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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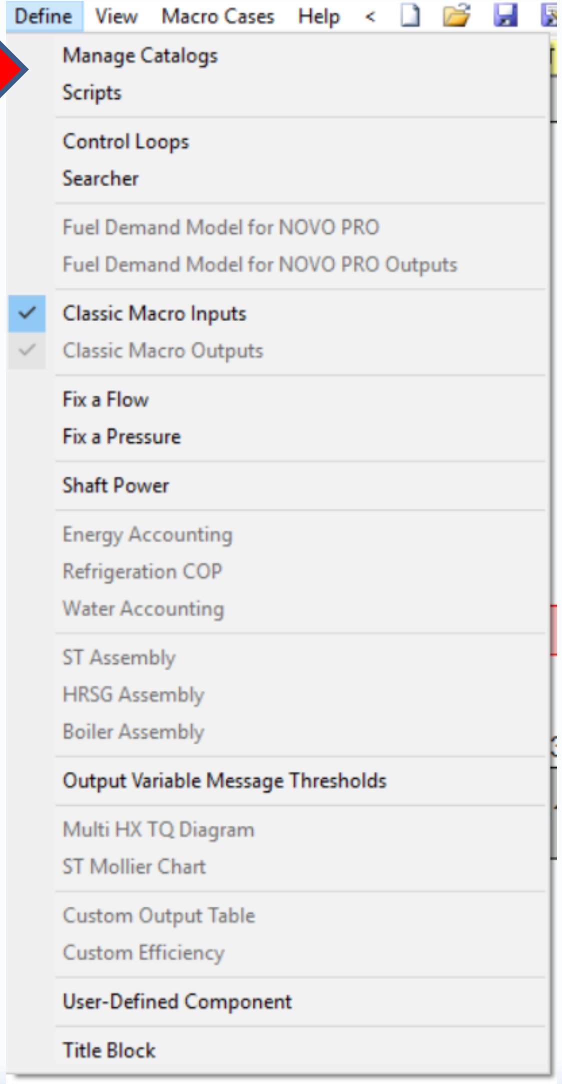
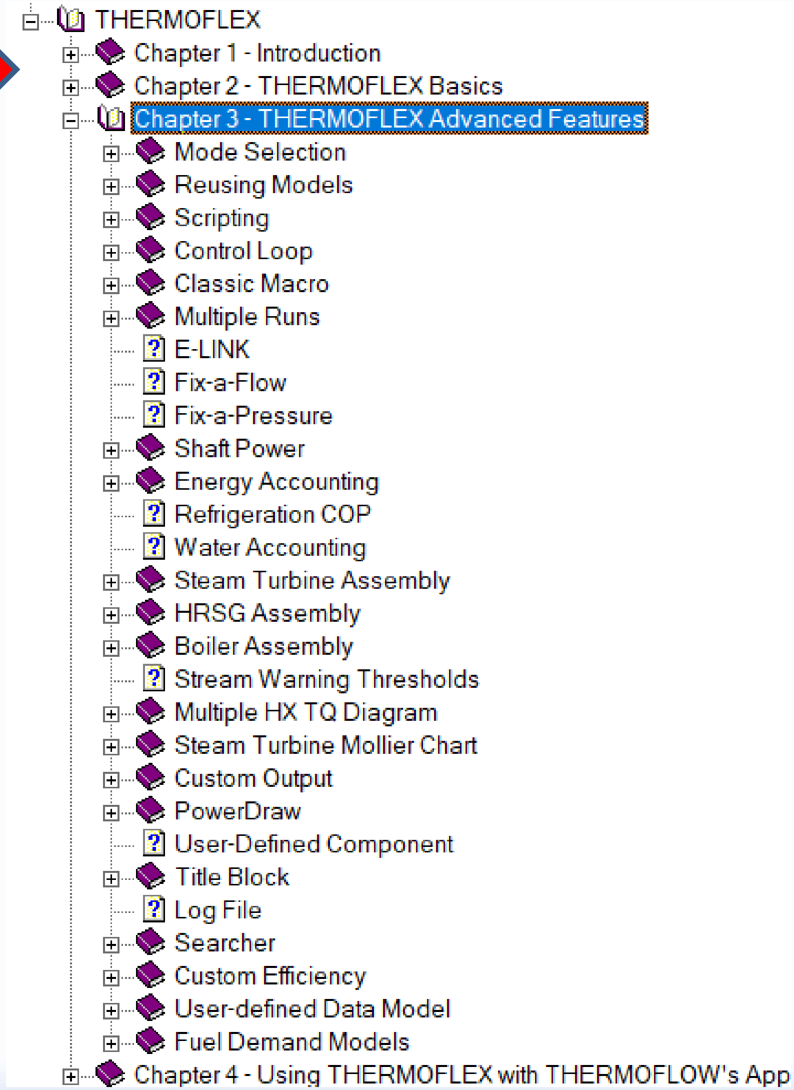
Support: Meritt Elmasri (U.S. HQ)

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

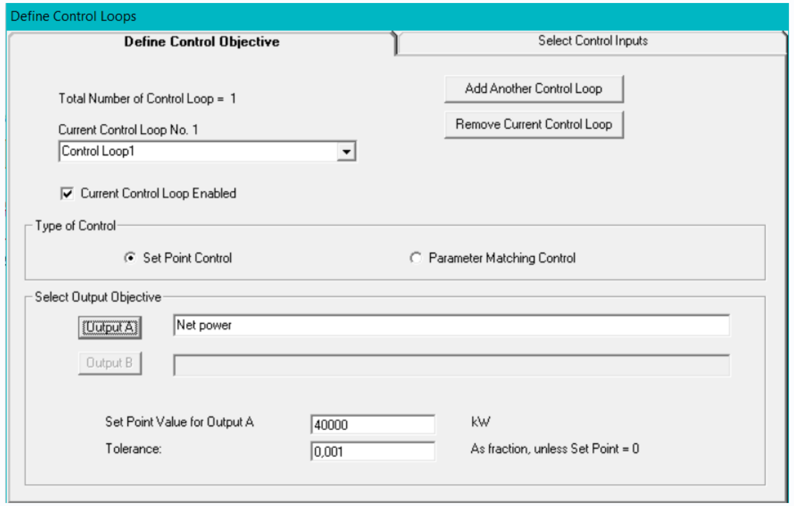
→ Check the predefined **Samples** (detailed description in Help / Appendix A)

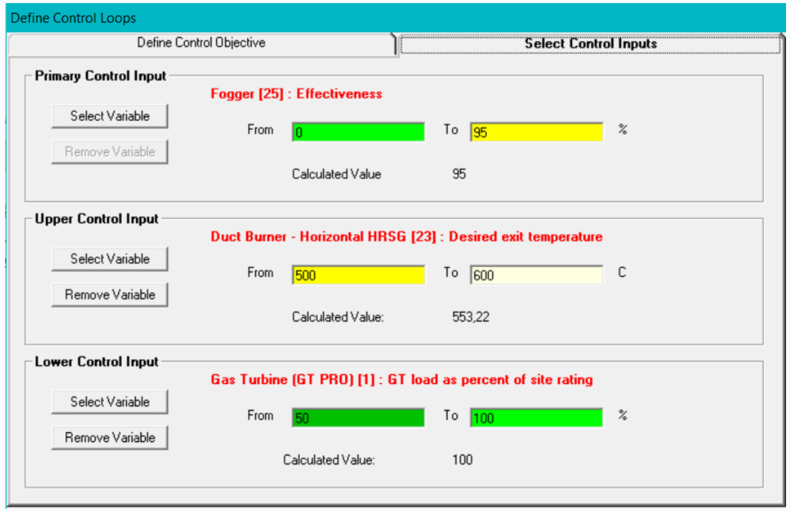
Control Loop

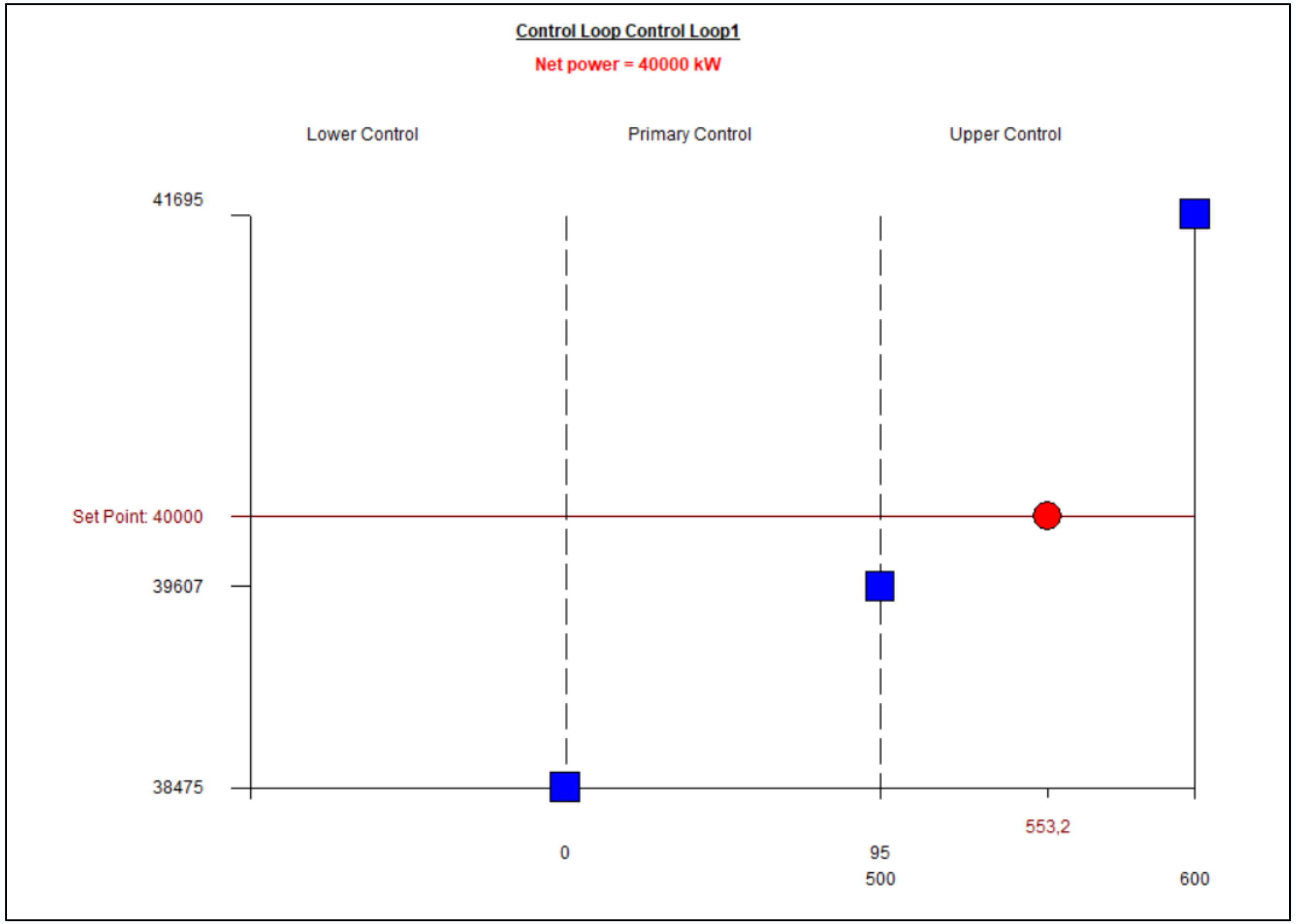
- **Function**: Adjust certain *Control Variables* to cause:
  - a *Set Point Variable* to attain a desired value →*Set Point Control*
  - a pair of variables to be equal →*Parameter Matching Control*

