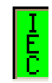
Contents

Quick start

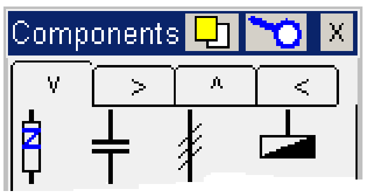
Purpose
This program calculates the currents and voltages in the network in the cases of different faults. The calculations can be carried out either according to the IEC 60909-standard, or using the a method similar to the superposition method (The method is equal with the superposition method, if Xd" = Xq"). In the latter case, the currents after the occurrence of the fault are calculated as a function of time. The prefault state can be calculated either by solving the network directly, or by solving the load flow problem for the network.

The short circuit calculation method is selected with the DYN(amic) / IEC -button 

/ 

Note: After a calculation, no results are visible, unless some of the display method described in "Display of the results" (below) is in use.

Construction of the single line diagram of the network



Drag and drop the components from the component menu. That is, position the cursor on the desired component in the menu, press the left mouse key, move (drag) the component with the mouse to the desired position, and release the mouse key.

The color of wires and buses and some other components can be selected by clicking the colored squares at the bottom of the component menu.

The color of (some) components that are already in the single line diagram can be changed by right-clicking the component, and selecting the color in the small menu that appears.

The symbol of an magnifying glass on the top of the menu is usede to find components in the diagram. The symbol with the two small rectangles is used to copy parameters of one component to another component of the same type.

It is not possible to rotate the components
Instead, one has to select the components with the desired orientation from one of the four pages on the component menu. The small arrows on the tabs of the pages indicate the direction of the positive current in the following way: **V** down, **>** right, **^** up, **<** left. On each page of the component menu, there are also components that have only one orientation (the same components on each page).

Parameter values

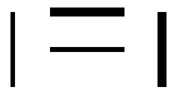
V	R	X	fi	Rg	Xg
621,8	0,1	0,1	0	0	0

When a component is dragged from the component menu to the diagram under constrcution, and each time a component in the single line diagram on the screen is clicked, the values of the parameters of the component appear either in a small window, or on a line in the the lower part of the screen together with a line containing the symbols of the parameters. The values on the line can be edited like a line in a text editor. That includes copying and pasting. The parameters are accepted by clicking almost anywhere on the screen: the OK-button, another component, some of the calculation buttons in the toolbar, etc.

The window containing the parameter table can be kept hidden by selecting "View | Parameter windows..." in the menu bar. The parameters of some components (transmission line, 2-w transformer, etc) can be displayed either in a table or on a line at the bottom of the screen. If the parameter window is kept hidden, the parameters of these components are displayed on the line at the bottom of the screen, when the component is clicked.

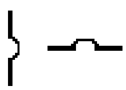
Units
This program uses basic units for all parameters (Volts, Amperes, Watts, ohms). The only exception seems to be the length of the transmission line, which is given in kilometers. However, for most components, the parameters can also be entered using the per-unit notation.

Connection wires and buses

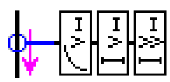


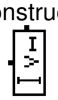
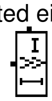
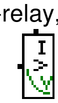
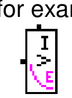
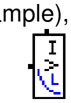
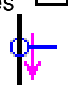
Wires (thin lines) and buses (thick lines) are just connection lines. They do not have any parameters. They are added to the diagram similarly as the other components, by dragging and dropping. They can be stretched up to a given length, and also shortened slightly. Put the cursor near to one end of the bus or wire, so that the cursor chages to a double arrow. Press the left mouse button, and move the mouse to stretch or shrink the wire or bus to the desired length.

Crossing wires

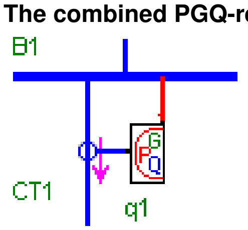


The crossing wires can cross (ordinary) wires without connection. They are just lines, and have no parameters. They cannot be stretched. Other components can be connected only to the ends of crossing wires. (If two ordinary wires or buses cross, then they are connected.)

Overcurrent relays 

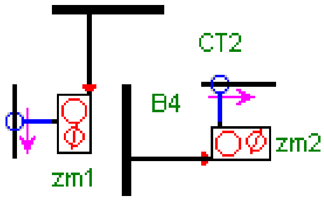
Relays are constructed either by connecting a combined relay (PGQ-relay, for example), or definite time modules   and at most one inverse time module     to a current transformer  . **Note:** The parameters of the current transformer are optional. It can also be used as a measurement point, without any parameters.

The combined PGQ-relay



The combined PGQ-relay is an overcurrent relay, that checks the **P**hase current, the sum current (or residual- or **G**round current) and the negative se**Q**uence current (multiplied by three!). Each of these currents can be checked using a combination of at most three relay modules: For this, there are available two definite time modules and one inverse time module. The relay cannot be connected to the other relay modules, it must be connected directly to the current transformer. **The electromechanical relay, the recloser relay, and the user defined relay** are similar combined relays as the PGQ-relay, but with different characteristics, and different parameter sets.

Mho distance relays



The distance relay measures the impedance, basically voltage divided by current. The connection point on the long side of the relay is connected (directly) to a current transformer. The connection point on the short side is connected to a bus or other component, either directly or using a wire. It "measures" the voltage. **The polygonal distance relay** is similar to the Mho distance relay, but with different characteristics.

The fault

The fault can be moved to the desired location by dragging and dropping like a normal component. The fault has no parameters.

Move one components or a group of components with the mouse
Any component, including the wires and buses, can be moved by dragging with the mouse.

A group of components can be moved in the following manner: Draw a rectangle around the group by pressing the left mouse button down and moving the mouse diagonally over the group. Release the mouse button and drag the rectangle to the desired position. Note: the connection wires do not follow the moving component(s). They must be stretched and/or added separately. The "select all" -button  can be used to draw a rectangle around the whole diagram.

The whole diagram can be moved with the arrow keys. Longer steps can be taken (up, down, right, left) by keeping the shift-key down, while pressing the arrow keys.

Deleting a component or a group of components
Left-click the component, and press the delete key on the keyboard. A group of components can be deleted in the following manner. First, draw a rectangle around the group with the mouse, as explained in the "move one component..." above. Next, press the "delete" key.
Alternatively, right click the component, or the component group, and click "delete" in the pop-up menu.
To undelete, click the undelete button, or click Edit | Undelete.

Copying a component or a group of components
Clilck a component, or draw a rectangle around a group of components, as explained in the "Move one component..." above. Click the copy-button 

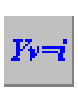
(or press ctrl-c on the keyboard). Click the paste button 

(or press ctrl-v on the keyboard). Drag the copied component(s) to the desired position. Note, that the component(s) is/are not copied on the Windows-clipboard, only to a local clipboard.

Moving other items on the screen
Almost all items appearing on the screen can be moved by dragging with the mouse: The component menu, the labels of the components, the boxes displaying the results, the title of the diagram, the lines with the parameter symbols and values (but only sideways).

Calculations

There is a separate button for each type of calculation.
Note: After a calculation, no results are visible, unless some of the display method described in "Display of the results" (below) is in use.

 Constant voltages: Solve the network by considering the generators and feeders as voltage sources with some internal impedance. The voltage parameter of the generator or feeder is the internal

phase to phase voltage.

Adjust voltages (without the tap chagners, or with the tap changers): Solve the network by considering the generators and feeders as voltage sources with some internal impedance. The voltage parameter of the generator or feeder is the phase to phase output voltage (at the terminals of the feeder or generator).

Solve the load flow problem (without the tap changers, or with the tap changers). The voltage parameter of the generators and the feeders is the output phase to phase voltage. The phase-parameter of the generators is not used in the load flow calculation.

Three phase fault calculation. Currents and voltages in the whole network are calculated. The fault is in the position shown by the fault component . It can be dragged and dropped like a normal component.

Phase to phase fault calculation.

Phase to earth fault calculation

Phase to phase to earth fault calculation.

Note: When one of the seven calculation buttons explained above is clicked, a picture of the button appears next to the network title, as a reminder of the latest operation. The picture can be hidden by clicking the small x in the upper left corner of the picture.

The initial, prefault state

The prefault state can be selected by the long, narrow button initial state ? below the fault buttons. If the button is not down, the initial state is recalculated by solving the network similarly as with the button). If the long button is pressed down, the short circuit calculation uses the results of a previous "adjust voltages" calculation (with the or the button), or of a previous Load flow calculation (with the or the button). The results of the most recent calculation are used.
Note: The above does not apply to the IEC 60909-calculation, because the standard does not take the prefault state into account.

Display of the results

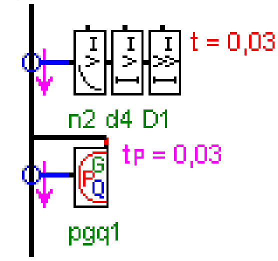
1) Clicking a component opens a small box, that shows the currents and/or voltages of that component. Can be disabled with the button. The box can be closed by clicking the (X) on the upper left corner of the box. **Note**, the displayed voltages are either sqrt(3) times the phase to ground voltages, phase to ground voltages as such, or phase to phase voltages, depending on the position of the √3 button. (The voltage parameters of the components are always phase to phase voltages).

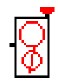
2) If the button is down, the value of the current or the power through the current transformer are shown beside the current transformers. One click of the button: current is shown, two clicks: power is shown.

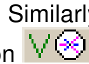
3) After a short circuit calculation, the clicking of a relay module (like) opens a new window that shows the characteristics of the relay, if defined, and the current in the current transformer connected to the relay. After a "dynamic" calculation, the current is shown as a function of time with a curve, but after

an IEC-calculation, only the initial current is shown with a small rectangle on the current axis.

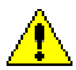
4) After a short circuit calculation, the activation time of the relays are shown on the right hand side of the relays. If the relay is not activated, the time is not shown. The shortest activation time is written in red.



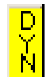
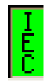
5) After a short circuit calculation, the clicking of a distance relay  opens a new form that shows the characteristics of the relay, and the measured impedance. The activation time and impedance of the distance relays are shown on the right hand side or under the relay.

6) When clicking a current transformer, the current is displayed in phasor form, if the "Show phasors of current transformers" -button  is down. Similarly, the voltage of a bus is displayed in phasor form, if the "Show voltage phasors of buses" -button  is down (not after an IEC-short circuit calculation).

Warnings

A warning sign  may appear in some cases. The warning-text can be seen either by keeping the cursor over the warning sign, or by clicking the warning sign. After clicking, the text will disappear, when the (X) in the text is clicked.

IEC 60909 short-circuit calculations

When the DYN / IEC button  /  is in the position IEC, the short circuit calculations are carried out according to the IEC 60909 standard. The program calculates the maximum initial current Ik" in the whole network. The peak current Ip and the breaking current Ib are calculated at the location of the fault. They are displayed in the result box, when the fault-component is clicked. When the DYN / IEC-button is in the position "DYN", the initial current is calculated using similarly as in the superposition method, and the currents are calculated as a function of time after the occurrence of the fault.

"IEC-parameters" of some components

Some components (generator, transformers, asynchronous and synchronous motors) need some additional parameters for the IEC-calculation. For example, the generator needs the nominal apparent power VAn, power factor pf, and the system (or network) voltage Vs. These parameters are not needed in the "dynamical" calculation, or when solving the network without a fault. On the other hand, there are several parameters that are needed in the "dynamical" calculations, but are not needed in the IEC-calculations. For example, in addition to the mentioned parameters, in the IEC-calculations, the generator needs only the nominal voltage Vn, the stator resistance Rs, the d-axis subtransient reactance X", and, in the cases of unsymmetrical faults, the zero- and negative sequence reactances X0, X2 .

Limitations

There are some (minor) limitations in the calculations.

The steady state current Ik is not calculated. When the DYN / IEC-button is in the position DYN, the steady state current is calculated and displayed, but **note**, this steady state current is typically smaller than that given by the IEC-standard. The standard assumes that the voltage controllers of the generators react in a given way. In this program, the controllers are not considered.

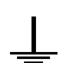
Only the maximum initial current Ik"max is calculated, not the minimum current.

The breaking current is calculated at 0.1s.

There can be only one fault in the network in the cases of unsymmetrical faults.

The standard defines a combination of a generator and a transformer as "a power plant block". The standard defines two methods for the impedance correction of such a block **:** A correction in the case of a block transformer with a step switch, and without such a switch. In this program, the correction factor is always calculated for "a block transformer with a step switch". There is no parameter in t his porgram that could be used to select the method.

Warning: If the fault is between the generator and the transformer of such a power plant block, then the correction factor of this program may not be exactly correct (The error is small in any case. I am still testing this.)

Warning: If there is a ground (earth)-component  in the network, the results may be completely wrong. The reason is the calculation method of the standard: The fault is replaced by a negative voltage source. The voltages of all other sources are set to zero. For example, if the fault is parallel with the branch with the ground-component, then the negative voltage at the fault causes a nonphysical current from ground.

Power factor of synchronous motors is assumed to be 0.8, because there is no power factor parameter for the syncronous motor in this program. The power factor is needed only for the impedance correction. The possible error caused by this assumption is (probably) small.

Additional issues

Voltages are not displayed, because they are not meaningful due to the calculation method.
The phases of the currents are not displayed, only the magnitude, for the same reason.
The powers through the current transformers are not displayed, because they are not meaningful.
The currents are not calculated as a function of time after the occurrence of the fault.
Some buttons of the toolbar are not available (show voltage phasors, show real+imag.components, etc)

Please note, Warning

1. Currents as a function of time, Warning !

Elplek calculates the currents as a function of time in the whole network after the occurrence of a fault (but not in the calculations according to IEC 60909). I have compared the currents calculated by Elplek with the transient simulation program ATP in different networks and with different faults. The currents agree well, so that I think the currents of Elplek are correct.

But, please note, there are two **simplifications** in Elplek.

1) Elplek assumes that the parameters (X", X', etc) are constants. In reality, they may change with time due to the saturation effects.

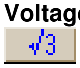
2) Elplek does not include the control system of the generators in the calculations. The control system may typically behave in two different ways in reality: Either it tries to keep the generator voltage at the desired value, or it may switch off the generator excitation. In the first case, the currents will be larger and in the latter case the currents will be smaller than those calculated by Elplek.

This means in practice, that the steady state currents after the occurrence of the fault are typically smaller in the "dynamical" calculations than the steady state currents according to IEC60909-calculations.

However, the currents calculated by Elplek durig the first few cycles (up to about 0.1s) are probably correct, because 1) the currents are typically so high that the saturation does not change during that time, and 2) because the generator control system is rather slow so that it does not react during the first few cycles.

2. Voltage convention

Voltage as a parameter: The voltage parameters (generator voltage, transformer voltage, etc, mostly Vn, but V1, V2 for transformers) of the components are phase to phase voltages. The phase-parameter is the phase angle of the phase to neutral voltage in the phase "a". (Here, as a parameter, Vn is the nominal voltage, but in the result boxes, Vn refers to the voltage of the neutral point.)

Voltage as a result: The voltages displayed as results of the calculations depend on the position of the


button.
- If the button is in the position of the picture, displaying sqrt(3), the voltages are sqrt(3) times the phase to ground voltages. The phase of the voltage (if shown) is the phase angle of the phase to ground voltage .
- If the caption of the button is "Ø n", phase to ground voltages are displayed.
- If the caption is "Ø Ø", phase to phase voltages are displayed.

Note: The phase to ground voltages are the same as phase to neutral voltages, except in the cases of line to earth and line to line to earth faults (of course). The circuits are always connected to ground in some way, mainly for numerical reasons. The earthing impedance of the neutral point of generators, feeders, and the Y-side(s) of transformers are always finite (at most about 1.e6 ohms). The zero sequence circuit of the D-side of a transformer is connected to the ground through a large impedance.

3. Units
Only basic units are used (Volt, Ampere, Watt, ohm). The only exception is the length of the transmission line. It is expressed in kilometers.

4. Comparison with other programs Warning!

If the calculation method is the same and the parameters are the same, then this program and other short circuit programs give the same results. There are a couple of sources for potential differences between the results from this program and other short circuit programs.

1) There are some limitations in the IEC 60909 -calculation of this program (Some parameters are not available, some currents are not calculated.)

2) There can be small differences in the way the superposition method is applied in this and other programs. (One well known program increases the internal impedance of feeders by a couple of percents in the case of a fault, for example.)

3) When the currents are calculated as a function of time, the method used in this program calculates the current of the fundamental frequency. The method is mostly equivalent with the superposition method, but there can be small differences.

The proper superposition does not take into account the q-axis subtransient reactance Xq", or, equivalently, it assumes that Xd" = Xq". In this program, Xq" is taken into account. This program may thus give different results compared with the superposition method in the cases when Xq" is not equal to Xd". Simulations (with ATP) show that the currents may contain higher harmonics when Xq" is not equal to Xd". This program calculates the rms-value of the fundamental frequency, and neglects the harmonics.
Note, warning: If Xq" of a generator is much smaller than Xd", then the initial short circuit current of the generator may be much larger in reality than that given by the superposition method. The results from this program agree reasonably well with the simulations with ATP, better than the results from the straightforward superposition method do .

It is assumed in this program that Xd = Xq, so that it is reasonable to assume that also Xd" and Xq" have similar values. But please remember to enter the value Xq" for the generator!

