REAL-TIME COST ESTIMATION OF THERMAL POWER STATIONS USING MATLAB

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Abstract:

The cost generated per unit in a thermal power station is dependent on fixed cost and variable cost. The duty of an electrical engineer is to generate the power without outage of a power and at the same time the cost of power generated per unit is as low as possible. An engineer can able to reduce the cost of generated power only when the engineer knows on what factors the cost of a generated power depends. Hence the engineer must know on what factors the fixed cost and variable cost may depend. The Central Electricity Regulatory Commission (CERC) has the power of deciding the tariff or electricity generated by various power stations [1]. Tariff is calculated on the basis of fixed cost and variable cost. The power plants have fixed and variable costs. The fixed cost dependent on return on equity, interest on capital loan, depreciation, interest on working capital, operation& maintenance cost, cost of secondary oil. The variable cost dependent on primary fuel costs, secondary fuel oil consumption and auxiliary energy consumption In the Availability Tariff mechanism, the fixed and variable cost components are treated separately.. Cost index is a useful parameter to monitor and compare cost of energy for specific products manufactured by the industry. In the event of an increase or decrease (due to perhaps a conservation measure) in cost index, the particular source can be investigated immediately. In this paper, a case study of three Power Stations namely Simhapuri Thermal Power Station, Nellore, Andhra Pradesh and Koradi thermal power station, Koradi, Nagpur and Sri Damodaram Sanjeevaiah Thermal Power Station, Muthukur, Nellore, Andhra Pradesh has been considered and Tariff calculations, Cost Index of thermal power plants have been implemented with MATLAB Environment and the effectiveness of the work will be verified and compared with real time analysis. The generated program in MATLAB can be applicable for any capacity of Thermal power station and any number of power stations.

***Keywords**:*

Plant load factor, fixed cost and variable cost, Generation Cost, Cost Index, Electricity Act, Electricity tariff, MATLAB

1. Introduction:

In most industrialized countries, electric power is provided by generating facilities that serve a large number of customers. These generating facilities, known as central station generators, are often located in remote areas, far From the point of consumption. The economics of central station generation is largely a matter of costing. As with any other production technology [2-3], central station generation entails fixed and variable costs. The fixed costs are relatively straightforward, but the variable cost of power generation is remarkably complex. The fixed costs of power generation are essentially capital costs and land. The capital cost of building central station generators vary from region to region, largely as a function of labor costs and "regulatory costs, "which include things like obtaining siting permits, environmental approvals, and so on. It is important to realize that building central station generation takes an enormous amount of time. In a state such as Gujarat (where building power plants is relatively easy), the time-to-build can be as short as two years. In Delhi, where bringing new energy infrastructure to fruition is much more difficult (due to higher regulatory costs), the time-to-build can exceed ten years. Table 1.1 shows capital cost ranges for several central-station technologies. Although the ranges in Table 1.1 are quite wide, they still mask quite a bit of uncertainty in the final cost of erecting power plants.

Operating costs for power plants include fuel, labor and maintenance costs [4-5]. Unlike capital costs which are "fixed" , a plant's total operating cost depends on how much electricity the plant produces. The operating cost required to produce each MWh of electric energy is referred to as the "marginal cost." Fuel costs dominate the total cost of operation for fossil-fired power plants. For renewable, fuel is generally free (perhaps with the exception of biomass power plants in some scenarios);and the fuel costs for nuclear power plants are actually very low. For these types of power plants, labor and maintenance costs dominate total operating costs.

In general, central station generators face a tradeoff between capital and operating costs. Those types of plants that have higher capital costs tend to have lower operating costs. Further, generators which run on fossil fuels tend to have operating costs that are extremely sensitive to changes in the underlying fuel price. The right-most column of Table 1.1 shows typical ranges for operating costs for various types of power plants.

From Table 1.1, the apparent tradeoff between capital and operating cost, comparing the overall costs of different power plant technologies is not always straight forward. Often times [5-6], you will see power plants compared using a measure called the "Levelized Cost of Energy" (LCOE), which is the average price per unit of output needed for the plant to break even over its operating lifetime.

