IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(5), 209-216.

EJ EconJournals

Falling Utilization Factor of Thermal Power Plants in India and Its Financial Impact

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Received: 01 March 2022 **Accepted:** 20 July 2022 **DOI:** https://doi.org/10.32479/ijeep.12959

ABSTRACT

Thermal power plants in India are operating under very low Utilization Factors. The average national Utilization Factor has come down to 53.37% in 2021-22 from 77.5% in 2009-2010. In the business-as-usual situation, it may further drop to 40% or below in next 3-4 years. There are many reasons behind such drop, including substantial addition of renewables in the grid. The situation is putting immense technical and financial pressure on thermal plants. The aim of this study is to find out how this situation is likely to impact Revenue and ROE of the thermal power plants, so that the developers, policymakers and regulators can deal with the situation appropriately. This is very important because, for safe and stable operation of the grid, coal-based generation is likely to play a very critical role in the foreseeable future. Until renewable energy and large-scale storage facilities are ready to takeover, both in scale and affordability, the coal-based generation cannot simply be wished away. In this paper, we explore the direct financial impact on the Revenue/Return on Equity (ROE) of thermal power plants under the falling PLF situation. We find that under the prevalent tariff regime, thermal power plants may see a reduction in Return on Equity (ROE) to the tune of the 26% if average Utilization Factor drops from a level of 90% to 35%.

Keywords: Thermal Power, Utilization Factor, Plant Load Factor, Return on Equity, Revenue, Flexibilization
JEL Classifications: Q40, Q41, Q42, Q43, Q48

1. INTRODUCTION

Thermal power plants in India are operating under very low Utilization Factors. (*The Utilization Factor of thermal power plants is known more commonly as Plant Load Factor (PLF) hence we use the term PLF to denote Utilization Factor in this paper*). The national average PLF of thermal power plants was 77.5% in 2009-10 which has come down to 53.37% in 2021-22. This situation has arisen partly because of substantial injection of renewable energy in the grid. Renewable energy (which is predominantly supplied by Solar and Wind plants), is dependent on weather conditions and hence provides intermittent supply to the grid. Thermal power plants have to do the balancing act in the grid by increasing or reducing output depending on the availability of renewable energy. With more and more integration of renewables into the grid, thermal power will have to do more of such output adjustments, and the PLF of thermal plants is expected to drop further (Financial Express, FE Burau (2019). Several studies and reports have indicated that in business-as-usual situation, the PLFs may drop to the levels of 40% as early in next 2-3 years. According to a KPMG report, PLFs of many thermal power plants might fall to 35-40%, in some time periods, if the capacity addition of 130 Giga-Watt (GW) of renewable energy happens by 2022. (KPMG, 2017). Such situation is going to put immense technical and financial pressure on the thermal power plants (Sengupta, D., The Economic Times, 2016) and (Alok K. T, 2021).

All key stakeholders including regulators, policy makers, power plant developers and lenders need to take notice of this situation. This is important because looking into the power demand trajectory of the country, availability of different types power generation resources, affordability of power and the technology maturity curve of renewable energy, the coal-based generation is likely to play a critical role in the foreseeable future for safe and stable operation of grid (ET, Energy World 2021) and (Joshi P, 2021). Under this backdrop, till we fully migrate to renewable energy, both renewable and coal-based generation should *not only coexist peacefully but both should also survive economically*.

However, the present era of coexistence of thermal and renewable is fraught with many challenges particularly for the thermal sector. Renewable energy, being environment friendly, has the special status of "*must run.*" It means that the buying entities (Distribution Companies) are under obligation to give preferential buying treatment to renewable energy while purchasing their energy requirements. This obligation comes from a govt. policy called Renewable Purchase Obligation (RPO). As per the current regulations in India, 21% of the total energy purchased by a power distribution company will have to come from renewable sources by FY22 (Business Line, 2018). Thermal has no such protection. It has to dance to the tune of renewables and the grid demand. This is called flexible operation (flexibilization) of thermal power plants. Such flexible operation of thermal power plants supports the grid imbalances and provides much needed reliability and affordability; but it comes at a cost.