4) The parameters of asynchronous machines may be given in different ways in different programs. The efficiency, for example, may be constant, independent of power in some programs. In this proram, the efficiency depends on the power in the way determined by the (well known?) equivalent circuit of the machine. The short circuit currents of asynchronous machines seem to be rather sensitive to the initial state and small differences in the eventual impedances between the machine and the fault.

5. small fonts / large fonts

If the "Font"-parameter of your display is set to "large fonts", change it to to "small fonts", please. The program looks (and works) better with small fonts, although it can be used also with large fonts. (go to Start | Control panel | Display | Settings | ...)

File menu (1): Open, Save, Clear, Delete

Open opens a single line diagram file, extension *.sld. If there is already a diagram on the screen, it is not cleared automatically. Instead, the program asks, should the diagram be cleared first. This feature can be used to combine several smaller diagrams into a larger one.

Save file As... saves the displayed single line diagram. Note, there is no pure "Save" command, only the "Save file as ..."-command, in order to minimize the risk of inadvertedly overwriting an existing file.

Clear diagram clears (wipes out) the diagram on the screen. A confirmation is asked first.

Remove (delete) file opens a dialog box for deleting a single line diagram (*.sld) file. The default file is the file that has been opened most recently. In this way, one can first check the contents of the file to be deleted.

The dialog box of the "Open" command can also be used to delete a file: Click File | Open, and select the file to be deleted in the list of files shown and press the "delete" key.

The differences between these two methods of deleting the file are:

The "Remove (delete) file" automatically selects the file that has opened most recently and deletes the file completely.

The delete using the "Open" dialog also selects the file that has been opened most recently, but the focus is in the file name, not in the file itself, so that the "delete" key only clears the file name. When the file has been selected manually, the "delete" key moves the file to the recycle bin.

Open breakers opens a dialog box for opening several breakers at the same time. The dialog box is used to read in a file with the labels of the breakers to be opened. All other breakers are closed. A file with the labels of all brekers can be generated using the "find a component" function. The breakers to be closed can then be "commented" away by adding some special character (not a letter, not a number) in front of the label.

An example is given by the following list:
/S1
S2
/S3
S4
/S5
S6
/S7
/S9
S10
/S11
The breakers S1, S3, S5, S7 and S11are "removed" by adding the slash (/) in the front of the laber, and will be closed. The breakers S2, S4, S6, S10 will be opened.

All breakers can be closed by clicking the "open breakers"-item, and canceling the reading of the file. The program works in such a way, that it first closes all breakers, then reads in the file, and opens the breakers mentioned in the file. All "ordinary" breakers (looking like a breaker in the component menu) can be closed by clicking view | buttons, and clicking the button with the caption "C" on the right of the toolbar.

File menu (2): Print, Printer scaling

Print opens a printer dialog for printing the diagram. With a color printer, the diagram is printed in colors, else different grey-scales are used. If the diagram is so large, that it does not fit in one paper, it is continued to a second sheet of paper, but not further.

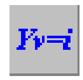
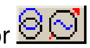
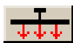
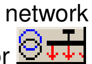
Printer scaling factor opens a small dialog for setting the printer scaling factor. The "normal" printer dialog (opened with the Print command) often contains a field for setting the scaling factor. In some printers this scaling factor also reduces (or enlarges) the printing area on the paper. This means that it is not possible to print a large diagram on a single paper even using the scaling factor of the "normal" printer dialog. If that is the case, try to set the scaling factor here. With this scaling factor, it should be possible to squeeze a large diagram on a single sheet of paper.

When all scaling factors are equal to 100 (%) or "normal", then the size of a typical component (for example a transformer, an impedance) is about 6 mm (about 1/4 inch) on the paper.

File menu (3): Export diagram

Export diagram ... allows one to save ("export") the diagram in six different formats:
- as a black and white bitmap (*.bmp)
- as a colored bitmap (*.bmp)
- as a colored windows metafile (*.wmf)
- as a *.dat file that can be used as an input file for EMTP-simulations
- as an *.atp file that can be used as input file for the ATP transient simulator
- as a Jpeg graphics file (*.jpg)

The bitmap, jpg-file and the windows metafile are graphics files that can be manipulated with graphics software and word processors.

NOTE: The network must be solved first, using one of the solution buttons  ,  or  , or  or  , before saving the diagram as a *.dat or an *.atp file. A short circuit calculation is not sufficient.

The *.dat file for the EMTP program

The *.dat file is a text file that can be edited with any text editor. The single line diagram is expanded into a three-phase network. Eaxch branch in the single line diagram becomes three separate branches. The machines are described as synchronous or asynchronous machines using the EMTP data format. **Note:** the inertia of the motors is set to be very large, so that the rotating speed does not change during the transient.The transformers are described as three single phase transformers that are connected in the desired way, as wye-wye, wye-delta etc. If the zero sequence impedance is different from the positive sequence impedance (the "0:1" parameter is not equal to 1 (or zero)), the difference (divided by three) is modeled as a contribution to the earthing impedance of the star point. This may lead to a negative earthing impedance, but the EMTP program seems to tolerate it (up to a point).

Note: The voltage parameters in this program are the effective values (rms) of the phase to phase voltages. The voltages are written to the *.dat file as amplitudes of the phase to neutral voltages. The reason is that it is easier to look at the amplitude than the rms-value in a transient.

If there is a fault in the network, it is described using switches. Three switches from the faulted phases to earth describe a three-phase fault, one switch between the phases a and b describe the line to line fault, and one switch from the phase a to earth describes the phase to earth fault. Only the switches describind the three-phase fault are active, the others are "commented" away. The line to line to earth fault is not included, but it can be constructed similarly using switches.

Default values have been used for the time step length, the simulation time and the closing (and opening) times of the switches describing the eventual fault. It is (highly) probable that the user must edit the *.dat file before entering it in the EMTP-program. If there are voltage sources (feeders) in the network, the initial state calculated by the EMTP program is not (always / usually / necessarily) an equilibrium state. The simulation time must then be increased from the default time, and the switching time of the fault switches must be delayed.

Only a couple of currents have been selected to be saved on the plot file (a "1" in the column 80 of the corresponding impedance). The user must (probable) add more currents for the plot file (more ones in the column 80 of the impedances).

Current transformers, overcurrent relays and distance relays are not included in the *.dat file. Similarly, the three winding transformer is still missing.

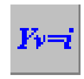
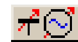
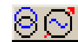
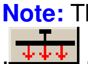
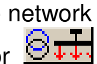
The *.atp file for the ATP program

The file is described on the next page.

ATP input file

The *.atp file for the ATP transient simulation program

The single line diagram can be exported as an input file for the ATP transient simulation program. The results of this program can be (easily) checked withe the ATP program using the generated *.atp file. The *.atp file is a text file that can edited with any text editor, and probably must be edited.

Note: The network must be solved first, using one of the solution buttons , , , , or , before saving the diagram as a *.atp file. A short circuit calculation is not sufficient.

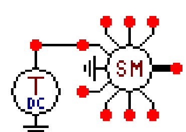
The single line diagram is expanded into a three-phase network. Each branch in the single line diagram becomes three separate branches, except for the branches connecting the neutral to earth. Only electrical components are inculded in the *.atp file. Switches, buses, current transformers and relays are not (yet?) included.

Note: The voltage parameters in this program are the effective values (rms) of the phase to phase voltages. The voltages are written to the *.atp file as amplitudes of the phase to neutral voltages. The reason is that it is easier to check the amplitude than the rms-value in a transient. Because the network is modeled as linear, the use of rms values or amplitudes does actually make any difference. The actual value of the voltage depends on the type of initialization, see below.

Default values have been used for the time step length, the simulation time and the closing and opening times of the switches used for the initialization of asynchronous motors, and for the switches describing the eventual fault. It is (highly) probable that the user must edit the *.atp file before entering it in the ATP-program. If there are voltage sources (feeders) or asynchronous motors in the network, the initial state calculated by the ATP program is not (always / usually / necessarily) an equilibrium state. The simulation time must then be increased from the default time, and the switching times of the switches must be delayed.

Only a couple of currents have been selected to be saved on the plot file (a "1" in the column 80 of the corresponding impedance). The user must (probable) add more currents for the plot file (more ones in the column 80 of the impedances). No voltages have been selected. Add the voltages to the end of the .atp-file, after the line "C node1 node2 node3 etc. six charaters/node" (two spaces in the beginning of the line).

Synchronous machines

The synchronous machies are described as ATP synchronous machine model 59 with 8 controls (Sm59_fc). Only the control for the exitation voltage is in use. The exitation voltage is set wtih a TACS DC-source (DC_01, step signal source). This is done automatically. The user does not usually need to worry or edit the exitation parameters, or any of the parameters of the synchronous machine. **Note:** the inertia of the motors is set to be very large, so that the rotating speed does not change during the transient. The amplitude, i.e. the "voltage at the terminals"-parameter of the SM59-model is set equal to the phase to neutral rms. voltage at the terminals of the synchronous machine of this program. The synchronous machine would be like this in ATPDraw: 

The transformers

The transformers are described as three single phase transformers that are connected in the desired way, as wye-wye, wye-delta etc. Because ATP needs impedances separately for both the primary and secondary windings, the reactance (X) of a transformer of this program is divided between the primary and secondary windings, in a somewhat arbitrary way. A small value is used, if the reactance is zero, because ATP does not accept a zero impedance.

If the zero sequence impedance is different from the positive sequence impedance (the "0:1" parameter is not equal to 1 (or zero)), the difference (divided by three) is modeled as a contribution to the earthing impedance of the star point. This may lead to a negative earthing impedance, but the ATP program seems to tolerate it.

The fault

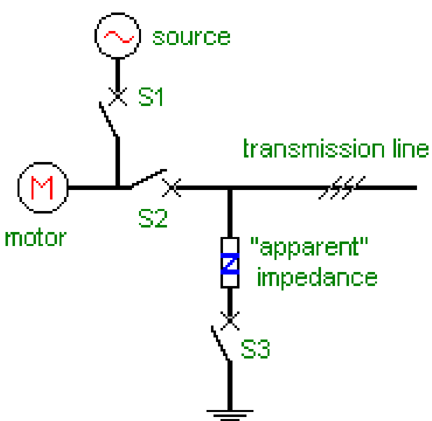
If there is a fault in the network, it is described using switches. Three switches from the faulted phases to earth describe a three-phase fault, one switch between the phases a and b describe the line to line fault, and one switch from the phase a to earth describes the phase to earth fault. Only the switches describing the three-phase fault are active, the others are "commented" away. The line to line to earth fault can be activated using switches for the line to earth fault and line to line fault.

The feeder

The feeder is described as three ungrounded voltage sources. The (eventual) internal impedance is modeled as a separate impedance. Actually, it may be better to set the internal impedance of a feeder of this program to zero, and to use a separate impedance for the internal impedance. The zero sequence impedance is modeled by adding one third of the difference between the zero sequence impedance and the internal impedance to the earthing impedance. The voltage amplitude of the source is set equal to the rms value of the internal phase to neutral voltage of the feeder. The actual value of the voltage depends on the calculation carried out by this program, as explained in the connection of the toolbar.

The asynchronous motor

The asynchronous motor is described with the unversal machine UM3-model of the ATP. Due to some peculiar features of ATP one motor is described with a small network, as shown in the picture below:



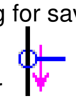
The transmission line is needed, if there are more than one induction motor in the network. ATP cannot handle several motors without such transmission lines. The length of the transmission line is as short as possible with the selected time step length. If the time step length is increased, the length of the trasmission line must be increased in proportion. Similarly, if the time step is shortened, the length of the transmission line can and should be shortened. The transmission line introduces an additional difference of some percents between the results from this program and from ATP. The difference can be decreased by shortening the time step length.

The additional source, impedance and switches are there for the initialization of the motor. The voltage of the source is equal to the voltage at the terminals of the motor in steady state. The "apparent" impedance is equal to the voltage at the motor terminals divided by the motor current in steay state. The switches S1 and S3 are closed initially. The network and the motor are initialized in ATP to the correct voltage and current. After a fraction of a second, the switches S1 and S3 are opened and the switch S2 is closed. Because these switchings may cause some additional transients, it is better to start the study of the network (to close the fault switches, for example) first after a small delay of at least one second. (The default switching times take this into account.)

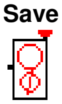
Note: The switches are included also when the motor acts as a generator (power or slip < 0), but they are not used. That is, S1 and S3 are open, and S2 is closed all the time. The reason is that the initialization of an asynchronous generator seems to be different from that of an asynchronous motor in ATP.

The rotating speed of the motor is kept constant. The speed is modeled by a DC voltage source and a capacitor that are connected to the mechanical node. The numerical value of the voltage of the source is equal to the angular rotating speed of the motor, in radians/sec.

File menu (4): Save currents, impedances,Exit

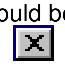
Save currents with time. The program calculates the currents in the network as a function of time in the cases of different faults. The "Save currents with time" opens a save dialog for saving the values of the currents at discrete points of time. The currents of each current transformer  are saved in the selected text file. The file contains nine or thirteen columns for each current transformer. The first colum gives the time. The next six columns show the absolute value (the rms-value) and phase angle of the currents of the three phases at the given time. The last columns show the absolute value of the residual current (the sum of the currents in the three phases) and its phase, and in the case of unsymmetrical faults, the magnitude and angle of the positive and three times negative sequence currents.

Before writing the values to file, the program asks **" Write all (Yes) or selected (No) ? "**. If the answer is Yes, then the currents of all current transformers are written to the file. If the answer is No, then only the currents of selected current transformers are written to file. The transformers are selected ("filtered") by adding the "filtered" (or selected) flag ¤ to the label of the component. The same flag is used in the reports. The flag can be added and removed either by right-clicking the component, and clicking the "Filter" item in the pop-up menu, or right-clicking the label itself. (The ' ¤ ' can also be edited directly to the label, of course.). All flags can be displayed or removed using the "Advanced" option in the menubar.

Save impedances with time. The program calculate the impedance at the locations of distance relays  in two ways: as phase impedance (type 21) and as ground impedance (type 21N). The values of the impedances are shown on the screen when the currents in the network have been solved. Only the initial values of the impedances are shown after a short circuit calculation. The menu item "Save impedances with time" opens a save dialog for saving the values of the impedances as a function of time for each distance relay and for each phase. The notation is the following: Zph(a) is the phase impedance (type 21) of phase ***a***, and Zgr(b) is the ground impedance (type 21N) of phase ***b***.

Before writing the values to file, the program asks **" Write all (Yes) or selected (No) ? "**. If the answer is yes, then the impedances of all distance relays are written to the file. If the answer is No, then only the impedances of selected distance relays are written to file. See above for the selecting method.

Exit closes the program (exits). If the single line diagram has been changed since opening, or saving, a message box appears that asks, whether the diagram should be saved.

Note: You can also exit the program using the exit button  in the upper right hand corner of the screen.

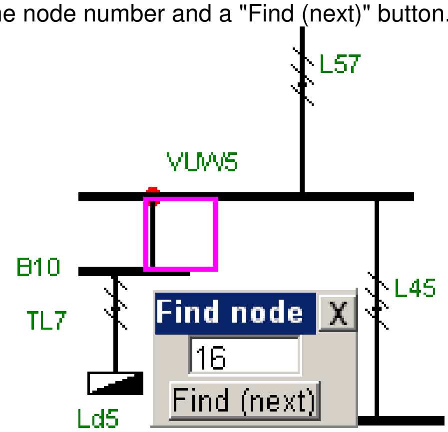
Edit menu

Undelete cancels ("undeletes") the latest delete operation by returning the deleted component(s). But note, the components are returned in exactly the same position where they were when deleting. If the diagram has been moved around, the previously deleted components may appear in a strange position. This "undelete" -peration can also be carried out with the the Undo-button. The difference is that the Undo-button "undoes" all (or most) operations, like adding, moving and deleting. The "Undelete"-command only cancels the delete operations.

Clear results clears all calculated results, so that the state (mainly) corresponds to a new or recently opened network.

Reselect selects again a group of components that was selected previoulsy (and unselected later) for moving or copying. This can be handy especially when working in the window containing the zoomed-out diagram. First, move the selected components roughly to the correct position in the zoomed-out diagram. Next, go to the main diagram, reselect the components, and move the components exactly in the desired position.

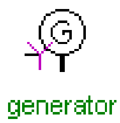
Find node...
The components are connected in nodes, or connecting points. The nodes are numbered from zero to some (large) number. Zero always refers to the ground. The numbers of the nodes may not often be of interest for the user. Some error messages refer to the node numbers, however. A given node (node number) can be found by clicking "Find node.." in the Edit menu. A small window opens with a box for the node number and a "Find (next)" button.



When the button is clicked, a purple (magenta) rectangle and a red dot appear on the component where the node of the given number is first found. When the button is clicked againg, the rectangle and the dot move to the next component where the node is found. Because several components can be connected to the given node, the rectangle and the dot may appear in several positions, when the button is clicked successively. In the picture above, for example, the node 16 connects three transmission lines (L57, TL7, L45) two busbars (WUV5 and B10), and some connecting lines (that are taken as components here).

