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OPTIMIZATION OF IN-HOUSE POWER CONSUMPTION BY REDUCING PRIMARY AIR PRESSURE IN SUPER CRITICAL COAL FIRED THERMAL POWER PLANT

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ABSTRACT

In Coal fired thermal power plants, part of energy generated by the power plant is being consumed by its own auxiliary drives. The power consumption by these auxiliary drives for power generation is called as In-house power consumption. In-house consumption in coal fired super critical thermal power plants of capacity 500 Megawatt and above with Turbine Driven Boiler Feed pumps should be 5.25% and with Motor driven boiler feed pumps should be 6.00% as per Indian Government norms stated by Central Electricity Regulatory Commission (CERC). But currently it is in the range of 7% (800 MW units) to 10% (500 MW units) of gross generated power at full load conditions in most of the thermal power plants in India. The excessive auxiliaries power consumption is caused by various factors such as part loading of the plant, poor coal quality used as fuel, excessive steam flow, draft loss, internal leakages/ingress in equipment, over loading of drives, distribution network losses, reduced power quality, ageing etc., Here we optimize the loading of one such major auxiliary equipment - primary air fan which is the second major contributor in auxiliary power consumption in a thermal power plant after the cooling water system, by reducing its outlet pressure without compromising on unit performance and boiler efficiency. The thesis also delves into quantizing the operational benefits that will be achieved by measuring the reduction in loading of each primary air fan and *estimating the overall benefits that can be attained and tabulating them. Thus optimizing the In-house power consumption of the plant and cost benefits associated with it by operational optimization.*

Key words: Friction Stir welding, Mechanical Properties, Microstructure

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1. INTRODUCTION

There are many equipments present in thermal power stations such as fans, pumps and other electric drives that are required for power generation. These drives are called as auxiliaries of the power plant. Power requirement by these drive is called as auxiliary power (AP), works power or parasitic power and can be classified into four broad groups as Unit auxiliaries (in-plant HT motors), Unit auxiliaries (in-plant LT loads), Common station auxiliaries (out-lying HT mo- tors) and Common station auxiliaries (out-lying LT loads). Major HT loads on power plants are Induced draft fans, primary air fans, secondary or forced draft fans, circulating water pumps, condensate extraction pumps boiler fill pumps, electro static precipitators and plant air compressors.

1.1. Break up of auxiliary power in typical coal fired thermal power plant

Given below is the break up (8.32%) of auxiliary power in the 660MW super critical coal fired thermal power plant[7].

S.No	SYSTEM	Aux Power %
1	Feed water system	3.22 %
2	Draft system	2.20 %
3	Cooling water system	1.20 %
4	Ash handling system	0.72 %
5	Coal handling system	0.58%
6	Water treatment plant	0.27%
7	Compressed air system	0.07%
8	Lighting loads	0.04%

1.2. Performance Indices

The performance of the AP system is quantified by per-formance indices as given below,

i. The auxiliary plant load factor (APLF) is defined as,

APLF = (auxiliary load)/(plant load)

ii. The auxiliary load factor (ALF) is defined as,

ALF = (auxiliary load)/(rated auxiliary capacity)

2. COMBUSTION IN BOILER

For complete combustion of coal to take place inside boiler, stoichiometric ratio of air is to be supplied. But in real, some amount of air which has been provided for combustion goes unreacted. This generally happens because of the quantity of fuel that is fed at once and variation in the sizes of fuel particles. So some amount of excess is provided for the complete combustion of coal inside the furnace. Complete combustion can be enhanced by three basic factors, referred as 3T's Time, Temperature and Turbulence.

Steam boilers are provided with balanced draft system for increasing the combustion efficiency and for keeping the unburnt carbon losses at minimum. In balanced draft system, primary air fan and forced draft fan sends in fresh air for combustion whereas induced draft fan removes out the flue gas from boiler and sends it out through chimney.

2.1. Primary air fans (pa fans)

Primary air is the basic amount of air required for complete combustion of fuel and it depends upon the composition and quantity of the fuel required by the boiler. Different types of coal requires different amount of primary air.

Primary air fans are high pressure fans used to supply the air for the transportation of coal directly from the pulveriser to the furnace. These fans provide a positive upstream pressure and takes the inlet from the atmospheric air.

Primary air is supplied by two primary air fans from the bottom to the two counter flow Tri-sector air preheaters for getting heated by the outgoing flue gases. Once heated, this primary air forms a common header and goes to the pulverising mills. There it helps in removing the inherent moisture content of the coal and also helps in increasing the temperature of the coal particles. Once the moisture is removed and mill outlet temperature is increased, it is feed to the various burners located at the four corners of boiler at elevations ranging from 15 metres to 35 metres. There is also a bypass duct before both the air preheater forming cold primary air. This is helpful in regulating the mill outlet temperature if the temperature increases causing the combustion to start inside the mill itself or in worst case leading to explosion of mill.