Table1.1: Typical capital and operating costs for power plants. [9]

Technology	***Capital Cost ($/kW)***	***Operating Cost ($/kWh)***
Coal-fired combustion turbine	500— 1,000	0.20—0.04
Natural gas combustion turbine	400—800	0.04—0.10
Coal gasification combined - cycle (IGCC)	1,000—1,500	0.04—0.08
Natural gas combined-cycle	600— 1,200	0.04—0.10
Wind turbine	1,200—5,000	Lessthan0.01
Nuclear	1,200—5,000	0.02—0.05
Photovoltaic Solar	4,500andup	Lessthan0.01
Hydroelectric	1,200—5,000	Lessthan0.01

In general, all generators share the following characteristics which influence the plant's operations:

- Ramp rate
- Ramp time
- Capacity
- Lower Operating Limit (LOL)
- Minimum Run Time
- No-Load Cost
- Start-up and Shut-down Costs

The minimum run time and ramp times determine how flexible the generation source is; these vary greatly among types of plants and are a function of regulations, type of fuel, and technology. Generally speaking, plants that are less flexible (longer minimum run times and slower ramp times) serve base load energy, while plants that are more flexible (shorter minimum run times and quicker ramp times) are better-suited to filling peak demand. Table 1.2 and Figure 1.3 show approximate (order-of-magnitude) minimum run times and ramp times for several generation technologies. It is important to realize that, in some sense, these are "soft" constraints. It is possible, for example, to run a nuclear plant for five hours and then shut it down. Doing this, however, imposes a large cost in the form of wear and tear on the plant's components. This table can also shown in fig

Table1.2: Typical ramp and run times for power plants.

Technology	***Ramp Time***	***Min. Run Time***
Simple-cycle combustion turbine	Minutes to hours	minutes
Combined-cycle combustion turbine	hours	Hours to days
Nuclear	days	weeks to months
Wind Turbine (includes offshore wind)	minutes	none
Hydro Electric (includes pumped Storage)	minutes	none

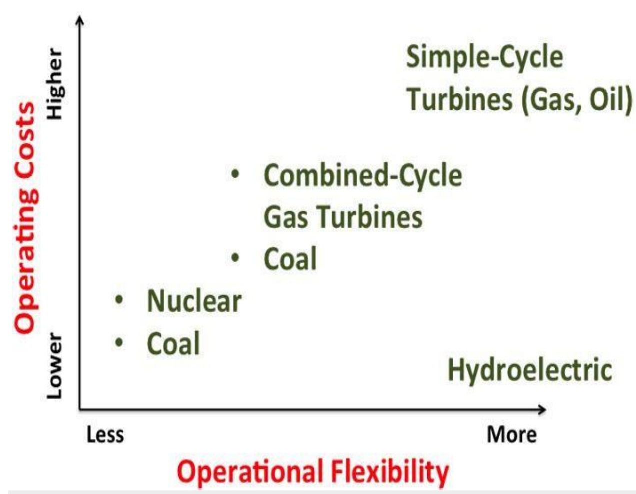

Figure1.1: Relative comparison of operating cost and Operational flexibility for Differen Power plant technologies

From fig 1.1, the cost structure for transmission and distribution is different than for power generation, since there is no fuel cost involved with operating transmission

And distribution wires. At the margin, the cost of loading a given transmission line with additional electricity is basically zero (unless the line is operating at its rated capacity limit)[5-7]. Capital cost thus dominates the economics of transmission and distribution.