Ironically, most of the thermal power plants were not originally designed for such flexibilization. They were designed to cater to a stable base-load situation and were expected to run consistently at around 80-90% capacity level. They now have to frequently come down to low output levels of 50-55% or even lower. Obviously, such situation has technical and financial bearing on the thermal power plants. Apart from the capital costs involved in retrofitting the units with flexibilization capabilities, the situation affects the top line and bottom line of thermal power plants. In this paper we explore the direct financial impact of lower PLF on thermal power plants in terms of Revenue and Return on Investment (ROE).

2. LITERATURE REVIEW

Many researchers have tried to model the costs involved in thermal power plants (Wu & Wang, 2018). Most works have concentrated on capital cost and variable cost of power generated. Most researches have focused on how the power tariff or cost of power is determined. Lot of work has also been done on the technical aspects and retrofits required in thermal power plants to make them flexible. There are also few research papers which have dwelled upon the costs arising out of load variations (flexibilization).

Kumar et al, (2015) have done cost modeling under the effect of PLF. They have brought out the impact of plant load factor (PLF) on O&M cost, Revenue and the Net Present Value (NPV), over the lifecycle of a plant. The study is done for coal-fired power plant of 210 MW subcritical units situated in India. They found that PLF has a direct bearing on earnings and hence on NPV. For the plant considered in the study, annual revenue has increased from INR 7537.3 Crores (US$ 1011 Million) to INR 9915.2 Crores (US$ 1330 Million), due to increase in the plant load from 168 to 221 MW.

Lew et al. (2013) show that flexibilization costs of thermal power plants include costs due to additional fuel requirements and increased O&M costs (caused by additional wear and tear of machinery). In addition, they have done scenario analysis to assess the possible impact of increasing Variable Renewable Energy on scheduling and flexibilization costs of thermal plants, particularly with reference to the US Western Interconnection.

Venkataraman et al. (2013) have done cost benefit analysis of flexibilization retrofits. The cost-benefit analysis has been done using Plexos simulations. The changes in generation costs and revenues (i.e., the benefits), have been determined.

Kang et al. (2018) have studied what factors get affected due to flexibilization of the plants. They opine that coal-fired units are originally designed for baseload operations and may suffer great losses as their operation mode changes. They find that losses happen due to changes in O&M Cost, APC, Heat Rate and Forced Outage Rates etc.

Keatley et al. (2013), bring out how large thermal power units, that were originally designed to operate as base load stations, are forced to operate flexibly due to market conditions and the substantial addition of variable renewable energy sources and how this is causing faster equipment deterioration (due to the fatigue).

Van den Bergh et al. (2015), find that flexible operation of conventional thermal plants provides much needed operational agility in the grid. The authors cite a wide variety of cost-related implications of flexible operation available in literature.

Hermans et al. (2016), opine that cycling of thermal plants is increasing with an increase in unpredictable renewable energy sources (RES). However, such cyclic operation of thermal power comes at a cost. The costs mainly relate to additional fuel costs that can be easily determined and calculated.

We find that in spite of the lot of good work done in the arena of flexibilization, there is no major scholarly work where impact of falling PLF on the Revenue/ROE of thermal power plants has been studied under the regulatory tariff regime in the Indian context.

3. FINANCIAL IMPACT OF FALLING PLF

When the thermal power plants run under low PLF, the financial impact occurs mainly because of the worsening of the efficiency parameters. Since the plants are designed to run at their best efficiency levels when they operate near full load (base load), lower loads result in worsening of the efficiency parameters (like, Heat Rate and Auxiliary Power Consumption (APC)). At lower loads, the plants thus consume more fuel per unit electricity generated, as compared to full load operations. Moreover, the plants lose "generation incentives" that they would have earned in monetary terms had they operated at high PLF. Accordingly, following are the components that we have considered in this paper for calculating cost implications of lower PLFs.

a. Loss due to running of the plant at lower *Efficiency* (higher Heat Rate)
b. Loss due to running the plant at higher *Auxiliary Power Consumptions* (APC)
c. Loss due to loss of *Generation Incentive* payable to the thermal power producer had the Utilization Factor (PLF) been beyond 85%
d. Startup Costs if the plant has to shutdown due to unsustainably low PLF.

