Confederation of Indian Industry

Best Practices Manual for
Indian Thermal Power Plants

Disclaimer

While every care has been taken in compiling this Manual, CII-Godrej-GBC does not accept any claim for compensation, if any entry is wrong, abbreviated, omitted or inserted incorrectly either as to the wording space or position in the manual.

The Manual is only an attempt to create awareness on Energy Conservation, Latest technologies and sharing of best practices being adopted in Indian thermal power plants.

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Foreword

India, the second most populous country in the world also stands as the fourth largest consumer of electricity. Out of the total power generated in the country, Coal and Gas based power plants together contribute the largest with 67.30%. However, with increasing dependence of the economy on electricity, monitoring and quenching the gap between the demand and supply is important to both the government and the industry.

Government of India is continuously taking efforts for reducing the demand-supply deficit with capacity addition, increase in capacity utilization and improvement in net station heat rates. Complementing initiatives of the government, the Indian thermal power plants are aggressively pursuing the adoption of latest technologies and implementation of best practices.

In alignment with the goals and objectives of the government and the industry stakeholders, CII – Godrej GBC has been promoting the concept of "Making Indian Power Plants World Class". As a part of the initiative, CII – Godrej GBC offers a platform for information exchange, sharing of best practices through visits to best operating plants both in National & International level and documenting the findings in manuals for widespread dissemination among the stakeholders. CII – Godrej GBC also organizes the "Power Plant Summit" every year as a flagship event for enabling continuous interactions among the Industry, technology providers and the government.

This manual is the 3rd in the series of Best practice manual for Indian Thermal Power Plants which intends to document few best practices, case studies and newer technological developments in Indian Power sector. The objective of this manual is to act as a catalyst in accelerating adoption of best practices and latest technologies across the sector. This manual highlights 34 numbers of case studies which have been implemented across the sector in India along with details of the technologies and cost economics. These case studies have a high replication potential and I am sure these will be useful to the Indian Power Sector.

I take this opportunity to thank the power sector fraternity for their contribution in preparing this manual and look forward to their continued support.

Thomas Joseph
Chairman, Power Plant Summit 2013 &
Executive Director (OS), NTPC

CONTENTS

Executive Summary

This manual **"Best Practices Manual for Indian Thermal Power Plants"** is intended to address the growing needs of energy conservation and energy efficiency in Indian thermal power plants. The manual showcases various energy conservation projects which are implemented across Indian thermal power plants along with few latest technologies which can be looked at by the sector. The manual is categorized into four sections:

- Boiler
- Turbine
- Boiler & Turbine Auxiliaries
- Balance of Plant (Compressors, Coal Mill and Electrical)

A total of 34 projects have been presented in the manual which provide the details in the following format:

- Background
- Project Description (or) Technology Description
- Benefits
- Financial Analysis

All the projects which are detailed in the manual are applicable for replication across utility, captive and gas based thermal power plants.

The objective of this manual is:

- To act as a catalyst in initiating continuous performance improvement in Indian power generating units and ultimately achieve world class standards
- To set clear goals and roadmap for improving the performance of Indian power generating units by working towards best operating parameters evolved for coal and gas based power plants.
- In addition to the best operating parameters, the best practices and latest technologies adopted in various power plants across the country have been compiled.
- These compiled best practices and latest technologies is intended to further assist Indian power plants towards replication of the best practices and to ultimately achieve world class standards
- The identified best practices may be implemented in individual power plants after suitable modification and fine tuning depending on the plant conditions.
- The collated best operating parameters and the best practices identified from various power plants need not necessarily be the ultimate solution. It is possible to achieve even better figures and develop better operation and maintenance practices which can be incorporated in other power plants in future.

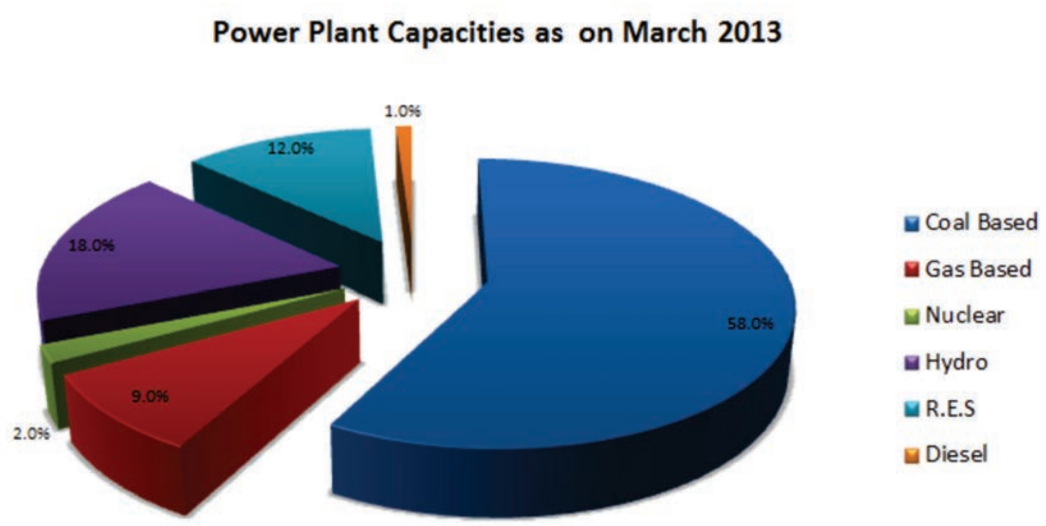
Therefore, the Indian power generation industry should view this manual positively and utilize this opportunity to improve the performance and move towards the world class standards.

Chapter 1
Overview of Indian Power Sector

Overview of Indian Power Sector

India despite being second most populous country in the world, it is the only fourth largest[1] energy consumer in the world after USA, China and Russia respectively. This factor clearly indicates that India's per capita power consumption is well below par when compared to the per capita power consumption of the developed countries. The per capita energy consumption in India as on March 2012 is estimated to be 879 kWh[2] which was way lower when compared to the per capita power consumption of the world which stood at 2782 kWh[3] in 2010 it self. The total installed capacity in the country as on March 2013 is 223.34 GW[4] . There is an additional capacity of 34.44 GW through captive power generation. Out of the total generated power, coal based power plants contribute 130.22 GW which is around 58.30% of the total power generated and gas based power plants contribute to 20.11 GW contributing to 9% of the total power produced. Hydro-electric power plants are the second major power contributors contributing to 18% of the total power generated in the country.

Figure 1: Installed capacities of Power Plants in India



The contribution of thermal power plants – Coal and gas based is significant and contributes to around 67% of installed capacity in the country. The capacity utilization of thermal power plants for the year 2010 – 11 is 75.07% and for the year 2011 – 12 is 72.81%. The total AT & C losses is 27.15%. The national demand for power is 78, 067 units for the year 2011 -12 with a deficit of 11.1% provisional. The reason for the deficit is due to the AT& C losses of 27%. Observing the distribution losses in other financial years, it has been observed that the major contribution of Aggregate Technical & Commercial losses is the distribution loss in the system.

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[1] Source: 12th 5 year plan Volume II (2012-2017)

[2] Source: Energy Statistics 2013

[3] Govt. of India – Press Information Bureau

[4] Source: CEA Monthly Report – March 2013

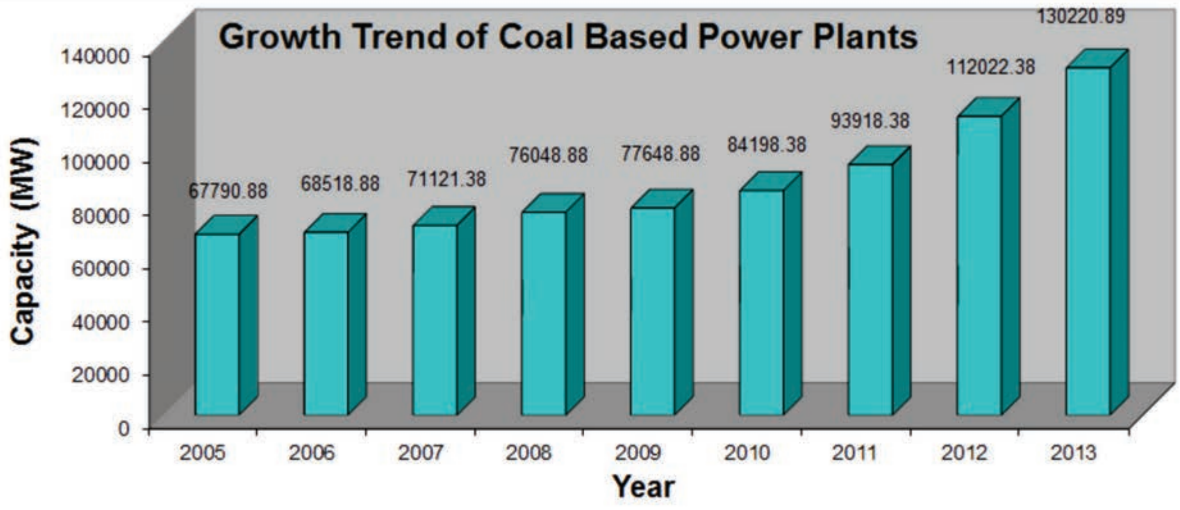
Growth Trends in Indian Power Plants:

India experienced a total capacity addition of more than 54,000 MW[5] in the 11th 5 year plan, out of which majority of the contribution, 47 % is from central government. Next contributor to the addition of power capacities is from state government with 34 % and private sector contributing to just over 19 %[6] . The annual average growth rate of the total energy requirement is expected to accelerate from 5.1 per cent per year in the Eleventh Plan to 5.7 per cent per year in the twelfth Plan[7] . The faster growth in supply in the Twelfth Plan is in part a reflection of the need to meet suppressed demand.

Growth Trends in Coal Based Power Plants:

The installed capacity of Coal based power plants experienced a steep growth every year from the year 2010. Despite the addition capacity, the power demand in the country was higher than the capacity every year.

Figure 2: Growth Trends - Coal Based Power Plants



Growth Trends in Gas Based Power Plants:

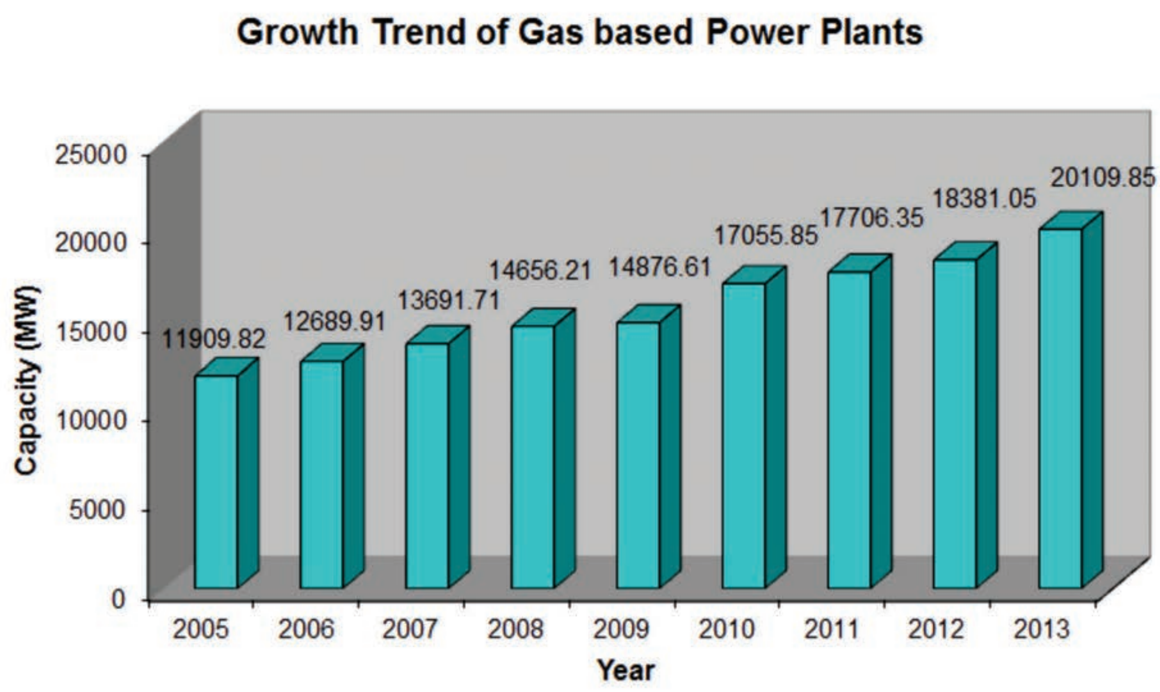
Gas based power plants experienced a steady increase in the installed capacities from 2005 to 2013. Many factors such as increased availability and exploration of gas resources added to the increase in capacities of gas based power plants.

[5] CEA – Annual Installed Capacity

[6] India Energy Congress Report

[7] 12th 5 year Plan Volume-II

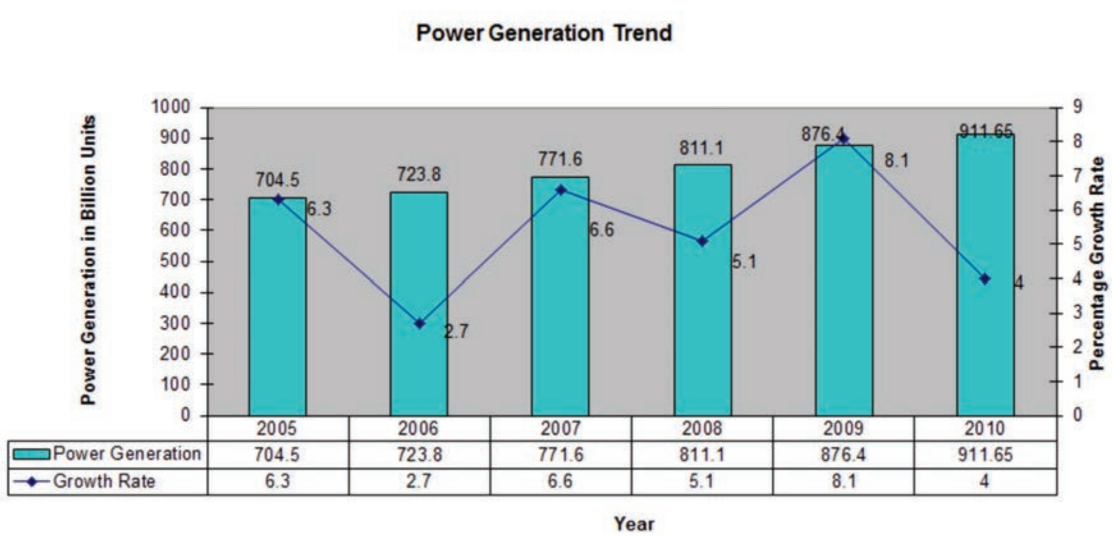
Figure 3: Growth Trends - Gas based Power Plants



Power Generation and Percentage Growth:

The electricity generation of power plants in India is increasing at a steady rate since 2007-08. Capacity addition since the 12th 5 year plan has been surged at a rapid rate. The capacity addition currently crossed more than 64,500 MW after the 11th 5 year plan. However, the percentage growth of power plants in India is fluctuating with power consumption increasing exponentially.

Figure 4: Power Generation and Growth rate

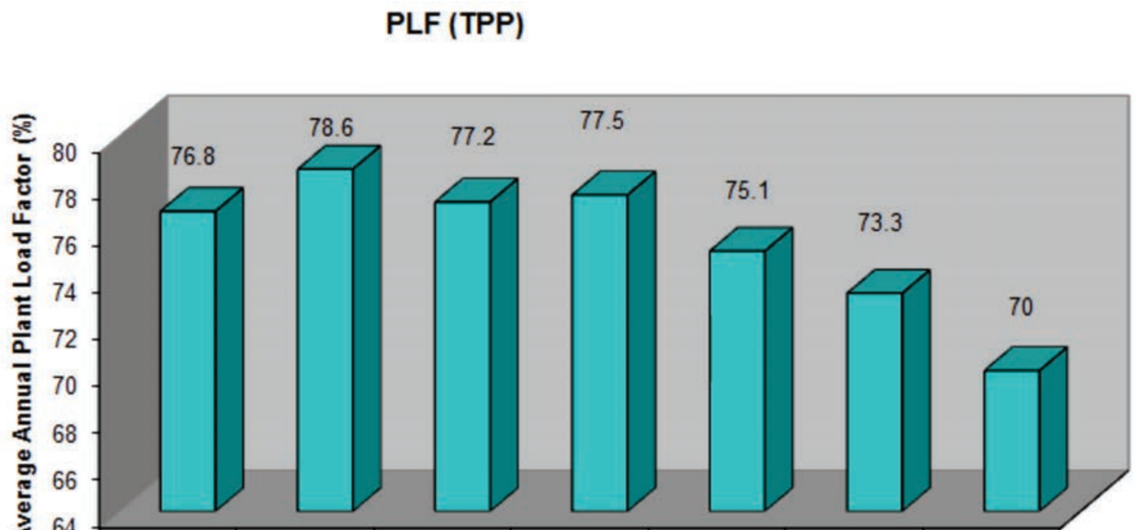


	2005	2006	2007	2008	2009	2010
Power Generation	704.5	723.8	771.6	811.1	876.4	911.65
Growth Rate	6.3	2.7	6.6	5.1	8.1	4

Average Annual Plant Load Factor:

Thermal Power plants are the major contributors in the Indian power sector with more than 50% of the total contribution to the total power generation capacity in the country. The average annual plant load factor (PLF) of all the thermal power plants in the country is on decreasing trend. There are several reasons attributing to the decreasing trend of PLF in India like the domestic production of coal and natural gases, increase in cost of coal imports etc.

Figure 5: Average annual plant load factor of Thermal Power Plants in India



	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
PLF	76.8	78.6	77.2	77.5	75.1	73.3	70

Chapter 2

Make Indian Power Plants World Class

Make Indian Power Plants World Class

To meet the demand supply gap, apart from augmenting the capacity, there is an immense need to improve the performance of the existing power generating units. The performance improvement of the existing power generating units can be taken up in the following areas:

- Availability
- Reliability
- Output
- Efficiency
- Cost
- Environment protection

CII-Godrej GBC in partnership with industry stakeholders' initiated a movement in Indian power sector with the theme "Make Indian Power plants World Class". The intent of this initiative is to catalyze and facilitate the performance improvement of Indian thermal power plants and ultimately achieve world class standards. The overall objective of the movement is to "Facilitate Continuous performance improvement and to assist industry in achieving world class standards"

As part of "Make Indian Power plants World Class" CII-Godrej GBC formed a pool of stakeholders and conducted the following activities to aid in achieving the objective.

- Technical consultation studies
  * Energy Efficiency Services / Energy Audits
  * Performance Audits / Monitoring Audits
- Technical Training Programs
  * In plant training programs
  * Technical training programs in common forum
- Workshops
  * Technical workshops in collaboration with international agencies like USDOE
- Technology Manuals & Publications
  * Publishing case study manuals on the best practices in Indian power sector
  * Technology and equipment supplier directory to assist the Indian power plants towards energy efficiency

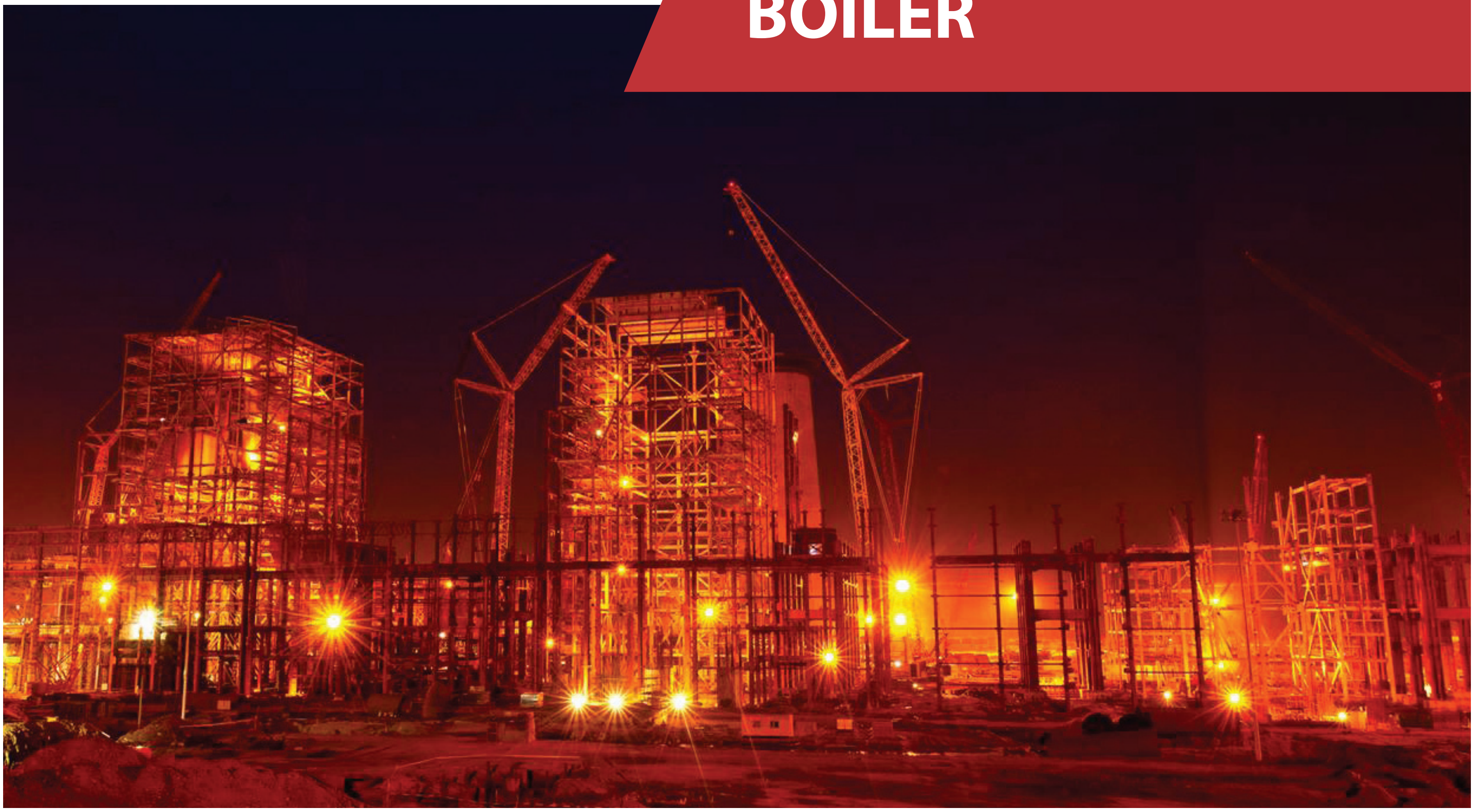
- National & International Missions
  * Identifying the best operating plants in the country and outside
  * Forming a core group of industry stakeholders and organizing visits to the best operating plants in India and outside India
- International Conferences
  * Conducting a two day conference exclusively on power plants involving all the stakeholders, technology suppliers and industry experts to enhance networking and disseminate knowledge sharing.

As a part of this initiative, many visits to best operating plants have been conducted. The 8th edition of Power Plant Summit was successfully completed in the year 2012 with wide participation from industry, government (CEA, etc) and technology providers. More than 10 international service providers participated from USA, Japan and China. More than 200 delegates attended the summit.

Chapter – 3

Case Studies & Latest Technologies for Performance Improvement

BOILER



CASE STUDY No. 1

ADVANCED COMBUSTION OPTIMIZATION TECHNIQUES FOR IMPROVING BOILER EFFICIENCY

Background

The opportunities for improvement in power plant performance are by inter-relating variables of performance of fuel quality, operation and maintenance, and plant reliability. Sustaining optimum plant performance and reliability is a needed. The following comprehensive areas can be evaluated for best practices. These areas help in evaluating opportunities for plant efficiency and heat rate improvement.

