Turbine Performance Monitoring and Optimization System

By

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System Technologies
How to Improve Efficiency?

First Step: low hanging fruits

- Improve efficiency by improving operation and maintenance

Next Steps:

- Audit or „map“ the plant using off line modelling tool e.g. Ebsilon
- Online optimization System for Turbine Performance Monitoring and Optimization System
Why to use the PADO tools?

DCS also has the information needed to do the calculation of efficiencies & heat rates

But what are the limitations?

1. DCS does not give the system wise efficiencies so you do not know where the losses occur.

2. Data from I/O points e.g. Temperature, pressure, mass flow could be wrong because of sensor errors, bad connectors etc. That makes calculation erroneous.

3. DCS does not give advice on what to do.
1. All relevant data from DCS which goes into calculation need to be validated i.e. all implausible values have to be replaced by plausible values.

2. All calculations must be done every 5 minutes so as to continuously monitor component and heating surface efficiencies.

3. Results should be presented in user friendly manner: state of components indicated by green, yellow, red and losses expressed in monetary value per hour.
PADO Functions

OFFLINE
- WhatIf
- SRx Visualisation

SRx (Datamanagement)

SRv
- Data Validation

SR4
- Diagnosis + Optimization

DCS
83 units order for PADO have been placed on SESI
27 units successfully commissioned till date

**National Thermal Power Corporation (NTPC)**
The largest power generating major of India generating power from Coal and Gas with an installed capacity of 34,194 MW, has standardised on Steag PADO for all future units including Super-Critical Units.

**Bharat Heavy Electricals Limited (BHEL)**
The largest supplier of power equipment with 70% of current installed market of Thermal Power Plants has a Framework Agreement with SESI for installation of PADO for all future units including Super-Critical Units.
55 units where PADO is commissioned or under commissioning

- NTPC Simhadri 2x500 MW
- NTPC Ramagundam 1x500 MW
- NTPC Rihand 2x500 MW
- NTPC Talcher 4x500 MW
- NTPC Kahalgaon 3x500 MW
- NTPC Sipat 2x500 MW
- NTPC Vindhyachal 2x500 MW
- NTPC Korba 1x500 MW
- NTPC Dadri 2x500 MW
- NTPC Farakka 1x500 MW
- Mahagenco Khaparkheda 1x500 MW
- Mahagenco Bhusawal 2x500 MW
- NTPC Simhadri (stage II) 2x500 MW
- NTPC Jhajjar 3x500 MW
- KPCL Bellary (KPCL) 1x500 MW
- RVUNL Stage 1 and 2 Chhabra 3 x 250 MW
- Shree cement Ltd. RAS (4X18 MW + 2X50 MW)
- DVC Maithan 2x500 MW
- GEB Ukai 2x500 MW
- NTPC Korba Extn 1x500 MW
- NTPC Bongaigaon 3x250 MW
- TNEB North Chennai 2x600 MW
- CSEB Marwa 2x500 MW
- CSEB Korba 1x500 MW
- L&T Rajpura 2x700 MW
- L&T Koradi 3X660 MW
- Sterlite Jharsuguda 4X600 MW
- NTPC Kudgi 3X800 MW
Advantages of PADO

- Improving the quality of measurements by data validation
- Evaluation of boiler, turbines, condenser and other components
- Optimization of unit operation (sootblowing, setpoints)
- Calculation of what-if scenarios
- Generation of daily and monthly reports
- Enhance the efficiency of the power plant!
Modules of PADO System for Turbine Cycle

- Fault Tree
- Statistical Process Control
- Data Visualization
- Data Validation
- Data Management System
- Epsilon Model
- What-If Analysis
- Turbine Performance Monitoring

Legend:
- Base Modules
- Fault Detection
- Performance Monitoring and Optimization
SR::x is the central data management in the SR product family

- Competitive server featuring a “state-of-the-art“ visualization
- Long-term storage of measured and computed values in time-oriented archives; base time class is ‘minute values’
- Automatic aggregation to higher time classes such as 5‘-, quarterly-, hourly-, daily-, monthly- or yearly-values
- Integrated mathematical formula editor
- Excel-Add-In and HTML-List Generator allow the generation of extensive reporting systems
SR::x Data Management System

SR::x is the central data management with “state-of-the-art” visualization
Data Validation System

Data Validation to replace data errors due to defective sensor or cable problems:
Incorrect Data – Wrong results
No data – No results

