HOW TO GUIDE

Private wire operation

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About energyPRO

energyPRO is a Windows-based modeling software package for combined techno-economic analysis and optimisation of complex energy projects with a combined supply of electricity and thermal energy from multiple different energy producing units.

The unique programming in energyPRO optimises the operations of the plant including energy storage (heat, fuel, cold and electrical storages) against technical and financial parameters to provide a detailed specification for the provision of the defined energy demands, including heating, cooling and electricity use.

energyPRO also provides the user with a detailed financial plan in a standard format approved by international banks and funding institutions. The software enables the user to calculate and produce a report of the emissions by the proposed project.

energyPRO is very user-friendly and is the most advanced and flexible software package for making a combined technical and economic analysis of multi-dimensional energy projects.

For further information concerning the applications of energyPRO please visit www.emd.dk.

Terms of application

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Contents

In this How To Guide you will learn about the ‘private wire’ operation strategy in energyPRO. In the end of the guide an example is shown to illustrate the private wire operation under different conditions.

Click the bullets below to jump to the relevant chapter.

Introduction

A private wire operation is relevant for energy systems including an electricity demand that can be covered by a CHP plant within the system although a connection to the distribution network allows electricity exchange with the surrounding markets. In such systems the electricity producing unit can either cover the local demand or export electricity to outside markets, and the economy associated with these two operation options are often very different due to electricity market prices, taxes and subsidies.

The private wire strategy aims at covering the local electricity demand and only exporting/importing electricity when it is necessary or profitable. In order to decide which operation that is the most profitable in every hour, an operation strategy for both options must be defined. For this reason, the option of defining two strategies appears in energyPRO when an electricity demand is present in the project. This is also referred to as "Private wire" operation.

Operation strategy

In energyPRO the operation strategy is defined by assigning each production unit priority numbers, which typically represents the unit's net production cost in each time step. Based on these priority numbers the optimal operation is calculated. Read more about priority numbers and how they affect the operation strategy in the How-to-Guide, "Setting up operation strategies in energyPRO" on our website.

Generally, each unit is assigned one priority number in every time step, but in a private wire operation several priority numbers are assigned in each time step. This is done in order to compare the two operating options for electricity producing units: Covering own demand or exporting electricity.

In the operation strategy window, shown in Figure 1 and Figure 2, you can see the calculated priorities of the electricity producing units when all the produced electricity is exported and when it is covering own demand, respectively.