There are numerous "low-hanging" opportunities for combustion and plant efficiency improvement. Some of these include:

- Coal pulverizer and Burner performance
- Improve lower furnace heat absorption
- Reduce exit flue gas temperature
- Reduce carbon in bottom ash
- Reducing air-leakages at upstream and downstream of air-preheater

Most of these factors at the boiler influence heat rate and efficiency, generation and environmental performance. A series of performance tests can be carried out for identifying opportunities of improvement. These include the measurements of:

- Gross Turbine Cycle Heat rate
- Mill (or) Fuel line performance
- Total Airflow Measurement and Calibration
- Furnace Exit Gas profiling
- Flue gas and Fly ash measurement for performance evaluation

The ultimate goal of such an evaluation is to determine the "Stealth" losses and the "Unaccountable" losses impacting the heat rate performance.

Once the assessment is completed, the plants can enhance their ability to maximize load generation and performance while simultaneously improving environmental performance. As it is not untypical to find thermal power plants operating between 5-10% lower than the plants design thermal efficiency and this correlates with a tremendous opportunity for heat rate improvement. Generally deviations are not related to turbine solely, but even the boiler performance and auxiliary power consumption are equally important.

Some of the key points for success are:

- Team training and the personnel commitment
- Installation of comprehensive diagnostic testing
- Optimization of excess oxygen as proven at the furnace exit was required to validate actual combustion performance
- Pulverizer performance and fuel balance is a critical component of optimization strategy
- Total airflow management is essential
- Burner tolerance and mechanical maintenance of the firing systems is essential
- Boiler efficiency and air ingress measurements are critical

Achieving energy efficiency within thermal power plants is an essential requirement for sustainable and responsible power generation and demands a fundamental and proven approach which needs to be demonstrated.

CASE STUDY No. 2

OPTIMIZATION OF SOOT BLOWERS AND SMART WALL BLOWING SYSTEMS

Background

The boiler performance including its ability to meet full load, auxiliary power consumption, net plant heat rate, availability of the unit, operation and maintenance cost etc are significantly affected by the fuel characteristics. Coal firing in the furnace form different kinds of deposits on the boiler tubes.

To improve the performance and thermal efficiency of the boiler, it is important to remove the deposits periodically and maintain the heating surface clean.

Boilers are designed such that the radiation and convective zone heat transfer surfaces absorb the released heat proportionately. Any deviation in heat transfer in radiation and convection zone will affect the function of feed water preheating in the economizer, steam super heating in LTSH, platen super heater and final super heater. This will result in reduction in boiler operating efficiency.

Smart wall blowing system (SWBS) is a selective wall blowing system, operating on auto mode. The operation is controlled based on super heater spray flow and furnace heat absorption at different zones. SWBS consists of an electronic logic system interfaced with existing normal blowing system. The system consists of water wall heat flux sensors installed between the wall blowers, which have in-built thermocouples for sensing the wall temperatures. The system helps to maintain the furnace heat absorption at optimum level thereby maintaining the super heater and re-heater sprays within limits.

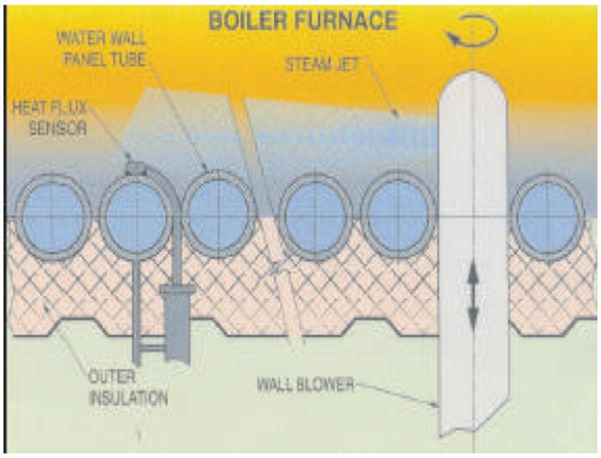
Project Description

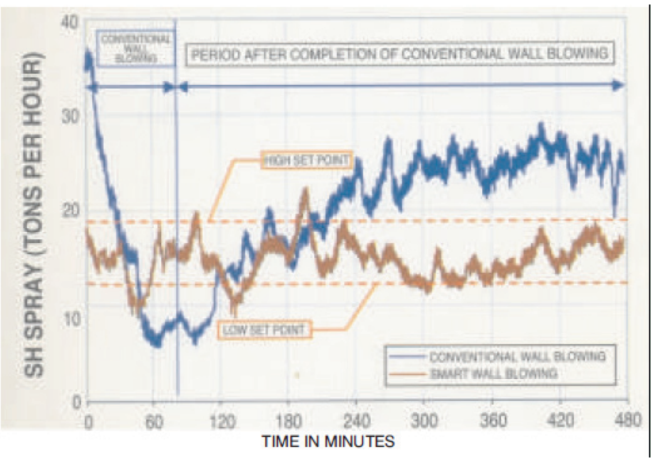
In a 210 MW coal based thermal power plant, the soot blowing system consists of 56 blowers arranged in four elevations. Out of the four, three rows are installed above the firing zone and the other below the firing zone. This system operates periodically, once in every 8 hours. All the 56 blowers are operated 3 times a day and the operation requires around 3.3 tons of steam per cycle.

The wall blowers, which are a part of the soot blowing system, are operated in a pre-determined period pattern of 90 minutes during the period of blowing. During the period of wall blowing and some period after it, the super heater spray reduces to a certain value due to the removal of ash deposits on the wall surface. The following are the issues observed with the wall blowing system:

- Providing more excess air when found slagging
- Keeping all the wall blowers in operating condition and operate them on a need basis rather than on a conventional mode

To overcome the above issues, the plant has installed a Smart Wall Blowing System (SWBS). In the SWBS, the wall blowers are activated by the signals of the heat flux sensors. These sensors measure the heat transfer due to ash deposits on the furnace walls. The SWBS activates the wall blowers automatically and the SH spray is kept within certain levels.





The SWBS system installed at the plant consists of the following:

- Heat flux sensors installed at four levels of elevation with each level having 8 sensors mounted on four sides of the wall
- The sensors are connected to the remote SWBS system control panel located at the control room through transmitters.

Benefits

- Avoids accumulation of ash deposits on the heat transfer surface
- Maintains the net total heat absorption level of the furnace at an optimum level
- Improves the heat rate/cycle efficiency
- Reduces the steam consumption by about 55-60% in comparison to the conventional soot blowing systems
- Offers less wear and tear of the equipment

Financial Analysis

The overall savings achieved by installing a SWB System was **Rs. 60 Lakhs**. Investment of **Rs 240 Lakhs** was made, providing a simple payback of **48 months**.

CASE STUDY No. 3

PERFORMANCE OPTIMIZATION OF ELECTROSTATIC PRECIPITATORS (ESP)

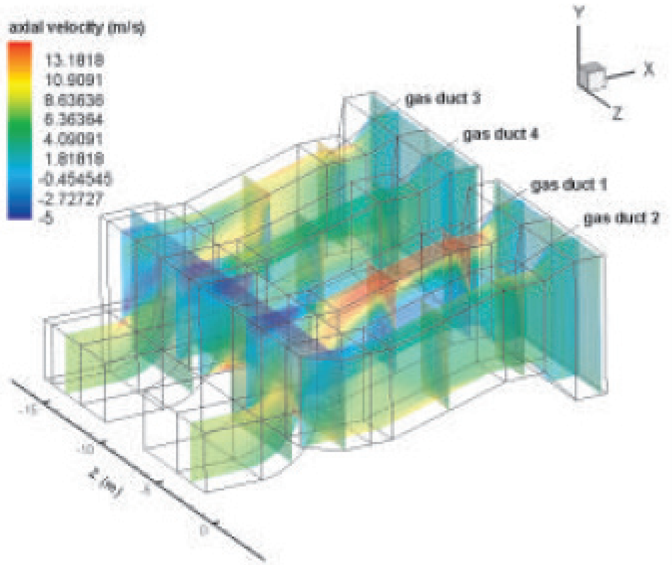
Background

The flue gas from a coal fired boiler contains suspended fine fly ash particles. The quantum of emissions of the suspended particulate matter (SPM) is required to be controlled as per the statutory requirements set by the Pollution Control Board. In Indian thermal power plants, the statutory norm for SPM limit is 150 mg/Nm^3.

The SPM level is universally reduced using Electrostatic Precipitators which function by imparting electric charge on the suspended particles by application of high potential and then collection on charged collector plates. The performance of ESP is critical for achieving the environmental performance desired by the plant and the statutory norms of the region.

The various factors that limit the performance of an ESP are:

- Excessive flue-gas velocity
- Skewed gas-flow distribution
- Un-optimized rapping
- Presence of un-burnt carbon in the flyash, etc



Axial velocity contours within ESP ductwork

The performance of ESP can be improved through Ammonia injection method.

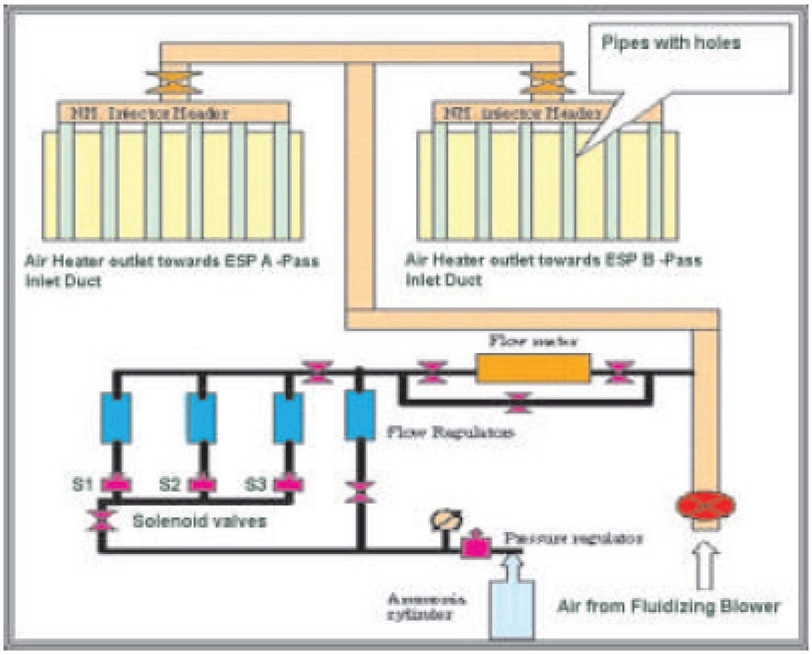
Project Description

In a 250 MW coal based thermal power plant, because of wide variation in the coal quality and outage of the ESP fields, the performance of the ESP was around 140 mg/Nm^3 which is near to the statutory requirement of 150 mg/Nm^3. The causes of poor performance are:

- Degraded performance due to higher ash resistivity
- Change of particle size distribution
- Changes in flue gas temperatures and moisture content from the design value
- Higher gas velocities

The plant decided to take up actions against this performance. Initially, some modifications were carried out on the rapping timer logic and sequence. There was also the replacement of conventional controllers with microprocessor based controllers. With the above modifications in place, the plant could still achieve a value of 100 mg/Nm^3. With a continuous upgradation of environmental standards, the plant decided to take a step towards Ammonia injection method.

Further conditioning with ammonia injection into the flue gas was found to be effective in terms of environmental protection and also cost benefits. The system includes ammonia cylinders, Masibus controller, control panel, volume flow meters, pressure gauges, isolating valves and carrier air bus.



The system description is as follows:

- Process logic is incorporated at Flyash PLC
- Stack SPM level is brought from DCS to a Masibus controller
- The Masibus controller generates three contact outputs with three set points, corresponding to three

levels of ammonia dosing. This activates the soft timers in the PLC. This in turn operates the solenoid valves in the auto control panel.

- Flow regulators on the downstream of the solenoid valves are set at 20 lpm flow for every 1 ppm dosage of ammonia in the flue gas
- Metering ammonia from the control panel is via carrier air bus to the ESP inlet

Benefits

- Reduction in emission levels to 75 mg/Nm^3
- ESP precipitator current and voltage improvement and reduction in spark rate

Financial Analysis

The material, fabrication and erection cost of ammonia dosing system is around **Rs 0.85 Lakhs**. Around 400 ammonia cylinders are required per annum and the approximate cost of operation per annum is **Rs 12 lakhs**.

CASE STUDY No. 4

MONITORING OF AIR INGRESS AND ADVANCED TECHNIQUES FOR IDENTIFICATION & ARRESTING THE SOURCES OF AIR INGRESS

Background

In general, the main source of the air infiltration into the flue gas circuit is at the Air Pre-heater (APH). It is mainly because of the pressure difference between the two sides of the air pre-heater. In the APH, the air side is under the positive pressure while the flue gas side is under the negative pressure.

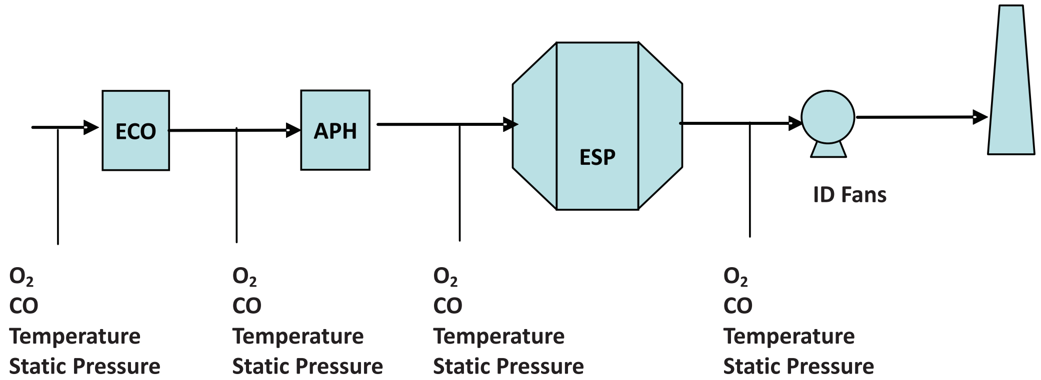
The air ingress results in the following:

1. Reduction in flue gas temperature and hence reduced heat recovery in the heat recovery units and the air preheater.

2. Increase in auxiliary power consumption

3. Reduction in collection efficiency of the electro static precipitator

Identification of the air ingress in the flue gas path is the key for arresting the leakage. The air ingress can be identified by measuring the oxygen level at various points in the flue gas path. Increase in the oxygen level at each section is an indication of the occurrence of air infiltration in the section.

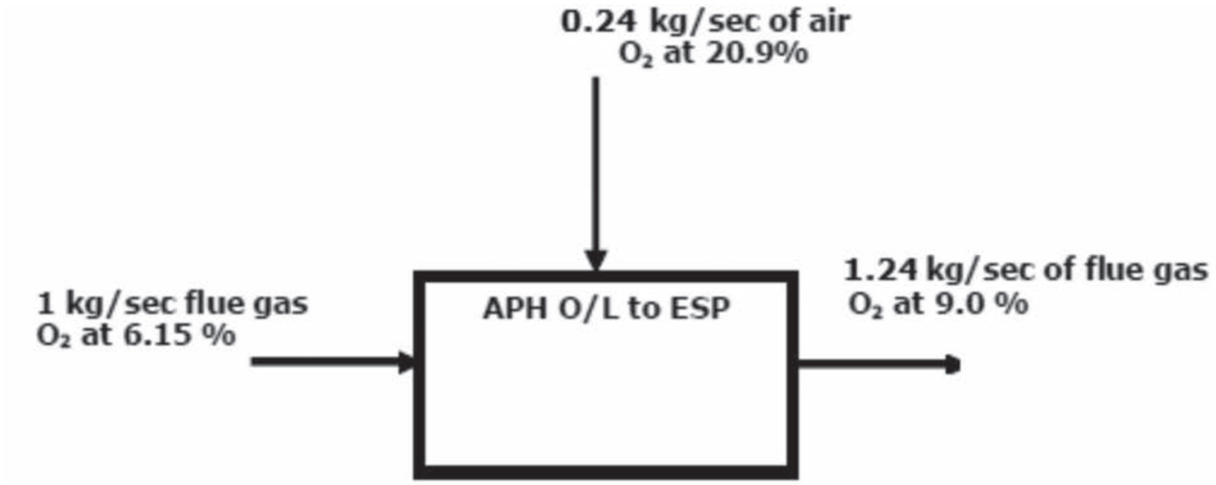


Due to air ingress, the temperature of the flue gas falls, and it also leads to increase in corrosion which leads to further increase in leakage.

Project Description

In a 250 MW coal based thermal power plant, the flue gas analysis was carried out at various locations. Following below are the results of the analysis:

	APH Inlet		APH Outlet		ESP Inlet				ESP Outlet			
	Pass A	Pass B	Pass A	Pass B	Pass A	Pass B	Pass C	Pass D	Pass A	Pass B	Pass C	Pass D
O_2	4.4	4.3	6.8	5.5	9	9	8.2	8.4	9	9	9.1	9.1
CO_2	14	14.3	12.8	13.5	8.5	10.6	11	11.7	10.6	10.6	10.6	10.4
CO	19	7	6	11	5	6	40	4	0	2	35	7



From the above analysis, the plant observed the trend of increase in oxygen concentration along the flue gas path. This clearly indicated the existence of air ingress into the path. The estimation of ingress of air into the flue gas was 24%. The plant then conducted a survey to spot the potential leakage spots along the flue gas path. It was observed that the leakages were due to damage of insulation, damage of seals near the dampers, and damages on the ducts.

The rectification of the identified issues of leakages and improper insulation was carried out by installation of thermo fabrics on the expansion joints and bellows. After the retrofit, the plant observed the percentage of oxygen in the flue gas was maintained around 4-5%. A quantifiable reduction of 50% of air ingress was observed due to the arresting. The below are the savings observed on the fans:

	Before	After
ID Fan 1A	1490 kW	1340 kW
ID Fan 1B	1540 kW	1390 kW
FGD Booster fan	824 kW	752 kW

Benefits

- A total Power of 372 kW was saved on the fans associated along the path (ID and FGD Booster)

Financial Analysis

The overall savings achieved for this project was **Rs. 104.16 Lakhs** (unit cost – Rs 3.5/ unit). Investment of **Rs 10 Lakhs** was made, providing a simple payback of **2 months**.

CASE STUDY No. 5

HEAT RECOVERY FROM CBD DRAIN FOR PRE -HEATING MAKE-UP WATER

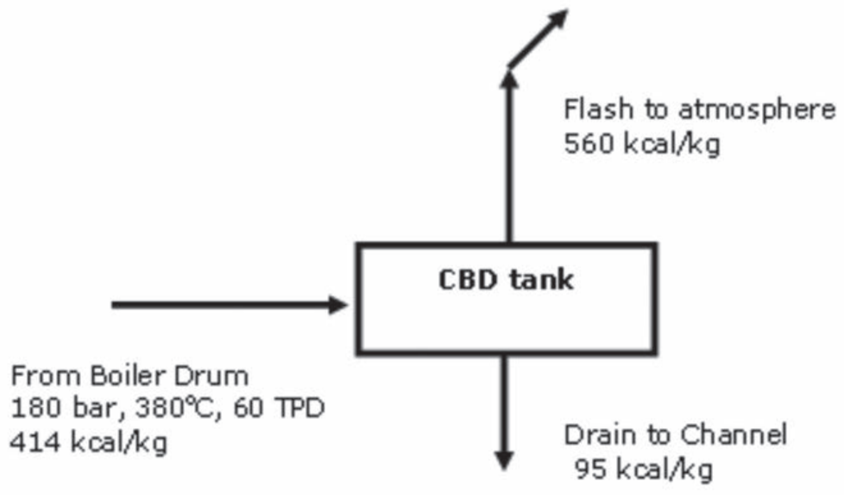
Background

Blow down can be done continuously or intermittently depending upon the requirement and water quality. Blow down is an essential process for TDS and silica removal, and hence cannot be avoided completely. The blow down water is at very high pressure and temperature. Thus, blow down leads to energy loss. This heat can be recovered and utilized for heating the make-up water.

In case of continuous blow down, the flash steam from the blow down tank is generally utilized at the de aerator. However, the drain will be let out at a temperature of about 90-95°C into the drains. There is a good opportunity to utilize the drain for preheating the feed water partly.

Project Description

In a 300 MW coal based thermal power plant, the practice of blow down is continuous to maintain the TDS & silica levels. Presently, hot water from the boiler drum is sent into the CBD tank where it is flashed. The heat and mass balance of the CBD tank is as below:

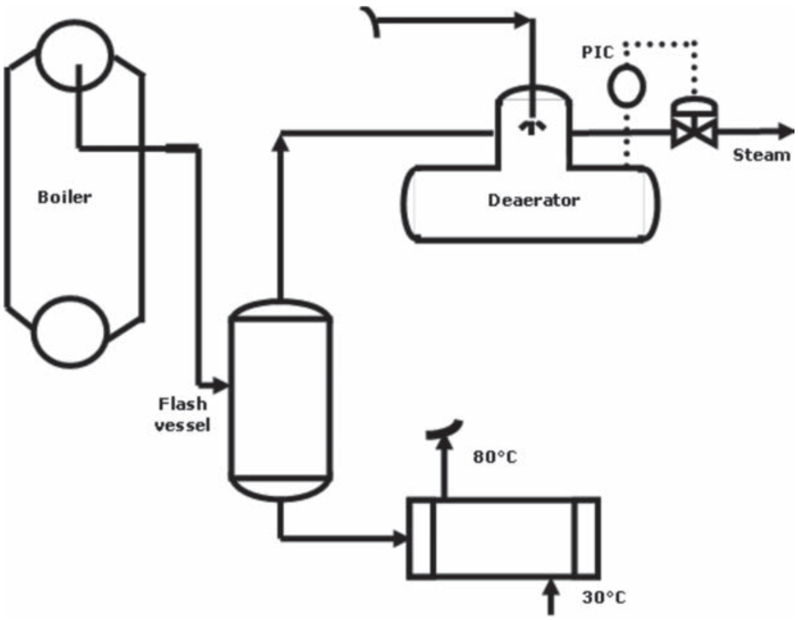


The quantities of flash steam and CBD drain were calculated using the Energy balance.

Flash Steam	0.85 TPH
CBD drain	1.71 TPH

The existing recovery system utilizes only the heat from the flash steam and the CBD drain was unutilized for its heat content. The new recovery system for utilizing the heat from the CBD drain was installed with the necessary modifications.

- A Level control valve installed in the tank to allow the flash steam to the de-aerator
- A Heat exchanger was installed for pre-heating the make-up water



Benefits

- The pre-heating of make-up water leads to savings in LP steam.

Financial Analysis

The overall savings achieved by heat recovery from heat recovery of CBD drain was **Rs. 13 Lakhs** (steam cost – Rs 200 / ton of steam). Investment of **Rs 4 Lakhs** was made, providing a simple payback of **4 months**.

CASE STUDY No. 6

PERFORMANCE IMPROVEMENT OF AIR PRE-HEATER AND IMPROVING THE OPERATING EFFICIENCY OF THE BOILER

Background

Air pre-heater performance is very critical for maintaining heat rate closer to the design of the system. If the air pre-heater performance gets affected, it results in multiple issues like reduction in flue gas temperature and corrosion issues, high volume of air to be handled by the ID fan resulting in excess power consumption, etc.