Validation – A 3 tier Process
1) Plausibility Check using Neural Networks
2) Plausibility Check based on range of Values
3) Data validation / reconciliation based on “First Principle Thermodynamic” model
Data Validation System (1)

based on Neural Network...
Data Validation System (2)

based on “First Principle Thermodynamics”...
Data Validation System (3)

check the quality of measurements ...
main steam measurements left and right
(left not plausible)
Neural network generated the value 477 °C for not available value of tag 70HAH30CT129_XQ03
# Data Validation Report

**point in time**: 05.05.04 11:25:00

<table>
<thead>
<tr>
<th>datapoint</th>
<th>description</th>
<th>raw value</th>
<th>plausibility checked value</th>
<th>reconciliation data point</th>
<th>value from reconciliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20HAC10CP101</td>
<td>plausible value FW PRESS AT ECO I/L</td>
<td>196.3 kg/cm²</td>
<td>196.3 kg/cm²</td>
<td>20HAC10CP101_V</td>
<td>196.3 kg/cm²</td>
</tr>
<tr>
<td>20HAC10CT101</td>
<td>plausible value FW TEMP AT ECO I/L</td>
<td>257.1 °C</td>
<td>257.1 °C</td>
<td>20HAC10CT101_V</td>
<td>257.1 °C</td>
</tr>
<tr>
<td>20HAD01CP101</td>
<td>plausible value DRUM PRESS</td>
<td>190.4 kg/cm²</td>
<td>190.4 kg/cm²</td>
<td>20HAD01CP101_V</td>
<td>190.4 kg/cm²</td>
</tr>
<tr>
<td>20HAD01CP102</td>
<td>plausible value DRUM PRESS</td>
<td>190.0 kg/cm²</td>
<td>190.0 kg/cm²</td>
<td>20HAD01CP102_V</td>
<td>190.0 kg/cm²</td>
</tr>
<tr>
<td>20HAD01CP103</td>
<td>plausible value DRUM PRESS</td>
<td>189.7 kg/cm²</td>
<td>189.7 kg/cm²</td>
<td>20HAD01CP103_V</td>
<td>189.8 kg/cm²</td>
</tr>
<tr>
<td>20HAH21CT101</td>
<td>plausible value SH DESH I/L TEMP (L)</td>
<td>400.0 °C</td>
<td>400.0 °C</td>
<td>20HAH21CT101_V</td>
<td>400.2 °C</td>
</tr>
<tr>
<td>20HAH22CT101</td>
<td>plausible value SH DESH I/L TEMP (R)</td>
<td>401.1 °C</td>
<td>401.1 °C</td>
<td>20HAH22CT101_V</td>
<td>401.1 °C</td>
</tr>
<tr>
<td>20HAH23CP101</td>
<td>plausible value SH DESH O/L PRESS (L)</td>
<td>184.1 kg/cm²</td>
<td>184.1 kg/cm²</td>
<td>20HAH23CP101_V</td>
<td>183.9 kg/cm²</td>
</tr>
</tbody>
</table>
Red - Critical
Yellow - Suboptimal
Light Green – Optimal
Dark Green – Time gap to next action
Visualization Aid 2: Data values as tags & in tables with coded Background colors
Interpretation of Background Colors

White – Measured Value

Grey - Calculated Value

Violet – Replaced value (Originally non plausible or not available)
Performance Monitoring

- Compares the actual values of critical parameters with the best achievable under current operating conditions.
- Shows monetary loss against each sub optimal operating parameter, defining the scope of improvement.
Turbine Performance Monitoring

