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# IMPACT OF CLIMATE CHANGE ON POWER PLANTS IN BANGLADESH

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***Abstract****-The global climate change makes Bangladesh a high risk country. The sea level rise due to global warming compels a significant coastal area of Bangladesh to go under water displacing millions of people and rendering lands and infrastructures unusable. One of the main driving forces for the economic activities in Bangladesh is adequate power generation. Over the decade, several dozens of small and large power stations have been set up in different cities and low lying coastal regions of the country. Most of these power plants commissioned without taking into consideration of the effect of global climate change. The purpose of this study is to identify the impact of climate change on existing power plants based on its geographical location. Here, we identified the required factors for the power plant design, site selection and risk assessment to minimize the effects of climate change on power plant operation.*

**Keywords:** Impact on Power Plant, Global Climate Change, Site Selection, Sea Level Rise.

## 1. INTRODUCTION

For a sustained economic growth, an uninterrupted energy source is paramount. The vulnerability of energy sector on regards for climate change draws the importance of adaptation and mitigation. Recently, the disruption of energy supply observed due to the extreme weather conditions across the globe. Due to global climate change, the frequency of extreme and unpredictable weather patterns also increased. Among industrial sector, the energy sector has a significant impact due to the extreme weather events. In 2009, Brazil energy supply experienced blackout due to extreme weather conditions. About 40% of Brazilian National Power Grid System's load was interrupted (Ordacgi Filho, 2010). Thermal power plants are generally affected by the high ambient temperature (Linnerud et al., 2011). The scale and level of impacts depends on the geographical location of the power plant and ambient conditions. IPCC (2008) reported that the frequency of periods characterized by water shortages and by high water temperatures will increase in Europe and elsewhere in the future. For cooling, power plants require a constant supply of freshwater as impurity (eg. salinity, contaminant etc.) can have significant effect on cooling capability of the plant. One of the most vulnerable countries due to the global climatic change is Bangladesh. It is located on the foothill of the Himalayan Mountain in the north and the Bay of Bengal to the south. The entire country is almost created by the sediments carried by Asia's two giant rivers: the Ganges and the Brahmaputra. The most of its 145,000 km square area is just several meters above the sea level. Floods are frequent and cause the great economic and human losses. The flooding problems are exacerbated by sediment transported by three major rivers- the Ganges, Brahmaputra and Meghna. The impacts of higher temperatures, more variable precipitation, more extreme weather conditions, and sea level rises are already felt in Bangladesh and will continue to intensify in the future. The risk assessment of installation, site selection and design of country's power plants has not yet undertaken. The adaptation of climate change in Bangladesh is in very early phase. A nationwide impact assessment on different industries is yet to be conducted. There is a lack of study on which power plants are in high risk zone to global climate change. Future planning of power plant installation and commissioning have not yet considered the threat of global climate change. Therefore, a study on the impact of global climate change on the power plant of Bangladesh is very important for a safe and sustainable future of Bangladesh. In this paper we have identified the potential climate change impact on power plant in Bangladesh. We have identified the climate change risk on the existing and upcoming power plant based on their locations in different regions in the country.

## 2. POWER GENERATION IN BANGLADESH

Bangladesh power generation is far away to reach its current demands by the grid connected households and commercial users. Only around 18% of the population (25% in urban areas and 10% in rural areas) has access to the electricity, and per capita commercial energy consumption is among the lowest in the world (Siddiqui, M.H., 2008). For a sustained economic growth, the country needs uninterrupted power supply for residential, agricultural and industrial sector. Despite governments interest for foreign investment in industry and infrastructure sector, the foreign and local invests are slow due to severe shortage of power generation and supply. In order to meet the current demands and accelerating industrialization, currently government has undertaken a series of initiatives both in public and private sectors installation of new power plants across the country. The current power plants (till 2010) and the power plants in the pipeline that will be commissioned by 2016 are shown in figure 1.

