The Journal of CPRI,
Vol. 7, No. 1, March 2011 pp. 89–100

Enhancing Energy Efficiency of Auxiliary Power in a Coal - Fired Thermal Power Plant

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This paper describes the auxiliary power consumption in Indian coal-fired thermal power plants. The factors influencing the auxiliary power are discussed in detail increase in auxiliary power due to lower plant load factor causes for lower PLF are enumerated. The effect of poor coal quality on auxiliary power is discussed. The effect of operational optimization, adoption of new energy efficient technologies, design deficiencies, etc., is discussed in detail along with remedial measures to reduce the auxiliary power. The energy conservation measures reduce the auxiliary power of 210 MW power plant from 11.59 % to 8.50 % with a payback period of 1–5 years.

Keywords: *Auxiliary power, Energy efficiency, Plant load factor, Coal quality, Operational optimization.*

1.0 INTRODUCTION

The present total installed power-generation capacity in India is 182.7 GW, out of which 100 GW is from coal-based thermal power plant that forms 54.8 % of total installed capacity by 14 Dec. 2011 [1]. The auxiliary power used for coal-fired power plants varies for different plant sizes from 30 MW plant to 500 MW plants, varied between 5.2 % and 12.3 %. The estimated auxiliary power used for running the coal-fired power plants in India is about 8400 MW that forms about 8.4 % of coal-based power plants and 4.6 % of total installed capacity [2]. The thermal power plant availability depends largely upon the operational reliability of the auxiliary equipment and the capability of the auxiliary system [2,3]. The net overall efficiency of the coal-fired thermal power plants is in the range of 19.23 % (30 MW plant) and 30.69 % (500 MW plant). The auxiliary power consumption varies between 5.2 % (500 MW plant) and 12.3 % (30 MW plant). In India, the auxiliary power consumption is on higher side compared to other developed countries [4] due to poor plant load factor, the use of poor coal quality, excessive steam flow, excessive water flow, internal leakage in equipment, inefficient drives, lack of operational optimization of equipment, aging of equipment, hesitation in technology upgradation, obsolete equipment, design deficiencies, oversizing of equipment, use of inefficient controls, etc. If the auxiliary power of coal-fired stations in India is improved by 1 %, about 1000 MW of power can be pumped into grid with nominal investment for plant performance improvement.

The auxiliary power consumption can be reduced by improving the plant load factor, operational optimization, adoption of advanced control techniques and implementation of energy conservation measures. By reducing the auxiliary power, additional power will be available at grid.

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2.0 AUXILIARY POWER

The auxiliary power in a thermal power plant is the power used to drive the auxiliary equipment required to start and run the power plants. The auxiliary power is broadly categorized into in-house auxiliary power and out-lying (common) auxiliary power. The in-house auxiliary power is the power that is essential and directly related to the individual units; whereas, the out-lying (common) auxiliary power is the power used to run the common auxiliaries and other out-lying equipments.

Figure 1 gives the schematic of the in-house major auxiliary equipment in a typical coal-fired power plants

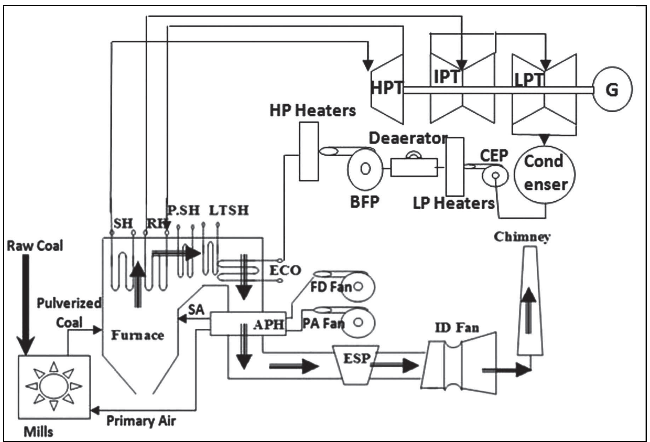


FIG .1 SCHEMATIC OF THERMAL POWER PLANT

The turbine auxiliary system accounts for about 52–58 % of the total auxiliary power followed by the boiler auxiliary equipment that accounts for about 30–35 % of the total auxiliary power for a typical 210 MW plant.

The out-lying (common) auxiliary power is used to run the common and out-lying auxiliaries which will be common for the total station or stage (more than one unit) and have to run irrespective of individual units.

