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Efficiency assessment of state owned electricity generation companies in India using data envelopment analysis

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ABSTRACT : This paper presents a framework for accessing efficiency analysis of State Owned Electric Utilities (SOEUs), which have been mainly responsible for the generation, distribution and transmission of electricity in India. Efficiency Performance of Thirty state owned generation companies was evaluated using the Data Envelopment Analysis (DEA) for the time periods 2006-07. This efficiency performance of regulated electric utilities of India is very important for future requirement. The results give a mixed technical and scale efficiency scores showing that State owned electric utilities (SOEU) generation companies are inefficient in operation and need improvement.

Keywords : Data Envelopment Analysis (DEA), SOEU, Installed capacity, Auxiliary consumption, Energy losses, Units generated

I. INTRODUCTION

During the last two decades, many developing countries like India, Pakistan etc have started the reforms in electricity sector. The main aim behind these reforms was to shift the ownership from state owned and centralized organization of infrastructure to private participation. The reasons for this shifting of ownership were the burden of price subsidies, low service quality, low collection rates, high network losses, and poor service coverage [3]. Due to these problems, it is realized that governments are no longer willing to or able to support the existing arrangements. So as a result, the reforms have sought to transform the state–owned and centralized electricity sector into decentralized, market oriented industries with private sector participation. The new Electricity Act 2003 is the step forward in the way of reforms in the sector [4].

Efficiency measurement is an important issue in power sector. Efficiency measurements have been carried out in the power and energy sector of many countries for many years [1]. In the era of restructuring and privatization of vertically integrated electric utilities around the world, efficiency assessment has become a serious matter of concern. Among many possible efficiency measurement approaches, Data Envelopment Analysis (DEA) is probably the most widely used mathematical approach for benchmarking of generation units.

It is a linear programming based relative efficiency measurement tool, which uses optimization technique to automatically calculate the weights assigned to the inputs and outputs of the production units being assessed [2]. The actual input and output variables are then multiplied with the weights to determine the efficiency of the Decision Making Units. (DMUs). Since its introduction, DEA has undergone several modifications and developments. Application of DEA in power system is not a recent phenomenon. DEA has been used to assess the performance of several electricity generation and distribution systems in the recent past.

This paper presents a case study in which Data Envelopment Analysis is applied to evaluate the efficiency of Indian generation companies for the year 2006-07. The aim of this study is to identify the efficient/inefficient generation company using DEA model. A non-parametric approach to frontier analysis, commonly known as Data Envelopment Analysis has been used in the present work to obtain the efficiency scores for the various performance parameters of generation companies.

II. PRESENT INDUSTRY STRUCTURE

Electricity is a main engine for economic activities and industrial growth. Reliable, secure and cheaper electricity supply is needed for commercial activities. In developing countries, it is one of the main sources of employment, revenue for government. India is the world's largest democracy with 1.1 billion inhabitants, and it is one of the fastest growing developing countries. India is the world's fifth largest consumer of energy and by 2030 it is expected to become the third largest, overtaking Japan and Russia. The total present installed capacity of India is 1,51,073.41 MW [5]. The demand-supply gap is around 9.3 % for the base – energy shortage whereas in peak hours the demand is 13.9 % higher than the supply. To bridge the demand-supply gap, India requires a capacity addition of nearly 1,00,000 MW in the coming 4-5 years. The ministry of power (MoP) has ambitious mission of "POWER TO ALL BY 2012". This mission would require that our installed generation capacity would be at least 2, 12,000 MW by 2012 from the present level. This paper reports a study of technical efficiency in electrical generation sector of India for the year 2006-07.

The Indian electricity sector remained a complete State monopoly with social objectives till the year 1991. By the 1990s, however the losses of SEBs had reached unsustainable levels on accounts of huge pilferage in the system as also the reluctance to allow tariffs to cover reasonable costs. Reforms in India, introduced since 1991, did not result in significant improvement in the financial creditworthiness of the SEBs and could not induce capacity addition in the sector [6]. Initial attempts to get significant amount of private investment in generation and transmission did not succeed. The government was therefore, inclined to take steps that would expedite the reforms and would revamp and restructure the power industry. Driven by a set of factors, many States brought about legislative changes to facilitate Unbundling of the Boards. Unbundling in India was aimed at enforcing accountability, better management and promoting efficient operations, unlike in the west where unbundling was considered necessary primarily for promoting competition. The Union Parliament enacted the Electricity Act, 2003 laying down a road map for evolving a competitive electricity supply industry in the country. The Act is a move toward creating a market-based regime in the Indian power sector and consolidates the laws relating to generation, transmission, distribution, trading and use of electricity. The intent of the Act is to provide complete commercial autonomy to buy and sell power.