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

Control Loop







Control Loop

Considerations:

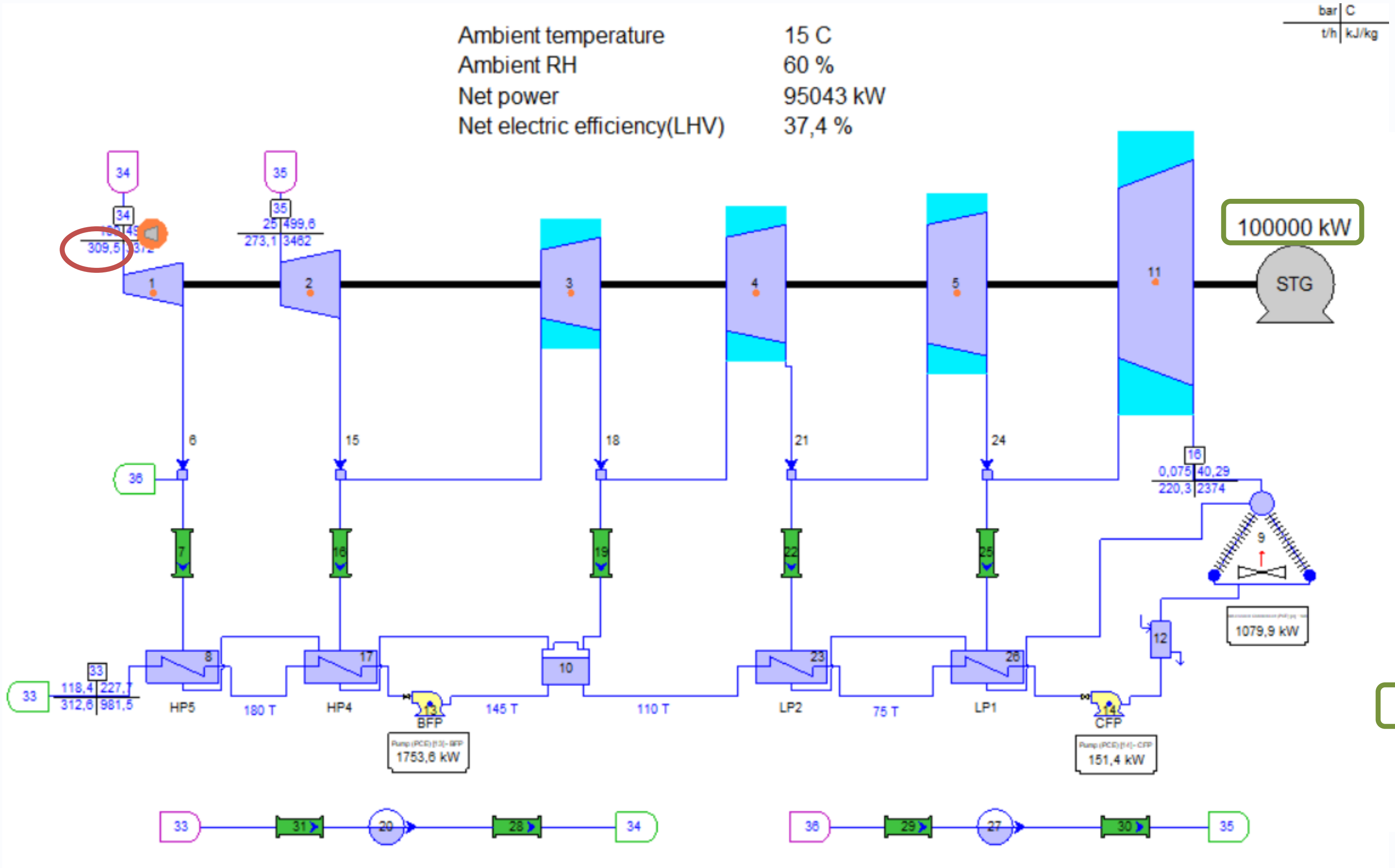
- Can be used in TD-ED & OD modes
- Can be used to represent a real Control Loop or just to meet the value of a variable which doesn’t have a direct input
- Check the upper / lower control limits to ensure continuity
- Compatibility:
  - Classic Macros: always enabled
  - Multiple Runs: maybe enabled / 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