The rectangle and the red dot disappear, when the Find node-window is closed

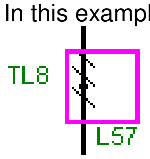
Note: The node numbers are defined when a calculation (solve net, calculate fault currents,... etc) is carried out.
Note: There are also nodes that do not connect components. The reason is that each variable (current or voltage) is associated with a node, for computational reasons. If a component has some internal variables, then a node must be defined for that variable. For example, the generator component



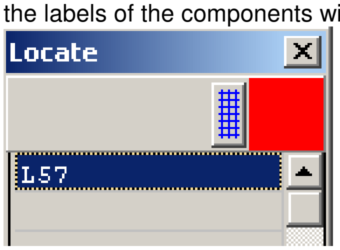
has two internal variables: the internal voltage and the current out. Thus, totally three nodes are associated with the generator: one for connecting it to other components, and two for the internal variables. The output voltage is associated with the connecting node.

Find overlapping

It is difficult to see when a component is on top of another component, especially if that another component is of same type as the first component.
In this example, there are two transmission line-components (TL8 and L57) in the same position



Such a situation is mostly undesirable and can lead to errors. Such overlapping components can be found by clicking "Find overlapping" in the Edit menu. If there are overlapping components, a list with the labels of the components will appear (Only one label in each overlapping pair).



When the label is clicked in the list, a purple rectangle appears on the overlapping components.

Note: Overlapping components are automatically checked in the beginning of calculations.

View menu

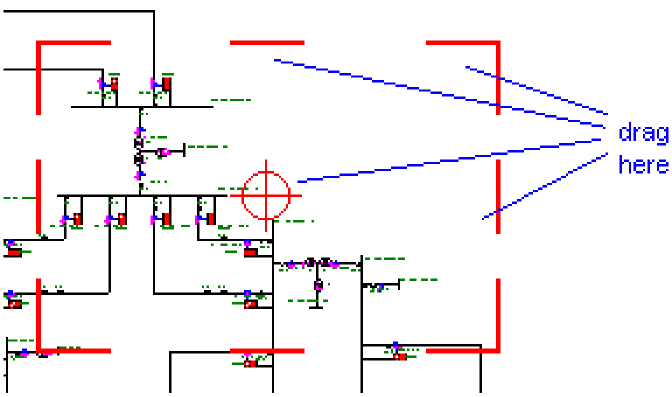
The View menu

Report
 allows the user to see or to hide the report. The report is a (tabbed) notebook, that is used to save the results from the calculations.

Note Block
opens a small text editor for notes etc. The notes are saved and retrieved together with the single line diagram.

Per Unit calc. displays the calculator for converting impedances from "per unit" convention to ohms. The calculator can also be called using the PU calc-button, that appears when the parameters of a component are edited.

Zoomed Diagram
opens a new window where the single line diagram is drawn in reduced size, as "zoomed-out". An icreased, or zoomed-in diagram can aso be shown, see the chapter for the zoomed diagram.. The zoomed-out diagram can be used to navigate in the main (proper) single line diagram. The red corners and lines (and the circle) show which part of the main (proper) sinlge line diagram is visible in the main window. Drag one of these red lines or corners or the circle to the desired position (the others follow). When you release the mouse button, the main diagram moves so that the part of the single line diagram indicated by the new position of the red corners and lines becomes visible in the main window. (Drag: move the cursor inside one of the corners or near to a line, or on the circle in the middle, so that the cursor changes to a double arrow. Press the left mouse button down and move the mouse. Release the mouse button at the desired location .)



Buttons
makes a couple of buttons visible on the toolbar. These buttons are (mainly) for testing. Presently, three buttons become visible:
- a button marked with "N" determines the connections between the components, i.e. determines the nodes of the network.
- a button marked with "+ -" or " with "Ø" determines which method is used by the distance relays to determine the direction of the fault.
- a button with the caption "C". It can be used to close all "oridnary" breakers (looking like a breaker in the component menu).
- a button with the caption "G". It can be used to carry out the automatic change of parameter groups of relays.
- a button with the caption "m". If this button is down, the Thevenin impedances are displayed in milliOhms, else in Ohms. The calculation is carried out withe the Z012-button.
- a button with the caption "tr". If this button is down, the transformers are modeled as ideal transformers = zero impedance, zero magnetizing current.

Parameter report
 allows the user to see or to hide the parameter report. The parameter report is a (tabbed) notebook,

that is used to save the parameters of the components in the network.

Sequence impedances
Display / hide the sequence impedances (Z0, Z1, Z2). but only if the impedances have been calculated.

Note: The impedances are calculated only by clicking the "Calculate sequence impedances"-button , they are not calculated automatically. The calculated values are saved until a new calculation is carried out. Thus, the saved values may be outdated, if the single line diagram or some parameters have been changed.

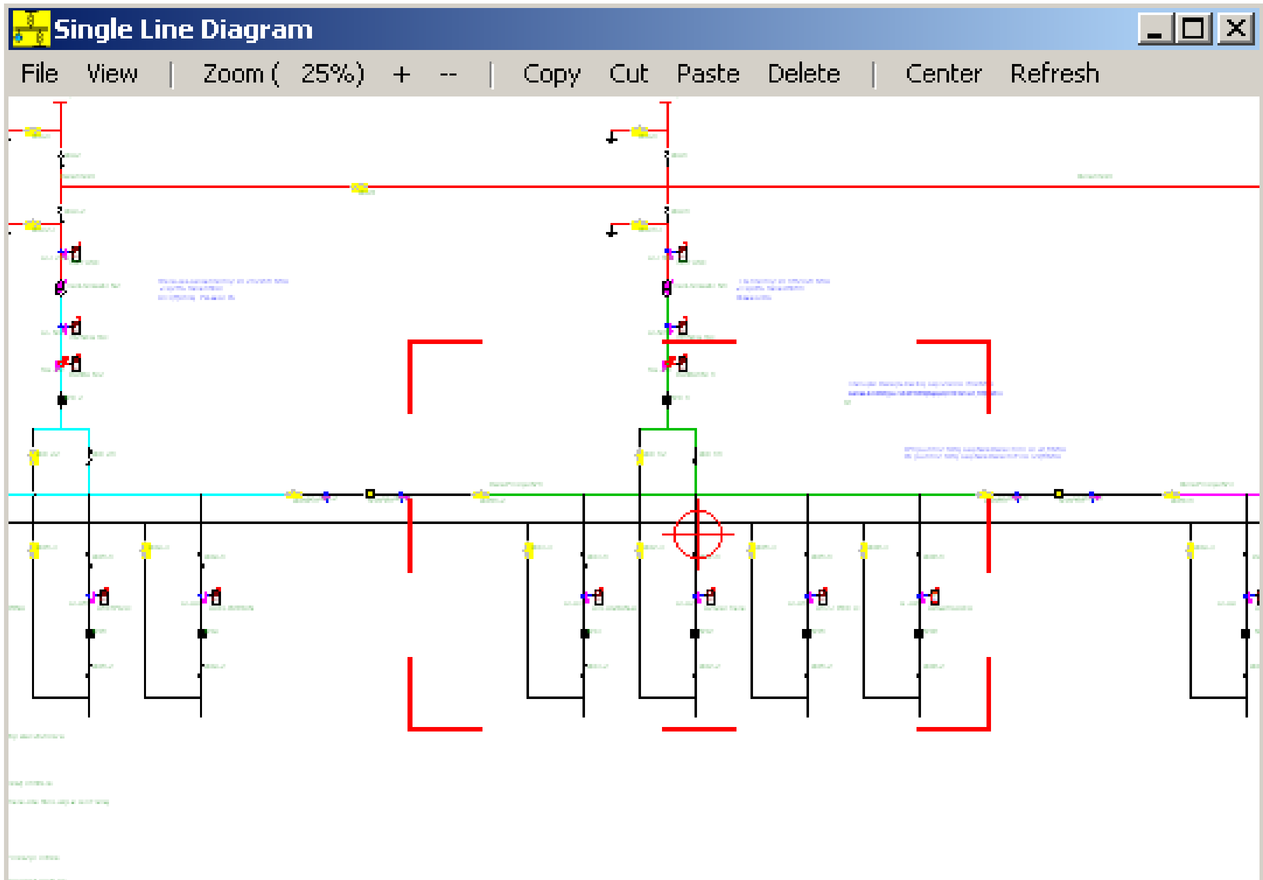
Parameter windows
Some relays and a few other components have so many parameters, that the values of the parameters are viewed and edited on a small window. This window becomes visible when the component is clicked. These parameter windows can be kept hidden by unchecking the corresponding tick box in the "show parameter window"-menu.

Note: If the box is not checked, the main parameters of some components (generator, feeder, 2w-transformer, etc) are displayed on a line at the bottom of the screen, in the same way as for the components that do not have parameter windows.

The buttons
OK accepts the states of the tick-boxes.
Cancel cancels the changes in the tick-boxes
Set all sets all tick boxes in the "checked"-state
Clear all removes the checking from all tick-boxes

Zoomed diagram

A zoomed (out or in, see below) single line diagram becomes visible in a separate window, when the user clicks "view | Zoomed Diagram" in the menu bar.



The red corners and lines show the part of the diagram that is visible in the main window. Drag one of these red lines or corners or the circle to a new position (the others follow). When you release the mouse button, the main diagram moves so that the part of the single line diagram indicated by the new position of the red corners and lines becomes visible in the main window.

The zoomed diagram can be moved with the arrow keys: up, down, left, right. Longer steps are taken, if the shift-key is kept down when using the arrow keys.

The menu bar in the window of the zoomed diagram

File | **Exit** closes the window of the zoomed diagram

View | **Indicator**
When the Indicator is selected (checked) the red corners and lines are visible. They show the position of the main window.

Zoom
The zoom ratio can be selected in the menu that appears. If the "width" is clicked in the menu, the zoom ratio is adjusted so that the whole diagram fits to the width of the zoom-window. If the width of the window is changed, the size of the zoomed diagram changes accordingly.

The **+ and --** can be used to increase or decrease the zooming ratio by one step.

The **Copy Cut Paste Delete** can be used for just that, copying, cutting, pasting, or deleting component(s). But before that, some component(s) must be selected in the zoomed diagram, see below. Keys in the keyboard can also be used: ctrl-c for copying, ctrl-x for cutting, ctrl-v for pasting, and the delete-key for deleting.

Note: that the copying and cutting copies the selected component(s) to a local "clipboard", not to the windows-clipboard.
Note: The copy/cut/paste/delete of the zoomed window can be used only for operations in the zoomed window. Similarly, the copy/cut/paste of the main window can be used only for operations in the main window.

Center moves the diagram in the zoomed window so that the center of the main window is displayed in the center of the zoomed window. This can be handy, if the zoomed diagram has been drifted out of sight due to zooming and moving operations.

Refresh redraws the zoomed diagram.

Operations in the zoomed diagram

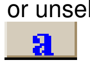
Some simple construction operations can be carried out in the zoomed diagram. They are move, copy, cut, paste, and delete. But before that, some component(s) must be selected. There are two ways to select components: to click a component or to draw a rectangle around the component(s) with the mouse, similarly as in the main diagram.
Several separate components can be selected by keeping the ctrl-key down while clicking the components successively with the mouse in the zoomed diagram.
A group of components can be selected by drawing a rectangle with the mouse around the components. Separate components and one group of components can be selected by keeping the ctrl-key down while clicking the components, and/or while drawing the rectangle.
Note: Only one rectangle can be drawn (with or without the ctrl-key). (Several rectangles can be drawn in the main diagram, if the ctrl-key is down.)
Note: A single component can be moved in the zoomed diagram with the mouse, but only after it has been selected by clicking it with the mouse, or by drawing a rectangle around it.

Options, Advanced

Options

Show 3*Ineg, 3*Izero, 3*V2, 3*V0

When this option is selected (checked) the **numerical values** of negative and zero sequence currents and voltages are displayed multiplied by three. When this option is not checked, the numerical values of the negative and zero sequence currents and voltages are displayed as such.

This option can be selected or unselected also by pressing the Alt-key, when clicking the "display data of phase a or b or c"-button 

Note: This option has no effect on the graphical display of the currents. When a PGQ-relay is clicked after an unsymmetrical fault calculation, the multiplier of currents depends on the selected plane: phase plane, or negative sequence plane, and, for the negative sequence currents, on the selection of "I2" or "3*I2", see below.
- -

IEC impedance correction

When this option is selected, the IEC-impedance correction is included in the calculations of the short circuit currents according to IEC 60909. The correction can be switched off by unselecting this option. This may be useful when testing.
- -

Show trafo tap in %

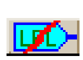
When this button is up, the tap position is displayed as a multiplier for the transformation ratio of primary voltage over the secondary voltage. When the button is down the tap position is displayed as the relative change in the secondary voltage in percent. See also the explanation in connection with the calculation buttons.

Show component notes...

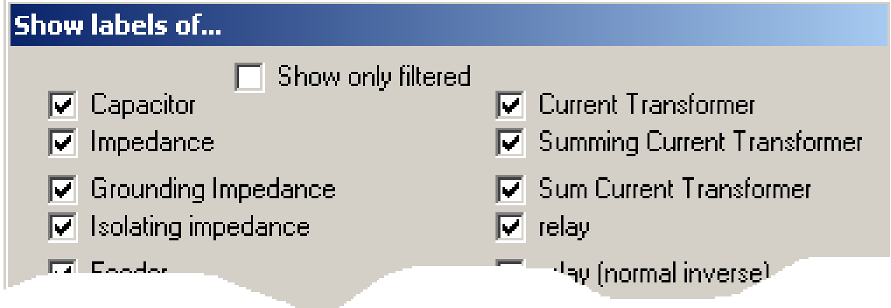
Some relays have a text-box where the user can write notes. These notes can be displayed in the main window (over the single line diagram), when the cursor moves over the relay. If the option "**Show component notes...**" is clicked, a small submenu appears for displaying these notes in the main window. If the item **"Show notes"** is selected (checked) in the submenu, the notes become visible, when the cursor is moved over the component. If the item **"Show filtered"** is checked, then the notes of only the "filtered" relays (with a ¤ in the label) are displayed. If the **"Do not show"**-item is checked, the notes are not displayed.

Unselect automatically
A group of components can be selected for copying/pasting or moving by drawing a rectangle around the components with the mouse. If the "Unselect automatically"-option is selected (checked), the group of the components are no more selected after finishing the moving or the copy-paste operation, else the group remains selected after the operation. The components can be unselected by clicking an empty space on the diagram.

Copy with labels
When components are copied with copy-paste (ctrl-c, ctrl-v), the labels (identifiers) are also copied, if the "Copy with labels"-option is selected (checked). If not, then the labels are not copied, and default labels are used.

Show labels...
When the "Hide component labels"-button  in the tool bar of the main window is down, the labels (identifiers) of the components are not shown. But when the button is up, the "Show labels..."-option can be used to select the component types for which the labels are shown. When the "Show labels..." item is

clicked, a small dialogue window opens



The component types for which the labels are shown can be selected in this window by checking/unchecking the boxes for the component types.
If the "Show only filtered"-box is checked, then the labels of filtered components only are displayed (see also below).

The buttons in the lower part of the "**Show labels of..**" window
OK shows the labels of the selected component types, and hides the labels of the unselected. Closes the window.
Apply as OK, but does not close the window
Cancel cancels the changes, closes the window
Set all checks all component types (all labels shown)
Clear all unchecks all component types (no labels shown)
Hint displays a small help-memo

3w trafo impedances checked

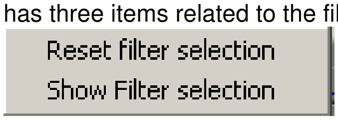
When the impedances between windings of a three-widing transformer are normalized to the same voltage, then every impedance should be smaller than the sum of the other two. That is, Z12 < Z13+ Z23(norm), etc. When this "3w trafo impedances checked"-item is selected, then the impedances of three winding transformers are checked and corrected, so that the abovementioned condition holds. The correction is done by reducing the largest (normalized) impedance. If this item is not selected, the impedances are checked but not corrected, only a warning is given, if needed.

Use I2 (not 3*I2) in relays
The user can selected, is the negative sequence current (I2) used as such, or as multiplied by three (3*I2) in the coordination graphics and when checking the activation of relays (but not elsewhere).

- -

Advanced

Filter
Components can be "filtered", i.e. selected for reports of results, or reports of parameters. This submenu has three items related to the filtering (selecting)



The "Reset filter selection" removes the "filtered" (or selected) flag from all filtered components.
The "Show Filter selection" highlights the filtered components, i.e. draws a grey rectangle under the filtered components in the single line diagram, in order to show which components are filtered (selected). The grey rectangles disappear by clicking on some empty point on the screen.
The "Restore filter selection" restores the filtering of components to the state immediately before the "Reset filter selection" was clicked.

Short Circuit all buses opens a dialogue for calculating the short circuit currents or the sequence impedances in all buses and voltmeters successively. The dialogue and the calculations are described in more detail in the chapter "Short circuit in all buses and voltmeters"

Relay parameter groups... opens a small menu for the parameter groups of the relays. The items in the menu are:

Parameters changed automatically when this item is checked, the parameter groups of relays are checked and possibly changed, when any breaker is opened or closed

Clear all conditions clears all conditions for all relays to change the parameter groups

Manual mode all relays sets all relays in manual mode with respect to the parameter groups. That is, the conditions are not checked and parameter groups are not changed when breakers are opened or closed

Reset relay curves It is possible to show the complete characteristic curve of combined relays, only the inverse time part, or only the definite time part by changing the value of the "Show curve and Act. test"-parameter in the window for relay parameters. The clicking of the "Reset relay curves"-item in the Advanced menu resets this parameter for all (combined) relays, so that the complete curves will be shown.

