WS.SteamTurb-simulator

Version 1

USER MANUAL

January 2008
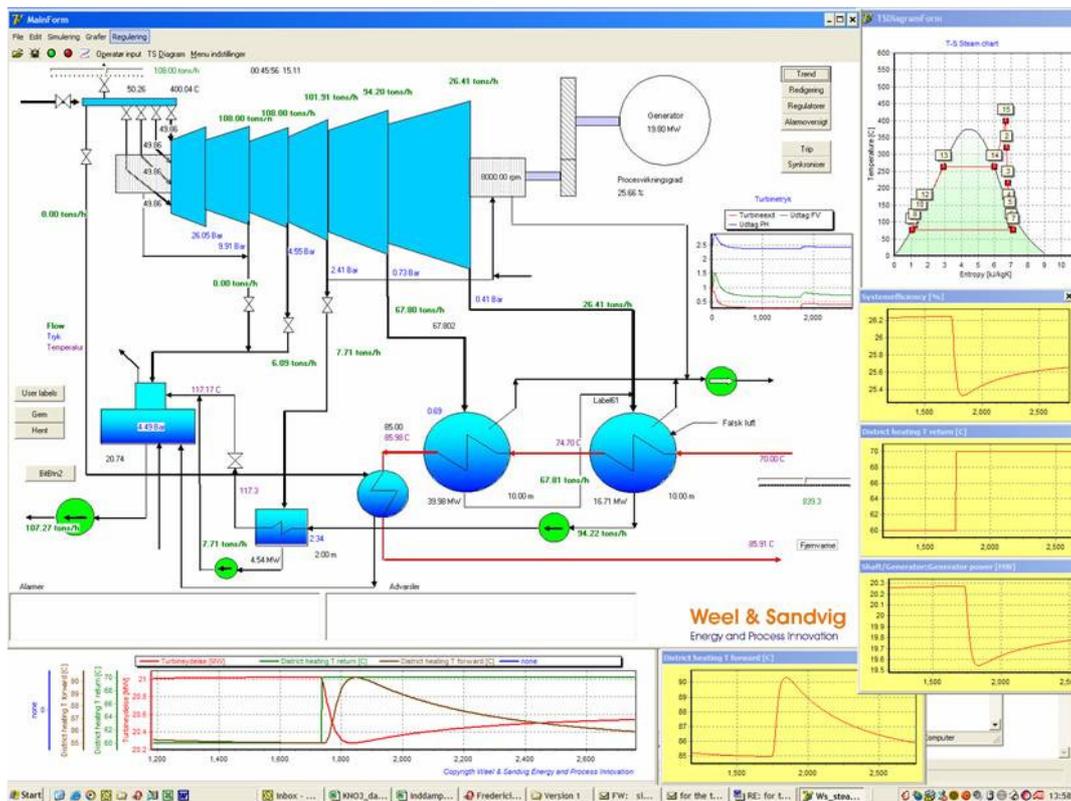
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Content:

This manual describes the features of and how to use the *WS.SteamTurb-simulator*. The simulator is developed for simulation of dynamic conditions in complex steam turbine systems including condensers for district heating. The software is developed by:

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License
A standard license for the *WS.SteamTurb-simulator* is valid for installation on up to three PC's located at the same address. The installation and license need being renewed each year. To renew your license contact Weel & Sandvig and we will send a new license file valid for one year.
It is under now circumstances allowed the licensee to distribute the software outside his address referred to in the license agreement.

Installation
The software is installed simply by copying the files to a suitable place on the hard disk of the PC.

WS.SteamTurb-simulator Version 1.0

The *WS.SteamTurb-simulator* is a software tool for simulation especially of the dynamic behaviours of steam turbine systems integrated with district heating condensers, preheaters etc. The simulation package is among others suitable for analyses of various control strategies and for training of operational staff.
In the standard version the simulator comes as a model of the *"Turbine 1"* at *Amagerforbrænding I/S*, having a norm power of approximately 20 MW. The simulator can for an extra fee be tailored for your specific turbine system layout.

To start the WS-SteamTurb-simulator
The simulator is started by running the file *WS-STEAMTURB.EXE* either through a linked icon or double clicking the filed itself in your file browser.

You are then requested to type in your Password._____

The software starts with the main screen (see Figure 1). Here the main screen menu the configuration of the turbine system, with district heating condensers, feed water preheater and steam boiler. In the main menu also a number of property data are shown and the deaerator.

Activating menus and showing trends of properties.
Menus (buttons) can be activated by left clicking your mouse. Trends of presented data on screen can be viewed in a graphical window simply by double clicking the value (see Figure 3). Double clicking condensers a window pops up with 4 tabs for viewing: Temperature **Profile** plot, **Performance**, **Sections** and **Parameters** (see Figure 4).

How to save and start a saved simulation case

In the **File** menu a previously stored simulation case can be loaded by pressing **Open**… (or Ctrl+O). Storing a simulation is applied by pressing **Save as** (or Ctrl+S) in the **File** menu. When saving a case all properties and conditions valid at the time the simulation was stopped are saved and the simulation will continue from this state next time opening the case.

Set up of calculation speed and sampling intervals

In the menu **Simulation** by pressing **Settings** the speed of calculation can be increased by specifying large time steps and vice versa. Also the sampling rate is specified here. The default value of time step is 0.03 seconds and the sampling rate (time interval) is 5 seconds.

Normally calculation speed for a PC with a processor clock frequency of 2 GHz the simulation speed is about 8 to 12 times real time.

For training exercises, where the user has to control the plant (the simulator) in manual, this is too fast. In such cases a time step less than 0.01 seconds is most likely more appropriate.

In some cases it is necessary to decrease the time step in order to escape problems for the numerical solver and for improving accuracy.

The sampling rate can be varied in order to avoid a too large data file with results. In case fast transients need being investigated the sampling rate should be specified fast (small time period like for instance 0.5 seconds) in order to be able to identify eventual peaks.

Printing trends, cut 'n' paste of trend pictures, export of data to MS Excel, zoom of pictures etc.