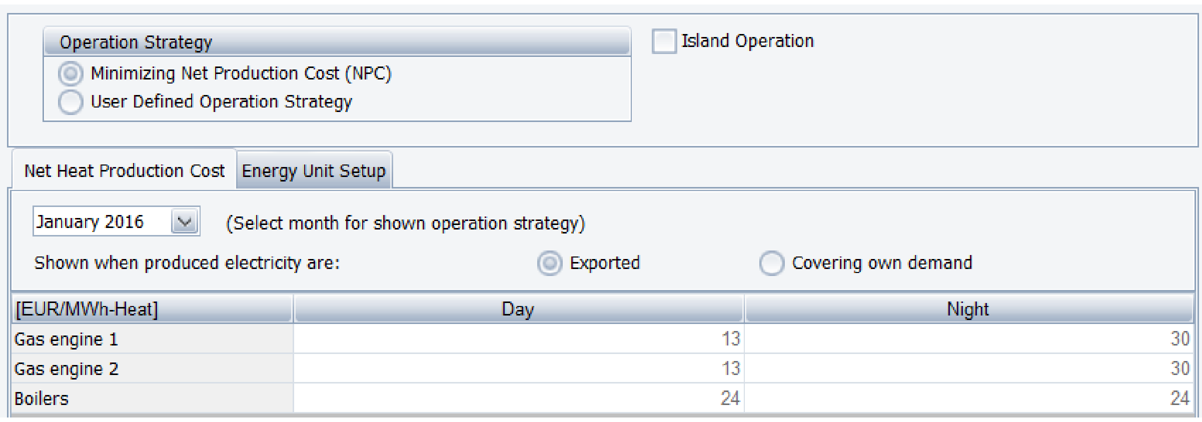

Figure 1. Priorities when exporting all produced electricity

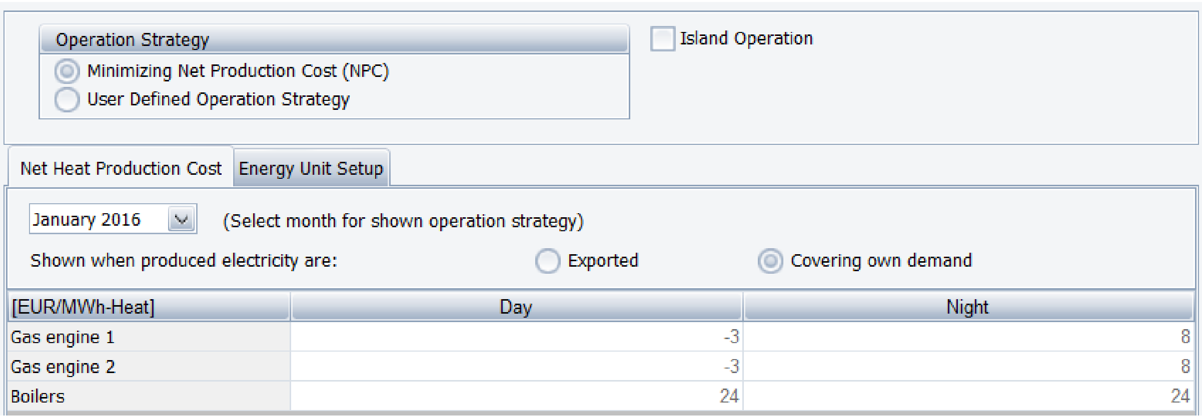

Figure 2. Priorities when covering own electricity demand

As it appears from the above figures the net heat production costs of the gas engines are lowest when covering own electricity demand.

Note that these priorities are only valid for full load operation where either all electricity is exported or covering own demand. However, the operation of the different units can also be a combination of the two options. For this reason, it is necessary to calculate load specific priority numbers for each unit based on the above tables, the electricity demand and on the units' load curves.

Calculation of load specific priorities

For electricity producing units that are allowed to part load, two priority numbers are calculated in each time step. The two priorities are calculated at different loads:

1. $NHPC_{red}$: At part load equal to residual electricity demand, but not less than minimum load
2. $NHPC_{full}$: At full load

NHPC is short for net heat production cost and the priority numbers are based on the payments related to the operation of the unit in question.

The priority number, $NHPC_{red,}$ is calculated for a unit covering the electricity demand with a load curve equal to the residual electricity demand. If the residual electricity demand is below the minimum load of the unit, $NHPC_{red}$ is calculated as weighted average of the priority when covering the electricity demand and when exporting the electricity, both calculated at minimum load.

$NHPC_{full}$ is found as a weighted average of the priority number of covering the residual electricity demand and of the priority number when exporting the electricity, both at full load.

Example: Cogeneration plant on fixed tariffs in private wire

In the following, a simple example is given of how the $NHPC_{red}$ and $NHPC_{full}$ differ from initial priority numbers in the operation strategy window, depending on the electricity demand and the power curves of the energy conversion unit.

The energyPRO project used in this example is available in the library, which is automatically included in the energyPRO installation. By default the library is located in the directory, "C:\energyPRO Data (Dev)\English\Project examples". The name of the example is "Cogeneration plant on fixed tariffs in private wire_DESIGN module.epp".

In the example, the priorities are calculated for a gas engine supplying an electricity demand of A) 750 kW and B) 2000 kW in a certain hour.

Assume the following load curves for the gas engine:

	Fuel [kW]	Heat [kW]	Electricity [kW]	Elec. Efficiency
Max	5,000	2,100	2,000	40%
Min	2,000	630	600	30%

Note that the efficiency of the gas engine is reduced when running at minimum load compared to maximum load.

A) *Electricity demand of 750 kW*

If the electricity demand in a given hour is 750 kW, the gas engine can either run part load at 750 kW, covering own electricity demand or run at full load, covering own demand and exporting 1250 kW. The priority of these two operations are described by $NHPC_{red}$ and $NHPC_{full}$ as shown in the below table.

Priority numbers	Day	Night
Exporting, at full load	13	30
Covering own demand, at full load	-3	8
$NHPC_{red}$	10	21
$NHPC_{full}$	7	22

Note that the priorities "Exporting, at full load" and "Covering own demand, at full load" are based on the relevant payments and calculated for both the Day and Night tariff period.