Load scenario and multiplier opens a small window for selecting the load scenario, that is, an alternative set of parameters for the loads. The global scaling factor (multiplier) can also be set in this window. Note: The selected scenario and scaling factor are applied to all load-components.

Protection calculator starts the Differential Protection Calculator, program matrixpr, if the file matrixpr.exe is in the same directory as elplek.exe. See http://pp.kpnet.fi/ijl/matrix.htm

k0 calculator starts the k0 calculator, program k0calcpr, if the file k0calcpr.exe is in the same directory as elplek.exe. See http://pp.kpnet.fi/ijl/prog.htm

Line impedance sum starts the calculator for calculating the sum of impedances etc. of several transmission lines.

Shunt capacitor calculator

Shunt capacitor banks are used to improve the quality of the electrical supply. This calculator calculates diverse variables for shunt capacitor banks, when the main parameters are given. The results include currents and voltages in the case of faulted capacitors. The calculator has a separate help-file. (Click "help" in the menu bar of the calculator)

Relay coordination calculator

opens a window for coordination of relays protecting transmission lines.

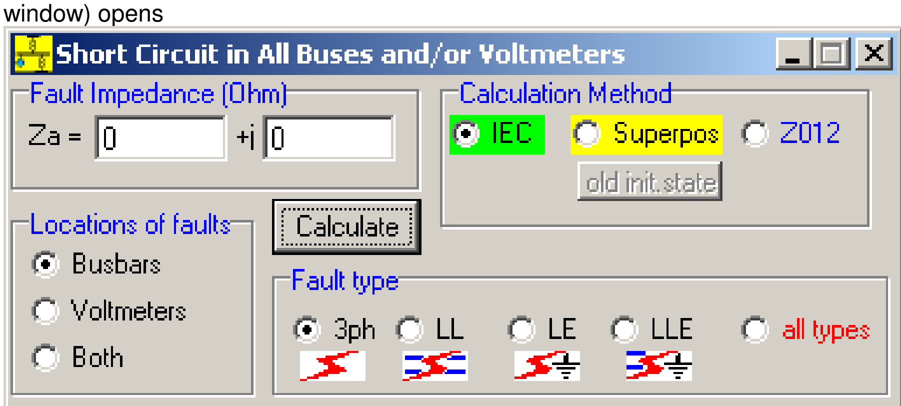
PGQ relay equations

opens a window for editing PGQ relay equations in human readable form

Short circuit in all buses and voltmeters

Short circuit or the sequence impedances in all buses and voltmeters

When the user clicks "Advanced | Short Circuit all buses" in the menu bar, the following dialogue (or window) opens



The window can be used to calculate the fault current or the sequence impedances for a fault in all buses and voltmeters in turn. (The symbol of a voltmeter is a small circle, a voltmeter is practically the same as a bus).

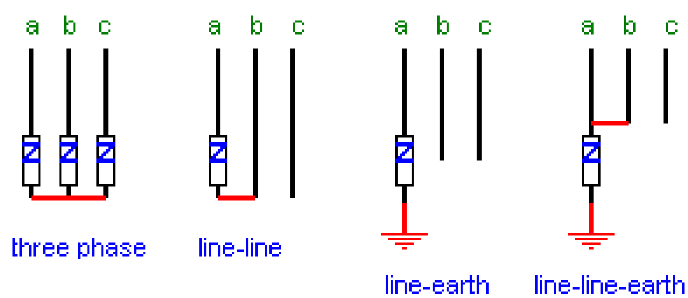
For testing purposes, the calculatios are also carried out at the location of an eventual short circuit component.

Note: Only the initial symmetrical fault current is calculated, neither the peak nor the breaking current at the fault and not any currents in the network itself.

Note: When a bus or a voltmeter is clicked after the calculations, the fault current or the sequence impedances for that bus or voltmeter is/are displayed in the result box. But if some other component than a bus or a voltmeter is clicked, the result box does not appear.

The fields in the dialogue

Fault impedance (Ohm) **Note:** Not used, when the sequence impedances are calculated)
Enter the real and imaginary components of the impedance of the fault in the small fields. The fault impedances are defined in the following way for the four different types of faults:



Note: One cannot define the impedance of the fault in a "normal" fault current calcuation, when there is only one fault (or a few faults) in the network. A separate impedance component must be used to describe an eventual fault impedance. But the resulting "fault impedance" will be slightly different from the impedance decribed in this chapter. Compare the figures above with those in chapter "The Toolbar (3): faults", especially the line-line and line-line-earth faults.

Calculation method
Two calculation methods can be used: the method according to the the IEC 60909-standard, and the superposition method. This time, the "superposition method" is really the proper superposition method.

The normal, dynamical calculation uses a method that calculates the current of the fundamental frequency, as is described in section "Comparison with other programs. Warning!".

The third "method" marked with Z012 is used to calculate the sequence impedances.

If the superpostion method is selected, the user can select the initial state (similarly as in the normal fault calculation): A precalculated initial state is used, when the "old init. state" button is down. A "fresh" initial state obtained by a straightforward solution of the network is used, when the "old init. state" button is up

Locations of faults

The user can select the locations of the faults: all buses only, all voltmeters only, or both all buses and all voltmeters.

Fault type

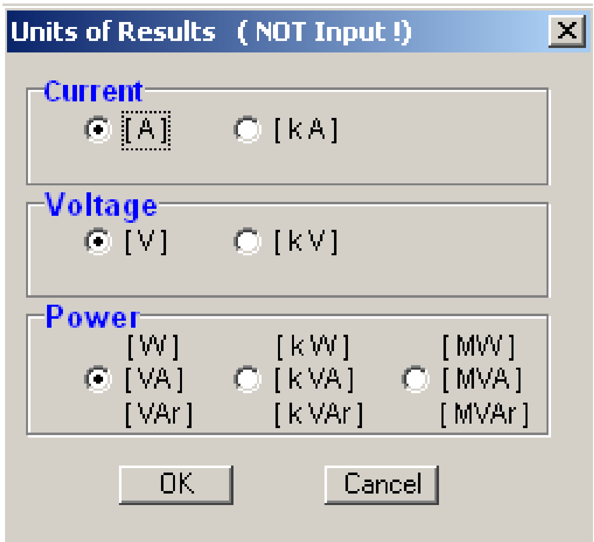
The user can select any of the four fault types: a three-phase fault, a line-to-line fault, a line-to-earth fault, or a line-to-line-to-earth fault, or, as a fifth alternative, all fault types in one calculation. Not used, when the sequence impedances are calculated.

The calculations are carried out when the "Calculate" button is pressed.

Units of results (V, A ,W (VA)

The units for current, voltage, and power of the displayed results can be selected by clicking the item in the tool bar labeled as V, A, W (VA).
Note: The label can also read kV, A, MW(MVA), or kV, kA, kW (kVA), or..., because the label displays the units that are in use.
Note: The units can only be selected for the results, the parameter values of the components must always be entered in basic units.

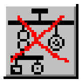
When the user clicks the V A W-label, a small dialogue appears

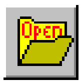


The units are selected by clicking one of the radio-buttons. The OK-button accepts the new units. The Cancel-button cancels the selection of the units, so that the previous selection is valid.

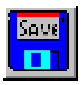
Note: The selected units are also used in the report.

Toolbar (1): Clear, Open, Save As

 clears (wipes out) the single line diagram on the screen. Same as the menu command File | Clear diagram.

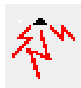


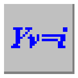
opens a single line diagram file, extension *.sld. If there is already a diagram on the screen, it is not cleared automatically. Instead, the program asks, should the diagram s be cleared first. This feature can be used to combine several smaller diagrams into a larger one. Same as the menu command File | Open file.



saves the displayed single line diagram using a file name defined by the user. Note, there is no pure "Save" command, only the "Save file as ..."-command, in order to minimize the risk of inadvertedly overwriting an existing file. Same as the menu command File | Save file As ....

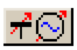
Toolbar (2): solve the network

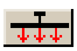
Note: An eventual fault  in the network is neglected when solving the network with the buttons described on this page.

 solves the network in a straightforward way. The generators and feeders are considered as voltage sources with some internal impedance. The voltage parameter Vn of generators and V of feeders is the internal phase to phase voltage. The loads and motors are considered as fixed impedances, the power is not forced to the value given by the power-parameter.

Note: If there is an unsymmetrical load-component in the net, then this straightforward solution of the network is the only calculation available. The other calculation buttons described on this page are not enabled.

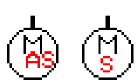
When one of the "open line fault"-buttons  is pressed, the steady state currents are calculated in the network with an one- or two phase open line fault in phase c or in phases b and c at the location indicated by the "open line fault"-component 

 solves the network in a straightforward way. The generators and feeders are considered as voltage sources with some internal impedance. The internal voltages of synchronous generators (but not the asynchronous generators) and feeders are adjusted so that the the phase to phase output voltage, at the terminals is equal to the voltage parameter Vn or V, respectively. The loads and motors are considered as fixed impedances, the power is not forced to the value given by the power-parameter.

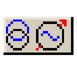
 carries out a load flow calculation. The active power of generators (connected to a PV bus) and the active and reactive power of loads (connected to a PQ bus) are given. A "load" can be positive = consuming load, or negative = generating "load".The absolute value of the output voltages of the generators (the voltage at the terminals) are given. The phase parameter (fi) of the generator is not used. For the feeders, the output voltage and its phase are given (voltage and phase at the terminals). Actually, there should be only one feeder, the "slack bus".

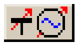
The program solves the phase of the generator voltage, the generator reactive power, and the active and reactive power of the feeder, and the magnitude and phase of the voltages of the loads. When these are known, the voltages and currents in the whole network are solved. If the load flow problem cannot be solved (does not converge), a warning is given, and some "reasonable" set of votlages and currents is given as the solution.

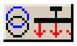
Note: There are no constraints on the reactive power of the generators. The absolute value of the voltages of the generators are not adjusted.

Note: The motors  are considered as impedances. The size of the impedance is calculated from the nominal voltage, desired power etc., and it is fixed in the load flow calculation. If the voltage of the motor is near to the nominal voltage, then the power of the motor is near to the desired power. But the load flow calculation does not force the power of the motor to the desired value, as is done with the "proper" loads.

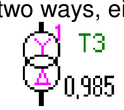
Note: The eventual asynchronous generators (asyncronous motors with a negative power parameter) are modeled as an impedance with a negative resistive component (and a positive reactance). The power or voltage is not adjusted in any way. But if the voltage is near to the nominal value, then the power out of the generator is near to the desired power.

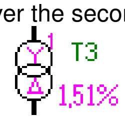
 solves the network and adjusts the transformer tap positions. The calculation is the basically

same as with the  button above. The transformer taps are adjusted so that the secondary voltage of the transformers is equal to the secondary system voltage given by the Vs2-parameter of the transformer. (If Vs2 is zero, then the secondary voltage parameter V2 is used.) The resulting tap position is displayed near the transformer.

 solves the load flow problem and adjusts the transformer tap positions.

Note: The tap position is a continuous variable, there are no steps.

Note: The tap position can be displayed in two ways, either as a multiplier for the transformation ratio of primary voltage over the secondary voltage 

, or as the relative change in the secondary voltage in percent 

. In the first picture of this example, the tap as the multiplier of the transformer ratio is tap = 0.985. This measn that the tap is in such a position that the transformation ratio is 0.985 * (V1nom/V2nom), where V1nom / V2nom is the nominal transformation ratio. The second picture of this example tells that the relative change in the secondary voltage in percent is 100*dV2/ V2nom = 100*(1/tap - 1) = 1.52 %.

The display of the tap can be changed by clicking "Options | Show trafo tap in %" in the menu bar.

The tap position is limited by the transformer parameters tmin and tmax. These must be given as the multiplier for the transformation ratio of the primary voltage over the secondary voltage. Typical values are tmin = 0.85 and tmax = 1.05. The default value is equal to one for both tmin and tmax. This means that the tap is fixed at 1 (or 0%) as a default.

Buses in the Load Flow problem

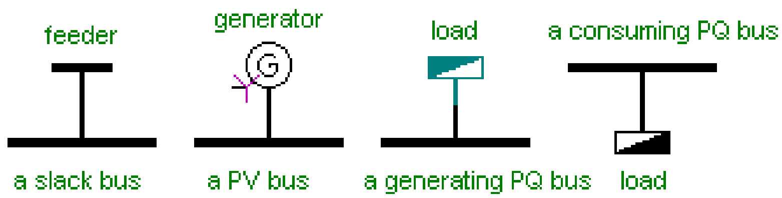
The buses in a Load Flow problem

There are three different types of buses in a load flow problem:

- a slack bus (or a swing bus). The magnitude and phase of the voltage are defined. The real and reactive power are calculated.
  There should be only one slack bus in a network.
- a PV-bus. The real power and the magnitude of the voltage are defined. The phase of the voltage and the reactive power are calculated.
- a PQ-bus. The real and reactive powers are given. The magnitude and phase of the voltage are calculated. The power can be generated or consumed.

In Elplek, a bus is a thick line without any parameters. It just connects components. It can be thought to be a wire with zero impedance.

A bus of elplek becomes a bus of a given type (defined above) by connecting a suitable component to it.



- a slack bus: connect a feeder to the bus. There should be only one slack bus in the network.

- a PV-bus: connect a generator to the bus

- a PQ-bus: connect a load to the bus. The parameters of a load (in elplek) are the apparent power VA, the nominal phase to phase voltage Vn, and the power factor pf. The sign convention of the apparent power is such that a load has positive apparent power, a negative apparent power indicates generated power. The symbol of the load changes color, if the apparent power is negative.

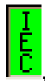
NOTE: A generating PQ-bus (load with negative power) can be used only in load flow calculations, not in a short circuit calculation, for example. (It is replaced by an impedance.)

If you need to carry out short circuit calculations with a generating PQ-bus, you can proceed in the following way:
- Carry out a normal load flow calculation
- Observe the voltage at the generating PQ-bus (at the load component, acting as a PQ-bus).
- Replace the generating PQ-bus (the load component) with a feeder. Set the voltage of the feeder equal to the observed voltage. Set suitable values to the impedances of the feeder (this may be problematic!).
- Carry out an new load flow calculation.
- Push the "calculate initial state/ use old initial state"-button down (the long button under the short circuit buttons).
- Carry out the short circuit calculation
Note however, that the results may depend strongly on the impedances you selected for the feeder.

Toolbar (3): faults

When the "DYN / IEC" button is in the position 

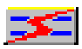
, the initial currents are calculated with the superposition method (actually, with an equivalent method), and the currents are calculated as a function of time.

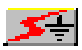
When the button is in the position 

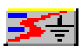
, the initial, peak and breaking currents are calculated according to the IEC60909 standard, with some minor limitations, see "IEC 60909 short circuit calculations".

Note: In the case of the three phase fault, there can be several (or no) faults in the network. For the other faults, there must be exactly one fault in the network. The reason for this is the solution method.

 calculates the currents in the case of a three-phase short circuit (fault)

 calculates the currents in the case of a line-to-line short circuit (fault). The fault is between the phases b and c.

 calculates the currents in the case of a line to earth short circuit (fault). The fault is in phase a.

 calculates the currents in the case of a line-to-line-to-earth short circuit (fault). The fault is in the phases b and c.

 calculates the Thevenin impedance ZTh and the sequence impedances Z0, Z1, Z2 as seen at the location of the fault.
The impedances are calculated in three cases: Using "normal" impedances, using transient impedances, and using subtransient impedances. The impedances are normally displayed Ohms, but if the "m"-button is down, the impedances are displayed in milliohms. The m-button is normally not visible. It can be set visible by clicking view|buttons in the toolbar.

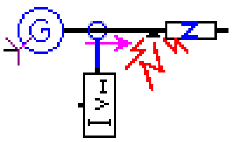
The "normal" impedance of asynchronous machines is calculated as the nominal voltage divided by the current at the given power or slip. A large value is used as the "transient" impedance of asynchronous machines, because the asynchrnonous machines are neglected when transient currents (or impedances) are calculated.

The negative sequence Thevenin impedance (Z2) is, in principle, the same in all three cases (normal, transient, subtransient). But because the asynchronous machines are neglected in the transient case, Z2 is (re)calculated in the transient case without the asynchronous machines.

Note: The following components are not included in the calculations: The unsymmetrical load, generating PQ-bus, open-line-fault. The fault calculations are not possible if there is an unsymmetrical load-component in the network. The generating PQ-bus is replaced by an impedance, and the open-line fault is neglected.

The results can be hidden or displayed by clicking "View | Sequence impedances". The results are saved until a new calculation of impedances is carried out. This means that the results may be outdated, if the diagram has been modified, or some parameter values have been changed.

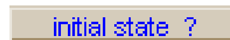
The location of the short circuit is given by the location of the short circuit component . The short circuit can be dragged with the mouse to the desired location. Note, the short circuit component must be in a reasonable place. For normal components, it must be at one end of the component, like

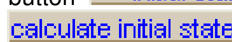

.

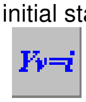
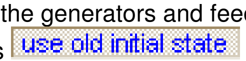
For wires and buses the short can also be on the wire or bus, as

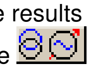
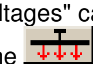
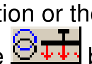

.