We analyze here the impact of above factors on *three different thermal power plant units* of different capacities - (i) 660 MW (Supercritical), (ii) 800 MW (Supercritical) and (iii) 500 MW (Sub critical). These plants (Units) represent the most widely used units in India and also represent the most likely future capacity additions in the country.

(*Main financial calculations are in Indian Rs (INR). But wherever financial figures are given in Indian Rupees (INR or Rs), equivalent US$ has also been given in bracket or in another column or just below the INR figure. Exchange rate of 1 US$ = INR 74.5, as prevailing as on 05.01.2022 has been taken for conversions. (https://in.tradingview.com/symbols/USDINR/*).

4. BASE ASSUMPTIONS FOR FINANCIAL IMPACT CAUSED BY THE VARIATIONS IN CAPACITY UTILISATION (PLF)

Before calculating the financial impact, we need to create baseline data of tariff, revenue and ROE. Here we have used CERC (Central Electricity Regulatory Commission) Tariff Norms-2019-2024 (CERC, Electricity Tariff 2019-24) and operating data from thermal power plants to create the baseline. As explained above, we have considered three typical power plants that represent the most widely used units in India and also the most likely future capacity addition units in the country. The principles of calculation used here are replicable for other plants also (operating under regulatory regime). At the heart of our calculations is the premise that the Variable Cost of electricity that a power producer receives under regulated tariff through the Energy Charge Rate (ECR), should be equal to the Actual Cost that it incurs to produce electricity. If the producer earns less through ECR than the expenditure it makes as Variable Cost, then it is not fully recovering its Variable Cost of producing electricity. This is where falling PLF becomes a matter of concern because it can bring the power plant to such a situation.

In the regulatory regime in India, the electricity tariff has two components - The Fixed Charges and the Variable Charges. The Fixed Charge elements - like producer's profit margins (Return on Equity), Interest on Loan, Interest on Working Capital, Depreciation, and Operation and Maintenance Cost are recoverable as Capacity Charges (Fixed Charges), if the power producer is "ready and capable of generating" and *declares it capacity (DC)* at high levels. The Fixed Charges thus get paid irrespective of actual PLF, provided the DC is above the threshold level of 85%. However, the Variable Charges and Generation Incentives do get affected by PLF. The power generator is paid Variable Charges based on regulator defined levels of efficiency parameters. The efficiency parameters (e.g. Heat Rate, Auxiliary Power Consumption (APC) and Sp Oil), so determined are called "Normative Values." If a power station runs at an efficiency level worse than the "Normative Values" it will end up spending more for generating one unit of electricity than it can recover through tariff. This happens because the Variable Charges that it can bill to customers must be as per "Normative Values" of efficiency parameters. This is a situation of negative *marginal contribution.* In case the plant runs with better efficiency levels than the Normative Values, it can make a gain, or a positive *marginal contribution*. However, in case of such gain, the producer has to share it in the ratio of 50-50%, i.e., only 50% of the gain is retained by the power producer, rest 50% is to be passed on to

Table 1: Base assumptions for calculation of tariff

S. No.	Particulars	Plant 1	Plant 2	Plant 3	Units/Remarks
1	Plant Capacity	660	800	500	MW
2	Capital Cost (Rs Cr/MW)	4.9 (0.66)	6.1 (0.82)	5.1 (0.68)	Rs Cr/Mw (US$ Mn/MW)
3	Debt Equity Ratio	70/30	70/30	70/30	%, Ratio
4	Equity	0.3	0.3	0.3	Times of Capital Cost
5	Debt	0.7	0.7	0.7	Times of Capital Cost
6	Return on Equity (RoE)	15.5	15.5	15.5	%, as allowed in tariff
7	Interest on loan	10	9	10	%, Assumed as per market and as allowed in tariff
8	Working Capital	472 (63.35)	595 (79.86)	312 (41.88)	Rs Cr (US$ Mn), Approximation as per tariff and actual values of typical plants
9	Interest on Working Capital	12	13	12	%, Assumed as per market and as allowed in tariff
10	Rate of Depreciation	0.0528	0.0528	0.0528	%, as per stipulations of tariff
11	O&M cost	20.26 (0.027119)	18.23 (0.02447)	22.51 (0.03021)	Rs Lacs/MW (US$ Mn/MW), as per tariff
12	Plant load Factor	0.85	0.85	0.85	%, Assumed
13	Plant Availability Factor	0.85	0.85	0.85	%, Assumed
14	Specific Oil Consumption	0.5	0.5	0.5	Ml/Kwhr
15	Price of Oil	51000 (684.56)	51000 (684.56)	51000 (684.56)	Rs/KL, (US$/KL), as per market
16	Gross Calorific value of Oil	10700	10700	10700	Kcal/Liter
17	Station Heat Rate	2317	2271	2390	Kcal/Kwhr, as per tariff
18	Cost of Coal	2300 (30.87)	2500 (33.56)	2200 (29.53)	Rs/Ton (US $/Ton), as per market
19	APC	6.25	6.25	6.25	%, Assumed, as per tariff
20	Plant Life	25	25	25	Years, as allowed in tariff
21	Gross Calorific value of Coal	3700	3800	3700	Kcal/Kg, as per actual observed values