2.2. Forced draft fans

It is also called as the secondary air fans. It takes suction of atmospheric air and raises it to medium pressure. It supplies air directly into the furnace through burner nozzle itself. The burners are designed in such a way that fuel and primary air nozzle is located in the centre of the burner and secondary nozzles are located surrounding the fuel nozzle in concentric manner.

2.3. Induced draft

They are high pressure fans, removing the flue gases from the boiler after combustion. Hence it handles hot and dirty gases with ash and other volatile particles. A dedicated hub cooling fan is provided for these ID fans. The outlet of ID fan is given to the chimney and then to the atmosphere.

2.4. Furnace Pressure

The pressure inside the furnace is always maintained in negative compared to atmospheric pressure. This is done so that the flames of fire from the furnace does not comes out through the peep holes and man holes. If the furnace pressure goes very much negative is will starting sucking in the atmospheric air through the peep holes and man holes reducing the temperature of furnace and decreasing the efficiency of the boiler.

2.5. Soot blowers

Soot blowers are canon of steam targeted on specific areas of boiler such as water walls, superheater coils, reheater coils, air preheaters, economisers to remove the ash particles deposited on them. If the ash deposition is not removed regularly the heat transfer in that particular area will be affected.

2.6. Pulverising Mills

Mills are the crushing equipment used to reduce the size of the raw coal from 25cms to less than 80microns. This is done by low speed hydraulically loaded grinding rollers. The size of the coal particles should be crushed because, then only each coal particle will combine with sufficient air particles and combustion will be complete. This is also done to increase the residence time of coal particles in the furnace. If heavy coal particles are directly fed due to heavy weight they fall into the bottom without getting carried along the flue gas path.

2.7. Mill differential pressure

Mill DP as it usually called is the pressure difference between the outlet and inlet of primary air inside the mill. This has to be maintained above 400 pascals. If this DP reduces, it indicates that mill is choked either because too much coal is dumped as compared to incoming primary air or incoming primary pressure is insufficient to lift the coal particles from mill to the burners.

2.8. Oxygen content in APH flue gas inlet

Amount of oxygen present in the flue gas inlet of Air preheater is measured. This is live and active method to ensure sufficient amount of air is supplied at any given time for complete combustion of coal particles.

2.9. Unburnt Carbon

Bottom ash and fly ashes are analysed visually and chemically for the carbon content. This is the passive method for ensuring complete combustion and sufficient air supplied inside furnace. If carbon content in ash is more, it indicates that sufficient air is not available for complete combustion, hence more unburnt carbon.

2.10. Air – fuel ratio

There is a fixed air-fuel ratio for every fuel. It is the amount of air required for complete combustion of that fuel. At any point of time, the total air flow i.e sum of primary air flow and secondary air flow should be always greater than this ratio. Generally it will be 1:1.5 for South African coal, 1:1.8 for Indonesian coal and 1:2 for Indian coal.

3. COMPONENTS OF PRIMARY AIR FANS

- - Mesh screen
- - Silencer
- - Inlet duct and supports
- - Inlet guide vane mechanism
- - Rotor and rotor housing
- - Aerofoil backward curved blades
- - Fan motor shaft

- - bearing pedestal and bearings.
- - Diffuser
- - Outlet ducts
- - Outlet damper
- - Link rod actuator mechanism
- - Lubrication oil system

For proper combustion inside the furnace, the coal particles from the pulveriser has to fed into the furnace at a velocity of 25m/s to 30m/s. If this velocity increases, then the fire ball inside diameter will be reduced concentrated only in the centre of furnace, thus reducing the convective heat transfer near the water walls and increasing the radiative heat transfer to pendent super heater hanging above. This leads to adverse reactions such as overheating of super heater coils and shoot up of steam temperatures with high levels of attemperation.

On the other hand if the feed velocity of coal from the burner tip is reduced that is if PA flow is reduced, combustion will occur near the burner itself eroding the burner nozzle tip and heavy slagging of water walls. This leads to reduced convective heat transfer area in long run.

The parameters of the primary air fan and motor is tabulated below

Table 2 Primary Air Fan Name Plate Details

S.No	Description	Rating	UOM
1	Fan type	Axial	-
2	Volumetric Flow	165	m3/s
3	Static pressure	18	Kpa
4	Efficiency	80	%
5	Motor power	3750	Kw
6	Voltage	11	Kv
7	Full load current	236	A
8	Power factor	0.87	-
9	Speed	1490	Rpm

4. METHODOLOGY

When the unit is running in stable condition without any major changes in load all the critical parameter readings are noted down in dedicated log sheet. All the controllers such as load control, boiler master, turbine master, furnace pressure control, primary and secondary air dampers, feed water control, deaerator level control all are kept in auto mode. Sample of bottom ash and fly ash is taken and analyzed for unburnt carbon present in it also physical color of bottom ash is checked. Greyish ash indicates less amount of unburnt carbon and dark black colored ash shows traces to heavy unburnt carbon in it. Wall blowers, long retractable and short retractable soot blowers, air preheater soot blowers are operated. Rate of change of metal temperatures along the water walls, superheater coils and reheater coils is monitored for excursions continuously.

