be possession of more mechanical equipment and electricity driven motors in induced draft cooling towers than natural draft cooling towers.
- In natural draft cooling tower only CW and ACW pump are used and makeup water will be supplied from CLF by gravitational pressure contributing to the reduced utilization of electricity.
- In induced draft cooling tower there are many pump used such as, CW pump, ACW pump, CT pump, induced fan, etc. So

that electric power consumption is more as compared to the natural draft cooling tower.

- At full load condition the induced draft cooling tower consumes 159.75 MW/day more power.
- Mass of air required for cooling in the rainy days more than summer seasons. As we seen in the result L/G ratio in summer is 2.16 where as in rainy days L/G ratio is .8.
- The effectiveness of natural draft cooling tower is good at full load, but at part load it is not efficient.
- Losses in rainy season (1.43%) are quite less compare to summer season (1.61%), Due to climate effect water loss are maximum in summer season. So that make up water is more required in summer season.
- In the induced draft cooling tower effectiveness is very good for all varying load (full load or part load).
- Natural draft cooling tower needs very large mass flow rate of water so it is generally used for super thermal power plant; its usage is not recommended for captive power plants.
- Induced draft cooling tower works on all type of mass flow rate of water. Therefore, the range of its applicability will be more and hence it can be recommended for use in captive power plant and also can be comfortably used in the super thermal power plant.

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