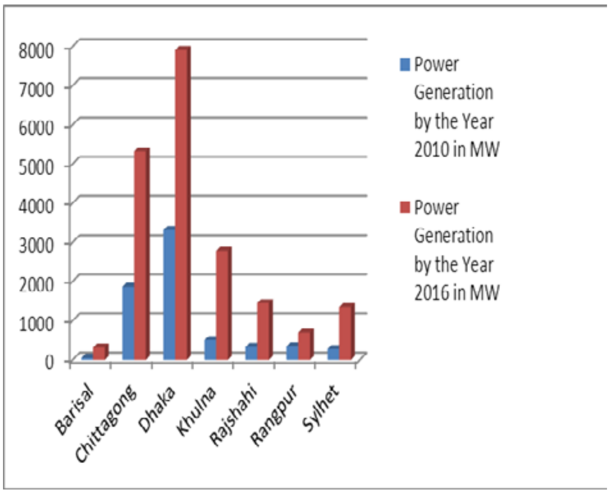


Fig. 1: Current (2010) and under construction power plants (2016).

Figure 2 illustrates the district wise power generation capacity throughout the country by 2016. Both figures indicate that the power generation will be more than double in 2016. In figure 2 it can be seen that a large amount of power generation will be operating in the coastal regions. These regions are mainly Khulna, Bhola, Barisal, Feni and Chittagong. Beside that a large number of power generation capabilities will be established in the region of Dhaka

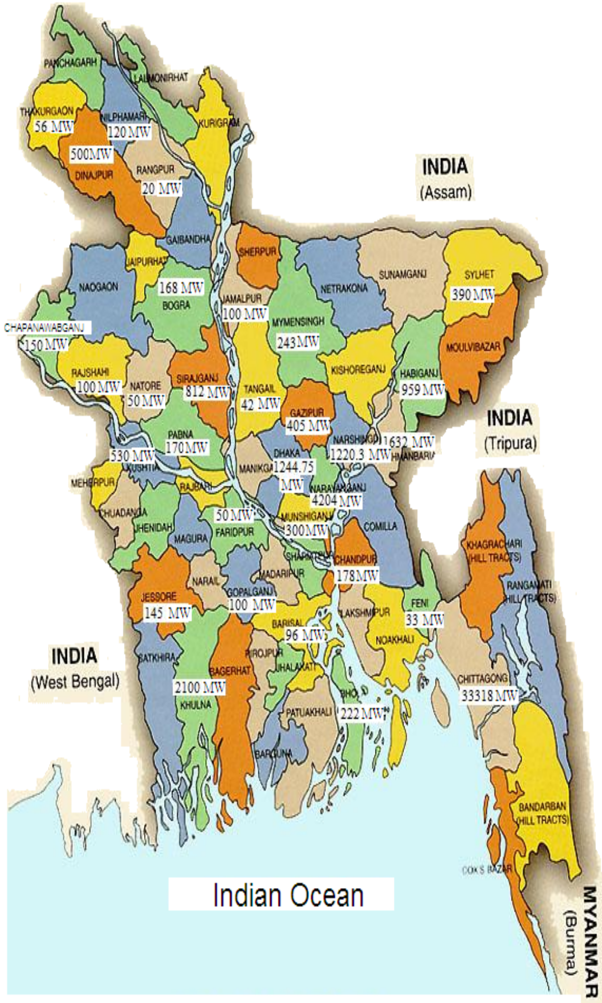


Fig. 2: Projected district wise power generation by 2016.

## 3. IMPACT OF CLIMATE CHANGE

### 3.1 Impact of temperature

Cooling system of power plant and hence the production efficiencies will be greatly affected by climate change. In general, there are three kinds of cooling systems which are used in power plant cooling. One is once through system which directly intake cooling water from water source such as river and discharge it directly into the water source. Another type of cooling is once through cooling system with a cooling tower. After passing through the power plant the water goes to cooling tower where the temperature is reduced and then discharged to river. Third type of cooling system is a closed circuit system where the water re-circulates in the system after condensation and the heat reduction in cooling tower. Figure 3 shows a schematic of three cooling systems used for various power plants around the world. Due to the increase in temperature, the water temperature will also be raised. The lower the temperature of intake water, the higher the efficiency of cooling system and hence the higher power production efficiencies and reduced water usages.

