Performance Improvement of Process Draft Fans in Coal Based Power Plants

Rajashekar P. Mandi, Udaykumar R. Yaragatti

Abstract: Indian energy sector mainly depends on the fossil fuel based power plants especially coal based power plants. The performance of coal based power plants in India is poor compared to other advanced countries due to prolonged use of smaller size power plants who have served more than 35 – 40 year with refurbishments and poor coal quality. The auxiliary power in thermal power plant plays a major role in performance of plants because the average auxiliary power consumption varies between 7.5 – 14.3% of plant load depending on the plant size. In this paper the avenues for improving the power plant performance by implementing the energy conservation measures like reducing the hydrodynamic resistance in flue gas & air ducts through clearing the debris, control of illegal furnace ingress, efficient control techniques, cleaning air baskets in air pre-heaters, operational optimization, variable frequency drives, etc. that reduces the energy consumption by 5.5 to 6.5 MU/year which reduces the overall auxiliary power by 0.5% of plant load.

Keywords: auxiliary power; energy conservation; induced draft fans; forced draft fans; primary air fans; air pre-heaters;

I. INTRODUCTION

The power generation capacity in India is about 357 GW as on 31st March 2019 out of which 61% of power is being added by coal fired power plants in India and the energy share by coal fired power plants is 74.5% of total energy consumption. Therefore, in Indian power sector development, thermal power generation play a major role in energy security [1, 2].

The performance, reliability and availability of thermal power plant (TPP) depend on the coal quality, water quality and the operational reliability of auxiliary power equipment [3, 4]. The boilers used are of balanced draft corner fired pulverized coal type. Therefore, the draft system plays an important role in maintaining the energy efficiency, operational optimization and safety of boilers. The draft system consists of forced draft fans (FDF) to provide the secondary air for proper combustion, primary air fans (PAF) fans to lift the coal from mills to burner for proper combustion and induced draft fans (IDF) to extract the flue gas from boiler and to throw out the flue gas through chimney to atmosphere.

The auxiliary power (AP) is the power used to operate all the auxiliary equipment to generate the power at TPP. In Indian power plants, the AP is on higher side due to use of high ash content (30 - 50%) and low calorific value coal (2600 – 3900 kcal/kg), higher air ingress in furnace due to erosion due to high ash content coal, higher hydrodynamic resistance in air and flue gas ducts accumulated debris, poor efficiency of drives, mismatch of equipment drives, ageing of equipment, obsolete equipment, etc. [5, 6, 7].

II. AUXILIARY POWER

The test is conducted on the boiler of 500 MW power plants as per BIS standard by maintaining the plant load constant for minimum of 120 minutes. The auxiliary power of process draft fans is measured by using power analyser and computed the specific auxiliary power (SAP) and is presented in Figure 1. As the PLF increases, the auxiliary power consumption decreases. Therefore, the plants have to be operated near to their full load [8]. The total specific auxiliary power for draft fans is computed by using the following curve fit:

$$SAP_{draft\ fans} = 0.0008 \times PL^2 - 0.1502 \times PL + 9.21\%........[1]$$

The power for ID fans is computed by using following curve fit:

$$SAP_{ID} = 0.0004 \times PL^2 - 0.0721 \times PL + 4.41\%........[2]$$

The power used by FD fans is computed by using following curve fit:

$$SAP_{FD} = 9E - 05 \times PL^2 - 0.017 \times PL + 1.0591\%........[3]$$

The power used by PA fans is computed by using following curve fit:

$$SAP_{PA} = 0.0003 \times PL^2 - 0.61 \times PL + 3.7409\%........[4]$$

The various reasons for higher specific auxiliary power are

a) Operational parameters:

- Design constraints: equipment oversize
- Hesitation in adopting new advanced technologies.
- Sub-optimal equipment performance due to poor loading
- Age old control techniques and poor Instrumentation control.
- Forced outages
- Poor capabilities of operators for optimum operation due to lack of training and motivation

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Dr. Rajashekar P. Mandi, Director, School of Electrical and Electronics Engineering, REVA University,
Udaykumar R. Yaragatti, Director, Malaviya National Institute of Technology (MNFIT), Jaipur.
b) External factors like coal shortages, inferior water quality, poor coal quality, etc. which are not in the control of power plant officials.

c) Grid specific factors like backing down of plants due to surplus power & support of reactive power by the units also not directly in the control of plant officials.

