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Effect of Temperature Hike on Coastal Thermal Power Plants in India: A Case Study of Mundra

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Abstract - Mundra is a town in the Kutch district of Gujarat with the largest private port in India. Being on the coastal front and in the Gulf of Khambat, the micro-climate is atypical. With the rising global temperatures, several regional factors have also been responsible for the climate change. The Ultra Mega Power Plant (UMPP) installed in Mundra is one of the industry affected by the temperature rise. The temperature hike has resulted into the energy sector being at risk. It has been observed that the increase of temperature of 0.1^{o}C has led to the decrease in thermal efficiency by 2.22 %. This is showing an alarming rise in the necessity to control the climate change.

Keywords - Climate Change, Temperature Rise, Thermal Power Plant, Thermal Efficiency.

I. INTRODUCTION:

With the COP21 summit in sight, it is essential to know that with every single year, the climate is adversely changing. And the driving agency of this climate change has been arguably the energy and the transport sector. However, every step taken towards the sustainable development and economic growth is powered by the energy sector. With the vision of becoming a developed country by 2020, India has to seriously consider its energy sector. But as all the production processes have a significant impact on the environment, certain aspects of the environment also have an impact on the working of the industrial sector. The changes in temperature and rainfall patterns due to the climate change can have significant implications for the existing and future power plants and power infrastructure. Weather and climate can affect all major features of the power sector, including electricity generation, transmission and distribution systems as well as the end-user demand for power (Neve *et. al.*, 2015).

The impacts of climate change on industry include both direct impacts on industrial production and indirect impacts on industrial enterprises due to the implementation of mitigation activities (*Climate Change 2014: Impacts, Adaptation, and Vulnerability* Fifth Assessment Report of IPCC). Power plants use water for cooling the steam and condensing it to water. This cooling water is generally taken from a fresh water source like river or in case of coastal power plants, often from the sea. Higher temperature of the cooling water generally reduces the efficiency of the cooling system and thus that of the power plant. Sudden instances of heat waves or even draught-like situations increase the temperatures, reducing the cooling capacity of the power plant. Energy industry is one of the largest industry in India with its extent ever increasing to meet the needs of the ever-increasing population. Being a tropical peninsular region, India is impacted by Climate Change through various different ways. Thus, identifying how severely the dynamic changes in climate affects the power plants is very important.

II. IMPACT OF CLIMATE CHANGE ON INDIA:

Climate change is impacting the natural ecosystems and is expected to have substantial adverse effects in India, mainly on agriculture on which 58 per cent of the population still depends for livelihood, water storage in the Himalayan glaciers which are the source of major rivers and groundwater recharge, sea-level rise, and threats to a long coastline and habitations. Climate change will also cause increased frequency of extreme events such as floods, and droughts. All these factors are also linked with the increase in the surface and the water body temperature of the rivers, oceans as well as other reservoirs. These reservoirs form a source of water for the process and the cooling mechanism in the thermal power plant. And the increase in these parameters will have a direct impact on the efficiency of the plant.

The All-India mean annual temperature has shown significant warming trend of 0.05^{o}C/10 yr during the period from 1901-2003. The recent period of 1971-2003 has seen a relatively accelerated warming of 0.22^{o}C/10 yr mainly due to the unprecedented warming during the last decade (Kothawale et al., 2010). 14 of the 15 Hottest years ever measured have been since 2000. While 2014 has been recorded as the hottest year ever being the 38th consecutive year with the global temperature average above the 20th century average (NASA/GISS). Northern India have endured it longest heatwave ever in June 2014. In 2013, Maharashtra state has suffered its worst drought in more than four decades (Praneeta Dandekar, 2013).

90% of the extra heat trapped by global warming goes into Oceans. This has led to the increase in surface water temperatures of the peninsular water bodies as well as the inland reservoirs. With every 1 °C increase in the air temperature, the water holding capacity of air increases by 7%. There is already 4% more water vapor over the oceans than it was 30 years ago. This results into huge downpours and deluges like the one in Mumbai on July 26, 2005. Floods have also increase several folds in terms of their probability, occurrence and intensity which has claimed several thousands of lives, rendered millions homeless and destructed property worth millions as well.

