Evaluation of Technical Efficiency of a Thermal Power Plant

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***Abstract*—This paper evaluates the efficiency of a coal based thermal power plant using data envelopment analysis (DEA) for the year 2015. Slack analysis is carried out to explore the specific areas that need to be focused on for efficiency improvement. The result of this analysis may assist the management of a power plant and review their system for optimal uses of resources.**

***Keywords*— DEA, relative efficiency, slack analysis**

I. INTRODUCTION

Economic growth of India depends upon the power sector. The electric energy demands in the last two decades have increased at enormous space. In 1947, the total generation was only 1360 MW. But the total installed capacity in India as on July 31, 2015 is 275,911.62 MW. The fact is that thermal energy is the major source of power generation itself shows the importance of thermal power generation in India-more than 60% of electricity power is produced by thermal power plants. This position is likely to continue due to large pit head plants being set up. A thermal power station is a power plant where water is heated and turns into steam and spins a turbine. This turbine is coupled with generator. So, the generator is rotated. After steam passes through the turbine, the steam is condensed in a condenser. After condensing, it is recycled to where it is heated; this is called a Rankin cycle as shown in a Fig.1.

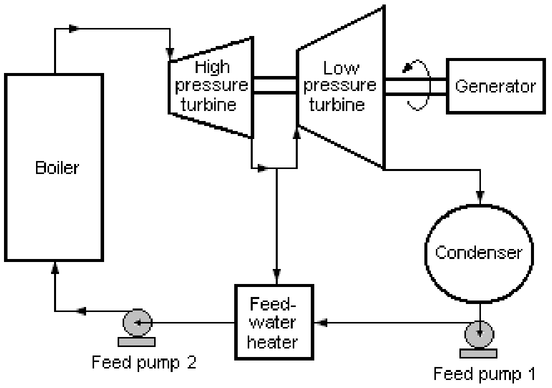

Fig.1: Basic model of a thermal power plant

The thermal efficiency of thermal power plant defined as the ratio of the heat equivalent of mechanical energy transmitted to the turbine shaft and the heat of combustion is quite low about (30%). Overall efficiency of the power plant, defined as the ratio of heat equivalent of electrical output to the heat of combustion, is about 29%. The overall efficiency is determined by multiplying the thermal efficiency of power plant by the efficiency of generation. Losses occurring in steam power plants summarized as Boiler 16.0%, Turbine losses as Heat rejected to condenser 54% Alternator losses 1% Thus output is about 29%. Losses occurring in a steam power plant more than 50% of total heat combustion is lost as heat rejected to the condenser. This loss of heat energy is unavoidable as heat energy cannot be converted into mechanical energy without a drop in temperature and the steam in condenser is at the lowest temperature. The thermal efficiency of thermal power plant mainly depends upon three factors (i) pressure (ii) temperature of the steam entering the turbine and the pressure in the condenser.

II. INTRODUCTION TO DEA TOOL

DEA is data envelopment analysis. DEA tool is multi-factor performance measurement and improvement tool. It is a non-parametric approach. DEA was proposed by Charnes et al. (1978) and Banker et al. (1984), which was built on the idea of Farrell (1957) as a tool to quantify relative efficiencies of decision-making units (DMUs), viz. schools, hospitals, power plants, etc. DEA provides a “measure of efficiency” of each DMU allowing, in particular, to separate efficient from non-efficient DMU and to indicate for each non-efficient DMU its “efficient peers”.

A. DMU’s (Decision Making Units)

Mostly, DMUs are non-profit organizations, where the measurement of performance efficiency is difficult. The problem is complicated by the fact that the DMUs consume a variety of identical inputs and produce a variety of identical outputs.

Decision-making units can include manufacturing units departments of big organizations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, defense bases, a set of firms or even practicing individuals such as medical practitioners.

B. Relative Efficiency:-

It is defined as a ratio of weighted output to weighted input. "A DMU is to be rated as fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs." The efficiency, referred to as "technical efficiency" in economics can, however, be extended to other kinds of efficiency when data such as prices, unit costs, etc., are available for use in DEA.

C. Basic Models and Mathematical Aspects

Here we describe DEA models which are important in the development of DEA methodology.

1) CCR MODEL

CCR DEA model was the first DEA model. It was named after the three authors (Charnes, Cooper, and Rhodes). In DEA, the organization under study is called a DMU. A DMU is an entity responsible for converting input(s) into output(s) and whose performances are to be evaluated. Consider there are *n* DMUs: DMU*1*, DMU*2*… and DMU *n*. Each DMU*j*, (*j* = 1, 2… *n*) uses *m* inputs *xij* (*i* = 1… *m*) and generates *s* outputs *yrj* (*r* = 1… *s*). Let the input weights $v_j(i = 1\ldots \mathrm{m})$ and the output weights $u_r(r = 1\ldots s)$ as variables. Let the DMU*j* to be evaluated on any trial be designated asDMU*0* (*0* = 1, 2… n). The efficiency of each DMU*0*, *e0*, is thus found by solving the linear programming below, which is known as multiplier form in DEA,

$$\mathrm{e}_{\circ} = \max \sum_r u_r\, y_{r_\circ} \qquad (1)$$

subject to

$$\sum_i v_i\, x_{i_\circ} = 1$$
$$\sum_r u_r\, y_{r_\circ} - \sum_i v_i\, x_{i_\circ} \le 0$$
$$u_r v_i \ge 0$$

