Functional Productivity and Factors of Thermal Power Plants

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Abstract: *Present research paper attempts to yardstick the enactment of coal fired power plant (CFPPs) by estimating their operational efficiency and its determinants using Data Envelopment analysis (DEA). Data Envelopment Analysis (DEA), a comparative or relative method for calculating output that uses multiple variables to compare certain defined units with each other.* ***Key words:*** *Operational efficiency, Thermal power plants, DEA*

1. History

Using a production function, a company's input and output combinations are represented in microeconomic development theory. The maximum efficiency that can be demonstrated using a production function. DEA was founded about 30 years ago.

Building on the concepts of Farrell (1957), "Measuring the Efficiency of Decision-making Units" (1978) first uses linear programming (LP) to estimate quantitative output engineering limits. The method was historically used in Germany to estimate the average efficiency of R&D and other output factors (Brockhoff 1970). Since then, DEA has written several books and journal articles or applied DEA to various sets of issues. In addition to a company's assessment of performance across DMUs, DEA was also used to measure business efficiency. But DEA also tackles various scale returns, including CRS (constant scale returns, VRS (variable), non-increasing scale returns, or Ylvinger (2000) non-decreasing scale returns. Seiford & Thrall (1990) recorded the major developments of DEA in the 1970s and 1980s.

2. General Introduction

India faces a huge challenge in its power sector over the next few decades. The per capita energy consumption of India is actually much lower than that of China and other industrialized nations. However, the country is one of the five fastest growing economies in the world, and the only country of those five with a gross domestic product (GDP) of over $1 trillion, according to Nasdaq. Bloomberg estimates that 240 million Indians do not have access to affordable electricity. Thus, one challenge India faces is providing affordable electricity to a staggering number of people, while managing emissions. Improving steam power plant efficiency is one tool that will help the nation achieve this objective.

3. Energy Consumption Trends in India

The Economic Times projects that India's energy consumption is set to grow at an average annual rate of 4.2 percent through 2035. This is the fastest growth rate of any major economy in the world. The growth rate for renewables in India is expected to be much higher than for fossil fuels, but consumption of oil, gas, and coal are all expected to more than double by 2035.

With the rapid growth in fossil fuel consumption, India will be challenged to meet its climate commitments. On April 22, 2016, India became a signatory of a treaty negotiated by 195 countries in Paris. The goal of the Paris Accord is to arrest the rise of the world's carbon dioxide emissions. The agreement seeks to achieve "global peaking of greenhouse gas emissions as soon as possible," according to The New York Times. As part of the Paris Accord, the Indian government committed to reducing the country's emissions intensity by 33–35 percent below the 2005 level, per unit of GDP, by 2030.

India's commitment to renewable energy will help the country meet its climate goals. An expansion in the country's nuclear power—projected to grow by more than 300 percent by 2035—will further help India manage its emissions as energy consumption rises. However, nearly 71 percent of India's power capacity is based on fossil fuels, with over 62 percent from coal, according to India's Central Electricity Authority. India's coal consumption is projected to grow by 105 percent in the next 20 years, according to The Economic Times, so it will be critical that India's coal plants are operated as efficiently as possible.

In addition, as the country expands its renewable portfolio, it will need to incorporate more load-following power plants. These load-following plants are typically gas turbines that can be started up quickly to balance out the load from variable renewables. They require fast response times to handle transient loads.

4. Improving Steam Coal Plants

Conventional steam power plants have long supplied the largest share of the world's electricity, according to Power. However, coal has the highest carbon intensity of the primary sources of electricity. According to the EIA, the production of 1 kWh of power from coal generates over 80 percent more carbon dioxide than the same electricity production from natural gas. Also, coal contains certain impurities like mercury and sulfur that can enter the environment when coal is burned in a power plant.

Thus, it is crucial to use the best pollution-control technologies available at new and existing coal-fired power plants and to maximize steam power plant efficiency. In addition to reducing the carbon dioxide emissions per unit of power production, operating plants at higher efficiency also reduces the level of pollutants such as mercury, particulate emissions (PM), NOx, and SOx per unit of power production. Technologies are available to address each pollutant individually, but an integrated solution is the best option in most cases.

Finally, employing a carrot-and-stick approach often achieves the best results. While the Indian government has announced new pollution control limits for coal-fired power plants (the "stick"), it could also provide incentives (the "carrot") to allow power generation companies to keep more of the efficiency savings. Current regulations only allow the developer to retain 60 percent of the efficiency savings. This leads to longer payback times for these projects, which decreases the incentive for generating companies to invest in retrofitting older power plants with state-of-the-art technologies to manage emissions.