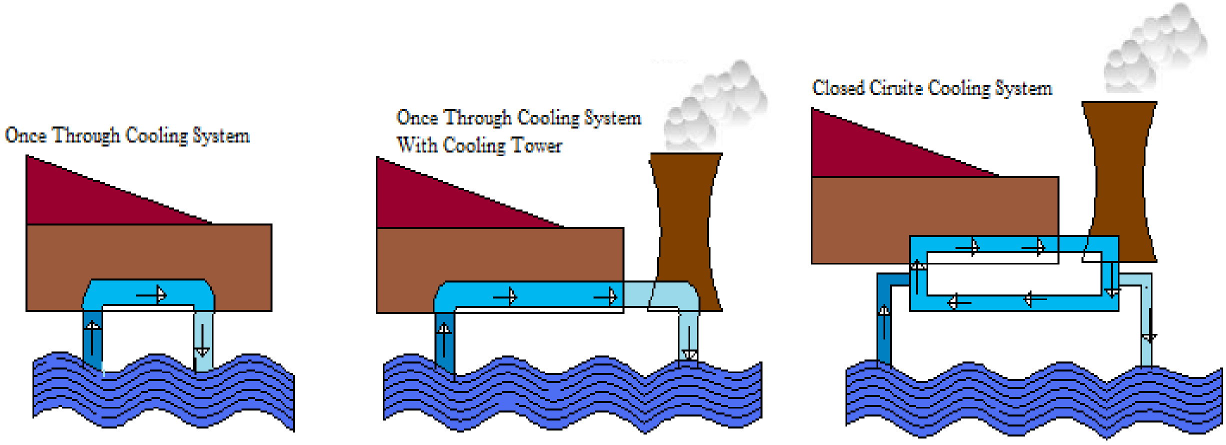


Fig. 3: Schematic of three widely used different cooling system for power plant.

As presented in Koch & Vögele (2009) and Rübbelke & Vögele (2011), the demand of freshwater for cooling purpose of a thermal power plant can be expressed as:

$$Q^F = \frac{KW \cdot h \cdot 3.6 \cdot (1-\eta_{total})/\eta_{elec} \cdot (1-\alpha) \cdot (1-\beta) \cdot \omega}{\vartheta \cdot c \cdot AS} \cdot EZ \qquad (1)$$

Equation (1) illustrates the interrelation among energy conversation, fuel, waste heat generation and cooling water demand. Generally, power plants produce electricity by using only 30% to 55% of the input energy. Rest of the energy is converted to heat, which is wasted through by cooling water or air. The amount of total waste heat can be calculated based on the electricity produced in a period (KWh) and data on efficiencies. From equation (1), the amount of waste heat that the cooling water will remove from total waste heat results from total waste heat (*KW.h.* 3.6. $(1-\eta_{total})/\eta_{elec}$) multiplied by different correction factors accounting for, e.g., the share of waste heat released into the air (Rübbelke & Vögele, 2011).

Problems associated with cooling of power plant will arise for two reasons, such as if there is a limitation of water use and if there is a limitation of water temperature. To heat up 1 liter of water to 1ºC, we need 4.2 kJ. If the maximum allowable heating temperature is 28ºC and the intake water temperature is 18ºC, so we need 1m$^3$ of water to dissipate 42MJ of heat. If the intake water temperature increases to 23ºC and maximum allowable temperature is 28ºC, we need 2 m$^3$ of water to dissipate 42MJ of heat. If the intake water amount is limited, then a power plant needs to reduce its production to 50%. On the instance of limitation of cooling water temperature and cooling water shortage, the capacity of the power plant must be reduced to,

$$KW = \frac{Q^F \cdot \vartheta \cdot c \cdot AS}{h \cdot 3.6 \cdot \frac{1-\eta_{total}}{\eta_{elec}} \cdot \lambda \cdot (1-\alpha) \cdot (1-\beta) \cdot \varpi \cdot EZ} \qquad (2)$$

So the equation (2) depicts that if the temperature of the cooling water increases or if there is a limitation of intake cooling water amount then the production of the power plant needs to be decreased. We can observe this reduction in once through cooling system. In closed circuit cooling system the amount of required water will also be increased as due to increased evaporation of discharge water in increased temperature.

