Introduction

- Name: Bram Kroon
- Company: Engie
- Department: Energie Nederland (Generation)
- Location: Eems & Lelystad Power Plant
- Position: Process Engineer
- Thermoflex: Eight Years of experience in Modelling (CCGT and coal fired)

< - Eems:
CCGT 5 x 360 MW

Maxima: ->
CCGT 2 x 440 MW
The Challenge

- The spark spreads for CCGT's are small and under pressure
- Actual performance needs to be as close as possible to optimal performance
- Availability needs to be high
- Small deviations in operational data can be an indicator for developing faults
- But the optimal performance of a CCGT is not a fixed number it depends on
  - Load
  - Ambient air temperature
  - Ambient air pressure
  - Cooling water temperature
  - Gas quality
  - Etc.

The challenge is how to accurate and reliable monitor the performance
Our solution

- Use a thermodynamic model that takes all the variables into account
- Make real-time calculations with on-line data
- Model calculated data are written to PI
- Compare the actual measurements with the model calculated results
- Use trends to see the behavior in time more clearly

Advantages:
- Fuel savings due to early alarming when small performance deviations are detected;
- Prevent (big) damages by being able to see that a component stays within its operating window
Technology used

- Thermoflex (modeling software)
- PI (Process database)
- Excel and VBA (Data exchange between Thermoflex and PI)
- PI processbook (Visualisation)
Output of the tool (PI Processbook)

- Dashboard (operators)
  - Most important indicators
  - Alarm when deviation reality/model too high

- Heat Balance sheet (process specialist on site)
  - Compare flow, temperature, pressure model and real measurement
  - Alarm when deviation too high

- Trends (process specialist on site / Thermodynamic Expert)
  - Compare measurements, performance indicator over time
  - Analytic tool
High level view: dashboard (Main user: operator)

### Maxima Power Plant - Performance Dashboard

<table>
<thead>
<tr>
<th>Unit</th>
<th>Flevo 4 04-10-2017</th>
<th>Flevo 5 04-10-2017</th>
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</thead>
<tbody>
<tr>
<td>Nett Power</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Green" /></td>
</tr>
<tr>
<td>Nett Efficiency</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Green" /></td>
</tr>
<tr>
<td>Gasturbine</td>
<td><img src="image" alt="Green" /></td>
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<tr>
<td>Compressor Inlet Flow</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Green" /></td>
</tr>
<tr>
<td>Compr. Pressure</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Red" /></td>
</tr>
<tr>
<td>Compr. Efficiency</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Green" /></td>
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<tr>
<td>Condenser</td>
<td><img src="image" alt="Green" /></td>
<td><img src="image" alt="Green" /></td>
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<tr>
<td>Gradigkeit</td>
<td><img src="image" alt="Green" /></td>
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</tbody>
</table>

Reference date & time:
- ![Date and Time](image)
Second level view: Heat balance sheet, with alarms (Main user: Process responsible on site, thermodynamic expert)
Third level: trends (Main user: thermodynamic expert from EOS, process specialist from site)
Benefits of Thermodynamic Model (Off-line)

- Knowledge building during model development and discovering faults
  - Measuring failures: Wrong: ranges, calibrations, $P_{\text{gauge}} \rightarrow P_{\text{abs}}$, Gas properties, etc.
  - Make real correction curves (ambient $T$, $P$, $\text{rel}\%$, $T_{\text{coolw}}$, $\text{LHV}$, $C/H$, etc.), (non commercial) It's necessary to know the exact heatrate.
  - Findings: Steam temperatures in part load were higher than design temperatures. (creep)

- What if studies
  - Minimum load studies and testing: $P_{\text{min}} 280\text{MW} \rightarrow 110\text{ MW}$
  - Increase efficiency: Using: inlet air heating, flex load-path, max IGV.
  - Reduce home-load: Optimize condenser cooling water flow. Reduce feedwater pressure setpoint.
  - Gas-preheating and building-heating on stack-loss basic design.
  - Basic design study for new desuperheater. (Challenging design of OEM)
  - Optimize control-loops: Developing Energie-balance Feed Forward signals
  - Solving LP-drum-Level instabilities: Increasing minimum pressure IP steam.
Benefits of Thermodynamic Model (On-line)