Project Description

In a 300 MW coal based thermal power plant, the flue gas analysis was carried out at various locations. Following below are the results of the analysis:

Boiler A	APH Inlet		APH Outlet		ESP Inlet				ESP Outlet				ID fan outlet	ID fan outlet
Side	**A**	**B**	**A**	**B**	**A1**	**A2**	**B1**	**B2**	**A1**	**A2**	**B1**	**B2**	**A**	**B**
O2, %	2.8	3.6	3.7	5.8	5.3	5.2	6.5	5.2	5.8	5.3	6.3	6.2	6.2	6.6
CO, ppm	5	2	3	0	0	0	1	1	0	1	0	0	0	0
CO2, %	15.8	15.3	14.8	13.4	13.8	13.7	12.5	13.7	13.3	13.6	12.9	12.9	12.9	12.7
Temp, Deg-C	330	329	149.5	132	136.5	133.5	125	136	135	137	128	131	135	128

The composition of coal was estimated from the proximate analysis method. The results of are as below:

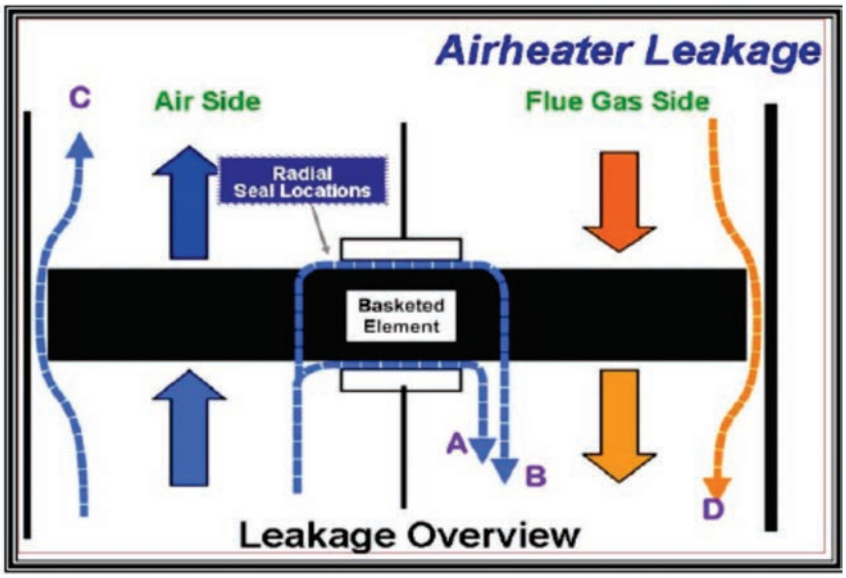
Proximate Analysis	
Total Moisture	14.33 %
Ash	32.59 %
Volatile Matter	24.46 %
Fixed Carbon	28.62 %

The boiler efficiency was determined as 87.89% using Indirect method. The heat losses are:

Heat losses	Boiler
Heat loss due to dry flue gas (Sensible heat loss)	4.33 %
Heat loss due to moisture and hydrogen in coal	6.22 %
Heat loss due to moisture in air	0.16 %
Heat loss due to radiation and convection	1.00 %
Heat loss due to unburnt carbon in Fly and Bottom ash	0.40 %

The increase in oxygen levels and the heat loss figures represent poor performance with the air preheater due to leakages. The plant quantified the leakage to be around 86 TPH at the air pre-heater and 62 TPH in the duct from APH to ESP. The effects and reasons of leakage are

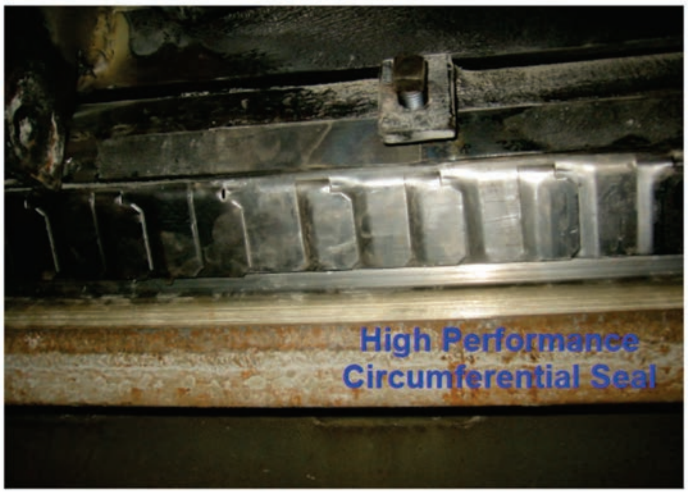
- Increased de-superheating spray
- Poor flame stability
- Faster air preheater plugging
- Increased Loss on Ignition
- Higher Auxiliary Power consumption
- Poor Coal drying



The plant arrested all the leakages occurring in the ducting and also inside the Air pre-heater.

Before Contact

Contact with Sector Plate



Benefits

- Avoided leakage in duct, which resulted in a saving of 75 kW on the ID fan
- Saving of 2363 tons of coal per annum due to arresting air leakage inside the Air Pre-heater

Financial Analysis

The overall savings achieved for this project was **Rs. 118 Lakhs** (unit cost – Rs 3/ unit). Investment of **Rs 20 Lakhs** was made, providing a simple payback of **2 months**.

CASE STUDY No. 7

SONIC SOOT BLOWING IN COAL FIRED THERMAL POWER PLANTS

Background

Ash fouling is a major problem in coal fired thermal power stations which affects operation economy and performance of boiler, APH, and downstream installations of ESP, SCR, baghouse filters, and IDF. Ash formation is sensitive to temperature so that it can appear as slag, clinker, and fly ash at different temperature zones with different surface adhesion propensities.

1 mm thickness of ash has a thermal resistivity equal to over 200 mm of steel; hence this excellent thermal insulator must be promptly removed as soon as it lands on heat exchange surfaces. Objective of soot blowing is to economically strike a feasible dynamic balance between the rate of ash landing and its removal from heat exchange surfaces in order to maximize thermal gain and reduce fuel consumption.

Slag removal in furnace is well developed and effective; and ash removal in other locations and installations can be equally effective and efficient if sonic soot blowing as a system solution is used. DIY style of applying sonic soot blowing is ineffective.

Technology Description

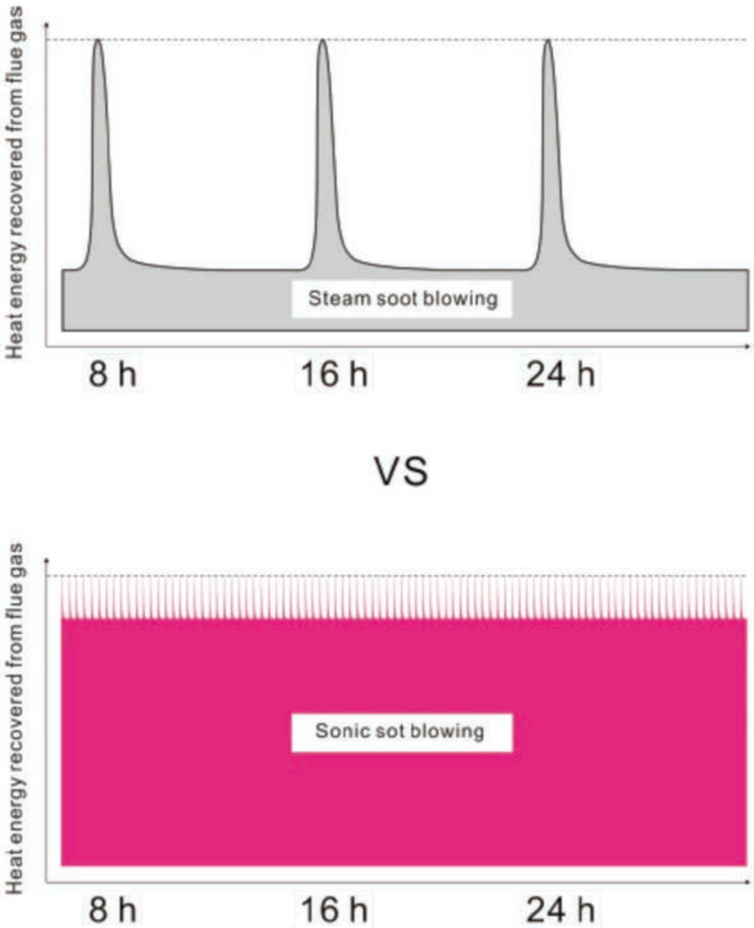
A typical sonic soot blower has a horn mouth and a sound generator; inside is a diaphragm which repeatedly buckles when supplied with compressed air to produce sound waves at 170 ~ 220 Hertz, and there is no moving part. It is simple, light weight, user friendly, easy to install, simple to maintain,

Sound waves sent into the enclosed space for cleaning reach into all corners to fluidize SPM (small particulate matters) which jump away from surfaces and are carried away by the flue gas stream (or fall into hoppers in ESP).

Sonic soot blowing cleans with minute forces in repetitive on-off short cycles; e.g., a cleaning cycle of 15 seconds "on" and 15 minutes "off" cleans 4 times hourly or 96 times daily. "On" time is governed by the ease of ash removal, i.e., the easier ash can be removed, the less time it takes to clean and the shorter is the "on" time. "Off" time is governed by the rate of ash deposit, i.e., the faster ash deposits or higher the ash loading, the more frequent it must clean and the shorter is the "off" time. Cycle time settings are adjustable at DCS stations to suit operating conditions and require minimum instrumentation for control and monitoring.

General Service compressed air at 7 bar maximum is used for driving the sonic soot blowers and exits into the flue gas stream afterwards. With low compressed air consumption and at low production cost, and that sound forces are minute and will not damage tubes or structures and is harmless to human, it is feasible to operate sonic soot blowing on-line continuously around the clock to target at short payback period.

A healthy spin-off of sonic soot blowing is air pollution reduction. When boiler back pass is being cleaned 4 times an hour, ash discharge is in small batches and can be effectively captured by ESP to reduce exit dust loading and produce a clear stack.



Comparing Steam and Sonic Soot Blowing

Sonic soot blowers always work in group to saturate the enclosed space with sound energy and optimize cleaning effect. The number and layout of sonic soot blowers in a group depends on physical size and shape of the enclosed space, complexity of its internal parts, and how easy it is to remove the ash. Grouping arrangement is applied without exception to superheaters, reheaters, economizers, APHs, each field in ESP, each layer in SCR, each chamber in baghouse filter, and IDFs.

It is interesting to note that sonic soot blowing rotary APH posts a slightly different case, as the heat exchange baskets have tightly packed corrugated plates which discourage effective penetration of sound waves. The common practice is to apply both steam and sonic soot blowing to extend the time to replace plugged baskets.

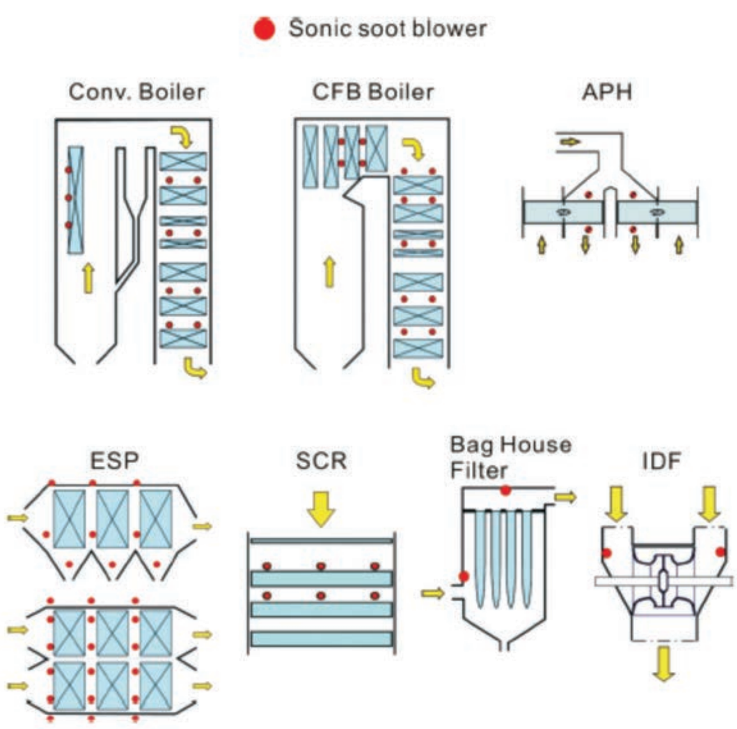
Sonic soot blowing ESP is very effective in cleaning collection plates and emission wires to restore dynamic balance between collection and removal efficiencies, and is applied to the first 3 fields where nearly 100% of inlet dust loading is captured. Sound waves can travel in flue gas with little energy loss to directly fluidize SPM and dislodge them from plates and wires; and sound energy input is adjustable when ESP inlet dust loading changes. It is usual to retain existing mechanical rapping system as support even though vibration velocities degenerate quickly when passing through the plates and wires, and neither can it be replenished nor augmented. Given the same ESP output dust loading, it is feasible to operate with fewer fields when sonic soot blowing is used. Steam soot blowing cannot be used in cleaning ESP at all.

Sonic soot blowing SCR is equally very effective in cleaning catalyst layers, as steam soot blowing and mechanical rapping can easily damage the catalyst carriers.

In baghouse filters, sonic soot blowing is more superior to the 3 common cleaning methods of jet pulse, mechanical shaking, and reverse gas flow, again because sound waves can travel in the dust laden gas to directly fluidize SPM and dislodge them from fabric bags without damages. Physical size and shape of baghouse filters is no hurdle to sonic soot blowing at all.

In IDF, the impeller rotor can sometimes be fouled with dust caking to induce out of balance vibrations and damage rotor bearings and the drive mechanism. Sonic soot blowing can remove the dust cakes and extend the time between bearing damages and its replacement.

Successful application of sonic soot blowing is a powerful tool for cleaning different installations in a thermal power station. Its effective and efficient application can produce financial and operational gains from deployment of management resources which are too valuable to lay wasted otherwise.



Sonic soot blowing applications in TPS

TURBINE

CASE STUDY No. 8

PERFORMANCE EVALUATION OF CONDENSER AND TECHNIQUES FOR PERFORMANCE IMPROVEMENT

Background

Condenser performance play a vital role in efficient operation of the plant as major share of heat rejection takes place here. It is very well known that major deviations from the design value of the heat rate are to a great extend due to under performance of the condenser largely reflected in non-achieving the desired vacuum. Maintaining Vacuum conditions meeting the design aids in augmenting power generation of the unit. Higher is the Rankine cycle efficiency, if lower is the temperature at which heat is rejected. Hence maintaining condenser back pressure at design value is important. Condenser performance is based on expected values of Heat load, C. W. Inlet temperature and quantity of insoluble gases. If any one or more of these values exceed the design value higher than expected, back pressure may result.

Guidance for Condenser leakage identification

Principle: In case of leaks in the condenser tubes, cooling water seeps into the condenser tube & contaminates the Steam/ Condensate. Condensation creates vacuum on the steam side and in a running condenser where one half of the condenser is isolated from CW system the vacuum due to condensing process still continues and due to this air gets sucked into leaking condenser tube. This process is equivalent to the leak into a vacuum system. The air is leaking into the vacuum system going from high pressure to low pressure. This transition creates turbulence in the air. This turbulence in air is associated with "Ultrasonic/ Acoustics" noise. The Noise generated is picked up by acoustics leak detector & is predominant at a frequency of 40 KHz. This ultrasound can be heard through a headphone. The user can accurately pinpoint the location of these ultrasounds to the location of the leakage.

Instrument: The instrument used for conducting leakage test in the condenser is ultrasonic noise detector. It consists of basic hand held unit which is simple to use with headphones & an analog/digital meter with a sensitivity adjustment. The instrument when used for condenser tube leak identification, a fixed frequency band of 40 KHz is recommended. The ultrasonic or Acoustic noise is converted to audible range by the process called heterodyne & is heard through head phone connected to the instrument.

Environmental Measures: As we are well aware that in a running unit where one half of condenser is in charged condition & acoustics test is carried in isolated half of the condenser, even then from human perspective it is not recommended to stay inside the condenser for a long time due to higher temperature & humidity conditions. So to make it more comfortable, portable AC/pedestal fans can be arranged during testing.

Fully covering the tube opening to block any external noise picked up by equipment

Sensitivity adjustment Knob with analog reading panel

Latest types of equipments used for Acoustics leak detection:

- Ultra probe 9000
- SDT-170

Project Description

In a 30 MW coal based thermal power plant, the condenser vacuum that was achieved was only about -0.86 kg/cm^2 (0.14 ata) even during favorable climatic conditions. The generation potential was found to be 284.8 units/ ton-condensing.

The plant conducted an ultra-sound leak test to identify any possibilities of air ingress into the condenser. They found few major areas where the leakage was considerably large.

After identification and arresting the leakages in the condenser, the plant was able to achieve a vacuum condition of -0.90 kg/cm^2 (0.1 ata). This increased the generation potential from 284.8 to 288.3 units/ ton-condensing.

Benefits

- The plant achieved a total benefit of 3.7 units/ ton-condensing.

Financial Analysis

The overall savings achieved for this project was **Rs. 36 Lakhs** (cost per unit of condensing steam – Rs 1.32/ unit). Investment of **Rs 4 Lakhs** was made, providing a simple payback of **2 months**.

CASE STUDY No. 9

EVALUATION OF PERFORMANCE OF HEAT EXCHANGERS AND IMPROVEMENT OPPORTUNITIES

Background

Heat exchangers play a vital role in determining the performance of a thermal power plant. The effectiveness of the heat exchangers such as HP heater, Condenser, LP heater, feedwater heater and de-aerator determine the heat rate of the station.

Among the above mentioned heat exchangers, one of the critical equipment is the HP heater. To determine its performance, the following are the key parameters used:

- Economizer inlet feed water temperature
- Terminal Temperature Difference (TTD)
- Drain Cooler Approach (DCA)
- Steam flow through the HP heater which is estimated based on heat balance

The key parameters used to evaluate the performance of LP/HP heaters are TTD and DCA. They are defined and calculated as follows:

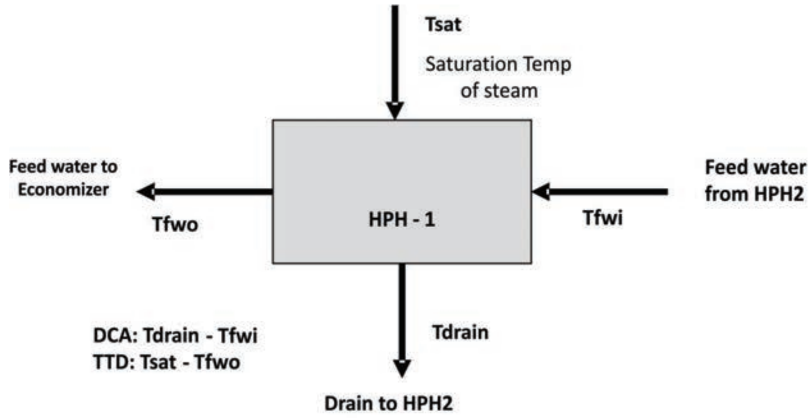
Terminal Temperature Difference (TTD) is the difference between the heater outlet feedwater temperature and the saturation temperature of steam. It is calculated as:

- $TTD = T_{sat} - T_{fwo}$

Drain Cooler Approach (DCA) is the difference between the drain temperature and the inlet feedwater temperature. It is calculated as:

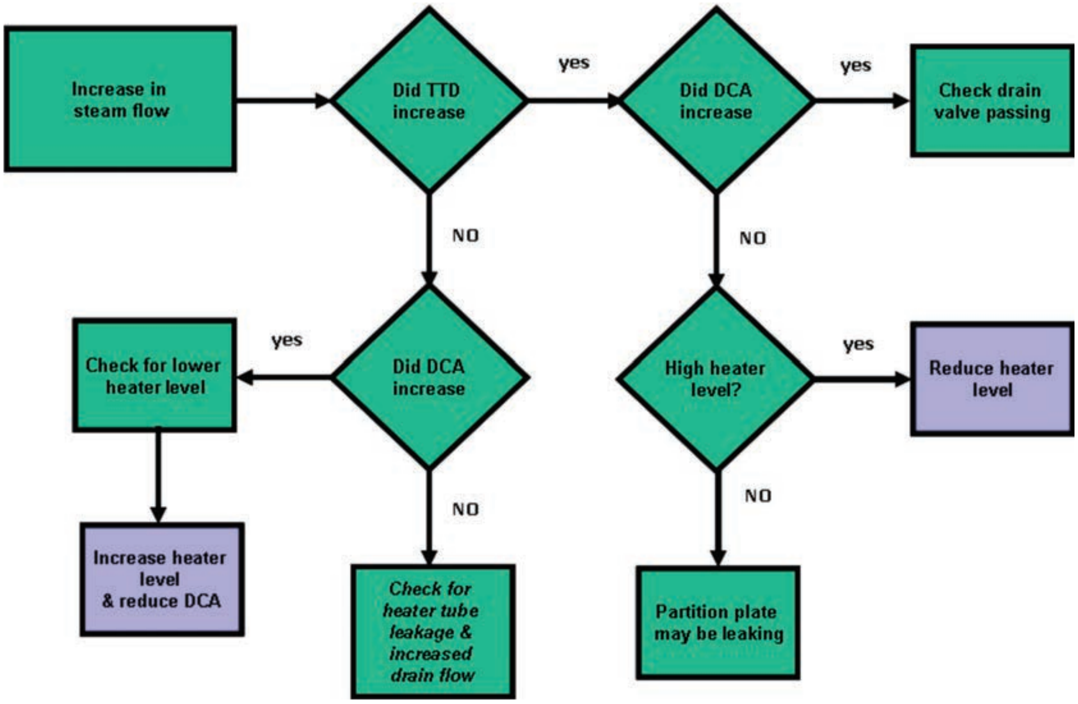
- $DCA = T_{drain} - T_{fwi}$

The schematic of the HP heater with the terminologies can be as shown below:



Due to the de-superheating zone in the heater, the feed water outlet temperature may be greater than the saturation temperature of steam, giving a negative value of TTD. In the case where de-superheating zone of the heater is removed, the feed water outlet temperature will be less than the saturation temperature, resulting in a positive TTD. The practical lower limit of TTD is +1.1°C. In the case of heaters where de-superheating zone is used, the TTD limit will depend on the amount of extraction steam entering the heater.

The guidelines for assessment of the heater performance are presented in a flowchart , explained below.



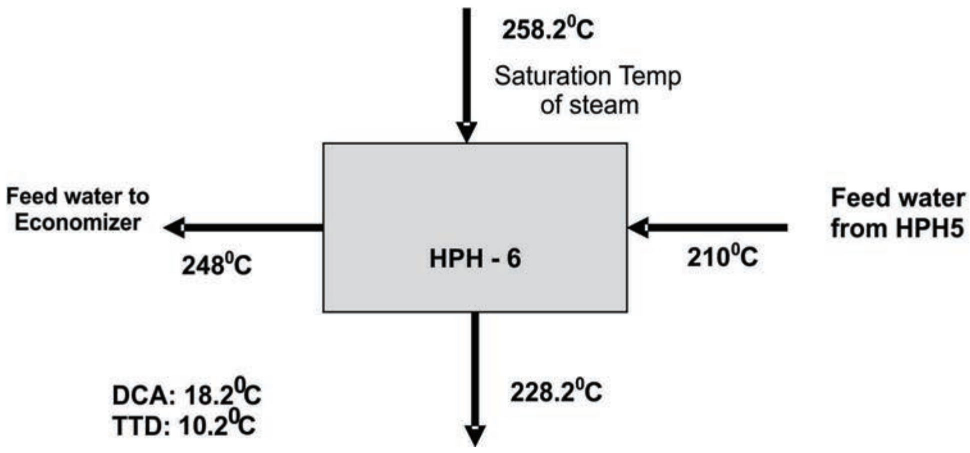
If the steam flow to the LP/HP heater increases, the flowchart can be used for evaluation. After the increase in steam flow to the heater, most importantly the variation in TTD and DCA from the design values has to be observed. Based on the increase/decrease in TTD and DCA the flowchart can be evaluated to determine the cause of the problem.

