Emission Reduction Program (ERP) For Existing Pulverized Fuel Fired Thermal Power Plants

Stochiometric combustion through Coal Mass Flow Balancing & Online Unburnt Carbon In Ash Measurement

Anup Shukla - Techfab systems
**Unit wise Breakup of Installed capacity**

<table>
<thead>
<tr>
<th>UNIT Capacity MW</th>
<th>Before 31.3.2003 MW</th>
<th>No of Units</th>
<th>1.1.2004 onwards MW</th>
<th>No of Units</th>
<th>Total MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-110 MW</td>
<td>6875</td>
<td>77</td>
<td>258</td>
<td>4</td>
<td>7133</td>
</tr>
<tr>
<td>111-250MW</td>
<td>39277</td>
<td>198</td>
<td>17211</td>
<td>81</td>
<td>56488</td>
</tr>
<tr>
<td>251-499MW</td>
<td>0</td>
<td>0</td>
<td>12690</td>
<td>43</td>
<td>12690</td>
</tr>
<tr>
<td>500MW</td>
<td>13500</td>
<td>27</td>
<td>27500</td>
<td>55</td>
<td>41000</td>
</tr>
<tr>
<td>&gt;500MW</td>
<td>0</td>
<td>0</td>
<td>61640</td>
<td>96</td>
<td>61640</td>
</tr>
<tr>
<td>Total</td>
<td>59652</td>
<td>302</td>
<td>119299</td>
<td>279</td>
<td>178951</td>
</tr>
</tbody>
</table>

**Units Below 60MW not included. Source CEA**
Mandate by NTPC and CEA

• Plants after 2003 have SOFA installed but need modifications on dampers and ducts
• Low NOx burners to be retrofitted
• Wall fired boilers needs dynamic classifiers
• Tangential fired boilers need combustion optimization and OFA installed
• Combustion optimization
• FGD to be installed or ESP modification
Actual status

- OFA installed but not utilized on account of unbalanced fire ball
- Fireball balance can be done following 13 rules of combustions with effective tools
- No effective coal balancing tool available in plants
- NO UBC measurement available
- Air flow measurement is not effective due to fouling fly ash in the secondary air
What is auditable

- Every month balancing of the each mill is checked using coal mass flow measurement
- Necessary adjustment of coal mass flow using variable orifice valves is done
- The report and screen shot with date time stamp will ensure that it is adhered to and being done meticulously
Emissions Reduction Program (ERP)

Reasons of NOx Emission

• Nitrogen in coal is responsible for approximately 80% of the total Nox formed during coal combustion.
• During normal combustion process only 20% to 30% of the N₂ content in the fuel is converted to Nox. The conversion of fuel nitrogen is weakly temperature dependent but depends strongly upon local burner stoichiometry.
• Nox generated by coal combustion is a combination of nitric oxide (NO) nitrogen dioxide (No₂). NOX in the flue gas from coal combustion is from 80% to 95% NO.
Emissions Reduction Program (ERP)

Combustion Control Methodology

• Equal coal mass flow & air/fuel ratio through each burner at all elevations of boiler is balanced and centralized.
• This will help in further Reduction of excess air thus Nox. Reduction in excess air can be done through online unburnt carbon and secondary air flow measurements.
• Minimum a week, the audit of the balancing of pulverized fuel flow is done. The balancing can be done dynamically using variable orifice valves.
Emissions Reduction Program (ERP)

Present Scenario of Power Boilers

- Increased Pollution Load On Environment
- Higher Furnace Exit Gas Temperature
- Higher NOX, CO and specific CO$_2$ emission
- Higher un-burnt carbon in ash/ LOI

Reasons :-

- Use of Low quality fuel - *Cannot be Controlled*
- **Unbalanced flame alignment/decentralized fire ball** - *“Can be Controlled”*
- Higher Fuel Consumption by higher Excess Air/O$_2$ - *“Can be Controlled”*
Emissions Reduction Program (ERP)

Causes of High Thermal NOx

- **High Excess Primary Air**
  It facilitates increased nitrous oxide emission as it is a major part of total air in the high temperature root of the burner flame rather than secondary air.