The station auxiliary power is the difference between the gross energy generation and net energy export into the grid. The station auxiliary power (%) is computed by:

$$AP_{Station} = \left[\frac{\left(\sum_{l=1}^{l=q} (E_{UAT})_l + \sum_{j=1}^{l=p} (E_{ST})_j \right)}{\sum_{i=1}^{l=n} (E_G)_i} \right] \times 100 \quad (1)$$

where E_G is the gross energy generated by the individual unit in MWh/month; i is the number of generators in the station (i varies from 1 to n units); E_F is the energy sent (export) by the individual feeder into grid (MWh/month); k is the number of outgoing feeders in the station (k varies from 1 to m feeders); E_{ST} is the energy consumption by the station transformers (MWh/month); j is the number of station transformers in the station (j varies from 1 to p station transformers).

Generally, in many of the thermal power stations, the auxiliary power is computed by:

$$AP_{Station} = \left[\frac{\left(\sum_{k=1}^{k=m} (E_F)_k + \sum_{j=1}^{j=p} (E_{ST})_j \right)}{\sum_{i=1}^{i=n} (E_G)_i} \right] \times 100 \quad (2)$$

where E_{UAT} is the energy consumpted at individual UAT Bus (measurement on 6.6 kV Bus) (MWh/month) and l is the number of UAT Bus in the station (l varies from 1 to q UATs).

But in these calculations, the losses in Generator Transformers (GT), Unit Auxiliary Transformers (UAT) and excitation power to generators are not accounted. This loss will be varying in the range of 0.5–0.6 % of gross energy generation [5].

Computing the auxiliary power for individual units is rather difficult because it is difficult to proportionate the common auxiliary power (like power used by coal handling plant, ash handling plant, water treatment plant, air compressors, air-conditioning, lighting, etc.) on all the individual units. At some power plants, the total station auxiliary power is divided equally on all the units. Therefore, the unit auxiliary power (%) used by individual unit is computed as:

$$AP_{Unit} = \frac{\left(\sum_{l=1}^{l=q} (E_{UAT})_l + \frac{\sum_{j=1}^{l=p} (E_{ST})_j}{n} \right)}{E_G} \times 100 \qquad (3)$$

where n is the number of units in that station or stage.

This auxiliary power does not include the losses in GT, UAT and excitation power to generators (static excitation system). This loss will be varying in the range of 0.5–0.6 % of gross energy generation.

To account these losses and excitation power, the unit auxiliary power is computed by:

$$AP_{Unit} = \frac{\left(\sum_{l=1}^{l=q} (E_{UAT})_l + \frac{\sum_{j=1}^{l=p} (E_{ST})_j}{n} \right) + (L_{ST} + L_{UAT} + L_{EX}) \times 720}{E_G} \times 100 \qquad (4)$$

where L_{GT} is the loss in GT (MW) and is computed as:

$$L_{GT} = P_G - \left[P_{GTOP} + \sum_{j=1}^{l=p} (P_{UAT})_l + L_{UAT} + P_{Ex} \right] \qquad (5)$$

where P_G is the average power generation by unit in MW; P_{GTOP} is the power measured at GT secondary side in MW; P_{UAT} is the auxiliary power individual UATs in MW; P_{Ex} is the average excitation power for generator in MW; and L_{UAT} is the loss in all UATs in that particular unit (MW) and is computed as:

$$L_{UAT} = \frac{\sum_{l=1}^{l=q} \left(NL_{UAT} + FL_{UAT} \times \left(\frac{P_{UAT}}{PR_{UAT}} \right)^2 \right)_l}{1000} \qquad (6)$$

where NL_{UAT} is the no load loss of UAT (kW); FL_{UAT} is full load loss of UAT; P_{UAT} is the average power (MVA); and PR_{UAT} is rating of UAT (MVA).

As the size of the unit increases, the auxiliary power as a percentage of gross generation decreases. Therefore, the present trend has been to add larger unit sizes of 250 MW/500 MW/630 MW/800 MW capacities. Alongside the growth in unit sizes, considerable technological innovations have also been taken place in upgradation of auxiliary systems and improvement in designs of auxiliary equipment. These changes have increased the operational reliability and efficiency of the auxiliaries. Still the older units are operating with their age old technologies without technological change or advancement.

The variation of auxiliary power (%) with plant capacity (PC) can be computed by:

$$AP = 12.565 - (0.0193 \text{ x } PC) + (1.594 \text{ x } 10^{-5} \text{ x } PC^2) \qquad (7)$$

where AP is auxiliary power (percentage of gross energy generation) and PC is plant capacity or unit size (MW) varying between 30 MW and 500 MW.