Project Description

In a power plant of 250 MW, the steam flow to HP heaters has increased from the design value. The steam flow to the HP heaters increased, a result of an uncontrolled extraction of steam to the LP/HP heaters.

The plant team has compared TTD and DCA values of the HP heaters in the plant with the design values of the system. The HP heater performances were then evaluated based on the flowchart provided above. The TTD and DCA values of HP heaters in the plant are provided below:

Heater	Operating		Design	
	DCA	TTD	DCA	TTD
HPH6	18.2	10.20	6.8	2.6
HPH5	5	7.21	6.8	2.6



The values of TTD and DCA have found to be high in HPH6. The plant team had found that the drain valve to the dearator was passing and have replaced the existing drain valves with a multi – stage drag valves.

The principle of multi – stage drag valve is to reduce the pressure drop by creating a treacherous path for the fluid to dissipate energy uniformly rather than with a shock wave effect, which is usually observed in the normal drain valves. The material of construction and the pattern of the drag valves are designed to reduce the velocity of entrained fluid, thereby minimizing the impact of erosion of the valve.

Benefits

- Replaced drain valve with multi – stage drag reduction valve.
- Savings of 2 kCal/kWh was achieved by the plant by operating the HP heater close to the design value

Financial Analysis

The overall savings achieved for this project was **Rs. 25.00 Lakhs** (Coal cost : Rs 5000/-). Investment of **Rs 10.00 Lakhs** was made, providing a simple payback of **5 months**.

CASE STUDY No. 10

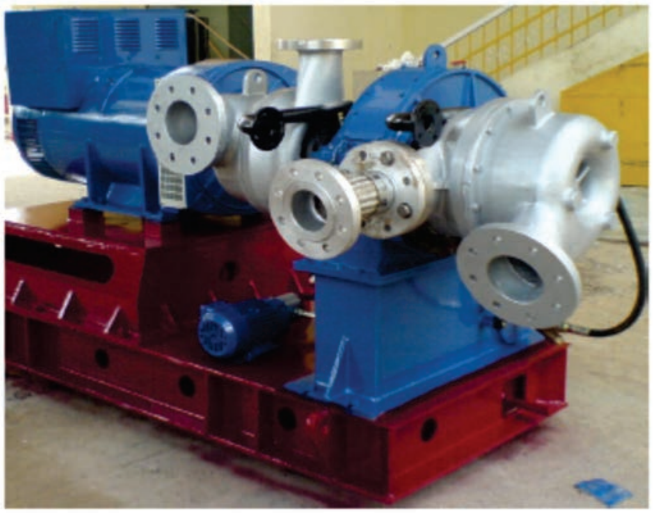
INSTALL MICRO TURBINE FOR ADDITIONAL POWER GENERATION AND MINIMIZE STEAM FLOW THROUGH PRDS

Background

In thermal power stations, the auxiliary requirement is drawn from the main header and passed through PRDS for reducing the pressure to the required level of 15 kg/cm^2. The auxiliary steam is used for the heating applications such as fuel heating, tracing, ejector requirement etc. The flow varies depending upon the requirement from 4-10 tons/hr in power stations.

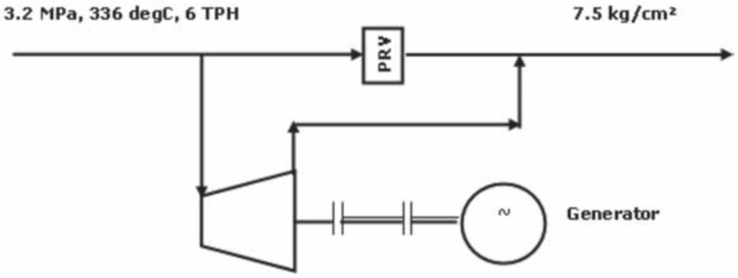
In some of the plants, the steam is drawn from the cold reheat line. This is much better option compared to drawing it from the main header. Still the pressure reduction across the PRDS is significant. There is a good potential to generate additional power / drive the equipment with the support of micro turbines.

The micro turbines are tailor made. The turbines are available with various capacities from 130 kW.



Project Description

In a 300 MW Coal based Thermal Power plant, the Auxiliary Pressure Reduction De-Superheating System (APRDS) caters for the auxiliary steam requirements. APRDS is charged through Cold Re-heat (CRH) line. On a continuous operation, 6 TPH of steam flows through PRDS, but when soot blowing is in service, the requirement is around 8 TPH.



The conditions of steam are:

- CRH line: 3.2 MPa, 336 degC
- APRDS Station: 9.5 kg/cm^2

The plant had installed micro-turbine through which the desired conditions of pressure reduction of steam can be met along with an additional benefit of power generation.

The plant installed the micro-turbine, in parallel to the PRDS operation. The micro-turbine generates around 160 kW in its normal operation and more during soot blowing. The details of steam parameters and the power generation is given below:

Inlet Pressure	28.00	kg/cm2(g)
Back Pressure	10.50	kg/cm2(g)
Saturated Steam Temp. at Inlet	*232*	*C*
Inlet Temperature	331	C
Steam Flow Rate	6.00	x 1,000 kg/h
Steam Condition at Inlet	*100%*	*Super-Heated!*
Enthalpy at Inlet	*3,078*	*kJ / kg*
Isentropic Enthalpy Drop	***208***	***kJ / kg***
Actual enthalpy Drop	***114***	***kJ / kg***
Generator Efficiency	95%	
Temperature at Exit	*240*	*C*
Enthalpy at Exit	*2,964*	*kJ / kg*
Steam Condition at Exit	*100%*	*Dry-Saturated!*
Electrical Power Output:	***166***	***kW***

Benefits

- The operation of PRDS has been minimized significantly.
- Additional power generation of 160 kW was achieved the Micro-turbine during continuous operation

Financial Analysis

The overall savings achieved by installing micro-turbine was **Rs. 32 Lakhs** (unit cost – Rs 2.5/ unit). The Investment of **Rs 60 Lakhs** was made, with a simple payback of **23 months**.

BOILER & TURBINE AUXILIARIES

CASE STUDY No.11

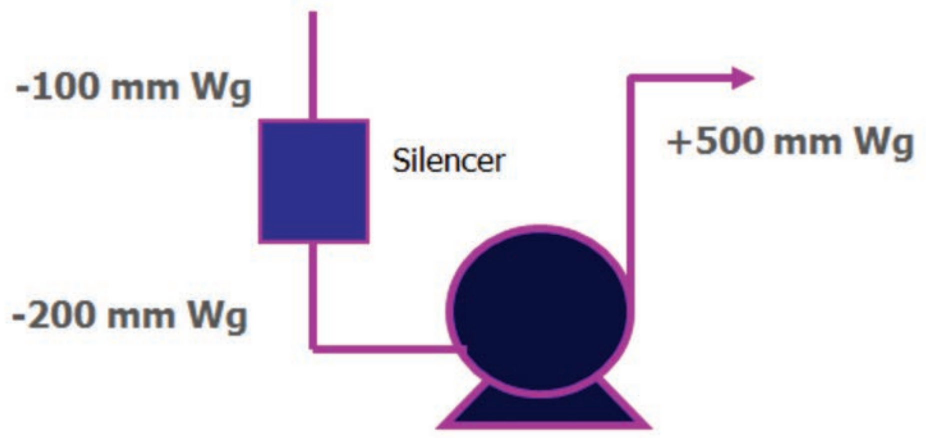
IMPROVING FD FAN EFFICIENCY BY REDUCING SUCTION PRESSURE LOSS

Background

Forced Draft (FD) fans provide atmospheric air for the combustion of fuel in the furnace. As with every fan, the power consumption is dependent on the volume of air and the pressure head developed by the fan. The suction side pressure is one of the areas which receive the least importance and this could play a vital role in the overall efficiency of the fan. Hence while taking measures in improving the efficiency of the fan, care should be taken to ensure resistance free movement for air.

Project Description

In a 15 MW captive power plant, there were two boilers supporting it. Each boiler had two FD fans, of which, one was in operation and the other was in standby for supplying the combustion air to boiler. The plant team had installed VFD for both the forced draught fans at design stage itself and this had substantially reduced the power consumption in the FD fan especially during variable load conditions. Later on it was observed that the suction pressure of FD fans was on higher side. The pressure values were as shown in the figure below



Design

Flow - 55 TPH

Head - 850 mmWc

As per the values it was observed that there was a huge pressure drop at the suction of the silencer and also across the silencer itself. The plant team decided to widen the suction duct into a bell mouth opening to reduce the pressure drop at suction and also decided to remove the silencer thereby saving energy corresponding to 100mm pressure drop.

After modification, the plant observed the following

1. Huge reduction in the suction pressure
2. About 18% reduction in power

3. As the suction resistance reduced, the flow of the fan increased and as it was equipped with VFD, the speed of the fan was reduced further.

Benefits

- Power saving of 64 kW was obtained from both the FD fans

Financial Analysis

The overall savings achieved for this project was **Rs. 11.69 Lakhs** (unit cost – Rs 4.3/ unit). Investment of **Rs 6 Lakhs** was made, providing a simple payback of **6 months**.

CASE STUDY No.12

REPLACEMENT OF BOILER PA FANS WITH CORRECT SIZE HIGH EFFICIENCY FANS

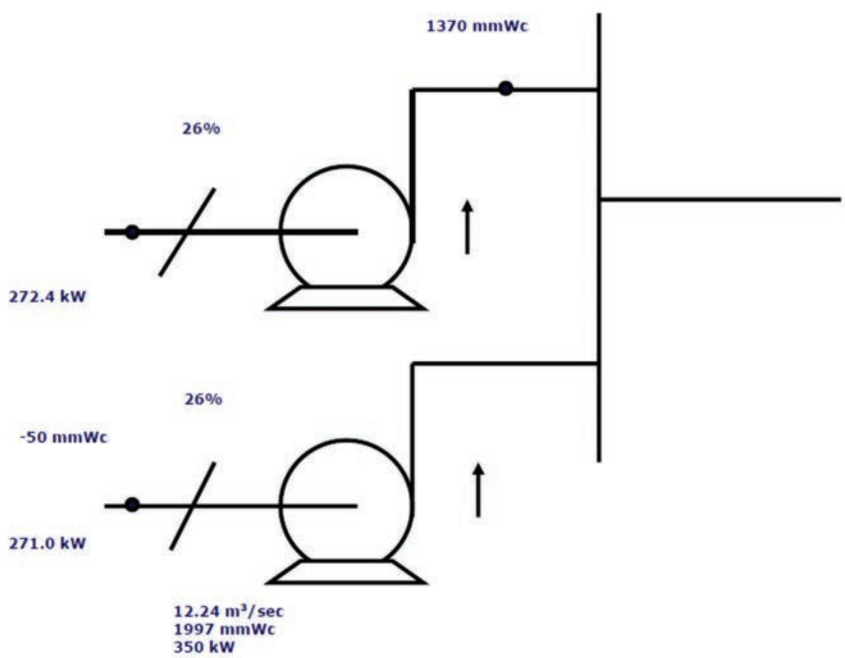
Background

Primary air (PA) fan conveys coal to the boiler, dries it and provide atmospheric air for the combustion of fuel in the furnace. As with every fan, the power consumption is dependent on the volume of air and the pressure head developed by the fan. The operating efficiencies of the fans can be calculated and opportunities of replacing with an energy efficient fan can be seen. Those fans which operate with damper control can switch to VFD, which can give good benefits to the fans in part load operation thereby avoiding energy loss due to pressure drop across damper

Project Description

In a power plant of 50 MW, two PA fans were in operation, each with following design details.

- Capacity : 12.24 m^3/sec
- Head : 1997 mm WC
- Motor : 350 kW



The following are the power consumption of both the PA fans.

- PA fan A : 272.4 kW
- PA fan B : 271.0 kW

The PA fans were controlled with the help of IGV in order to maintain a flow of 21.5 kg/sec which is equivalent to 16.67 m^3/sec. The IGV's of both the fans were about 26% open and the measured operating head of the fans was about 1420 mmWC.

Based on the flow, operating head & power, the operating efficiency of the PA fans were estimated to be 46.4%.

The plant team replaced the overdesigned PA fans with correct size fans of 75% efficiency with VFD control.

Benefits

- Improved PA fan efficiency from 46.4% to 75%.
- Avoided energy loss due to damper control.
- A total power of 170 kW was saved

Financial Analysis

The annual savings potential is **Rs. 68.00 Lakhs**(with Rs 5.0/unit), the investment required is about **Rs. 60.00 Lakhs**. This gets paid back within **11 months**.

CASE STUDY No.13

INSTALLATION OF HT VARIABLE FREQUENCY DRIVE FOR CONDENSATE EXTRACTION PUMP (CEP)

Background

Motor-driven equipment and systems are designed with safety margins for handling peak and extreme conditions. This margin in return causes inefficiency and leads to excess power consumption of the equipment. A Speed control is a good method to reduce the power consumption on running load and also keep in line with the margin for safety during extreme conditions.

The Variable Frequency Drive (VFD) is a drive which varies the speed of the motor by changing the frequency and voltage of the motor. VFD's are used for the following reasons:

- To vary the capacity of the motor in sync with the changing load of the machine
- To minimize the energy losses due to excess margin built in the equipment
- For precision in control of the equipment

In general, for a thermal power plant, reduction in auxiliary power consumption is a focus to enhance the throughput of power export and thus profitability. Typically, all the auxiliaries are designed with excess margins to ensure reliability and also meet the extreme conditions of the plant. The condensate extraction pumps offer good opportunity for reducing the power consumption by installing the variable frequency drives.

Project Description

In a 250 MW coal based thermal power plant, there are two Condensate Extraction Pumps installed, with one in operation and other as stand-by. The design conditions of the pump are:

Description	Values
Flow	870 TPH
Head	205 m
No of Stages	5
Power	650 kW

The operating parameters of the CEP during the normal operating conditions are as below:

	Values
Discharge Pressure	21.3 kg/cm^2
Deaerator Pressure	6.9 kg/cm^2
Flow	640 TPH
Motor Speed	1450 rpm (50 Hz)
Power Consumed	590 kWh

The control valve in the line was heavily throttled, about 60% open. This is clearly representing an excess margin in operating the condensate extraction pump. The pressure loss across the control valve is about 7.5 kg/ cm^2.

To reduce the pressure drop across the control valve, VFD was installed on the motor of CEP. This provided the benefit of power saving due to speed control along with precision control of the pump. The feedback to the VFD was given as the differential pressure across the control valve of the drum.

Benefits:

- The energy saved by operating with a VFD was around 150 kW per hour
- Lower maintenance cost due to extended life of bearings due to lower operating speed
- Controlled ramp-up speed eliminated water hammer issues
- Safety for protecting equipments with lower tolerance for high torque

Financial Analysis:

The overall savings achieved by running the CEP with a VFD was **Rs. 48 Lakhs** (unit cost – Rs 4/ unit). The investment of **Rs 60 Lakhs** was made, providing a simple payback of **15 months**.

CASE STUDY No.14

INSTALLATION OF HT VARIABLE FREQUENCY DRIVE FOR BOILER FEED WATER PUMP (BFP)

Background

The boiler feed water supply to the drum is controlled using the feed water control station. The three element signal is used for controlling the boiler feed water supply to the drum. The feed pump delivers the same quantity of water irrespective of the requirement in the boiler. Hence the power consumption remains the same.

There is a good potential to optimize the power consumption of boiler feed pumps by installing speed control. The speed can be controlled using variable fluid coupling or the variable frequency drives. In latest plants the boiler feed pumps are fitted with the variable fluid couplings by design.

Installations of HT variable frequency drives can be explored in old plant where the boiler feed pumps are operating with constant speed. This will vary the feed water supply depending upon the requirement, which will lead to significant reduction in energy consumption. Since the variable frequency drive reduces the speed to match with the requirement, the increase in power consumption due to excess margin built in the feed water pump will also be reduced.

Project Description

In a 180 MW Combined Cycle Gas Turbines (CCGT), the share of steam turbine is 60 MW. The specifications of the WHR boiler are as below:

	Design	Operating
Capacity	226.8 TPH	190.8 TPH
Pressure	70 kg/cm^2	68 kg/cm^2

There are two boiler feedwater pumps among which one is in operation and the other as a stand-by. The pump operates continuously for transferring the feedwater from the Feedwater tank to the HP drum. Below is the specification of the BFP

	Design	Operating
Flow	320 m^3/hr	212 m^3/hr
Head	1231 m	1222 m
No of Stages	6	6
Power	1800 kW	1210 kW

The control valve in the line was heavily throttled, about 35-40% open. This is clearly representing an excess margin in the operating boiler feed water pump. Pressure measured at the discharge of the pump was 122.2 kg/cm^2 and the pressure at the inlet valve of the drum was 75 kg/cm^2. The pressure drop across the control valve was about 45 kg/cm^2.

The variable frequency drive was installed with a feedback control. The differential pressure across the three element control valve was given as feedback control. The differential pressure across the control valve is maintained about 1-1.5 kg/cm^2.

If there is reduction in feed water requirement, based on the three element signal the control valve will get throttled which will lead to increase in pressure drop. The pressure will be immediately sensed and the VFD will reduce the speed of the pump to maintain the set pressure drop of about 1.5 kg/cm^2. On the other hand if there is a need for increase in feed water requirement, the control valve opening will increase based on the three element signal which would result in reduction pressure drop across the valve. The VFD will increase the speed and maintain the pressure drop across the valve.

Benefits

- The energy saving has been achieved due to reduction in speed during the low feed water requirement and optimization of excess margin built in the pump at the design stage.
- The energy saved by operating with a VFD was around 310 kW per hour

Financial Analysis

The overall savings achieved by running the BFP with a VFD was **Rs. 99.20 Lakhs** (unit cost – Rs 4/ unit). The investment of **Rs 180 Lakhs** was made, providing a simple payback of **22 months**.

CASE STUDY No.15

INSTALLATION OF HIGH EFFICIENCY DYNAMIC SEPARATORS FOR COAL MILLS

Background

Grinding operation is one of the in-efficient operations with respect to energy. The efficiencies range between 10-15%. In a utility power plant, the coal needs to be pulverized before being fired in the burners of the boiler. The fineness of the coal is important in determining the combustion efficiency, un-burnt carbon in bottom ash and fuel-to-air ratio.

In today's generation, the static separators need to be replaced with high efficiency dynamic separators. These separators in general have the advantages of a precise fineness control for coal. They are:

- Over grinding results in higher power consumption and precise control of it results in reduction of power consumed by the mill.
- Narrow particle size distribution of fine coal results in better combustion of coal in the boiler
- Better fuel-to-air ratio is maintained
- Lower percentage of un-burnt coal in bottom ash
- Technology Description

In a 250 MW coal based thermal power plant, there are two coal mills installed for providing the pulverized coal for the boiler. The specifications of the ball mills are:

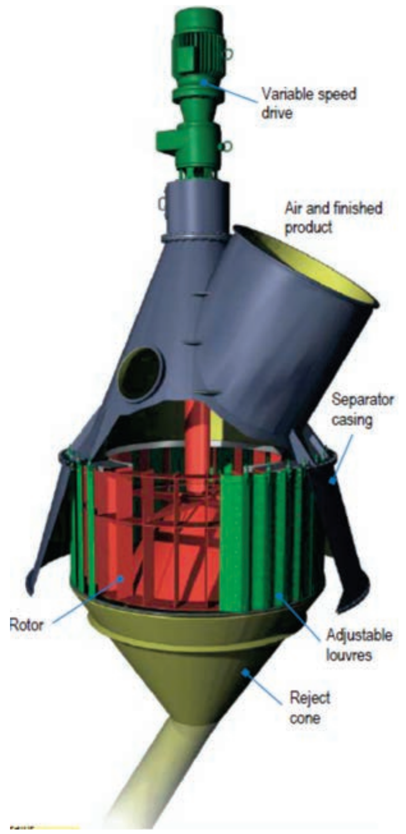
	Values
Capacity 76T Ball loading	84.8 TPH
Capacity 103.5T Ball loading	98.7 TPH
Inlet size	25 mm
Outlet (through 200 Mesh)	70%
Drive Motor	2350 kW
Drive Voltage	6.6 kV
Drive Full load Current	260.6 A

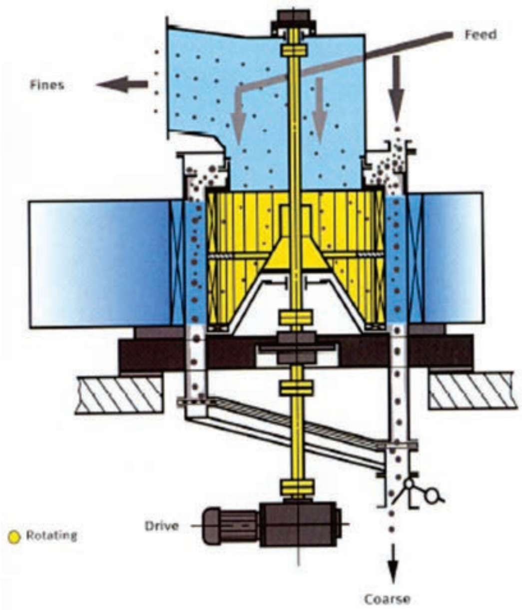
The coal pulverizing section at the plant is operating with a static classifier and the required fineness of coal mill is 70% pass through 200 size mesh. On an average, the power consumption of each coal mill is around 1350 kW.

The plant studied the fineness of the coal in detail. The following were the results:

Mill	50 Mesh (300µ) % Retention	100Mesh (150µ) % Pass	200 Mesh (50 µ) % Pass
1	0.20	98.70	96.48
F	1.42	81.19	45.88

The variation observed in the analysis is due to the disadvantage with the static separator. In this scenario, the installation of the dynamic separator was explored.





Working principle of Dynamic separator

In a dynamic separator, the fine material and the coarse material are separated at the periphery of the rotor cage in a vortex predetermined by air deflectors and the rotation of the cage. The air stream is horizontally fed and it propels the fine material particles against the centrifugal force, inwards to the separator wheel to the fine material discharge. The coarse materials are pushed away from the separator wheel by the centrifugal action and are dropped into the coarse material discharge.

The fineness of the finished product is quickly and accurately set by the cage speed. Changes to the fineness and quantity flow of the feed material have only a minor effect on the fineness of the finished product. The quality of the product remains constant.

Benefits:

- Reduction of variation in particle sizing of coal and thus aiding in reduction of un-burnt carbon in the bottom ash of the boiler.
- Over-grinding can be avoided which can result in a power saving of 270 kW per hour.

Financial Analysis:

The overall savings which can be achieved by installing a high efficiency dynamic separator is **Rs. 75 Lakhs** (unit cost – Rs 3.5/ unit). This will require an investment of **Rs 225 Lakhs**, providing a simple payback of **36 months.**

CASE STUDY No.16

INSTALLATION OF MULTI-STAGE PRESSURE REDUCTION DRAG VALVES FOR BOILER FEED WATER PUMPS FOR MINIMIZING THE RE-CIRCULATION

Background

The Boiler Feed Pump (BFP) transfers the feed water from the de-aerator to the Drum through heat exchangers like HP Heaters and Economizer. The circuit also consists of Feed Regulating Station (FRS) which regulates the flow of feed water into the drum.

In a condition where the drum requires lower quantity of feed water, the FRS starts closing to regulate the flow from the BFP. This process builds up back pressure at the discharge of BFP and to avoid excess pressure, automatic recirculation valve, recirculates the excess water back to the deaerator.