A Design constraints

In coal fired power plants two streams of air cycle and flue gas cycle (left & right or A side - B side) are used in most of the power plants to operate the power plant at least at 60% of plant load with one stream of both air & flue gas cycle whenever there is problem in second stream [9, 10]. To accommodate this constraint, the draft fans are designed with high reserve capacities depending on nature of equipment.

The design and operating capacities of draft fans are given in Tables 1 to 3 for typical 500 MW & 210 MW power plants. Figure 2 gives the variation of capacities of major fans.

### Table 1: Capacity utilization of ID fans

| Sl No. | Particulars | Unit | 500 MW plant | 210 MW plant |
|--------|-------------|------|--------------|--------------|
|        |             | 100 % | 100 %         | 100 %        |
|        |             | fan cap. | MCR | fan cap. | MCR | fan cap. | MCR |
| 01     | Motor rating | kW (nos) | 1800 (4) | 1400 (2) |
| 02     | Flue gas flow | m³ | 255 | 228 | 192.2 |
| 03     | Total load | mmWC | 480 | 341 | 284 | 205 |
| 04     | Fan efficiency | % | 88.18 | 72.90 | 86.50 | 59.15 |
| 05     | Fan output power | kW | 1372 | 819.8 | 935.5 | 596.2 |
| 06     | Motor efficiency | % | 95.05 | 94.49 | 94.89 | 94.86 |
| 07     | Motor input power | kW | 1493.9 | 999.8 | 1143.2 | 729.1 |
| 08     | Overall efficiency | % | 89.37 | 66.88 | 72.64 | 60.39 |
| 09     | Reduction in overall efficiency | % | 11.45 | 12.27 |

### Table 2: Capacity utilization of FD fans

| Sl No. | Particulars | Unit | 500 MW plant | 210 MW plant |
|--------|-------------|------|--------------|--------------|
|        |             | 100 % | 100 %         | 100 %        |
|        |             | fan cap. | MCR | fan cap. | MCR | fan cap. | MCR |
| 01     | Motor rating | kW (nos) | 1750 (2) | 600 (2) |
| 02     | Flue gas flow | m³ | 249 | 216.9 | 301 | 229 |
| 03     | Total load | mmWC | 430 | 287.6 | 340 | 230 |
| 04     | Fan efficiency | % | 88.01 | 76.90 | 76.48 | 63.95 |
| 05     | Fan output power | kW | 1505.1 | 991.1 | 1143.2 | 205.9 |
| 06     | Motor efficiency | % | 92.30 | 86.20 | 95.65 | 86.54 |
| 07     | Motor input power | kW | 1286.2 | 814.2 | 1022.7 | 541.5 |
| 08     | Overall efficiency | % | 91.09 | 69.04 | 71.62 | 59.67 |
| 09     | Reduction in overall efficiency | % | 17.20 | 11.95 |

### Table 3: Capacity utilization of PA fans

| Sl No. | Particulars | Unit | 500 MW plant | 210 MW plant |
|--------|-------------|------|--------------|--------------|
|        |             | 100 % | 100 %         | 100 %        |
|        |             | fan cap. | MCR | fan cap. | MCR | fan cap. | MCR |
| 01     | Motor rating | kW (nos) | 2800 (2) | 1300 (2) |
| 02     | Primary air flow | m³ | 109 | 88.8 | 74.3 | 52.27 |
| 03     | Total load | mmWC | 1210 | 746.8 | 925.8 | 596.2 |
| 04     | Fan efficiency | % | 88.00 | 22.90 | 38.50 | 30.38 |
| 05     | Fan output power | kW | 2105.9 | 651.13 | 909.32 | 240.59 |
| 06     | Motor efficiency | % | 93.70 | 85.84 | 93.65 | 82.45 |
| 07     | Motor input power | kW | 2555.5 | 1046.6 | 1243.7 | 423.1 |
| 08     | Overall efficiency | % | 92.40 | 62.23 | 71.51 | 50.08 |
| 09     | Reduction in overall efficiency | % | 20.23 | 15.48 |

Induced draft fans have an additional capacity (for 210 & 500 MW plants) for flow in the range of 20 – 23.2 %, pressure in the range of 23.2 – 28.5 % and output power in the range of 35.2 – 42.8 %. The overall efficiency of ID fans is lowered by about 11.45 – 12.27 % due to oversizing cause higher auxiliary power of ID fans is about 311.3 – 568.4 kW.
The flue gas pressure in furnace and flue gas duct is maintained negative till the suction of ID fans and at the ID fan exit it will become slightly positive to throw out the flue gases to atmosphere [14]. The flue gas draft profile of ID fan circuit is presented in Figure 3. The power and loss in different components in ID fan circuit for a typical 210 MW plant is given in Figure 4. Some of the energy conservation measures to enhance the performance of ID fans are as follows:

1. The flue gas pressure drop (PD) across furnace (i.e., in SH, RH, Platen SH, LTSH, etc.) is measured in the range of 49 – 55 mmWC which is higher compared to design value of 30 mmWC that increases the energy consumption by 0.73 MU/year. This can be reduced by clearing the debris in flue gas ducts during overhaul.
2. The PD across Economizer coils is measured in the range of 27 – 40 mmWC which is on higher side as compared to the design value of 26 mmWC. This pressure drop can be reduced by clearing the debris in the economizer section that will help in reducing the energy consumption by 0.41 MU/year.
3. The PD across APH is measured in the range of 192 – 201 mmWC as compared to the design value of 192 mmWC. The higher pressure drop may be due to blockage in APH baskets. The cleaning & clearing the blockage in APH baskets will reduce the energy consumption by 0.26 MU/year.

i) The flue gas pressure drop (PD) across furnace (i.e., in SH, RH, Platen SH, LTSH, etc.) is measured in the range of 49 – 55 mmWC which is higher compared to design value of 30 mmWC that increases the energy consumption by 0.73 MU/year. This can be reduced by clearing the debris in flue gas ducts during overhaul.
ii) The PD across Economizer coils is measured in the range of 27 – 40 mmWC which is on higher side as compared to the design value of 26 mmWC. This pressure drop can be reduced by clearing the debris in the economizer section that will help in reducing the energy consumption by 0.41 MU/year.
iii) The PD across APH is measured in the range of 192 – 201 mmWC as compared to the design value of 192 mmWC. The higher pressure drop may be due to blockage in APH baskets. The cleaning & clearing the blockage in APH baskets will reduce the energy consumption by 0.26 MU/year.
iv) The Electrostatic precipitator (ESP) is used to extract the fly ash from the flue gas just before flue gas entering ID fans. The ESP cause the pressure in flue gas which is measured in the range of 10 – 50 mmWC which is on higher than the design value of 27 mmWC. The flue gas PD in ESP is reduced near to design value which will reduce the energy consumption by 0.67 MU/year.

The variation of secondary air pressure profile in secondary air circuit. The power used by fan and the associated power loss in FD fan circuit is presented in Figure 6. The energy conservation measures are discussed below:

The measured secondary air pressure in cold air duct from FD fan discharge to APH inlet is varying between 12 – 35 mmWC and is more than the design value of 10 mmWC in a typical 210 MW power plant. The higher pressure drop causes increased energy consumption of 0.26 MU/year. This can be reduced by clearing the debris in the cold air duct during overhaul.

Figure 6 gives the variation of secondary air pressure profile in secondary air circuit. The power used by fan and the associated power loss in FD fan circuit is presented in Figure 6. The energy conservation measures are discussed below:
iii) The PD in hot air duct from APH to windbox is varying between 10 – 26 mmWC which is slightly lower than the design value of 48 mmWC.

iii) PA fans

PA fan circuit consists of primary air path through cold air duct, APH, hot air duct and mills [16, 17]. The main purpose of PA fans is to provide the primary air to carry the pulverized coal from mills to burners and to maintain the coal-air mixture temperature to around 85 – 90 °C. The auxiliary power consumed by PA fans is about 0.72 % of plant load for 500 MW, 0.76 % for 210 MW and 0.88 % for 110 MW power plants.

The primary pressure profile in PA circuit is presented in Figure 7. The auxiliary power used by PA fans and losses in PA ducts for typical 210 MW power plant is given in Figure 8. The energy conservation measures for PA circuit are as follows:

1. The measured primary air pressure in cold air duct from PA fan discharge to APH inlet is varying between 15 – 33 mmWC which is higher compared to design value of 12 mmWC which cause an additional energy consumption of 0.15 MU/year. This can be reduced by clearing the debris in the cold air duct during overhaul.

2. The pressure drop in APH is measured in the range of 49 – 120 mmWC and is higher than the design value of 43 mmWC due to blockage of APH baskets which cause and additional energy consumption of 0.56 MU/year. This can be reduced by cleaning the APH baskets during overhaul.