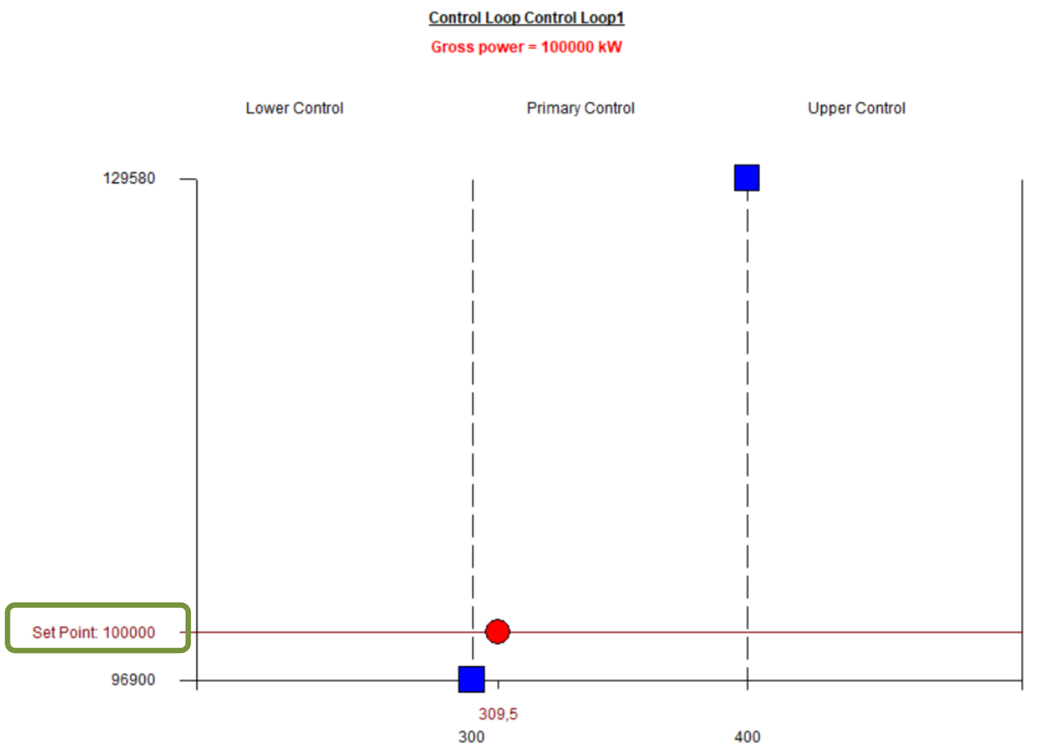
Control Loop

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

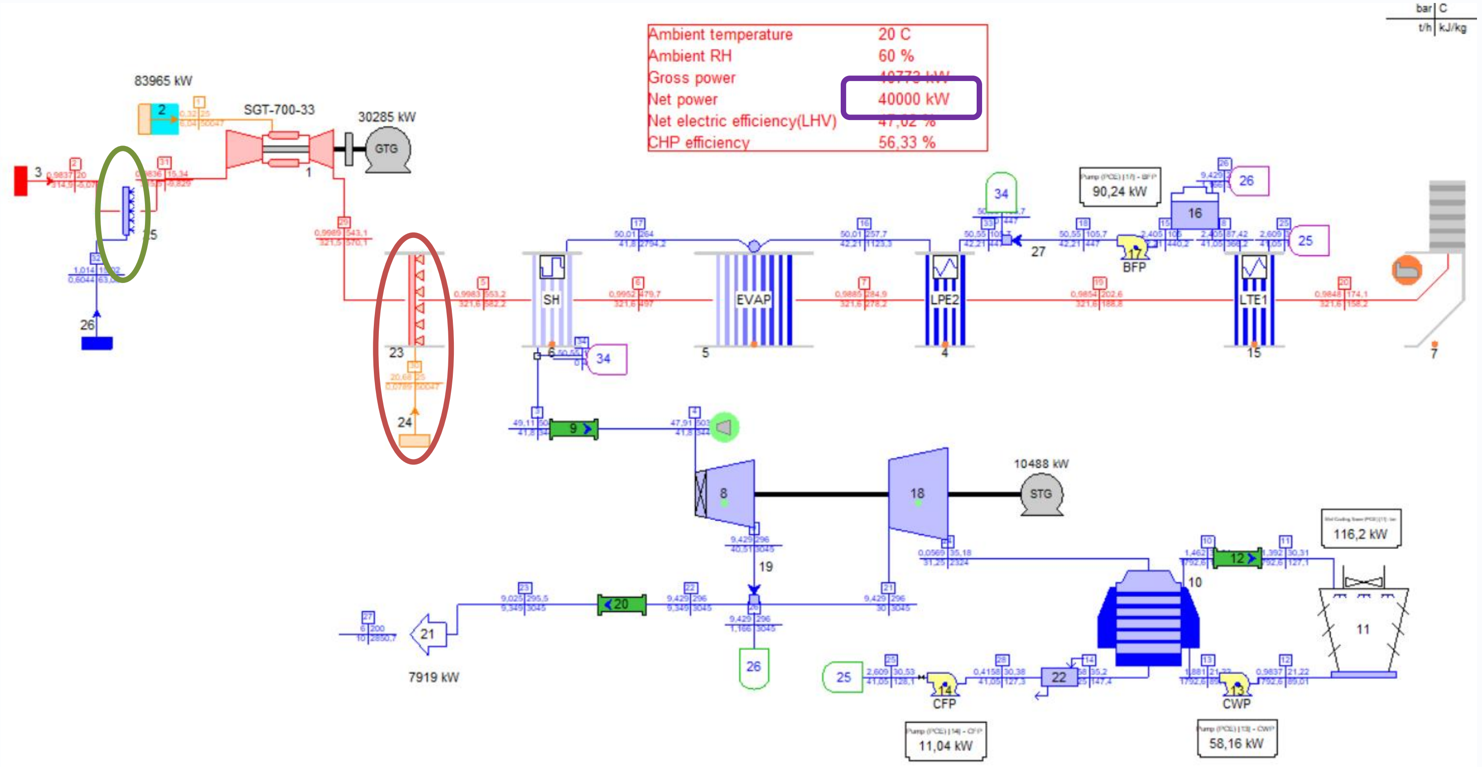
Control Loop

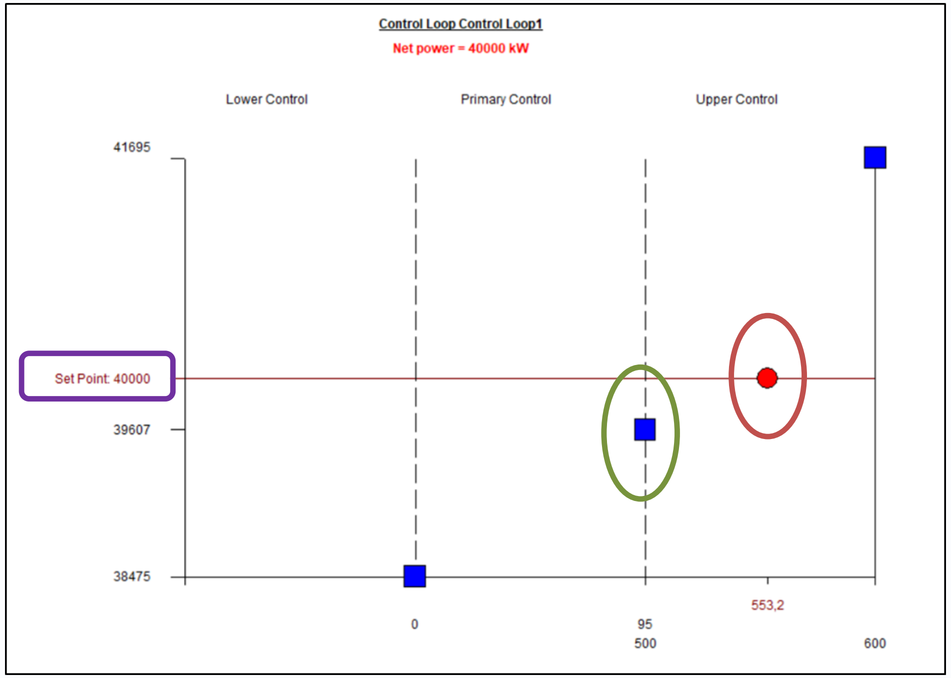




Primary Control: Package Boiler [20] : Defined outlet steam flow = 309,5 t/h

Control Loop

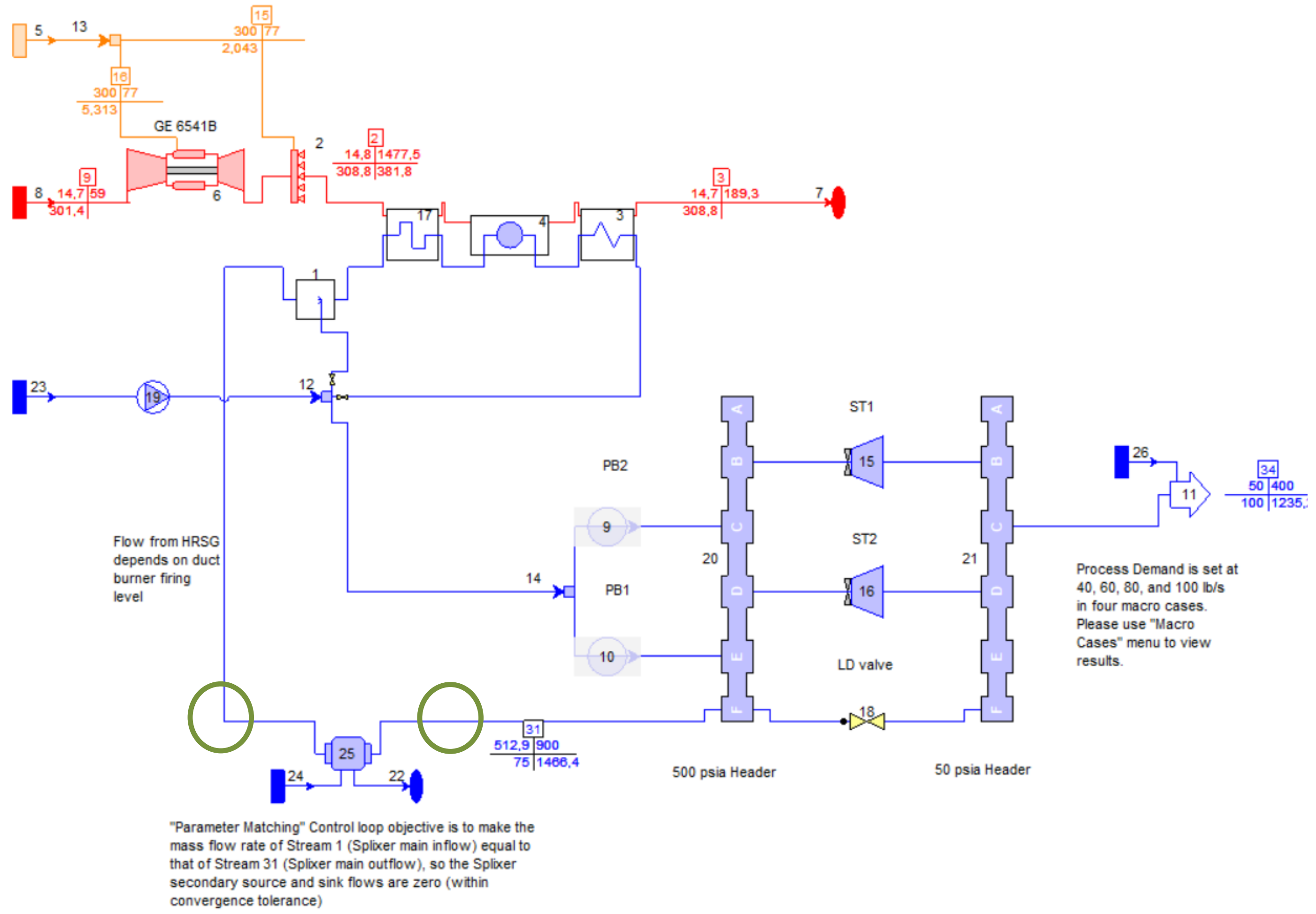


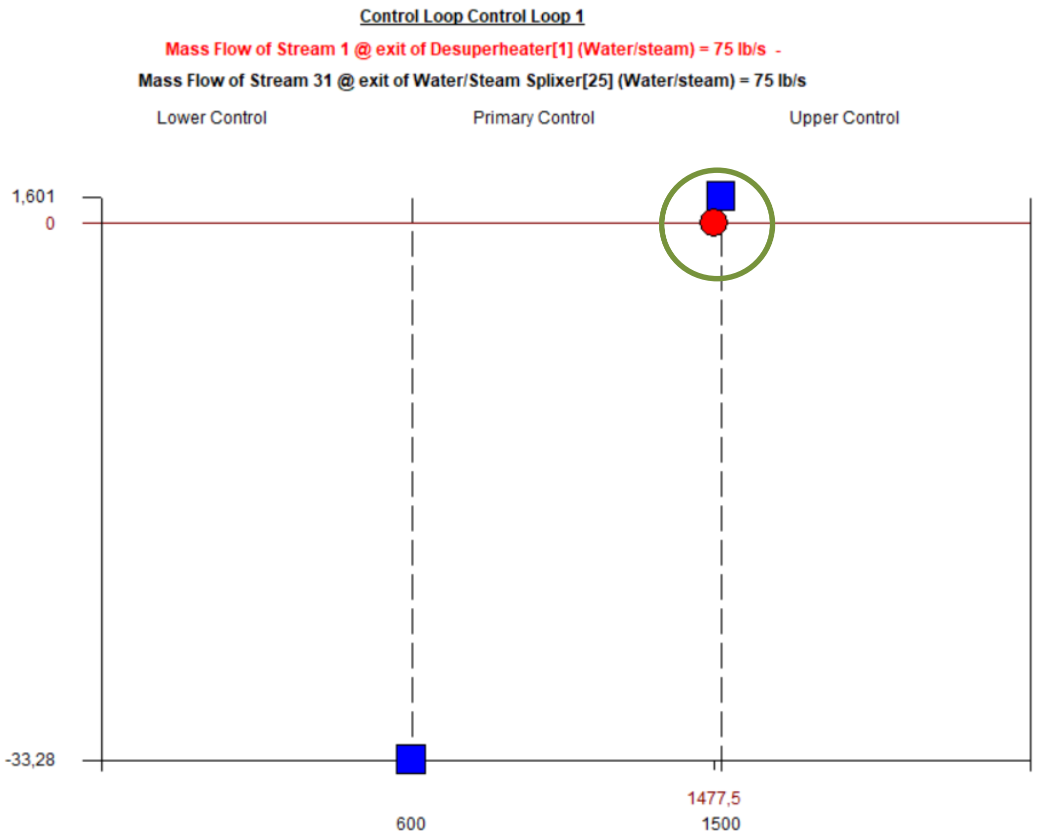


Lower Control: Gas Turbine (GT PRO) [1] : GT load as percent of site rating = 100 %
Primary Control: Fogger [25] : Effectiveness = 95 %
Upper Control: Duct Burner - Horizontal HRSG [23] : Desired exit temperature = 553,2 C

Control Loop

Parameter Matching





Lower Control: GT load as percent of site rating = 100 %
Primary Control: Duct Burner[2]: Outlet temperature = 1477,5 F