The auxiliary power is measured at a plant load factor of 82.38 % (173 MW) in a case study for a typical 210 MW plant and the results are given in Table 1.

TABLE 1

AUXILIARY POWER OF 210 MW PLANT

Sl. No	Particulars	Actual Measured Power (kW)	Actual measured value, % of gross gen.	Possible value, % of gross gen.
01	BFP	5109.23	2.95	2.25
02	CEP	402.44	0.23	0.22
03	IDF	2357.66	1.36	0.90
04	FDF	551.32	0.32	0.24
05	PAF	1873.84	1.08	0.80
06	Mills	1158.71	0.67	0.45
07	In-house Aux.	11453.20	6.62	4.86
08	CHP	424.50	0.25	0.15
09	AHP	352.92	0.20	0.15
10	WTP and RWP	205.90	0.12	0.08
11	Air Compressor	162.89	0.09	0.07

12	CWP CTLP and CT	3989.30	2.31	1.45
13	GSP/ACW	722.27	0.42	0.35
14	Out-lying Aux.	5857.78	3.39	2.25
15	Excitation power	595.00	0.34	0.34
16	GT losses	448.64	0.26	0.26
17	Other LT and losses	1355.69	0.78	0.70
18	Total	19710.31	11.39	8.41
19	Abnormal cyclic operations	344	0.20	0.09
20	Total annual station auxiliary power	20054.31	11.59	8.50

The total in-house auxiliary power is 10.79 % of gross energy generation and is on higher side due to higher power consumption at ID fans, BFPs, etc. The total net auxiliary power considering GT losses, excitation power and abnormal cyclic operation is 11.59 % of gross energy generation. The overall auxiliary power is higher than the normative figure given by Central Electricity Regulatory Commission (CERC) of 8.5 % for 200 MW.

3.0 FACTORS RESPONSIBLE FOR HIGH AUXILIARY POWER

The factors responsible for high auxiliary power consumption in a coal-fired thermal power plant can broadly be classified into three categories:

(a) Plant-specific factors

(b) External factors

(c) Grid-specific factors

3.1 Plant Specific Factors

Plant-specific factors are the factors that are unit specific and are directly related with performance and operation of the plant or unit. These factors can be further classified into:

(a) Plant load factor

(b) Specific fuel consumption

(c) Equipment oversizing

(d) Technology

(e) Control and Instrumentation

(f) Operational optimization

(g) Equipment efficiency

Some of the important plant-specific factors are discussed below.

3.1.1 Plant Load Factor

The Plant Load Factor (PLF) is the important performance parameter to judge the healthiness and condition of the power plant and computed as:

$$PLF = \frac{EG}{PC \times 8760} \times 100 \qquad (8)$$

where EG is energy generated (MWh/year).

The instantaneous plant load factor (%) is computed by

$$PLF = \frac{P_{Gen}}{P_{rating}} \times 100 \qquad (9)$$

The percentage of auxiliary power with gross energy generation is greatly influenced by PLF. Common auxiliary equipment will draw the same power at partial plant load and some of the in-house equipment does not draw power proportional to the plant load. According to the plant performance reports published by ICRA, 2003 [6], MECON Ltd. report for MSPGCL plants, 2007 [7], RTPS, 2008 [8], DVC, 2005 [9], the percentage of auxiliary power varies with PLF for 210 MW plants. At lower plant load factor, the percentage of auxiliary power is on higher side.

The variation of in-house, out-lying and total auxiliary power with plant load factor for a typical 210 MW plant is presented in Figure 2. The variations in in-house, out-lying and total auxiliary power (%) are curve-fitted to:

$$AP = 218.34 \times PLF^{-0.696} \qquad (10)$$

$$AP_{in-house} = 103.81 \times PLF^{-0.594} \quad (11)$$

$$AP_{out-lying} = 209.75 \times PLF^{-0.997} \quad (12)$$

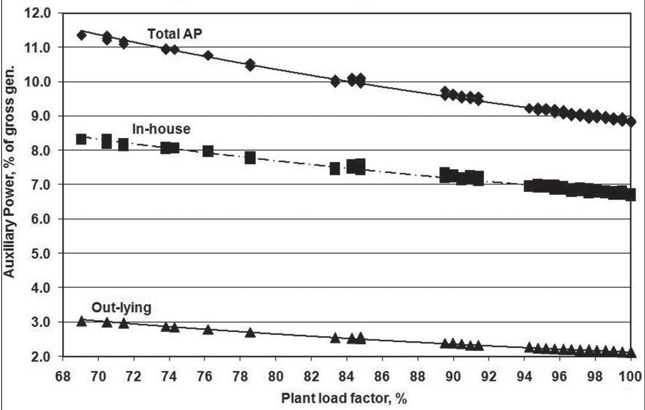


FIG. 2 VARIATIION AUXILIARY POWER WITH PLF

The deviation in auxiliary power is computed by differentiating the auxiliary power at actual operating condition at 100 % MCR condition and the deviation in in-house, out-lying and total auxiliary is presented in Figure 3. The deviations in in-house, out-lying and total auxiliary power (%) are curve-fitted to:

$$DAP = 111.84 - (1.3966 \times PLF) + (0.0028 \times PLF^2) \quad (13)$$

$$DAP_{in-house} = 77.918 - (0.7776 \times PLF) + (1 \times 10^{-5} \times PLF^2) \quad (14)$$

$$DAP_{out-lying} = 221.87 - (3.3698 \times PLF) + (0.0115 \times PLF^2) \quad (15)$$

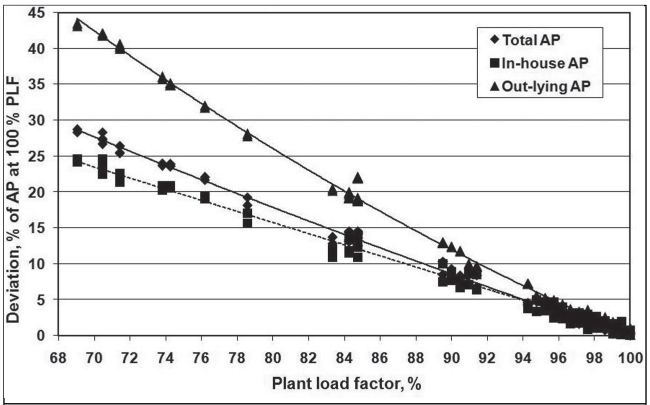


FIG. 3 DEVLIATION IN IN-HOUSE, OUT-LYING AND TOTAL AUXILIARY POWER WITH PLF

The turbine output is directly proportional to main stem flow, pressure and enthalpy, and condenser vacuum. The main steam pressure and flow depend on the feed water flow and pressure. The condenser vacuum is dependent on the circulating water temperature and flow at condenser inlet [10]. Therefore, the increase in turbine output will increase the auxiliary power of BFP, CEP, CWP and other out-lying auxiliary equipment.

The plant load factor of the units will be lower due to following reasons:

(a) Poor coal quality: High ash coal reduces the capacity of mills, steaming rate, overloading of ID fans, ESPs, etc.

(b) Poor performance of ESPs: This overloads the ID fans that cause hurdle in maintaining the negative furnace pressure [11].

(c) Erosion of ID fan impellers: Reduces the capacity of ID fans and will not be able to maintain the furnace pressure [12].

(d) Poor condenser vacuum: Reduces the loadability of turbine.

(e) Inadequate circulating water temperature at condenser: Reduces the vacuum at condenser.

(f) Air leakage in APH: Overloading of ID fans, FD fans and PA fans [13,14].

(g) Higher flue gas pressure drop across APH, ESP, Economizer, ducts, etc.: Reduces the capacity of ID fans.

(h) Inadequate primary air supply: Reduces the capacity of pulversized coal lifting from mill to burners.

(i) Non-availability of Mills, PA fans, etc.

(j) Restriction in auxiliary equipment like BFP, CEP, Mills, PA fans, FD fans, ID fans, etc.

(k) Inadequate coal supply.

(l) Less demand in grid.

The reduced plant load factor reduces the power output at generator terminal that reduces:

(a) Steam consumption and feed water flow at BFPs

(b) Condensate flow at CEPs

(c) Coal flow at mills

(d) Air flow at PA fans and FD fans

(e) Flue gas flow at ID fans

But the energy indices, i.e. specific steam consumption (SSC), specific fuel consumption (SFC) and Specific energy consumption (SEC) increases.

Therefore, the plant load factor increases the auxiliary power (% of gross generation) of major in-house equipment like BFP, CEP, ID fans, FD fans, PA fans and mills.