**TURBINE CYCLE**

- HRH
  - 1468 t/h
  - 528 °C
- 43.0 kg/cm²
- 4.4 kg/cm² Reheat pressure drop

**Controllable Losses**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual</th>
<th>Reference</th>
<th>HR Dev. [kcal/kWh]</th>
<th>Losses expr. in extra fuel</th>
<th>Monetary loss [Rs/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throttle temperature</td>
<td>538 °C</td>
<td>537 °C</td>
<td>-0.335</td>
<td>-0.1 t/h</td>
<td>-74</td>
</tr>
<tr>
<td>Throttle pressure</td>
<td>163 kg/cm²</td>
<td>170 kg/cm²</td>
<td>2.879</td>
<td>0.5 t/h</td>
<td>634</td>
</tr>
<tr>
<td>Reheat temperature</td>
<td>528 °C</td>
<td>537 °C</td>
<td>4.397</td>
<td>0.8 t/h</td>
<td>1101</td>
</tr>
<tr>
<td>Reheat pressure drop</td>
<td>4.4 kg/cm²</td>
<td>4.5 kg/cm²</td>
<td>3.872</td>
<td>0.6 t/h</td>
<td>809</td>
</tr>
<tr>
<td>Condenser back pressure</td>
<td>-0.87 kg/cm²</td>
<td>-0.87 kg/cm²</td>
<td>-2.965</td>
<td>-0.5 t/h</td>
<td>-1</td>
</tr>
<tr>
<td>Superheater spray flow</td>
<td>30.5 t/h</td>
<td>0 t/h</td>
<td>6.190</td>
<td>1.0 t/h</td>
<td>1364</td>
</tr>
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<td>6.190</td>
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<td>1364</td>
</tr>
<tr>
<td>Reheat spray flow</td>
<td>32.5 t/h</td>
<td>0 t/h</td>
<td>20.944</td>
<td>3.5 t/h</td>
<td>4614</td>
</tr>
<tr>
<td>Final FW temperature</td>
<td>255 °C</td>
<td>254.3 °C</td>
<td>0.346</td>
<td>0.1 t/h</td>
<td>76</td>
</tr>
<tr>
<td>Blow down flow</td>
<td>0 t/h</td>
<td>48.4 °C</td>
<td>8.449</td>
<td>1.4 t/h</td>
<td>1861</td>
</tr>
<tr>
<td>Auxiliary steam flow</td>
<td>13.6 t/h</td>
<td>10.0 t/h</td>
<td>8.449</td>
<td>1.4 t/h</td>
<td>1861</td>
</tr>
<tr>
<td>Frequency</td>
<td>49.38 Hz</td>
<td>50.00 Hz</td>
<td>0.042</td>
<td>0 t/h</td>
<td>23</td>
</tr>
<tr>
<td>Make-up flow</td>
<td>22.2 t/h</td>
<td>0 t/h</td>
<td>43.613</td>
<td>7.4 t/h</td>
<td>9608</td>
</tr>
</tbody>
</table>

**TG heat rate gross, actual** | 2054 kcal/kWh |
**TG heat rate net, actual**  | 2117 kcal/kWh |
Statistical Process Control

Statistical methods to evaluate partly automatic, early & reliable detection of changes where deterioration is slow.
Key measurements in power plants usually depend on
- load,
- operation mode
- fuel quality
- ambient conditions
- etc.
And are superposed by noise
KPIs measure the quality of the process / component.

They do not depend on external disturbance variables.

KPI = act-value / ref-value
STATISTISCHE PROZESSKONTROLLE
04.11.2007 06:00:00 - 12:00:00
Blockstatus: in Betrieb
SPC Status: unbekannt
Stromertrag: 9477 MWh

Prozessgüteüberwachung

<table>
<thead>
<tr>
<th>SPC</th>
<th>KPI</th>
<th>Shawhart</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>1.12</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0.94</td>
<td>0</td>
</tr>
<tr>
<td>0,144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Zustandsüberwachung

Kesselpumpen 1
40LAC10CY221_XG60, Lagerschwingung vertikal
40LAC10CY222_XG60, Lagerschwingung horizontal
40LBB10EX0366_XG60, Stromaufnahme

Kesselpumpen 2
40LAC20CY221_XG60, Lagerschwingung vertikal
40LAC20CY222_XG60, Lagerschwingung horizontal
40LBB10EX0363_XG60, Stromaufnahme

SPC Ergebnisse für 20.01.2009 15:45

SPC_KNO2, Kondenstatorge, KPI (SR: EPDS)
40LAC10CP011_XG60, Druckverlust Luxo, luftdruck (TEST)
SPC_LUVW_HYDR, LUVO Druckverlust, KPI (SR: EPDS)
40LBB10CTI01_XG60, Dampftemperatur Zu-Austritt

SPC_FLG1_SWL_KPI

SPC_SGZ1_SWU - Saugzug 1 - Schwingung Lager unten

Text 2 (Kontrollgrenze überschritten) war positiv.
Text 5 (2 von 3 Werten liegen im äußeren Kontrollbereich) war positiv.
Mittelwerte Referenzwert ist 1.
Standardabweichung ist 0,25.
Kontrollbereich ist 0,5 bis 1,5.
Der äußere Kontrollbereich ist unter 0,67 bzw. über 1,33.
Fault Trees

- Models and analyzes faults in the process.
- Composed of logic diagrams that display the state of the system and the states of the components.
- Constructed using Drag & Drop technique.
- Does not need programming expertise for building such trees.
Thank You

... Ideas & Solutions for Tomorrow