III. SOURCES OF ENERGY IN INDIA:

The Indian power sector is one of the most diversified in the world. Sources for power generation range from commercial ones such as coal, lignite, natural gas, oil, hydro and nuclear power to other viable non-conventional sources such as wind, solar, and agriculture and domestic waste. The demand for electricity in the country has been growing at a rapid rate and is expected to grow further in the years to come. In order to meet the increasing requirement of electricity, massive addition to the installed generating capacity in the country is required.

As per the International Energy Agency (IEA) publication on World Energy Statistics 2013, India ranks 5th in Electricity production and 110th in the per-capita consumption of electricity. Electricity production in India (excluding captive generation) stood at 911.6 TWh in FY13, a 4 per cent growth over the previous fiscal. During FY14, electricity production stood at 967 TWh.

Table No. 1. All India Installed Capacity (MW) region wise as on 30-04-2015

Region	THERMAL				Nuclear	Hydro	RES	Grand Total
	Coal	Gas	Diesel	Total				
Northern	39843.50	5331.26	12.99	45187.75	1620.00	17431.78	5935.77	70175.30
Western	66407.01	10915.41	17.48	77339.90	1840.00	7447.50	11271.07	97898.47
Southern	30342.50	4962.78	939.32	36244.60	2320.00	11398.03	13784.67	63747.30
Eastern	28582.87	190.00	17.20	28790.07	0.00	4113.12	432.86	33336.05
North-East	60.00	1662.70	142.74	1865.44	0.00	1242.00	256.67	3364.11
Islands	0.00	0.00	70.02	70.02	0.00	0.00	11.10	81.12
ALL INDIA	165235.88	23062.15	1199.75	189497.78	5780.00	41632.43	31692.14	268602.35

Source: Executive Summary, April 2015, CEA.

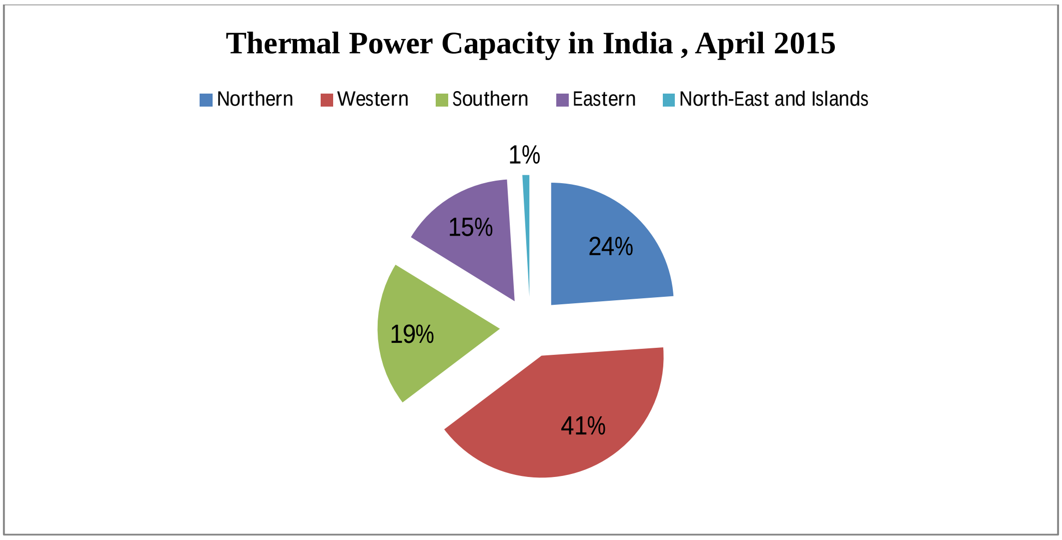

Fig. No. 1. Region-wise Thermal Power Capacity in April 2015

A total of 189497.78 MW of energy has been sourced from the Thermal Power which is used all together in the Central, State as well as the Private Sector. Out of the total installed capacity, 70.55% share is of Thermal Energy, 2.15% of Nuclear Energy, 15.49% of Hydro Energy and 11.79% being Renewable Energy sources. The Transmission and Distribution losses have been gradually decreasing form 23.97% in 2010-11 to 23.04% in 2012-13. The Aggregate Technical and Commercial losses have also shown a dip from 26.35% in 2010-11 to 25.38% in 2012-13.

IV. FUTURE OF POWER GENERATION IN INDIA:

In order to identify the long-term impact of climate change on the thermal power plants, it is essential to project the power generation in India for a considerable period of time.