Figure 4 shows the variation in specific auxiliary power used at major auxiliary equipment with PLF. It can be seen from the above figures that the specific auxiliary power is high at low PLF. The deviation in specific auxiliary power is computed with respect to the auxiliary power at 100 % MCR condition and the results are presented in Figure 5. It can be seen from the figures that the deviation is more for FD fans because the loading of FD fans is very less.

The deviations in auxiliary power of in-house major HT equipment (%) are curve-fitted to:

$$DAP_{BFP} = 73.991 - (0.9391 \times PLF) + (0.0021 \times PLF^2) \quad (16)$$

$$DAP_{CEP} = 258.51 - (4.6035 \times PLF) + (0.0203 \times PLF^2) \quad (17)$$

$$DAP_{IDF} = -26.086 + (1.5081 \times PLF) - (0.0124 \times PLF^2) \quad (18)$$

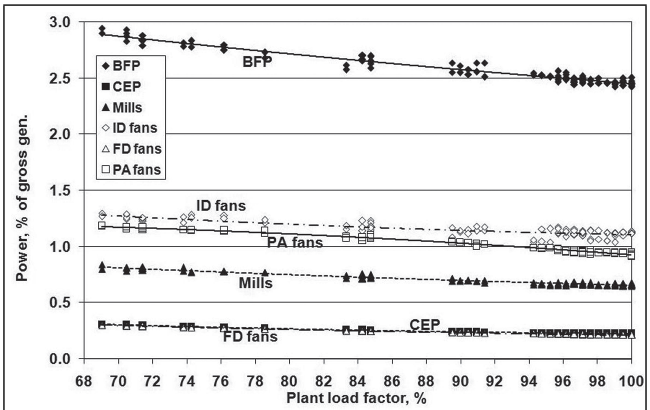


FIG. 4 VARIATION OF POWER OF IN-HOUSE AUXILIARY EQUIPMENT WITH PLF

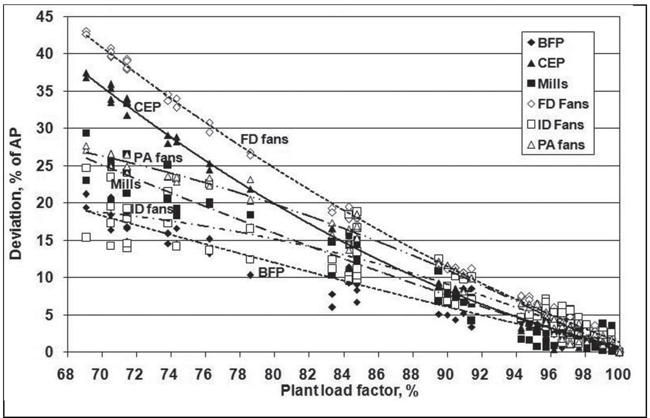


FIG. 5 DEVIATION IN AUXILIARY POWER OF IN-HOUSE EQUIPMENTS

$$DAP_{FDF} = 237.12 - (3.85 \times PLF) + (0.0149 \times PLF^2) \quad (19)$$

$$DAP_{PAF} = 5.4164 + (1.1237 \times PLF) - (0.0118 \times PLF^2) \quad (20)$$

$$DAP_{Mills} = 114.27 - (1.5854 \times PLF) + (0.0045 \times PLF^2) \quad (21)$$

3.1.2 Specific Fuel Consumption (SFC)

SFC is the amount of coal used in Kilograms to generate one unit of electricity in kWh. SFC is higher in many plants due to poor coal quality and the poor efficiency of boiler, turbine, generator and auxiliary equipment. For higher SFC:

(a) Specific coal flow through mills is higher that increases the specific auxiliary power of mills and coal-handling plant equipment.

(b) Specific air quantity required is high that increases the auxiliary power of FD fans and PA fans.

(c) Specific flue gas flow is also more that increases the auxiliary power of ID fans.

3.1.3 Equipment Oversizing

Generally, to keep the safety margins and to operate the plant more than 60 % of the capacity by operating with single stream (air cycle or water cycle) due to nonavailability of other stream, the fans and pumps are designed with high reserve capacities.

Table 2 gives the design and operating capacities of ID fans for 210 MW plants. Operating the equipment at partial load reduces the efficiency of ID fans that consume more auxiliary power.

ID fans are oversized by 18.6 % in flue gas flow, by 30.2 % in pressure (total head developed by fans), by 54.4 % in output power. The ID fan efficiency at their 100 % rated capacity is 76.5 %.