- Detections of small deviations between model and real power plant
  - Drifting measurements, fouling, leakages, performance deviations, parameters changes etc..
  - Examples of found deviations:
    - Lower TIT temperatures after C inspection (retuned by the OEM);
    - Influence of gas composition change on performance;
    - Condenser air in-leakage and condenser fouling;
    - Leaking of a desuperheater attemporation-valve;
    - Leaking draining-valves
    - Fouling of compressor and inlet filters;

- On-line saved model data can be used in RCA’s
  - to find and analyze deviations afterwards.;
  - or change operations or maintenance instructions.
Thermoflex (online) helps to maximize the performance

- The Flevo’s drops less than 0.4% in relative efficiency after 50000 EOH
  - According OEM the Relative Efficiency drops 1.7% after 8000 EOH. {not realistic??}
- Full savings since commissioning up to 9M€ (partly contributed by Thermoflex Model)
  - 1.3 % x (50000–8000)hr x ~380MW x ~6100MJ/MWh x ~7€/GJ
Example of checking errors: Dashboard alarm!! measured power 3MW lower than expected: Increasing home load FL4 -> the model accuracy detects testing cooling water pumps FL5

Model accuracy:
- Load transient (<10MW/min) ± 1.0%
- Stable load ± 0.5%
Example of measurement failure:
After the mothball period the measured efficiency is too high.
ThermoFlexOnline detected that the gas chromatograph was not working properly.
Example of air leaking in condenser:
After condenser repair the Terminal Temperature Difference is back to nominal: $dT \text{ 3°C} \rightarrow 1-3\text{MW} \rightarrow 300000\text{ euro/yr.}$
Available software

- Steag (software: SR::EPOS;EBSILON). Used mainly on coal fired power plants
- General Physics (software: etaPro).

- Possible Thermoflow (software: thermoflex). They are not active in this market.

- Advantage of combination of PI and Thermoflex / Elink
  - Thermodynamic models of KA26 & GE9FA CCGT’s in Thermoflex are available;
  - All Engie power plants have the use op PI Processbook
  - Lot of knowledge of CCGT’s in house available also operational experience;
  - Model development costs lower than the market and we keep the knowledge in house
Questions?

Or if time

1. Live DEMO

2. ThermoFlex expert subjects
Requirements to build an accurate model

- The design specifications of the plant components:
  - Heat-exchangers, pumps, steam-turbine exhaustloss curves, glandsteam leakages, gas turbine cooling airflows, etc.

- OEM heat balances and correction curves:
  - Only for starting modelling

- Understand the unit control logic's:
  - Gas turbine load path, fixed pressures.

- Check of key measurements and corrections:
  - A control value is not always a physical value. (TAT corrections, TIT calculations, Flow calculations, static heights pressure transmitters)
  - Gas heat input, mass flow and LHV
  - Compressor air mass flow, Bellmouth calculation
TF standard GT26 has not enough outputs for TFO
GT26 Heat balance  first design

38 % of compressor flow is cooling air!
GT26 has a very complex Cooling flow system

- SEV lance carrier air
- HP turbine heat shield, blade, disk purging and HPT disk cooling air
- HP cooler
- CVC2 Chip HPC disk cooling and purging air

Temperature indicators:
- 340 °C
- 540 °C

Drum leakage release to MBH20
Drum leakage release to MBH30
MBH40 Cooling Flow leakages to MBH30 and MBH20

MBH20 is a mixture of Bleed and MHB40 cooling

Compressor end Is cooled with OTC MBH40 air
Real: TIT’s, TAT’s and Pressure Ratio’s

TAT1 measurement
Exhaust flow + part air from MBH30

Pressure drop SEV burner
Compressor maps not be available from OEM

4 Compressor maps $\rightarrow$ $4 \times 4 \times 10 = 160$ tables
export PI data $\rightarrow$ Excel $\rightarrow$ import in ThermoFlex