Since the pressure difference between the pump discharge and the deaerator is very high the recirculation valves seats quite often gets eroded and leads to continuous passing. The recirculation leads to increase in power consumption in the feed water pumps.

Project Description

In a 210 MW Coal based Thermal Power Plant, there are 3 nos of boiler feed pumps installed, out of which 2 run continuously for supplying feed water to boiler drum and the other is used as stand-by. It was observed that there was a difference between the discharge of the pumps and the inlet flow to the boiler drum. The details are as below:

Flow of Pump-1	425 TPH
Flow of Pump-2	390 TPH
Flow to Boiler drum	700 TPH
Difference (Re-circulation)	115 TPH
% difference	19%

The difference in flow is mainly due to re-circulation through ARV. Under normal conditions, the recirculation valve needs to be closed and it should not allow the feed water to flow back to the de-aerator. Due to recirculation, there is a loss of pumping energy at the BFP. Below is the rated and actual power of both the BFP's:

	Rated	Actual
BFP-1	4000 kW	3374 kW
BFP-2	4000 kW	3013 kW

The recirculation valves have a high probability of failure due to high pressure conditions. To avoid the recirculation of feed water back to the de-aerator, ARV's were replaced with Multi Stage Pressure reduction Drag Valves. The ARV's of both the boiler feed water pumps were replaced with drag valves.

Drag valves are typically represented as below:

These drag valves operate on the principle of "Adiabatic Flow with friction". The principle is to reduce the pressure by creating a treacherous path for the fluid to dissipate energy uniformly rather than with a shock wave effect. The material of construction and the pattern of the drag valves are designed to reduce the velocity of entrained fluid, thereby minimizing the impact of erosion.

These valves regulate pressure by incorporating multiple disks (or) stages for pressure reduction and are purely based on design. These drag valves thus aid in eliminating the issue of leakages in the re-circulation during closed conditions saving energy consumed by the BFP due to re-circulation.

The plant replaced the ARV's with Multi Stage Drag Valves on both the operating BFP's.

Benefits

- The plant team was able to stop the recirculation completely. There was no excess flow of feed-water through the boiler feed water pump to the de-aerator
- The energy saved by avoiding the recirculation of ARV's was around 300 kW per hour

Financial Analysis

The overall savings achieved from this project was **Rs. 124.80 Lakhs** (unit cost – Rs. 5.2/ unit). The investment of **Rs. 60 Lakhs** was made, providing a simple payback of **6 months**.

CASE STUDY No.17

OPTIMIZATION OF EQUIPMENT COOLING WATER PUMP

Background

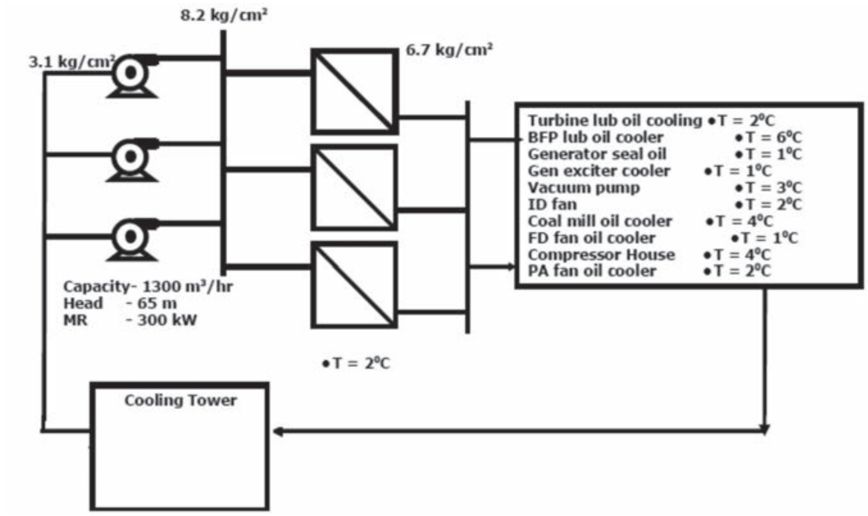
Equipment cooling is very essential for removing the heat generated by the rotating parts of the machine. If desired cooling is not attained, it can lead to lowering of efficiency of the machine. The Equipment Cooling Water (ECW) pump in a power plant supplies cooling water to Turbine lube oil cooling, BFP cooling, CEP, Generator seal oil, Vacuum pump, Generator Hydrogen cooler, PA, ID fan, Coal mill, APH, Compressor house, etc. In certain plants, sea water can also be used for cooling, which is an open circuit.

Project Description

In a 250 MW coal based thermal power plant, three centrifugal pumps are installed to cater the cooling water load of auxiliary equipment. Two are pumps in operation to supply cooling water to all the auxiliary equipments through plate type heat exchangers. The design and operating conditions of the pumps are

	Design	Pump-1	Pump-2
Head (m)	65	51	51
Capacity (m^3/hr)	1300	1850	1910
Power (kW)	300	430	460
Efficiency	81%	62.90%	60.7%

The operating parameters indicated the lower head requirement at the user end. The operating efficiencies of the pump were in the range of 61%. Due to lower operating head, the flow was higher than the design, leading to higher power consumption of the motor. Along the circuit, at the plate type heat exchanger, it was also observed that the pressure drop across the exchanger was 1.5 kg/cm^2. As per the design, it shouldn't been more than 0.6 kg/cm^2, thereby leading to loss in energy corresponding to 0.9 kg/ cm^2. The temperature profile of all the heat exchangers was taken and the delta-T was observed to be 2^0C across the plate heat exchanger and 1-4 ^{0}C across all users.



To counter the low head and high flow conditions, the plant installed new pumps with specifications corresponding to the operating condition. After installing the same, the plant continuously monitored the temperature difference across the heat exchangers such as turbine lub-oil coolers, generator hydrogen coolers etc.

Further to this, plant team throttled the valves of each heat exchanger such that the temperature difference across is at a minimum of 5^0C. This was done at full load condition so that there is no drastic change in temperature even during different load conditions. By doing this, the plant reduced the total flow by about 20%.

Benefits

- Close to 20% reduction in power consumption was achieved.
- Improved temperature profiles across cooling water, DM water and Oil cooling

Financial Analysis

The overall savings achieved for this project was **Rs. 46.78 Lakhs** (unit cost – Rs 3.4/ unit). Investment of **Rs 31 Lakhs** was made, providing a simple payback of **8 months**.

CASE STUDY No.18

UTILIZING GRAVITY FOR TRANSFER OF MAKE-UP WATER TO CONDENSER HOT WELL

Background

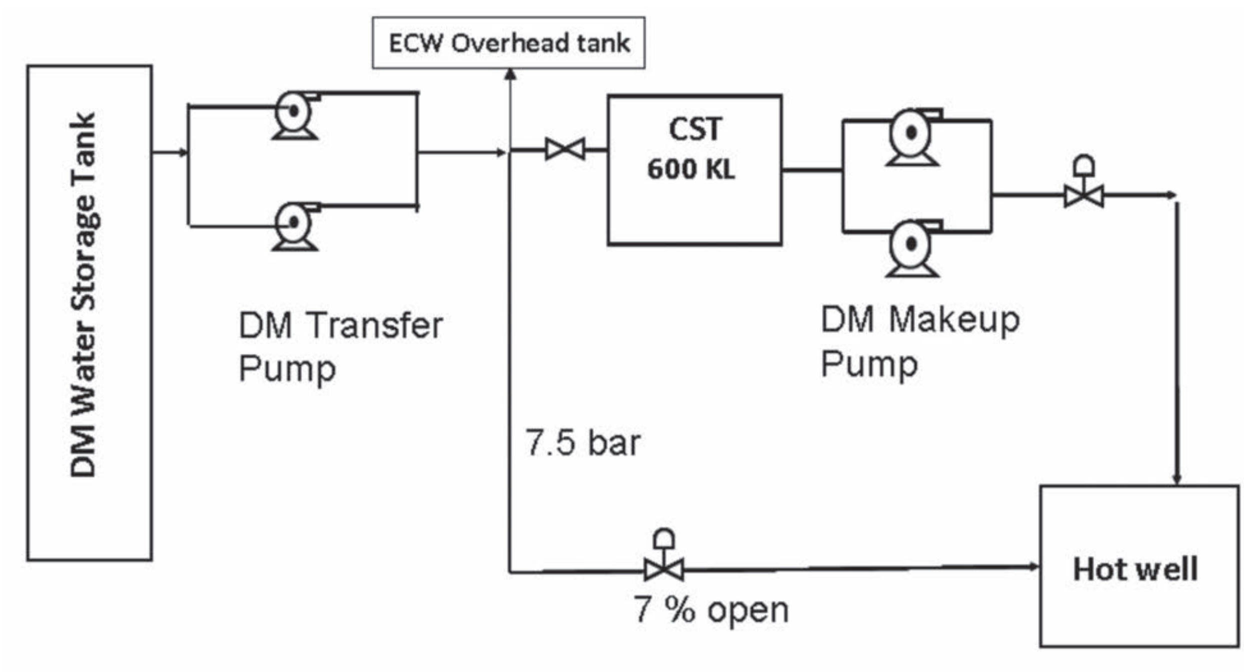
The makeup water is added to the steam-water circuit for supplementing the losses due to

blow-down, venting, leakage etc. This makeup water is generally added from a Condensate Storage Tank (CST) to the hot-well, with the help of a makeup water pump based on the requirement.

Project Description

In a 250 MW Coal based Thermal Power Plant, there is a CST tank installed at site with a capacity of 600 KL catering the make-up requirement of the unit. The per day make-up requirement was about 50 Tons. There were 2 pumps installed, among which 1 operates on a continuous basis and other stays as a stand-by.

The previous arrangement is shown below

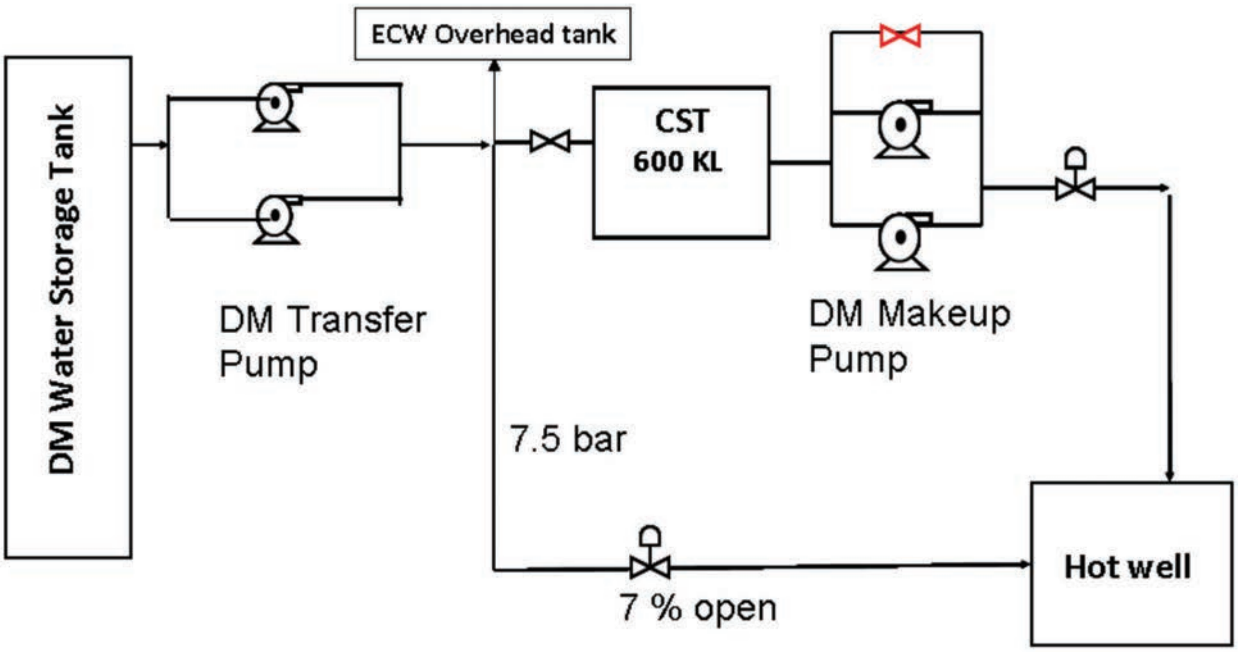


The pump has a design capacity of 40 m^3/hr and the required flow is 50 m^3/day i.e about 2 -2.5 m^3/hr. Due to this, the control valves were throttled and the recirculation line stayed opened for considerable amount of time. The pump operated continuously through-out the day and consumed about 16 kW per hour with an operating efficiency of 61%.

Possibility of utilizing gravity flow for adding make up water in the hot well was explored based on the availability of head in the CST tank and the vaccum level in the condenser. In that plant, the static height of 5-6 m in the CST tank was sufficient for ensuring make up water addition in the hot well.

A by-pass line was installed across the DM make-up pump with an isolation valve as shown in the figure below. The hot-well is at vacuum and was in the range of 0.08 – 0.10 kg/cm^2 (a) and the minimum level of water in the CST was maintained at 5-6 meters. With the vacuum and the adequate head in the CST, water was easily drawn with the help of gravity. The DM makeup pump was completely stopped and was used only in case of emergency.

Project Implemented is as shown below



Benefits

- The plant team was able to stop the pump completely.
- The energy saved on operating power consumption was around 16 kW per hour

Financial Analysis

The overall savings achieved by stopping the pump was **Rs. 5.12 Lakhs** (unit cost – Rs 4/ unit). This project needed marginal investment for piping and valve fitting. The **payback was immediate**.

CASE STUDY No.19

PERFORMANCE EVALUATION OF VARIABLE FLUID COUPLINGS AND IMPROVEMENT OPPORTUNITIES

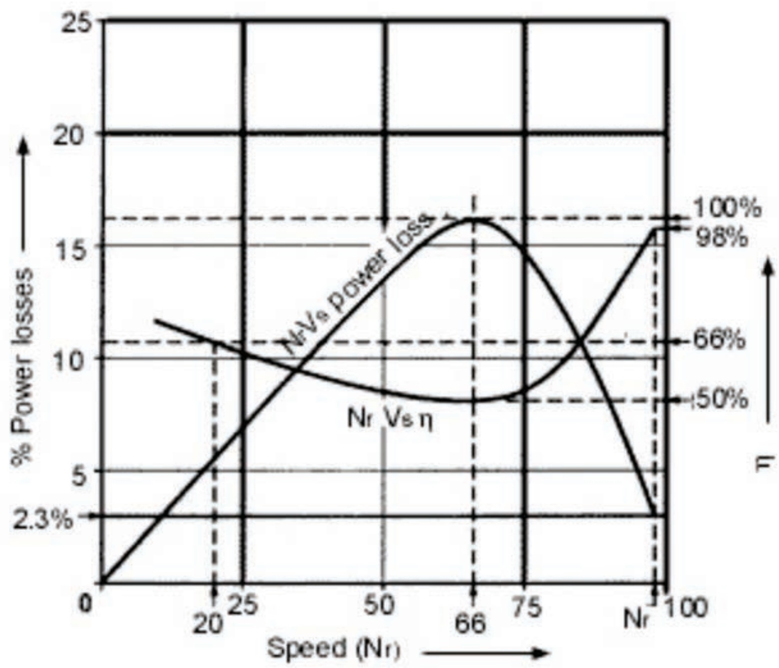
Background

The variable fluid coupling works on the principle of hydrodynamics. It consists of an impeller and rotor enclosed in a casing. The impeller is connected to the prime mover, while the rotor is connected to the driven machine. The coupling is filled with fluid, usually mineral oil.

In these devices, the mass of the working fluid can be changed while the machine is operating and infinitely variable output speed is achieved. Variation of oil quantity can be accomplished in four ways: scoop-trimming couplings, leak-off couplings, scoop-control couplings, and put-and-take couplings.

The energy loss in VFC is estimated by measuring the cooling water flow and the temperature difference between the inlet and outlet cooling water. At full load, the heat gained by the fluid is minimum whereas at part load the heat gained is maximum. The cooling water that is circulated takes-off the heat from the fluid and is rejected into the cooling tower. The efficiency of VFC reduces drastically at part load i.e., to the tune of 50% efficiency at speeds less than 65%. At these speeds, the temperature gained by the fluid might be so high that the equipment may trip due to high fluid temperature.

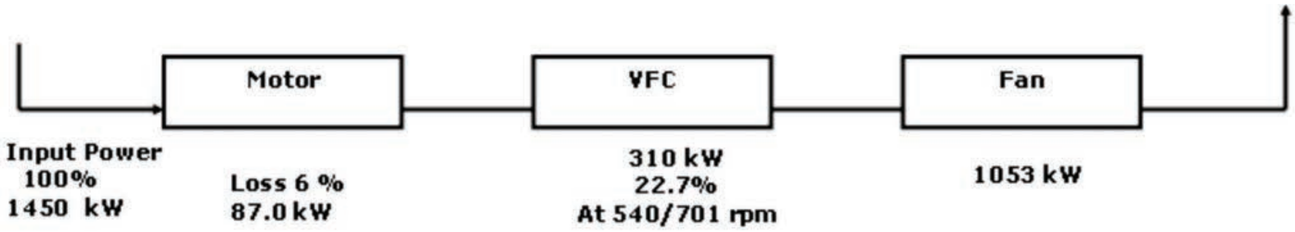
In many plants, to avoid tripping due to high fluid temperature, the VFC speed is locked at a certain minimum value and the process flow control is done with the help of conventional system i.e, dampers.



Project Description

In a 250 MW coal based thermal power plant, there are two ID fans operating with Variable Fluid Coupling (VFC). Each ID fan is designed to take-up 60% of the boilers full load.

The oil circulated in the VFC system generated more heat at lower speeds. This heat was removed using cooling water which exchanged heat through a heat exchanger. The following was the scenario when the ID was loading at less than 65-70% with a VFC.



The loss across the VFC was 310 kW which was estimated through the heat load taken off by the cooling water.

The plant installed a VFD to control the speed of both the ID fans in line with VFC at 100%. Overall, power savings were observed both during low load and full load due to speed control of ID fans with VFD.

The plant took an extra step in energy saving by bypassing the VFD to avoid the minimum losses of 2-3% at 100% load conditions.

S.No	Fan Speed	VFC efficiency	VFD efficiency
1	100%	85%	97.2 %
2	90%	75%	97.2 %
3	80%	65%	97.3 %
4	70%	56%	97.4 %
5	60%	46%	97.6 %

The above table showcases the variation in efficiencies of VFC vs. VFD with respect to fan speed.

Benefits:

- The efficiency of VFD is almost constant in all variations of load.
- The cost of auxiliary cooling for VFD is lesser compared to VFC
- In the event of failure of VFC, it cannot be bypassed by PLC whereas VFD can be bypassed and motor can be controlled with conventional control.
- Power saving of 600 kW was obtained on installing VFD for both the ID fans

Financial Analysis:

The overall savings achieved for this project was **Rs. 150 Lakhs** (unit cost – Rs 3.5/ unit). Investment of **Rs 280 Lakhs** was made, providing a simple payback of **22 months**.

CASE STUDY No. 20

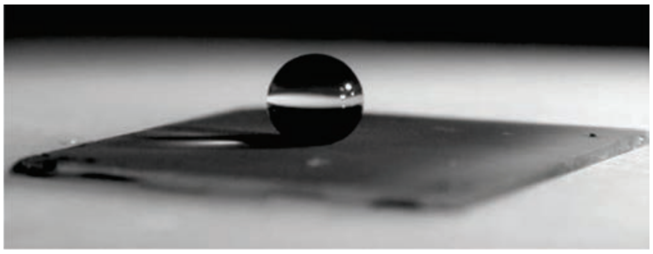
IMPROVING PUMP EFFICIENCY BY HYDROPHOBIC COATING

Background

In a pumping system, the efficiencies of the motor and the pump are important to determine the energy consumption of the system. Due to erosion and corrosion the operating efficiency of the pump reduces gradually. The reduction in operating efficiency is depending upon various factors such as working fluid, operating conditions etc.

One of the opportunities to save energy and increase efficiency of a pumping system is to address the loss due to friction. Reduction of friction in a pump can be attained with the help of hydraulic coatings. The coating is hydrophobic in nature. This characteristic of the coating helps in reducing the friction between the surface and the fluid. The coatings can be applied inside the casing of pump, on the impeller and inner lining of a pipe. The picture below depicts the characteristic of a surface in contact with a water molecule.

Attractive Surface



Hydrophobic Surface

When the coating is applied to a new pump, there is a potential of increase in efficiency by 3-5%. For old pumps, the improvement in efficiency can range between 5 - 8%. Not just for the pump, the coating for the pipes also result in energy saving. Application of coating in a pipe results in lowering the frictional coefficient (C-Value) and results in a reduction of frictional losses up to 40%.

Project Description

In a 210 MW Coal based Thermal Power Plant, there are two cooling water pumps operating with the following parameters:

Pump	Flow (m3/hr)	Head (m)	PowerConsumption (kW)	Efficiency
1A	14250	22.2	1267	73.91%
1B	13570	22.2	1239	72.93%

The design efficiencies of the pumps are about 80%, whereas the operating efficiency of the pumps was in the range of about 72-73%. The deterioration in operating efficiency has happened over a period of time.

Even with controlled water quality and regular maintenance, a 1% reduction in efficiency is observed in most of the industrial water pumps annually.

For improving the efficiency of the pumps without replacement, both the pumps were coated with the hydrophobic coating. After the hydrophobic coating the operating efficiency has improved and the new operating efficiency after the coating was found to be 78%.

Benefits

- The plant team was able to run the pump closer to the design efficiency.
- The efficiency improved by 5 %.
- The energy saved on operating power consumption was around 150 kW for each pump.

Financial Analysis

The overall savings achieved by the plant for improved efficiency of the operating pump was **Rs. 24.0 Lakhs** (unit cost – Rs 2.0/ unit). The investment done for application of the coating for both the pumps was **Rs 16.00 Lakhs**. This provided a simple payback of **8 months**.

CASE STUDY No. 21

INSTALLATION OF VACUUM PUMPS REPLACING STEAM EJECTORS

Background:

In thermal power plants, maintaining vacuum in the condenser is critical for maintaining the operating efficiency of the plant. Typically the design vacuum level is about 0.08 kg/cm^2(abs).

For maintaining the vacuum level both the steam ejectors and the vacuum pumps can be utilized. The old thermal power plants were installed with the steam ejectors and the modern plants are installed with the vacuum pumps. In some of the plants still ejectors are utilized.

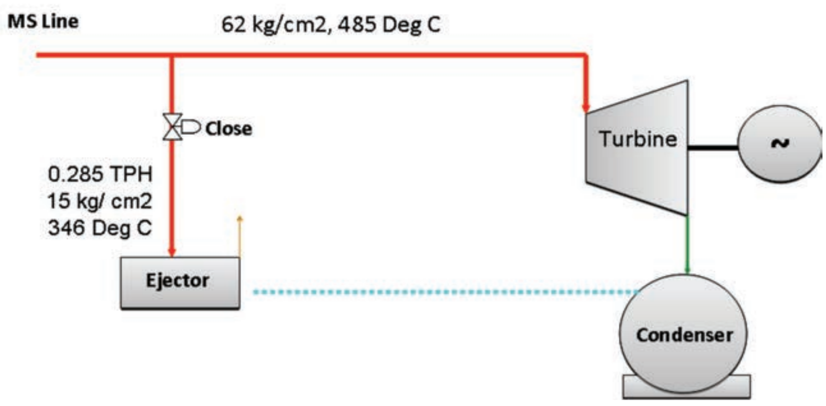
The steam pressure requirement for the steam ejector is about 10-15 kg/cm2. Usually the required steam is drawn from the main header and then reduced to the required pressure using the pressure reducing and de-super heating station (PRDS). Though the energy content remains the same after the PRDS the opportunity for the additional power generation is getting lost.