The ID fan efficiencies at 100 % maximum continuous rating (MCR) of plant is reduced to 63.91 %. The oversizing of ID fans has reduced the overall efficiency by 12.27 % that increased the auxiliary power of ID fans by 209 kW (0.1 % of gross energy generation) in a case study at 210 MW power plant.

3.1.4 Technology

As the most of the unit size below 210 MW are installed before seventies, the auxiliary equipments are of very old technologies. The same are being continued with lesser efficiency and higher auxiliary power. If these older technology equipments are replaced with new technology, the substantial amount of auxiliary power consumption can be reduced.

(a) Variable frequency drives for ID fans: The load on ID fans will be continuously varying between 60 and 75 %. It is beneficial to install the variable frequency drives. The installation of VFD will reduce the energy consumption, and other advantages over the prevailing technology of hydraulic and fixed speed motor drives are:

- Smooth control of flue gas
- No voltage dips in the system from direct-on-line starting of large-size motors
- Increased efficiency over wide operating speed range
- Simple arrangements and no necessity of large cooling equipment for hydraulic coupling

Table 3 shows the performance results of ID fans with and without VFD in a case study at a typical 210 MW power plants. The installation of VFD

TABLE 2

PERFORMANCE RESULTS OF ID FANS

Sl. No	Particulars	Unit	210 MW plant	
			Design value (fan 100% cap.)	100% MCR
01	Motor rating (Nos.)	kW (Nos.)	1400(2)	
02	Flue gas flow	m^3/s	228	192.2
03	Total head developed	mmWC	384	295
04	Fan efficiency	%	76.50	63.91
05	Fan output power	kW	858.89	556.2
06	Fan input power	kW	1122.73	870.3
07	Motor efficiency	%	94.96	94.46
08	Motor input power	kW	1182.31	921.4
09	Motor load factor	%	80.20	62.17
10	Overall eff.	%	72.64	62.17
11	Reduction in overall eff.	%	12.27	

TABLE 3

PERFORMANCE RESULTS OF ID FANS WITH AND WITHOUT VFD

Sl. No	Particulars	Unit	210 MW plant	
			Without VFD	VFD
01	Suction Pr.	mmWC	–265.0	–266.0
02	Discharge Pr.	mmWC	8.0	4.5
03	Flue gas flow	t/h	439.41	427.47
04	Electrical power input	kW	889.35	621.96
05	Mechanical power output	kW	439.37	423.52
06	Operating ov. efficiency	%	49.40	68.09
07	SEC	kWh/t	2.02	1.45
08	Energy saving per fan	MU/year	2.12	

reduced the energy consumption by 2.12 MU/year per fan. The average SEC had decreased from 2.02 to 1.45 kWh/t of flue gas.

But these VFD drives inject harmonic currents in the system; 5th and 7th individual current harmonics are on higher side. The current total harmonic distortions (THD) are in the range of 25.7–26.1 %. These harmonics can be suppressed by either passive or active harmonic filters.

(b) Steam driven BF pumps: Boiler feed pump (BFP) is the single largest auxiliary in a power plant and accounts for approximately 2.2–3.0 % of the gross generated power. If the BFP is re-powered by a service steam turbine drive instead of the present electric motor, the efficiency of conversion can be enhanced from 33 % to 35 % and the equivalent electrical power of about 7 MW can be released to the grid in a 210 MW power plant. Steam-driven BFPs are in use in 30 MW, 62.5 MW and a few 110 MW units apart from 500 MW units. The steam-driven BFPs provide better controllability (capacity modulation) compared to electric motor. Presently, the BFP outlet pressure is constant and is reduced by a valve at the turbine inlet. The BFP outlet pressure can be varied according to the load, savings in energy consumption of the BFP can be achieved at part loads.

(c) FRP fan blades for cooling towers: The replacement of CT fan blades from GRP to FRP material had reduced the power by 34.4 %; the cooling tower *range* had improved from 9.7°C to 11.6°C; the *approach* had reduced from 11.0°C to 9.7°C, the overall heat removal capacity (*Effectiveness*) had improved from 46.86 % to 54.46 %; the fan air delivery capacity had also increased from 4632 to 6030 m^3/s (an increase of 30.2 %) and the SEC had decreased from 26.12 to 13.17 W/t of air [15]. The total energy saving measured for one 210 MW (i.e., nine CT fans) was 1.84 MU/year. The investment was ₹ 33.75 lakhs and the payback period was 1.6 years in a case study at typical 210 MW power plants.