India is the world's fourth largest economy as well as the fourth largest energy consumer. India imports a substantial portion of its energy — 80 per cent of its oil, 18 per cent of its gas, and now even 23 per cent of its coal. As the Indian economy continues to grow, so will its energy consumption, especially as the growth of its manufacturing sector catches up with services and agriculture (McKinsey & Company, 2014).

The total installed capacity at the beginning of The Eleventh Five Year Plan (1 April, 2007 – 31 March, 2012) was 132,330 Megawatts (MW). This comprised 34,654 MW Hydro-electricity, 86,015 MW Thermal power (including Gas and Diesel), 3,900 MW Nuclear power and 7,761 MW from Renewable Energy Sources. This was insufficient to cover demand; the country faced peak shortages of 13,897 MW (13.8 per cent) and a total energy shortage of 66,092 MU (9.6 per cent) at the start of the Plan. Report of the Working Group on Power for the 11th Plan set the additional capacity target for the plan at 78,700 MW. In the event, an additional capacity of 34,462 MW was achieved between 2007 and 31 March, 2011.

India's twelfth five year plans estimates that an additional capacity of 75,785 MW is required over the plan period, giving a total capacity of approximately 276,000 MW. To decrease the gap between peak demand and peak deficit and to permit the retirement of older, inefficient energy plants, the plan target has been fixed at 88,537 MW. Of this added capacity, the Plan estimates that thermal energy derived from coal and lignite will account for 79 per cent, up from 76 per cent in the previous plan. Overall, the projected growth rate in power generation over the period 2012-2017 is expected to be 9.8 per cent.

V. IMPACT OF CLIMATE CHANGE ON POWER PLANTS IN INDIA:

It is expected that energy utilization will grow due to demographic and socio-economic issues. On the other hand, average and peak energy demands are also associated to climatic circumstances. With the planet getting warmer year-by-year, the summers in India have also stretched their traditional boundaries, both in terms of tenure as well as intensity. 2014 was already the hottest year ever. Now that the effects of scorching heat are evident right from the onset of March 2015, the trend of heat seems to continue. This will, quite obviously, result into higher requirements of cooling and air conditioning demanding a lot of energy.

These changes cause a great impact on power stations, electricity transmission and distribution networks, oil and gas product storage and transport facilities and off-shore oil and gas production.

VI. OBSERVATIONS AND CASE STUDY:

Hannah Forster and Johan Lillestam (2010) had proposed a mathematical model to compute the thermal efficiency of the power plant based on the temperatures of the condensation water and its flow rate. It was primarily used for the water intake from the river. On modifying the conditions for coastal power plants, given that sea water would be used for the purposes of cooling, the reduction in the thermal efficiency was computed. The formula used for these computations was:

Electricity output:

$$P_{el} = \frac{-v\,(T_1 - T_0)\rho C_v}{1 - \frac{1}{\beta}}$$

Where,
P_{el} = Net Power Generation (MW)
V = Intake Capacity (Pumping) (m^3/s)
T_0 = Intake Water Temperature (K)
T_1 = Outlet Water Temperature (K)
ρ = Density of intake water (kg/ m^3)
C_v = Specific Heat Capacity (MJ/ kg K)

β = Cooling Factor = 0.5

Equation summarizes the variables used to depict electricity production in a steam power station with once-through cooling. Since the water in the consideration here is the sea water, the temperature, density and specific heat capacity implies to that of the sea water. The density of sea water is taken as 1020 kg/m^3 (EIA Report, Mundra) while the specific heat capacity is taken as 0.00401 MJ/kg K (www.engineeringtoolbox.com).

Coastal Gujrat Power Ltd.'s Thermal Power plant was taken as a case study. This thermal power plant is located on the coast of Mundra on the coast of Gulf of Kutch on the west coast of India. It uses coal for the purpose of electricity production with the help of a steam turbine. The water used for steam generation is taken from the sea and is purified using the thermal desalination unit. The cooling mechanism installed is a once-through cooling system that has a shell and tube mechanism. The hot steam is condensed by passing it through the tubes that gives away the heat and cools it down to a considerably low temperature. The water used for condensation is taken from the sea, used to take up the heat from the steam and then let back into the sea after its temperature is brought down by a seal well discharge channel arrangement.