Trends can be stored, presented and printed for a number of variables. In a plot, up to four different trends can be presented at the same time. By double clicking the trend curves a menu pops up allowing for copying the picture, exporting the data etc. It is possible to store predefined masks (e.g. steam flow, pressure, district heating temperature and power).

While pressing the right mouse button and drag the cursor from the upper left to the lower right you can zoom the trend picture (see).
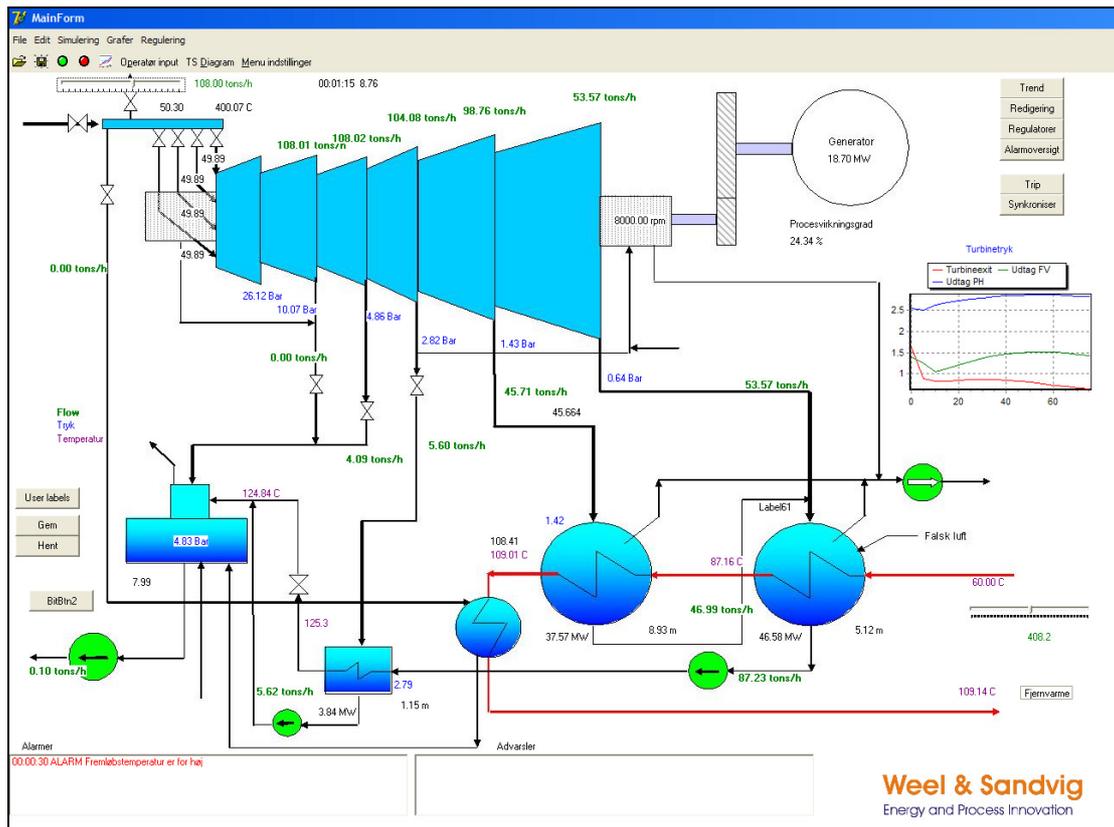
Figure 1. Main screen.
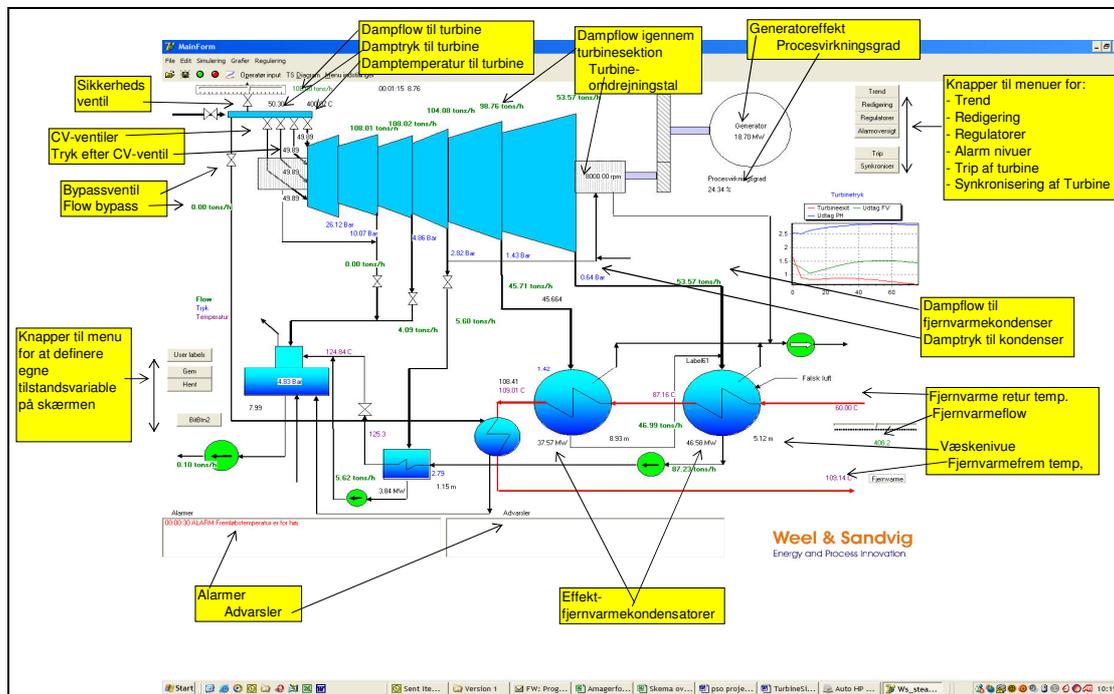
Figure 2. Explanation of parameters on the main screen menu.
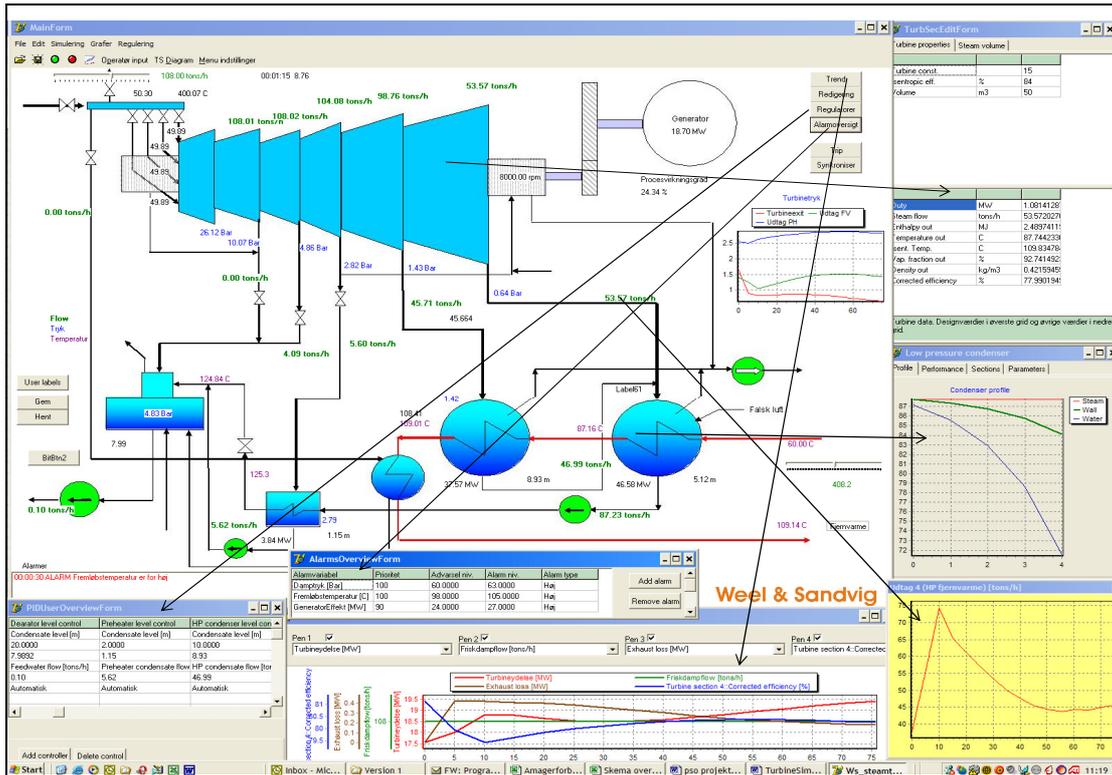
Figure 3. When double clicking process values trend curves popup or clicking buttons information will popup.
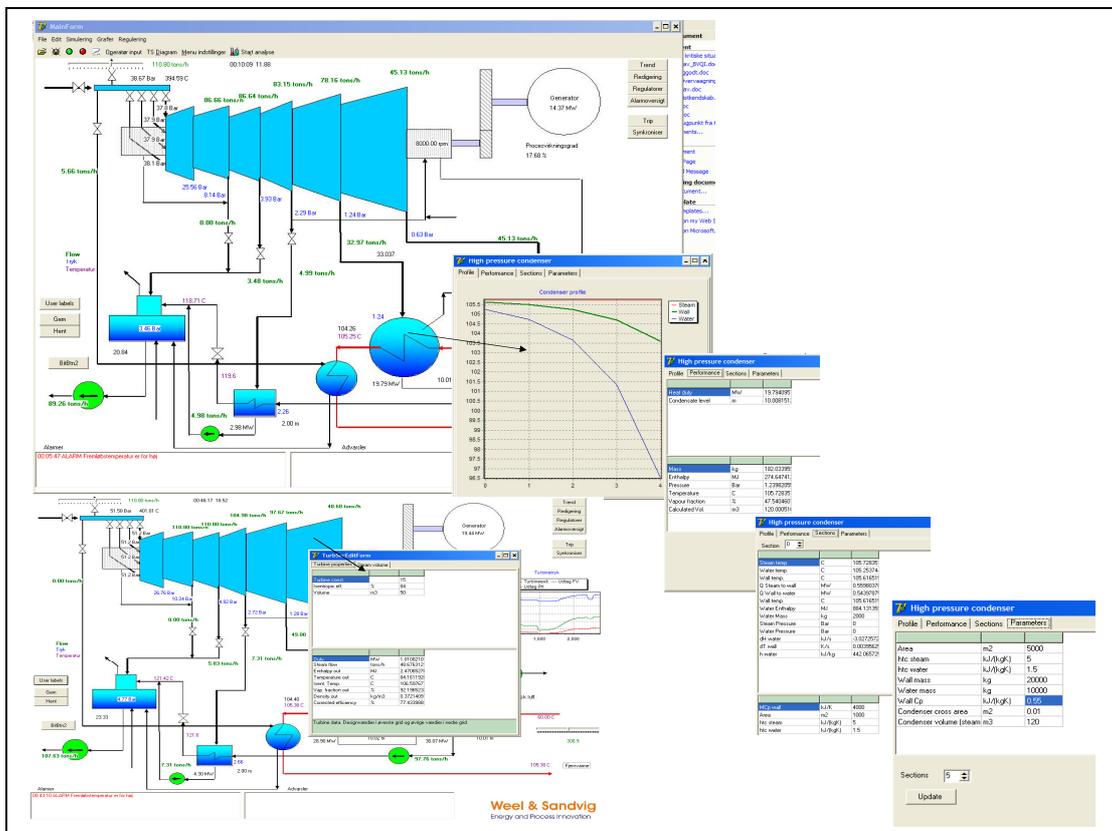
Figure 4. Showing design values and property data for heat exchangers, condensers and turbine sections.

