IMPROVEMENT IN PERFORMANCE OF COOLING TOWER OF THERMAL POWER PLANT

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Abstract— The first law analysis of the coal fired thermal power station namely Gandhinagar Thermal Power Station (GTPS).In research paper, a detailed energy study is shown for 210MW, of coal fired thermal power plant at Gandhinagar Thermal Power Station (GTPS) to evaluate the plant and subsystem [feed water heaters (high pressure and low pressure)],etc. efficiencies. Research represent cooling tower effectiveness of thermal power and gives suggestion for improvement of cooling tower performance.

Keywords- Power generating plant, cooling tower, first law analysis, effectiveness and characteristic of cooling tower.

I. INTRODUCTION

In a coal based power plan coal is transported from coal mines to the power plant by railway in wagons or in a merry-go-round system. Coal is unloaded from the wagons to a moving underground conveyor belt. This coal from the mines is of no uniform size. So it is taken to the Crusher house and crushed to a size of 20mm. From the crusher house the coal is either stored in dead storage (generally 40 days coal supply) which serves as coal supply in case of coal supply bottle neck or to the live storage (8hours coal supply) in the raw coal bunker in the boiler house. Raw coal from the raw coal bunker is supplied to the Coal Mills by a Raw Coal Feeder. The Coal Mills or pulverizer pulverizes the coal to 200 mesh size. The powdered coal from the coal mills is carried to the boiler in coal pipes by high pressure hot air. The pulverized coal air mixture is burnt in the boiler in the combustion zone [10].

Generally in modern boilers tangential firing system is used i.e. the coal nozzles/guns form tangent to a circle. The temperature in fire wall is of the order of 1300deg.C. The boiler is a water tube boiler hanging from the top. Water is converted to steam in the boiler and steam is separated from water in the boiler Drum. The saturated steam from the boiler drum is taken to the Low Temperature Super heater, Platen Super heater and Final Super heater respectively for super heating. The super-heated steam from the final super heater is taken to the High Pressure Steam Turbine (HPT). In the HPT the steam pressure is utilized to rotate the turbine and the resultant is rotational energy. From the HPT the out coming steam is taken to the Reheater in the boiler to increase its temperature as the steam becomes wet at the HPT outlet. After reheating this steam is taken to the Intermediate Pressure Turbine (IPT) and then to the Low Pressure Turbine (LPT).The outlet of the LPT is sent to the condenser for condensing back to water by a cooling water system. This condensed water is collected in the hot well and is again sent to the boiler in a closed cycle. The rotational energy imparted to the turbine by high pressure steam is converted to electrical energy in generator [10].