- **High Excess Secondary Air**
  It provides oxygen in excess to combine with N/N2 in fuel/air leading to formation of NOx.
Emissions Reduction Program (ERP)

Fire Ball Centralization accomplished with Variable Orifice Valves

With reliable on-line information of absolute coal mass flow, on-load mass flow to the burners can be balanced through dynamically controlled variable orifice valves and Fire Ball can be Centralized.
Important rules for efficient combustion

Directly Controlled Fuel Injection

- Primary air flow needs to be measured and controlled to a tolerance of 3% of full scale value

- Fuel velocities shall always be higher than 23 m/sec

- Velocities shall be balanced to 2 m/sec

- Mill outlet temperature shall be consistent and controlled temp to a tolerance of 5 K

- The pulsation rate of the coal mass flow shall be below 5% (variance of the actual value to the mean value)

- The coal mass flow distribution shall be within a tolerance of 5%
Important rules for efficient combustion

- Secondary air distribution controlled to a tolerance of 5%

- Overfire air distribution controlled to a tolerance of 5%

- Swirl air settings controlled to a tolerance of 5%

- Excess air level reduced to the point where UBC is below max target value (usually 5%)
Combustion

- Combustion:
- 1kg coal (C H O N S) with 8kg air (N2,O2) → CO2, HO2, NOx, SO2 - (N2, O2, C, Ash)

Thermal energy: 20-35 MJ/kg

Heat transfer by radiation in the boiler and convection in SH, RH and ECO

Furnace Exit Gas Temperature °C with HVT

| Axis | 0,0 m | 0,5 m | 1,0 m | 1,5 m | 2,0 m | 2,5 m | 3,0 m | 3,5 m | 4,0 m | 4,5 m | 5,0 m | 5,5 m | 6,0 m | 6,5 m | 7,0 m | 7,5 m |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 2    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 3    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 4    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 5    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 6    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 7    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 8    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 9    | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 10   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 11   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 12   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 13   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 14   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 15   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 16   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 17   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 18   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 19   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
| 20   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   | 392   |
**Fluegas**

1. Economizer outlet
2. O2 Measurement
3. (SCR)
4. Airpreheater
5. Filter (ESP)
Selective Catalytic Reaction SCR

Selective catalytic reaction Dosing of ammonia in dependency of primary NOX, reaction in catalyst demands temperatures between 300 and 400°C:

- High Dust between ECO and APH
- Low dust after ESP
- Tail End (reheat necessary)

Basic reaction formula:
\[
\begin{align*}
4 \text{NO} + 4 \text{NH}_3 + \text{O}_2 &\rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O} \\
6 \text{NO}_2 + 8 \text{NH}_3 &\rightarrow 7 \text{N}_2 + 12 \text{H}_2\text{O}
\end{align*}
\]

Side effect formula:
\[
\begin{align*}
\text{SO}_2 + \frac{1}{2} \text{O}_2 &\rightarrow \text{SO}_3 \\
\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O} &\rightarrow \text{NH}_4 \text{HSO}_4
\end{align*}
\]
Selective Non Catalytic Reaction SNCR

SNCR Works without Catalyst, needs high temperatures 1000°C

Ammonia / Urea injection between furnace outlet and the area of Superheaters H

Basic reaction with ammonia

\[
4 \text{NO} + 4 \text{NH}_3 + \text{O}_2 \rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O}
\]

Urea

\[
\text{NH}_2\text{CONH}_2 + \text{H}_2\text{O} \rightarrow 2 \text{NH}_3 + \text{CO}_2
\]

Nitro- hydrogen radicals are formed with Oxygen:

\[
\begin{align*}
\text{NH}_3 + \text{O} & \rightarrow \text{NH}_2 + \text{OH} \\
\text{NH}_3 + \text{OH} & \rightarrow \text{NH}_2 + \text{H}_2\text{O}
\end{align*}
\]

To reduce The NO content:

\[
\text{NH}_2 + \text{NO} \rightarrow \text{N}_2 + \text{H}_2\text{O}
\]
DeSOx

- Wet cleaning in scrubbers with chalk milk
- Dry cleaning with hydrated Lime Injection in combination with bagfilters

\[
Ca(OH)_2 + SO_2 \rightarrow CaSO_3 \cdot \frac{1}{2}H_2O + \frac{1}{2}H_2O
\]

\[
2SO_2 + 2Ca(OH)_2 \rightarrow 2CaSO_3 + 2H_2O
\]

\[
2CaSO_3 + O_2 + 4H_2O \rightarrow 2[Ca[SO_4] \cdot 2H_2O]
\]

\[
2SO_2 + 2Ca(OH)_2 + O_2 + 2H_2O \rightarrow 2[Ca[SO_4] \cdot 2H_2O]
\]
Filter - ESP

ESP:
- High Voltage applied to discharge electrodes 30 kV
- Collecting Electrodes are cleaned by shaking
- Higher energy demand

Bagfilter
- Bags cleaned with pressurized air
- Combined with dry DeSOx and hydrated lime injection
- Higher pressure drop, higher fan capacity needed
Ashhandling

Ash is collected in hoppers underneath the filter units, further ash handling transports ash in (high pressure) dense phases to sylos. Pressure isolation between filer and conveying done by valves.
Sorting according to quality.

