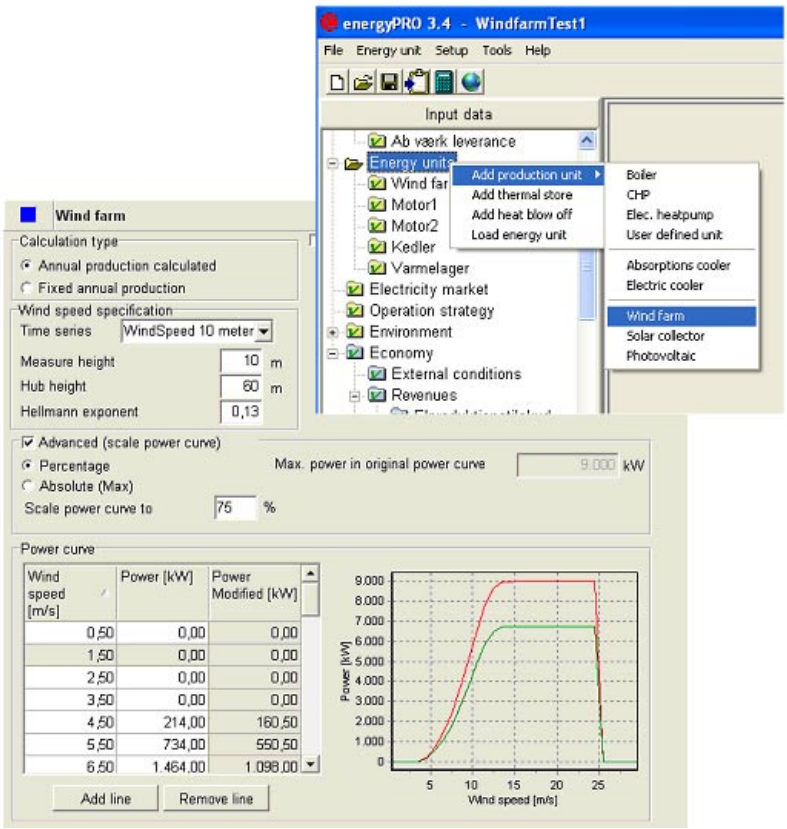
Wind farm in energyPRO



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1. Introduction

The new wind farm in energyPRO is a specialised production unit that makes it much easier to model wind farms than before.

All approaches require that a time series holding wind speed is available and present in the "External conditions"-folder.

