AUXILIARY POWER MEASUREMENT, OPTIMIZATION & ANALYSIS

Steag Energy Training Center

EEC WORKSHOP-25.09.2013 to 27.09.2013
Heat Input into a Large Coal Fueled Power Plant- Sub Critical design.
Power Plant – Fossil fuels

• Fossil fueled fired generating stations have very precise definition of Thermal efficiency.
• It is the ratio of heat equivalent of Fuel fired to the heat equivalent of electricity sent to transmission net work.
• Auxiliary power consumption has two components.
• Unit auxiliary power consumption & station auxiliary power consumption.
Power plant cycle efficiency

- Role of Steam Generator is to generate steam which is used to convert heat energy into kinetic energy.
- Conversion cost includes usage of steam produced for internal consumption such as SCAPH, TDBFP, Air Conditioning based on VAS.
- Aux. power consumption would depend on coal quality and on type of cycle.
- Why not use better coal, which would lower auxiliary power consumption and an optimum performance can be sustained with less expenditure on O&M Cost.
The definition of net unit heat rate, expressed in terms of its component parts (Figure 1), provides a set of potential heat rate improvement options. Reducing auxiliary power use is an important option for improving net unit heat rate.
To illustrate the magnitude of this effect, a sensitivity analysis was performed for an 800-MW (gross) power plant with a turbine cycle heat rate of 8,000 Btu/kWh and boiler efficiency of 85%. The baseline auxiliary power use was 80 MW, and baseline net unit heat rate was 10,458 Btu/kWh. The results, presented in Figure 2, show that a 10% reduction in auxiliary power use will improve net unit heat rate by approximately 1.1%. 
The breakdown of auxiliary power loads for a large coal-fired power plant is presented in the Table. The feed water system loads are determined by operating parameters of the Rankine cycle (where boiler feedwater pump power depends on the main steam pressure), and there is little opportunity for reducing these auxiliary power loads except in the selection of drives. The feed water system loads include the main feedwater pumps and condensate booster pumps. **Auxiliary power use in coal-fired power plants by technology.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Subcritical</th>
<th>Supercritical</th>
<th>Ultra-supercritical</th>
<th>Future ultra-supercritical</th>
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<td>4.2</td>
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<td>11.9</td>
<td>11.6</td>
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<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
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</table>
Power plant cycle efficiency

• Gross boiler efficiency at any point of operation can be improved by consuming more electricity through Mills & fans.

• When we are using low cost – inferior coals- we consume more auxiliary power consumption to improve operating efficiency.

• Usage of an additional pulverizer to handle poor coal results in increased power consumption, however, corresponding improvement in Gross boiler efficiency may not be achieved.
IMPORTANCE OF AUXILIARY POWER CONSUMPTION

• DEGRADATION OF EQUIPMENT PERFORMANCE CAN BE READILY GUAGED FROM POWER CONSUMPTION.

• UNIT OR BOILER POWER CONSUMPTION IS MONITORED AS % OF GENERATION WHICH IS JUST A GROSS INDEX.

• POWER CONSUMPTION GUARANTEE ON BOILER COVERS ALL MAJOR DRIVES.

• POWER CONSUMPTION SHOULD BE MEASURED TOGETHER IN A TYPICAL BOILER EFFICIENCY TEST.
Change in plant Conditions with time increases Auxiliary power

- Air in leakage to boiler gas enclosure
- Fouling of Boiler heating Surface – higher dry gas loss would increase power consumption
- Higher draft loss due to air ingress and ash deposition.
- Air heater leakage / Air ingress after APH’s
- Deterioration of Turbine Steam Path Condition.
- Condenser pressure/ condenser cleanliness- air ingress and extent of tube pluggage
- Steam and water leaks from drains and vents.
Comparision of Flue Gas Oxygen Levels at APH Inlet/HVT with Oxygen at Eco Outlet from DAS (500 MW Unit)

Flue Gas Oxygen at Eco Left (DAS) % vs. Oxygen %

- APH Inlet FG Oxygen
- Furn Exit Gas Oxygen

**Legend:**
- Avg. Furnace Exit (HVT) Oxygen
- APH Gas Inlet Oxygen %
Oxygen % at various locations in boiler
NET HEAT RATE