Searcher

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

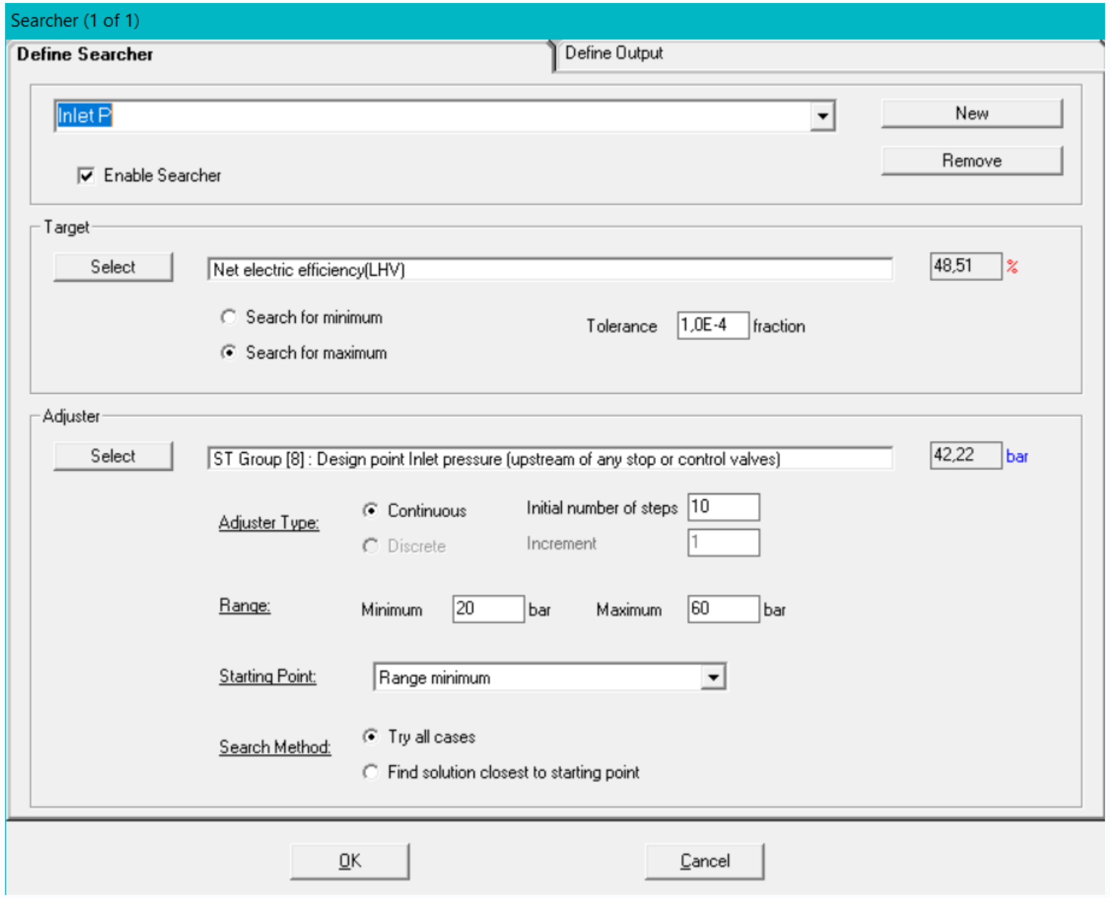
- **Procedure**:
  - Edit Inputs mode: Define / Searcher
  - Enable Searcher
  - Select the Target, maximum or minimum and the tolerance
  - Select the Adjuster and define:
    - Adjuster type: *continuos* (number of steps) or *discrete* (increment)
    - Range: minimum and maximum
    - Starting point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

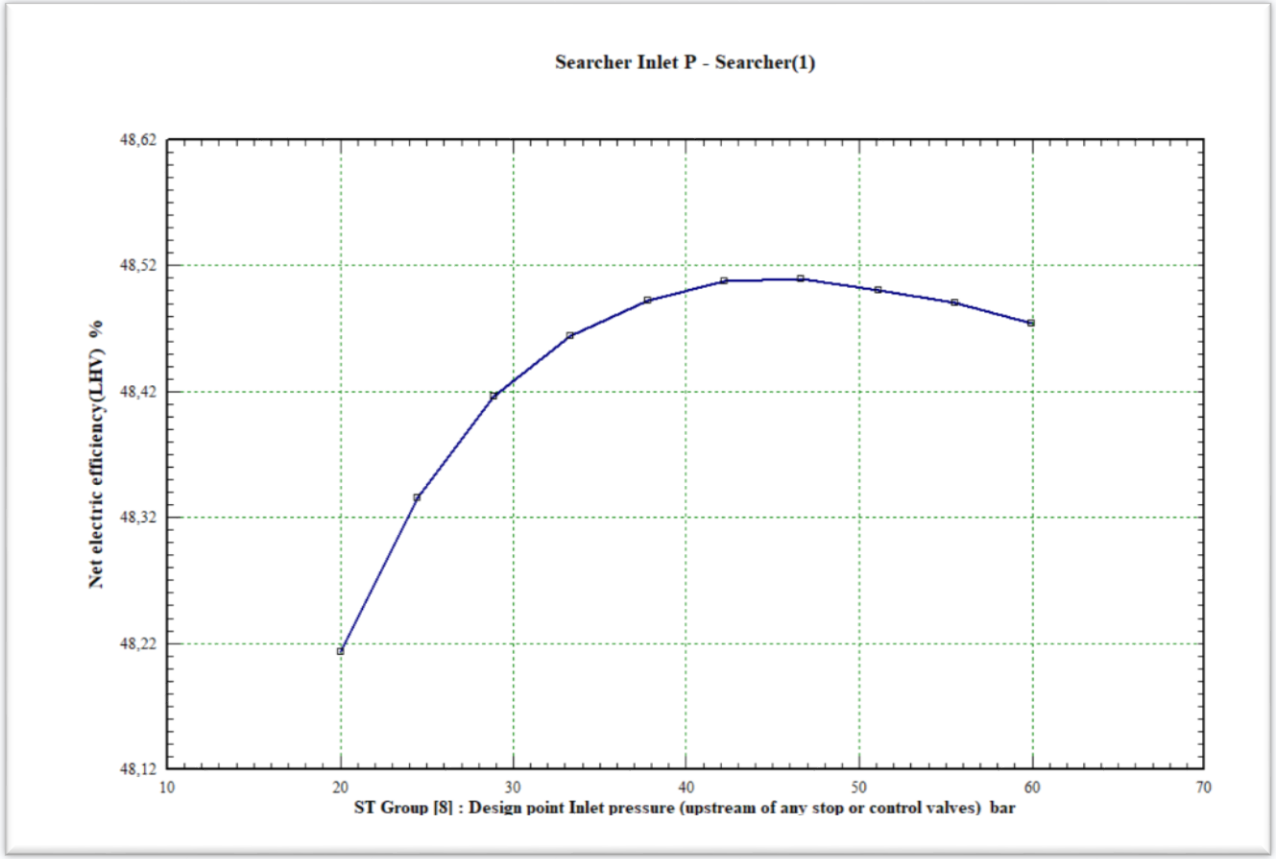
Searcher

- **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

Searcher Inlet P		Units	1	2	3	4	5	6	7	8	9	10
ST Group [8] : Design point Inlet pressure	Adjuster	bar	20,00	24,44	28,89	33,33	37,78	**42,22**	46,67	51,11	55,56	60,00
Net electric efficiency(LHV)	Target	%	48,21	48,34	48,42	48,46	48,49	**48,51**	48,51	48,50	48,49	48,47





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

Searcher

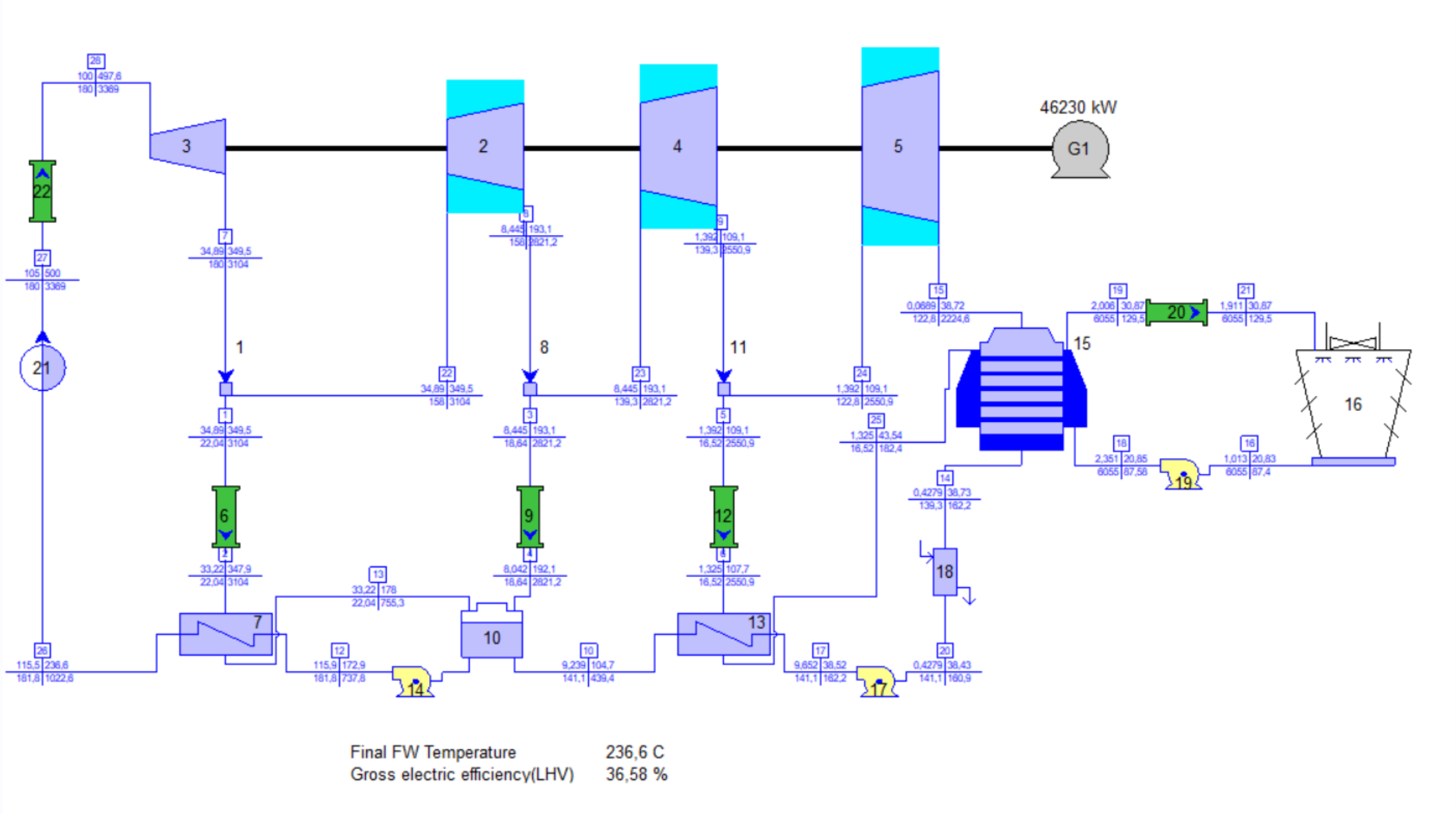
Examples:

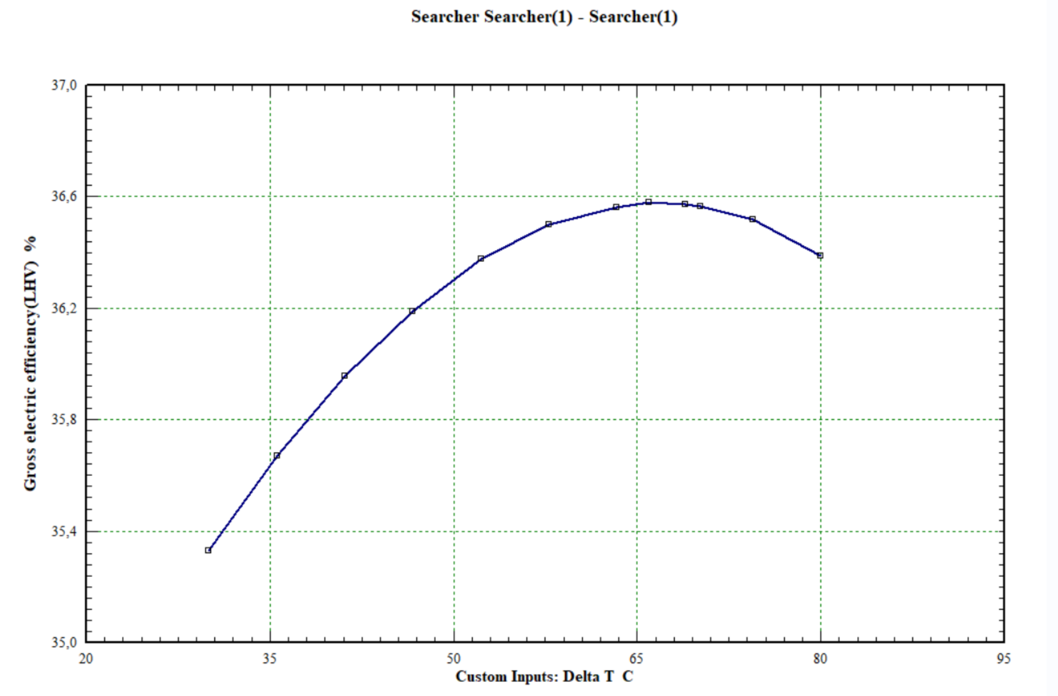
- CC 1P at TD: ST inlet Pressure to maximize Efficiency
- Rankine cycle at TD: FWH Delta T to maximize Efficency (Scripts)
- Sample (S5-10a): OD number of operating ACC cells to maximize Net Power (discrete)
- Sample (S2-38): OD number of operating CT cells to maximize Net Power (continuos)
- ELINK: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

Searcher

ST Inlet Pressure to maximize
the Efficiency (TD Mode)

Searcher Searcher(1)		Units	1	2	3	4	5	6	7	8	9	10	11	12
Custom Inputs: Delta T	Adjuster	C	30,0	35,6	41,1	46,7	52,2	57,8	63,3	66,0	68,9	70,2	74,4	80,0
Gross electric efficiency(LHV)	Target	%	35,33	35,67	35,96	36,19	36,38	36,50	36,56	36,58	36,57	36,56	36,52	36,39

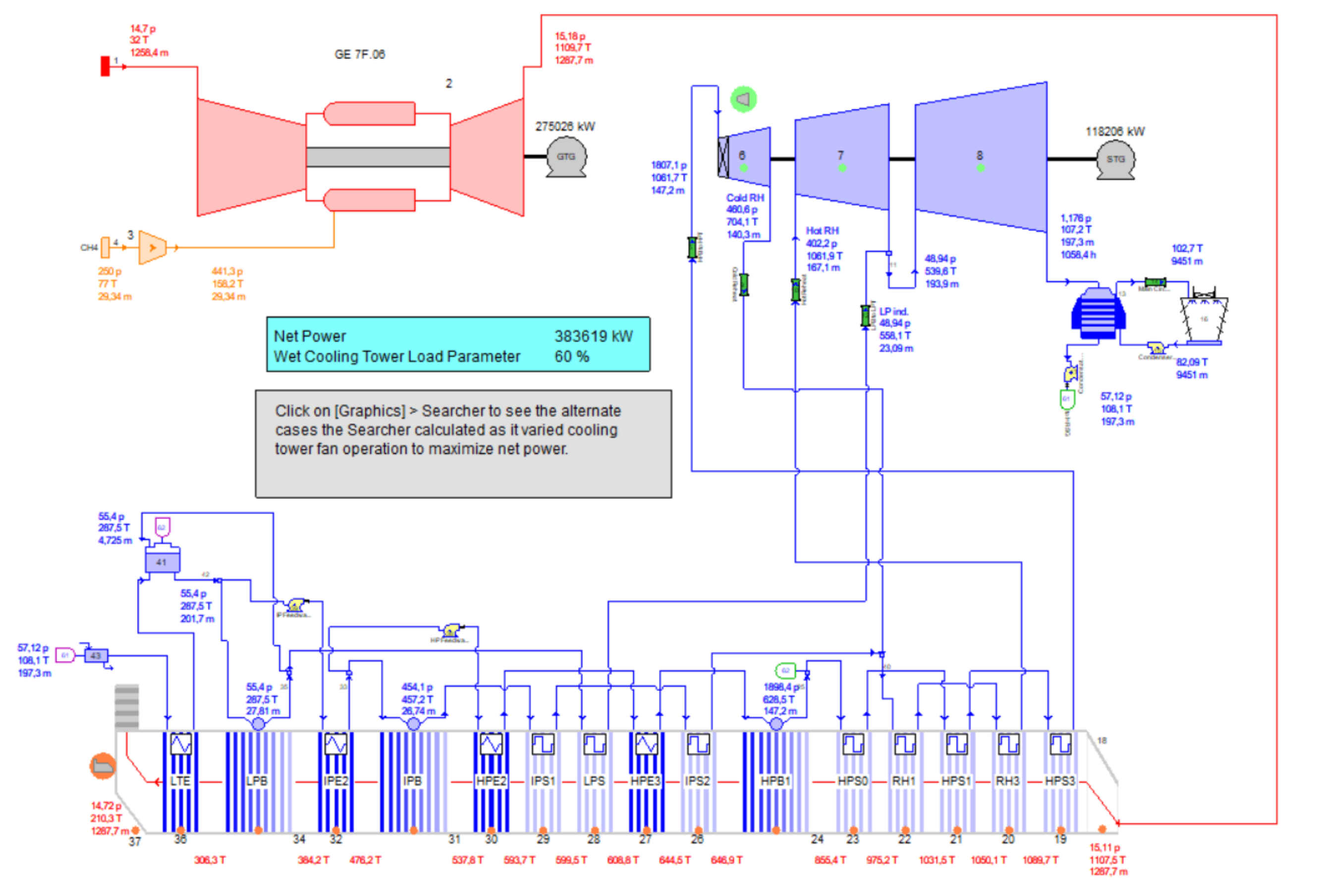


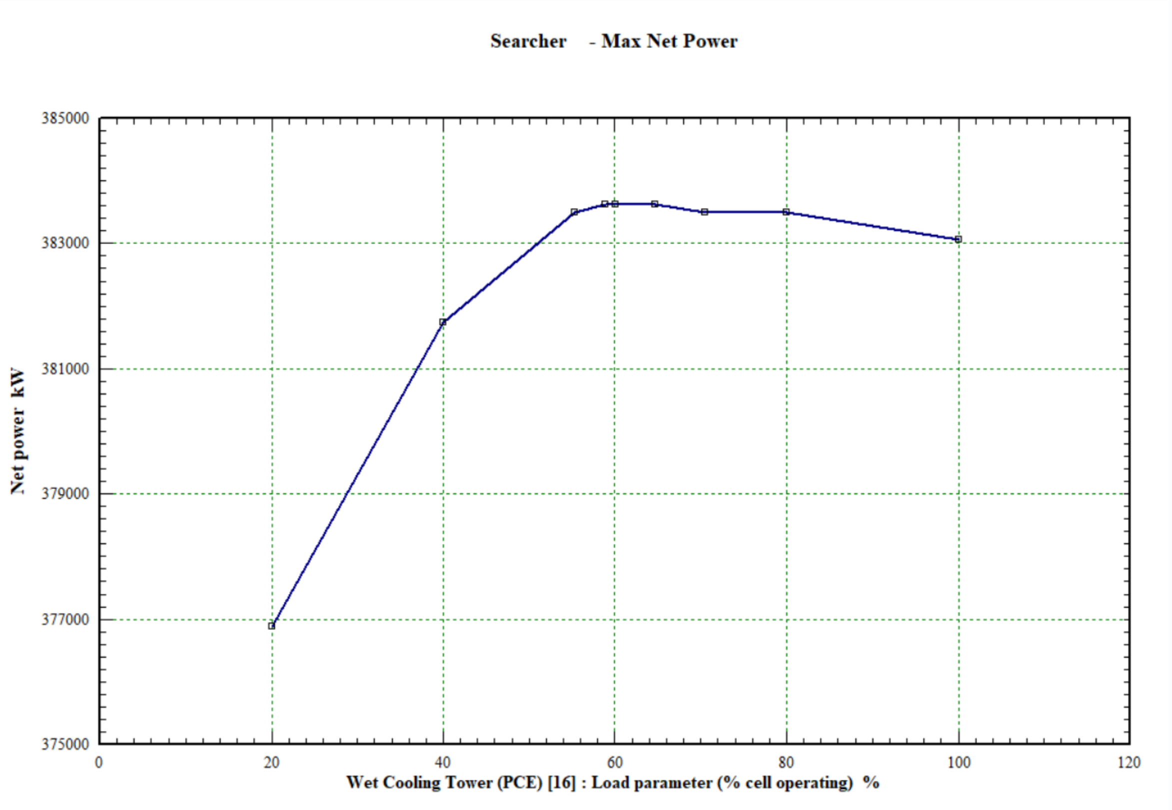


Searcher

Number of operating Cooling Tower Cells to maximize the Net Power (OD Mode)

Searcher		Units	1	2	3	4	5	6	7	8	9
Wet Cooling Tower (PCE) [16] : Load parameter (% cell operating)	Adjuster	%	20,0	40,0	55,3	58,9	60,0	64,7	70,6	80,0	100,0
Net power	Target	kW	376.891	381.743	383.503	383.619	383.619	383.619	383.495	383.495	383.063