User input

The following process input variables are directly accessable when pressing the button **Operator input** on the toolbar.

1. Steam flow to the system.
2. Steam temperature.
3. Mass flow in district heating system.
4. Return temperature of district heating.
5. Set point of foreward temperature of district heating.

In addition input can be specified according to a time schedule or time series by clicking the menu **Time input**.

In the menu **Time input** the following are to be specified.

Steam flow [ton/h]   time [sec]   Steam flow [ton/h]   time [sec]

Steam temperature [C]   time [sec]
District heating return tempearture [C]   time [sec]

The simulator will ramp up or down the mass flow after the above given specifications with the ramp speed:

$$Ramp\ speed = \frac{(Steam\ flow1 - Steam\ flow2)}{Time1 - Time2}$$

It is possible to specify to repeat the sequence by checking the check box **Loop**.

Analyse

The simulator facilitates a tool for analysing the running operational economy. The user specifies in advance the time period for the analysis to apply.
The analysis then quantifies and sums up the economic influence (both with respect to short and long term) from a number of process property values present during the simulation.

The analysis will calculate and sum up the economic benefit and cost for the following:

1. Income from generated electricity
2. Income from generated heat
3. Cost for producing steam
4. Number of alarms (cost)
5. Time period with alarms active (cost).

The total revenue is then calculated as: 1+2-3-4-5

To start an analyse click the submenu **Start analyse** from the main menu **Simulation** or simply press the button **Start analyse.**

Controllers

The simulator is equipped with a set of controllers typical for a steam turbine system connected to at district heating system. In PID-controllers the three parameters: amplification (proportional factor), integration time and derivative time must all be specified with positive values (larger or equal 0). In addition a band (minimum and maximum value) for the process input parameter must be specified corresponding to 0 and 100% output signal from the controller.

Finally for a PID-controller you need to specify weather it should act as a **Direct** of **Inverse** controller in the actual system set up.

Direct means that if the process variable (the variable that needs to be controlled at a specified set point) has a higher value than the set point, the output signal of the controller will decrease the value of the process input variable (e.g. the opening of a valve when having a flow controller). Inverse means the opposite. That is if the process value has a lower value than the set point the output signal will increase the value of the process input parameter.

Activating a PID-controller is done by clicking the check box **Aktiv**, corresponding to the term "auto" mode, some times used. The controller will now attempt to control the process value close to the set point by changing the process input.

If the check box is unchecked, the output signal from the controller is "frozen" to the value that was present at the time the check box was unchecked or at a value specified by the user afterwards in order to manually control the process. The controller is therefore said to be in manual mode, when the check box is unchecked.

The following controllers are available:

1. Temperature district heat:
   - Set point: Forward temperature of district heat.
   - Process input variable: Flow of district heat through condenser.
2. Turbine pressure:
   - Set point: Pressure of steam before turbine.
   - Process input variable: Position of governor valve.
3. Level controllers for HP condenser, LP condenser, bypass condenser, LP feed water preheater and deaerator :
   - Set point: Level in the items respectively.
   - Process input variable: Flow outputs.
4. Temperature deaerator:
   - Set point: Temperature in deaerator.
   - Process input variable: Valve position on steam extraction.
5. Release valve pressure:
   - Set point: Release pressure on steam.
   - Process input variable: Position of release valve.
6. Bypass condenser:
   - Set point: Steam pressure - bypass level
   - Process input variable: Position of bypass valve.

As an option controllers can be defined by the user.

Controllers can be presented in a table by pressing the button **Controllers** or from the main menu **Control** and in the submenu **View of controllers**. In the table the main parameters for the individual controllers are presented. Double clicking a controller the parameters can be edited (see Figure 5).
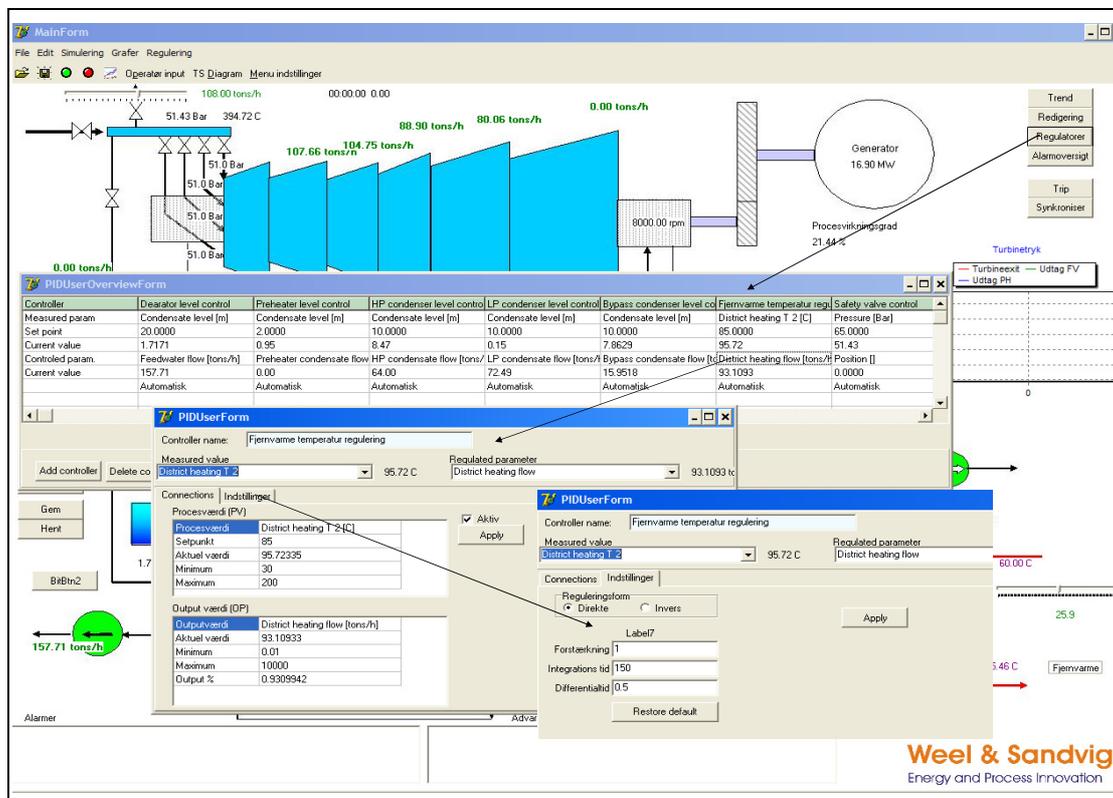
Figure 5. Overwiew and defining controllers

Definition o fuser variables

You can define you own user variables, to be calculated from the parameters available. Click **Edit** on the main menu and click the **User variables** on the submenu.