Base assumptions - Source -CERC Norms, CEA data and Motghare et al. - Generation Cost Calculation for 660 MW Thermal Power Plants

Table 2: Fixed cost calculations

Fixed Cost Calculations Rs Cr (US $)						
Components	Plant 1		Plant 2		Plant 3	
	(Rs Cr)	(US$ Mn)	(Rs Cr)	(US$ Mn)	(Rs Cr)	(US$ Mn)
Capital Cost Rs Cr/US$ Mn	3234	434.1	4880	655.0	2550	342.3
Equity Rs Cr/US$ Mn	970.2	130.2	1464	196.5	765	102.7
Debt Rs Cr/US$ Mn	2263.8	303.9	3416	458.5	1785	239.6
Return on Equity Rs Cr/US$ Mn (a)	150.381	20.2	226.92	30.5	118.575	15.9
Interest of Loan Rs Cr/US$ Mn (b)	226.38	30.4	307.44	41.3	178.5	24.0
Interest on Working Capital Rs Cr/US$ Mn (c)	56.64	7.6	77.35	10.4	37.44	5.0
Depreciation Rs Cr/US$ Mn (d)	170.7552	22.9	257.664	34.6	134.64	18.1
O&M Cost Rs Cr/US$ Mn (e)	133.716	17.9	145.84	19.6	112.55	15.1
Total Fixed Cost (a to e) Rs Cr/US$ Mn	737.8722	99.0	1015.214	136.3	581.705	78.1
Total Power Generation (Million Units) at 85% PLF	*4914.36*		*5956.8*		*3723*	
Fixed Cost per Unit in Rs/Kwhr/US$/Kwhr	1.5015	0.02015	1.7043	0.02276	1.5625	0.02097

Fixed Cost Calculation - Source -CERC Norms, CEA data, power plant data, and Motghare et al. - Generation Cost Calculation for 660 MW Thermal Power Plants

Table 3: Variable Cost

Variable Cost Calculations - Rs Cr (US $)			
Components	Plant 1	Plant 2	Plant 3
Cost of Oil Consumption (Specific Oil x Cost of Oil) - Rs/Kwh (US$/Kwh)	0.0255 (0.00034228)	0.0255 (0.00034228)	0.0255 (0.0034228)
Heat Consumed from Oil (Kcal/Kwh)	5	5	5
Heat Consumed from Coal (Kcal/Kwh)	2312	2266	2385
Specific Coal Consumption (Kg/Kwh)	0.624864865	0.596315789	0.644594595
Cost of Coal Consumption Rs/Kwh (US$/Kwh)	1.437 (0.01928859)	1.491 (0.02001342)	1.418 (0.01903355)
Total Variable Cost per Unit Rs/Kwh (US$/Kwh)	1.463 (0.01963341)	1.516 (0.02035288)	1.444 (0.01938255)
Total Variable Cost after deducting APC (Normative ECR as per Normative Heat Rate & APC), Rs/KWh (US$/Kwh)	1.5602 (0.02094231)	1.6173 (0.02170872)	1.5398 (0.02066845)

Variable Cost Calculation - Source - CERC Norms, CEA data and Motghare et al. - Generation Cost Calculation for 660 MW Thermal Power Plants

Table 4: Total costs

Tariff	Plant 1	Plant 2	Plant 3
Fixed+Variable Cost (Rs/Kwh)	3.0617 (0.04109615)	3.3217 (0.04458617)	3.1023 (0.04164177)