2. Tariff calculations

The Electricity Act (supply) 1948 has been replaced by Electricity Act 2003 by Government of INDIA [3]. According to this act, the rights of determination of tariffs, for the power generated by central, state and private power generating stations, based on specific terms and conditions has been given to the Central Electricity Regulatory Commission (CERC).Section 61 of the Act empowers the Commission to specify and regulate the terms and conditions for determination of tariff in accordance with the provisions of the said section along with the National Electricity Policy and Tariff Policy. As per the Electricity Act 2003, the CERC in March 2004, had put forth tariff regulations for the FY 2004-09 and on expiry of this, CERC had notified new tariff regulations on January19, 2009 for the next regulatory period FY 2009-14. The new regulations were applicable to all power generating stations (excluding stations based on non-conventional energy sources) and transmission licensees, except those entities which are determined through bidding process in accordance with the guide lines issued by the central government.

Operation and Maintenance Expenses such as expenditure incurred for operation and maintenance of the project, or part thereof, and includes the expenditure on manpower, repairs, maintenance spares, consumables, insurance and overheads but excludes fuel expenses and water charges; The CERC has specified O&M Costs for thermal power stations on the normative parameters (Rs. lakh/MW), depending on the class of the machine installed by the power station. The normative O and M expenses in table 2.1 .

Table2.1. Operations & Maintenance Costs in Rs: Lakh/MW for different capacity power plants.

Year	***200MW***	***350MW***	***500MW***	***600MW & Above***
2011-2012	20.34	17.88	14.53	13.08
2012-2013	21.51	18.91	15.36	13.82
2013-2014	22.74	19.99	16.24	14.62
2014-2015	23.90	19.95	16.00	14.40
2015-2016	25.40	21.21	17.01	15.31
2016-2017	27.00	22.54	18.08	16.27
2017-2018	28.70	23.96	19.22	17.30
2018-2019	30.51	25.47	20.43	18.38

From this table, the data corresponding to Operations & Maintenance Costs in Rs: Lakh/MW for different capacity power plants for the financial year 2015-2016 was considered.

Auxiliary Energy Consumption in relation to a period in case of a generating station means the quantum of energy consumed by auxiliary equipment of the generating station, such as the equipment being used for the purpose of operating plant and machinery including switch yard of the generating station and the transformer losses with in the generating station, expressed as a percentage of the sum of gross energy generated at the generator terminals of all the units of the generating station: Provided that auxiliary energy consumption shall not include energy consumed for supply of power to housing colony and other facilities at the generating station and the power consumed for construction works at the generating station;

Declared Capacity in relation to a generating station means, the capability to deliver ex-bus electricity in MW declared by such generating station in relation to any time-block of the day as defined in the Grid Code or whole of the day, duly taking into account the availability of fuel or water, and subject to further qualification in the relevant regulation;

Expenditure Incurred means the fund, whether the equity or debt or both, actually deployed and paid in cash or cash equivalent, for creation or acquisition of a useful as set and does not include commitments or liabilities for which no payment has been released;

Generating Unit in relation to a thermal generating station(other than combined cycle thermal generating station)means steam generator, turbine-generator and auxiliaries, or in relation to a combined cycle thermal generating station, means turbine-generator and auxiliaries; and in relation to a hydro generating station means turbine-generator and its auxiliaries;

Gross Calorific Value in relation to a thermal generating station means the heat produced in k Cal by complete combustion of one kilo gram of solid fuel or one liter of liquid fuel or one standard cubic meter of gaseous fuel, as the case may be;

Gross Station Heat Rate means the heat energy in put in k Cal required to generate one kWh of electrical energy at generator terminals of a thermal generating station;

Generating Station means any station for generating electricity, including any building and plant with step-up transformer, switch-gear, switch yard, cables or other appurtenant equipment, if any, used for that purpose and the site there of; as it intended to be used for a generating station, and any building used for housing the operating staff of a generating station, and where electricity is generated by water-power, includes penstocks, head and tail works, main and regulating reservoirs, dams and other hydraulic works, but does not in any case include any substation[6];

Energy Charges (for recovery of Primary fuel costs) Energy charges for thermal power stations are linked to the normative operational parameters as specified by the regulator[7]. The normative parameters are given in table 2.2.

