Overall Performance Analysis of 210 MW Cooling Tower in Thermal Power Plant.

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Abstract:

In this project work, the factors affecting the performance of cooling tower have been studied on Induced draft cooling tower of 210 MW thermal power plant. The parameters which affect the cooling tower performance are evaporation loss, cooling capacity, inlet air temperature, heat loss and shape of the cooling tower (Hyperbolic or Rectangle). Power required to run the cooling tower fan is also a factor. Reduction in power consumption by implementing variable frequency drive to control fan speed and minimizing heat absorption at concrete walls by silicone coating are the two main parameter's considered for the performance analysis of cooling tower.

Keyword(s): Cooling Tower, Induced Draft, Variable Frequency Drive and Silicone Coating.

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1. INTRODUCTION:

In Thermal Power Plant cooling tower system is most important and the tower water absorbs the latent heat of steam in the condenser and converts the steam in to hot water. Temperature of the cooling water increases because of heat transfer in condenser. The cooling water takes the latent heat of steam, by which the temp of water increases.

It is necessary to cool the hot water coming from condenser before using it again. In cooling towers, the warm water is discharged from the condenser and fed the cooled water back to the condenser. The rate of evaporation of water in the cooling tower and the subsequent reduction in water temperature depend upon the following parameters i) The explosive time, ii) Amount of water surface exposed iii) Relative humidity of air, iv) Velocity of air and v) Accessibility of air to various parts of cooling tower.

In induced draft cooling tower, the draft fan is installed at the top of tower and air is drawn through it. The hot water is sprayed through the nozzle to pass it over the air and the water is cooled. The air is moving in the upward direction to cool the water.

The cooling towers, where air and hot water mix at 180^0 with air moving vertically through the packing is called counter-flow cooling tower. In cross-flow towers, air and water mix at 90^0 with air moving horizontally through the packing. The counter-flow tower is inherently more effective as all the air eventually approaches saturation at the hottest water temperature.

Draft fan is the one of the important component in the cooling tower to provide the required air drag to cool the water. This fan is also called as induced draft fan which is powered by electric motor through helicopter gear box which runs in a speed which will not vary rapidly.

2. EXACT PROBLEM

Cooling tower fan rotates with constant speed during the entire day. This consume more power for operation, both in peak load and average load. It reduces efficiency of cooling tower. Environmental temperature affects cooling tower performance. Concrete wall of cooling tower transfer more environmental heat into tower. This reduces efficiency of cooling tower.

3. METHODOLOGY

3.1 Variable Frequency Drive

A variable-frequency drive (VFD; also termed as the adjustable-frequency drive, “Variable-voltage/Variable-Frequency drive (VVVF)”, Variable Speed Drive (VSD), micro drive or inverter drive which is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor’s speed and torque by varying motor input frequency and voltage.

VFDs are used in applications ranging from small appliances to large compressors. About 25% of the world's electrical energy is consumed by electric motors in industrial applications, which can be more efficient when using VFDs in centrifugal load service; however, VFDs global market penetration for all applications is relatively small.

Over the last four decades, power electronics technology has reduced VFDs cost and size which has improved performance through advances in semiconductor switching devices, drive topologies, simulation and control techniques, and control hardware and software.

Different VFDs made are low-voltage AC-AC, medium-voltage AC-AC and DC-AC topologies.

The synchronous speed of an induction motor is primarily a function of the number of poles and the frequency. A slip between actual and synchronous speed is generated by the applied load torque. This slip is usually small, typically 1-3% of synchronous speed. A way to achieve a variable speed is by varying the frequency. Such a device is called a frequency converter. Frequency converters are also called as variable speed drives.