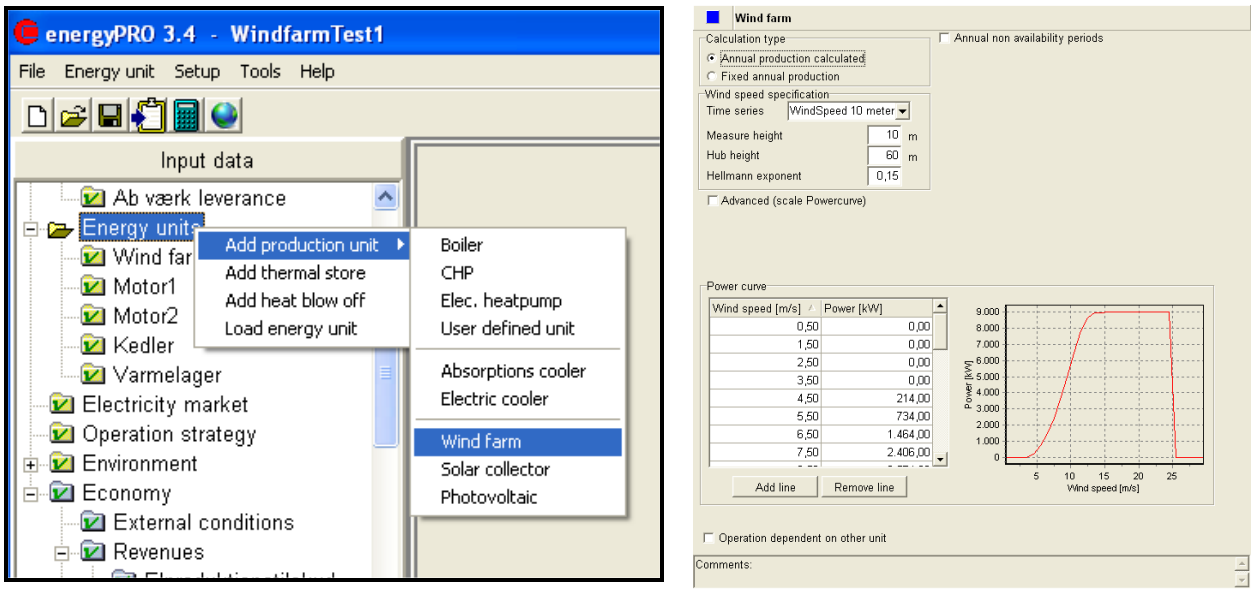

Figure 1.1: Select and specify the production unit - Wind farm

The new wind farm uses an external time series with measured wind speed and a wind farm power curve to calculate electric production form the wind farm. The time series with wind speed must be present in the "External conditions"-folder, and the power curve must be specified in the wind farm editing window.

2. Calculation type

There are two main approaches to calculating wind farms in energyPRO.

1. Annual production calculated, divided into two sub cases
    a. Farm power curve is used directly
    b. Power is scaled to another level
2. Fixed annual production (wind speed is scaled)

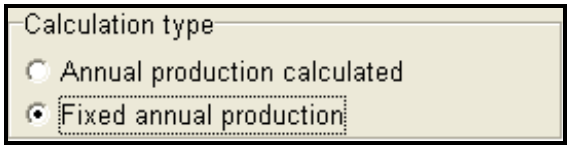

Figure 2.1: Select Calculation type

Annual production calculated. In this case the productions from the wind farm is calculated based on the wind speed specification and power curve of the wind farm. As an advanced setting, there are options to scale the power curve and thereby the production.

Fixed annual production. This option serves to distribute a desired annual production given a specified wind farm power curve. All wind speeds specified through "Wind speed specification" (see next section) are scaled by the modification factor that makes agreement between the annual production, the power curve and the wind speeds. This factor is found through iterations.

3. Wind speed specification

The wind speed at hub height is defined through the following parameters, which is used for converting the wind speed in measure height to wind speed at hub height.

1. A time series holding the wind speed time series
2. The measure height of the time series
3. The hub height of the turbines
4. The Hellmann exponent

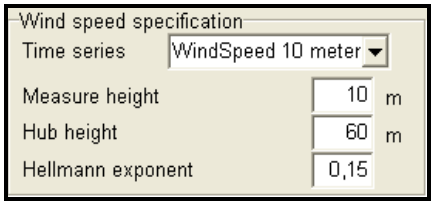

Figure 3.1: Wind speed specification

Ad 1) The time series must be established in External conditions prior to the specification.

4. Specification of power curve

The power curve consists of a data set of values containing the wind speed and the corresponding power output from the turbines. In the calculation, the power output is assumed linear between two data elements. The power curve is specified through a data table and shown on a corresponding graph, see Figure 4.1.