From the table, it can be seen that in the given hour during the Day period, the best option will be to run at full load, covering the electricity demand and exporting the rest of the production ($NHPC_{full}$ = 7). Since this operation is a combination of

"Exporting, at full load" and "Covering own demand, at full load", the number $NHPC_{full}$ is calculated as the weighted average:

$$NHPC_{full} = \frac{-3 * 750\ kW + 13 * 1250\ kW}{2000\ kW} = 7$$

The second best option in that hour during the day is to run the engine at part load, covering the demand without exporting ($NHPC_{red}$= 10). This number is higher than "Covering own demand, at full load because the engines efficiency at part load is lower than at full load. The reduced efficiency affects the cost per produced MWh heat and thereby the priority of the unit.

Assuming the electricity demand of 750 kW during a given hour in the night period, it is can be seen that it is better to run the engine at part load ($NHPC_{red}$= 21), covering only the electricity demand. Despite the fact that the efficiency of the engine is much lower at part load, it is better to part load during the night because exporting during the night has a very high priority number (Exporting, at full load= 30).

Keep in mind that the aim of the operation strategy is to cover the heat demand in the cheapest possible way and the unit's productions will therefore be inserted in hours with the lowest priority numbers first – not in a chronological order. In this case, the units will seek to produce as much as possible during the Day tariff period and as little as possible during the Night tariff period by utilizing the thermal storage tank.

If the engine is first started at part load, a new priority number, $NHPC_{exp}$, for running at full load is then calculated for the marginal load from part load to full load. This is explained in further details in the next section.

B) Electricity demand of 2,000 kW

If the electricity demand in a given hour is 2,000 kW, the gas engine will only have the option of running at full load. The unit will therefore only have a priority number, $NHPC_{full}$ as shown in the table.

Priority number	Day	Night
Exporting, at full load	13	30
Covering own demand, at full load	-3	8
$NHPC_{red}$	-	-
$NHPC_{full}$	-3	8

As before, the $NHPC_{full}$ is calculated as the weighted average of the priority numbers for "Exporting, at full load" and "Covering own demand, at full load", but since the full load electricity production is equal to the demand, $NHPC_{full}$ is equal to “Covering own demand, at full load”.

Recalculating priorities during calculation

In every time step, each electricity producing unit allowed to part load are appointed the above mentioned two priority numbers.

Every time an electricity producing unit is successfully entered in a given time step, the preconditions for the calculation of priorities in this particular time step is changed and the priorities are recalculated for each unit. Every recalculation in a time step depends on the already planned operation of the unit in question and the residual electricity demand:

- The recalculation of a unit’s priority numbers is only made if the unit is not already running full load.
- If residual electricity demand is above zero and the load of the unit in question is zero, both $NHPC_{red}$ and $NHPC_{full}$ are calculated.
- If the residual electricity demand is zero and the load of the unit in question is also zero, only the $NHPC_{full}$ is calculated.
- If the residual electricity demand is zero and the unit in question is running part load, $NHPC_{exp}$ is calculated.

$NHPC_{exp}$ is a priority number for the marginal load from part load to full load. As mentioned above it is therefore only calculated for units that are operated at part load. The number is based on the marginal power curve, which is found by subtracting the power curve at full load with the power curve at part load.

If for instance the unit in the above example is first inserted in a given hour at minimum load, the $NHPC_{exp}$ is calculated as the priority number of uploading the unit to full load. This is based on the difference between the power curves at maximum load and minimum load as shown in the below table.

	Fuel [kW]	Heat [kW]	Electricity [kW]	Elec. Efficiency
Max	5,000	2,100	2,000	40%
Min	2,000	630	600	30%
Upload	3,000	1,470	1,400	47%

By subtracting the maximum load curve with the minimum load curve, the marginal load curve (Upload) is found. This is used to calculate the $NHPC_{exp}$ priority number.

Example of private wire operation

In this example, the operation of a private wire operation is presented. The model consists of two gas engines, a boiler, a thermal store, a heat demand and an electricity demand, as shown in Figure 3.