Electricity sector restructuring, also popularly known as deregulation is expected to draw private investment, increase efficiency, promote technical growth and improve customer satisfaction as different parties compete with each other to win their market share and remain in business. The deregulation of the electric power industry forces the companies to produce more electricity for less in order to survive in the competitive market. Even in a non-competitive environment, productivity and efficiency are important because of scarce resources.

The Indian power sector is divided into five Regions: Northern, Western, Southern, Eastern, and the North-Eastern Region; and each state in India has its own SOEU. The Central Electricity Authority (CEA) is responsible for power planning at the national level. CEA advises the Ministry of power (MoP) on matters concerning the national power policy, and national power planning. Regulatory matters in the center are taken care by the Central Electricity Commission (CERC) and the State Electricity Regulatory Commission (SERC) take care corresponding regulatory issue at the state level.

As on 31st march, 2007, there were eight State Electricity Boards existing in the country. There were eighty nine companies, Power Corporations, Management Boards under Central, State or Joint partnership existing in the countries which were engaged in generation, transmission and distribution apart from thirteen Electricity Departments in the States and Union Territories. There were twenty two Power Trading Companies existing in the country as on 31.03.2007. There were sixty numbers of private licensees which includes sixteen Electric Supply Co-operative Societies. There were three Municipal licensees existing at the end of the year 2006-07.

III. WHY PERFORMANCE STUDY OF INDIAN GENERATION COMPANIES ?

Electric Utilities in developing countries are in the process of privatization and restructuring, with primary focus on efficiency improvement in electricity generation, transmission, and distribution. As the investment required in generation of electricity is huge, even a small improvement in production efficiency may result in significant benefits. This has created increasing interests in productive efficiency of electricity generation.

An inadequate timely capacity addition has been the inescapable long-run experience of under-utilization of the existing capacity itself in the country [6]. One important causative factor of such low capacity utilization is the poor technical efficiency, reinforced by an inability to attain and assimilate significant technological progress over time. Technical efficiency in generation in general is determined by plant availability (which in turn is determined by forced outages), by plant load factor (PLF), as also by auxiliary consumption. In addition to this technical inefficiency in energy generation is the higher level of auxiliary consumption at generation end that eats into the energy available for transmission.

IV. METHODOLOGY

A. Analytical framework used in this paper

DEA is an efficiency modeling approach that can be described as an extension of simple input-to-output ratio analysis, rigorously generalized to handle multiple inputs and multiple outputs [3]. DEA has been widely used to evaluate the relative efficiency of different decision-making units (DMUs). DEA uses mathematical modeling to calculate an “efficient frontier.” The frontier provides a yardstick against which to judge the comparative performance of all other firms or organizations that do not lie on the frontier. The efficient frontier is formed from the observed performances of the participating firms in the sample, determined by the relationships between the inputs and outputs of the firms in the sample. It is important to note that DEA calculations, because they are generated from actual observed data for each DMU, produce only relative efficiency measures. The relative efficiency of any DMU is calculated by forming the ratio of a weighted sum of outputs to a weighted sum of inputs, where the weights (multipliers) for both outputs and inputs are to be selected in a manner that calculates the efficiency measure of each DMU, subject to the constraint that no DMU can have a relative efficiency score greater than unity.

The technique was suggested by Charnes, Cooper and Rhodes and is built on the idea of Farrell. To regulate the electrical power most of the countries have adopted benchmark regulations using model of efficient firm concept.

It corresponds to a company whose investments are economically adapted to demand and operates under an optimal operation plan. To design an efficient firm the regulator must specify the production technology with which the service will be delivered, the price of inputs and cost of assets involved [7].

B. Selection of inputs and outputs

To evaluate the performance of the generation companies of India, there can be a number of input/output variables. The Following key inputs and outputs were chosen in this analysis.

Inputs :

(*i*) ***Installed capacity of the plant***. It is measured as nameplate rating in MW. This represents the gross capacity of the power plant.

(*ii*) ***Auxiliary consumption***. means the quantum of energy consumed by auxiliary equipment of the generating station. It is represented in GWh.

(*iii*) ***Energy losses***. It is expressed in GWh.

Outputs :

(*i*) ***Energy generated by the plant***. It is the annual energy generated by each plant, measured in GWh.

The quantities of inputs and outputs can be measured either in physical or in monetary units. Technical efficiency measures refer to the relationship between the physical quantities of resources used to produce a physical unit of output. However, it is not always possible or desirable to measure inputs and outputs in physical units only.