- Pressurized vessels with time controlled discharge cycles
- Cellular wheel with fluidized transport in polysius channel
Boiler Combustion Optimization

**MECONTROL**

**UBC**
On-line measurement of the unburned carbon in the fly ash

**Coal**
On-line measurement of the coal mass flow between the mill and the burner

**Air/Gas**
On-line flow measurement of preheated excess air or flue gas

**Flow**
Modification of ductwork and flow dampers for better distribution
Emissions Reduction Program (ERP)

- Ways to Reduce $\text{NO}_x$:
  1) Post Combustion Technology - SCR & SNCR - very expensive

2) Improved Combustion Control – Balancing Fuel mass – very economic

Balancing Equal mass flow in each PF pipe with help of PF mass flow measurement and adjustments of Variable orifice valves will help to reduce thermal NOx through improved combustion
Fuel combustion in the old days

VW Golf 1, 70 hp, fuel consumption 10.5 l/100km
Fuel combustion nowadays

VW Golf 7, 115 hp, fuel consumption 4.3 l/100km
Difference between Carburetor and Electronic Fuel Injection EFI:

**Basic Carburetor (Cross Section)**

- Air Cleaner
- Choke Valve
- Venturi
- Float Valve
- Float Arm
- Float Chamber
- Jet
- Throttle Valve

**EFI**

- Fuel injection system
- Electronic control

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Difference between feeder- and windbox controlled combustion, and Directly Controlled Fuel Injection
Technology Highlights

• Online & absolute measurement system for pulverized fuel flow Air fuel ratio to individual burner pipes.
• Onload adjustable orifice valves at mill discharge.
• Online unburnt carbon in fly ash measurement at ESP hoppers.
• Online Secondary (excess) Air measurement through reliable, drift free “Electrostatic charge Correlation” based technology.
Coal flow balancing and measurement systems

Automated Coal Flow Dampers

Coal Flow Sensors
Onload - Dynamically Adjustable Variable Orifice Valves
Adjustment of coal velocities

Adjustment of coal flow velocity

Example Pipe Arrangement

Coal Valve

Pulverizer

Splitter Box

Burner

MECON TROL Coal
Proposed system

4.1 Measurement of coal mass flow and primary air

Coal mass flow measurement
MECON TROL Coal
Velocity Balance

Stationsnummer: 03  Geschwindigkeiten

Velocities

[m/s]

18:24  19:31  20:38  21:46  22:53  00:00  01:08  02:15  03:22  04:29

14.12.99

Rohr 21
Rohr 22
Rohr 23
Rohr 24
Rohr 25
Rohr 26
Rohr 27
Rohr 28
Adjustment of mass flow

C1煤粉管内的煤粉流量明显高于其它3个煤粉管内煤粉流量

C1C2管入口安装煤粉调节器后，煤粉质量流量变化趋势。

2014年9月7日
MECONTROL Coal
Absolute Mass Flows and Velocities

Coal-G3 History Trend Data

Mass Flows / Velocities per pipe - 02G3

Date/Time: 08/05/2003 11:20:02

Legend: Trend-1 Signal Name [t/h]
- G3 MF MST02 Kanal 01
- G3 MF MST02 Kanal 02
- G3 MF MST02 Kanal 03
- G3 MF MST02 Kanal 04

Legend: Trend-2 Signal Name [m/s]
- G3 Geschw. Kanal 01
- G3 Geschw. Kanal 02
- G3 Geschw. Kanal 03
- G3 Geschw. Kanal 04
Adjustment of coal mass flows

Same coal mass flow to every burner

Coal distribution before the adjustment

Coal distribution after the adjustment
Adjustment of coal velocities

Here a large velocity spread has been corrected by a variable orifice
Highlights Of The ERP Program

• Online coal mass flow measurement in each individual mill discharge pipe through a proven microwave based technology
• Onload adjustment of the fuel flow through adjustable variable orifice valves
• Online measurement of un burnt carbon in fly ash at ESP hopper’s to fine tune the excess air/O₂ requirement
• Measurement & controls may be hooked up with existing DCS to achieve the results.
Online Carbon In Ash Measurement at ESP Hoppers
What is auditable

- Every month balancing of the each mill is checked using coal mass flow measurement
- Necessary adjustment of coal mass flow using variable orifice valves is done
- The report and screen shot with date time stamp will ensure that it is adhered to and being done meticulously
Thank you!!