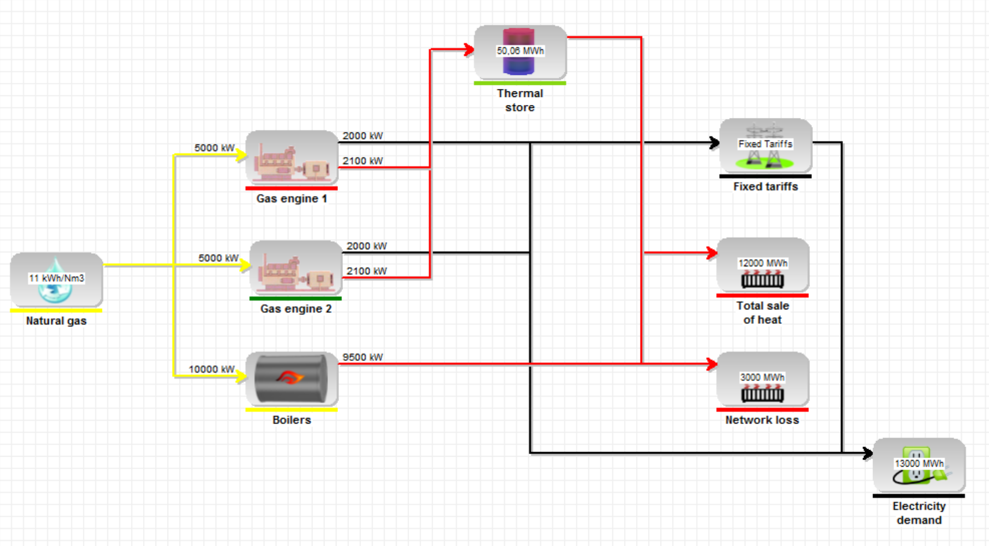

Figure 3. Schematic of the model used in the example

Furthermore, a fixed tariffs market is included in the model with high electricity prices during the day (except weekends) and low electricity prices during the night (and weekends).

The operation strategy applied in the model is shown in Figure 1 and Figure 2. All of the production units are allowed to part load, but only the gas engines are allowed to send heat production to the thermal store.

In Figure 4, the operation of the units in the example is presented. The graph window includes four different graphs. From the top, the graphs show; the priority numbers for each unit, the heat production and heat demand, the electricity production and electricity demand and finally the heat store's content and capacity.

Figure 4. Graphical presentation of the operation in the example

As it appears from the Priorities graph, the gas engines have different priority numbers over the period, even though they are exactly identical. This is because Gas engine 1 can cover all of the electricity demand and the entire electricity production from Gas engine 2 must thereby be exported. As described in the previous chapters, this affects the priorities significantly.

Initially, two priorities are calculated for each unit and whenever a production has been accepted, priorities are recalculated, based on the residual electricity demand. The priorities shown in the graph are always the last used priority – or if the unit is not put into operation, the best of the last calculated priorities.

Note that the Priorities graph also include a dashed line for the “upload” priorities. These priority numbers indicate the priority number for the unit’s marginal operation from part load to full load, which is described earlier as $NHPC_{exp}$. In the figure this is seen from Tuesday evening to Wednesday morning. The dashed line shows the priority for uploading Gas engine 1 from part load to full load in this period, but in this case there is not enough capacity in the heat store to increase the production.

To illustrate the private wire method, Figure 5 shows what happens in the same four days when there is no electricity demand.

Figure 5. Operation, no electricity demand

The priorities on the priority graph match the numbers in Figure 1, since all of the electricity production must be exported. The units are operating according to the priority numbers and the heat demand.

In Figure 6, the electricity demand is so high that the gas engines have no option of exporting electricity. The priorities on the priority graph now match the numbers in Figure 2.