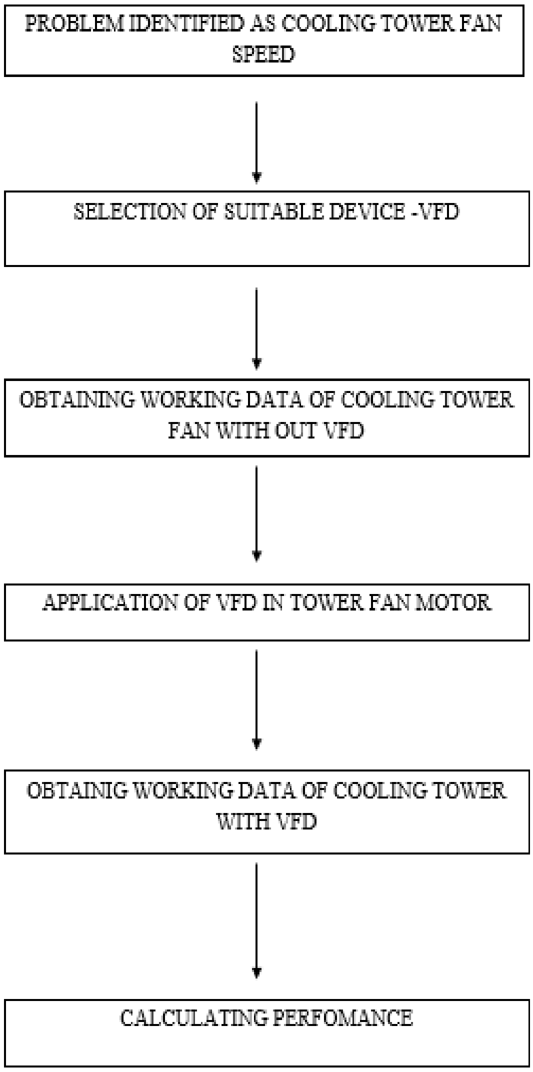

Fig.1 V FD (Flow Diagram)

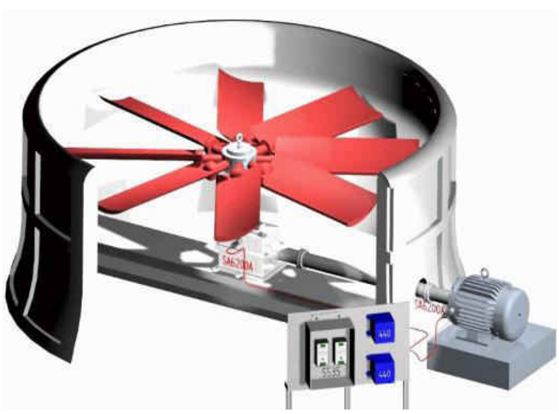

Fig.2 Induced Draft Fan Motor with VFD

3.2 Silicone Coating

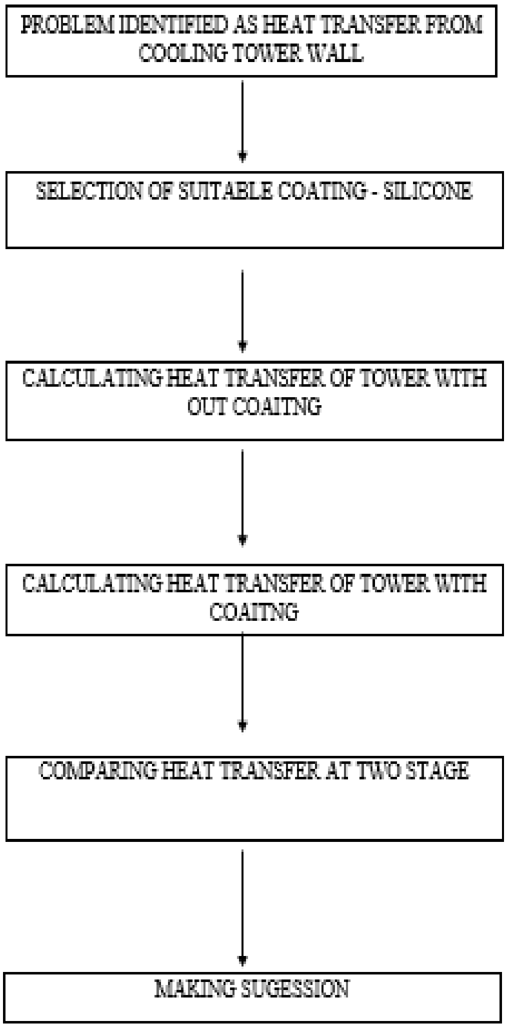

Fig.3 Silicone Coating (Flow Diagram)

Silicone is generally used as heat resistant material and they are used in many forms such as silicone wax, silicone resin, silicone paint, etc., because Silicone has high heat resistant property. Silicone is used in cooling tower wall in the form of silicone paint Silicones are widely used as thermal protectors, water sealants etc.