• NET HEAT RATE MONITORING WOULD COVER IMPACT OF AUX. POWER CONSUMPTION OF DIFFERENT DRIVES
• NET HEAT RATE MONITORING CAN BE ADOPTED FOR INERNAL PROCESSES.
• THIS WOULD CALL FOR INDIVIDUAL MONITORING OF DRIVES USING ACCURATE ENERGY METERS.
• SUCH A SYSTEM IS BEING INTRODUCED AS A RETROFIT IN ALL OLD PLANTS IN NTPC & CONSUMPTION LEVELS ARE BEING TRACKED FROM OVERHAUL TO OVERHAUL.
MAJOR DRIVES

• DRIVES ARE LISTED FOR A TYPICAL 500 MW UNIT.

• AUXILIARY POWER CONSUMPTION MEASUREMENT CAN BE DONE AS PER A STANDARD TEST CODE.

• HOWEVER NO TEST CODE COVERS CORRECTION METHODOLOGY WHICH WOULD BE WORKED OUT BASED ON PROCESS DESIGN.
MEASUREMENT-METHODOLOGY

- ACCURATE ENERGY METERS OF 0.25% ACCURACY DULY CALIBRATED ARE USED FOR POWER MEASUREMENT.
- ALL DRIVES INCLUDING UNIT AUX. TRANSFORMER SHOULD BE COVERED.
- ENERGY METERS SHOULD BE CAPABLE OF CONNECTION IN A RUNNING UNIT.
- MEASUREMENT TO BE DONE ALONG WITH BOILER EFFICIENCY TEST.
PERFORMANCE ANALYSIS

• MEASURED TOTAL POWER COULD BE DIFFERENT FROM BASE LINE VALUES FOR CHANGES IN OPERATING REGIME

• IT SHALL BE HIGHER WHEREVER BOILER PERFORMANCE HAS DEGRADED

• GROSS POWER COULD BE SAME BECAUSE SOME AUXILIARIES MAY BE DOING BETTER AND SOME OPERATING AT WORSE POINT DUE TO PERFORMANCE DEGRADATION
CORRECTION METHODOLOGY

• CORRECTION METHODOLOGY IS JOINTLY DEVELOPED WITH VENDOR AS IT IS NOT GENERALLY COVERED IN TEST CODES

• APPLICATION OF CORRECTION REQUIRES ACCURATE MONITORING OF PROCESS PARAMETERS USING ACCURATE OFF LINE INSTRUMENTS

• COAL VARIATION WOULD HAVE MAJOR EFFECT ON UNIT PERFORMANCE AND THUS POWER CONSUMPTION.
BOILER FEED PUMP

• BOILER FEED PUMP IS NOT A BOILER AUXILIARY AND ITS POWER CONSUMPTION VARIES IN RESPONSE TO TURBINE MODE OF WORKING AND ITS DEGRADATION

• BFP POWER CONSUMPTION CAN BE OPTIMIZED USING VARIABLE PRESSURE OPERATION; REDUCTION OF SPRAY RATES WOULD ALSO HELP.
BOILER FEED PUMP

• BFP POWER CONSUMPTION CONSTITUTE A MAJOR CHUNK OF POWER CONSUMED BY UNIT AUXILIARIES.

• USAGE OF STEAM DRIVEN FEED PUMP RESULTS IN REDUCTION OF APC %.

• USAGE OF TURBO DRIVEN FEEDPUMP IMPROVES CYCLE EFFICIENCY .

• ANY FEEDBACK ON TDBFP PERFORMANCE DUE TO CONDENSER DEGRADATION !
## Boiler Feed Pump Performance Testing

<table>
<thead>
<tr>
<th>BFP</th>
<th>Flow (t/hr)</th>
<th>Train Efficiency (%)</th>
<th>Power Consumption (kw)</th>
<th>BDLO Flow (t/hr)</th>
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<tbody>
<tr>
<td>A</td>
<td>327</td>
<td>61</td>
<td>2761</td>
<td>29.4</td>
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<tr>
<td>B</td>
<td>337</td>
<td>62</td>
<td>2760.8</td>
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<tr>
<td>C</td>
<td>319</td>
<td>51.4</td>
<td>3128</td>
<td>42.2</td>
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</table>
Wanakbori Unit 5  BFP Performance Test, May 31 - June 2, 1998
BFP / BFBP Motor Power vs Volumetric Flow