India is one of the world's largest power consumers, and the country's energy consumption is set to expand dramatically in the next two decades. As a result, the country faces the challenge of managing its emissions while providing affordable power for its citizens. The emissions issue is of worldwide concern, and India is a signatory of the Paris Accord—committed to controlling global greenhouse gas emissions. An integrated solution that addresses emissions, efficiency, and flexibility, especially as variable power grows, will go a long way to help India meet its goal of providing affordable energy.

Consider, for example, a situation with K DMUs, with M inputs and N outputs each. Let X i^kbe input level I in DMUk and let Y j^kbe output level j in DMU k. Inputs and outputs are supposed to be described in a way that allows for better consideration of lower inputs and higher outputs. DMU k's relative efficiency, known as byw k, is calculated by the following linear equation being solved.

$$\text{Maximize } w_k = \sum_{j=1}^{N} \beta_j Y_j^k$$

Subject To:

$$\sum_{i=1}^{M} \alpha_i X_i^k = 1$$

$$\sum_{j=1}^{N} \beta_j Y_j^t - \sum_{i=1}^{M} \alpha_i X_i^t \le 0\,, \quad \forall\, t = 1, 2, \ldots, \text{K}$$

$$\alpha_i, \beta_j \ge 0$$

The basic idea in this approach is to transform input and output sets using αandβ weights into a single' virtual input' and a single' virtual output.' The performance associated with DMU is defined by the ratio of digital output to virtual input.

Over the past three years, India's power sector has undergone an unprecedented turnaround.

Today, the country boasts a situation in which 3000-4000 mw of surplus power is available in real time and at competitive power exchange rates to state and distribution companies at any time of the day.

Fuel	MW	% of Total
Total Thermal	2,18,960	66.2%
Coal	1,92,972	58.3%
Gas	25,150	7.6%
Oil	838	0.3%
Hydro (Renewable)	44,963	13.6%
Nuclear	6,780	2.0%
RES* (MNRE)	60,158	18.2%
Total	**330,861**	

* Installed capacity in respect of RES (MNRE) as on 30.09.2017.

Figure 1: Percentage of Installed Capacity for Electricity based on Fuel type- http://www.powermin.nic.in

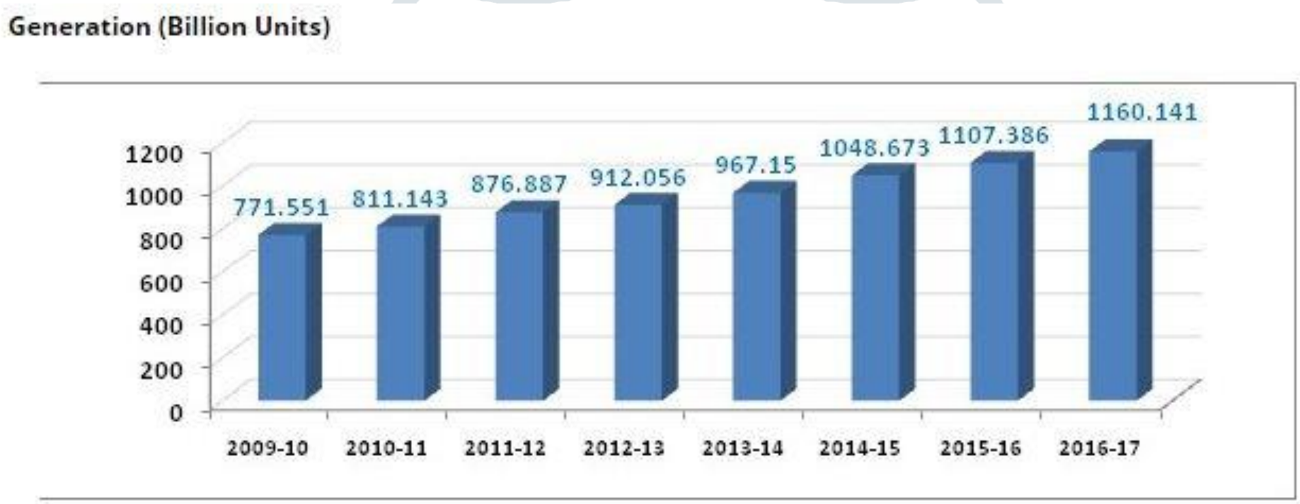

Figure 2: Electricity Generation over the year

Source- http://www.powermin.nic.in

Growth was 6.9% in 2014-16.