Silicone has immense heat resistive property. Silicone is coated on the tower wall by spray gun method or manual application method. The outer and inner temperature of tower before and after silicone coating can be considered for calculation.

4. CALCULATIONS

4.1 Statistical approach for V F D

Range:
Cooling tower range = hot water temperature- cold water temperature

Approach:
Cooling tower approach water outlet temperature - wet bulb

Effectiveness% = range/(range+approach)*100

L/G ratio = Water flow in kg/air flow in kg

Air mass flow/cell = flow*density of air

Make up water consumption = evaporation loss/(coc-1) coc = 1.45

Total heat transfer = k*s(hw-ha)

Where,

K = Heat transfer co-efficient.

Tower characteristics NTU (L/G)m

Cooling load $Q_1 = ma(ha_2-ha_1)$

Convective heat transfer ratio

$Q = mw*cpw\ (Tw_i–Tw_0)$

Humidity = pw*mw/(p-pw)ma

Where,
pw = pressure of water.

mw = mass of water.

Evaporation loss in (m3/hr) = 0.00085*1.8*circulation rate * $(T_1- T_2)$

Efficiency:
Efficiency = T1-T0/ Ti-Twb*100

Heat load (D) = L*range = 20794*9.5 = 197543m

Density ratio = actual air density/0.075

Where,

Twb = wet bulb temperature.

4.2Analytical approach for silicone coating

Heat flow:

$$Q = KA\,\frac{T_1 - T_2}{L} \quad \text{(OR)} \quad Q = \frac{\Delta T}{R}$$

Heat resistance

$$R = \frac{1}{A}\left[\frac{1}{h} + \frac{L_1}{k}\right]$$

For two layers, Heat flow

$$Q = \frac{\Delta T}{R}$$

Heat resistance

$$R = \frac{1}{A}\left[\frac{1}{h_a} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{1}{h_b}\right]$$

$$Q\text{overall} = \frac{\Delta T}{R_{overall}}$$

Roverall = R1 + R2 + R3 + R4 + Rn

Where,

h → Heat transfer co – efficient

k → Thermal conductivity

A → Area

A_{square} = (b x h)

$A_{triangle}$ = ½ x b x h

A_{circle} = πr2

5. WORKING PRINCIPLE

In cooling tower, VFD is fixed with the induced draft fan motor. VFD is connected to the main control board at which motor power is supplied. Each VFD can control two motors. Six VFDs are used in the cooling tower which has eleven fan motors. The pulse fire rating and frequency rating are preloaded into VFD.

The fan blade spins at maximum speed during peak load and at required speed during constant load. VFD can vary the frequency from 10HZ to 60HZ. Once the fan is started the VFD controls its speed. Readings are observed from the cooling tower with VFD and without VFD. Calculations and results are obtained based on the readings tabulated.

5.1 Tabulation of Readings

COOLING TOWER (Unit – I)				
Readings taken with VFD on 26-02-2018 and on 27-02-2018				
Time/date	**26.2.18 10.0 am**	**26.2.18 3.00 pm**	**27.2.18 12.00 pm**	**27.2.10 4.30 pm**
Motor speed in rpm	**1500**	**1400**	**1350**	**1450**
Motor current (amps)	**70**	**62**	**56**	**60**
Voltage (volts)	**433**	**387**	**360**	**410**
Power (KW)	**47**	**40**	**33**	**44**
Frequency (HZ)	**50**	**46.7**	**43.4**	**48.3**
Air velocity m/s	**5.5**	**4.8**	**4.3**	**5**
Air flow : m^3/min	**340**	**332**	**295**	**336**
Hot water temp °C	**41**	**37.1**	**37.2**	**38**
Cold water temp °C (east)	**31.5**	**29**	**27**	**28**
Cold water temp °C (west)	**24**	**24.7**	**23.4**	**25**
Atmospheric temp °C	**33**	**32**	**31**	**33**
Relative humidity %	**40**	**35**	**32**	**33**
Wet bulb temp.	**26**	**22**	**21**	**19**
Atmospheric temp °C – C_w I/L temp.	**7.2**	**5.4**	**2.9**	**3.5**
Range (hot water-cold water)	**9.5**	**11**	**9.7**	**10**
Approach (cold water – wet bulb) East	**3.8**	**4.2**	**4.5**	**4.6**
Approach (cold water – wet bulb) West	**3.9**	**3**	**4.8**	**4.9**
Designed air flow : 1945950 m^3/hr.				
Designed air velocity : 6.88 m/sec				