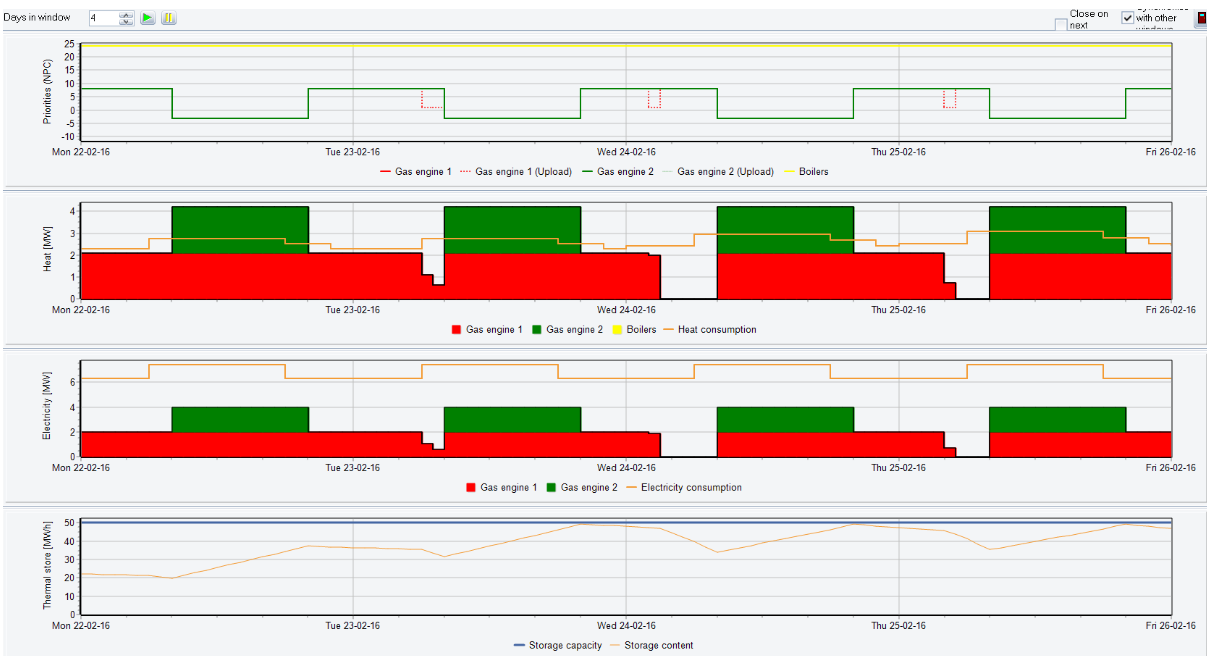

Figure 6. Operation, very high electricity demand

Also in this example, the upload priorities are shown as a dashed line for when the units are operated at part load.

In the next example, the electricity demand matches the production capacity of Gas engine 1. In this case, the priority numbers of Gas engine 1 equals the number in Figure 2, covering own demand. The priorities of Gas engine 2 equal the number in Figure 1, exporting all electricity.

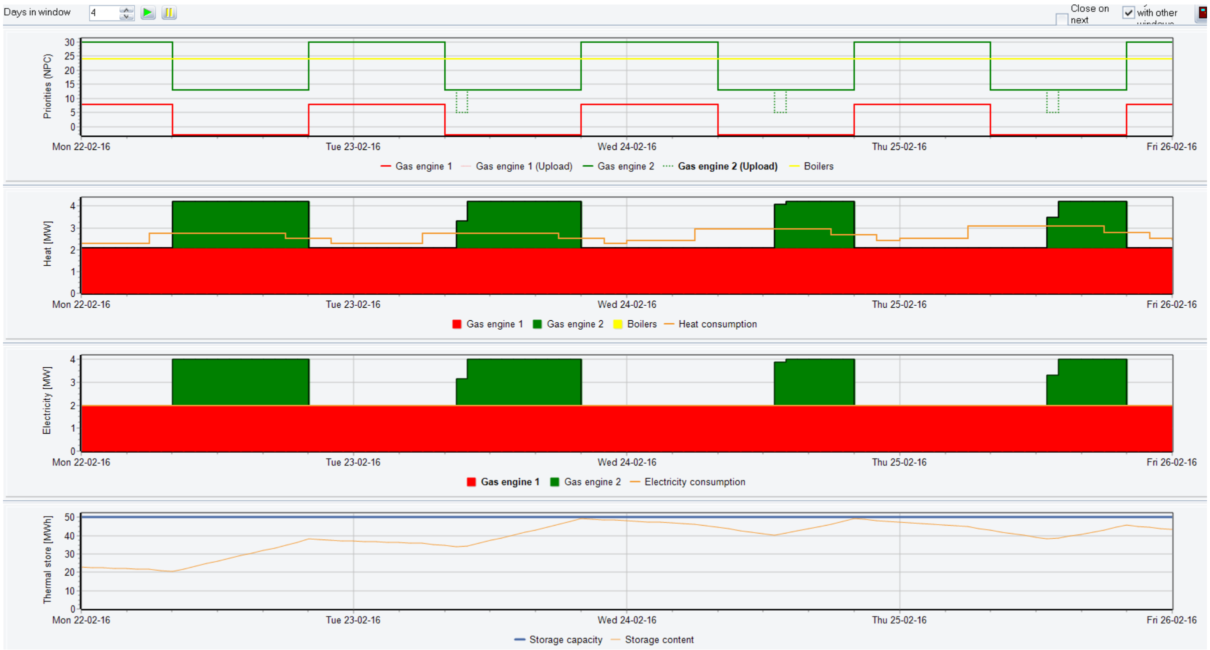

Figure 7. Electricity demand matching the capacity of Gas engine 1

Please notice, that you can find more information on how to use energyPRO in the How to Guides, User's Guide and tutorials on EMD's website:

http://www.emd.dk/energypro/