Total Cost Calculation - Source - CERC Norms, CEA data and Motghare et al. - Generation Cost Calculation for 660 MW Thermal Power Plants

Table 5a: Variations in heat rate

Variation in he at rate with load				
Avg% Heat Rate increase per% of PLF Drop	Plant 1	Plant 2	Plant 3	Avg% increase in Heat Rate per% PLF drop
Heat Rate at 100% MCR (Load)	2207	2156	2256	0.17
Heat Rate at 80% MCR (Load)	2230	2179	2279	
Heat Rate at 70% MCR (Load)	2295	2244	2344	
Heat Rate at 60% MCR (Load)	2361	2310	2410	
Heat Rate at 50% MCR (Load)	2427	2376	2476	0.28
Heat Rate at 30% MCR (Load)	2604	2553	2653	

Table showing changes in Heat Rate in case PLF variations, Source - OEM curves and inputs from literature review, (Hasananto et al. 2021)

Table 5b: Variations in APC

Variation in APC with Load	
5% Change in PLF	0.2% increase in APC

Table showing changes in APC in case of PLF variations, Source - OEM curves and inputs from literature review

Table 6a: No of reserve shutdowns

Number of reserve shutdowns			
PLF%	Plant 1	Plant 2	Plant 3
50	4	4	4
45	6	6	6
40	8	8	8
35	9	9	9
30	10	10	10
25	12	12	12

Table showing Reserve Shutdowns. Source- Data from operating power plants and inputs from literature review

the customer. When the PLF gets too low, the power plants will actually operate in a *negative marginal contribution zone* because efficiency parameters worsen badly due to the lower PLF. In present operating conditions of low PLF in India, seldom does a plant make a positive marginal contribution. Many are operating under negative marginal contribution. Faced with such situation, at the representation of power producers, the regulator has provided some margins (allowance) in the efficiency parameters, if a plant has to operate at lower loads caused by grid conditions. However, our calculations show that such margins may not be inadequate because the plants are facing lower and lower PLFs and higher and higher Reserve Shut Downs. Moreover, there is also loss of Generation Incentive to the producer if PLF goes down. (The Generation Incentive is provided in tariff to reward power producers if they are able to run their plants at high Plant

Load Factors (PLF) i.e., >85%). Based on these premises, we state the base assumptions for determining the tariff of three different types of sample thermal power units in Table 1.

Table 6b: Oil consumption in start up

	Start up fuel costs		
	Plant 1	Plant 2	Plant 3
Oil Consumption (KL)	200	300	150

Table showing Oil Consumption. Source- Data taken from the operating power plants and inputs from literature review

Based on our assumptions, we determine the tariffs (Fixed Cost, Variable Cost and Total Cost) of the three different sample pants in the tables (Tables 2-4).

Cost of Start-ups-Reserve Shutdowns

When the requisition of power from a thermal power station is so low that the plant cannot remain stable at such load (currently, this level is fixed by the regulator at 55% of full load capacity), the plant might be ordered by grid operator to shut down till demand picks up. Such a situation is called Reserve Shutdown

Table 7a: Plant-1 (660 MW-Supercritical)