*Table 1. Cooling Tower Readings **with VFD***

COOLING TOWER (Unit – II)				
Readings taken WITHOUT VFD on 26-02-2018 and on 27-02-2018				
Time/date	26.2.18 11.30 am	26.2.18 4.00 pm	27.2.18 10.30 am	27.2.18 3.30 pm
Motor speed in rpm	1490	1500	1480	1490
Motor current (amps)	70	68	70	69
Voltage (volts)	433	430	433	428
Power (KW)	47	46	47	48
Frequency (HZ)	60	54	48.4	50.3
Air velocity m/s	5.5	5.4	5.4	5.4
Air flow : m^3/min	380	390	375	382
Hot water temp °C	40.8	37.9	37.5	38.3
Cold water temp °C (East)	33	30	31	30
Cold water temp °C (West)	28	27	28	29
Atmospheric temp °C	33	32.6	31	32.7
Relative humidity %	45	42	41	36
Wet bulb temperature	26	23.1	22	21.7
Atmospheric temp °C – C_w I/L temp.	7.4	5.6	3	3.7
Range (hot water-cold water)	7.5	9	8.5	8
Approach (cold water – wet bulb) East	7	3.9	5	4.9
Approach (cold water – wet bulb) West	3.6	2.6	4.4	4.3
Designed air flow : 1945950 m^3/hr.				
Designed air velocity : 6.88 m/sec				

*Table 2. Tower Readings **without VFD***

6. RESULTS & DISCUSSION

6.1 Experimental Results (V F D)

The cooling tower can be operated at variable speeds and easily operated during the critical conditions. For optimized working method, the cold water temperature is expected to improve by 2 to 3 degree Celsius with less usage of power. Improvement in heat transfer rate is 12-18 kcal/kwh in condenser. Power savings about 638 kW per day is possible. Annual savings of rupees 1.6 – 2.3 million for 210 MW unit can be obtained.

6.2 Analytical Results (Silicone Coating)

Environmental heat flow of concrete is 87.24 mw/sq.m. By calculating with silicone coating, environmental heat flow of cooling tower wall is reduced to 82.8 mw/sq.m. The implementation of silicone coating can successfully resist the heat flow.

One dimensional heat flow equation is used to derive the results of silicone coating. It shows the approximate heat flow reduction as 4.44 mw/sq.m. Heat flow is by using silicone coating, hence it is suggested to coat the cooling tower wall with silicone to improve efficiency.

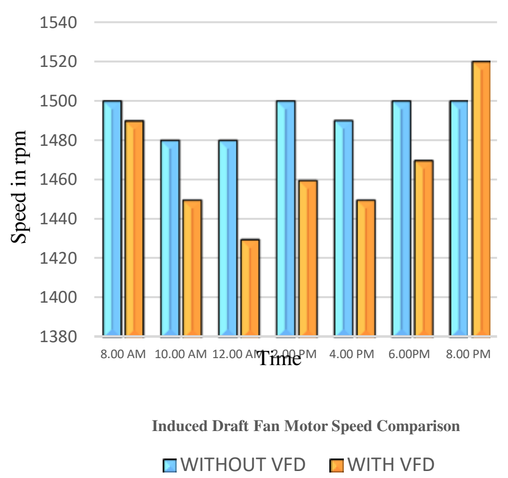

*Fig 3. Fan Speed **with & without VFD***

7. CONCLUSION:

The installation of variable frequency drive has increased the cooling tower performance level up to 63.33% efficiency, where the performance before installation was 52.70%. The fan can be operated at variable speeds during variable climatic conditions. The implementation of silicone coating on cooling tower to resist the external heat flow through walls may be done in future work.

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