The model is run n times in identifying the relative efficiency scores of all the DMUs. Each DMU selects a set of input weights v_i and output weights $u_r$that maximize its efficiency score. Generally, a DMU is efficient if it obtains the maximum score of 1; else, a DMU is inefficient. For every inefficient DMU, CCR identifies a set of corresponding efficient DMUs that can be utilized as benchmarks for improvement.

$$\text{Min } \theta_\circ \qquad (2)$$

Subject to

$$\sum_j \lambda_j\, x_{ij} - \theta_\circ x_{i_\circ} \le 0$$
$$\sum_j \lambda_j\, y_{rj} - y_{r_\circ} \ge 0$$
$$\lambda_j \ge 0$$

Problem (2) has an optimal solution when $\theta = 1$, $\lambda = 1$, and $\lambda \ne 0$. The DMUs with the optimal solution are referred to as efficient DMUs. For inefficient DMUs, CCR projects them onto the efficient frontier (the segment formed by efficient DMUs) by reducing each input by the proportionality factor θ, which is obtained from the envelopment model above, while maintaining the output levels. Another way of projecting the inefficient DMUs to the efficient frontier is by increasing the outputs by a proportionality factor $1/\theta$.

Despite its simplicity, CCR has some limitations. First, an inefficient DMU and its benchmarking DMUs may not be similar in their operations. The reason, as pointed out in is due to the composite DMU does not exist in reality. To surmount this problem, performance-based clustering methods have been used by researchers to cluster similar DMUs into groups. The efficient DMUs in a cluster are utilized to benchmark other inefficient DMUs in a particular cluster.

The second limitation of CCR model is that it assumes constant return to scale (CRS), which may not be true for some applications. To address this issue, researchers have implemented variable return to scale (VRS) into the original DEA model. The basic VRS model is known as BCC (Banker, Charnes, Cooper) model which will be explained in the following section.

D. Slack Analysis

In order to identify improvement directions, in quantitative terms, specific to each inefficient power plant, a nonzero slack analysis is carried out. Slack in input factors indicates possibility of reduction in input utilization to produce the same output, thereby improving performance of the inefficient plants. Alternatively slack in output gives the amount of additional outputs required for an inefficient power plant to become an efficient one.

III. PROBLEM FORMULATION

Here our main problem is to find out the relative efficiency of the decision making units as efficiency consider as the most important parameter to attain the economic effects of any organisation. To attain efficient units we need to overcome the losses happened in the units.

This work deals with the an investigation to calculate the relative efficiency of a coal thermal power plant using classical DEA tool by CCR model and examine the reasons of the losses happened in the decision making units. Consistent data is collected of a thermal power plant of the present year of five months (May to September) to analyse our study. As DEA tool is very effective tool to analyse the performance of any unit.

A. Objective Function

- To study the DEA tool under CCR model to calculate the relative efficiency and analyse the ways to make inefficient units into efficient units.
- To examine the reasons of the inefficient units. **Methodology**

Here we introduce a way to calculate the relative efficiency of frontier analyst.

B. Selection of Input and Output Variables and Graphical Representation-:

As in this work we calculate the relative efficiency of the present year (2015) for five DMU's. Here we take two inputs and two outputs as DEA tool is many input and many output tool for calculating relative efficiency. Here x1 x2 y1 y2 are considered as a input and output parameters where x1 is fuel oil consumption (KL) and x2 is coal consumption (MT) and y1 is Net generation (MU's) and y2 is losses (MU's).

The outcome of efficiency evaluations using DEA is significantly influenced by the choice of input and output variables.

All the power plants, which are using the same input parameters to produce the same output parameters, belong to a homogeneous group for evaluation. These plants operate at different scales of inputs and outputs, which make them relatively low or highly efficient. The total electricity generated is an important constituent of output, as it is the most pragmatic measure of the performance of any power plant. Coal consumption is considered as an input, as this parameter portrays a true picture of managerial effectiveness of any power plant. To portray the technical impact of these power plants, losses are included in this analysis as output. It is well known that to improve the performance of plants, output needs to be increased keeping the losses minimal.

