Welcome!

Webinar #32: Advanced Features in Thermoflex
07 Mar 2019

Agenda:
* Introduction
* Control Loops
* Searcher
* Classic Macros
* Shaft Power
* Q & A Session

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Support: Meritt Elmasri (U.S. HQ)
Advanced Features in THERMOFLEX

Edit Inputs / Define

HELP
Advanced Features in THERMOFLEX

- Previous Webinars
  - Catalogs → Webinar 25
  - Scripts → Webinar 2 & 24
  - Assemblies → Webinar 1
  - User Defined Data Model → Webinar 30
  - User Defined Component → Webinar 19
  - Link / Import to other TF programs → Webinar 8

- Current Webinar
  - Control Loop
  - Searcher
  - Classic Macro (Multiple Runs / Excel)
  - Shaft Power

- Future Webinars
  - Graphical Options and customized outputs
  - Fuel Demand Model → NOVOPRO
Advanced Features in THERMOFLEX

- The **Intention**
  - What is the function and objective of each feature
  - How and where to activate the feature
  - What are the inputs which need to be defined
  - What are the outputs we get, where we can find them and how to define UD outputs
  - Show interesting considerations of each feature
  - Show how the features work through examples

→ Go to HELP for further details

→ Check the predefined **Samples** (detailed description in Help / Appendix A)
Control Loop

- **Function**: Adjust certain *Control Variables* to cause:
  - a *Set Point Variable* to attain a desired value → *Set Point Control*
  - a pair of variables to be equal → *Parameter Matching Control*

- **Procedure**:
  - Edit Inputs: Define / Control Loops
    - Enable Control Loop
    - Define Control Objective: Select *Output Objective*, set **Value** and **Tolerance**
    - Select Control Inputs: Select *Control Variable(s)* and set the **limits**
  - Outputs: Graphics / Control Output
Control Loop

The diagram illustrates the control loop for Power, showing SetPoint at 40000 kW. The lower control input is Gas Turbine GT F(%) [1]: GT load as percent of site rating, with a calculated value of 100%. The calculated values for the upper and primary control inputs are 553.2 and 39607 respectively. The control objective is to maintain output power at 40000 kW.
Control Loop

Considerations:
- Can be used in TD-ED & OD modes
- Can be used to represent a real Control Loop or just to meet the value of a variable which doesn’t have a direct input
- Check the upper / lower control limits to ensure continuity
- Compatibility:
  - Classic Macros: always enabled
  - Multiple Runs: maybe enabled / disabled
  - Elink: use formulas to enable / disable
- In TFX it’s possible to have several CL in the same file (only 1 in GTM)
- In TFX most of the variables are available (just a few in GTM)
- TFX doesn’t save and store intermediate computation files
Control Loop

Examples:
- Rankine Cycle, TD mode: steam massflow to attain a certain Gross Power
- CC1P, OD mode: GT % - Fogger Effectiveness – Duct Burner to attain a Net Power
- Sample S3-14: Parameter Matching
- Sample S2-07, similar to CC1P OD
- Sample S3-13, valve pressure control
Control Loop

Ambient temperature 15 C
Ambient RH 60 %
Net power 95043 kW
Net electric efficiency (LHV) 37.4 %

Control Loop Control Loop 1
Gross power = 100000 kW

Lower Control Primary Control Upper Control

Primary Control: Package Boiler [20]: Defined outlet steam flow = 309.5 t/h
Control Loop
Control Loop

Parameter Matching

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Searcher

- **Function**: to maximize or minimize an output parameter (*Target*) by varying an input parameter (*Adjuster*)

- **Procedure**:
  - Edit Inputs mode: Define / Searcher
  - Enable Searcher
  - Select the Target, maximum or minimum and the tolerance
  - Select the Adjuster and define:
    - Adjuster type: *continuos* (number of steps) or *discrete* (increment)
    - Range: minimum and maximum
    - Starting point
    - Search Method
Searcher