The recent trend is installing the water ring vacuum pump in parallel to the existing ejector and utilizing the vacuum pump for regular requirement. If there is an opportunity for additional power generation in the turbine, the steam can be passed through the turbine for producing additional power. Otherwise, the steam generation in the boiler can be reduced to save the fuel.

Project Description

In a 37 MW steam turbine, steam ejector is used for maintaining the vacuum inside the condenser. The specifications of the steam ejector are:

- Working Pressure: 10 ata
- Steam temperature: 350^{0}C
- Steam consumption: 1000 kg/hr
- Suction pressure: 0.035 ata
- Capacity of dry air: 20.4 kg/hr
- Dry air + Water vapor: 65.4 kg/hr



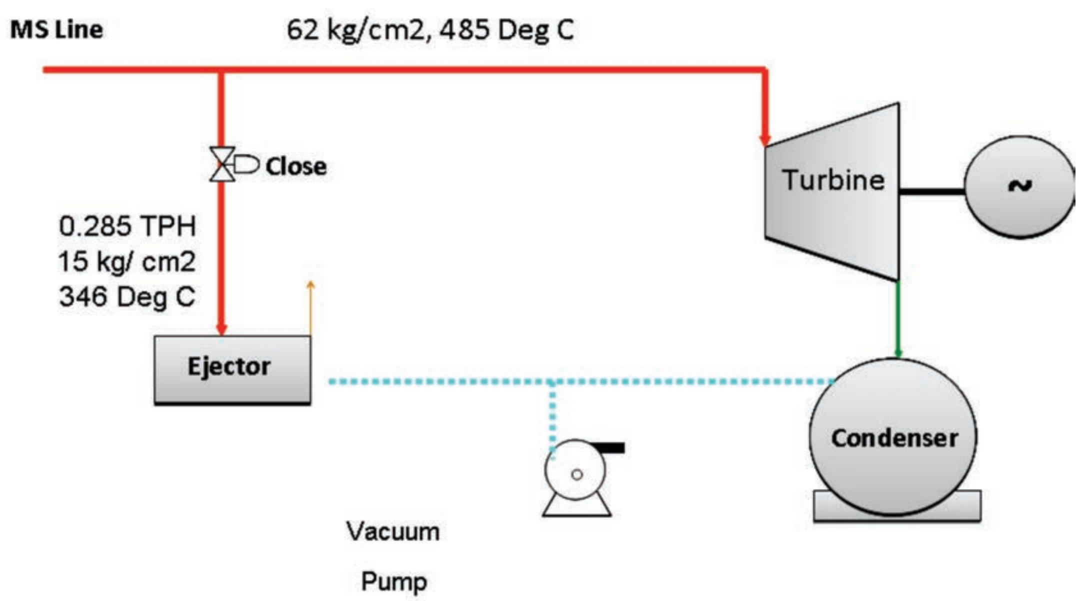
Main steam was utilized as auxiliary steam for steam ejector. The quantum of steam utilized is about 1 ton/hr. The steam quantity can be estimated based on the heat balance in the ejector condenser.

From the turbine characteristic curve, it was estimated that the power generation potential in steam turbine is about 250 units per ton of steam.

To reap the benefit of power generation from steam, a new vacuum pump was installed. The specification of the vacuum pump installed was:

- Pressure: 660 mmHG
- Capacity: 0.3 m^3/sec
- Power Consumption: 47 kW

The diagram given below depicts the running of a vacuum pump, replacing the steam ejector.



Benefits

The net benefit of replacing steam ejector with a vacuum pump is 100 kW

Financial Analysis

The overall savings achieved replacing the steam ejector with a vacuum pump was **Rs. 48.00 Lakhs** with an investment of **Rs 15.00 Lakhs** for procurement and installation of the vacuum pump, providing a simple payback of **4 months**.

CASE STUDY No. 22

CFD ANALYSIS – OPPORTUNITIES FOR REDUCING PRESSURE DROPS IN THE DUCTS AND IMPROVE FAN EFFICIENCY

Background:

The ducting system in a thermal power plant plays a role in the energy consumption of the fan associated with it. The pressure drops created at the cross-sections of the ducts will directly reflect in the excess energy consumption in the fan. There are even cases where it can affect the throughput of the station. Hence, considering an optimum design for the ducting system is important. The solutions can be looked at design as well as retrofit using CFD techniques.

Computational Fluid Dynamics, in short CFD, is a field of science which studies the governing laws of flow of fluids under various conditions. The method uses various numerical methods and algorithms to solve and analyze the problem that involves fluid flows. CFD analysis could be employed to pinpoint high pressure drop zones in ducts.

CFD predicts the fluid flow with the simultaneous equations of heat transfer, mass transfer, phase change and chemical reaction. Most of the plants designed using the past technology or the needs at that time are operating close to its design limits in the current scenario as there is increase in the demand. With the rapid advancement in computers, Computational fluid dynamics is used across the world in all industries for validating designs, troubleshooting, maintenance and upgrading so that they operate safely and at peak efficiencies with optimum cost.

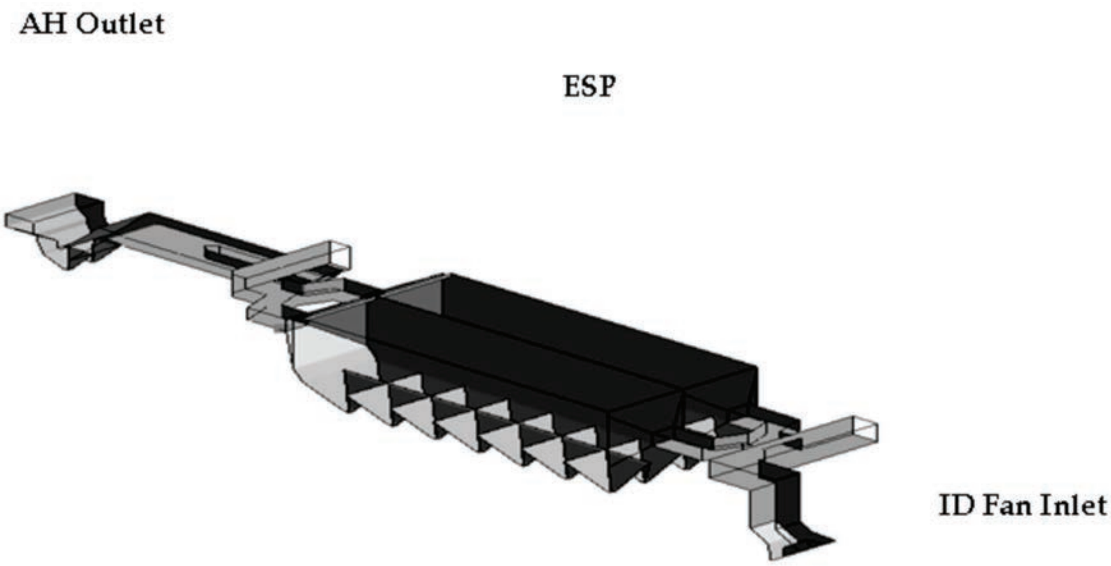
Project Description

In a 210 MW thermal power plant, the duct connecting APH out and ESP inlet was subjected to high erosion and also a high pressure drop was occurring. This resulted in lowering the capacity utilization of the plant

To reduce the erosion rate in the duct and the high turbulence, the existing duct was removed and was replaced with a new duct along with guide vanes for streamlining the flow at bends which was completely redesigned with the help of CFD. The study was focused on the following:

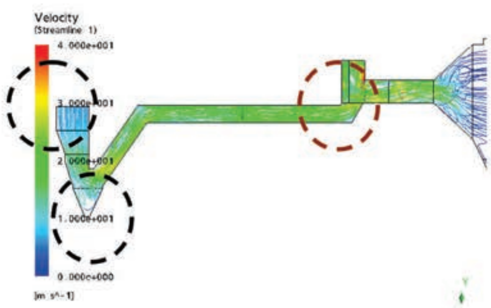
- Analysis of Existing Duct by CFD technique
- To optimize turbulence (eddy formation and formation of re-circulation zones) by designing the Deflector plates
- To obtain equal mass flow rates through ducts
- To reduce pressure drop
- To achieve uniform distribution of flue gas at ESP inlet

The following are the results before modification:

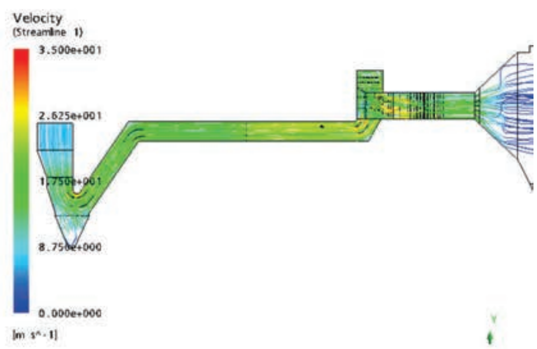


3D-Computational Model considered for CFD Analysis after Modifications

CFD Results comparison



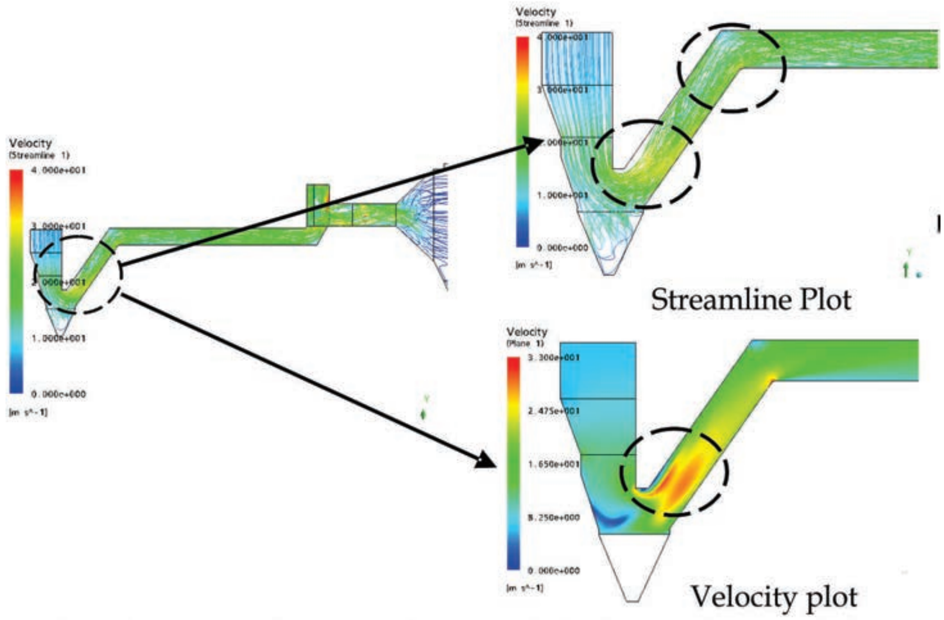
EXISTING 3D-CFD RESULTS



MODIFIED 3D-CFD RESULTS

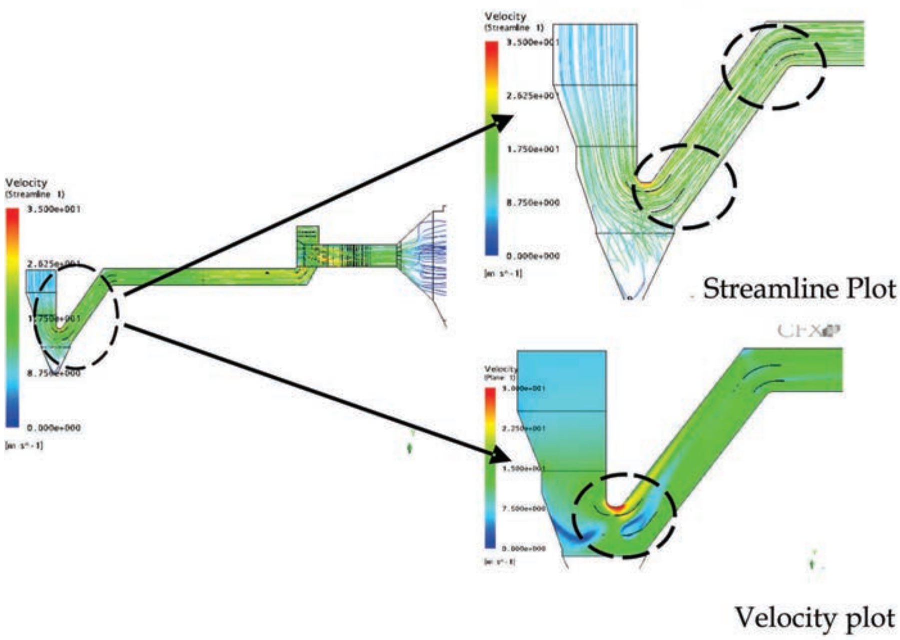
Streamline Plot :3D-Streamlines are showing the turbulence area and highest velocity region in the marked portion ,after modification the max. velocity & turbulence has been reduced

Detailed CFD Results in duct for Existing Case



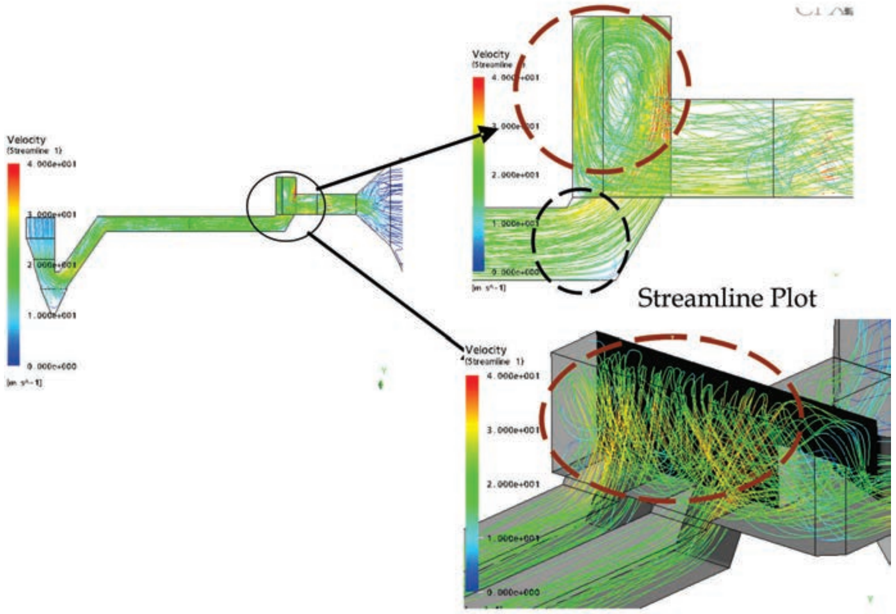
CFD Plot :Marked Portion showing the high turbulence with high velocity concentration which will cause the Pressure drop as well as Erosion in the Duct

Detailed CFD Results in duct for Modified Case



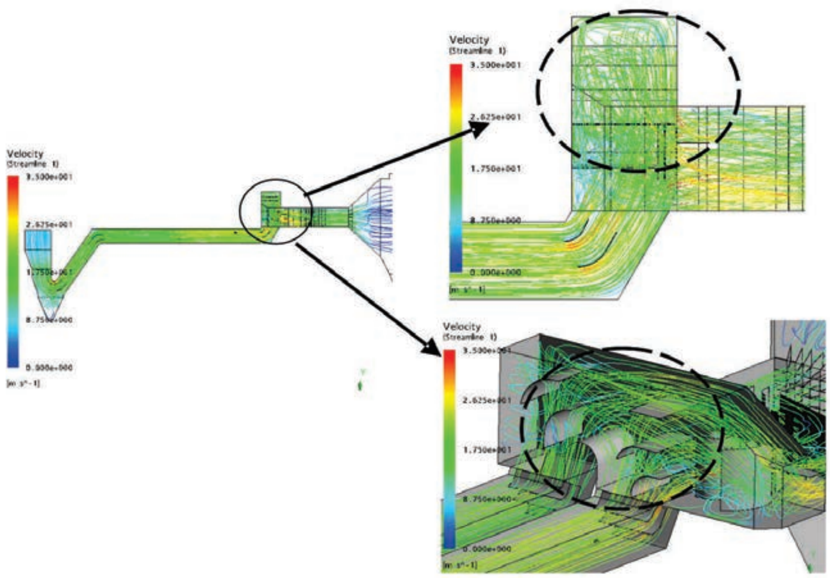
CFD Plot :Marked Portion showing the reduction in turbulence after Designing the deflectors as well as reduction in highest velocity.

Detailed CFD Results in duct for Existing Case



CFD Plot :Marked Portion showing the very high turbulence with recirculation & highest velocity at the back surface of the duct, which will cause highest pressure drop in the duct.

Detailed CFD Results in duct for Modified Case



CFD Plot :Marked Portion showing that the turbulence & recirculation has been avoided also reduction in highest velocity after Modification in the duct which will reduce the pressure drop

Benefits

The following are the results in comparison:

Sr. No.	Parameters	Pre Installation	Post Installation
1	Load MW	210	210
2	ID Fan A current (amp)	123	Stand By
3	ID Fan B current	126	134
4	ID Fan C current	120	130
5	FD Fan current A	50	45
6	FD Fan current B	50	43
7	Windbox Pressure	101	88
8	Air Heater Inlet Pressure	70	69
9	Air Heater Outlet Pressure	150	146
10	**SPM**	**138.73**	**113.22**

The following are the benefits reaped from the project:

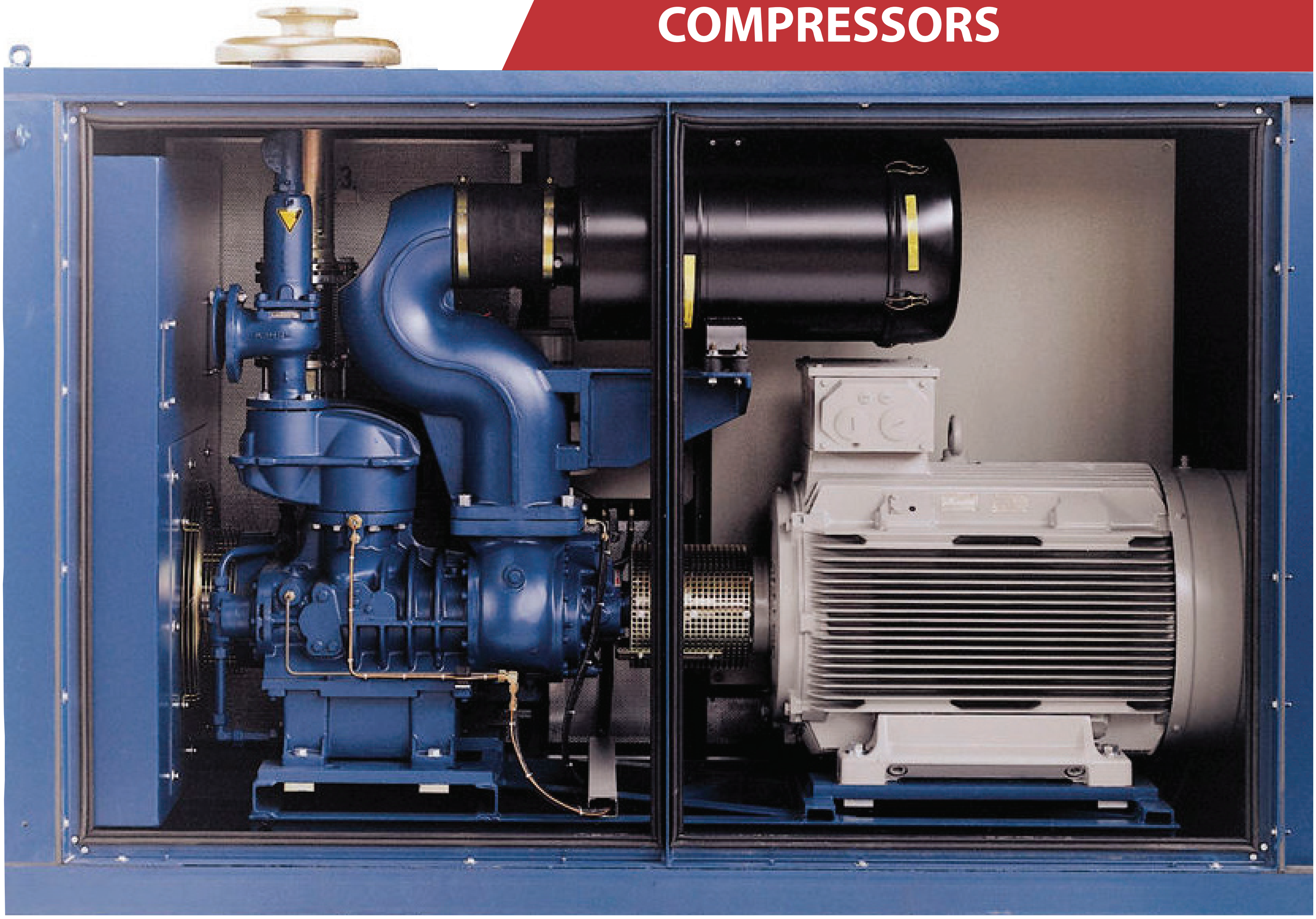
- By Design modification using CFD in duct ,the uniform flow distribution has been achieved
- There is huge reduction in pressure drop by which one ID fan (ID Fan A) is on Stand by saving of 105 Amp. Current
- Flow distribution in the ESP has been improved by honeycomb design resulting improvement in the ESP performance.
- There is reduction in SPM level by adopting CFD applications of MDT Screen at outlet of ESP & honey comb arrangement

Financial Analysis

The overall savings achieved by implementing the recommendations of the CFD study was **Rs. 166.3 Lakhs** (unit cost – Rs 5/ unit). Investment of **Rs 41.2 Lakhs** was made for the study, supply and the erection, with a simple payback of **4 months**.

BALANCE OF PLANT

COMPRESSORS



CASE STUDY No. 23

UTILIZING CENTRIFUGAL COMPRESSOR FOR BASE LOAD REQUIREMENT AND INSTALL A SCREW COMPRESSOR WITH VFD TO CATER PART LOAD REQUIREMENT OF COMPRESSED AIR

Background

Centrifugal compressors have the lowest specific power consumption on full load operation compared to other types of compressors like reciprocating and screw compressors. However when the compressor is not fully loaded, the specific power consumption of a centrifugal compressor is higher than a screw compressor.

The capacity control of a centrifugal compressor is done by inlet guide vane (IGV) and by – pass valve opening. The inlet guide vane restricts the amount of atmospheric air entering the compressor and the by – pass valve opens when there is more compressed air generated than what is required in the plant.

Screw compressors are the most common types of compressors in a power plant. The specific energy consumption of the screw compressors is highest compared to all types of compressors. In screw compressors the speed can be varied by a variable speed drive depending upon the requirement are therefore suited best for fluctuating or variable requirement.

At set pressure of 7 kg/cm^2, the specific energy consumption for various compressors are mentioned below

Type of Compressor	Pressure (kg/cm^2)	Specific Energy Consumption (kW/CFM)
Centrifugal	7	0.132
Reciprocating	7	0.137
Screw	7	0.164

Due to the lowest specific energy consumption, centrifugal compressors are best suited to cater the base load requirement of compressed in the plant. The variable load can be catered by a screw compressor with a variable speed drive.

Project Description

In a 4 x 250 MW power plant with four boilers, the maximum quantity of the compressed air requirement was calculated in the design stage and is about 8565 CFM, taking 20% margin for leakages. Three centrifugal compressors of 4485 CFM are installed to meet the requirement in which two compressors are in continuous operation and one compressor is in standby.