In the window popping up the already defined variables are presented in a list. Defining a new variable press the **Add** button and a window with to the right *All available variables* appears. Select from those variables the ones needed by draging them from the right table to the left table (*Possible equation variables*). From this table double clicking a variable will enter the variable in the expression line above, where also a toolbar with calculating symbols is present.

Pressing the button **Test var** the expression is calculated, and by pressing **Accept** the new variable is ready for use.

Figure 6. Defining your own variables.

Presentation of not predefined variables on screen

1. Press the button **User var** to open the dialogue window.
2. Select the variable from the drop-down menu.
3. Press **Ok** and close the window
4. Now the variable can be moved with the mouse by pressing the right mouse button while moving the cursor to the wanted position.
5. To store the variable press the button **Gem**.
6. The saved variables can be presented by pressing the button **Hent**.

Figure 7. Displaying non predefined variables on screen.

Display the actual process in a T-S diagram

The steam turbine process (Rankine cycle) can be displayed in a T-S diagram (see Figure 8) by pressing the menu **T-S Diagram**. Similarly a H-S diagram can be presented by pressing the menu **H-S diagram**.

In the T-S diagram the Rankine process with propertie data for the following points are displayed graphically an updated as the simulation runs.

1. Turbine inlet.
2. Wheel chamber.
3. Extraction 1, (secondary supplier to the deaerator).
4. Extraction 2, (primary supplier to the deaerator).
5. Extraction for the low pressure (LP) feed water preheater.
6. Extraction to the high pressure (HP) condenser.
7. Extraction to the LP condenser.
8. Condensate to HP condenser.
9. Condensate to LP condenser.
10. Condensate feed to LP feed water preheater.
11. Feed water from deaerator.

12. Feed water after HP feed pumps.
13. Feed water at saturation.
14. Saturated steam.
15. Superheated steam at turbine inlet.
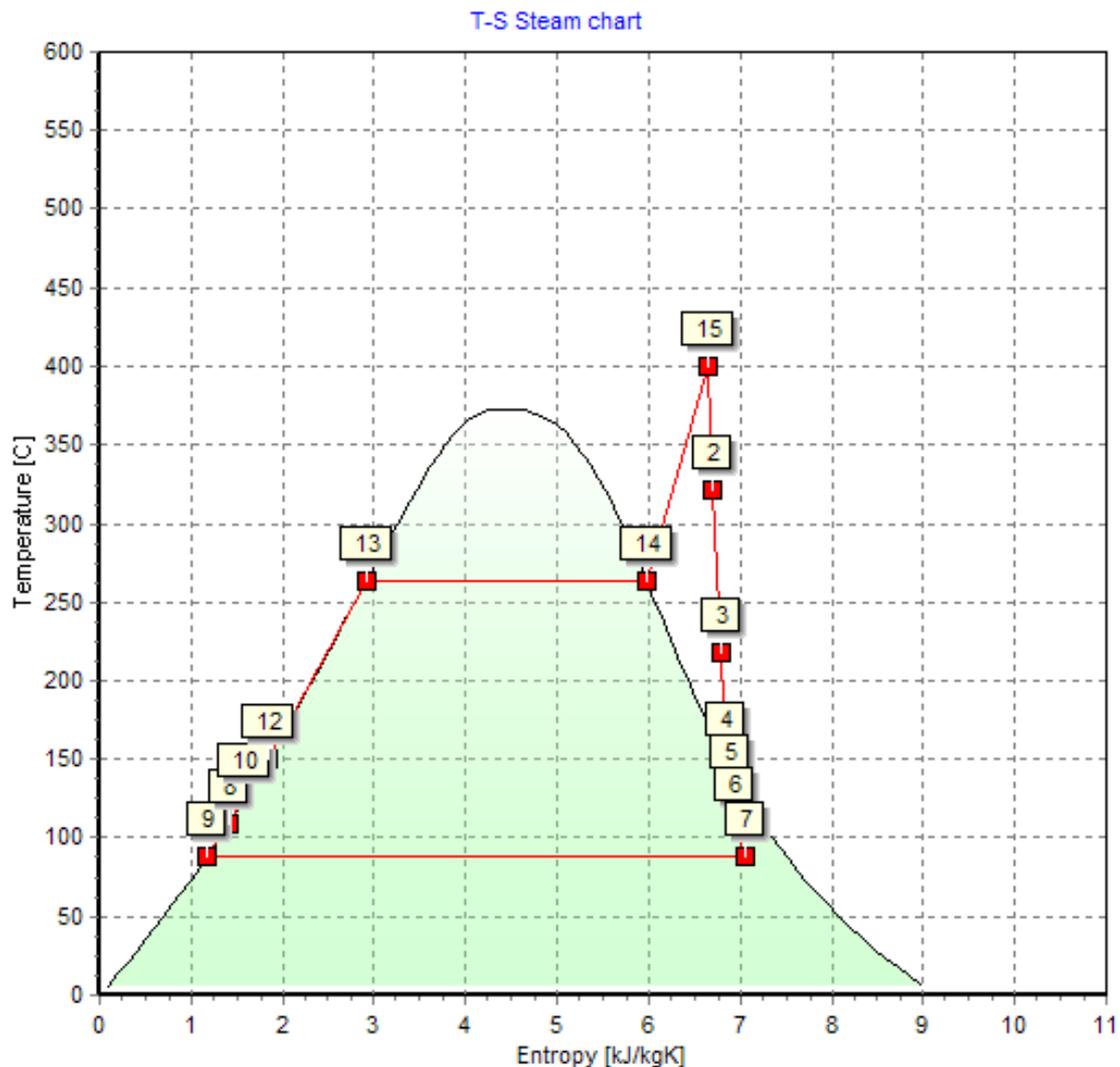
Figure 8. Display of the Rankine process in a T-S diagram while the simulation runs.