The initial, prefault state for the superposition method

The prefault state can be selected by the long, narrow button 

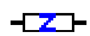
below the fault buttons. If the button is up, either as it is initially, or as 

, the initial state is calculated before the fault calculation by solving the network similarly as with the  button. In this calculation, the voltage parameter of the generators and feeders is the internal phase to phase voltage . If the long button is pressed down, as 

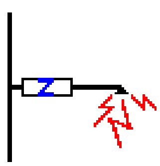
the short circuit calculation uses the results of the "adjust voltages" calculation or the Load flow calculation (calculated with the  or the  button, or with the  or the  button, respectively). The results of the most recent calculation are used. No warning is given, if no "adjust voltage" or load flow calculation has been carried out. The results are meaningless in such a case.

When the DYN / IEC- button is in the position DYN, the currents are calculated over a period of 1s, 10s, or 100s depending on the position of the 

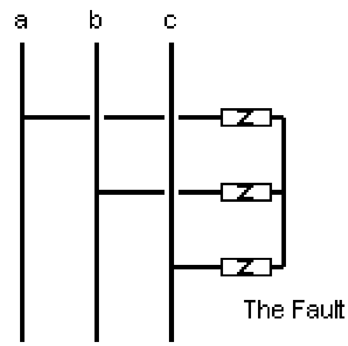
button.
Note: The calculation time can be rather long when the calculation period is 100s, especially if there are several induction motors in the network.

Note: The short circuit has no parameters. The impedance of the short is always zero. A nonzero impedance can be introduced using a separate impedance component  or . Because the single line diagram actually describes a three phase network, the (eventual) impedance models three indentical impedances, one in each phase. This means that a reasonable fault impedance can be set with an impedance component in the cases of the three-phase fault, the line-to-line fault and the line to earth fault, but (actually) not in the case of a line-to-line-to earth fault. The three impecances would look like the following pictures in the three phase network in the cases of the different faults.

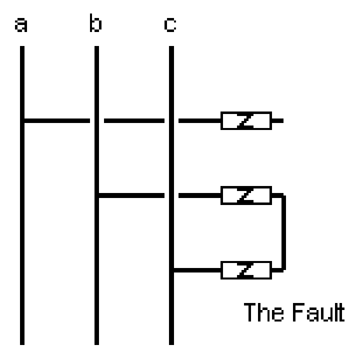
The fault and the impedance look like this in the single line diagram:



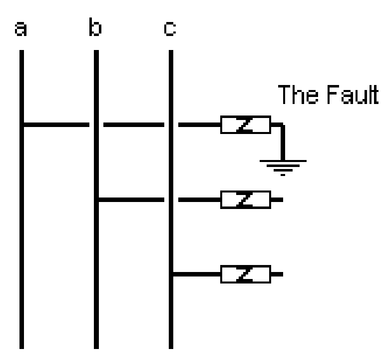
and this shows, how the fault and the impedance are modeled in the cases of the different faults:



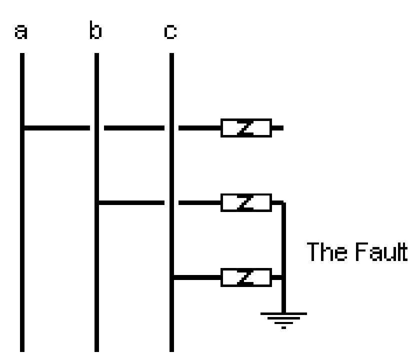
a three-phase fault with the impedances



a line-to-line fault with the impedances



a line to earth fault with the impedances.



a line to line to earth fault with the impedances.

Toolbar (4): show, hide

When pressed, the appearance of the button changes to . The currents through the current transformers are shown near the current transformer, as The absolute value of the current and its phase are shown. After a short circuit calculation, the initial current Ik" and its phase are shown. When the button is pressed a second time, the appearance changes to (not after an IEC-fault calculation). The power through the current transformer is displayed as . The upper value is the real power, and the lower one is the reactive power. The sign of the real power indicates the direction of power flow. If positive, then power flows in the direction of the arrow of the current transformer symbol.

When the button is pressed down (once), the appearance of the button changes to and the magnitude of the voltages at buses are displayed in volts (or kV). as The value and format of the displayed voltage depends on the selected unit (V or kV), selected voltage (phase-phase, phase-neutral, or sqrt(3)*phase-neutral), selected phase or sequence (a, b, c, +, -, 0) , similarly as the display of voltages in the result boxes.

When the button is pressed once more, the appearance changes to , and the voltages are displayed in per unit. The nominal, phase-phase voltage-parameter Vn of the bus must have a reasonable value, else the per unit value is not meaningful (of course). If the per unit voltage is larger than the maximum per unit voltage (parameter puVmax) or smaller than the minimum per unit voltage (parameter puVmin), then the voltage is displayed in red, else in black. The position of the displayed voltage can be moved by dragging with the mouse.

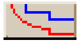
When down, the calculated impedances, zones, activation times of the distance relays are not shown.

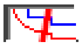
is used to select the phase (a, b, or c), or the sequence (+, -,or 0) for which the current or voltage is displayed in the result boxes and near to the current transformers.

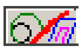
The sum current (the residual current) i.e. three times the zero sequence current and three times negative sequence current can be displayed in the result boxes and near to the current transformers instead of the plain negative and zero sequence currents by selecting "Options | Show 3*Ineg, 3*Izero" in the menu bar. This option can also be selected by keeping the alt-key down while the phase button is clicked. The "display mode" can be changed back to "normal" in the same way, either using the options menu, or by keeping the alt-key down when clicking the phase button. **Note:** The display of the currents of the phases a,b,or c, and the positive sequence current, and the voltages are not affected by the change of this "display mode".

Symmetrical (sequence) components (positive, negative and eventually the zero sequences) are shown only after an unsymmetrical fault. This button applies to the current shown near to the current transformers (as described above) and the result boxes, that are shown when a component is clicked. **Note:** the graph showing the current as a function of time is not affected by this button.

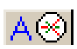
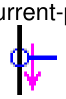
When the caption of the button is , the result boxes display the real and imaginary parts of the voltages and currents. When the caption is , absolute value and phase of voltages and currents are shown.
Note: the current transformers always show the absolute value and the phase.
Note: This button determines also the format of the results written to the report: either real and imaginary parts, or absolute value and phase.

 When a relay module is clicked after a short circuit calculation, a new window opens (unless already open) that shows the characteristics of the relay, and the current through the current transformer that is connected to the relay module. When this "Show char. of all clicked relays"- button is down, and a relay is clicked, the characteristics of that relays is shown in the same picture without wiping the characteristics of the previously clicked relays. The characteristics of up to ten relays can be shown in the same picture in this way. The characteristics are normalized to the voltage level of the relay that was clicked last. The current of the relay clicked last is shown in the graph ,either as a function of time (after a "dynamical" calculation) or as a point (after an IEC-calculation). This feature (button) may be useful in relay coordination studies. **Note:** The tap-parameters of the transformers do not (yet?) have any effect of the voltage levels of the relays (should they?).

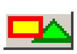
 If the same button is clicked once more, the button remains in the down-position, but a red slash appears over the button. In this case, the curves and parameters of the relays do not appear. If the curves are already visible, they are hidden.
Note: The parameters of the single overcurrent relay modules still appear at the bottom of the screen.

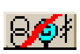
 The graphs and parameters of distance relays are not displayed, when this button is down.
Note: There are separate buttons for the coordination of distance relays

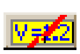
determines the equation used to calculate the impedance in the distance relays, i.e. the type of the relay, 21 or 21N.
In the position "auto", the equation depends on the fault type: 21N for the line to earth fault, type 21 for the other faults.
In the position "phase", type 21 is used for all faults.
In the position "grnd", type 21N is used for all faults.

 When this current-phasor button is pressed down, the current-phasor window opens. When a current transformer  is clicked in the single line diagram while this button is down, the phasors of the current through the transformer are shown in the current-phasor window.

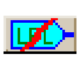
 When this voltage-phasor button is pressed down, the voltage-phasor window opens. When a bus is clicked in the single line diagram while this button is down, the phasors of the voltage at the bus are shown in the voltage-phasor window.

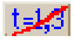
 When pressed, the menu for drawing graphical elements becomes visible.

 When pressed, the component menu is hidden.

 Normally, when a component is clicked, a small result box appears showing the voltage(s) and current(s) of that component. But if this button is down, the box does not appear. The boxes that are already visible on the screen are not affected. They stay visible and are updated after calculations. They can be hidden by clicking the (X) on the upper left corner of the box.

 determines which voltage is shown as the result of the calculations.
- If the button is in the position of the picture, displaying sqrt(3), the voltages are sqrt(3) times the phase to neutral voltages. The phase of the voltage (if shown) is the phase angle of the phase to neutral voltage .
- If the caption of the button is "Ø n", phase to neutral voltages are displayed.
- If the caption is "Ø Ø", phase to phase voltages are displayed.
This button determines also the format of the voltages written to the report.

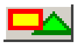
 When the button is down, the labels of the components are not shown. If the button is up, the user can select the component types, for which the labels are shown, by clicking "Options | Show labels...".

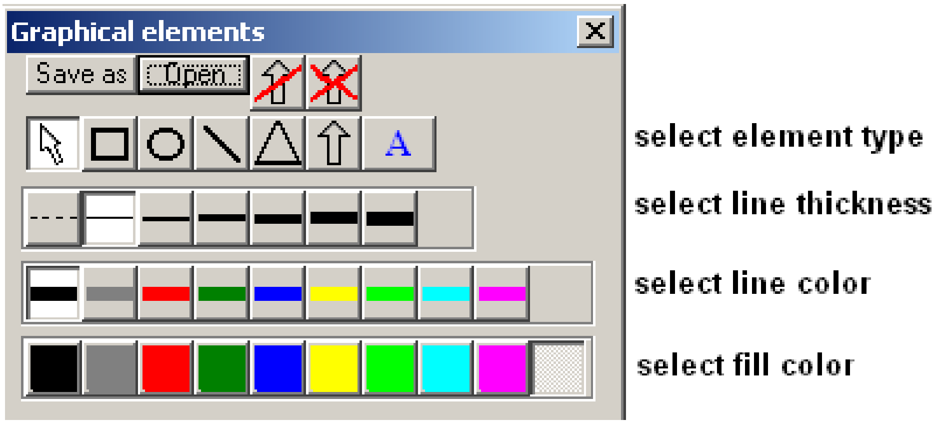
 When this button is down, the activation times of the relays are not shown.

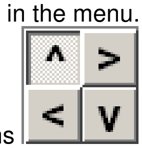
 When this button is down, the text components are not shown.

Note: Some of the settings (button states) described on this page are saved in the *.ini file, so that the buttons "remember" the state they had when the program was closed.

Graphical elements

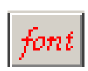
When the button  for the menu of graphical elements is pressed down in the menu bar of the main window, the menu appears.



It can be used to draw different shapes and texts on the screen within the single line diagram. The drawing is done in the same way (almost!) as in other graphical programs. First, select the element type (rectangle, ellipse, etc), the line thickness and color, and the fill color in the menu. If the triangle, arrow or text is selected, select also the direction with the "direction"-buttons 

(the symbols ^, <, V, > on the buttons describe arrows, showing the direction of the graphical element, up, left, down, right).

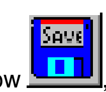
Next, draw an (imaginary) rectangle around the shape on the screen by moving the mouse (the cursor) from one corner of the rectangle to the opposite corner. If the text-element has been selected, the text can be written and edited in the (now visible) rectangle. The size of the text-rectangle is adjusted automatically according to the number and length of the lines.

A font-menu appears, when the font-button 

is pressed. After editing the text, click some empty space on the screen, and the surrounding rectagle disappears.

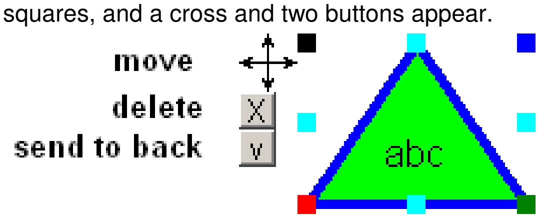
The graphical elements can be saved to a file and recalled with the "save as" and "open"-buttons


NOTE: Only the graphical elements are saved or recalled on/from a separate file with these buttons, not the single line diagram.

NOTE: When the single line diagram is saved using the "save as"-button on the main window 

, or by clicking "file | save as" in the toolbar, the graphical elements are saved on a file together with the single line diagram.

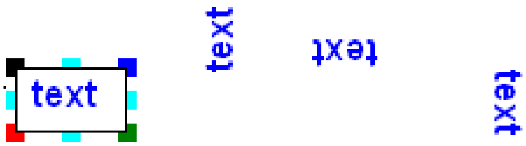
When an existing graphical element on the screen is clicked, the element is surrounded by small squares, and a cross and two buttons appear.



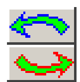
The cross is used to move the graphical element with the mouse. The size and shape of the element can be changed by moving the small squares with the mouse. The button with an "x" is for deleting the graphical element. The button with a "v" is used to send the graphical element behind some overlapping element. (The "v" in the button describes a down-arrow.) In this way, a graphical element can be set as background for some text, for example.

In addition, the line thickness and color, and the fill color, and the direction (for triangles, arrows and texts) of the clicked element can be changed by clicking the corresponding button in the menu of graphical elements.

When the direction of the text is changed with the "direction"-buttons, the text rotates around the upper left corner of the (original) horizontal text.



NOTE: If the menu for the graphical elements is not visible, then the clicking of the element has no effect.

NOTE: The "undo"- and "redo"-buttons  in the toolbar of the main window work only partially with the graphical elements. They can be used to undo/redo only such move-operations where also some (electrical) components have been moved. That is, the deleting of graphical elements cannot be undone, for example.

Toolbar (5): select, cut, copy, paste, undo, redo, frequency, display time

 selects all components. This is indicated by rectangles drawn around every component and the whole diagram. The selected components can then be moved, copied or deleted. **Note:** If the diagram is larger than the screen, the rectangles are actually drawn only around an area that is slightly larger than the visible part of the diagram (due to resource limitations). All components are selected, however.

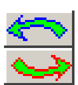
 displays a list of open breakers. Actually, three lists are displayed, one for both types of the "ordinary" breaker symbol, and one for all symbols of breaker-2.
Note: The lists are the same that are used when locating (finding) components. Thus, it is not possible to simultaneously display lists of open breakers and to locate components. But it is possible to locate an open breaker with help of the list of open breakers. Just click the label in the list.

Cut, Copy, Paste 

Copy: Copies the selected component(s) to the local clipboard. **Note**, the components are not copied to the proper windows clipboard! One component can be selected by clicking the component. Several components can be selected by drawing a rectangle around the components: Put the cursor in one corner of the (planned) rectangle, press the left mouse button down and move the mouse diagonally over the components to the opposite corner of the (planned) rectangle. Release the mouse button. A grey rectangle appears around each selected component, and a larger rectangle around the group of the selected components. The ctrl c key sequence can also be used instead of this copy-button. (Press and keep the ctrl key down and press the c key.)

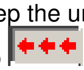
Cut: as copy, but copies <u>and</u> deletes the selected component(s).

Paste: pastes the component(s) from the loca clipboard to the screen. After pasting, only rectangles marking the component(s) are seen. The rectangles can be dragged with the mouse to the desired location. When the mouse button is released, the pasted component become visible. The pasted components also become visible by clicking (almost) anywhere on the screen, or by a repeated click of the paste button. The ctrl v key sequence can also be used instead of this paste-button. (Press and keep the ctrl key down and press the v key.)

Undo, Redo 

The undo button cancels ("undoes") the last operation, and the redo-button cancels ("undoes") the previous undo-operation. Only some defined operations can be undone. These are: move one or more components, add or paste one or more components, delete one or more components. Other types of operations cannot be undone. For example, the changing the parameters of a component or the label of a component cannot be undone.

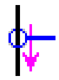
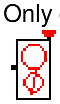
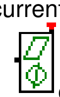
The number of operations that can be undone successively (called also undo-levels) is about twenty. However, the exact number depends on the type of the operations.

Successive move-operations of the whole diagram can be undone with one press of the undo button in the following way. Press and keep the undo-button down for a while, about half a second, until the picture on the button changes to . Release the button, and watch all successive movements of the whole diagram do be undone.

NOTE: The "undo"- and "redo"-buttons work only partially with the graphical elements. They can be used to undo/redo only such move-operations where also some (electrical) components have been moved. That is, the deleting of graphical elements cannot be undone, for example.

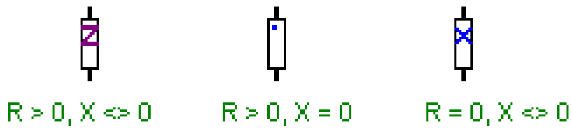
The frequency of the network can be selected, either 50 Hz or 60 Hz. This has very little effect, because the component parameters are mostly resistances, reactances and susceptances. The frequency is used only with the capacitors, and when saving the single diagram as a *.dat file for the EMTP simulation program, or as an *.atp file for ATP-calculations.

The currents are calculated as a function of time after the occurrence of a fault (but not when calculating according to the IEC60909-standard). The initial currents are displayed after a short circuit calculation. These arrows and this edit box can be used to select some other time > 0, for which the currents of current transformers, and impedances, currents, and voltages for distance relays are displayed. Write the time in the box, or increase or decrease the time by clicking the up- and down-arrows.

Note: Only currents for current transformers  , and impedances, voltages and currents for distance relays   can be displayed at the given nonzero time. The eventually displayed results for all other components are **hidden**, when a nonzero time is entered in this edit box.