The temperature data for different seasons shows that the temperature is increasing in monsoon season (June-August) in Bangladesh. Ahmed and Alam (1999) identified that the average monsoon maximum and minimum temperature is increasing at a rate of 0.05 and 0.03ºC in each year. According to Ahmed and Alam (1999) the average increase in temperature would be 1.3ºC by the year 2030 and 2.6ºC by the year 2075. The study also shows that the temperature increase will be 1.3ºC in winter and 0.7ºC in summer for 2030 and 2.1ºC for winter and 1.7ºC for summer for 2075. The National Adaptation Program of Action (NAPA) of the Government of Bangladesh recommended 1.0, 1.4 and 2.4 ºC temperature rises by the year 2030, 2050, 2100 respectively. This temperature rise will affect cooling system of all the power plants in Bangladesh. The water obtained for cooling of power plants is mainly from the river network. Due to the temperature rise the river water temperature will also high. Due to this high temperature, the cooling capacity will be reduced and hence the production efficiencies be reduced.

Table.1: Risk of Power Generation in Coastal region Due to Climate Change

| Risk Type | Barisal | Bhola | Chandpur | Chittagong | Feni | Jessore | Khulna | Risk of Generation |
|---|---|---|---|---|---|---|---|---|
| **Inundation** | √ | √ | √ | √ | √ | | √ | 5947 MW |
| **Salinity** | √ | √ | √ | √ | √ | √ | √ | 6092 MW |
| **Storm Surge** | √ | √ | | √ | √ | | √ | 5769 MW |
| **Tidal Wind** | √ | √ | | √ | √ | √ | √ | 5914 MW |
| **Cyclone** | √ | √ | √ | √ | √ | √ | √ | 6092 MW |

### 3.2 Inundation Risk to Power Generation Plants

Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2007) projected a sea water level rise of 9 to 88cm from 1990 to 2100. Due to man-made activities and warming, the global-mean sea level will rise significantly within 21st century. Bangladesh has 710 km long coastline. The coastal zone is low-lying with 62% of the land have an elevation below 3 m and 86% below 5 m (Mohal et al. 2007). Mohal et al. (2007) made a mathematical model of the Indian Ocean which identified the sea level rise of the deep sea to the inland tidal river network and the Meghna Estuary region. They used a one-dimensional model for inland tidal rivers and two dimensional model for Meghna Estuary region. Based on 88 cm sea level rise, about 11% area (4,107 km2) of the coastal zone will be inundated. Sea water will enter at Chandpur, which is 80 km upstream from estuary. Due to 32 cm sea level rise, 84% of the Sundarbans will be deeply inundated within 2050 and for 88 cm sea level rise the whole of Sundarbans will be under sea water within 2100. Power plant in Chandpur, Bhola, Khulna, Barisal, Feni, and Chittagong will be affected due to the inundation. Table 1 indicate that a total of 5947 MW power generation capacity in 2016 will be directly impacted due to the inundation.

### 3.3 Increase in Salinity Intrusion

The increase in sea level will increase the salinity near coastal areas. The study of Mohal et al. (2007) shows that the 5 ppt saline front will enter about 40 km inland for sea level rise of 88cm. As the sea level continues to rise the associated effects of permanent inundation is likely to increase the salinity all coastal areas. The study also shows that 5 ppt saline front will penetrate about 40 km inland for the sea level rise of 88 cm which is going to affect the fresh-water of the Tentulia River in Meghna Estuary. The study also reveals that sea water will enter up to Chandpur region. All the coastal areas including Jessore will experience high salinity due to the climate change. A total of 6092 MW power generation will be in a risk of increased salinity of the river water (as river is the main source of cooling water of all power plant) as shown in table 1. The densification factor EZ is introduced in equation (1) and (2) for increase in salinity in cooling water due to evaporation of cooling water at increased temperature. It shows that increasing salinity has a negative impact on power plant production. Increased salinity will increase corrosion of the equipment and pipes across the power plants. It will reduce the cooling capacity of the power plant. Hence, 6092 MW of power plants in coastal area will greatly experience adequate cooling and hence reduced power production.