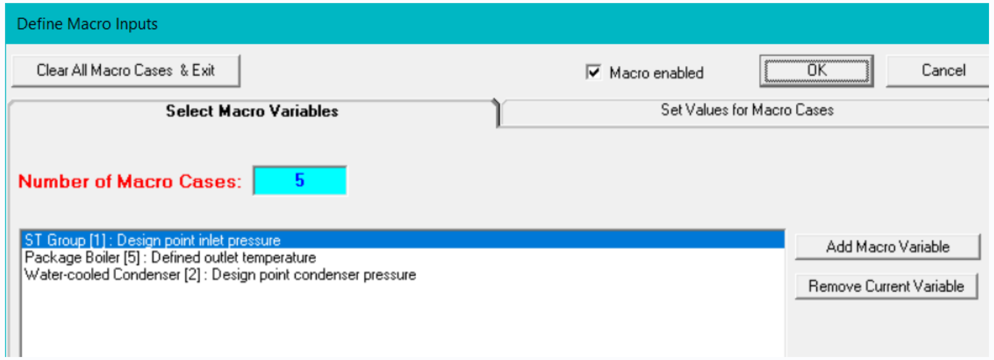




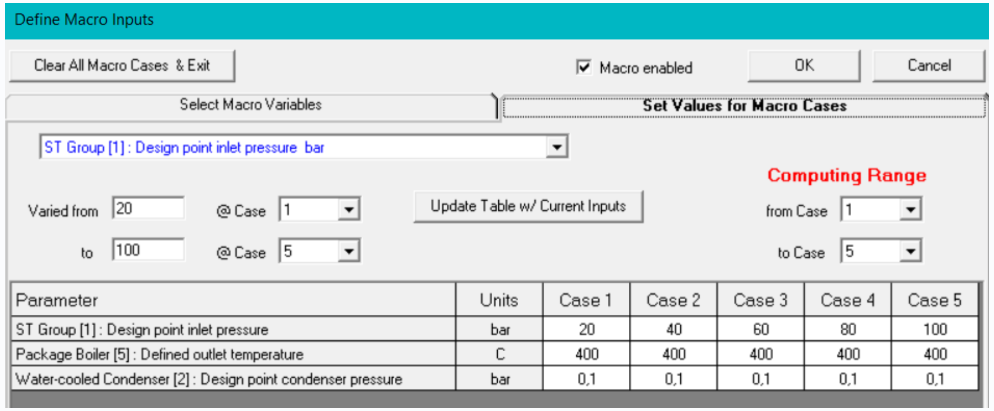
Classic Macros

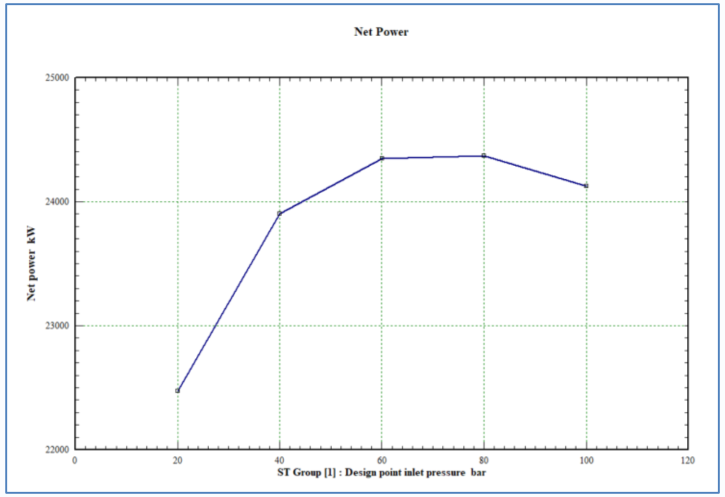
- **Function**: to perform calculation of a series of cases with varying input parameters
- **Procedure**:
  - Edit Inputs mode: Define / Classic Macro Inputs
  - Enable Macros
  - Define number of cases to be run
  - Select the (inputs) Macro Variables
  - Set values for Macro cases
- **Outputs**: in 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

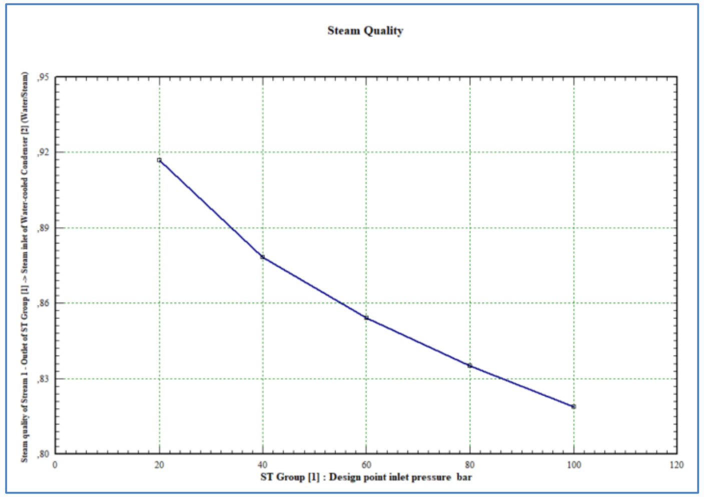
Classic Macros



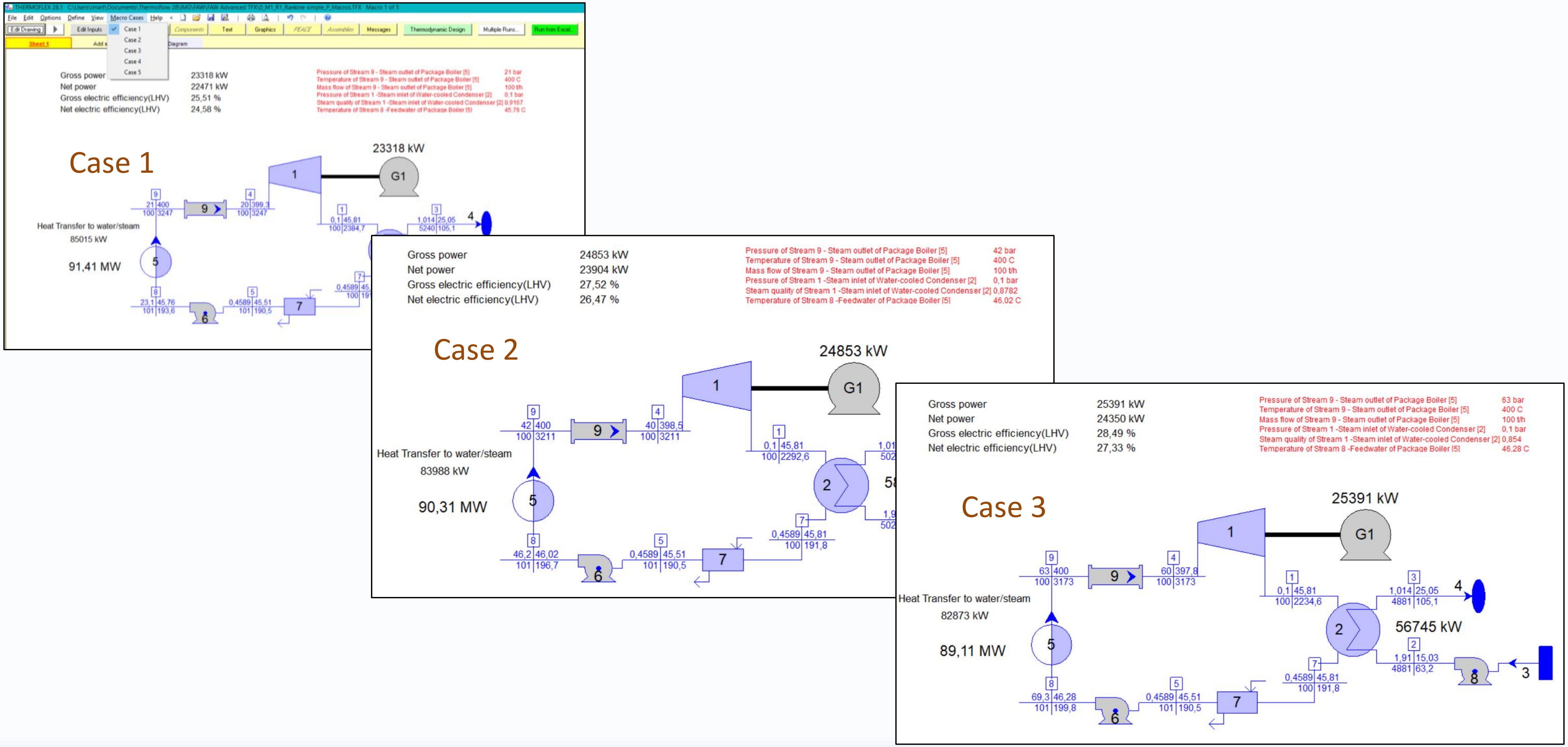
Parameter	Units	Case 1	Case 2	Case 3	Case 4	Case 5
ST Group [1] : Design point inlet pressure	bar	20	40	60	80	100
Package Boiler [5] : Defined outlet temperature	C	400	400	400	400	400
Water-cooled Condenser [2] : Design point condenser pressure	bar	0,1	0,1	0,1	0,1	0,1
Gross power	kW	23318	24853	25391	25500	25339
Gross electric efficiency(LHV)	%	25,51	27,52	28,49	29,04	29,32