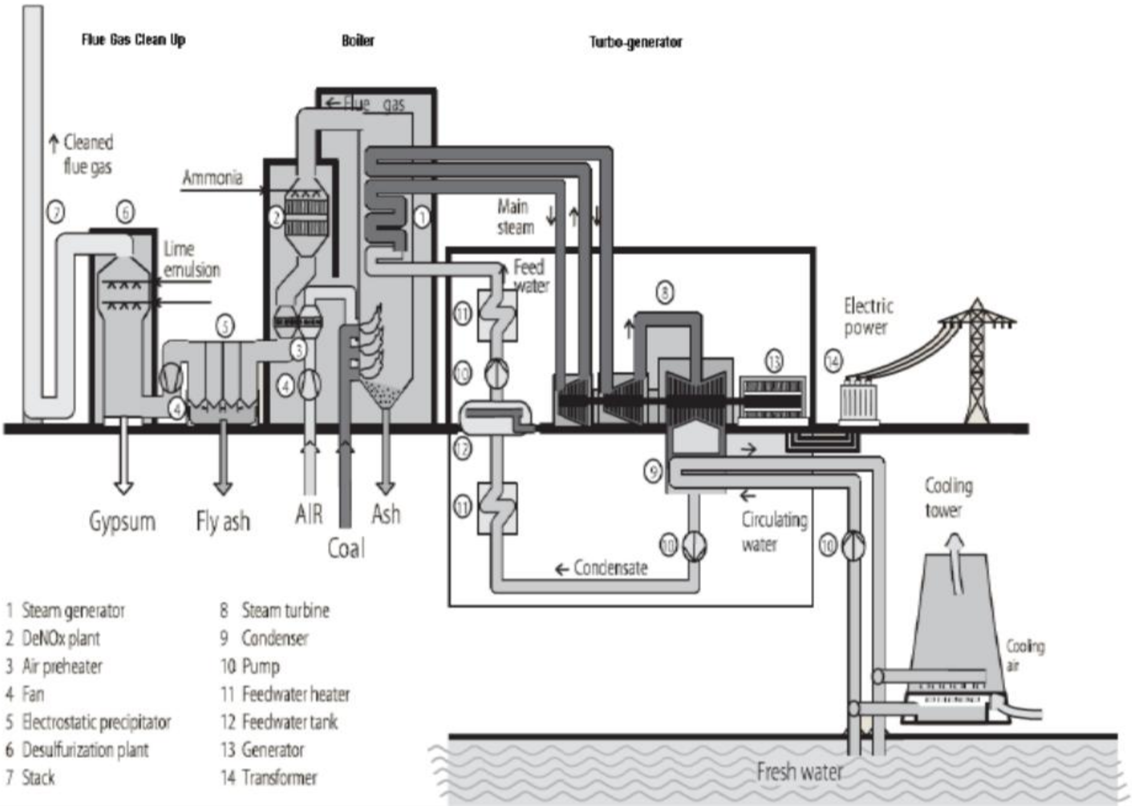

Figure 1. Diagram of a Typical Coal-fired Thermal Power Station

II. COOLING TOWER EFFECTIVENESS

Table 1 Observation Table for Cooling Tower

Sr. No.	Description	Value
1	Natural Draft Cooling Tower TYPE	Counter flow Film fill
2	Total Measured Cooling Water Flow	33,000 m^3/hr
3	Number of CT Cells on line with water flow	44
4	Inlet Cooling Water Temperature	41.3°C
5	Air Wet Bulb Temperature near Cell	27.2°C
6	Outlet Cooling Water Temperature near Cell	33°C

The important parameters, from the point of determining the performance of cooling towers, are:

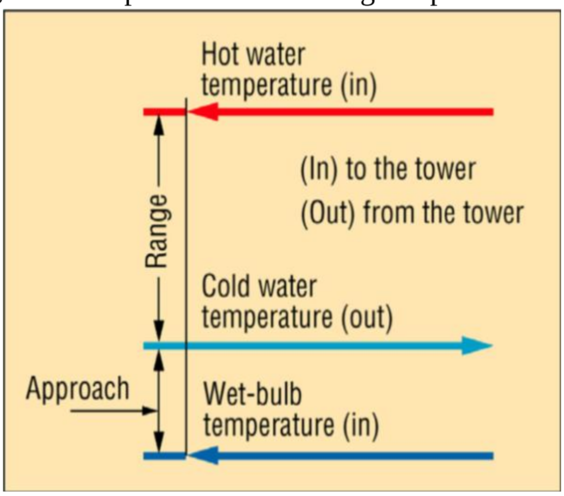

Figure 2 Cooling Tower: Range and Approach

ANALYSIS[3][4]

RANGE

The difference between the cooling tower water inlet and outlet temperature. CT water Flow/Cell, m^3/hr = 33000 / 44

CT water Flow/Cell, m^3/ hr =750 m^3/hr

CT Range= (CT Water outlet – CT Water inlet)

CT Range= (41.3–33)

Range =8.3°C

APPROACH

The difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.

CT Approach = (CT water inlet - Wet Bulb Temp.)

CT Approach = (33 – 27.2)

Approach = 5.8°C

COOLING TOWER EFFECTIVENESS

The ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is,

$\varepsilon = Range / (Range + Approach)$

ε = 8.3 / 8.3+5.8

ε = 0.5886

EVAPORATION LOSS

The water quantity evaporated for cooling duty and, theoretically, for every 10, 00,000 k Cal heat rejected, evaporation quantity works out to1.8m^3. An empirical relation used often is:

Evaporation Loss (m^3/ hr) =0.00085 x1.8 x circulation rate (m^3/ hr) x (T_1-T_2)