Financial Impact Due to low PLF-Plant -1-660 MW Unit (Per annum)									
S. No.	PLF (%)	Heat Rate (Kcal/Kwhr)	APC (%)	Actual Variable Cost (VC) Rs US$	Diff between Actual Variable Cost and Normative ECR (VC-Normative ECR) Rs US$	Marginal Profit//Loss (-) Assumptions- (i) only 80% of loss will be covered by Tariff if PLF goes below 55% (ii) Any additional gain will be shared in 50-50 ratio)-Rs Lacs US$ Mn	Incentive Loss (Rate assumed @53 Piase/KwHr (Avg of Peak and Off peak Hours) Rs Lacs US$ Mn	Start-up Costs if Reserve Shutdown is required -Assumption- Only 80% cost will be covered by Tariff Rs Lacs US$ Mn	Total Gain/Loss for one Unit Rs Lacs US$ Mn
1	100	2207	5.50	1.437 0.0193	0.123 0.0016	3552 4.7672	4596 0.6170		8148 10.9369
2	95	2226	5.75	1.453 0.0195	0.107 0.0014	2938 3.9442	3064 0.4113		6003 8.0573
3	90	2245	6.00	1.469 0.0197	0.091 0.0012	2366 3.1763	1532 0.2057		3898 5.2328
4	85	2264	6.25	1.485 0.0199	0.075 0.0010	1836 2.4643			1836 2.4643
5	80	2283	6.50	1.502 0.0202	0.058 0.0008	1348 1.8094			1348 1.8094
6	75	2302	6.75	1.519 0.0204	0.042 0.0006	903 1.2126			903 1.2126
7	70	2322	7.00	1.535 0.0206	0.025 0.0003	503 0.6749			503 0.6749
8	65	2342	7.25	1.552 0.0208	0.008 0.0001	147 0.1974			147 0.1974
9	60	2362	7.50	1.570 0.0211	−0.009 −0.0001	0 (Compensated by tariff)			0 0.0000
10	55	2395	7.75	1.596 0.0214	−0.035 −0.0005	0 (Compensated by tariff)			0 0.0000
11	50	2428	8.00	1.622 0.0218	−0.062 −0.0008	−357 −0.4791		−82 −0.1095	−438 −0.5886
12	45	2462	8.25	1.649 0.0221	−0.089 −0.0012	−461 −0.6187		−122 −0.1643	−583 −0.7829
13	40	2497	8.50	1.676 0.0225	−0.116 −0.0016	−536 −0.7194		−163 −0.2191	−699 −0.9385
14	35	2532	8.75	1.704 0.0229	−0.144 −0.0019	−581 −0.7804		−184 −0.2464	−765 −1.0269
15	30	2567	9.00	1.732 0.0232	−0.172 −0.0023	−596 −0.8005		−204 −0.2738	−800 −1.0743
16	25	2603	9.25	1.761 0.0236	−0.201 −0.0027	−580 −0.7786		−245 −0.3286	−825 −1.1072
Loss of Revenues per annum if the PLF drops from 90% to 35% Rs Lacs US$ Mn									4663 6.2597
Reduction in Profit if the PLF drops from 90% to 35% as% of ROE									31%

Table showing Financial Impact of lower of PLF-(Marginal Contribution, Incentives and Startup Costs variation due to PLF)- 800 MW Plant-Source - Data from operating power plants, CERC tariff provisions, Grid Code, literature review and calculations done by this research

(RSD). In such a condition, the power producer is entitled to start-up costs (cost of oil). However, as in the case of other tariff margins, the relief provided in tariff does not fully compensate for the oil required to start up the power station because the shutdowns end up being more than permitted RSDs. Table 6a and b below depict the predicted number of Reserve Shutdowns and consequent start-up oil consumption caused due to lowering of PLF.

5. FINANCIAL IMPACT (ON REVENUE) DUE TO VARIATION IN CAPACITY UTILISATION (PLF)

The Financial Impact (on Revenue and ROE) of lower PLFs in case of the three different types of plants considered in our study has been shown in the tables 7a-c. Three components affecting

Table 7b: Plant-2 (800 MW-Supercritical)