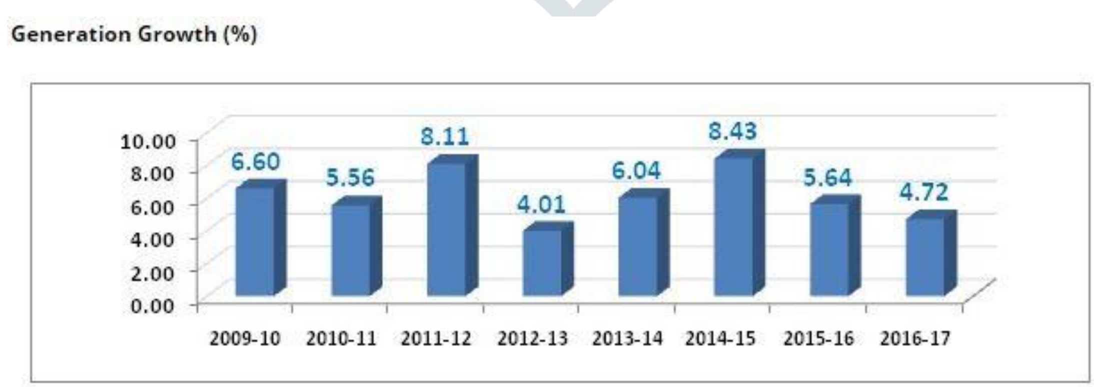

Figure 3: Electricity Generation growth in MUs over the year

Source- http://www.powermin.nic.in

Significantly, in 2017, India turned from a net importer of electricity to a net exporter of electricity exporting around 5,798 million units to Nepal, Bangladesh and Myanmar. We used the Data Envelopment Analysis (DEA) method in this research to determine the relative effectiveness of CFPPs. Using the DEA gives better insight into the asset management problems.

Project Objectives:

a) Identifies CFFPs which requires to be technically efficient
b) Identifies strength of individual power plant
c) It investigates the performance variables that emerge from it.
d) The study suggests a number of measures to improve efficiency.

5. LITERATURE REVIEW

Numerous researches have been conducted to evaluate the power generation and distribution sector's performance. Below are briefly mentioned several important studies:

Chitkara (1999) used the DEA approach to assess the inefficiencies in but also recognizing the triggers in different units of those inefficiencies.

Shrivastava et al. (2012) used the DEA test to measure the performance of thermal power units and compared size and ownership output.

Shanmugam et al. (2005) used the stochastic frontier function approach to analyze the performance of 56 coal-based thermal power plants over the period 1994-1995 and 2001-2002.

Wu et al. (2010) analyzed the shift in productivity in different settings in 30 Chinese CFPPs between 1999 and 2007.

Azadeh and Ghaderi (2007) determined productivity of 40 thermal power plants in Iran. Their study's unique feature was the use of a robust DEA approach.

Tyagi et al. (2009) used sensitivity analysis to assess the relative performance of IIT Roorkee's academic departments.

Fallahi et al. (2011) measured Iran's power generation businesses efficiency. Their sensitivity results indicated that all parameters had consistent efficiency scores and the analysis selected the best model.

Lam and Shiu (2001, 2004), calculated significance of impact of capability on the technical performance.

See and Coelli (2012) used stochastic frontier analysis to analyze the degree to which different factors affect output rates in Malaysian thermal power plants.

Yang and Pollitt (2009) implemented a 4-stage method to assess Chinese CFPP efficiency. Their results revealed relatively significant influence of uncontrollable variables.

Using the Tobit test, Fleishman et al. (2009) analyzed the effects of air eminence legislation on U.S. power plant performance. Authors have shown that more stringent regulations on sulfur dioxide have a negative effect on the output of coal plants. On the other hand, NOx regulations do not seem to have any significant impact on the efficiency of coal plants.

Sirasoontorn (2005) analyzed Thailand's state-owned electricity production business and the findings showed that the plant life had a significant positive effect on the level of technical inefficiency.

6. Conclusions

In this paper, the introduction and literature review of thermal power plants has been completed. Moreover some of the aspects from the thermal power plants in India has been discussed. To add to this, project objectives have also been discussed. In the next chapter, the efficiency of the Indian thermal power plants has been discussed in detail.

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