Where, T_1= Temp. of hot water outlet=41.7°C

T_2= Temp. of cold water inlet=33°C

Evaporation Loss (m^3/hr) =0.00085*1.8*750*(41.3-33)

Evaporation Loss (m^3/hr) =9.52425m^3/ hr

Evaporation Loss (%) = 9.52425/750 * 100

Evaporation Loss (%) =1.2699%

CYCLES OF CONCENTRATION (C.O.C)

The ratio of dissolved solids in circulating water to the dissolved solids in make up water. Here, we have taken,

C.O.C. = 2.7

LIQUID/GAS (L/G) RATIO

L/G Ratio of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments. Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air,

$L (T_1-T_2) = G (h_2-h_1)$

L/G = (2575.8 – 2561) / (41.3 - 33)

L/G = 1.7831

Where, L/G=liquid to gas mass flow ratio (kg/kg)
T_1 = hot water temperature (°C) =41.3°C
T_2 = cold water temperature (°C) =33°C
h_2 = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature
= 2575.8KJ/Kg
h_1 = enthalpy of air-water vapor mixture at inlet wet-bulb temperature
=2561KJ/Kg

BLOW DOWN LOSS

Blow down losses depend upon cycles of concentration and thee vaporation losses and is given by relation:
Blow Down = *Evaporation Loss* / (*C.O.C.* –1)
Blow Down = 5.6025 m^3/ hr

DRIFT LOSS

Drift losses in the Cooling Towers It is very difficult to ignore drift problem in cooling towers. Now-a-days most of the end user specification calls for **0.02% drift loss**. With technological development and processing of PVC, manufacturers have brought large change in the drift eliminator shapes and the possibility of making efficient designs of drift eliminators that enable end user to specify the drift loss requirement to also was 0.003–0.001%.

MAKE UP WATER REQUIREMENT

Make up water requirement/cell in m^3/ hr, = Evaporation Loss + Blow down Loss
= 9.5242+5.6025
Make up water requirement/cell in m^3/hr = 15.1267 m^3/ hr

III. RESULTS

Table 2 Cooling Tower: Performance Calculation Summary

Sr. No.	Description	Value
1	Range	8.3°C
2	Approach	5.8°C
3	CT Effectiveness, ε	0.5886
4	Evaporation Loss	9.52425 m^3/hr
5	L / G Ratio	1.7831
6	Blow Down Loss	5.6025 m^3/*hr*
7	Make up water requirement /cell	15.1267 m^3/*hr*

IV. EXPERIMENTAL INVESTIGATION AND RESULT

DESIGN SPECIFICATION OF COOLING TOWER

Following are the design specifications of existing of cooling tower.
CWT: 33 ºC,
Approach: 5.8 ºC,
Range: 8.3 ºC,
Flow: 33000 cum/hr,
WBT: 33 ºC,
HWT: 41.3 ºC,
RH: 40%

EXPERIMENTAL SETUP

The test is conducted for 4 hours with measurement of hot water temperature, cold water temperature, dry bulb temperature, wet bulb temperature and wind velocity taking readings every minute at the locations shown in Fig. 3 below:

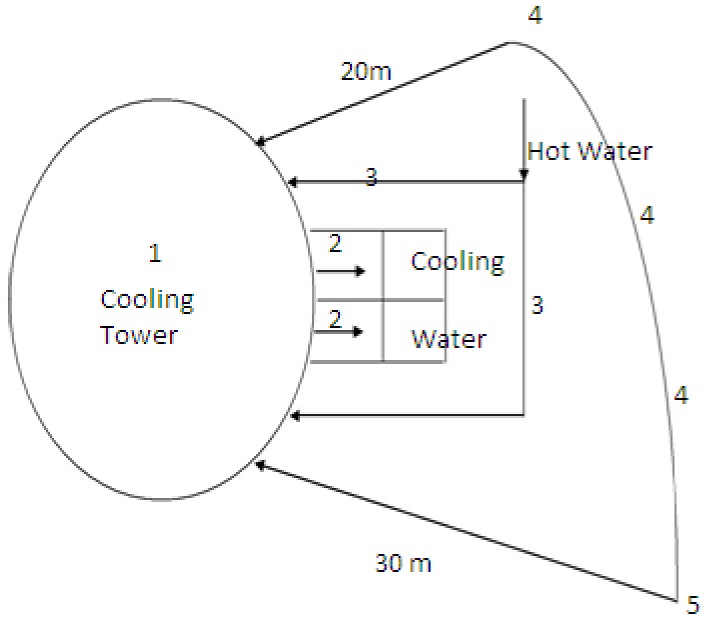

Figure 3 Location for Measurement of Parameters in CT

1. Hot Water Temperature measurement
2. Cold Water Temperature measurement
3. Water Flow Rate
4. DBT&WBT
5. Wind Velocity

The average values of each parameter for one hour duration s are obtained from these.

EXPERIMENTAL INSTRUMENTATION

All measurements for this test were carried out using calibrated instruments. Long Mercury-in-glass thermometers (0.1ºC graduations), Swirling Psychrometer with long mercury-in-glass thermometers (0.1ºC) are used for temperature measurements. Vane anemometer with digital display was employed for wind velocity measurements. Mano meters, for measurement of water flow velocity, indicated as head in the manometers. Ultrasonic flow meter was also used to measure the flow.

EXPERIMENT PROCEDURE

HOT WATER TEMPERATURE

Two locations Hot water duct inside the tower were chosen for HWT measurement, and the average of the readings for each one hour duration, is taken for each location. The average from the two locations is considered for calculations.

COLD WATER MEASUREMENT

Two locations were chosen for CWT measurements and from the average one hour duration for each location, the final average is obtained.

DBT/WBT

At properly chosen three locations in the vicinity of the tower, both DBT and WBT were noted, taking care to wet the wick around the mercury bulb of the Wet Bulb

Thermometer, and whirling the psychrometer every time a reading is taken, the average of the readings from three locations, for each hour is taken for evaluation purposes.

WIND VELOCITY

The vane type anemometer is oriented to face the wind flow direction, and kept above the head level, every time a reading is taken.

FLOW MEASUREMENT

Flow is measured by using ultrasonic flow meter. Readings obtained from ultrasonic flow meter are considered for further evaluation. The total flow into the tower is obtained as the sum of the two main flow risers and the two auxiliary flow risers. Using the Performance curves evaluation is done from the average values for stable one hour for HWT and CWT, Range R is obtained, and likewise RH from DBT and WBT average values. Temperature readings of hot water and cold water between time periods 12.00 to 13.00 hr are more consistent. Load was constant besides fairly good values of range, WBT which are closer to design values.

SUMMERY OF READINGS

Parameter	Average
HWT	41.44
CWT	32.15
Range	9.29
DBT	34.93
WBT	27.82
RH	58
Wind Velocity	15

V. Calculation

The calculations are performed to compare the present performance of CT (with optimal water distribution) with previous performance of CT (with uniform water distribution). The past record of CT available with company is as follows.

PREVIOUS PERFORMANCE (WITH UNIFORM WATER DISTRIBUTION)

Flow: 33000 cum/hr
WBT: 33 ºC
HWT: 41.3 ºC
RH: 60%
Wind velocity=15 km/h
CWT: 33 ºC
Range = HWT-CWT
= 8.3 ºC
Approach = CWT-DBT
=5.8ºC
Efficiency = Approach / (Range + Approach) = 58.86%

CURRENT PERFORMANCE (WITH OPTIMAL WATER DISTRIBUTION)

Flow: 32000 cum/hr

WBT: 27.8 ºC
HWT: 41.44 ºC
RH: 58%
Wind velocity=15 km/h
CWT=33.15 ºC
Range = HWT-CWT
= 9.29 °C
Approach = CWT-DBT
= 4.35 °C
Efficiency = Approach / (Range + Approach) = 68.10 %

Table 3 Comparison of actual and predicted performance of CT

Sr. No.	Parameter	Previous	Current
1	Range	8.3	9.29
2	Approach	5.8	4.35
3	Efficiency	58.86	68.10