Due to lower requirements, one centrifugal compressor is running in part load condition with IGV and bypass valve operation. The power consumption of the partly loaded centrifugal compressor is on the higher side.

Plant team has installed two screw compressors of 2120 CFM each and replaced the partly loaded centrifugal compressor with two screw compressors. Out of two screw compressors, one screw was continuously loaded and the other screw compressor were installed with a variable speed drive which took care of the varying load.

Benefits

- Saving in power consumption of 3000 units per day.
- Reduced start up time compared to centrifugal compressors
- Increased reliability – since tripping in centrifugal compressors is reduced.

Financial Analysis

- Savings achieved by installing two screw compressors was **Rs. 720.0 Lakhs** (unit cost – Rs 3.0/ unit). The investment made was **Rs 115.0 Lakhs**. This provided a simple payback of **2 months.**

CASE STUDY No. 24

OPTIMIZE THE PRESSURE OF INSTRUMENT AIR COMPRESSOR AND INSTALL VFD TO THE COMPRESSOR TO AVOID UNLOADING POWER OF THE COMPRESSOR

Background

Compressed air is used for instrumentation and service air applications. Instrument air is used in pneumatic control valves, for gland sealing, power cylinders operation and for bag filter purging in a power plant. Service air in a power plant is used for fly ash conveying, floor cleaning etc.

Instrument air users like control valves require a maximum pressure of 3.5 kg/cm^2. Normally, the bag filter purging requires a compressed air pressure of 5.0 kg/cm^2.

Project Description

In a 300 MW Coal based Thermal Power Plant; one instrument air compressor was in operation with the following design specifications

Rated Power - 110 kW

Rated CFM - 650 cfm

Max. Pressure - 10.0 bar

Type of compressor - Screw compressor

The operating parameters of the instrument air as follows:

Equipment	Operation	Set Pressure (kg/cm^2)	% load/un-load	PowerConsumption (kW)
Compressor	Loading	7.0	60	110
	Unloading	8.0	40	44

The pressure difference between the compressed air generation and the end users in the plant was not more than 0.2 kg/cm^2.

The instrument air requirement in the plant was catered by a screw compressor. The Screw compressor was running at loading and unloading conditions. Normally, a screw compressor has unload power consumption of around 30% of its full load power

Since, the users of instrument air compressors did not require a pressure greater than 5.0 kg/cm^2, plant team had optimized the compressed air generation pressure, by changing the loading and unloading set points to

Load pressure : 5.2 kg/cm^2

Unload pressure : 5.8 kg/cm^2

Optimizing the pressure setting of the instrument air compressors with load pressure of 5.2 kg/cm^2 and unload pressure of 5.8 kg/cm^2 reduced the average generation pressure of the compressor and in turn reduced the power consumption of the compressor. By reducing the average operating pressure, the average loading power consumed by the compressor has been reduced by 13%.

Even after optimizing the set pressure of the compressor, the compressor continued to run in loading and unloading conditions. The plant team had installed a VFD for the compressor and avoided the unloading power consumption of the compressor by giving the receiver pressure as a feedback to the VFD of the compressor. The receiver set point was maintained at a pressure of 5.2 ± 0.1 kg/cm^2 and the compressed air generation pressure was maintained at 5.3 ± 0.1 kg/cm^2. The pressure drop across the dryer was insignificant and was only 0.1 kg/cm^2. By installing VFD to the compressor the plant team had achieved a saving of around 15%.

Benefits

- By reducing the load pressure set point to 5.2 kg/cm^2 and unload pressure set point to 5.8 kg/cm^2 the average loading power consumption reduced by 22 kW was achieved by the plant
- By installing a VFD for the compressor, the unload power consumption has been avoided and power savings realized was to the tune of 17kW

Financial Analysis

- The savings achieved by reducing the pressure setting was **Rs. 7.50 Lakhs** and savings achieved by installing a VFD for the compressor was **Rs. 5.50 Lakhs**. The investment done for installation of VFD was **Rs 6.60 Lakhs**, which was paid back in **7 months**.

CASE STUDY No. 25

OPTIMIZING COMPRESSED AIR PRESSURE FOR FLY ASH CONVEYING

Background

Service air in a power plant is majorly used in fly ash conveying and floor cleaning. General practice for service air compressors is to have higher pressure settings so as to negate the effects of any blockages or choking in the line. The commonly observed pressure setting in power industries is in between 4.0 kg/cm^2 to 5.0 kg/cm^2.

The requirement of compressed air pressure for fly ash conveying is however not more than average pressure of 2.5 kg/cm^2, provided , the number of bends and line sizing for fly ash conveying is proper. Higher pressure setting results in higher power consumption in the compressor.

Project Description

In a 300 MW Coal based Thermal Power Plant; there is one service air compressor running with design specifications

Rated Power	–	75 kW
Rated CFM	–	520 cfm
Max. Pressure	–	7.0 bar
Type of compressor	–	Reciprocating compressor

The operating parameters of the service air compressors are as follows:

Equipment	Operation	Set Pressure (kg/cm^2)	Power Consumption (kW)
Compressor	Loading	4.2	80
	Unloading	4.8	29

The plant reduced the pressure setting of the above compressor has been reduced to load pressure of 3.2 kg/cm^2 and unload pressure of 3.7 kg/cm^2. By reducing the average operating pressure to 3.45 kg/cm^2 from 4.5 kg/cm^2 the average loading power consumed by the compressor has been reduced by 19%. Optimizing the pressure setting of the compressors with load pressure of 3.2 kg/cm^2 and unload pressure of 3.7 kg/cm^2 would reduce the overall power consumption of the compressor.

Benefits

- By reducing the pressure setting of the compressor, load pressure to 3.2 kg/cm^2 and unload pressure to 3.7 kg/cm^2 the average loading power consumption reduced by 15 kW.

Financial Analysis

- The savings achieved by reducing the pressure setting was **Rs. 5.0 Lakhs** (unit cost – Rs 4.3/ unit) with nil investment for the booster compressor.

CASE STUDY No. 26

PERFORMANCE EVALUATION OF COMPRESSORS AND OPERATING ENERGY EFFICIENT COMPRESSOR

Background

Generally, the compressor performance would be constant during the first four to five years of its operation. During the later stages, even with proper maintenance and overhauling, the compressor performance may degrade, especially in the case of a reciprocating compressor, where the maintenance of cylinder bore, piston rings, suction valves etc. has to be rigorously maintained.

Compressed air requirement is continuous in a power plant except during plant shut down. In this scenario of continuous running plant, performance evaluation of compressors is not easy if an individual compressor and a receiver can't be isolated to conduct the free air delivery test of the compressor. However during the plant shut down, the performance evaluation of all the compressors can be performed and the most efficient compressors can be used for operation.

Performance evaluation of the compressors can be done by evaluating the free air delivered by the compressor and then measuring the power consumed by the respective compressor. The specific energy consumption (SEC) of each compressor can be then obtained by taking the ratio of power consumed (kW) to the free air delivered (CFM).

Project Description

In a 250 MW Coal based Thermal Power Plant, three reciprocating compressors of 1150 CFM rated capacity have been installed out of which one compressor (Compressor 1) operates continuously. During the plant shut down, the Free Air Delivery (FAD) of each compressor has been tested using pump up method. The load pressure set point of the compressor is at 5.0 kg/cm^2 and unload pressure set point is at 6.0 kg/cm^2.

In the pump up method, the compressor and the receiver has been completely isolated by closing the discharge valve of the receiver. Then the receiver has been completely drained out. The compressor is then started and the time taken by the compressor to build the pressure for each bar in steps has been noted down till the compressor has reached the set pressure of 6.0 kg/cm^2.

The free air delivered (FAD) by the compressor is determined by

Average Compressor Delivery = $[(P_2\text{-}P_1) \times V_r] / (P_0 \times T)$

Where P_1 – Initial Pressure in the receiver

P_2 – Final Pressure in the receiver

P_0 – Atmospheric Pressure

V_r – Volume of the receiver and the pipeline

T – Total time taken for charging the receiver from P_1 to P_2

The Specific energy consumption is measured with the FAD and power consumption of each compressor is mentioned in the table below

Equipment	Rated CFM	Design Pressure (kg/cm²)	Avg. Operating Pressure (kg/cm²)	Actual CFM (FAD)	Power Consumption (kW)	kW/CFM
Compressor 1	1150	7.0	6.0	782	180	0.23
Compressor 2	1150	7.0	6.0	918	186	0.20
Compressor 3	1150	7.0	6.0	1069	180	0.168

The specific power consumption norm of a reciprocating compressor should be 0.15 kW/CFM at 6.0 bar pressure.

From the above measured values, the power consumption of all the compressors were similar. The specific energy consumption (kW/CFM) of compressor 3 was the lowest and is closest to the specific energy consumption norm of a reciprocating compressor.

Therefore the plant team had operated compressor 3 and took the overhauling of the other compressors in an effort to improve the specific energy consumption. The specific energy of the other compressors improved after overhauling and the test was repeated to operate the compressor with the least specific energy consumption.

Benefits

- The plant team was able to evaluate the performance of the compressors.
- The energy saved by operating compressor 3 was around 35 kW (% loading of the compressor was 90%)

Financial Analysis

The overall savings achieved running compressor 3 instead of compressor 1 was **Rs. 8.4 Lakhs** (unit cost – Rs 3/ unit) and there was no investment required for this project.

CASE STUDY No. 27

INSTALLATION OF DEMAND SIDE CONTROLLERS AND REDUCTION IN COMPRESSED AIR CONSUMPTION

Background

The compressed air demand in a plant can suddenly increase, especially for a situation where the compressed air is used for floor cleaning in the plant. The pressure is reduced in the entire upstream till the compressor, reducing the generation pressure much lower than the load set – point of the compressor. Sometimes this compressed air pressure reduces below the tripping limit of the plant.

Due to this lag of catering the compressed air requirement in the plant, the compressed air pressures are set for higher pressure to cater for any sudden increase of compressed air demand.

Demand side controllers constitute of an intermediate intelligent flow controller which controls the air pressure being delivered to the plant. The intermediate controller is installed after the receiver and the dryers of the compressors. The controller has an additional buffer storage for compressed air, which isolates the compressors from sudden peaks & troughs and provides constant air supply with optimum pressure. The intelligent controller with a built-in microprocessor, monitors the rate of change of pressure reduction at the user end and provides the required amount of compressed air from the buffer storage to cater the artificial demand in the plant.

Project Description

A 150 MW power plant installed a 90 kW, 500 CFM screw compressor to cater instrument air requirement in the plant. The compressor operating conditions were

Equipment	Operation	Load/Unload pressure set point	% load/unload	Power Consumption (kW)
Compressor	Loading	5.8 kg/cm^2	80	90
	Unloading	6.4 kg/cm^2	20	30

The maximum pressure required for instrumentation air was 4.5 kg/cm2. The compressor was loading for 80% and unloading for 20% of the time, during normal condition. Whenever there was an artificial demand of compressed air in the plant, the generation pressure of the compressor reduced to 4.7 kg/cm2. The tripping limit of the compressed air system was 4.5 kg/cm2. In order to run the plant on a continuous basis and avoid tripping of the compressor for equipment safety reasons, the average generation pressure of the compressors were set at a higher limit.

Demand side controller was installed for the compressor and the loading percentage was increased due to the buffer storage available for the compressor. After installation of demand side controller with additional buffer storage, the fluctuation in the compressed air system has reduced in the plant.

Due to buffer storage for compressed air the deficiency of compressed air during artificial demand was eliminated by the plant team. After the installation of demand side controller the load and unload pressure setting of the compressors were reduced to, load pressure setting of 5.0 kg/cm2 and unload pressure setting of 5.5 kg/cm^2.

Benefits

- Savings of 8.0 kW has been achieved by the plant.
- Reduction in loading hours of the compressors.

Financial Analysis

The savings achieved by installing a demand side controller was **Rs. 1.9 Lakhs** (unit cost – Rs 3.0/ unit). The investment made was **Rs 4.0 Lakhs.** This provided a simple payback of **25 months**.

CASE STUDY No. 28

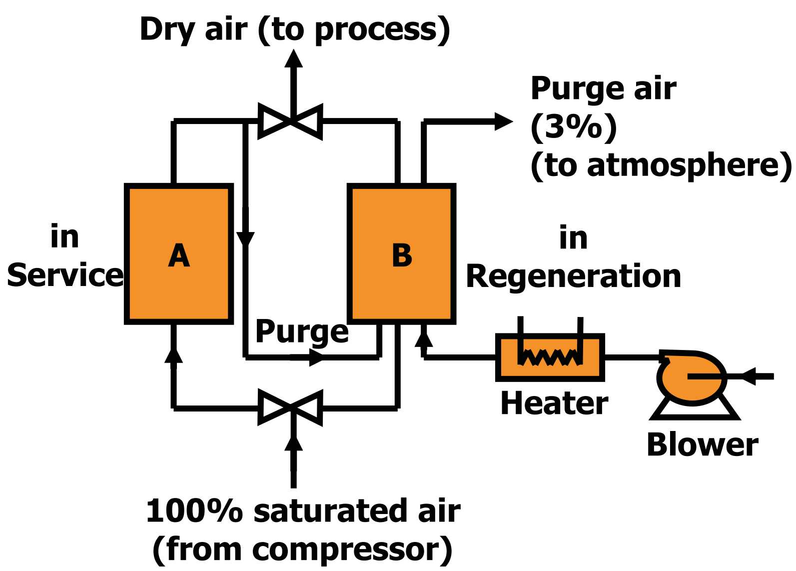
REPLACING HEATED TYPE DRYERS WITH HOC DRYERS

Background

The moisture carry over in a compressed air system can cause a variety of problems in a compressed air system. These problems include corrosion in piping and equipment, malfunctioning of pneumatic process control instruments, fouling of processes etc. Dryers are used for reducing the moisture content in the compressed air. The two types of dryers used in power plants are refrigeration dryers and desiccant type dryers.

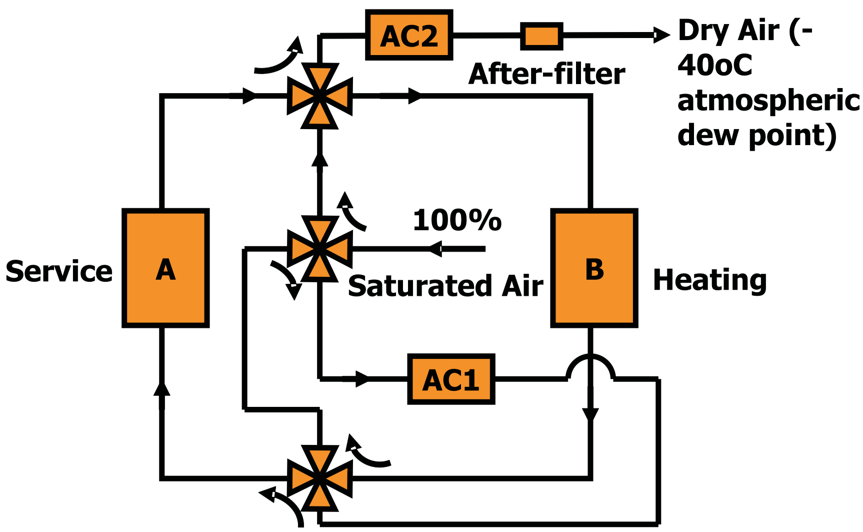
The desiccant heated type dryers use compressed air purging for heating of desiccants for regeneration. The desiccant heated type dryer is shown below. The desiccant heated type dryer consists of a blower, heater and compressed air purging. When one desiccant is in service the other dessicant is used for regeneration. The blower takes in heat from the atmosphere and is heated using a heater. About 3% of compressed air is purged for regeneration of desiccant along with the heated air from the blower.

Air Dryer - Dessicant Heated Type



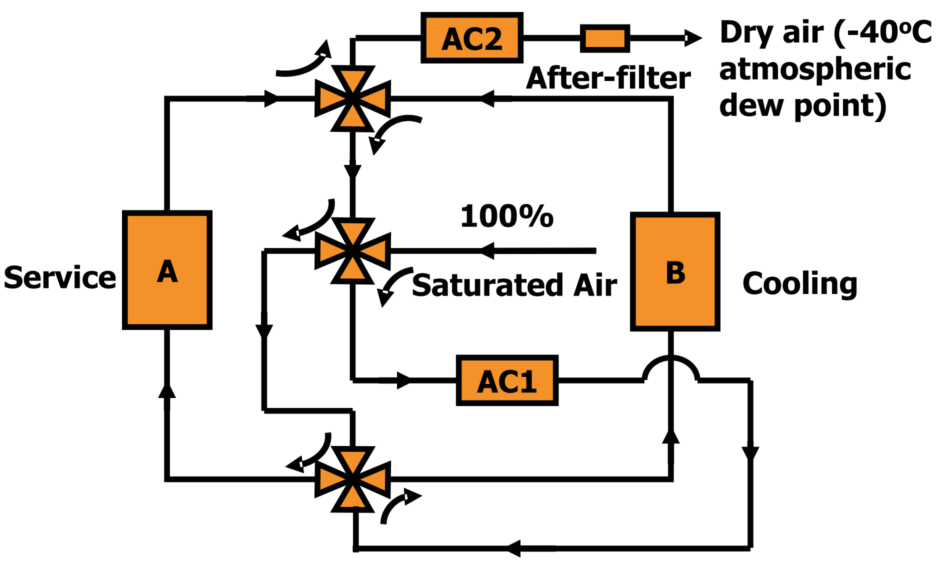
Latest trend is to go for Heat of compression dryers which uses compressed air for regeneration of desiccants. The schematic of a HOC dryer is shown below. In HOC dryers, compressed air is taken directly from Air compressor discharge to Air dryer inlet through insulated pipelines, at 120˚C (minimum) temperature.

Heat of Compression (HOC) -
Air Dryer



This hot air is passed through one drying vessel where saturated desiccant (activated alumina or molecular sieve desiccant) is regenerated by this hot air. After picking up moisture from desiccant bed, the air is cooled in an intermediate cooler. In the intermediate cooler, moisture is condensed and removed by an auto drain valve. The compressed air is cooled to 40˚C and passed through the second drying vessel where moisture gets adsorbed and dry air comes out. Cycle time is 4 hours regeneration and 4 hours drying. After 4 hours the changeover of vessels takes place automatically. Regeneration cycle heating of the bed is for 2 hours, and thereafter the bed is cooled by dry air. After bed cooling, dry air is again cooled to 40˚C in another cooler and delivered as dry air at 40˚C temp.

Heat Of Compression (HOC) -
Air Dryer



Project Description

In a 25 MW Coal based Captive Power Plant with two boilers of 110 TPH; there are three instrument air compressors with design specifications

Rated Power	-	90 kW
Rated CFM	-	500 cfm
Max. Pressure	-	7.0 bar

A heated type dryer with rated flow of 1735 m^3/hr and rated maximum pressure of 8.8 kg/cm^2, was previously installed to the common header of the instrument air compressors. The heated type dryer has an electrical heater which consumed 2.32 kW power and also uses 3% of the total compressed air for its operation.

This heated type dryer was replaced with a HOC dryer by the plant team. The HOC dryer doesn't require any power or compressed air purging for its operation. Therefore the savings due to dryer operation and purging of 3% compressed air was saved.

Benefits

- Saving in heater power consumption of the heated type dryer.
- Reduction in 3% of compressed air used for purging in the heated type dryer.

Financial Analysis

- Savings achieved by replacing the heated type dryer with HOC dryer was **Rs. 2.2 Lakhs**. The investment for installation of HOC dryer was **Rs 4.5 Lakhs**. This provided a simple payback of **25 months**.

COAL & ASH HANDLING PLANTS

CASE STUDY No. 29

IMPROVING THE LOADING OF THE COAL CRUSHERS AND MINIMIZING THE NUMBER OF OPERATING HOURS

Background

Independent power plants generally use bowl mills for coal crushing in the coal handling plant while captive power plants use impact crushers.

Coal crushers have an intermittent hopper before the crusher for a smoother operation. In majority of the power plants, the coal handling plant is manually operated by checking the level of the hopper.

Technological advancements like level sensors help avoid manual operation thereby reducing the issues of idle running of equipment and thereby reducing the power loss and labor hours.

Project Description

In a captive power plant of 3 x 25 MW, the coal requirement for each 110 TPH boiler of was 1500 TPD. Impact crusher of 250 TPH was installed for coal crushing in the coal handling plant. The coal handling plant was manually controlled and the operation was based on the hopper levels. The coal crusher was observed to be operating even when the hopper was empty, i.e. on no load due to manual intervention.

The plant team installed a level sensor in the hopper with a feedback to the coal handling plant operation.

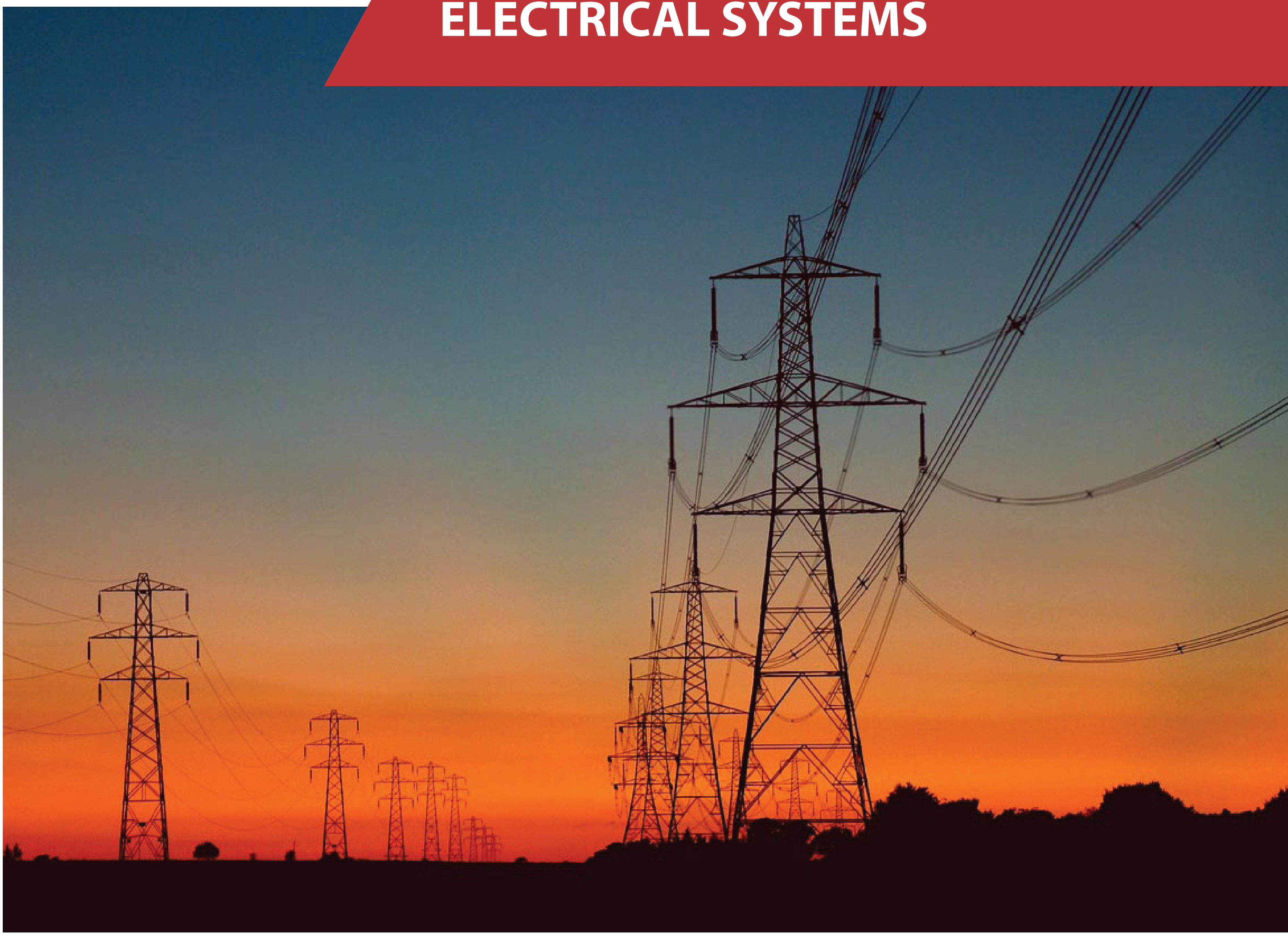
Benefits

- Crusher idle operation avoided
- Belt conveyors idle running reduced.