3. The pressure drop in hot air duct from APH to mills is measured in the range of 16 – 47 mmWC which is slightly lower side compared to design value of 112 mmWC.

4. The pressure drop across mills is varying between 216 – 245 mmWC and is lower side compared to design value of 299 mmWC.

D. Operational optimization.

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

- Motor current with different frequency and voltage.
- \(O_2\) in flue gas at APH inlet with different load.
- Suction pressure and discharge pressure of fans with different loading.
- Winding temperature of motors.
- Bearing temperature of motors.
- Air – coal ratio in mills.
- Primary and secondary air flow.
- Furnace draft, windbox pressure and flue gas pressure at different locations for different plant load.

III. CONCLUSIONS

Some of conclusions from the study are as follows:

i. Optimizing & reducing size of fan and motor to appropriate size reduces the auxiliary power considerably.

ii. Introducing the variable frequency drives for fans will reduce the energy consumption and the technoeconomics of implementation of VFD is quite attractive.

iii. Reduction of hydrodynamic resistance of ducts will reduce the energy consumption at ID fans, FD fans and PA fans.

iv. Operation optimization of auxiliary equipment will help in reduction of auxiliary power.

v. Minimization of furnace ingress and air leakage through APH and ducts will reduce the auxiliary power by about 0.2 to 0.3 %.

vi. Implementation of energy conservation measures reduces the energy consumption by 5.5 to 6.5 MU/year which reduces the overall auxiliary power by 0.5% of plant load.

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AUTHORS PROFILE

Dr. Rajashekar P. Mandi. Director, School of Electrical and Electronics Engineering, REVA University, holds Doctorate from NITK, Surathkal in the area of "Power and Energy" and holds M. Tech. degree with 3rd Rank in "Energy Systems Engineering" from BV Bhoomaraddi College of Engineering & Technology, Hubli of Visveswaraiyah Technology University (VTU), Belgaum. He has five year of teaching experience. Prior to venturing into the field of academia, he has worked in Central Power Research Institute (CPRI) for 26 years in the areas of Energy conservation, Energy audit, Power quality, Power system and Renewable energy systems. His teaching experience includes, teaching subjects like – Power quality, FACTS controller, Electric Vehicle, Energy management, Renewable energy systems, etc., at the post-graduate level and PhD research scholars, and Electric power utilization, Electric machines, etc., at the undergraduate level. His area of interest is Energy conservation, Power quality, Power system and Renewable energy system. He is a professional member of IEEE. He is a member of CII task force committee for Power and Infrastructure in Karnataka. He is accredited energy auditor from Bureau of Energy Efficiency (BEE), Govt. of India. He is presently chairman of Society for Energy Efficiency & Manager (SEEM) Karnataka Chapter. He was member of several BIS committee in the area of electric lamps, electrical fans, solar PV, Batteries, electrical appliances, etc. He was also member of fixing of star label for LED lamps and electrical appliances for Bureau of Energy Efficiency, Govt. of India. He worked as nodal officer in Accelerated Power Development & Reforms Programme (APDRP). His research interests include renewable energy systems, energy conservation, strengthening of electrical distribution systems, electrical safety, power quality, LED lighting systems, etc. He had written 3 book chapters on energy conservation in Thermal Power plants and 2 book chapters in distributed power generation. He had published more than 155 technical papers in International & Indian Journals, Conferences & Seminars in the field of energy conservation, power quality, LED lighting system and renewable energy systems.

Udaykumar R. Yaragatti is Director, Malaviya National Institute of Technology (MNTI), Jaipur. Previously he was Dean, Head & Professor at Department of Electrical and Electronics Engineering, National Institute of Technology Karnataka, Surathkal. He received Ph.D. in Energy Systems Engineering from Indian Institute of Technology, Bombay, M.Tech. in Ind ustrial Electronics and B.Tech in Electrical Power from NITK Surathkal (formerly KREC).

His working experience includes teaching and research in the area of Power Electronics, Solid State Drives, PV System and Applications, Electrical Machine Design, Electrical Measuring Instruments, Electrical Machines, Principles and Practices of Management, Electrical Energy Systems, Energy Management, Energy Auditing, etc. He is specialized in Power Electronics and Drives, Energy Systems Engineering, Photovoltaic/Wind Power Systems, etc. He has published more than 150 technical papers in International & Indian Journals, Conferences & Seminars in the field of Electrical Power, Electrical Electronics, Energy Conservation and Renewable Energy Systems.