3.1.5 Control and Instrumentation

The control and instrumentation play a major role in energy conservation. At many plants, the malfunctioning of instruments draws more auxiliary power. For example, the closure of damper at mill inlet, the indicator at control room will display the damper closed fully but at site the damper is partially closed and air is passing through the non-working mill. Sometimes, the placing of oxygen probe in the flue gas duct also misleads about the excess air. The oxygen probe must be at the center of the duct. The measurement of flue gas temperature at flue gas circuit also misleads sometimes. Therefore, the instruments need to be calibrated once in a year.

The idle operation of crusher and conveyor motors can be avoided by providing the automatic control signal to the crusher and conveyor motors sequentially with minimum time lapse. The other control techniques like FD fan pitch operation can be put in automatically by sensing the oxygen in flue gas; PA air flow to the mill can be controlled by sensing the coal air mixture temperature and coal–air ratio, etc.

When the wet bulb temperature is low, the circulating water temperature at condenser inlet will be low, the condensate is cooled below its saturation temperature; for example, when all fans are in service, the condenser's absolute pressure is 9.0 kPa, the corresponding saturation temperature of condensate is 43.76^{o}C but the actual condensate temperature at hot well was 38.7^{o}C (less by 5.06^{o}C). This temperature has to be gained in LP heaters. Therefore, in order to maintain the correct CW temperature, *automatic controller for CT fans* can be installed. The CT fan operation can be controlled by sensing the CW water temperature at condenser inlet.

3.1.6 Operational Optimization

Some of the operational parameters to be monitored on-line continuously to keep the plant healthy and operate with energy-efficient are as follows:

(a) O_2 in flue gas at APH inlet with different load.

(b) Suction pressure and discharge pressure of pumps and fans with different loading.

(c) Feed water flow, condensate flow, primary air flow, secondary air flow, flue gas flow, coal flow, etc.

(d) Specific energy consumption of major auxiliary equipments like BFP, CEP, ID fans, FD fans and PA fans continuously on-line.

(e) Air-coal ratio in mills.

Some of the parameters to be monitored off-line and necessary actions required are:

- Water-to-ash ratio (on daily basis): The water flow of HP and LP flush pumps may be adjusted.
- Pulverized coal fineness (once in a week for each mill): The classifier adjustment.
- O_2 measurement at APH outlet, ESP inlet and outlet, and ID fan inlet (on weekly basis).
- Un-burnt carbon in fly ash and bottom ash (daily basis).

3.2 External Factors

3.2.1 Poor Coal Quality

It is a common experience in most of the power plants that the coal received deviates from the design values in terms of calorific value as well as ash content. The increased ash content in the coal increases the auxiliary of mills, PA fans and ID fans. The increased ash content also increases the power consumption of crushers and conveyor system. The presence of stones in the coal increases the auxiliary power of crushers and conveyor system. 20 % stone in uncrushed coal will increase the auxiliary power of crushers by 12 % and 4 % of conveyor system. The other effects of high ash content in coal are:

(a) Lower calorific value of coal and additional requirement of milling capacities. The existing design of power plants does not consider the effect of high particulate presence on heat transfer and estimated value of gas temperatures. This quite often leads to high exit flue gas temperatures and consequent loss of efficiency.

(b) Higher loading of electrostatic precipitators (ESPs). Compared to design coal quality, the additional quantity of fly ash had to be handled for worst quality coal. However, providing extra field for ESPs to capture this extra ash has an impact on the length of duct and consequently the ID fan capacity.

Owing to this limitation, the ESP upgrade efforts are limited to reduce stack emissions to the extent possible and reduce energy consumption with pulse energization of ESPs.

(c) The ash handling system has to be run for longer durations because of an increased fly ash quantity to be handled. This increases the auxiliary power consumption of ash-handling plant.

(d) Fouling of heat transfer surfaces results in forced outages due to tube leakages.

The coals from USA and China have calorific value almost twice that of Indian coal [16]. The SFC for Indian coal is about 0.7 kg of coal to generate 1 kWh of power compared to 0.4 kg/kWh for USA and China coal. The power used by CHP and milling system is almost double for Indian coal. However, Indian boilers are designed with calorific value between 4500 and 4800 kcal/kg. The increased ash content in the coal increases the auxiliary power of mills, PA fans and ID fans. The Indian power plants are designed with ash content of about 10 %, the increased ash content increases the flue gas flow and fly ash that will increase the burden on ID fans and the increased power for ID fans (%) can be curve-fitted to:

$$P_{ID-Ash} = -2.7662 + (0.2554 \times PAC) + (0.0029 \times PAC^2) \quad (22)$$

where PAC is the measured ash content in coal (%).