Model of the district heating system

A very simple district heating system can be modelled in the simulator. The model can be activated by double clicking **Fjernvarme** (lower right of the screen) and write **yes** in stead of the default **no** in the cell after **Use model** (see Figure 9).

When the model is activated, the return temperature is calculated based on demanded heat and the total mass of water in the district heating system. The model act as one large tank where heat is extracted from (heat demand). Inlet to the tank is the flow of district heat at the forward temperature and outlet is the same flow at the district heat return temperature calculated as the temperature of a perfectly mixed tank.
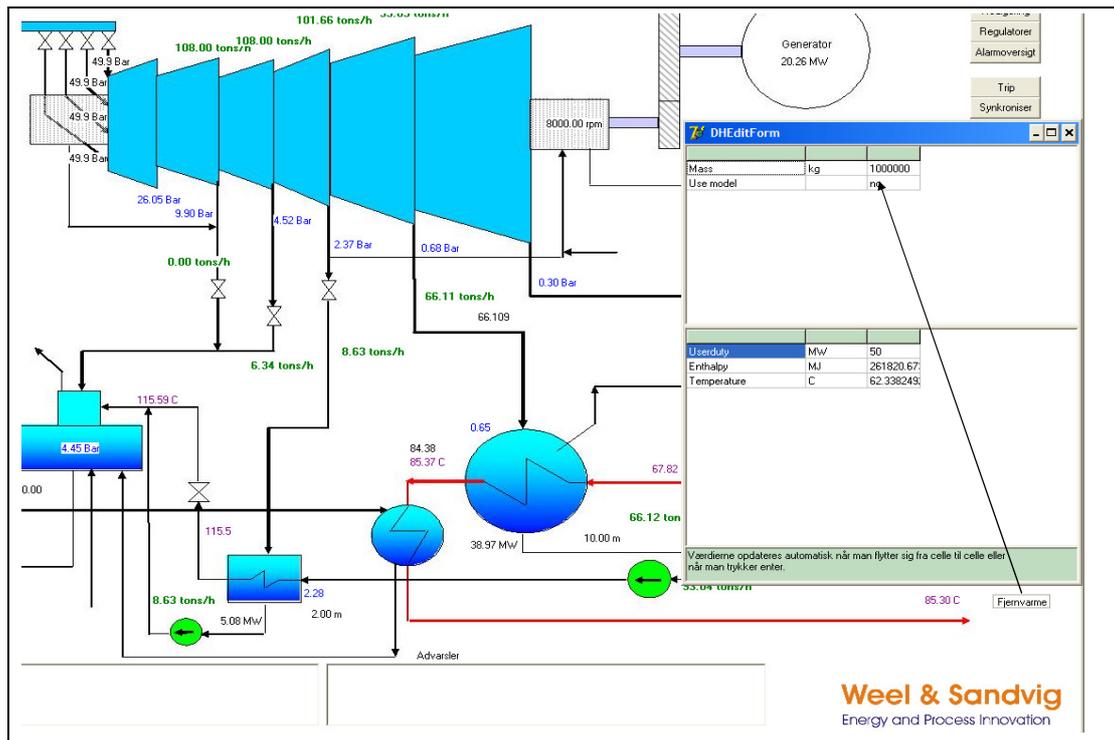
Figure 9. Activating a simple district heating model.

Vacuum pump and false air in the condensing system

The influence from air leakage (air entering the condensing system when operating at lower pressures than surroundings) can be simulated as well with **WS.SteamTurb-simulator.**
The air enters through small leakages in the flanges between the turbine outlet and the condensers. If the steam blocking system with maze sealing does not work properly, also air can enter this way at the vacuum side of the turbine shaft.

The amount of air leakage is specified by double clicking the vacuum pump and type in an equivalent leakage area (**Areal**) in square meters (e.g. 0.0001 m^2). Also the capacity of the vacuum pump can be edited here in m^3/h (see Figure 10). The equivalent area corresponds to a leakage through one circular hole of the specified area.