- **Outputs**: in outputs mode:
  - Default outputs:
    - Text outputs ➔ Table: Adjuster and Target
    - Graphics outputs ➔ Graphic: Target vs Adjuster
  - User Defined Outputs:
    - Edit Inputs mode: Define /Searcher /Define Outputs
      - Add Plots (Select X and Y) ➔ Graphics Output
      - Define Table: Select Table parameters ➔ Text Output
Searcher

Considerations:

- Can be used in TD-ED & OD modes
- Allows to select cost or financial outputs as Target
- TFX doesn’t save and store intermediate computation files
- Compatibility with ELINK
- Difference with Control Loop: unknown vs known target output
- Difference with Macro /MR /ELINK: target value vs trends
Examples:

- CC 1P at TD: ST inlet Pressure to maximize Efficiency
- Rankine cycle at TD: FWH Delta T to maximize Efficiency (Scripts)
- Sample (S5-10a): OD number of operating ACC cells to maximize Net Power (discrete)
- Sample (S2-38): OD number of operating CT cells to maximize Net Power (continuos)
- ELINK: same as S2-38 with 1 or 2 CW Pumps in operation
ST Inlet Pressure to maximize the Efficiency (TD Mode)
Number of operating Cooling Tower Cells to maximize the Net Power (OD Mode)

<table>
<thead>
<tr>
<th>Units</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>20.0</td>
<td>40.0</td>
<td>55.3</td>
<td>58.9</td>
<td>60.0</td>
<td>64.7</td>
<td>70.6</td>
<td>80.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
| Net power | Target kW | 376.891 | 381.743 | 383.503 | 383.619 | 383.619 | 383.619 | 383.495 | 383.495 | 383.063

Click on [Graphics] > Searcher to see the alternate cases the Searcher calculated as it varied cooling tower fan operation to maximize net power.
Classic Macros

- **Function**: to perform calculation of a series of cases with varying input parameters

- **Procedure**:
  - Edit Inputs mode: Define / Classic Macro Inputs
  - Enable Macros
  - Define number of cases to be run
  - Select the (inputs) Macro Variables
  - Set values for Macro cases

- **Outputs**: in outputs mode: Define / Classic Macro Outputs
  - Macro Cases: view the outputs of the different cases
  - Define Macro Table → Text outputs
  - Define Macro Plots → Graphics outputs
### Classic Macros

#### Define Macro Inputs

- **Number of Macro Cases**: 5

#### ST Group [1] : Design point inlet pressure (bar)

- **Case 1**: 20
- **Case 2**: 40
- **Case 3**: 60
- **Case 4**: 80
- **Case 5**: 100

#### Package Boiler [5] : Defined outlet temperature (°C)

- **Case 1**: 400
- **Case 2**: 400
- **Case 3**: 400
- **Case 4**: 400
- **Case 5**: 100

#### Water-cooled Condenser [2] : Design point condenser pressure (bar)

- **Case 1**: 0.1
- **Case 2**: 0.1
- **Case 3**: 0.1
- **Case 4**: 0.1
- **Case 5**: 0.1

#### Gross power (kW)

- **Case 1**: 23318
- **Case 2**: 24853
- **Case 3**: 25391
- **Case 4**: 25500
- **Case 5**: 25339

#### Gross electric efficiency (LHV) (%)

- **Case 1**: 25.51
- **Case 2**: 27.52
- **Case 3**: 28.49
- **Case 4**: 29.04
- **Case 5**: 29.32
Classic Macros

Considerations:
- Can be used at TD- ED & OD modes
- Differences with *Multiple Runs* and *ELINK*
  - Only available in TFX
  - Limitations in the range of parameters, especially PEACE components
  - No base case to compare with
- All the cases saved in a single file
Classic Macros

Examples:

- Rankine cycle at TD: effect of the ST inlet Pressure variation (above)
- Sample (S3-02a): GT Cogeneration plant at OD across a range of ambient T
## Classic Macros