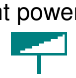
Note: The display time is reset to zero when a short circuit calculation is carried out.

impedance, load



Impedance: a resistance and a reactance in series.
R = resistance (ohms) can be zero
X = reactance (ohms) can be negative
Note: R or the absolute value of X must be at least 0.001 ohm
Note: The symbol of the impedance depends on the values of the resistance R and reactance X of the impedance. If the reactance is zero, the impedance appears as a rectangle, with a small point to indicate the orientation of the component. If the resistance is zero, the impedance appears as a rectangle with an X inside. If both the resistance and reactance are nonzero, the impedance appears as a rectangle with a Z inside.

Load

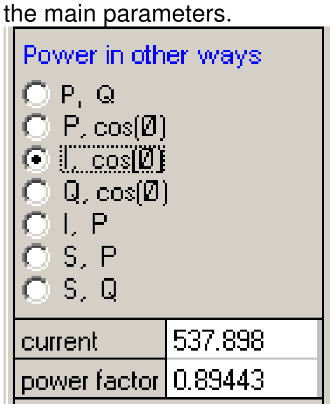
A load can be a proper, consuming load, or a generating "load". The generating load should be used only when solving the load flow problem. A proper, consuming load has a positive apparent power parameter (VA > 0) , a negative apparent power (VA < 0) indicates a generating "load". The symbol of a generating "load" has a greenish color 

A consuming load is a resistance and reactance in series, connected in a star, with unearthed neutral.

VA = nominal apparent power (sum of all phases), VA, positive = consumption, negative = generation
Vn = nominal phase to phase voltage,
(in a load flow calculation Vn is used as a first guess only)
pf = power factor (cos fii) > 0, and <= 1
m = scaling factor, or multiplier, multiplies the apparent power VA

Note: there are two scaling factors for the loads, one local (the parameter m above), and one global. The global scaling factor multiplies the power of all loads. It can be set with "Advanced | Load scenario and multiplier" in the menu bar of the main window. (The scenarios are alternative sets of parameters for the loads.)The power parameter VA is multiplied by the product of the local and global scaling factors.

The power of the load can be entered in other ways, that can be selected with the radio buttons under the main parameters.



P, Q real and reactive power
P, cos(Ø) real power, power factor

I, cos(Ø)   current, power factor
Q, cos(Ø) reactive power, power factor
I, P   current, real power
S, P   apparent power, real power
S, Q   apparent power, reactive power

When one of these ways is selected (the radio button is chekced), the values of the corresponding parameters are displayed in the table under these radio-buttons. These values can be edited, and the values of the "proper" or "primary" parameters in the table in the upper part of the window will change accordingly. Note: The parameters are saved from the upper table, so that there may be small round-off errors, when the parameters are recalled.

The local and global scaling factors, and the selected scenario are displayed around the load component:

The local scaling factor is displayed in blue, the global in reddish and the scenario as a green letter (A,B,C). A multiplier equal to one is not displayed. Similarly, the scenario is not displayed, if none is selected, i.e. the "normal" parameters are used.

In the Load Flow calculations the impedance of the consuming load is adjusted so that the power and the power factor are equal to the given values.

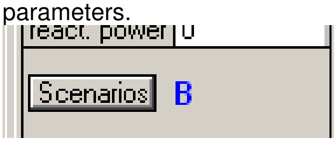
When the network is solved in a straightforward way (in the i = Yu or the "adjust voltage" calculations) the consuming load consists of an impedance (in each phase). The impedance is calculated from

R = Vn*Vn*pf / VA
X = Vn*Vn*sqrt(1-pf*pf) / VA

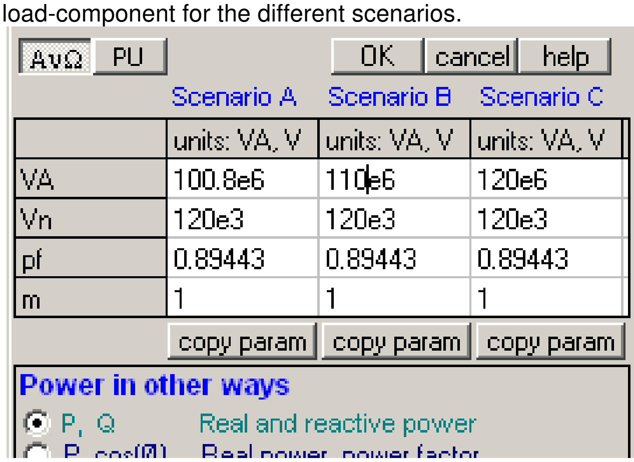
In the "dynamical" short circuit calculations, the load is an impedance, that is either equal to R + j X calculated above, or equal to the load impedance solved in the load flow calculation. Which one is used, depends on the selected initial state. In the IEC-short-circuit calculations the loads are neglected.

Load scenarios

The load scenarios are alternative sets of parameters of the load components. The parameters can be edited in a small window that opens with the "Scenarios"-button in the window for the "normal" load parameters.

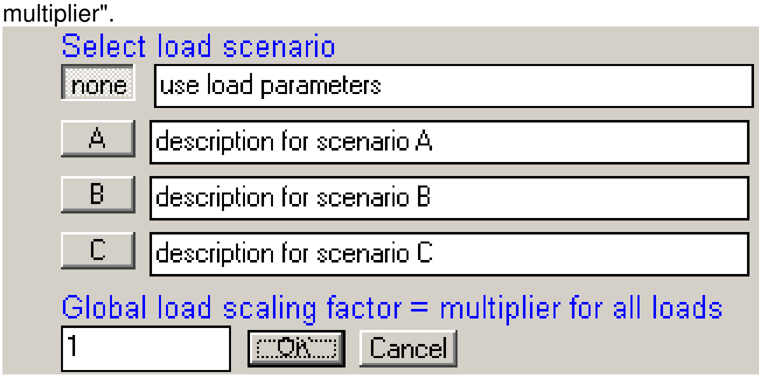


The letter on the right of the button shows the selected scenario, A, B, C, or N (for none).
When the "Scenarios"-button is clicked, a small window opens for editing the parameters of the selected load-component for the different scenarios.



The parameters are entered in the same way as the parameters in the window for the "normal" parameters of the load-component.
The "copy param"-buttons can be used to copy the "normal" parameters to the scenarios.

The scenario is selected in the menu bar of the main window, by clicking "Advanced | Load scenario and multiplier".

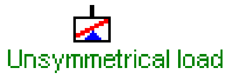


The scenario is selected with the buttons on the left hand side. If "none" is selected, then the "normal" parameteres of the load components are used.
The fields on the right of the buttons are for brief descriptions of the scenarios.
Note: the selected scenario (A, B, C, or none) is used for all load-components in the network (diagram). Thus, the corresponding scenario-parameters must be defined for all load-components.

The **"Global load scaling factor"** can also be set in this window. It multiplies the (apparent) power of all load components

The unsymmetrical load

The unsymmetrical load

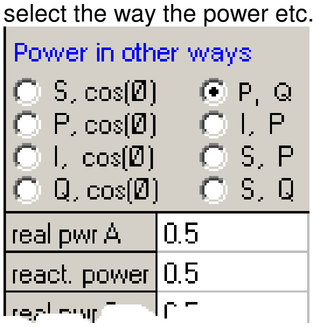


Three different impedances in phases a,b,c connected in a star.
The star (neutral) point is connected to earth with an impedance

Note: Can only be used in a straightforward solution of the currents and voltages in the net (using the " Yv = i " button)

Ra, Xa the resistance and reactance (Ohms) in phase a (in series)
Rb, Xb the resistance and reactance (Ohms) in phase b (in series)
Rc, Xc the resistance and reactance (Ohms) in phase c (in series)
Rg, Xg the grounding resistance and reactance (Ohms, in series)
Can be zero, but must be finite
Vn nominal phase-phase voltage. Needed only if the impedances are defined using powers, see below
m multiplies the load = divides the impedances

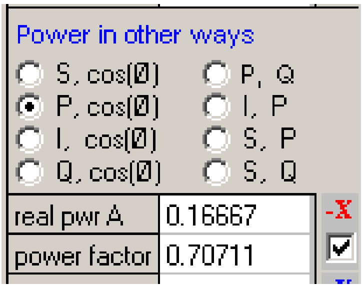
The impedances can also be given by defining the corresponding one-phase power, power factor, current, etc. in different ways. The radio buttons in the lower part of the parameter window are used to select the way the power etc. is given.



The different ways are:
S, cos(Ø) apparent power, power factor
P, cos(Ø) real power, power factor
I, cos(Ø) current, power factor
Q, cos(Ø) reactive power, power factor
P, Q real and reactive power
I, P current and real power
S, P apparent and real power
S, Q apparent and reactive power

Note: The powers are given as one-phase powers!.
Note: The calculated powers (may) agree with the given powers only if the voltage of the load is equal to the nominal voltage Vn, and if the grounding impedance is zero (Rg = Xg = 0).

Because the power factor cos(Ø) is the same for leading and lagging current, the type of the power factor, leading or lagging must be entered separately. Three check-boxes are used, one for each phase, labeled with -X in different colors.



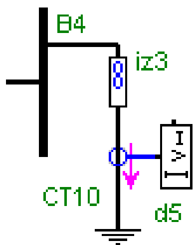
A checked box indicates a leading power factor, i.e. a negative reactance X.
Note: The state of these boxes cannot be changed when reactive power Q has been selected with the radio buttons above.

Isolating impedance, sequence impedance

The isolating impedance
is a nonphysical component, meant for tests. It behaves as a normal impedance (resistance and reactance in series), except for that it does not drain current from the component(s) to which the upper end is connected to. The current in the isolating impedance is equal to the voltage over the component divided by the impedance. But it does not drain this current from the connected components, so that the other components do not "see" the isolating impedance.

R = resistance (ohms)
X = reactance (ohms)
R and X are in series.

It can be used to transform voltage to current, and to get voltage displayed as a function of time after a "dynamical" short circuit calculation. Set the resistance to one ohm, reactance to zero. Connect the upper end to the point at which the voltage is to be measured. Connect the lower end to ground through a current transformer. A relay connected to the current transformer displays the voltage as a function of time in this way:



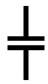
The sequence impedance

The sequence impedance-component is a simple impedance, that can have different values for the positive, negative and zero sequence networks.
The parameters are
R1, X1 positive sequence resistance and reactance (in series)
R2, X2 negative sequence resistance and reactance
R0, X0 zero sequence resistance and reactance

Note: The sequence impedance does not "generate" any unsymmetry in the network. The negative and zero sequence impedance values of the component are used only when there is an unsymmetrical fault or similar in the network.

Note: The sequence impedance may not represent any physical component, but it might have some educational use (I think).

Capacitor



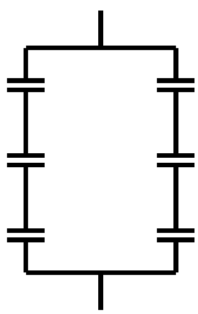
Capacitor

The parameters are

C capacitance in Farads (one capacitor)
Np number of parallel capacitors
Ns number of capacitors in series
V voltage over one capacitor (phase to neutral)
Q apparent power of of one capacitor

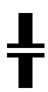
One capacitor symbol in the diagram can also desicribe a capacitor bank consisting of several capacitors in parallel and in series. The parameter Np gives the number of parallel capacitors and Ns the number of capacitors in series in the capacitor bank.

For example



Np = 2, Ns = 3

Here Np = 2 and Ns = 3.
If the number of parallel capacitors of capacitors in series is larger than one (Np > 1 or Ns > 1) then the symbol of the capacitor changes so that the connecting lines are drawn using a thick line



Np > 1 or Ns > 1

Total capacitance

C7

AvΩ PU

	F, V, VA	per unit
C (one cap.)	0.001	3.1831
Np	2	2
Ns	3	3
V (one cap.)	1000	1
Q (one cap.)	314.16e3	0.31416

C eq = 666.67e-6F
Nt = 18 capacitors

The total (equivalent) capacitance is displayed under the parameter table, where also the total number of capacitors in the bank is displayed. Note that there is one capacitor in each phase, so the the total number of capacitors is Nt = 3*Np*Ns

The capacitance can also be expressed by giving the apparent power Q of the capacitor and the voltage over the capacitor,

$$Q = 2\pi f C V^2$$

where f = frequency, C = capacitance, V = voltage

Note that the Q is the apparent power of one capacitor in the case of a capacitor bank. Similarly, V is the voltage over one capacitor (or the line-neutral voltage). Alternatively, one can think that Q is the total apparent power of three capacitors (one in each phase) and V is the line-line voltage.
When the capacitance parameter C or the voltage parameter V is edited in the table, the value of the apparent power parameter Q changes accordingly. When the apparent power Q is edited, the value of the capacitance changes.

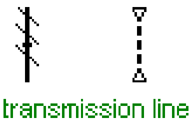
The parameters can also be given using the per-unit notation, by pressing the PU-button down. This is explained in some detail in the chapter over transformers.

The ampacity limits can also be entered, when the "Ampacity"-button is pressed down. This is explained in some detail in the chapters over transmission lines or transformers.

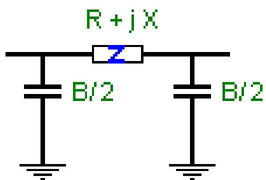
Note that the ampacity limits are for one capacitor. This is important, if there are parallel capacitors, i.e. Np > 1.

Transmission line

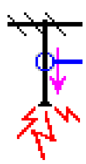
Transmission line



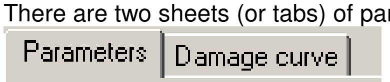
Transmission line is modeled as a "pi" network.



A fault (or some other component) can be connected to the middle of the line. The parameter s1 determines the relative position of the fault in the line. If s1 = 0.1, for example, the distance of the fault from the upstream end is 0.1 * the lenght of the line. (The upstream end has two crossing, oblique bars, the downstream end only one.)



There are two sheets (or tabs) of parameters.

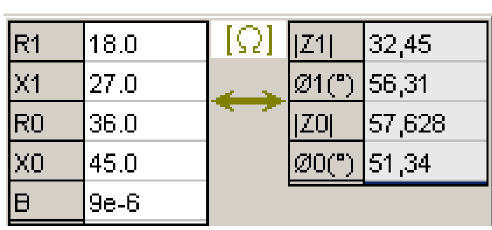


The "parameters"-sheet contains the "actual" parameters used in the calculations, length, impedance etc. The "damage curve"-sheet contains parameters for displaying the damage curve of the transmission line in the relay coordination graphics. The parameters of the "parameters"-sheet are described here. The damage curve and its parameters are described on a separate page.

The "actual" parameters are

length the length in km
s1 the relative length of the upstream section of the line 0...1
(the upstream section has two crossing, oblique lines)

R1 pos. and neg. sequence resistance (in series with X1)
X1 pos. and neg. sequence reactance (in series with R1)
B susceptance (sum of the two capacitors)
R0 the zero sequence resistance
X0 the zero sequence reactance
(The zero sequence susceptance is equal to B)

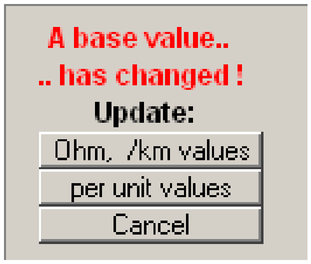


R1	18.0	[Ω]	|Z1|	32,45
X1	27.0		Ø1(°)	56,31
R0	36.0		|Z0|	57,628
X0	45.0		Ø0(°)	51,34
B	9e-6			

Impedances in (total) Ohms (and 1/Ohms), either in rectangular or polar form.

The impedances (and susceptance) can be given in Ohms/km (and 1/Ohm*km), in Ohms (1/Ohms), or using the "per unit"-convention. In addition, the impedances can be given either in rectangular components (resistance and reactance), or in polar form (magnitude and phase). There is a small table for each of these ways for entering the parameters. When values are entered in one table, the entries in the other tables are automatically updated.

The base power and voltage for the pu-notation are entered in MVA and kV, respectively.

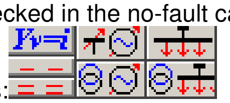


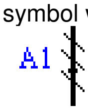
When a base value (power or voltage) is changed, the user must decide, which parameter values are changed: the per-unit values, or the values in physical units. The selection is done by clicking the suitable button in a small panel that opens when a base value is changed. The "cancel" button cancels the change in the base value. The panel can be moved with the mouse.

Note: The parameters are saved only in physical units / km (ohms/km etc). There may be small round-off errors, when the values are converted into other units.

Ampacity limits [A]

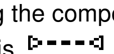
A1	A2	A3	A4
700	800	900	1000

Four different ampacity limits can be entered, denoted by A1...A4, the smallest first. The ampacity limits are checked in the no-fault calculations, and in the cases of open line faults, started with these buttons: 

The exceeding of the ampacity limits is indicated near the transmission line symbol with the identifier of the limit that was exceeded, A1...A4. Here, the limit A1 has been exceeded 

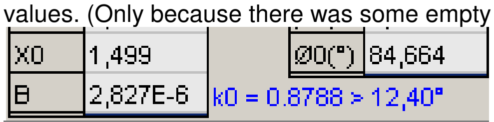
The four buttons on the top or the parameter window can be used to select the parameters to be displayed.