Now the primary air pressure controller is taken into manual mode from auto mode. This is done to avoid the equal loading of both the primary air fans when one fan inlet guide vane control is throttled. Initially the set point of one fan is reduced to two percentage. All the parameters initially noted down is again noted for deviations and excursions. Once system is stabilized, again the set inlet guide vane is throttled for another two percentage. Same is repeated for another primary air fan. Likewise the primary air pressure is brought down from 9900 pascals to 8900 pascals without much deviations in the above said parameters. Summary of the observations at various pressure and current taken by the fans is tabulated and presented below.

5. OBSERVATIONS

For this primary air fan pressure before the Air pre-heater inlet was maintained at 9900 Pascals and Air Pre-heater outlet pressure was maintained at 9400 Pascals that is pressure drop across the air pre-heater is 500 pascals. At the inlet of the pulveriser, primary air pressure will be 6000 Pascals. Both the primary air fans are always partially loaded. Their operating current will be in the range of 110 amperes.

The loading of PA fan depends on the opening of the inlet guide vanes, fan outlet discharge dampers, load of the plant, number of mills in service, coal quantity and quality used and furnace pressure maintained.

Now the loading of the PA fan is reduced gradually by

i. Throttling the inlet guide vanes of both fans from 50% to 45%

ii. The PA outlet pressure reduces from 9900 Pascals to 8900 pascals.

iii. PA outlet pressure after air preheater reduces to 8900 pascals 9400 pascals.

iv. No changes in mill inlet and outlet PA differential pressure indicating no chocking of mills

v. No accumulation of pulverised coal particles observed in mill reject handling system.

iv. The total air flow decreases to 2200 tonnes per hour from 2300 tonnes per hour.

v. The furnace pressure comes down from (-120) pascals to (-80) pascals.

vi. The oxygen at APH inlet drops mildly from 3.48% to 3.42%.

vii. Load generated is not disturbed. No disturbances absorbed in flame front and metal temperatures of water wall tubes.

viii. Unburnt carbon in the bottom ash and fly ash remains the same 1.5% and 1.68% respectively

Table 3 Critical Paramaters and Achievements

PA Fans			*Unit*	*27/08/2018*		*16/09/2018*		*08/10/2018*	
				Fan – A	***Fan – B***	***Fan – A***	***Fan – B***	***Fan – A***	***Fan – B***
Load/frequency			*MW*	660/49.98		661/49.97		660/50.00	
Current			*Amps*	**110**	**111**	**104**	**106**	**97**	**96**
Blade pitch pos.			*%*	55	56	48	50	42	43
Fan I/L Pressure & temperature			*kpa / ^0C*	-0.41/29.81	-0.39/29.92	-0.41/29.80	-0.39/29.86	-0.40/29.36	-0.38/29.65
Fan O/L Pressure			*kpa / ^0C*	**10.6**	**10.9**	**9.82**	**9.75**	**9.23**	**9.16**
Winding Temp(U/V/W)			*^0C*	54/55/53	56/58/57	52/54/53	55/55/54	52/53/52	54/55/54
Fan Bearing temp (Max)		*DE*	*^0C*	0.648	0.564	0.443	0.489	0.243	0.387
		NDE	*^0C*	0.586	0.634	0.234	0.543	0.352	0.432
Motor Brg temp		*DE*	*^0C*	66	67	65	64	62	61
		NDE	*^0C*	53	50	51	54	52	49
Motor Vibration		*NDE-(X/Y)*	*mm/sec*	0.128	0.324	0.267	0.376	0.375	0.217
		DE-(X/Y)	*mm/sec*	0.231	0.431	0.312	0.218	0.264	0.216
Fan Vibration		*NDE*	*mm/sec*	0.798	0.685	0.573	0.498	0.679	0.856
		DE	*mm/sec*	0.845	0.745	0.865	0.813	0.834	0.763
Oil system		*LOP i/s*	*A/B*	A	B	A	B	B	A
		Header DP	**	OK	OK	OK	OK	OK	OK
		Oil Temp	*^0C*	52	50	51	54	52	52
		Electric Heater i/s	*A*	OFF	OFF	OFF	OFF	OFF	OFF
Cold PA Header Pr.			kpa	9.82	9.86	9.45	9.52	*9.16*	*9.06*
Hot PA APH O/L Pr. & Temp.			Kpa / ^0C	9.34/351	9.36/354	9.05/348	9.08/351	*8.92/350*	*8.91/349*
MILLS		Mill - A	Mill - B	Mill – C	Mill – D	Mill - E	Mill - F	*Mill - G*	*Mill - H*
Current/coal flow	*A/TPH*	140	136	138	129	146	139	*STANDBY*	*STANDBY*
Feeder Speed, Current	*Rpm/A*	603/4.56	654/4.98	635/4.52	698/5.45	625/5.67	598/4.23	-	-
Mill HAD / CAD position	*%*	70/30	70/30	65/55	65/55	70/30	70/30	-	-
Mill inlet PA Pr./Temp	*Kpa /^0C*	**6.5/250**	**6..2./234**	**5.9/170**	**5.6/164**	**6.1/238**	**6.0/234**	-	-
outlet temp/velocity	*^0C/m/s*	**65/27**	**63/29**	**50/25**	**52/24**	**64/28**	**67/28**	-	-
Mill PA & Seal Air DP	*Kpa*	**0.34**	**0.38**	***0.43***	**0.38**	***0.43***	***0.43***	-	-
OBSERVATIONS									