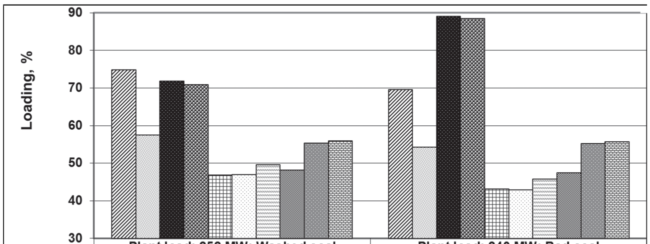
For increased ash content, the PA fans have to supply more primary air to lift pulverized coal to burners and to maintain the required coal-air ratio. The increased power for PA fans is curve-fitted to:

$$P_{ID-Ash} = -6.8869 + (0.6667 \times ASH) + (0.0037 \times ASH^2) \quad (23)$$

For increased ash content in coal, the specific fuel consumption of unit increases for which mills have to handle more quantity of coal. The increased coal consumption increases the SEC of mills and the increased power by mills is curve-fitted to:

$$P_{ID-Mills} = -0.3469 - (0.0511 \times ASH) + (0.0123 \times ASH^2) \quad (24)$$

At typical 250 MW, power plant study was conducted to evaluate the performance of auxiliary power with washed (good coal average CV: 4200 kcal/kg) and with bad coal (average CV: 2800 kcal/kg). Figure 6 gives the variation of loading of major HT equipment. With washed coal, it was possible to raise the plant load to 252 MW and with bad coal, the maximum plant load achieved is 240 MW due to restriction to maintain furnace draft. The ID fan loading is increased from average value of 70.3 % (252 MW PL) to 88.7 % (240 MW PL). The specific increase in loading is by 24.4 %.



	Plant load: 252 MW; Washed coal	Plant load: 240 MW; Bad coal
BFP 1A	74.8	69.5
CEP 1A	57.4	54.2
ID fan 1A	71.8	89.1
ID fan 1B	70.8	88.4
FD fan 1A	46.8	43.1
FD fan 1B	46.9	42.9
PA fan 1A	49.5	45.7
PA fan 1B	48.1	47.4
Mill 1CD	55.3	55.2
Mill 1EF	55.9	55.6

FIG. 6 LOADING OF MAJOR HT EQUIPMENT WITH WASHED AND BAD COAL

3.3 Grid Specific Factors

3.3.1 Backing Down of Units

Power demand in the system varies widely over a 24-hour period. The ratio of peak to off-peak demand is of the order 1.8–2. This requires backing down of substantial thermal capacity during the night off peak hours in order to regulate the frequency.

As the thermal (coal based) units are primarily designed for base load operation, backing down of units can have the following impacts on efficiency:

(a) Percentage of auxiliary consumption is higher at part load

(b) Operational constraints restrict the reduction in the number of auxiliaries in service during part load operation.

(c) There are some technical constraints in reducing the output of auxiliaries during part load operation. Major auxiliaries like ID fans do not have variable speed drives (VSD). Control is affected by inlet guide vane control resulting in higher losses at part loads.

3.3.2 Reactive Power Generation by Units

Owing to mismatch of reactive power requirements in the grid and generation by the generators, the system voltage will vary. To stabilize the system voltage profile, generating units are asked to reduce the active power generation and increase the reactive power generation from the unit. This is done by increasing the excitation that reduces the efficiency of generators and increases the specific auxiliary power. The increased reactive power generation results in higher auxiliary power consumption.

4.0 CONCLUSIONS

The overall auxiliary power consumption of coal-fired power plants forms about 4.6 % of total installed capacity. Reduction of auxiliary power leads to release of about 1000 MW into grid. Operating the plants near to their full capacity helps in reducing the auxiliary power. Operational optimization, use of advanced technology equipment, reduction of hydrodynamic resistances in flue gas circuit, air circuit, water circuit and steam circuit, etc. will reduce the auxiliary power considerably. Operating the plants energy efficiently will help reduce the auxiliary power of a typical 210 MW power plant from 11.59 % to 8.50 % with a payback period of 1–5 years.

ACKNOWLEDGMENT

Authors wish to thank the management of CPRI for conducting the research work and permitting to publish this paper.

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