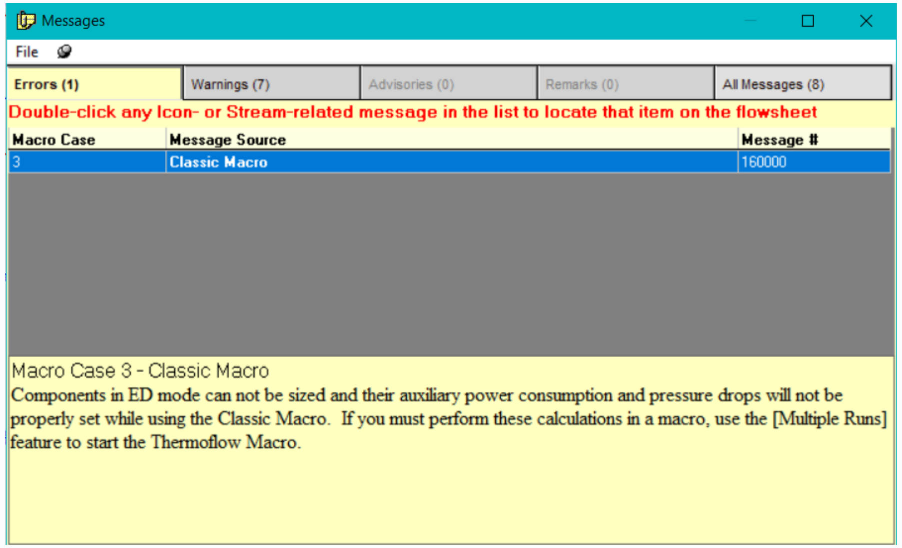
Classic Macros



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

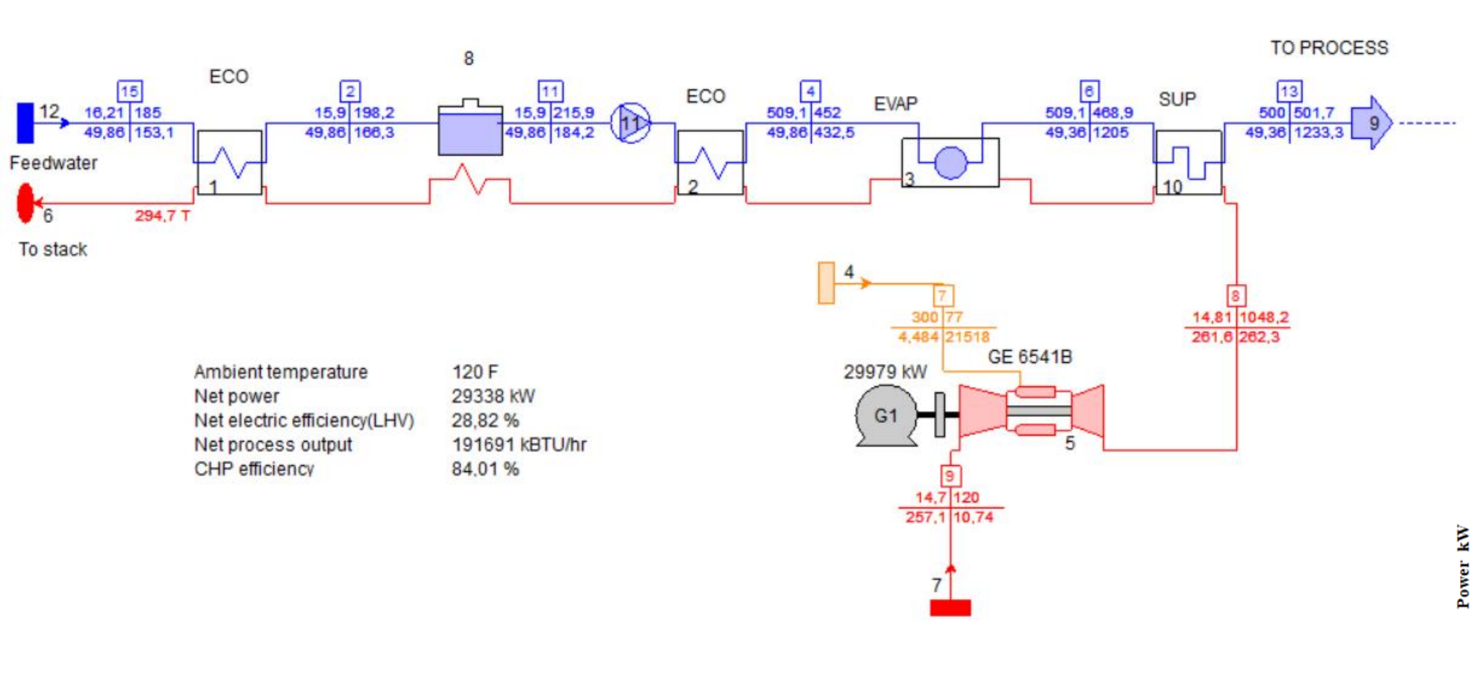
Examples:

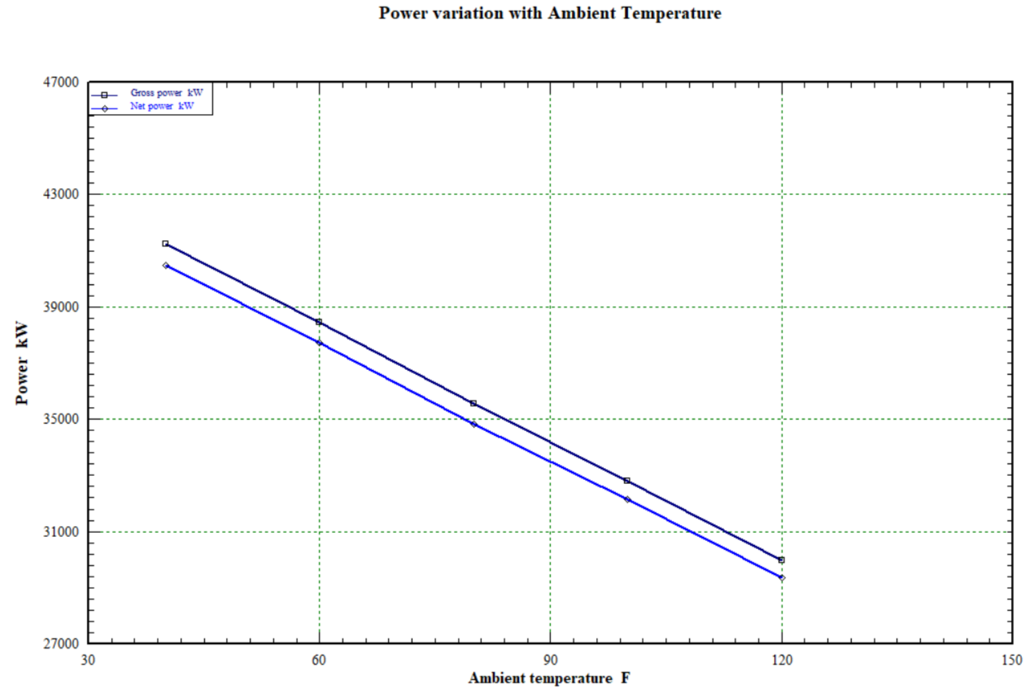
- Rankine cycle at TD: effect of the ST inlet Pressure variation (above)
- Sample (S3-02a): GT Cogeneration plant at OD across a range of ambient T

Classic Macros

Effect of the Ambient Temperature

Parameter	Units	Case 1	Case 2	Case 3	Case 4	Case 5
Ambient temperature	F	40	60	80	100	120
Gross power	kW	41.225	38.451	35.535	32.802	29.979
Net power	kW	40.467	37.722	34.837	32.132	29.338
Gross electric efficiency(LHV)	%	32,49	31,93	31,24	30,48	29,45
Net electric efficiency(LHV)	%	31,89	31,32	30,63	29,86	28,82
CHP efficiency	%	78,75	80,04	81,38	82,71	84,01
Mass Flow of Stream 13 @ exit of Superheater	lb/s	52,39	51,65	50,80	50,01	49,36





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

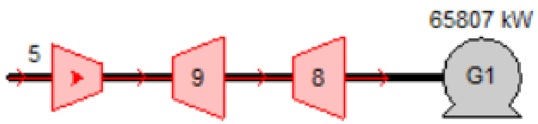
Shaft Power

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

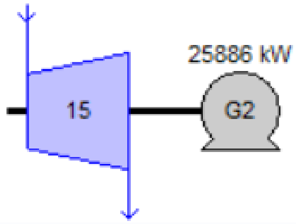
Shaft Power

Description	Model	Add sheet	Shaft Diagram



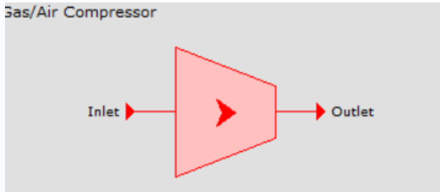
Shaft 1

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



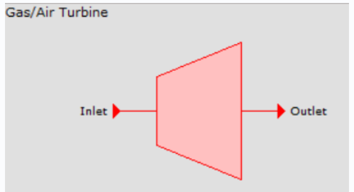
Shaft 2

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



Gas/Air Compressor [5] | 0 - Design

1. Mode			0 - Design
2. Design point overall pressure ratio			12
3. Design point polytropic efficiency		%	91
4. Design point dP/P at inlet			0
5. Design point dP/P at outlet			0
6. Current RPM			3600
7. Design RPM			3600
8. Compressor driven by			1 - External shaft
9. Shaft number (=0: program will assign shaft number)			1
10. Mechanical efficiency		%	99,5
11. Off-design operating mode			NA



Gas/Air Turbine [8] | 0 - Design

1. Mode			0 - Design
2. Design point overall pressure ratio			5,2386
3. Design point polytropic efficiency		%	91
4. Normalised leakage at inlet			NA
5. Normalised leakage at outlet			NA
6. Mechanical efficiency		%	99,5
7. Current RPM			3600
8. Shaft number			1
9. Design point dP/P at inlet			0
10. Design point dP/P at outlet			0
11. Sizing flow / design point flow			1

ST Group [15] | Thermodynamic Design

Main Inputs | Exhaust Loss & Miscellaneous

Efficiency Definitions

Specify dry step efficiency	90	%
Specify exit enthalpy (before exhaust loss)	966	BTU/lb
Reference pressure ratio for ST expansion step	1,35	
Condensation quality (Wilson line)	0,97	
Moisture efficiency penalty (Baumann coefficient)	0,72	
Moisture efficiency penalty method, 0=Old, 1=New	0	

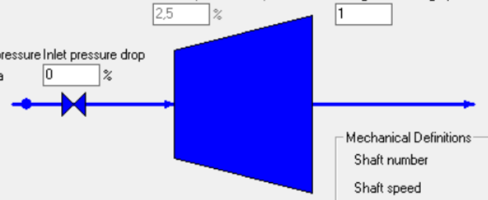
Inlet pressure control: Uncontrolled (sliding pressure)