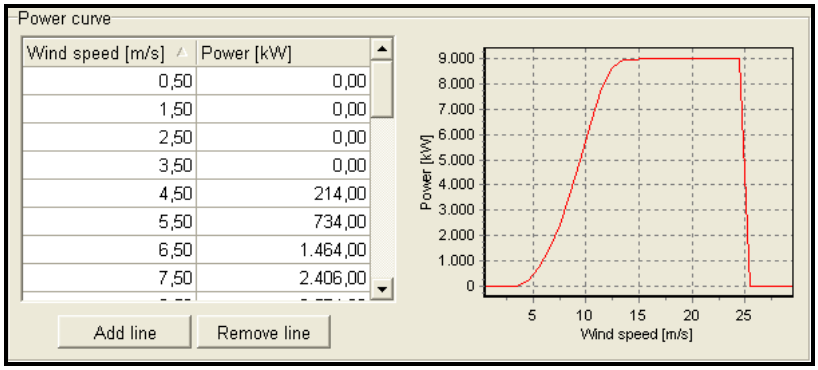

Figure 4.1: The power curve of the wind farm

The functionalities of the table are comparable to the other energyPRO tables. This includes unlimited number of values, add line and delete line buttons. Data is added by typing data into the table or it can be pasted via the clipboard. It is possible to copy a calculated wind farm curve from WindPro® via the clipboard to the wind farm power curve in energyPRO, see Figure 4.2.

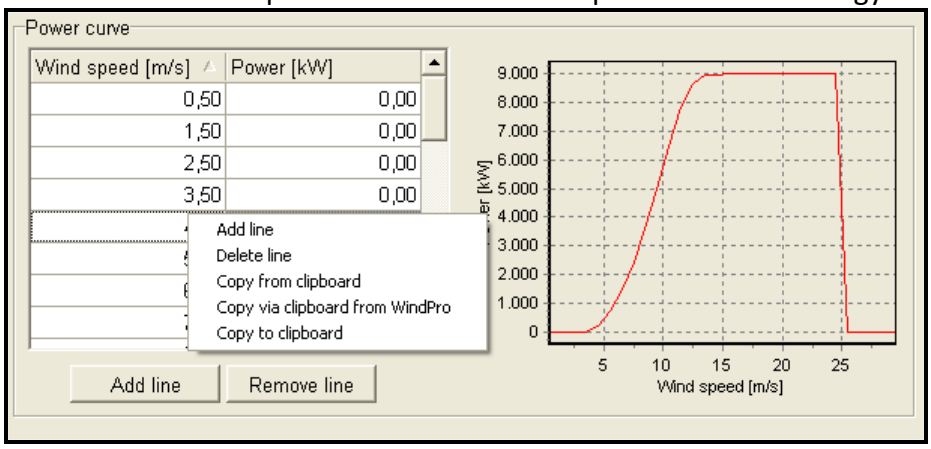

Figure 4.2: The power curve. Values can be copied via clipboard, including wind farm power curve calculated in WindPro

4.1 Annual production calculated

4.1.1 Annual production calculated, not advanced

Figure 4.3 shows the content of the wind farm editing-window if "Annual production calculated" is selected. This window contain the data described in this window, plus an advanced option.