4. ADVANTAGES OF REDUCING THE PRIMARY AIR PRESSURE

- When the primary air header pressure is reduced from 9900 pascals to 8900 pascals the laoding of the primary air fans is apprecibly decreased upto 200 kilowatts per fan, and hence turning upto 800kilowatts for four fans. The findings of each fan has been tabulated along with loading and inlet guide vane position and the same is shown above.
- Reduced power consumption thus, auxilliary power consumption gets reduced.

- Apart from this, decreasing the load on fans decreases loading of air preheaters and reduced pressure drop across APH.
- Air leakages from the cold air side into the hot air of the air preheaters decreases. This increases the overall boiler efficiency.
- Less load means less wear and tear and less erosion of ducts and air preheater baskets, heance reduced maintenance.
- Improvement in mill outlet air temperature and mill efficiency.

7. RESULTS AND CONCLUSION

Table 5: Primary Air Fan Savings for Various Outlet Pressures.

PA fan saving in KW by reducing PA header pressure from 9.9kpa to 8.9 kpa								
	U#1 PA fan high PA		**U#1 PA fan Low PA**		**U#2 PA fan high PA**		**U#2 PA fan Low PA**	
	PA-1A	**PA-1B**	**PA-1A**	**PA-1B**	**PA-2A**	**PA-2B**	**PA-2A**	**PA-2B**
Load (MW)	660	660	660	660	660	660	660	660
Header pressure (Kpa)	**9.9**	**9.9**	**8.9**	**8.9**	**9.9**	**9.9**	**8.9**	**8.9**
	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732
Current Amps	**108.2**	**108.6**	**96**	**92.64**	**108.7**	**108.2**	**94.8**	**95.5**
Voltgae	11000	11000	11000	11000	11000	11000	11000	11000
P.F	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	1000	1000	1000	1000	1000	1000	1000	1000
	1752212	1758690	1554643	1500230.7	1760310	1752212	1535210	1546546
Energy in KW	1752.212	1758.69	1554.643	1500.2307	1760.31	1752.212	1535.21	1546.546
	PA-1A		**PA-1B**		**PA-2A**		**PA-2B**	
Fan wise saving in KW	**197.56924**		**258.459432**		**225.09938**		**205.66634**	
	Unit-1 PA fans				**U#2 PA Fans**			
Unit wise saving in KW	**456.028672**				**430.76572**			
Total saving in KW	**886.794392**							

- It is evident that when the outlet pressure of the primary air fan is reduced, its loading gets reduced, which in turn reduced the auxiliary power consumption of the plant. Initially when the primary air outlet pressure was 9900 pascals the loading of the fan was 258Kw. When the pressure is gradually reduced without affecting any linked parameters, its loading reduced to 198 Kw.
- It is proved that even upon reducing the primary air inlet pressure, the stable operation of the mills is not affected. The outlet velocity and coal carrying capacity of the primary air remains intact.
- Thus replicating the same in all four numbers of primary air fans a total of 890kw has been reduced which directly contributes in the minimization of auxiliary power consumption by operational optimization.
- Total air flow to boiler is reduced with same amount of coal firing without any clinker formation and complete combustion of coal[8.] This is ensured by mill outlet temperature[9]
- The pressure drop and leakage loss across air preheater is reduced. Thus performance of air preheater and efficiency of boiler is increased.
- As the primary air pressure is reduced the furnace pressure drops to negative therefore to maintain the furnace pressure loading of induced draft fan is reduced. This in turn saves considerable amount of energy savings.

- The stress on boiler tubes, waterwalls, hot air and cold air dampers, mill outlet valves are reduced

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