Financial Impact Due to low PLF-Plant -1-800 MWUnit (Per annum)									
Sl No.	PLF (%)	Heat Rate (Kcal/ Kwhr)	APC (%)	Actual Variable Cost (VC) Rs US$	Diff between Actual Variable Cost and Normative ECR (VC-Normative ECR) Rs US$	Marginal Profit//Loss (-) Assumptions- (i) only 80% of loss will be covered by Tariff if PLF goes below 55% (ii) Any additional gain will be shared in 50-50 ratio)-Rs Lacs US$ Mn	Incentive Loss (Rate assumed @53 Piase/ KwHr (Avg of Peak and Off peak Hours) Rs Lacs US$ Mn	Start-up Costs if Reserve Shutdown is required -Assumption- Only 80% cost will be covered by Tariff Rs Lacs US$ Mn	Total Gain/ Loss for one Unit Rs Lacs US$ Mn
1	100	2156	5.50	1.524 0.0205	0.093 0.0012	3255 4.3693	5571 0.7478		8826 11.8476
2	95	2174	5.75	1.541 0.0207	0.076 0.0010	2532 3.3986	3714 0.4986		6246 8.3841
3	90	2193	6.00	1.558 0.0209	0.059 0.0008	1861 2.4986	1857 0.2493		3719 4.9914
4	85	2211	6.25	1.576 0.0211	0.042 0.0006	1245 1.6708			1245 1.6708
5	80	2230	6.50	1.593 0.0214	0.024 0.0003	683 0.9163			683 0.9163
6	75	2249	6.75	1.611 0.0216	0.007 0.0001	176 0.2366			176 0.2366
7	70	2268	7.00	1.629 0.0219	−0.011 −0.0001	0 (Compensated by tariff)			0 0.0000
8	65	2288	7.25	1.647 0.0221	−0.029 −0.0004	0 (Compensated by tariff)			0 0.0000
9	60	2307	7.50	1.665 0.0223	−0.047 −0.0006	0 (Compensated by tariff)			0 0.0000
10	55	2339	7.75	1.692 0.0227	−0.075 −0.0010	0 (Compensated by tariff)			0 0.0000
11	50	2372	8.00	1.720 0.0231	−0.103 −0.0014	−722 −0.9694		−122 −0.1643	−845 −1.1337
12	45	2405	8.25	1.749 0.0235	−0.132 −0.0018	−830 −1.1138		−184 −0.2464	−1013 −1.3602
13	40	2439	8.50	1.778 0.0239	−0.161 −0.0022	−900 −1.2082		−245 −0.3286	−1145 −1.5368
14	35	2473	8.75	1.807 0.0243	−0.190 −0.0026	−932 −1.2513		−275 −0.3697	−1208 −1.6210
15	30	2508	9.00	1.837 0.0247	−0.220 −0.0030	−925 −1.2419		−306 −0.4107	−1231 −1.6526
16	25	2543	9.25	1.868 0.0251	−0.251 −0.0034	−878 −1.1784		−367 −0.4929	−1245 −1.6713
Loss of Revenues per annum if the PLF drops from 90% to 35% Rs Lacs									4926
US$ Mn									6.6124
Reduction in Profit if the PLF drops from 90% to 35% as% of ROE									22%

Table showing Financial Impact of lower of PLF-(Marginal Contribution, Incentives and Startup Costs variation due to PLF)- 800 MW Plant- - Source - Data from operating power plants, CERC tariff provisions, Grid Code, literature review and calculations done by this research

Revenue and ROE tabulated here are-Difference between Actual Variable Cost and Normative Energy Charge Rate (ECR) due to reduced PLF (also referred to as Marginal Contribution), (i) Loss of Generation Incentive due to PLF below 85% and (ii) Start-up Costs if the unit has to go in Reserve Shut Down (RSD) due to very low PLF levels. It is pertinent to add here that regulator has provided some relaxation in tariff anticipating such losses. However, the relaxation given by regulator in Heat Rate and APC is anticipated to cover the losses only up to the PLF level of 55%. Below 55% level, Heat Rate deteriorates sharply and APC also increases. Such losses are not compensated by the tariff. In the case of a Reserve Shutdown, the cost of start-up oil is compensated only to the extent of 80% of the actual expenditure because RSDs are anticipated to be more than what is allowed by the tariff on per annum basis. These assumptions are based on tariff provisions and the actual experience of the units under consideration.

Table 7c: Plant-3 (500 MW- Subcritical)