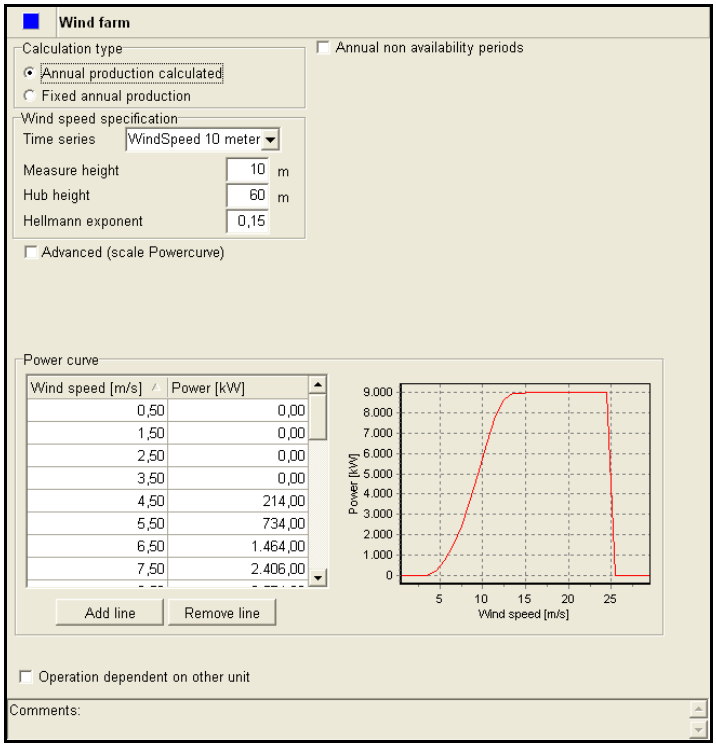

Figure 4.3: Wind farm, "Annual production calculated", not advanced

4.1.2 Annual production calculated (power curve scaled).

An example of this shown in Figure 4.4. Notice that the power curve now has a new resulting power curve both in the table presentation and in the graphic representation. There are two variants. It is possible to scale the power curve using a percentage or a new max. power curve value, see Figure 4.4 and Figure 4.5.

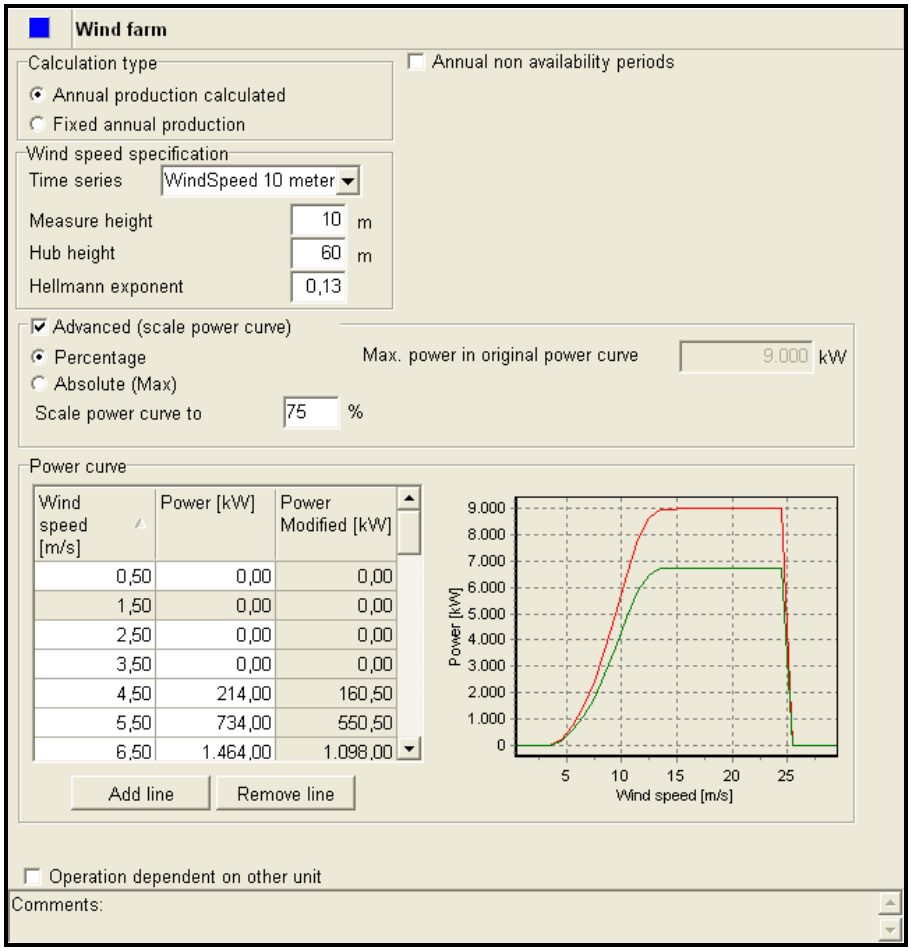

Figure 4.4: Wind farm, "Annual production calculated", power curve scaled with percentage