GRAPHICAL REPRESENTATION OF READINGS

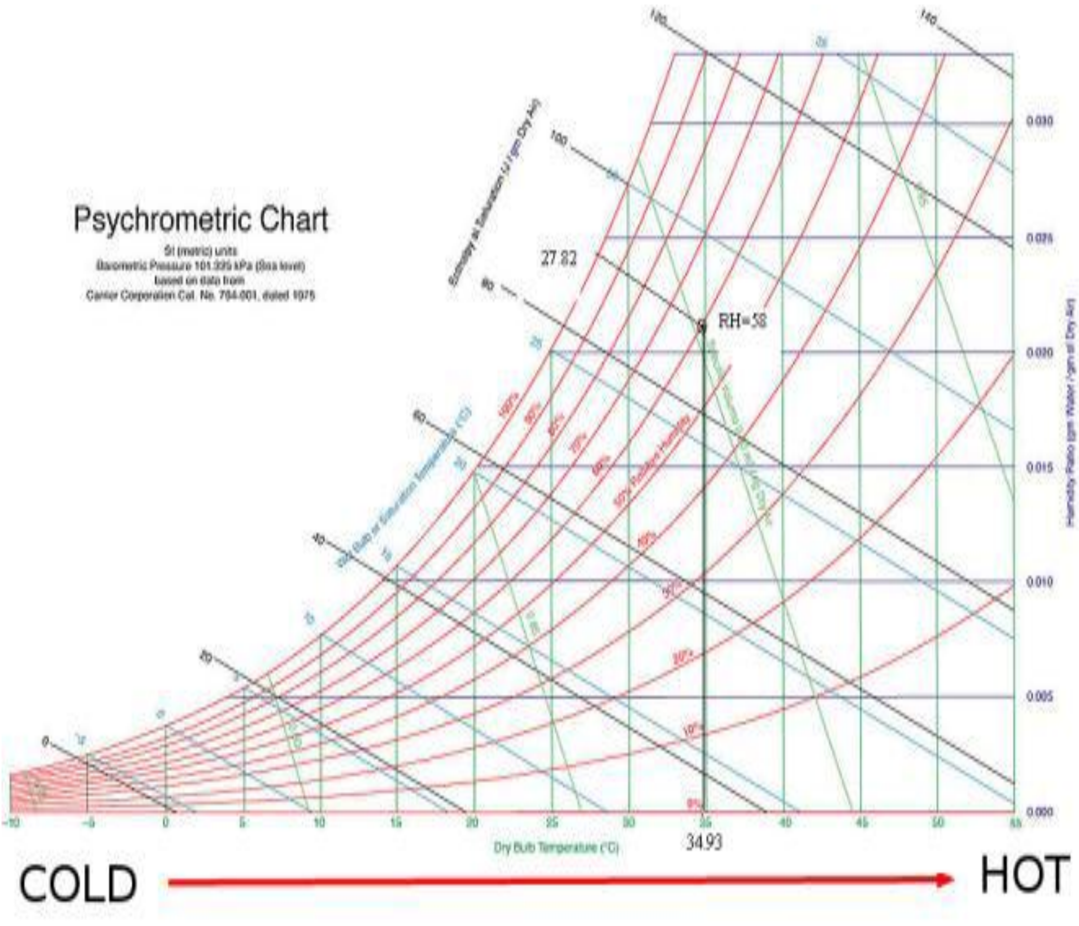

Figure 4 Psychrometric Chart

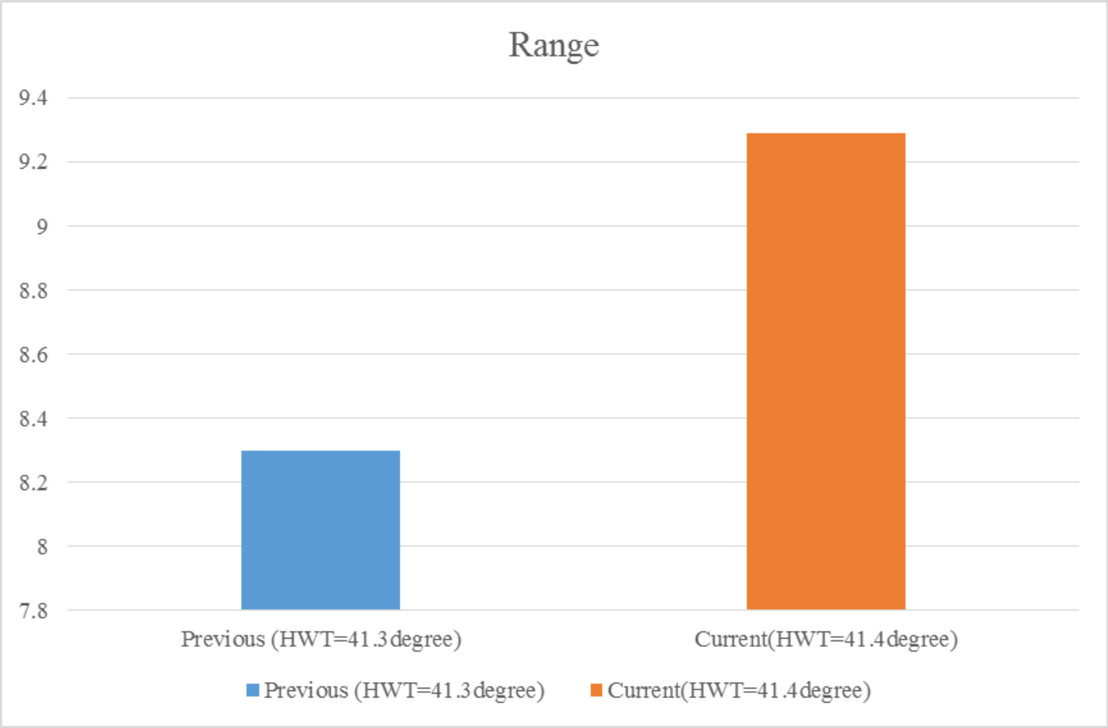

Figure 5 Range Vs. HWT

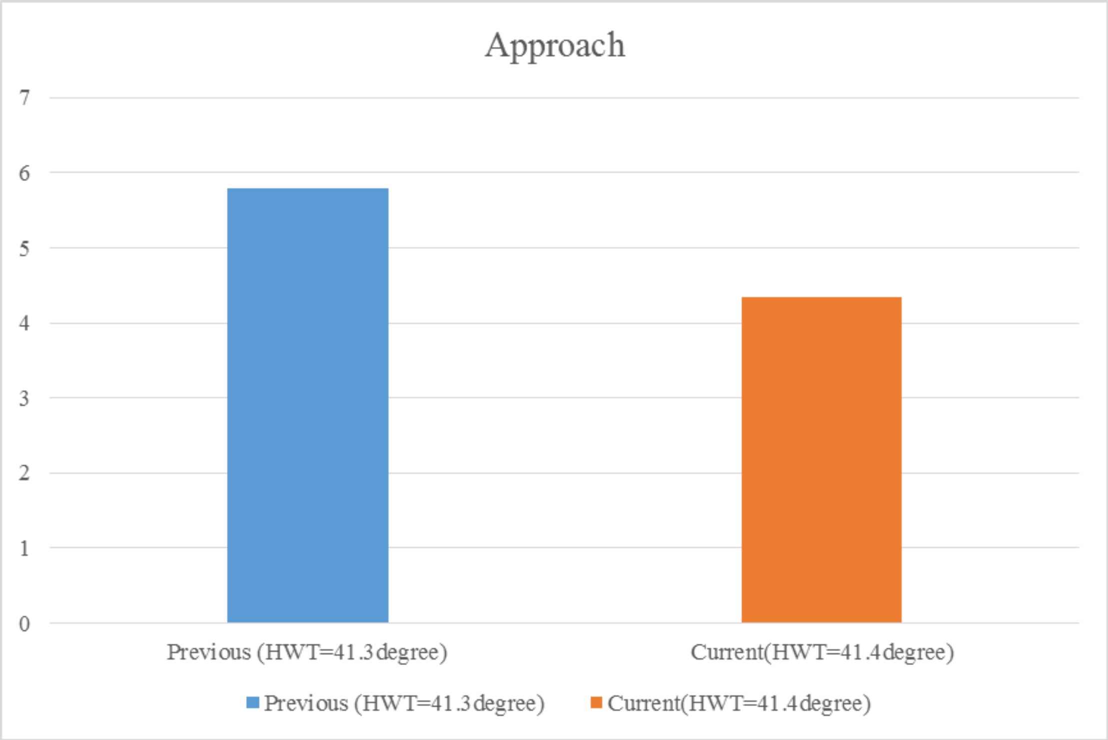

Figure 6 Approach Vs. HWT

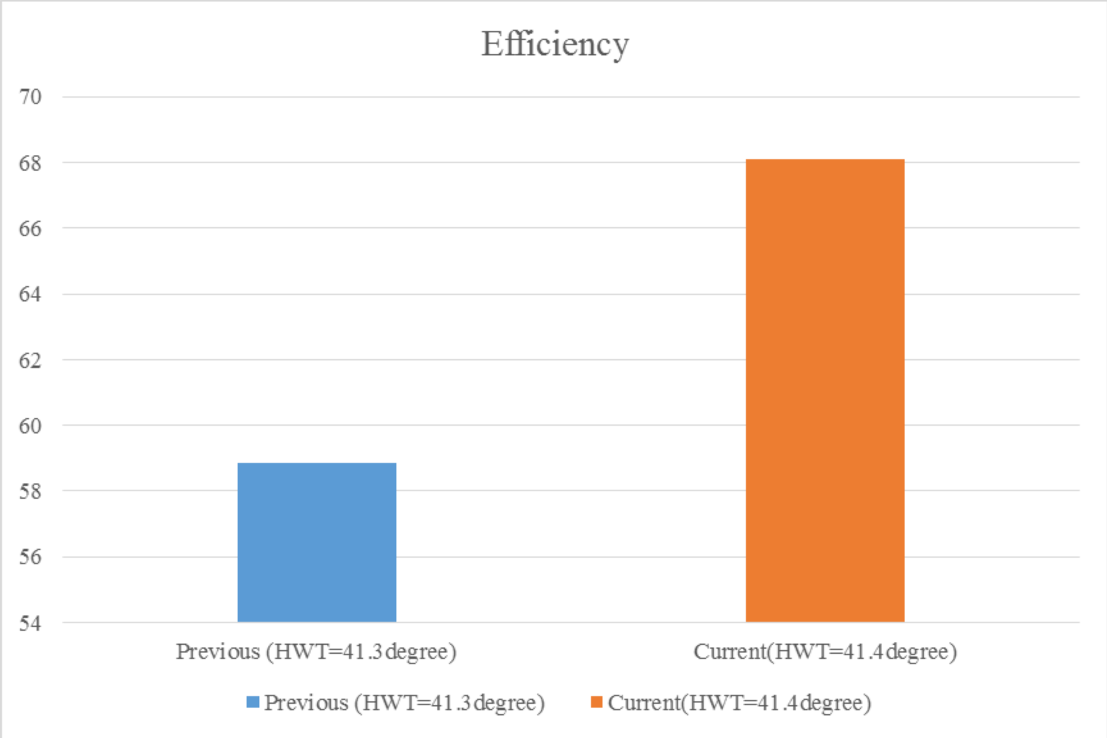

Figure 7 Efficiency Vs. HWT

VI. CONCLUSION

From the energy analysis made for the unit-4,210MW of the GTPS – the following conclusion are drawn:

• Coolingtowereffectivenessis0.5886andMakeupWaterrequirement/cellistobe15.1267 m^3/hr.

Measurements of the temperature and velocity fields in a cooling tower were performed for the given power plant parameters, cooling tower constructional characteristics and ambient air velocity conditions in the vicinity of the cooling tower. The last two parameters influence the homogeneity of the heat transfer, from which we can see the anomalies in the cooling towers operation. Homogeneity in the heat transfer could not only be achieved with fault free construction characteristics but also with a proper distribution of water across the plane area of the cooling tower. In this study, we have analyzed the water distribution across the plane area of the cooling tower. We have adjusted the amount of water to suit the air flow conditions, which cannot be influenced with natural draft cooling towers. In this way, the optimal moistening of the cooling tower packing is ensured, which results in a more effective heat transfer. With a optimal water distribution, a constant local water outlet temperature is obtained, which decreases the entropy generation and the exergy lost from the cooling tower. 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.

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