Control pressure drop: 2,5 %

Sizing flow / design point flow: 1

Design point pressure: 725,2 psia

Inlet pressure drop: 0 %



Mechanical Definitions

Shaft number	2	
Shaft speed	3600	RPM
Mechanical efficiency	99	%

Shaft Power

Balancing Shaft

- Edit Inputs mode: Define / Shaft Power

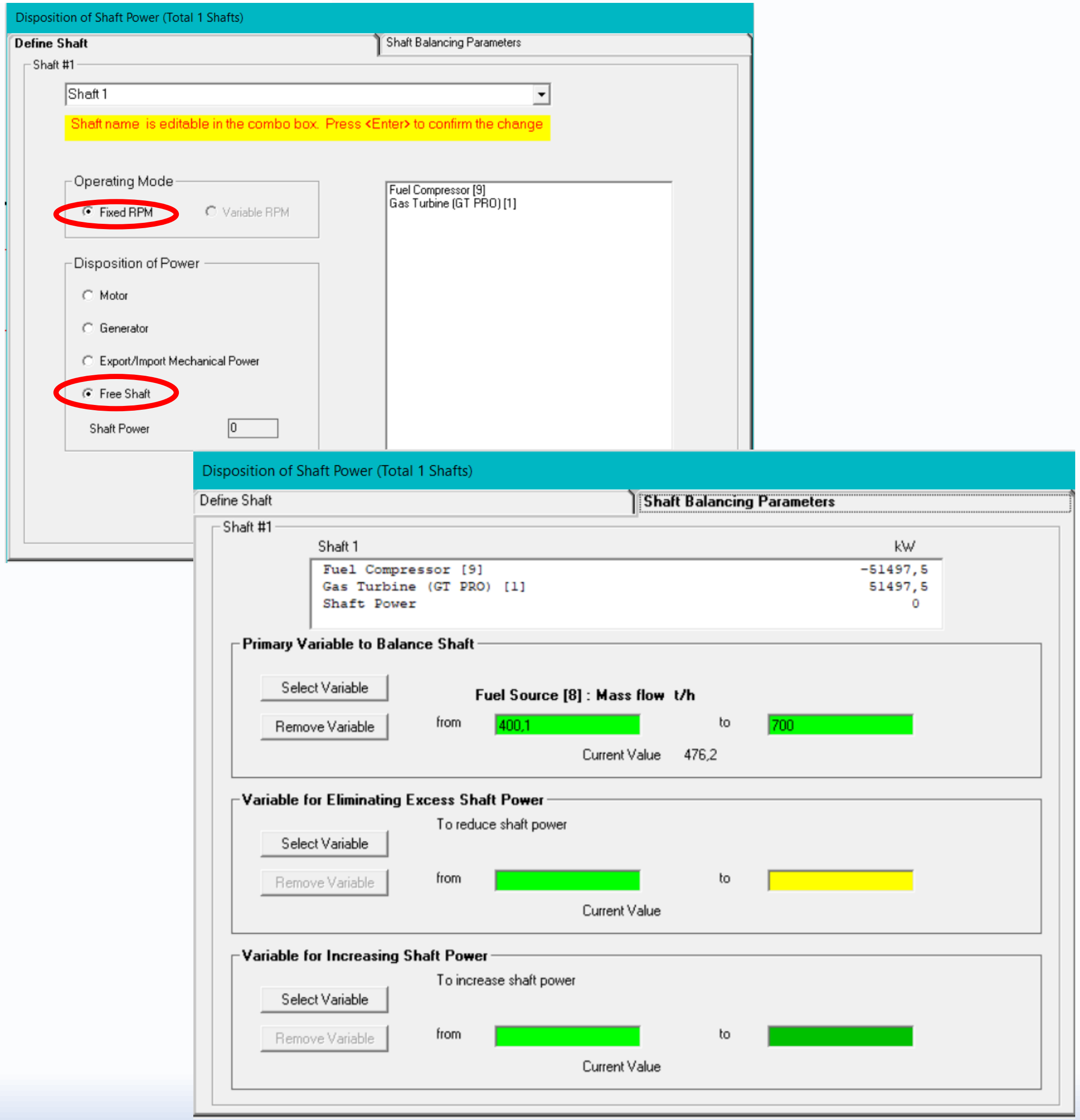
- Disposition of Power: Free Shaft

- 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

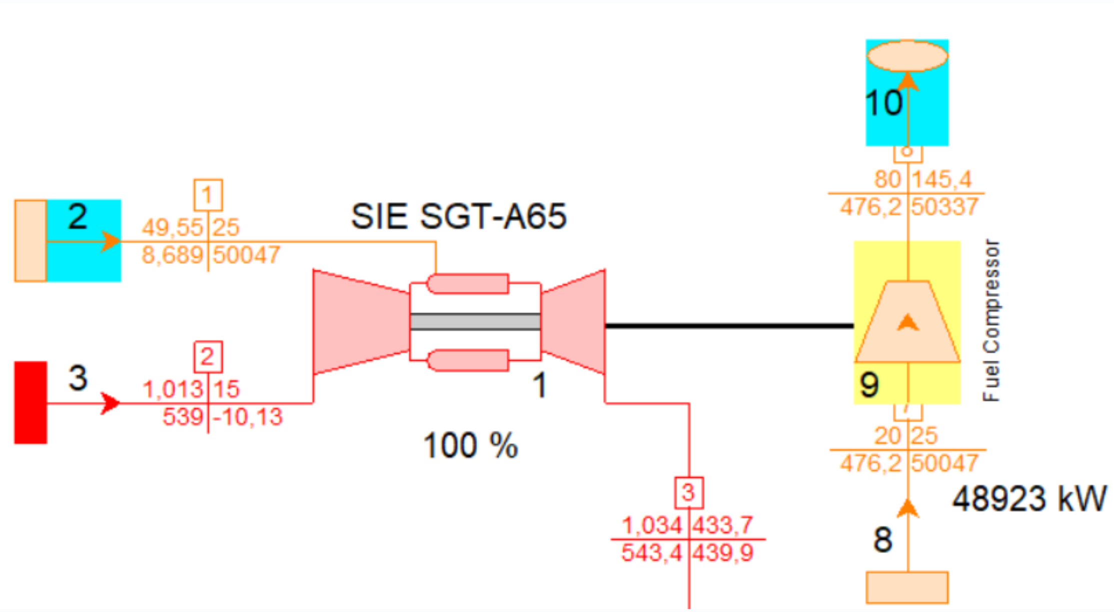
Shaft Power

- **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

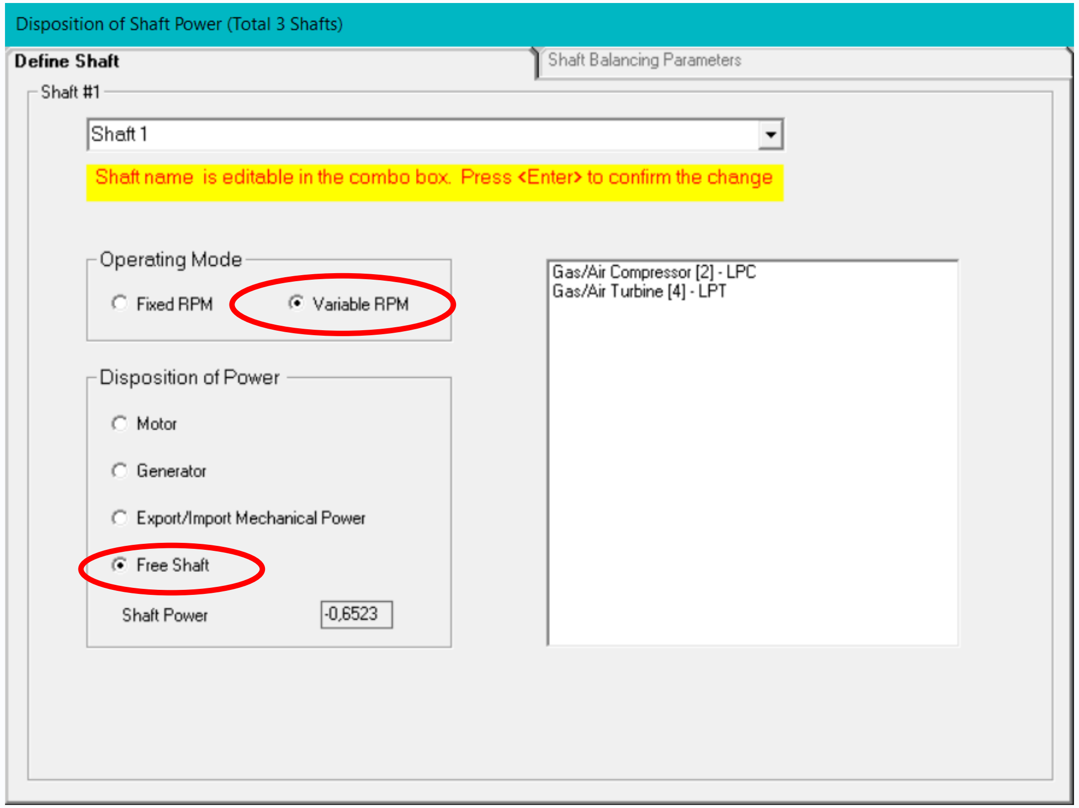
Shaft Power



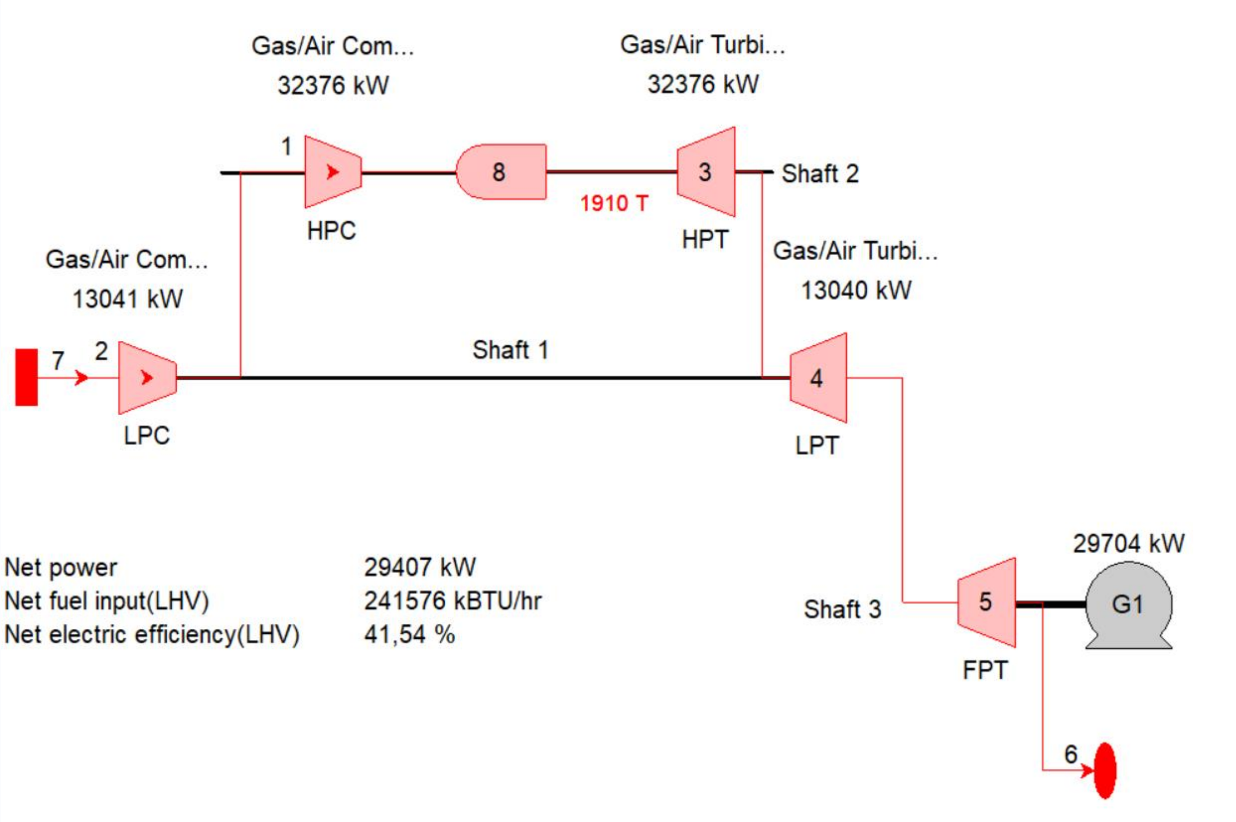
Balancing Shaft by varying the massflow of fuel to be compressed (TD Mode)



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!

IGNACIO MARTIN - SPAIN martin@thermoflow.com