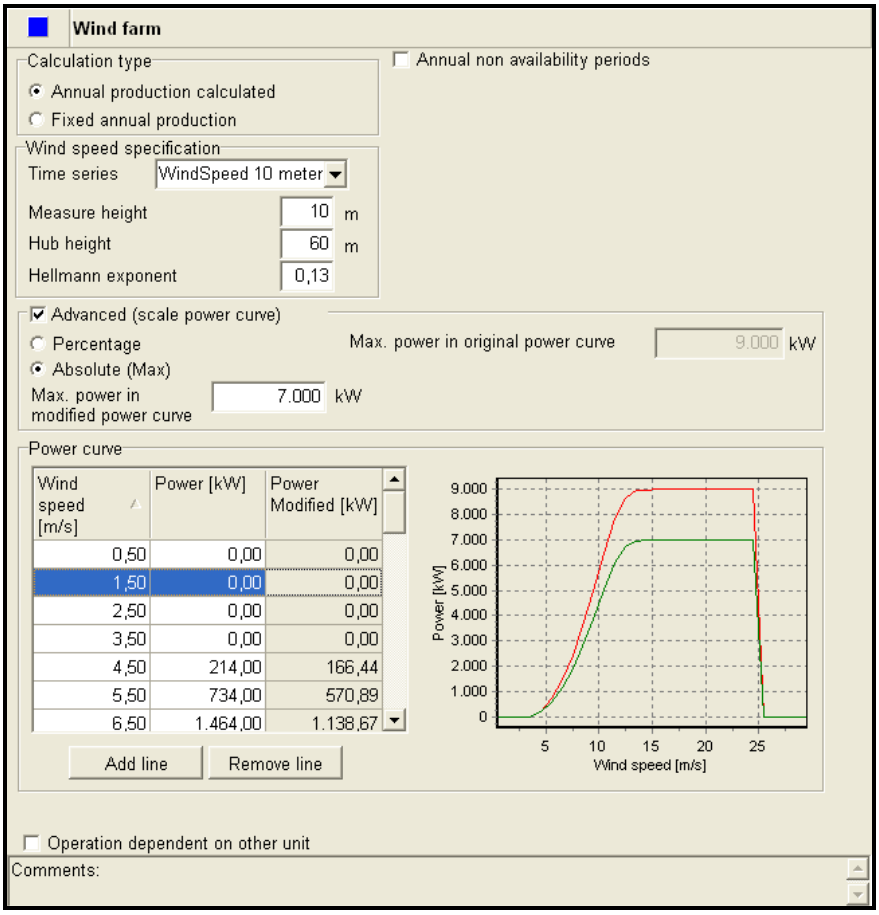

Figure 4.5: Wind farm, "Annual production calculated", power curve scaled with max power curve value

4.2 Fixed Annual production

If Fixed annual production is selected then the Annual production and the wind farm power curve is specified (e.g. calculated in WindPro). Given the power curve and a stated annual production all wind speed values are scaled by a factor. This factor is calculated, and is used when calculating the production at any time. See the description in section 5.