This temperature difference between the uptake water and the discharge water is an important factor in calculating the efficiency of power generation. The Central Pollution Control Board (CPCB) has laid down regulations for the discharge temperature of water to be not more than 5 ^oC of the receiving water body. The values of intake and outlet temperature and intake rate was taken from the sustainability report of the company. The intake water temperature was taken as 28.9 ^oC while the outlet water temperature was 34.4 ^oC. The intake water was taken from pumps with a discharge of 30.098 m^3/s.

The model has been simulated for the increase in temperature of 0.1 ^oC with the steps of 0.01 ^oC. Since the cooling mechanism is assumed to be the same, it would be letting out water at the same discharge temperature in all conditions. This implies a decrease in the difference in the inlet and the outlet temperature. The density and specific heat capacity was kept constant. Based on these calculations following results were observed :

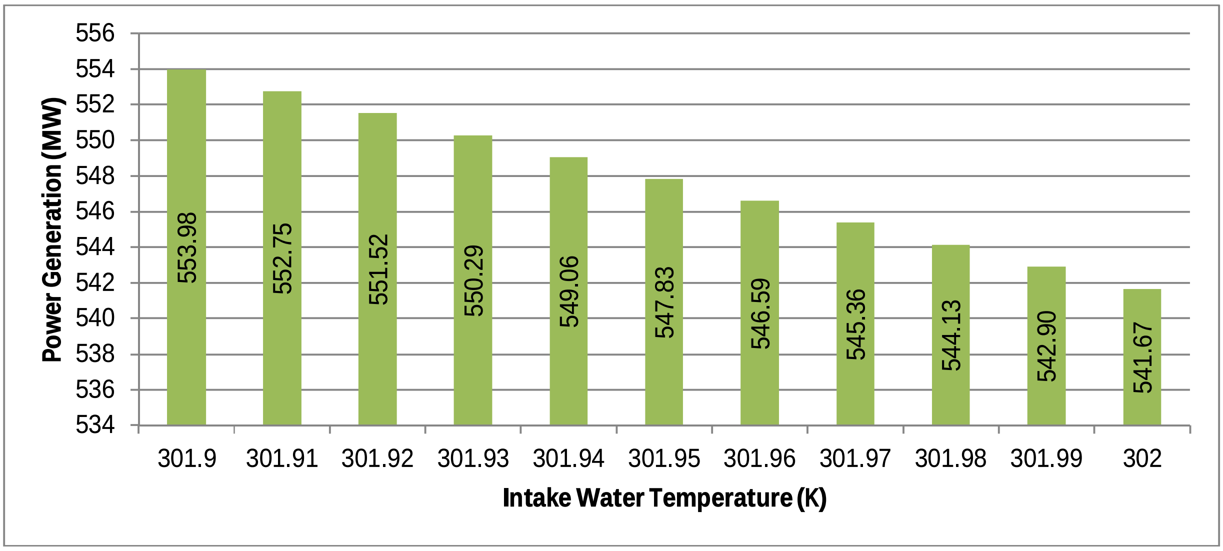

Fig. No. 2. Decreasing power generation with increasing temperature of inlet water

VII. RESULTS AND DISCUSSION :

Using the mathematical model and assigning the field conditions, it was observed that for a given cooling system and intake capacity, as the temperature of the water increases the power output goes on decreasing. The increase of water temperature by 0.1 ^oC results in the decrease of power generation by 12.31 MW i.e. a decrease by about 2.22 %.

The temperature of the inlet water i.e. the sea water taken for the condensation cannot be controlled. This would lead to the drop in the efficiency of the power generation cycle. Thus to restore this efficiency of the cycle, the power plant has to either increase the pumping capacity to absorb the heat from the steam in larger volume of sea water or to cool the discharge water further. Increasing the pumping capacity means to disturb the current infrastructure and to redesign the pipes for the altered pumping capacity. This would involve a lot of capital as well as increased pumping capacity means more electricity consumption for the pumps. Also, in order to reduce the temperature of the outlet water, a facility like an aerator or a cooling tower has to be installed which would also result in financial inputs.

The above decrease in power generation was scaled for just one single power plant but when it is compared to the national power generation a decrease of 2.22 % is fairly significant. In order to mitigate the long term impacts of climate change the efforts have to be taken so that it does not severely affect the productivity of the power generation cycle.

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