Investigations with the simulator

The simulator can be used for investigations on how the turbine system will react on disturbances like sudden increase in the district heat return temperature (see Figure 11).
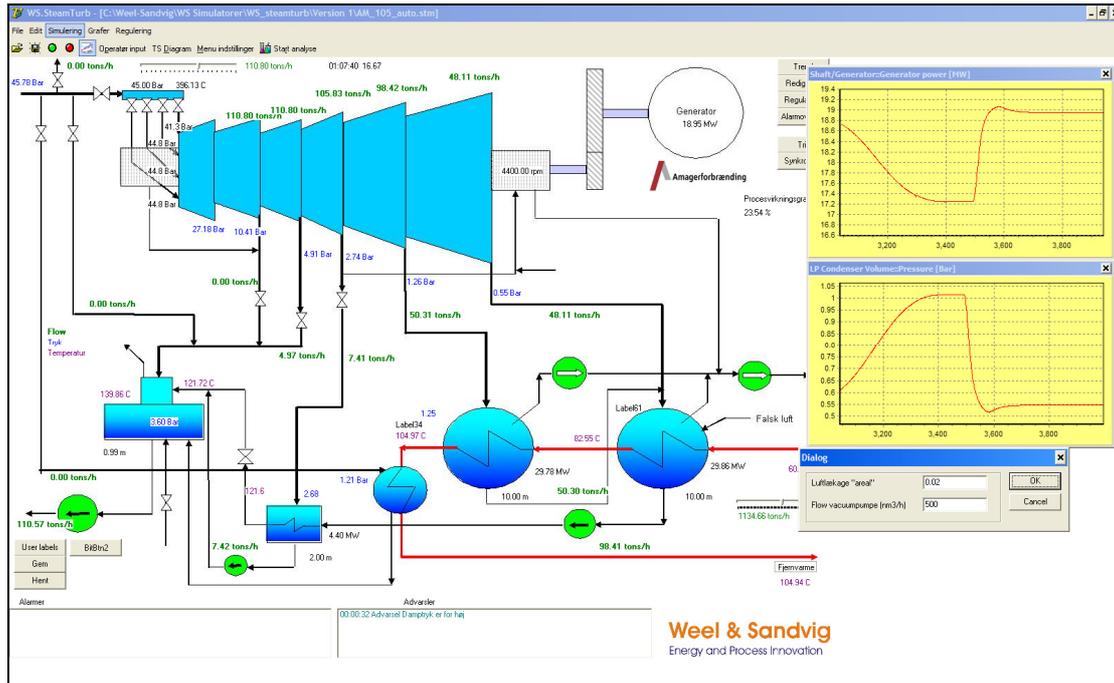
Figure 10. Specification of leakage area and capacity of vacuum pump. The upper curve shows turbine power and the lower curve shows pressure in the condenser during shut down and start up of the vacuum pump.
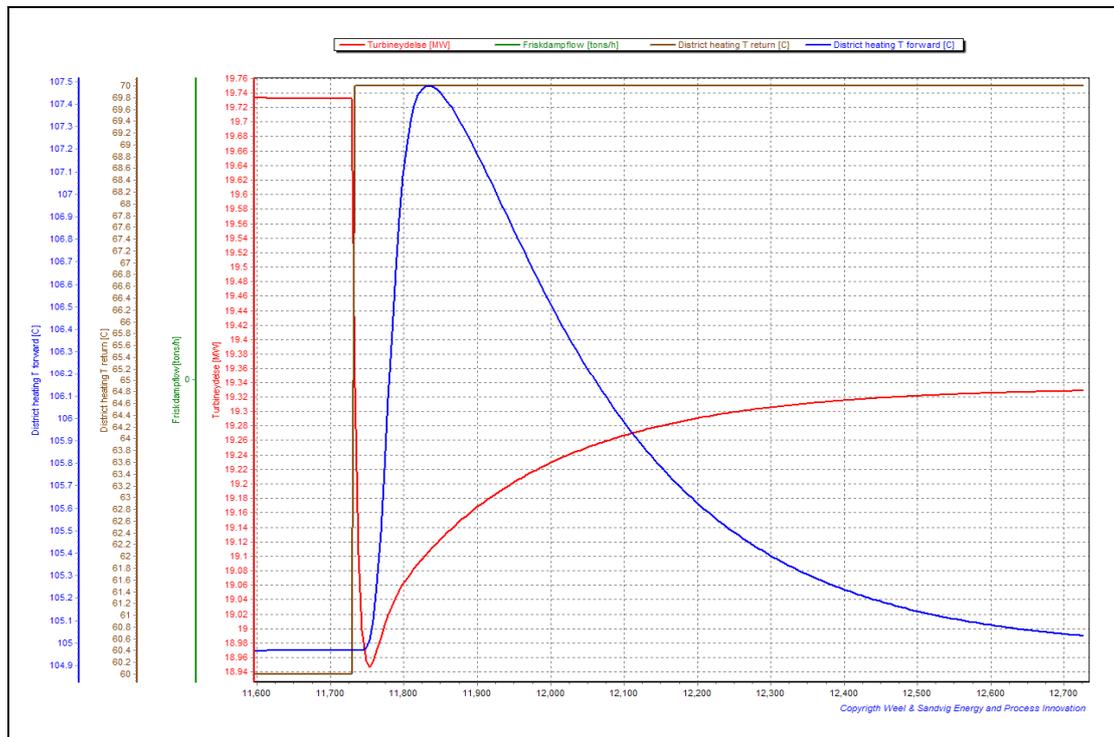
Figure 11. Example of the turbine response when suddenly the district heat return temperature change from 60 ºC to 70 ºC. The control system is activated.

Trip and synchronisation of turbine

A turbine system can trip of a number of reasons, either due to external conditions or due to internal process values are exceeded.

In the present version the turbine does not trip automatically when a acertain parameter is exceeded beyond the allowable limit. A trip is activated by pressing the button **Trip**, implying that the generator immediately is disconnected. Also the turbine security valve is not integrated in the trip simulation. That means that manually you have to close the security valve to reduce the steam flow.
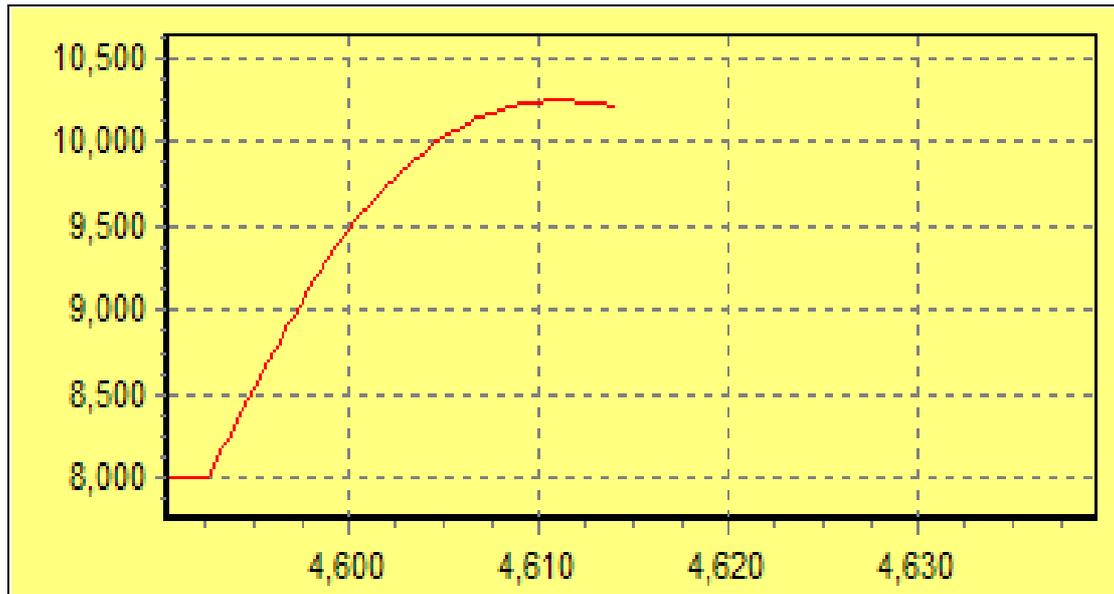
Figure 12. Change in turbine speed (RPM on vertical axis) when loosing the generator and afterwards trip of the turbine. The speed is increased from 8000 RPM to 9500 RPM with in 7.5 seconds (vertical axis displays seconds).