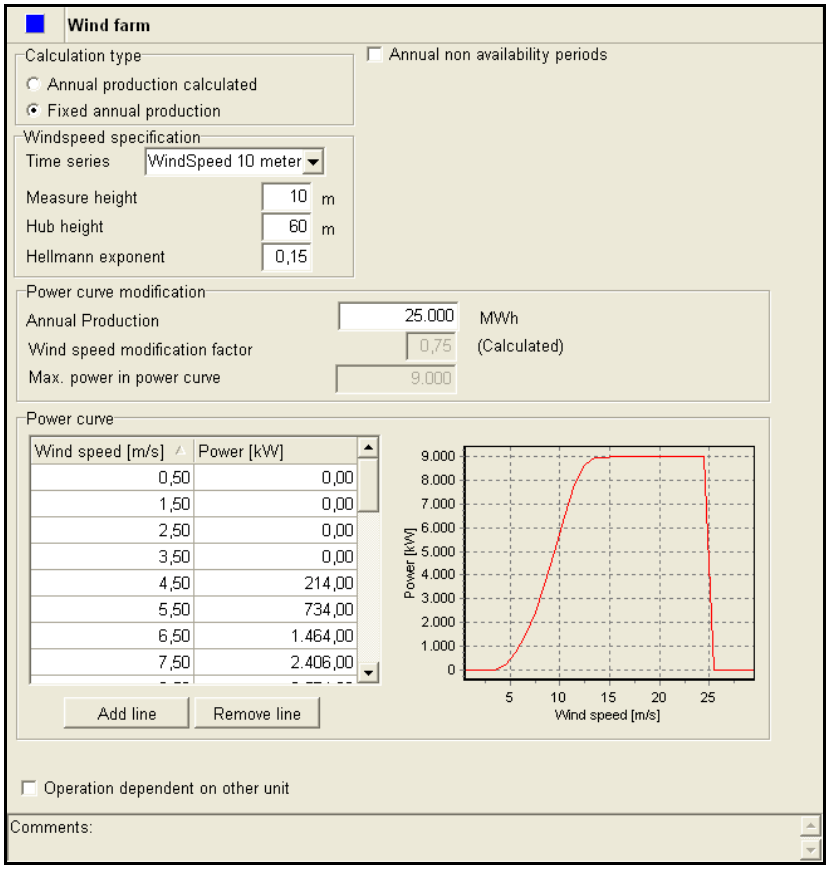

Figure 4.6: Fixed annual production (Scaling wind speed)

5. Method of wind farm calculation in energyPRO

The wind farm model in energyPRO cover three different cases.

1. Annual production calculated
    a. Power curve used directly
    b. Power curve is scaled to another level
2. Fixed annual production (wind speed is scaled)

5.1 Definitions

$WS_m(t)$ = Wind speed measured (m/s) at time t

$WS_C(t)$ = Wind speed calculated (m/s) at time t

H_m = Height of measurements (m)

H_h = Hub Height (m)

α = Hellmann coefficient

m_f = Wind speed modification factor

$PC(WS_c(t)$ = The power from the power curve based on the calculated wind speed at hub height and linear interpolation on power curve.

P_{MaxPC} = Max power value found in power curve

P_{Max} = Max Power stated

$P(t)$ = Production at time t

$P_{annualDesired}$ = Annual production desired (MWh)

$P_{annualCalc}$ = Annual production calculated (MWh)

5.2 Mathematical description

5.2.1 Wind speed at hub height

Calculated wind speed at hub height in cases 1a and 1b.

(1) $WS_c(t) = WS_m(t) * \left(\frac{H_h}{H_m}\right)^{\alpha}$

Calculated wind speed at hub height in case 2.

(2) $WS_c(t) = WS_m(t) * \left(\frac{H_h}{H_m}\right)^{\alpha} * m_f$,

Where the modification factor is found through iterations

5.2.2 Calculation of production at time t

(3) $P(t) = PC(WS_C(t))$ (Case 1a)

(4) $P(t) = PC(WS_C(t)) * P_{\max} / P_{\max PC}$ (Case 1b)

(5) $P(t) = PC(WS_C(t))$ (Case 2)

Where $PC(WS_C(t))$ return then power from the power curve based on the calculated wind speed at hub height and linear interpolation on power curve.

5.2.3 Calculation of wind modification factor

(6) $P_{annualCalc} = \sum_{t=0}^{t=H_{Year}} PC(WS_C(t)) * \Delta T$, where $WS_c(t) = WS_m(t) * \left(\frac{H_h}{H_m}\right)^{\alpha} * m_f$

Start guess $m_{f=1}$

In each Iteration is the annual production calculated (6) and compared with the desired value

If $P_{annualCalc} > P_{annualDesired}$ then decrease m_f

If $P_{annualCalc} < P_{annualDesired}$ then increase m_f

This is repeated until

$P_{annualCalc} \cong P_{annualDesired}$

then m_f is found.