Table. 2.2 Normative Operational Parameters for Coal based Thermal Power Projects

s.no	***Norms for operation***	***Factor***
1.	Plant Availability Factor	Utilization Factor is: Month:98.46 Year:93.56
2.	Gross Station Heat Rate For4*150MW above	2685K.Cal/Kwh; Efficiency:83% (150*4=600MWAVG Heat rate)
3.	Secondary fuel oil consumption Coal based	Year:293.43KL
4.	Auxiliary power Consumption	These are two types: With G T losses: Day: 1.105 MU (10.21%); Month: 33.556 MU (10.18%); Year: 431.728 MU (10.49%) Without GT losses: Day: 1.076 MU (9.95%); Month: 32.67 MU (9.91%); Year: 420.93 MU (10.23%).

Installed Capacity means the summation of the name plate capacities of all the units of the generating station or the capacity of the generating station reckoned at the generator terminals, as may be approved by the Commission from time to time;

Kilowatt- Hour means a unit of electrical energy, measured in one kilowatt or one thousand watts of power produced or consumed over a period of one hour;

Normative Annual Plant Availability Factor in relation to a generating station means the availability factor as specified in Regulation 36 and 37 of these regulations for thermal generating station and hydro generating station respectively;

Plant Availability Factor in relation to a generating station for any period means the average of the daily declared capacities (DCs) for all the days during the period expressed as a percentage of the installed capacity in MW less the normative auxiliary energy consumption;

Plant Load Factor in relation to thermal generating station or unit for a given period means the total sent out energy corresponding to scheduled generation During the period, expressed as a percentage of sent out energy corresponding to installed capacity in that period

And shall be computed in accordance with the Following formula:

$$PLF=10000\text{x}\sum_{i=1}^{N}SG_i/\{N\text{x}IC\text{x}(l00-AUX_n)\}\%$$

Where,

IC=Installed Capacity of the generating station or unit in MW,

SG_i=Scheduled Generation in MW for the i^{th} time block of the period,

N= Number of time blocks during the period, and

AUX_n=Normative Auxiliary Energy Consumption as a percentage of gross energy generation;

Thermal Generating Station means a generating station or a unit there of that generates electricity using fossil fuels such as coal, lignite, gas, liquid fuel or combination of these as its primary source of energy;

Useful life in relation to a unit of a generating station and transmission system from the COD shall mean the following, namely: Coal/Lignite based thermal generating station25years [8].

Transmission line (including HVAC & HVDC)

Procedure Regulations means the Central Electricity Regulatory Commission (Procedure for making of application for determination of tariff, publication of the application and other related matters) Regulations, 2004, as amended from time to time or any statutory re- enactment thereof.

3. Results and discussions

A MATLAB Program was written by considering the real data of three Coal Based Thermal Power Stations. The following table shows operational parameters of Coal based Thermal Power Station.

Table3.1: Operational Parameters for Coal based Thermal Power Station

S.no	***Particulars***	***Plant-1***	***Plant-2***	***Plant-3***
1	Plant Capacity	660MW	600MW	1600MW
2	Capital cost	6 Cr/MW	5Cr/MW	5.4 Cr/Mw
3	Debt equity ratio	70:30	70:30	70:30
4	Return on equity	15.50%	15.50%	15.50%
5	Interest on loan	10%	10%	10%
6	Working capital	396Cr	300Cr	960Cr

7	Interest on Working capital	10%	10%	10%
8	Rate of Depreciation	5.28%	5.28%	5.28%
9	O & M cost	15.62	15.31	16.27
10	Plant Load Factor	85%	78.11%	90%
11	Plant Availability Factor	85%	93.56%	90%
12	Specific Oil Consumption	1 ml/KWh	1 ml/KWh	2 ml/KWh
13	Price of Oil	Rs. 35000 /KL	56000	Rs. 35000 /KL
14	Gross Calorific value of Oil	10000 Kcal/L	92000	10000 Kcal/L
15	Station Heat Rate	2425 Kcal/Kg	2685 Kcal/Kg	2302 Kcal/Kg
16	Cost of Coal	Rs 2000 /Tonnes	Rs 3036 /Tonnes	Rs 2000 /Tonnes
17	Auxiliary Power	6.5%	10.18%	6.5%
18	Plant Life	25 Years	25 Years	25 Years
19	Gross Calorific value of Coal	3800 Kcal/Kg	4200 Kcal/Kg	3500 Kcal/Kg
20	Generation Cost	3.55 Rs/Unit	3.25 Rs/Unit	3.00 Rs/Unit

From table.3.1 is used for calculation of parameters whichareshownintable.3.2withthatdatatheproposed program was tested and the corresponding results are shown in table.3.2.