When starting up a turbine system it needs to be connected to a electricity grid. This is done by pressing the button **Synchronise**, when the turbine shaft speed is in an interval corresponding to a frequency of the generator between 49.75 and 50.25 Hz.

To start the turbine a start up file named **"Opstart1"** is used.

Error messages

If the message "floating point division by zero" appears, the simulator needs to be shut down and restarted. The simulation can start from the last saved state.
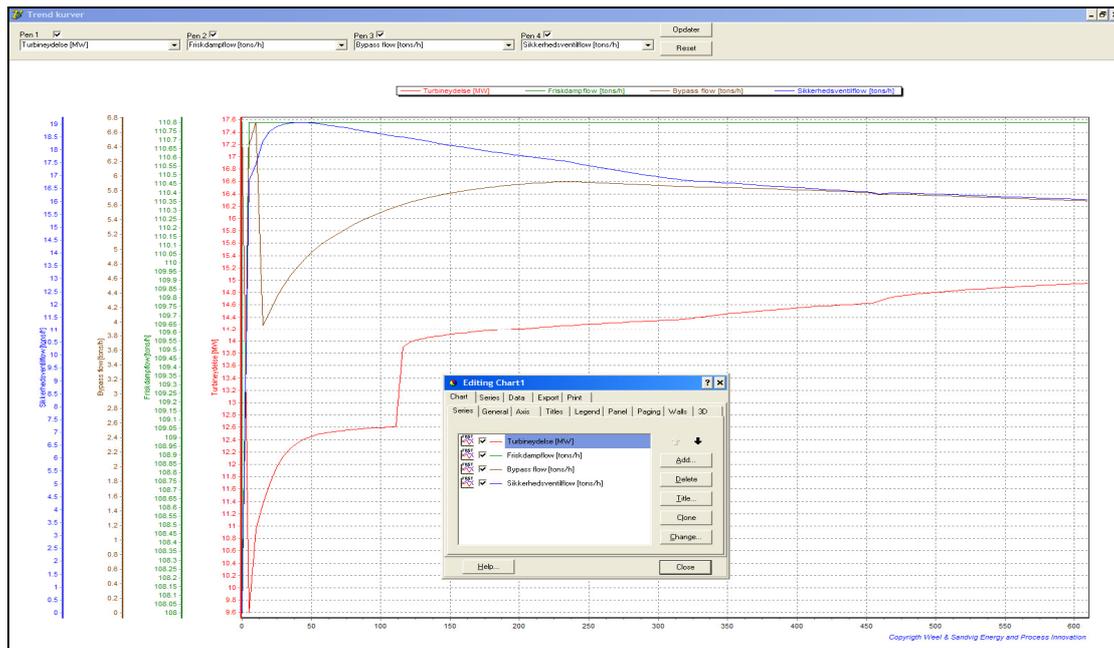
Figur 1. Export of trends is applied by double clicking the left mouse button. From the *Editing Chart1* window, that appears, select the *Export* sheet and specify what to export. While pressing down the right mouse button, with the cursor drag from upper left to lower right to get a zoomed view of the rectangle area encapsulated. To zoom out again simply drag the cursor the opposite way (from lower right to upper left while pressing down the left mouse button).

WS.SteamTurb-simulator new version.

Since 2009 W & S steam turbine simulators is delivered on a new platform which is more flexible then the older version. The new version has a platform common with the WS.WTE-simulator. With the new simulator it' possible to simulate both the steam boiler and steam turbine system at the same time.
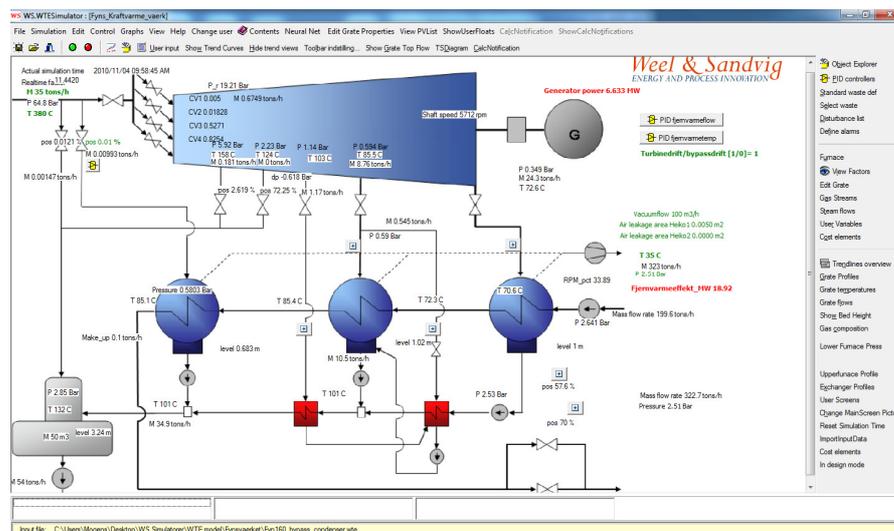
Figure 13 New version of the WS.SteamTurbine simulator