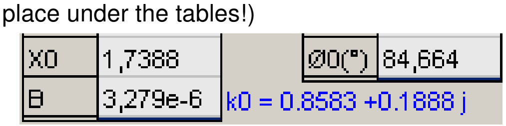
Note: the transmission line cannot be stretched. For a longer line, either put several transmission lines in a row, or use the connection wire (with no parameters) to extend the transmission line.

The symbol (picture) of the transmission line can be changed by right-clicking the component, and selecting "Symbol" in the pop-up menu that appears. The alternative symbol is  . It can represent an underground cable, for example.

The k0-factor

The value of the k0 factor of the transmission line is displayed in two ways: as magnitude and phase under the table for Ohm/km-values, and as real + imaginary components under the table for the Ohm-values. (Only because there was some empty place under the tables!)



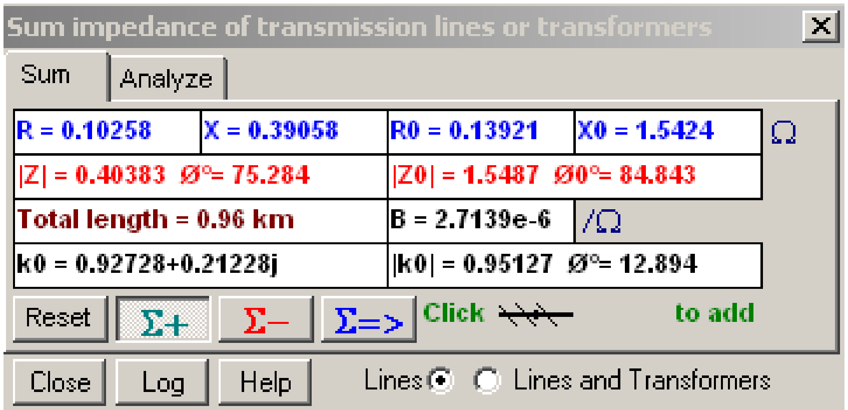


The k0-factor is defined as (Z0-Z1)/(3Z1), where Z0 and Z1 are the zero and positive sequence impedances, respectively. The k0-factor is needed in the distance relays. The k0-factor can also be calculated usin the k0-calculator, that can be started by clicking Advanced | k0 calculator in the toolbar.

Impedance sum calculator

The impedance sum calculator can be used to calculate the sum of either impedances of transmission lines, or impedances of transformers and transmission lines. The type of the components to be summed is selected with the radio buttons on the lower right in the calculator window. The sum of transmission line impedances is explained here, the sum of transformer and transmission lines is described on next page.

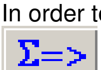
The calculator for the sum of transmission line impedances is started by clicking "Advanced | Impedance sum" in the menu bar of the main window. The calculator has two sheets:
The sum-sheet

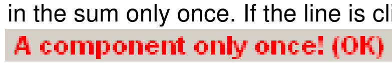


The sum-sheet is used to calculate the sum of resistances, reactances, etc. of several transmission line-components. It can be used if one has to replace several transmission line-components with only one component. Because the parameters of the transmission line component are given as per length (ohms/km), the sum of resistances, reactances, etc. are calculated by multiplying the parameters per unit length by the length of the line, and summing the products.

In order to sum the parameters, press the sum-button down 

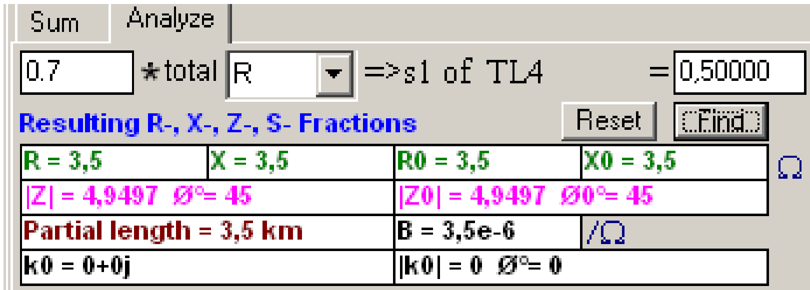
. When the button is down, click all the transmission lines to be summed in the single line diagram. The sum of the products (parameters) times (length) of the different parameters appear in the table. For subtracting, press the subtract-button down 

, and click the transmission line to be subtracted. This may be handy in correcting errors. In order to move the sum/length to a transmission line component, press the copy-sum-button down 

, and click the transmission line where the parameters are to be copied. Note that a given transmission line can be included in the sum only once. If the line is clicked twice with the sum-button down, an error message appears 

The **Reset**-button clears all data in the sum-sheet and in the analyze sheet.
The **Close** button closes the calculator.
The **Log**-button displays a log of the parameter of the transmission lines. The parameters of the subtracted components appear in red.
The **Help**-button displays a small help-window.

The analyze-sheet
Assume that several transmission line-components are connected in a row, and one has to connect a fault (or some other component) at a position, that corresponds to a given fraction of the total length, or total resistance, or total impedance or some other property of the combined line. The analyze-sheet can be used to determine the transmission line-component to which the fault has to be connected, and the fraction parameter s1 of that line, so that the fault is in the correct position.



First, sum the properties of the connected transmission line-components on the sum-sheet. **Note**: Start at the upstream end! Next, set the desired fraction in the box in the upper left corner of the sheet. Select the variable (resistance, reactance, impedance, etc) in the drop-down-menu, and press the "Find"-button. The label of the transmission line-component where the fault has to be connected appears in the top row, and the value of the s1-parameter appears in the box in the upper right corner. In addition, the transmission line-component is marked with a magenta square in the single line diagram.

An example: Five identical transmission line components TL1,...TL5 are connected in a row. It is desired to connect the fault at a fraction of 0.7 of the total resistance. The analyzer-sheet (see the picture above) tells that the fault has to be connected at TL4, and the s1-parameter has to be 0.5.

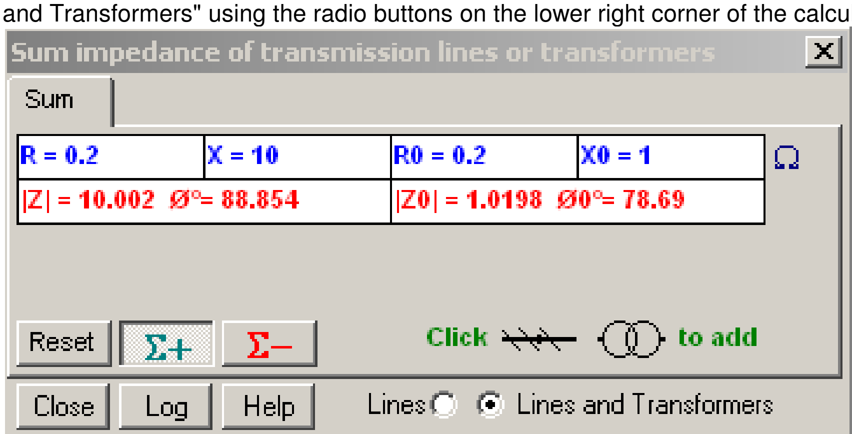
The sums of the resistances, reactances, impedances etc multiplied by the length (and the s1-factor for the last included line) from the upstream end of the connected transmission lines to the point where the fault (or other component) has to be connected are displayed in the table.

Note: The **reset**-button clears the data on the analyze-sheet only.

Impedance sum of transformers and lines

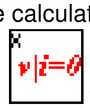
The impedances of transformers and transmission lines are summed in practically the same way as the impedances of transmission lines only.

The calculator for the sum of impedances is started by clicking "Advanced | Impedance sum" in the menu bar of the main window, and the impedance sum calculator becomes visible. Next, select "Lines and Transformers" using the radio buttons on the lower right corner of the calculator.



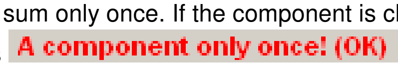
Press the sum-button 

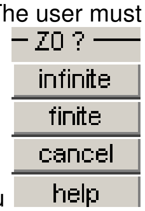
. down, and click the components to be summed.

Because transformers are involved, the impedances must be transformed to some common voltage. The voltage of the first component to be summed is selected as the common voltage. If the first component is a transformer, then the primary voltage is selected as the common voltage. The voltages of other components are calculated by solving the network with zero currents. This calculation is indicated by the symbol 

for the latest operation, displayed near the network title (the symbol is read as "solve voltage with zero current, i.e. v | i = 0 ").

Note: This calculation of the voltages overwrites the results of any previous calculation.

Note: A given component can be included in the sum only once. If the component is clicked twice with the sum-button down, an error message appears 

Generally, the sum is calculated in a straightforward way, but the zero sequence impedances of YD-transformers need some special attention. If it is thought that the fault (for which the impedance sum is calculated) is on the secondary side of the transformer, or further down, then the zero sequence current cannot go through the transformer. This means that the zero sequence impedance is very large. But if it is thought that the fault is on the primary side, then the proper zero sequence impedance of the transformer must be included in the sum. The user must select the impedance to be summed. The selection is done with a small pop-up menu 

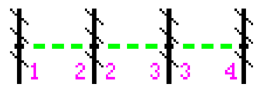
If the "infinite"-button is pressed, then a large value is summed to the zero sequence impedance sum. If the "finite"-button is pressed, then the proper zero sequence impedance is added. "Cancel" hides the menu, without summation, and "help" opens the help-menu of the impedance sum calculator.

Note: If the "finite"-button is pressed, then the sum of positive sequence impedances corresponds to a fault on the secondary side of the transformer (or further down), but the sum of zero sequence impedances corresponds to a fault on the primary side of the transformer.

Note: A very large ("infinite") zero sequence impedance is always and automatically selected for DY-, YYD-, and DD-transformers.

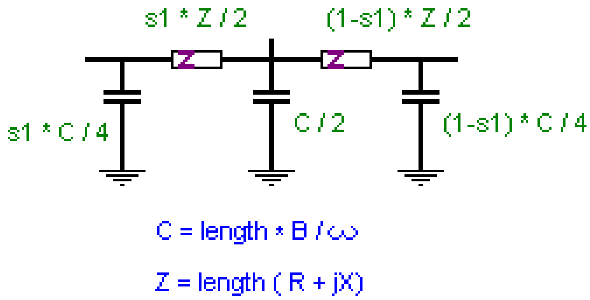
The user must select the winding pairs for a three-winding transformer to be included in the sum. This is done with another small pop-up menu 

Mutual impedance (transmission lines)

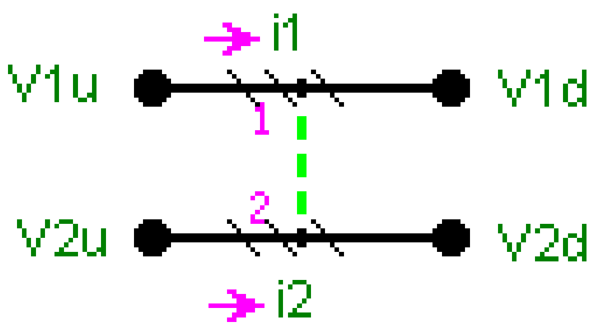


The mutual impedance component can be used to model 2 to 8 transmission lines that are coupled in zero sequence through mutual impedances.

Each transmission line is modeled as a (double) pi-network in positive and negative sequence networks.



In zero sequence networks, the coupling betwee lines must also be included. Consider two transmission lines:



The zero sequence voltage drop in line 1 is

V1u - V1d = Z0 * i1 + Z12 * i2, and simlarly for line 2. Here

V1u and V1d are the upstream and downstream voltages at the nodes of the line 1.
Note: Because there is the middle node in the line, the upstream node can be either the "proper" upstream node of the line, or the middle node. The downstream node is either the middle node or the "proper" downstream node.

Z0 is the zero sequence impedance of the line section
Z0 = (R + jX) * LengthT * s1 for the line section between the upstream and middle node. (Use 1 - s1 for the section between the middle node and the downstream node)

For R, X, LengthT and s1, see below.

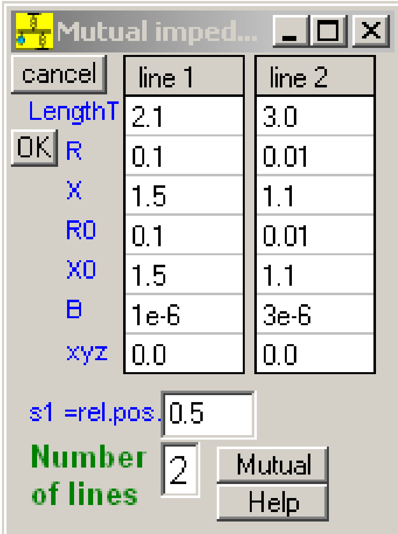
Z12 is the mutual impedance between the sections of the lines
Z12 = (rm0 + j xm0) * LengthP * s1   (again, replace s1 with 1-s1 for the section between the middle and downstream nodes)

for rm0, xm0, LengthP, see below

The parameters

There are two windows for entering the parameters, one window for the "self"-parameters, and the second for the mutual impedances. When the component is clicked, the window for the "self"-

parameters becomes visible:



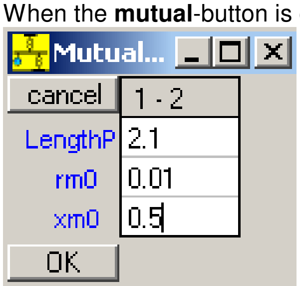
There is one column for the parameters of each transmission line of the component. The parameters in this window are

LengthT the total length of the line
R resistance/length (pos. and negative sequence)
X reactance/length
R0 zero sequence resistance/length
X0 zero sequence reactance/length
B the toal admittance / length of the capacitive coupling to earth
xyz not used (spare)

s1 the relative position of the middle node, from the upstream end (with two oblique lines in the symbol)
Note: s1 is the same for all transmission lines of the component. The assumption is that the middle node is used only for a sliding fault, in one transmission line a time.

Number of lines: The total number of (mutually coupled) transmission lines. Minimum is two, and maximum is eight lines.

When the **mutual**-button is clicked in this window, a window for the mutual impedance becomes visible:



There is one column of parameters for each pair of transmission lines. The parameters are

LengthP the length the lines in the pair run parallel
rm0 zero seq. mutual resistance / length
xm0 zero seq. mutual reactance / length

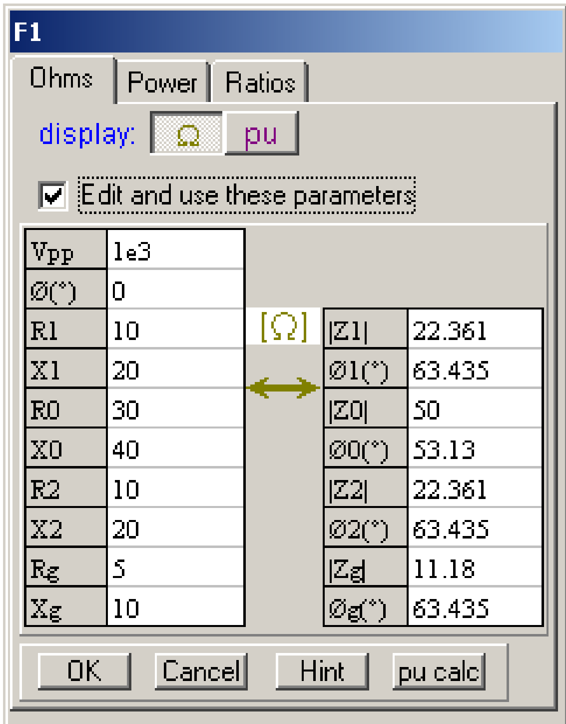
Feeder

The Feeder A voltage source behind an internal impedance.

The parameters of the feeder can be displayed either on a line at the bottom of the screen, as

Vpp	R1	X1	fi	Rg	Xg	R0	X0	R2	X2
1e3	10	20	0	5	10	30	40	10	20

or in a table in a separate small window, as

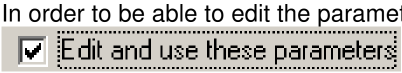


To select the way of displaying the parameters, click "view | parameter windows..." in the main window, and check/uncheck the "feeder"-box.

When the parameters are displayed and edited in the small window, there are three sheets (or tabs) available for entering the parameters in different ways, the **"Ohms", "Power",** and **"Ratios"**-sheets. The parameters can be given in four different tables on each sheet: in rectangular or polar coordinates, and using physical units or the per unit notation (where possible). However, the voltage is always entered in polar coordinates, as magnitude Vpp and phase Ø(°). The impedances in rectangular coordinates and the voltage in polar coordinates on the "Ohms" sheet in physical units (or on the bottom of the main window) are saved and used in the calculations. The parameters entered in other ways, in other tables are converted to these physical parameters before saving to the component. This may result in some round-off errors in the parameter values.

When a parameter is changed (edited) in one table, parameters on other tables will change accordingly, if they depend on the parameter being edited. For example, when the three phase short circuit current is being edited in the "Power"-sheet, the three phase short circuit power is changed accordingly on the same sheet. Similarly, the positive sequence impedance changes on the "Ohms"-sheet. Of course, this can be seen first when the "Ohms"-sheet is selected.

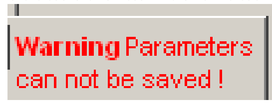
In order to be able to edit the parameters on a given sheet, the box



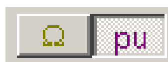
must be checked on that sheet. When a feeder is clicked in the diagram and the small window for the parameters appears, this "edit and use"-box is not checked on any sheet. This forces the user to decide which sheet is used to edit the parameters. The main reason for this is that some assumptions are made about the parameters on the "Power" and the "Ratios" sheet.