### Effect of the Ambient Temperature

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>°F</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Gross power</td>
<td>kW</td>
<td>41.225</td>
<td>38.451</td>
<td>35.535</td>
<td>32.802</td>
<td>29.979</td>
</tr>
<tr>
<td>Net power</td>
<td>kW</td>
<td>40.467</td>
<td>37.722</td>
<td>34.837</td>
<td>32.132</td>
<td>29.338</td>
</tr>
<tr>
<td>Gross electric efficiency (LHV)</td>
<td>%</td>
<td>32.49</td>
<td>31.93</td>
<td>31.24</td>
<td>30.48</td>
<td>29.45</td>
</tr>
<tr>
<td>Net electric efficiency (LHV)</td>
<td>%</td>
<td>31.89</td>
<td>31.32</td>
<td>30.63</td>
<td>29.86</td>
<td>28.82</td>
</tr>
<tr>
<td>CHP efficiency</td>
<td>%</td>
<td>78.75</td>
<td>80.04</td>
<td>81.36</td>
<td>82.71</td>
<td>84.01</td>
</tr>
<tr>
<td>Mass Flow of Stream 13 @ exit of Superheater</td>
<td>lb/s</td>
<td>52.39</td>
<td>51.65</td>
<td>50.80</td>
<td>50.01</td>
<td>49.36</td>
</tr>
</tbody>
</table>
Shaft Power

- **Function**: to organize and operate the different shafts from rotating components, and balance free shafts
- Thermoflex logic for assigning shaft numbers
- Shaft Diagram
- Balancing Shaft
Shaft Power

**Thermoflex logic** for assigning shaft numbers:

- Each GT PRO Gas Turbine is placed on its own shaft, driving its own generator
- All *Gas/Air Compressors, Gas/Air Turbines*, and *Cooled Turbine Stages* in a model are placed on one shaft
- All *Steam Turbines* components in a model are placed on one, common shaft, driving a generator
- All *Ammonia/Water Turbines* in a model are placed on one shaft
- *Pumps, Fans, Fuel Compressors, Refrigerant Compressors, Ammonia/Water Compressors, and Steam Compressors*, are each placed on its own shaft, each to be driven by its own motor.
- *Refrigerant Turbines* and *Water Turbines* are each placed on its own shaft
Shaft Power

Shaft 1
Mode: Generator
Shaft power: 66902 kW
Generator power: 65807 kWe
Speed: 3600 rpm

Shaft 2
Mode: Generator
Shaft power: 26493 kW
Generator power: 25886 kWe
Speed: 3600 rpm

Gas/Air Compressor
Inlet → Outlet

Gas/Air Turbine
Inlet → Outlet

<table>
<thead>
<tr>
<th>Description</th>
<th>Model</th>
<th>Add sheet</th>
<th>Shaft Diagram</th>
</tr>
</thead>
</table>

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Shaft Power

Balancing Shaft

- Edit Inputs mode: Define / Shaft Power

- Disposition of Power: Free Shaft

- Operating Mode:
  - Fixed rpm:
    - Select variable to balance the free shaft and set the limits
  - Variable rpm (only in OD mode):  
    - TFX finds the variable rpm to balance the shaft
Shaft Power

- **Examples**
  - GT driving a Fuel Compressor at TD: massflow of fuel which can be compressed
  - GT driving a Fuel Compressor at OD: % of GT to compress a given massflow of fuel
  - Sample (S2-24): 3 Shaft Aeroderivative GT, balancing 2 shafts at TD
  - Sample (S2-24a): 3 Shaft Aeroderivative GT, balancing 2 shafts at OD, variable speed
Shaft Power

Balancing Shaft by varying the massflow of fuel to be compressed (TD Mode)
Shaft Power

Balancing Shaft by varying the speed of the 2 free shafts (OD Mode)
Q & A Session

- Please forward your questions on the WebEx Chat
- Further questions by email to: info@thermoflow.com

- PP Presentation will be available on the Website / Tutorials
- Video will be available on the Service Center
Thank you!

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