C. Model orientation

In DEA models, efficiency can be assessed either on an Input-minimizing or output-maximizing basis. Efficiency improvements in power companies may be possible using less input, such as capital, labor and fuel or increasing outputs by using more advanced technologies [8]. For this paper, an input-minimizing approach was chosen for analysis since the objective of the analysis was to suggest benchmarks for cost efficiency and reduction of fuel consumption and energy losses in order to produce a given output at minimal cost. In this study, both DEA models were applied : the CCR model developed by Charnes et al. (1978) and BCC model developed by Banker et al. (1984). The CCR model generated the CRS efficiency frontier to evaluate overall (or aggregate) efficiency score, while the BCC model generated VRS efficiency frontier to evaluate the technical and the scale efficiencies.

D. Model formulation

In this study, CCR model, with constant returns to scale (CRS) and, the BCC model, with variable returns to scale (VRS), is used to evaluate the technical efficiency.

(*i*) The CCR model. This model assumes constant returns to scale (CRS) assumption. The efficiency score in the presence of multiple input and output factors is defined as

Efficiency = weighted sum of outputs/weighted sum of inputs

(*ii*) The BCC model. When the utilities do not perform at optimal scales, this model can be modified to account for variable returns to scale (VRS) conditions by adding a convexity constraint. This BCC model relaxes the CRS assumption of the CCR model and makes it possible to investigate whether the performance of each DMU was conducted in region of increasing, constant or decreasing returns to scale in multiple outputs and multiple inputs situations. The BCC model helps decompose the CCR efficiency into the Technical and Scale Efficiency components, thereby allowing investigating the scale effects.

V. ANALYSIS AND RESULTS

For the case of Electric power utilities, a number of studies have demonstrated that the CCR model is the one which is most appropriate for the study of electric utilities Hence, the CCR Model formed a natural choice for the initial investigation of the inefficiencies in the sector. CCR model assumes constant returns to scale and does not discriminate

Table 1 : Result of Analysis

Utility	Overall Efficiency (%)	Technical Efficiency (%)	Scale Efficiency (%)	Efficient Output Target (GWh)
Haryana	95	100	95	14141.69
Himachal Pradesh	100	100	100	3057.11
Jammu & Kashmir	64	66	97	1327.17
Punjab	99	100	99	24107.43
Rajasthan	94	97	97	22722.08
Uttar Pradesh	78	83	94	22969.2
Uttrakhand	89	100	89	4340.13
Delhi	82	100	82	5013.6
Gujarat	100	100	100	44352.79
Madhya Pradesh	85	90	94	18956.62

(*Cont...*)

Utility	Overall Efficiency (%)	Technical Efficiency (%)	Scale Efficiency (%)	Efficient Output Target (GWh)
Chhattisgarh	98	100	98	9609.71
Maharashtra	92	100	92	68962.87
Goa	100	100	100	354.59
Andhra Pradesh	100	100	100	38262.13
Karnataka	100	100	100	31122.81
Kerala	100	100	100	7960.44
Tamil Nadu	96	100	96	40734.31
Puducherry	100	100	100	270.6
Bihar	7	10	65	104.46
Jharkhand	72	72	100	6268.47
Orissa	99	100	99	10785.99
West Bengal	100	100	100	25783.39
Sikkim	59	100	59	35.15
Assam	35	35	100	982.07
Manipur	11	100	11	5.98
Meghalaya	62	76	82	394.51
Nagaland	25	100	25	33.58
Tripura	100	100	100	557.67
Arunachal Pradesh	25	65	38	72
Mizoram	11	87	13	12.11
Average	**76**	**89**	**84**	

between units based on their sizes in computation of their efficiencies. The results of this model shows overall efficiency presented in Table I.

It is evident from Table I that Indian Electric utilities display significant variations in efficiency levels. The total efficiency had a mean score of 76 for all the utilities and a majority of utilities (10 out of 30), lie below this average value. Nine utilities turned out to be the best practices. The remaining utilities exhibited varying degrees of inefficiencies. Table I also shows the efficient target to be achieved by utilities to become efficient.

VI. CONCLUSION

This study endeavored to measure inefficiencies of the SOEUs generation companies in the Indian Power Sector by application of data envelopment analysis. The results of the study indicate the existence of large inefficiencies; a majority of the SOEUs (and especially the larger ones) do not seem to operate at the optimal levels. The results of the study also indicate the existence of scale inefficiencies, and suggest that restructuring and downsizing the present operations may help the utilities to reduce their scale inefficiencies. To improve the performance of SOEUs, a number of policy measures such as encouraging competition, unbundling and restructuring can be considered.

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