### 3.4 Cyclone and Storm Surge

Historically Bangladesh is always in high risk of storm surge and cyclone due to its unique geographical location in the Indian Ocean. Coastal regions are in high risk of cyclones and storms due to its wide and shallow continental shelf, funnel shapes of the coast and its position on the path of tropical cyclones (Das, 1972). The country has experienced several devastating cyclones and storm surges, very frequently in the past. It has washed away millions of lives and damaged the infrastructures and resources enormously. Due to the climate change, the intensity of cyclones and storm surges will be increased. The global warming will increase the frequency of these natural calamities even more.

The study of Karim and Mimura (2008) shows that for a storm surge under 2ºC sea surface temperature rise and 0.3m sea level rise, flood risk area would be 15.3% greater than the present risk area and depth of flooding would increase by as much as 22.7% within 20km from the coastline. Within the risk area, the study identified 5690km$^2$ land (22% of exposed coast) as a high-risk zone (HRZ) where flooding of depth 1m or more might occur. This high risk zone is 1.26 times of the present coastal high risk zone of country. The study revealed that the flooding depths, especially within 20km from the coastline will be 30–40% higher with respect to previously estimated depths. In the study of Sarwar (2005), a sea level rise of 1m is expected inundate 17.5 % of land (25,000 km$^2$) of Bangladesh affecting mostly greater Patuakhali, Khulna and Barisal regions. The exposed districts are Satkhira, Khulna, Bagerhat, Barguna, Patuakhili, Jhalkati, Pirojpur, Barisal and Bhola. Table 1, indicates that about 6092 MW power generation will face the risk of storm surges and cyclones. The power generation site in Barisal, Bhola, Chandpur, Chittagong, Feni, Jessore and Khulna are in greater risk of storm surges and cyclones.

Table. 2: Flood Risks to Power Plants in Different Regions (adapted from Islam and Sado, 2000)

| High Risk | Power at the end of 2010 (MW) | Power at the end of 2016 (MW) | Very High Risk | Power at the end of 2010 (MW) | Power at the end of 2016 (MW) |
|---|---|---|---|---|---|
| **Brahmanbaria** | 779 | 1632 | **Narayanganj** | 1759 | 4204 |
| **Dhaka** | 44.75 | 1244.75 | | | |
| **Gopalganj** | 0 | 100 | | | |
| **Habiganj** | 277 | 959 | | | |
| **Munshiganj** | 0 | 300 | | | |
| **Natore** | 0 | 50 | **Sirajganj** | 312 | 812 |
| **Narsingdi** | 1142.3 | 1220.3 | | | |
| **Pabna** | 0 | 170 | | | |
| **Sylhet** | 0 | 390 | | | |
| **Tangail** | 22 | 42 | | | |
| **Total** | 2265.05 | 6108.05 | | 2071 | 5016 |

### 3.5 Risk of Flood on Power Generation

Islam and Sado (2000), made a comprehensive study on flood risk on different regions of Bangladesh. Based on their study and our quantification we find that the districts of Narayanganj and Sirajganj are in a very high risk of flooding. These regions currently produce power of 2071 MW and 5016 MW by the year 2016. Among these two districts Narayanganj has a large amount of power generation capacity of 1759 MW and 4204 MW by the year 2016. Besides the high risk zone, Islam and Sado (2000) also identified some other regions for high risk of flooding. Among these regions, ten districts power generation are directly under the threat, which currently constitutes 2265.05 MW and 6108.05 MW by the year of 2016. These districts are Brahmanbaria, Dhaka, Gopalganj, Habiganj, Munshiganj, Natore, Narsingdi, Pabna, Sylhet and Tangail. According to IPCC (2008), the flood intensity and time period of flooding will be increased due to the climate change. Hence the power generation in this region is in a high risk of flood.