- BFP / BFBP "A" Motor Power (kw)
- BFP / BFBP "B" Motor Power (kw)
- BFP / BFBP "C" Motor Power (kw)

Volumetric Flow Corrected to Design Speed (m³/hr)
ID FANS POWER CONSUMPTION

MEASURED ID FANS POWER CONSUMPTION IS GENERALLY HIGH FOR FOLLOWING DEVIATIONS

• HIGHER FLUE GAS VOLUME
• HIGH AIR HEATER LEAKAGE.
• HIGH ESP LEAKAGE.
• HIGHER FLUE GAS TEMPERATURE.
• HIGHER PRESSURE DROP CHIMENEY.
• IMPELLER EROSION REFLECTS DEGRADATION
TYPICAL CORRECTION DATA

- MEASURED POWER FOR ID FAN 2A       2427.5 kW
- CORRECTION FOR FREQUENCY                  -5.0 kW
- CORRECTION FOR HIGH GAS FLOW      -290.0 kW
- CORRECTED POWER CONSUMPTION   2132.5 kW

POWER CONSUMPTION CAN BE HIGH ON ACCOUNT OF HIGHER PRESSURE DROP ACROSS CHIMNEY.

THIS COULD BE ONE OF THE MAJOR CAUSE FOR ID FAN FULL LOADING IN MANY OF THE UNITS. NO CORRECTION APPROACH.
PRIMARY AIR FANS

- PA FANS DESIGNED FOR HIGH MARGINS TO HANDLE HIGH MOISTURE COAL AND INCREASED PRESSURE DROP ACROSS A. H.
- INTRODUCTION OF ADDITIONAL MILL WOULD INCREASE PA FAN LOAD AND RESULT IN HIGH AH LEAKAGE EXHAUSTING ID FANS MARGIN
- PA CROSS SECTION ACROSS AIR HEATERS HAS BEEN INCREASED TO HANDLE HIGH MOISTURE COALS & ADDITIONAL PA FLOW REQUIREMENT
- THIS HAS EASED OFF LOADINGS ON PA FANS AND IMPROVED ID FAN MARGINS.
- INCREASED PA FLOWS TO MILL COULD IMPROVE BOILER LOADING BUT IT IS AT COST OF INCREASED UNBURNT LOSS & HIGHER POWER CONSUMPTION.
CORRECTIONS TO PA CONSUMPTION

- HIGHER COAL MOISTURE
- HIGHER AIR HEATER LEAKAGE
- HIGHER AMBIENT TEMPERATURE
- MEASURED POWER FOR PA FAN 2A  1825.0 kW
- CORRECTION FOR FREQUENCY  -7.6 kW
- CORRECTION FOR HIGH PA FLOW TO MILLS  -255.0 kW
- CORRECTED POWER CONSUMPTION  1632.4 kW
FD FANS

- FD FANS POWER CONSUMPTION DEPENDS ON EXCESS AIR LEVEL AND WIND BOX PRESSURE SETTING
- ADDITIONAL MILL AND HIGH PA LOADING RESULTS IN REDUCTION OF FD FANS POWER
- POTENTIAL FOR FANS’ POWER CONSUMPTION OPTIMIZATION IS MAXIMUM AND A TOTAL REDUCTION OF 500 kW LOOKED ACHIEVABLE IN A 200 MW UNIT
- TWO SPEED FANS ARE USED IN SOME OF THE PLANTS TO IMPROVE PART LOAD OPERATION
**CORRECTION METHODOLOGY**

**CORRECTIONS APPLICABLE TO FD FANS COVER**

- COAL BEING DIFFERENT FROM DESIGN
- AMBIENT TEMPERATURE
- HIGHER AIR HEATER LEAKAGE
- BOILER OPERATION AT DIFFERENT EXCESS AIR

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<tr>
<th>Item</th>
<th>Value</th>
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<tr>
<td>Measured power for FD fan 2B</td>
<td>592.8 kW</td>
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<tr>
<td>Correction for higher air flow</td>
<td>-40.0 kW</td>
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<tr>
<td>Correction for frequency</td>
<td>0.0 kW</td>
</tr>
<tr>
<td>Corrected power</td>
<td>552.8 kW</td>
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PULVERIZERS