Table-1: Selected data of the input and output parameters

Unit name	Input's		Output's	
	Coal consumption (MT)	Oil consumption (kl)	Net generation (MU's)	Losses (MU's)
May-15	46345	183.16	68.753	7.772
June-15	107165	182.2	163.647	17.227
July-15	71723	208.23	107.917	12.747
Aug-15	64796	247.84	90.948	40.966
Sep-15	123330	280.84	165.836	17.448

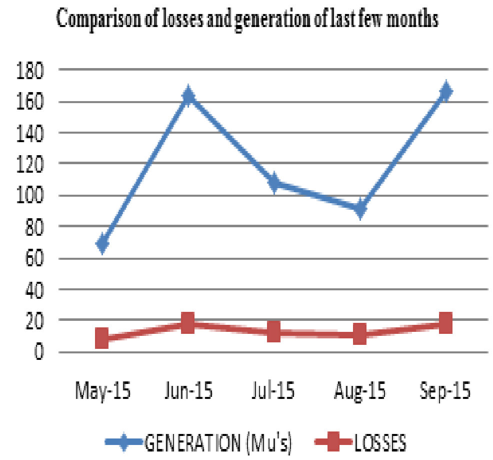

Fig.2: Comparison between losses and net gen of year 2015

The formulae used to calculate the net generation of the month is as following-:

Net generation = Generation- Auxiliary Consumption-Exc. & transmission losses

% losses for a month = (Net Generation/Total No. of losses) * 100

There are number of losses which occurred during the generation of electricity. Not only for a year or a month but for every day utilities have dome target for generating electricity. But the actual generation is somewhat different from the target generation.

Here losses occur in the form of auxiliary losses and technical losses when we generate electricity. Auxiliary losses are losses as in a power plant for a generation of electricity there are heavy machines are available which run upon heavy load then some amount of generation get consume there while generation which consider as a losses.

And then there are technical losses available these are those losses which occur during the generation of electricity.

IV. RESULTS AND DISCUSSION

The overall technical efficiency is tabulated in the following table which is resulted by frontier analysis of the DEA tool by CCR model.

Table-2:

UNIT'S		COMPARISON	
UNIT NAME	SCORE	EFFICIENT	CONDITION
Aug-15	95.20%		YELLOW
Jul-15	100.00%	HIGH	GREEN
Jun-15	100.00%	HIGH	GREEN
May-15	98.30%		YELLOW
Sep-15	88.10%		RED

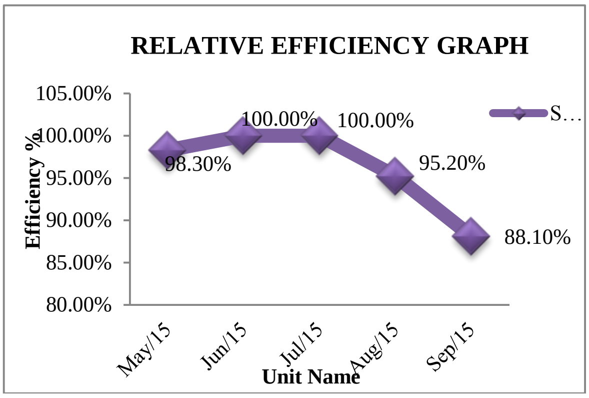

Fig.3: Graph of relative efficiency of a year 2015

From this we can concluded that efficient units do not need slack analysis but inefficient units need improvement, as we can do slack analysis on the inefficient units by giving the potential improvements. For the better improvement we have increase the output by controlling the input and decreasing the losses.

V. CONCLUSION AND FUTURE SCOPE

In this review paper we evaluate the relative efficiency of the coal-fired power plant during the month of May 2015 to Sep 2015. The TE of one plant is very low i.e. near about 88%. It is calculated under the CCR model. Lesser consumption of input not only reduce the cost of electricity generation thereby enhancing the competitiveness but also makes available scares inputs to generate more and more electricity. It also saves our non-renewable resources such as coal. Ultimately it states that DMU's helps to decrease or to control the input by which we get increases output.

Further we can research by not only considering quantity of our valuables resources but we can also take the amount of the materials so that we can do the economic analysis also. In the future scope we can do the economic analysis by taking the amount of the coal and fuel oil used which gave us the acknowledgment about the cost of the of the plant at which it will be work by controlling the input variables which directly effects the output variables of the plant which gave us the annual saving analysis. Energy audit seeks a way to reduce the losses within the constraints of the plant design 'as is', whereas a design assessment uses heat and material balances to provide a higher upper limit to the possible gains from a retrofit. We can use cross efficiencies under MCDEA tool and another models also.

REFERENCES

[1] A Azadeh, Fgahderi, “Performance assessment and optimization of thermal power plants by DEA BCC and multivariate analysis” by Journal of Scientific and Industrial Research, 15 may 2007.

[2] Mirzahassanhosseini, ”Evaluating the efficiency changes of the Thermal Power Plants in Iran and Examining its Relation with Reform using DEA Model”, Javadhasanpour in University of payamenoor, Tehran,Iran, 2011.

[3] P. Zhou, B.W. Ang, “A survey of data envelopment analysis in energy studies” Report of 2011-2012 under public sector undertakers by the PSTCL, 2007.

[4] Chaemtsekuah and kuan yewwong and farzadbehrouzi, “A review on data envelopment tool” under IEEE society, 2010.

[5] Vinodkumar Yadav, nirnajan Kumar, santosh Ghosh, Kanwardeep Singh, “Indian thermal power plant challenges and remedies via application of modified data envelopment analysis”, 2010.

[6] “Power generation energy efficient designs of auxiliary equipment’s in fossil fuel power plant”, A handbook by ABB company, 2008.