## 4. CONCLUDING REMARKS

There is no doubt that climate change will make a major impact on Bangladesh especially on its power generation. Frequent disruption due to increased natural disasters, power blackouts, technical problems, increasing threat on infrastructure due to inundation and river erosion, reduced production, cooling problem, machine failure, high maintenance cost etc will greatly be affected in coming years. Site selection for new power plants should undertake risk assessment. A nationwide climate change impact and risk assessment should also be undertaken on each region. Furthermore, an adaptation plan should be made for existing power plants. Master plan for the power generation under the Ministry of Power, Energy and Mineral Resource should include a risk assessment incorporating the effects on climate change. For comprehensive installation of new power plants in the coastal regions, impact of sea level rise should be carefully considered. Inundation, salinity intrusion, increased cyclone and storm surge, tidal wind etc. need to be considered in the coastal regions. Instead of applying a nationwide standard for the climate change, government needs to make a region based assessment and hence the standard and specification for power plants for each high risk zone.

## 5. REFERENCES


[1] D. Rübbelke, and S. Vögele, “Impacts of climate change on European critical infrastructures: the case of the power sector”, *Environmental Science & Policy*, vol. 14, no. 1, pp. 53-63, 2011.

[2] H. Koch, and S. Vögele, “Dynamic modeling of water demand, water availability and adaptation strategies for power plants to global change”, *Ecological Economics*, vol. 68, No. 7, pp.2031-2039, 2009.

[3] J. M. Ordacgi Filho, “Brazilian Blackout 2009”, *PAC World*, March 2010 Issue, 2010

[4] K. Linnerud, T. Mideksa, and G. Eskeland, “The impact of climate change on nuclear power supply”, *Energy Journal*, vol. 32, no. 1, pp. 149-168. 2011.

[5] M. H. Karim, N. Mimura, “Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh”, *Global Environmental Change*, vol. 18, no. 3, pp. 490-500, 2008.

[6] M. M. Islam, and K. Sado, “Development of flood hazard maps of Bangladesh using NOAA-AVHRR images with GIS”, *Hydrological Sciences-Journal-des Sciences Hydrologiques,* vol. 45, no. 3, pp.337-355, 2000.

[7] P. K. Das, “A prediction model for storm surges in the Bay of Bengal”, *Nature, vol.* 239, pp. 211-213, 1972.

[8] M. G. M. Sarwar, “Impacts of sea level rise on the coastal zone of Bangladesh”, Master’s Thesis, LUMES, Lund University, Sweden, 2005

[9] N. Mohal, Z. H. Khan, and N. Rahman, “Impact of sea level rise on coastal rivers of Bangladesh”, *in proceedings of the 10th International river symposium and environmental flows conference,* Brisbane, Australia, 2007.

[10] A. U. Ahmed, and M. Alam, “Development of climate change scenarios with general circulation models. In: Huq, S., Karim, Z., Asaduzzaman, M., Mahtab, F. (Eds.), Vulnerability and Adaptation to Climate Change for Bangladesh”, Kluwer Academic Publishers, Dordrecht, 1999.

[11] IPCC, “Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]”, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007

[12] IPCC (International Panel on Climate Change), “Climate change 2007: impacts, adaptation and vulnerability”, Cambridge University Press, Cambridge, United Kingdom and New Yourk, NY USA, 2008
[13] M. H. Siddiqui, “Climate and energy framework Bangladesh”, Report by Royal Danish Embassy, Dhaka, Bangladesh, 2008.
[14] NAPA (National Adaptation Plan of Action), “Formulation of Bangladesh program of action for adaptation to climate change project”, Ministry of Environment and Forests, Government of the People’s Republic of Bangladesh, 2005.

## NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| $Q^F$<br>KW | Cooling water demand<br>Installed capacity | ( $m^3$)<br>(kW) |
| h | Operations hour | (h) |
| $\eta_{total}$ | total efficiency | (%) |
| $\eta_{elec}$ | electric efficiency | (%) |
| $\alpha$ | share of water heat not discharge by cooling water | (%) |
| $\beta$ | share of water heat released in air | (%) |
| c | specific heat capacity of water | (MJ/t K) |
| $\omega$ | correction factor accounting for the effects of changes in air temperature and humidity within a year | (-) |
| $\upsilon$ | water density | (t/ $m^3$) |
| EZ | densification factor | (-) |
| AS | permissible temperature increase of the cooling water | (K) |