Financial Analysis

Savings achieved by installing a level sensor was **Rs. 4.8 Lakhs**. The investment for installation of the level sensor was **Rs 1.0 Lakhs**. This provided a simple payback of **3 months**.

ELECTRICAL SYSTEMS



CASE STUDY No. 30

VOLTAGE OPTIMIZATION OF DISTRIBUTION TRANSFORMER BY TAP REDUCTION

Background

The power supply to the power plant auxiliary is catered through the unit auxiliary transformer and from there to the distribution transformers and then to the auxiliaries. The applied voltage to the auxiliary varies with the grid voltage variation. The case study is applicable at places where the grid voltage variation is low.

The distribution transformers generally come with 5 to 7 taps with the centre tap as the default tap which reduces the HT voltage to 433 volts in the LT side which is applied to the load. Induction motors are generally rated for 415 volts and increased voltage to the motor increases the no load losses or the magnetization losses.

Project Description

In a power plant of 300 MW capacity, the four distribution transformers were operated at centre tap which reduced the HT voltage to 433 volts in the LT side. The rated voltage of the motor as per the name plate details is 415 volts while the applied voltage was around 430-435 volts.

Equipment	Load	Operating Voltage	Reduced Voltage
Transformer 1	311.1	436	420
Transformer 2	707.5	433	420
Transformer 3	567.3	440	420
Transformer 4	833.5	428	420

The plant team has reduced the tap position of the distribution transformers in steps to maintain the output voltage close to 420 volts.

Benefits

- Reduction in magnetization current and reduced iron losses.
- Reduced load current due to reduction in magnetization current
- Improvement in load factor and loading the auxiliary
- Increased power factor of the auxiliary equipment
- Improved operating efficiency of the auxiliary

Financial Analysis

The overall savings achieved by reducing the tap position of the distribution transformers was **Rs. 3.6 Lakhs** (unit cost – Rs 3/ unit) and there was no investment made for this project.

CASE STUDY No. 31

OPTIMIZATION OF DISTRIBUTION TRANSFORMER LOADING

Background

The distribution transformers in power plants are installed in different sections as per the connected load. The highest operating efficiency of the transformers is obtained when the no load losses are equal to the copper losses. The transformer loading can be optimized in two ways

1. Paralleling of Transformers
2. Isolation of one Transformer and improving the loading of other transformer

Power plants usually have multiple distribution transformers in a section and the load is distributed in both the transformers. The total transformer losses at a particular loading of the transformer are given by:

Transformer losses = No load losses + {full load copper losses x (% loading)2}

Project Description

Case-1: Paralleling of Transformers

In a power plant of 250 MW capacity, two distribution transformers of 2000 kVA were operated in a section. The loading of one transformer was 65% (1235 kW) and the other transformer was loaded for 11% (198 kW). The connected load to one transformer was on the lower side. The bus coupler between the two transformers was off.

Losses in the above operating conditions were:

Equipment	Load (kW)	Apparent Power (kVA)	Design Rating (kVA)	% loading	Losses (kW)
Transformer 1	1235	1300	2000	65	11.87
Transformer 2	198	220	2000	11	3.25

The impedance of both the transformers and the design specifications were same. So the plant team switched on the bus coupler and paralleled both the transformers so that the load sharing between the two transformers is equal and the loading of both the transformers is optimized.

Equipment	Load (kW)	Apparent Power (kVA)	Design Rating (kVA)	% loading	Losses (kW)
Transformer 1	716.5	760	2000	38	6.03
Transformer 2	716.5	760	2000	38	6.03

Due to paralleling of the transformers, the load was shared between the transformers and the reliability of the entire system was increased.

Benefits

- Improved loading of both the transformers
- Improved efficiency of the transformers
- Savings of 3.0 kW of power

Financial Analysis

The overall savings achieved by reducing the tap position of the distribution transformers was **Rs. 0.7 Lakhs** (unit cost – Rs 3/ unit) and this project was without any investment.

Case-2: Isolation of one Transformer and improving the loading of other transformer

In a power plant of 150 MW capacity, two distribution transformers of 2000 kVA were operated in coal handling plant section. The loading of one transformer was19.8% (397 kVA) and the other transformer was loaded for 5.5% (111 kVA). The connected loads on both transformers were on the lower side. The bus coupler between the two transformers was off.

Losses in the above operating conditions were:

Equipment	Load (kW)	Apparent Power (kVA)	Design Rating (kVA)	% loading	Losses (kW)
Transformer 1	357	397	2000	19.8	3.82
Transformer 2	98	111	2000	5.5	3.06

The plant team has switched on the bus coupler and shifted the entire load to one transformer by isolating the second transformer from the HT breaker. Therefore the loading on the operating transformer improved. The loss calculation with the new system is given in the below table

Equipment	Load (kW)	Apparent Power (kVA)	Design Rating (kVA)	% loading	Losses (kW)
Transformer 1	716.5	760	2000	38	4.34

Due to isolation of one transformer, the no load losses of one transformer has been avoided. The plant team is follows a systematic method of interchanging and loading the transformers every fortnight to overcome the moisture problem which can affect the transformers.

Benefits

- Improved loading of both the transformers
- Improved efficiency of the transformers
- Savings of 2.5 kW of power

Financial Analysis

The overall savings achieved by reducing the tap position of the distribution transformers was Rs. 0.6 Lakhs (unit cost – Rs 3/ unit) and there was no investment made for this project.

CASE STUDY No. 32

LIGHTING VOLTAGE OPTIMIZATION BY INSTALLATION OF LIGHITNG TRANSFORMER

Background

Lighting load in a power plant accounts to around 2 to 3% of the total auxiliary power consumption. Lighting loads are highly unbalanced loads since the loads are single phase and equal loading in all the phases or load balancing is uncommon. Lighting transformers reduces the voltage and then supply to the lighting loads and the reduction in voltage results in power savings.

In addition, lighting transformers also isolates the primary voltage from the load thereby reducing the high voltage spikes and the fluctuations from the incoming supply.

Project Description

In a power plant of 150 MW capacity, the total lighting load was measure to be 115 kW in the entire plant. The plant has installed two dedicated lighting transformers in the plant boundary for two sections in the plant from where the lighting load is being met. By installing the lighting transformers, the lighting voltage has been reduced from 243 volts to 210 volts.

Equipment	Load (kW)	Operating Voltage (V)	Reduced Voltage (V)
Transformer 1	67	243	210
Transformer 2	48	241	210

By installing lighting transformers, more than 10% voltage reduction to the lighting loads is achieved and corresponding 10% power reduction in the total lighting load has been achieved.

Benefits

- Increased life of lamps – reduction in failure rate
- Reduction in power consumption by 14 kW

Financial Analysis

The overall savings achieved by reducing the tap position of the distribution transformers was **Rs. 1.7 Lakhs** (unit cost – Rs 3/ unit). The investment of **Rs. 4.9 Lakhs** was made, providing a simple payback of **35 months**

CASE STUDY No. 33

INSTALLATION OF HARMONIC FILTERS

Background

Harmonics are voltage and current frequencies riding on top of the normal sinusoidal voltage and current waveforms. Usually these harmonic frequencies are in multiples of the fundamental frequency, which is 50 Hertz (Hz).

Harmonics are created by "switching loads" (also called "nonlinear loads," because current does not vary smoothly with voltage as it does with simple resistive and reactive loads). Each time the current is switched on and off, a current pulse is created. The resulting pulsed waveform is made up of a spectrum of harmonic frequencies, including the 50Hz fundamental and multiples of it. The higher-frequency waveforms collectively referred to as total harmonic distortion (THD), perform no useful work and can be a significant nuisance.

Sources of harmonics

Following are some of the non-linear loads which generate harmonics:

- Static Power Converters and rectifiers, which are used in UPS, Battery chargers, etc.
- Arc Furnaces
- Power Electronics for motor controls (AC /DC Drives)
- Computers
- Saturated Transformers
- Fluorescent Lighting
- Telecommunication equipment

Effects of harmonics

The harmonics have a multifold effect on various network elements present in a system. Whenever a harmonic current flows through an equipment,

- It causes additional losses due to its higher frequency in devices such as motors, transformers, etc. which has a laminated core have higher losses due to higher frequency of the harmonic current.
- In cables, the harmonic current tend to flow through the outer skin of the conductor due to skin effect and results in heating of these conductors.
- Harmonics can cause nuisance tripping of the relays and failure of capacitors installed in distribution system for power factor improvement

- Certain order of harmonic currents (for e.g. 5th harmonic) has the reverse phase sequence which means any electro mechanical device used for metering will not register true values. Similarly, in a polluted network a normal induction motor may not develop necessary torque because of harmonic current generating a torque in the reverse direction

- Higher order harmonics interfere with telecommunication system also. Whenever a telephone line runs parallel to a power line having harmonics, a noise is introduced in the telephone line. This phenomenon is known as telephonic interference

- A highly polluted voltage may lead to improper operation of devices such as thyristors, operation of which depend on the zero crossing of the voltage wave form. This may result in commutation failure in thyristors

- A high harmonic content also results in a low power factor. The angle between the fundamental component of current and voltage gives the Displacement Power Factor, whereas, the same between the voltage and rms current (fundamental and harmonic) gives the total Power Factor. In a linear load, the P.F. and D.P.F. are same, whereas for the loads which generate lot of harmonics, the P.F. is much lower than the D.P.F.

- Some of the harmonic current which are zero sequence current (3rd harmonic current) tend to flow in the neutral in a 3 phase, 4 wire system. In most of the domestic and commercial load, which are non – linear in nature generate substantial amount of 3rd harmonic current, the neutral conductor gets overheated and may lead into melting of the same. It has been observed that in extreme cases, the neutral current can exceed 1.5 times the normal line current

- The harmonic current affect the generator also, as most of the higher capacity generators operate at maximum capacity and they do not have excessive margin to accommodate heating losses resulting due to flow of harmonic current into it. All such heating losses result in deterioration of insulation used in electrical equipment.

Technology Description

Harmonic Mitigation can be performed in two basic methods:

- Reinforcing the distribution system to withstand the harmonics

- Installing devices to attenuate or filter the harmonics.

Reinforcing the distribution system can be done by installing double-size neutral wires or installing separate neutral wires for each phase, and/or installing oversized or K-rated transformers, which allow for more heat dissipation. There are also harmonic-rated circuit breakers and panels, which are designed to prevent overheating due to harmonics. This option is generally more suited to new facilities, because the costs of retrofitting an existing facility in this way could be significant.

Strategies for attenuating harmonics, from cheap to more expensive, include passive harmonic filters, isolation transformers and active filters.

Functions of Harmonic Filter

1. Reduces neutral current
2. Reduces transformer loading and over heating
3. Protects the neutral conductor
4. Minimizes impact on distribution transformers
5. Decreases system losses
6. Reduces Total Harmonic Distortion (THD)

Types of Harmonic Filters

1. Passive filters: Include devices that provide low-impedance paths to divert harmonics to ground and devices that create a higher-impedance path to discourage the flow of harmonics. Both of these devices, by necessity, change the impedance characteristics of the circuits into which they are inserted. Another weakness of passive harmonic technologies is that, as their name implies, they cannot adapt to changes in the electrical systems in which they operate. This means that changes to the electrical system (for example, the addition or removal of power factor–correction capacitors or the addition of more nonlinear loads) could cause them to be overloaded or to create "resonances" that could actually amplify, rather than diminish, harmonics.

2. Isolation transformers: are filtering devices that segregate harmonics in the circuit in which they are created, protecting upstream equipment from the effects of harmonics. These transformers do not remove the problem in the circuit generating the harmonics, but they can prevent the harmonics from affecting more sensitive equipment elsewhere within the facility.

3. Active harmonic filters: in contrast, continuously adjust their behavior in response to the harmonic current content of the monitored circuit, and they will not cause resonance. Active filters are designed to accommodate a full range of expected operating conditions upon installation, without requiring further adjustments by the operator.

IEEE Standards

IEEE Standard 519 (1992) has been already existing which specifies limits of the harmonics in power systems. The acceptable limit for harmonic distortion as per IEEE standard is as under:

Voltage Harmonics*

Table 11.1
Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and Below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

*Source: IEEE - 519

Current Distortion*

Maximum Harmonic Current in % of I_L

Maximum Harmonic Current Distortion in % of I_L						
Permissible Individual Harmonic Levels (Odd Harmonics)						
Isc / I_L	<11	11 - 16	17 - 23	24 – 34	>34	%TDD
< 20*	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd current harmonic limits above

Where, I_{SC} - Maximum short circuit current at Point of Common Coupling

I_L - Maximum demand load current at Point of Common Coupling

(Fundamental frequency component)

TDD – Total Demand distortion is the ratio of calculated harmonic current distortion

against the full load (demand) level of the electrical system

The allowable % current harmonics is based on the I_{SC} / I_L ratio at that customer's point of common coupling with the utility. The following example shows how to arrive at the I_{SC} / I_L of the transformer.

Consider a transformer of 2000kVA with rated full load current of 2666A. The transformer impedance is 6.42%.

Short Circuit Current I_{SC} $= I_L /Zi$

$= 2666/.0642$

$= 41,526$ A

Therefore I_{SC}/ I_L $= 41256/2666$

I_{SC}/ I_L $= 15.47$

Apart from G5/3, IEEE 519 (1992), other guidelines such as IEC 1000 - 2 -2 define acceptable limits of harmonics in power system. In India, till now no guideline has been published. However, the Central Board of Irrigation & Power (CBIP) is working in this direction and has published a finding on presence of harmonics at various voltage levels for industrial load as well as for utility supply system.

CASE STUDY No. 34

INSTALLATION OF ENERGY EFFICIENT MOTORS

Background

About 90-92 percent of the load in a power plant auxiliary constitutes three phase induction motors of various sizes. Induction motors come in different efficiency classes and the efficiency of the motors for the same rating varies with the efficiency classes.

We know that the motor power consumption is dependent on the load it is connected to, but still we can on an average say that 85% of the life cycle cost of the motor is its operating cost, whereas the initial cost of the motor is only 5% and the maintenance cost of the motor over its lifetime is only 10%.

Technology Description

An induction motor efficiency mainly depends upon the loading of the motor. The loading of a motor further affects the operating power factor. The motor life is enhanced and the efficiency is maximum when it operates close to the rated power and the motor life is adversely affected when the motors are under loaded due to inadequate cooling and the efficiency of the motor drastically comes down for a standard efficiency motor. The relation between the standard motor and energy efficient motors for different loading levels is shown in the graph below.

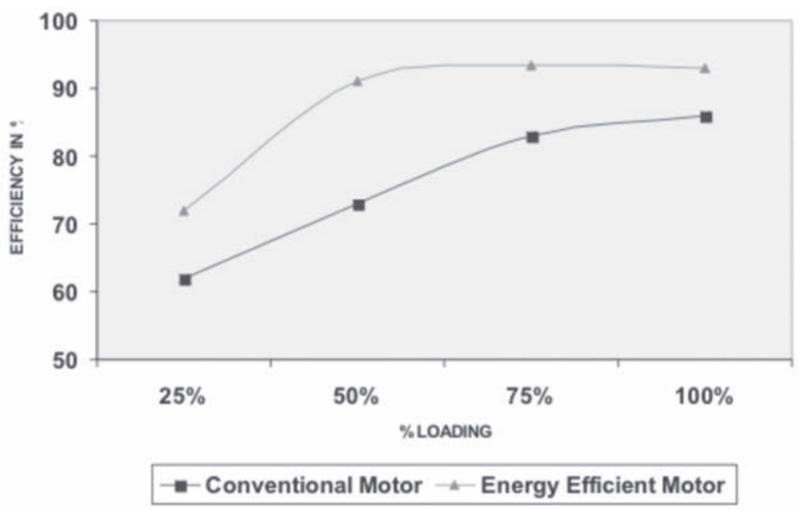


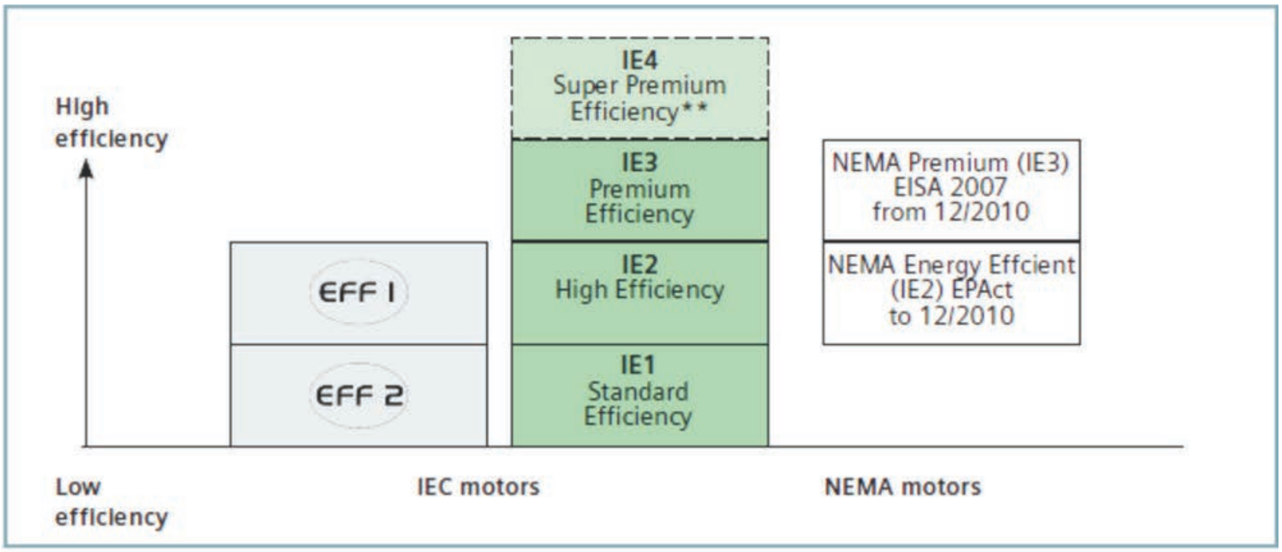
FIG 2: Loading vs. Efficiency

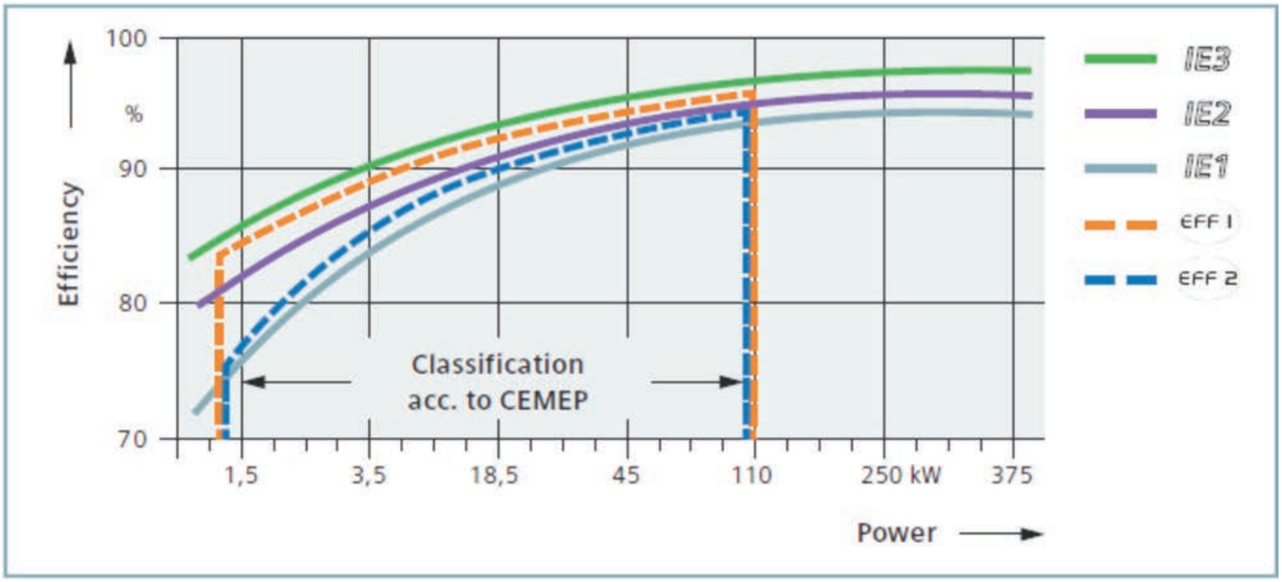
In Energy Efficient Induction motors, construction includes 20% more copper in the stator and rotor which reduces both stator losses viz. the no load losses and also the rotor losses. In addition, the energy efficient motors also come with precision air gap between the stator and the rotor core to reduce the windage losses. Improved insulation in the winding laminations is one more feature in the energy efficient motors which reduce the insulation damages and have lesser chances of insulation breakdown. Energy efficient motors also have lesser slip and have higher service factor which increases the flexibility in handling voltage fluctuations and imbalances. Due to reduced losses in the motor, the power factor of the motor is always on the higher side when compared to a standard efficiency motor.

One more advantage of energy efficient motors are, the efficiency curve of the energy efficient motors is flat for loadings above 40% compared to standard motors and therefore even during fluctuating loads; the efficiency of the motor is still maintained in an energy efficient motors.

Energy efficient motors have different standards and guidelines by different organizations all round the world. Few major standards followed all over the world are the International Electrotechnical Commission (IEC) Standards and National Electric Manufacturers Association (NEMA) standards.

IEC Standards have classified the Energy efficient motors into two categories like EFF1 and EFF2 motors with EFF1 as high efficiency and EFF2 as standard efficiency motors. Later, IEC in order to have a common standard world over, have introduced IEC 60034-30. As per IEC 60034-30, the efficiencies of a motor have been divided into three categories IE1, IE2 and IE3.





Benefits

- Improved operating efficiency at lower loading.
- Enhanced life of motor.

Financial Analysis

The overall savings will be achieved by the improvement in operating efficiency due to reduced losses. The initial cost of high efficiency motors (IE2) are **10% to 15%** excess compared to standard efficiency motors.

Chapter 4

Action Plan and Conclusion

Action Plan and Conclusion

Action Plan

- The individual Power Plants have to assess the present performance and should develop their own individual target for improving parameters concerning energy, water and environmental performance.
- Set and achieve voluntary target for heat-rate and auxiliary power reduction every year.
- The best practices and the performance improvement projects compiled in this manual may be considered for implementation after suitably fine tuning to match the individual plant requirements.
- If required, CII-Godrej GBC will help the individual units to improve the performance by providing energy audit services and identifying performance improvement projects specific to individual units to achieve the targets.
- The present level of performance and the improvements made by the individual units have to be monitored.

Conclusion

Developing "Best practices manual for Thermal Power Plants" is an effort to address the growing needs for energy conservation and energy efficiency. We are sure that the Indian Thermal Power Plants will make use of this opportunity, improve their performance and move towards World Class Energy Efficiency.

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