Table3.2: Calculated Parameters for Coal based Thermal Power Station

S. no	Parameters	Power Station-1	Power Station-2	Power Station-3
1	CAP	660	600	1600
2	TCC	3960	3000	8604
3	DA	2772	2100	6048
4	EA	1188	900	2592
5	ROEA	184.14	139.50	401.76
6	IOLA	277.20	210.00	604.8
7	IOWCA	39.60	30.00	96
8	DCA	209.09	158.40	456.19
9	TOAMC	103.09	91.86	260.32
10	TFC	8131200000	6297600000	18190720000
13	COPL	35.00	56.00	35
14	COOC	0.04	0.06	0.07
15	GCVOOIML	10.00	92.00	10
16	HCOO	10.00	92.00	20
17	HCOC	2415.00	2593.00	2282
18	SCC	0.64	0.62	0.65
19	COCINKG	2.00	3.04	2.0
20	COSOC	1.27	1.87	1.30
21	TVC	1.31	1.93	1.37
22	FVC	1.40	2.15	1.47
23	COPGPU	3.05	3.43	2.91
11	TPG	4914360000	4917513600	12614400000
12	FCPU	1.65	1.28	1.44

CAP: Capacity of a Power Station in MW
TCC: Total Capital Cost in Rs. Crores
DA: Debt Amount in Rs. Crores
EA: Equity Amount in Rs. Crores
ROEA: Return On Equity Amount in Rs. Crores IOLA: Interest on Loan Amount in Rs. Crores IOWCA: Interest on Working Capital Amount in Rs. Crores
DCA: Depreciation Cost Amount in Rs. Crores
TOAMC: Total Operation And Maintenance Cost in Rs. Crores
TFC: Fixed Cost Per All Units Of Power Generated in Rs. Crores
TPG: Total Power Generated in Million Units
FCPU: Fixed Cost Per Unit Of Power Generated in Rs
COPL: Cost Of Oil Per Lt in Rs
COOC: Cost Of Oil Consumption in Rs/Kwh
GCVOOIML: Gross Calorific Value Of Oil in milli Lts
HCOO: Heat Contribution Of Oil in Kcal/Kwh
HCOC: Heat Contribution Of Coal in Kcal/Kwh
SCC: Specific Coal Consumption in Kg/Kwh
COCINKG: Cost Of Coal in Rs Per Kilo Gram
COSOC: Cost Of Specific Oil Consumption in Rs
TVC: Total Variable Cost Of Power Generated Per Unit in Rupees
FVC: Final Variable Cost Of Power Generated Considering Auxiliary Power Per Unit in Rupees
COPGPU: Cost Of Power Generated Per Unit In Rupees

Table3.3: Generation Cost of a Power For different capacities of a Coal based Thermal Power Station

	Plant No	**Power Station-1**	**Power Station-2**	**Power Station-3**
	Capacity	660MW	600MW	1600MW
***GC**	MATLAB	3.43 Rs/Unit	3.05 Rs/Unit	2.91 Rs/Unit
	Power Plant	3.55 Rs/Unit	3.25 Rs/Unit	3.00 Rs/Unit

*GC=Generation Cost

WhileobservingtheTable3.3theGenerationcostfor three Power stations and generation cost will be lower for the Coal based Thermal Power Station compared to power plant and it shows that while increasing generation capacity the generation cost is decreasing the corresponding bar diagram as shown in figure3.1and3.2.

