RATIONAL OPERATION OF INDIAN THERMAL POWER PLANTS

*J.S. Khokhar**

The present study attempts to investigate whether the Indian thermal power plants operate to achieve some desired level of output. To this effect, the partial-adjustment hypothesis is tested with data pertaining to 44 plants over 11 years (1981-82 to 1991-92). The results indicate that our plants generate power to catch up with the level expected of them, with the plants of the western region being most efficient in doing so.

I. INTRODUCTION

In India, about 70 per cent of the electric power is generated by coal based thermal power plants. Such a plant consists of several electricity generating sets which may differ with regard to size (generating capacity), age (year of commissioning), and vintage (embodied technology). Since the installation of a set is heavily capital and fuel intensive, absorbs a major portion of the public expenditure, and holds back resources at least for five years in its construction, it is expected of every plant to generate as much electricity as possible from its installed capacity. But do the Indian thermal power plants really make an effort to realise the amount of output expected of their capacities? To look into this aspect of the operating behaviour of the power plants is the main purpose of this article.

II. BACKGROUND

For the purpose of developing a statistical exercise to find out the operating behaviour of power plants, it seems desirable to become aware of the relevant technical and operating features of a generating set.

Technically, a set is defined to be an interconnected apparatus of one boiler, one turbine, and one generator (see Ling, 1964, pp. 20-35). The set uses coal as the basic input for generating electric power. The boiler burns coal, and uses the heat to convert water into steam. The steam is directed to rotate the turbine. When the turbine, with which the generator is connected, rotates, the generator spins, producing electric power. The electric power so generated by all the sets of a power plant is transmitted to load (demand) centres for distribution among various kinds of consumers—agricultural, industrial, etc. Both the transmission and distribution of power are accomplished by means of underground or overhead wires.

As regards the operating aspect of a set, we need to mention that a set may not always function smoothly. Its functioning is broadly affected by two kinds of factors: demand and supply.

The demand factors refer to the locational and temporal levels of demand for electricity. Demand for electric power varies from place to place and hour to hour. Since electrical output cannot be stored on an economic basis, the set is bound to adjust its operation strictly in accordance with the fluctuations in the demand for electricity.

* Reader, Department of Economics, Shri Ram College of Commerce, University of Delhi, Delhi.

The supply factors are the forces which determine the ability of a set to generate power of various magnitudes. At any point of time, the set is either on or off line. As long as the set is generating electricity, it is declared on line; otherwise, off line. The set goes off line on account of three factors: (a) planned maintenance — periodical/ statutory overhauling of the various parts of the set; (b) forced outage — breakdown of the set on account of unpredictable failure of some constituent parts of the set; and (c) reserve shutdown — closure of the set caused by external factors like non-availability of fuel or spare parts, disturbances in the network of transmission lines, insufficient demand for electricity, etc.

The annual durations of (a), (b), and (c) are generally known as planned maintenance hours (PMH), forced outage hours (FOH), and reserve shutdown hours (RSDH) respectively. Subtracting the sum of PMH, FOH, and RSDH from the total number of hours in one year (TH), we get the number of operating hours (OH), the number of hours the set actually generated electricity during the year. The sum of OH and RSDH is known as available hours (AH). Finally, dividing AH of a set by TH, we get the availability factor of the set, which is usually regarded as an important index of the operating performance of the set.

III. THE MODEL

Our model is an exercise of the partial adjustment mechanism (see Gujarati, 1988, pp. 505-11, and 519-21; Hebden, 1983, pp. 41-43), according to which the movement of a variable to its expected equilibrium — desired, or optimal level — is spread over several years. Each year, the variable registers a partial adjustment towards its equilibrium level. In our case, the moving variable is the amount of electricity to be generated by a plant in one year. On the other hand, the equilibrium output for a plant to achieve cannot easily be quantified in objective terms. However, some notion of this output exists in the operation schedule of a plant. Since we do not have any access to such a schedule, nor do we know how such a schedule is prepared, it is quite plausible to assume that the optimal power expected of a plant during a year is dependent on two factors:size and availability factor. For instance, if there are two plants, the one with the higher size or availability factor is expected to generate more electrical output. Accordingly, the optimal output for a plant to achieve can be determined by means of the following regression equation:

$$X^*_t = a + bS_t + cA_t + e_t \quad \ldots \qquad (1)$$

$t = 1, 2, 3, \ldots . T$

Where,

X^*_t = optimal output, in millions of kilowatthours, fixed for year t that the plant is to achieve; S_t = size, in megawatts, of the plant during year t; A_t = availability factor, percentage, of the plant during year t; e_t = residual error for year t, which is assumed to satisfy all the requirements of the classical regression model (see Gujarati, 1988, pp. 52-60); a, b, c = parameters to be estimated ; and T = total number of years.

Now, the partial adjustment behaviour of a plant can be expressed in terms of the following equation:

$$X_t - X_{t-1} = \lambda(X^*_t - X_{t-1}) \quad \ldots \qquad (2)$$

Where,

λ = adjustment factor, $0 \leq \lambda \leq 1$.

It is essential to describe equation (2), where $(X_t - X_{t-1})$ stands for the actual change in output, and $(X^*_t - X_{t-1})$ represents the desired change in output. The equation shows an adjusting mechanism by means of λ. If $\lambda = 1$, the actual output is equal to the desired output, implying that the plant instantaneously adjusts its current output to the equilibrium level. On the other hand, if $\lambda = 0$, the plant does not need to change its operation. It has got to maintain just the previous level of output. Obviously when $0 < \lambda < 1$, the plant makes an effort to adjust its current output towards attaining the equilibrium output.