Financial Impact Due to low PLF-Plant -1-500 MW- Unit (Per annum)									
S. No.	PLF (%)	Heat Rate (Kcal/ Kwhr)	APC (%)	Actual Variable Cost (VC) Rs US$	Diff between Actual Variable Cost and Normative ECR (VC-Normative ECR) Rs US$	Marginal Profit//Loss (-) Assumptions- (i) only 80% of loss will be covered by Tariff if PLF goes below 55% (ii) Any additional gain will be shared in 50-50 ratio)-Rs Lacs US$ Mn	Incentive Loss (Rate assumed @53 Piase/ KwHr (Avg of Peak and Off peak Hours) Rs Lacs US$ Mn	Start-up Costs if Reserve Shutdown is required -Assumption- Only 80% cost will be covered by Tariff Rs Lacs US$ Mn	Total Gain/ Loss for one Unit Rs Lacs US$ Mn
1	100	2256	5.75	1.447 0.0194	0.093 0.0012	2030 2.7252	3482 0.4674		5512 7.3991
2	95	2275	6.00	1.463 0.0196	0.077 0.0010	1596 2.1427	2321 0.3116		3918 5.2587
	90	2295	6.25	1.479 0.0199	0.061 0.0008	1194 1.6022	1161 0.1558		2354 3.1602
4	85	2314	6.50	1.496 0.0201	0.044 0.0006	823 1.1045			823 1.1045
5	80	2334	6.75	1.512 0.0203	0.028 0.0004	484 0.6502			484 0.6502
6	75	2354	7.00	1.529 0.0205	0.011 0.0001	179 0.2404			179 0.2404
7	70	2374	7.25	1.546 0.0208	−0.006 −0.0001	0 (Compensated by tariff)			0 0.0000
8	65	2394	7.50	1.563 0.0210	−0.023 −0.0003	0 (Compensated by tariff)			0 0.0000
9	60	2414	7.75	1.580 0.0212	−0.041 −0.0005	0 (Compensated by tariff)			0 0.0000
10	55	2448	8.00	1.607 0.0216	−0.067 −0.0009	0 (Compensated by tariff)			0 0.0000
11	50	2482	8.25	1.633 0.0219	−0.093 −0.0013	−408 −0.5483		−61 −0.0819	−470 −0.6305
12	45	2517	8.50	1.660 0.0223	−0.120 −0.0016	−474 −0.6366		−92 −0.1232	−566 −0.7598
13	40	2552	8.75	1.688 0.0227	−0.148 −0.0020	−518 −0.6952		−122 −0.1643	−640 −0.8595
14	35	2588	9.00	1.716 0.0230	−0.176 −0.0024	−539 −0.7235		−138 −0.1848	−677 −0.9083
15	30	2624	9.25	1.744 0.0234	−0.204 −0.0027	−537 −0.7205		−153 −0.2054	−690 −0.9259
16	25	2661	9.50	1.773 0.0238	−0.233 −0.0031	−511 −0.6856		−184 −0.2464	−694 −0.9320
Loss of Revenues per annum if the PLF drops from 90% to 35% Rs Lacs US$ Mn									3031 4.0685
Reduction in Profit if the PLF drops from 90% to 35% as% of ROE									26%

Table showing Financial Impact of lower of PLF-(Marginal Contribution, Incentives and Startup Costs variation due to PLF)- 500 MW Plant- - Source - Data from operating power plants, CERC tariff provisions, Grid Code, literature review and calculations done by this research

6. CONCLUSION

The PLF of thermal power plants in India is going down due to changes in electricity market. This situation has substantial bearing on the financials of thermal power plants. In this paper, we have calculated the direct financial impact due to lowering down of PLF on three different types of power plant units (660 MW, 800 MW, 500 MW). The loss of Revenue and Return on Equity (ROE) occurring due to deterioration in performance parameters like Heat Rate, APC, Generation Incentives, and Startup Costs have been considered here. Calculations show that if PLF drops from 90% to 35%, it will result in reduced Revenues by Rs 4663 Lacs/US$ 6.2597 Mn, Rs 4926 Lacs/US$ 6.6124 Mn and Rs 3031 Lacs/US$ 4.0685 Mn and reduced ROE by 31%, 22%, and 26% respectively for one unit of 660 MW, 800 MW and 500 MW respectively (on annual basis). Taking an average (of the three typical plants), the ROE will get impacted to the tune of about 26%, if PLF drops from 90% to 35%, Attention needs to be given to this aspect to keep the thermal power plants economically sustainable, because they are critical for survival of the grid in the foreseeable future.

One suggested way is that the services being provided by the thermal power plant through ramp up and ramp down (flexibilization), may be recognized as Ancillary Services. This will help thermal power to survive this special situation.

This research has the following limitations, all of which can be future areas of research.

1. This research has not studied the capital infusion required to make the thermal power plants worthy of flexibilization.
2. This research has not considered the long-term effect on power plant equipment health due to the cyclic ramp-up and ramp-down of loads and its financial consequences.
3. This research has considered thermal power plants that operate under the regulated tariff mechanism. For plants operating in merchant mode, a separate study may be required.

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