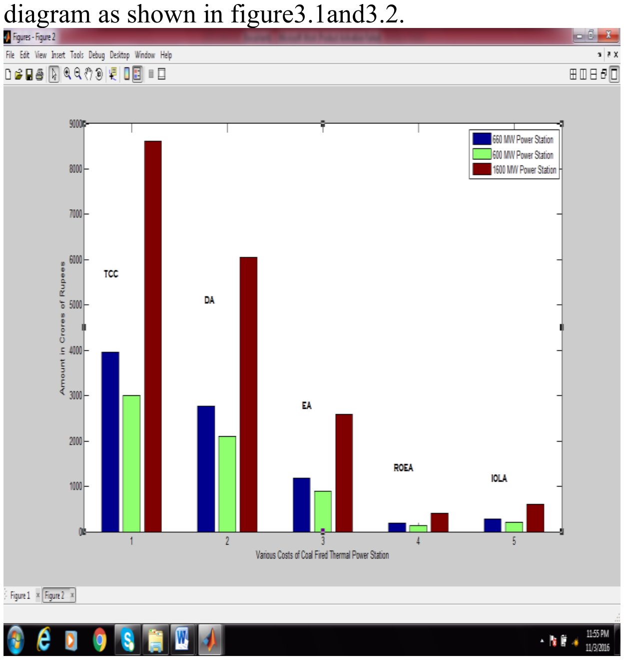

Fig3.1: Various Costs of a Coal Fired Thermal Station

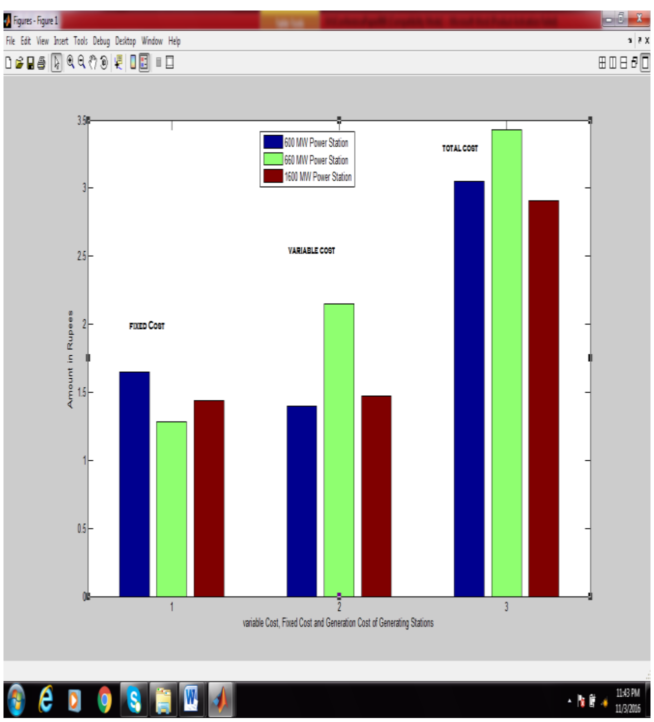

Fig3.2: Variable Cost, Fixed Cost and Total Generation Cost of Three Coal Fired Thermal Generating Stations.

From the Fig 3.1 and Fig 3.2, it was concluded that the generation cost will be lesser if the power station improve the Gross Calorific Value Of Oil, Heat Contribution Of Oil and Heat Contribution Of Coal. The Generation cost values shown in the figure shows that the generation cost of a Coal fired thermal power stations are low with increasing the capacity of a power station.

4. Conclusions

The proposed program is used to calculate the all the parameters to estimate the generation cost of a coal fired thermal power station for any capacity of generating station and any number of generating stations. The generation cost of a 600 MW, 660 MW and 1600MWCoal fired Thermal Power Station isRs.3.43, Rs. 3.05and Rs. 2.91per Unit respectively[9].By observing programming results the generation cost decreases with the higher capacity. This technique will also be extended to calculate the generation cost by virtually operating any change in the parameter which is not possible in practical case.

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