Substituting (1) into (2), we get

$$X_t = \alpha + \beta S_t + \gamma A_t + (1 - \lambda) X_{t-1} + \mu_t \quad \ldots (3)$$

Where $\alpha = a\lambda$, $\beta = b\lambda$, $\gamma = c\lambda$, and $\mu_t = \lambda e_t$

For the estimation of (3), it is essential that μ_t should satisfy all the requirements of the classical linear regression model. Since e_t has been assumed to fulfil them, it can easily be proved that μ_t will also satisfy them.

IV. DATA BASE

For the purpose of developing electricity supply industry, the entire territory of India is divided into five regions, namely, northern, western, southern, eastern, and north-eastern. Since the north-eastern region has a very few thermal plants, it has been merged with the eastern region.

The data sample of our study consists of 44 thermal plants : nine, fourteen, seven, and fourteen plants from the northern, western, southern, and eastern regions respectively. Moreover, all these plants are considered over a period of 11 years from 1981-82 to 1991-92.

The statistical information that we needed to compute the variables of equation (3) has been collected from the various issues of *Performance Review of Thermal Power Stations*, Ministry of Energy, Government of India.

Electrical output (X_t): The electrical output of a plant is measured in millions of kilowatthours, and is the sum of the amounts of electricity generated by all its sets.

Size (S_t) : The size of a plant is measured in megawatts, and is the sum of the capacities of all its sets.

Availability factor (A_t) : The availability factor, in percentage, of a plant is estimated as a weighted average of the availability factors of all its sets, with the weight of each set being equivalent to its share in the total capacity of the plant.

V. RESULTS

Equation (3) was computed separately for each region, and the statistical results are presented in Table 1, where the estimates of the parameters are mentioned regionwise.

The table brings out three main features of the operating behaviour of our plants.

In the first place, the estimates of β, γ, and $(1-\lambda)$ are all positive and significant across all the regions, implying that the derived values for b and c of equation (1) will also be positive for each region. For this reason, we can say that the desired level of output for a plant of every region to achieve will become higher as its size or availability factor goes up. This is expected as raising the size or availability factor of a plant is quite expensive.

In the case of each region, the positive estimates of β, γ, and $(1-\lambda)$ also bear on the current output of a plant. Looking back at equation (3), we come to know that a plant will always respond favourably to a change in its size, availability factor, or previous

Table 1 : Regression Results

Region		Estimates of			
	α	β	γ	$1-\lambda$	R^2
1 Northern	-1861.09 (-5.68)	2.17 (6.50)	26.18 (5.31)	0.62 (9.17)	0.96
2. Western	-1885.29 (-7.96)	2.60 (10.55)	25.07 (8.48)	0.47 (8.85)	0.96
3. Southern	-930.03 (-4.07)	1.71 (5.68)	12.20 (4.11)	0.72 (13.45)	0.97
4. Eastern	-407.95 (-4.77)	1.16 (5.79)	6.44 (5.13)	0.64 (11.46)	0.95

Note : The brackets contain t-values, which are all significant at 1 per cent level.

output. This tendency on the part of a plant should be appreciated in the present context of power shortages prevailing in India.

As regards the estimate of α intercept of equation (3), the table shows that it is negative for each region. There is nothing wrong with its negative sign. According to equation (3), the intercept is equal to the current output of the plant if its size, availability factor, and previous output are all equal to zero. There is always a minimum amount of electricity consumption at the site of a plant whether the plant is on or off line. Irrespective of the level of its own output, the plant needs power to meet the electrical requirements of its premises and offices, and the auxiliary parts of its various sets under maintenance. As a result, if the plant is not generating any power, it needs to import power equivalent to the absolute amount of its negative intercept.

Second, our regions significantly differ with regard to adjustment factor, λ. The λ-estimates for northern, western, southern, and eastern regions are calculated to be 0.38, 0.53, 0.28 and 0.36 respectively. These figures reveal that the plants of western region take 2 years to catch up with their equilibrium levels of output, those of northern and eastern region 3 years, and those of southern region 4 years. These variations in the speed of adjustment point out two things. One, the plants of the western region are most efficient, in the sense that they complete half of their move towards the desired output in one year. Another, the demand and supply forces do not affect the operation of a plant uniformly across the regions.

Finally, R^2, a general index for describing the extent to which a regression equation fits a sample of observations, is quite high for each of our regions. That is to say, our linear regression model represents the operation of a plant, irrespective of its location. Therefore, in all the four cases, the main determinants of the output of a plant are its size, availability factor, and previous output.

VI. CONCLUSION

Our empirical study reveals that the Indian thermal power plants always try to adjust their operations towards realising the levels of output expected of their available capacities, with the plants of western region taking the lead in doing so. Perhaps, the plants of other regions require an improvement in their operation and maintenance practices in accordance with those of the western region.

References

Gujarati, D.N. (1988), *Basic Econometrics*, McGraw-Hill Book Company, New Delhi.

Hebden, J. (1983), *Applications of Econometrics*, Heritage Publishers, New Delhi.

Ling, S. (1964), *Economies of Scale in the Steam-Electric Power Generating Industry*, North-Holland Publishing Company, Amsterdam.

Ministry of Energy, (1981-82 to 1991-92), *Performance Review of Thermal Power Stations*, Government of India.