- PULVERIZER POWER CONSUMPTION HAS MANY TRADE OFFS, SUCH AS MILL FINENESS, MILL OUTPUT & PA FLOW.
- REGULAR PERFORMANCE TESTING OF MILLS SHOULD ENABLE THE ESTABLISHMENT OF BASE LINE DATA FOR MILLS.
- COAL AND HGI DATA ARE TAKEN TO CORRECT FOR ANY DEVIATION.
TYPICAL CORRECTION METHODOLOGY

- CORRECTIONS FOR MILLS COVER,
- MEASURED POWER FOR MILL 2B 263.4 KW
- CORRECTION FOR FEEDER SPEED 24.0 KW
- CORRECTIONS FOR HGI FACTOR -40.0 KW
- CORRECTIONS FOR MOISTURE -10.0 KW
- CORRECTION FOR FINENESS 00.0 KW

- CORR. POWER CONSUMPTION 386.6 KW
Power plant cycle efficiency

• Impact of coal quality on expected Boiler Efficiency is rather difficult to predict.
• Modeling tools are generally not available with a station to understand the role of change in operating regime on expected performance.
• Based on actual Performance, we can revise our targets and instead of comparing performance with design values, we can compare with expected values.
## Summary - Boiler Performance Tests

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Predicted Data</th>
<th>Pre Outage</th>
<th></th>
<th></th>
<th>Post Outage</th>
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<tr>
<td></td>
<td></td>
<td><strong>Test 2</strong></td>
<td><strong>Test 2</strong></td>
<td><strong>Test 4</strong></td>
<td><strong>Test 5</strong></td>
<td><strong>Test 6</strong></td>
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<td><strong>MS Flow</strong></td>
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<td>700</td>
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<td><strong>SH Attemporation</strong></td>
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<tr>
<td><strong>RH Attemporation</strong></td>
<td><strong>T/hr</strong></td>
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<td><strong>FW Temp at Econ. Inlet</strong></td>
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<td>105</td>
<td>108</td>
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ELECTOSTATIC PRECIPITATOR

• IT IS AN AUXILIARY WHOSE POWER CONSUMPTION IS DEPENDENT ON ASH CHARACTERISTICS AND OF COURSE ON BOILER OPERATING REGIME.

• PULSE ENERGISATION SYSTEM HAS RESULTED IN MAJOR SAVINGS OF INPUT.

• EFFECTIVE RAPPING SHOULD HELP.

• UPGRADATION HAS BEEN UNDERTAKEN IN ALL UNITS TO REDUCE POWER INPUT.
ELECTOSTATIC PRECIPITATOR

• CORRECTION METHODOLOGY FOR ESP IS VERY DIFFICULT TO WORK.

• IT IS REGULATED BY ASH RESISTIVITY WHICH IS CONTROLLED BY GAS EXIT TEMPERATURE AND COAL MOISTURE.

• EFFECTIVENESS OF RAPPING SYSTEM SHOULD HELP TO REDUCE THE OPERATING POWER CONSUMPTION.

• SWITCHING OFF FIRST FIELD IS PRACTICSED AT SOME STATIONS WHICH IS DEBATABLE.
CONCLUSION

• AUXILIARY POWER CONSUMPTION AUDITS HAVE A TREMENDOUS PAY BACK AND INCREASE AWARENESS REGARDING EQUIPMENT PERFORMANCE.

• IT COULD BE VERY EFFECTIVE ADOPTED AS A PART OF ON LINE DAS SYSTEM AT A VERY NOMINAL COST.

• ASSESSMENT OF DEVIATION WOULD CALL FOR ACCURATE PROCESS DATA.
Fans' Aux Power on Different Oxygen Levels
Data From Boiler Optimization Tests

Flue Gas Oxygen Eco Outlet Left From DAS (%)

FD Fans  PA Fans  ID Fans  Fans' Aux. Power

<table>
<thead>
<tr>
<th>Aux Power (kW)</th>
<th>Total Fan Power (kW)</th>
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<tr>
<td>11</td>
<td>4600</td>
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<td>11</td>
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