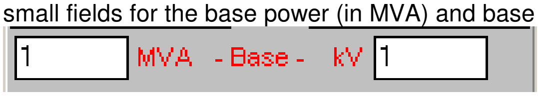
On the "Power" sheet, it is assumed that the positive and negative sequence impedances are equal, R2 = R1 and X2 = X1. If they are not equal initially, the negative sequence impedance is forced equal to the positive sequence impedance, when the "edit and use"-box is checked on the "Power"-sheet. This may change some parameters on the "Power"-sheet.

On the "Ratios" sheet, it is assumed that the X/R-ratio of the negative sequence is equal to the X/R-ratio of the positive sequence, X2/R2 = X1/R1. If the ratios are not equal initially, the X/R-ratio of the negative sequence is forced equal to the positive sequence ratio, when the "edit and use"-box is checked.

It is possible to enter nonreasonable or non-consistent parameter values especially on the "Ratios"- and "Power"-sheets . For example, it is not reasonable to define a small three-phase fault current and a large phase-to-ground fault current, because that would lead to a negative zero sequence impedance. In such cases, a warning is issued, as 

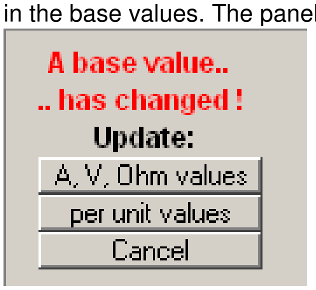
.The parameters cannot be saved as long as this warning is visible. If the window is closed while this warning is visible, all changes in parameter values are cancelled, as if the "Cancel"-button had been clicked. The warning disappears by itself, when reasonable values for the parameters are entered.

The Ohm and PU-buttons 

are used to select the tables to be displayed, either tables for physical units or for the per-unit notation, or both. When the tables for the per unit notation are visible, small fields for the base power (in MVA) and base voltage (in kV)


are visible below the tables, but on the "Ohms"-sheet only.

When the base kV- or base MVA-values is edited, the parameters either in physical units or in the per unit notation must change. The user selects the parameters to be changed in a small panel with buttons for physical units (A, V, Ohm values) and for per unit values. The cancel button cancels the change(s) in the base values. The panel with the buttons appears, when the base values are edited.



Parameters on the Ohms-sheet

The parameters in the table on the left hand side:
(Saved and used in physical units)

Vpp   phase to phase voltage
      = Internal voltage in i = Y U calculations
      = output voltage = voltage at terminals in load flow + adjust voltage calculations
Ø(°)   phase angle of phase to neutral voltage of phase "a", degrees

R1   pos.seq. internal resistance, can be zero
X1   pos.seq. internal reactance, can be zero
R0   zero sequence resistance
X0   zero sequence reactance
     R0 or X0 must be greater than zero (if zero, then 0.001 is used internally)
Note: The total zero sequence impedance of an earthed feeder is R0 + j X0 + 3 (Rg + j Xg)

R2 negative sequence resistance

X2 negative sequence reactance

Rg grounding resistance of the neutral point
Xg grounding reactance of the neutral point
Rg and Xg are in series
Rg and Xg can be zero
Rg and Xg should be <= 1e6
Needed in earth fault calculations

Table on the right hand side shows the impedances in polar coordinates

| Z1| magnitude of pos.seq. impedance
Ø1(°) phase of pos.seq. impedance (degrees)

| Z2| magnitude of neg.seq. impedance
Ø2(°) phase of neg.seq. impedance (degrees)

| Z0| magnitude of zero seq. impedance
Ø0(°) phase of zero seq. impedance (degrees)

| Zg| magnitude of earthing impedance
Øg(°) phase of earthing impedance (degrees)
- - - - - - - - - - - - - - - - -

If the short circuit power S (in VAR) and R1/X1 and the phase-phase voltage Vpp are given, the internal positive sequence resistance and reactance can be calculated :

Calculate first the impedance Z = Vpp Vpp / S
R = Z c / sqrt(1+c*c) where c = the given R/X
X = Z / sqrt(1+c*c)

Parameters on the "Power"-sheet

Table on the left hand side:

Vpp phase-phase voltage
Ø(°) phase of the line-neutral voltage (degrees)
I3ph three-phase fault current
Ø3ph phase of three-phase fault current (degrees)
I1ph line-ground fault current
Ø1ph phase of line-ground fault current
Rg earthing resistance
Xg earthing reactance

Table on the right hand side:
S3ph power of three-phase fault
X1/R1 pos.seq. reactance/resistance
S1ph power of line-ground fault
X0/R0 zero seq. reactance/resistance
| Zg | magnitude of earthing impedance
Øg(°) phase of earthing impedance

Power of the three-phase fault is defined as:

S3ph = sqrt(3) * Vpp * I3ph

Power of the line-ground fault is defined as:

S1ph = sqrt(3) * Vpp * I1ph

Parameters on the "Ratios"-sheet

Table on the left hand side:

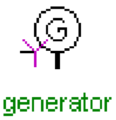
Vpp phase-phase voltage
Ø(°) phase of the line-neutral voltage (degrees)
I3ph three-phase fault current
X1/R1 pos.seq. reactance/resistance
Z2/Z1 neg.seq. impedance/pos.seq. impedance
X0/X1 zero seq.reactance/pos.seq. reactance
R0/X0 zero seq.resistance/reactance
Rg earthing resistance
Xg earthing reactance

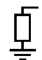
Table on the right hand side
S3ph three phase fault power
R1/X1 pos.seq. resistance/reactance
- - -
| Zg | magnitude of earthing impedance
Øg(°) phase of earthing impedance

Power of the three-phase fault is defined as:

S3ph = sqrt(3) * Vpp * I3ph

Generator

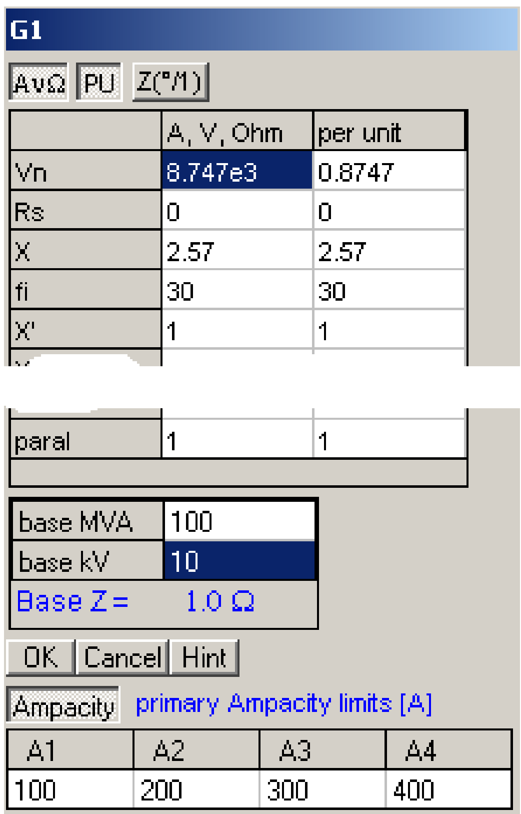


The Generator A round rotor generator. The star point can be connected to earth through an impedance by connecting the grounding impedance  component to the "Y" in the lower left corner of the generator symbol.

The parameters of the generator can be displayed either on a line at the bottom of the screen, as

Vn	Rs	X	fi	X'	X"	T'	T"	X0
8.747e3	0.1	2.57	30	1	0.321	0.25	0.1	0.3

or in a table in a separate small window, as



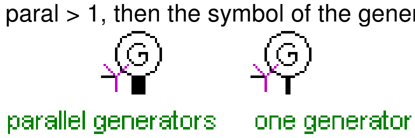
To select between these ways of displaying the parameters, click "view | parameter windows..." in the main window, and check/uncheck the "generator"-box.

When the parameters are displayed on a line, only the "basic" parameters are displayed.

The table displays all parameters, either using physical units or the per-unit notation, in the same way as the parameter tables of the two-winding transformers. Impedances can also be entered in the table using a "local" per-unit notation, where the nominal phase to phase voltage Vn and the nominal apparent power VAn are used as the base variables, see below.

The basic parameters are

Vn = nominal phase to phase voltage, Volts. It is the internal voltage in " i = Y U"calculations. It is the output voltage, i.e. voltage at the terminals of the generator in the "load flow" and in the "adjust voltage" calculations
Rs = stator resistance (one phase), ohms
X = direct axis reactance Xd (one phase), ohms = omeaga*(Ls+Ms), assumed: Xd = Xq
fi = phase angle (not used in Load Flow) of the phase "a" to neutral voltage, degrees
X' = direct axis transient reactance, ohms
X" = direct axis subtransient reactance, ohms
T' = direct axis short circuit transient time constant, seconds
T" = direct axis short circuit subtransient time constant, seconds
X0 = zero sequence reactance, ohms
X2 = negative sequence reactance , ohms
Xq' = q-axis transient reactance, ohms
Xq"= q-axis subtransient reactance, ohms
Tq' = q-axis transient short circ. time constant, seconds
Tq"= q-axis subtransient short circ. time constant
P = power, used only in Load flow, watts
VAn = nominal apparent power, Watts. It is used only in the IEC-
short circuit calculation.
pf = cos(fii) = nominal power factor (< 1). It is used only in the
IEC-short circuit calculation.
Vs = network voltage (system voltage). If Vs = 0, then Vn is used.
Vn is used only in the IEC-short circuit calculation
paral = number of parallel identical generators described by this one generator. This means in practice, that the impedances are divided and the power is multiplied by the number of parallel generators. If paral > 1, then the symbol of the generator changes slightly: The connection line becomes thicker.



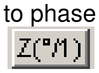
Note
must be X > X' > X" and X > Xq' > Xq"
It is assumed that Xq = X (= direct axis reactance Xd)

Note: The IEC 60909-calculation uses Vn, Rs, X", X0, X2, VAn, pf, Vs
(X0 and X2 are used only for unsymmetrical faults)

Additional parameters

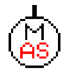
A1,...,A4 the ampage limits They are used in the same way as in the two-winding transformers or the transmission lines.

Impedances using the "local" per-unit notation

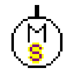
The impedances of the generator can also be entered in the table using a "local" per-unit notation, where the nominal phase to phase voltage Vn and the nominal apparent power VAn are used as the base variables. When the  button is pressed, the "per unit" column of the parameter table is hidden (if it was visible), and a new column, labeled (%/1), becomes visible. This column displays the impedances (reactances and resistances) of the generator using the per-unit notation, with Vn and VAn as the base variables. In addition, the time constants are displayed in this column, in seconds.

Note: The base variables Vn and VAn cannot be edited, when the (%/1)-column is visible. Depress the Z(%/1)-button first, before editing the base variables.
Note: When the values of the base variables Vn and VAn are changed (edited), the per-unit values in the (%/1)-column are automatically changed accordingly (although the column is not visible). It is recommended, that the base variables are entered first, before entering the impedances.

Motors



Asynchronous motor or generator



Synchronous motor

The asynchronous motor or generator
Note: The asynchronous machine is modeled as a generator, if the parameter P is negative. Note also, that all other parameters must be positive (this includes the nominal power and nominal slip).

Vn nominal phase to phase voltage (Volt) Vn > 0.5
Pn nominal power (Watts) Pn > 1
sn slip at nominal power 0.001 < sn < 0.125
pf power factor at nominal power 0.6 < pf < 0.995
eff nominal efficiency 0.7 < eff < 1-slip (at nominal voltage, nominal power, nominal slip. Efficiency decreases when loading decreases)
Note, the efficiency is the <u>electrical</u> efficiency = 1 - (electrical losses) / power input.
IsIn ratio of locked rotor current to nominal current, IsIn > 1.5
P actual loading (Watts) = the useful electrical power P > 1. The power taken by the motor is equal to P divided by the efficiency. But note that the efficiency depends on the power.
If P < 0, then the asyncronous machine acts as **an asynchronous generator**.
m number of pole pairs. Used only in the IEC-short circuit calculation. Must be > 0
Tstrt the starting time of the motor. Needed for drawing the starting curve
Cdisp if = 1, display (draw) the motor starting curve on the relay graphics

Note: if -1 < P < 1, then the value of P is taken as the value of the actual slip ! This applies both to the motor (P > 0) and the generator (P < 0).

Note: The motor or generator power is not adjusted. Instead, the slip is calculated to correspond to the given loading or power, assuming that the voltage = Vn (except for when the parameter P is between -1 and 1, see above)

Note: In the short circuit calculations, the actual slip should not be (much) larger than the nominal slip. Otherwise, accuracy may suffer. (That is, the power P should not be very much larger than the nominal power Pn)

Note: There is no such parameter as "the number of parallel motors". One asynchronous motor can be set to describe several identical parallel asynchronous motors, however. Simply multiply both the nominal power Pn and the actual loading P of one motor by the number of the parallel motors.

Note: When the asychnronous machine is a generator (P < 0), all other parameters except for P must be positive, as if they were given for a motor.

Note: The asynchronous machine as a generator is not "self-starting". That is, there must be some voltage source in the network (a feeder or a synchronous generator. Capacitors do not help here!).

The synchronous motor

Vn = nominal phase to phase input voltage (at motor terminals), volts
Rs = stator resistance (one phase), ohms
Xd = stator (d-axis) reactance, ohms
fi = phase angle, degrees
X' = d-axis transient reactance (Xd'), ohms
X" = d-axis subtransient reactance(Xd"), ohms
T' = transient short circuit time constant, seconds
T" = subtransient short circuit time constant, seconds
ef = efficiency >0 and <= 1
Load= loading of the motor, watts

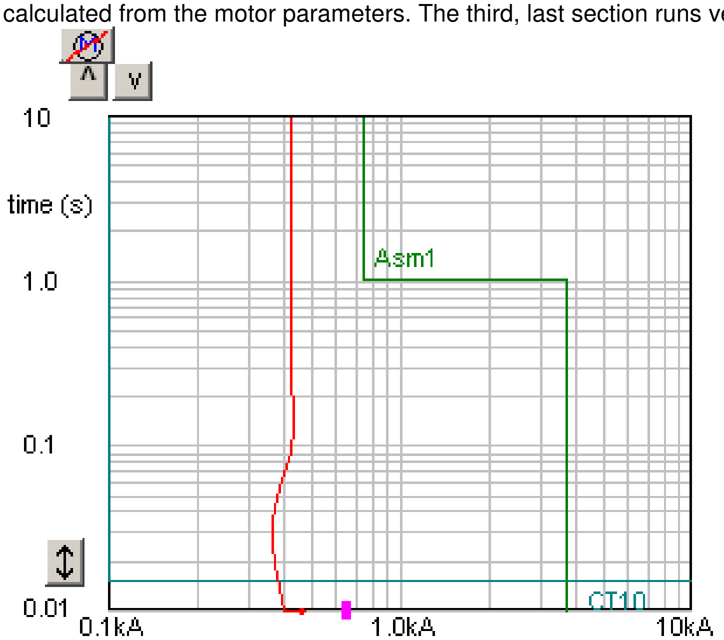
Xq' = q-axis transient reactance, ohms
Xq" = q-axis subtransient reactance, ohms
Tq' = q-axis transient short circuit time constant, seconds
Tq" = q-axis subtransient short circuit time constant, seconds
VAn nominal apparent power, used only in IEC short.circuit calculations

Note: It is assumed that the negative sequence reactance X2 = 0.5*(Xd" + Xq")
Note: The neutral point is not earthed, thus the zero sequence reactance X0 is not needed
Note: In IEC-calculation, it is assumed that the power factor = 0.8

Ampacity
Four different values for the ampacity (max. current) can be entered, when the ampacity-button is down. For more details, see transformer parameters.

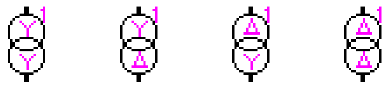
Motor starting curve

A very simple motor starting curve can be drawn on the coordination graphics. If the Cdisp-parameter of the motor is not zero, the curve is displayed (drawn). The curve has three sections. The first section starts at the bottom of the graph, at the locked rotor current. It goes vertically up to the starting current, that is defined with the Tstart-parameter. The curve continues horizontally to the nominal current, that is calculated from the motor parameters. The third, last section runs vertically at the nominal current.



When the starting curve of a motor is displayed on the graph, a small button with the motor symbol with a red line over it will appear on the upper left corner of the window of the graph. The curve can be removed by clicking this button.

Transformers



The small "1" in the symbol indicates the primary side

V1 = nominal primary phase to phase voltage, Volts
V2 = nominal secondary phase to phase voltage, Volts
X = reactance, ohms (as seen from the primary side) can be zero
R = resistance, ohms, can be zero
the resistance is seen from the primary side, R = R1 + R2 * (V1/V2)^2

Io1 = nominal primary open circuit current, A (secondary is open)
Must be > 0.
If the value of Io1 is not know, 0.001*nominal current (or just 0.5) is a reasonable guess
Io1 should not be too small, because that can lead to numerical inaccuracy.

R0, X0 the zero sequence resistance and reactance
Note: R0 or X0 cannot be larger than zero, if X or R is zero.
(This is a limitation in the program, due to the way the transformer is modeled.)

Rg1 = primary earthing resistance of neutral point, ohms (for YY and YD transformers)
Xg1 = primary earthing reactance of neutral point, ohms (for YY and YD transformers)
Xg1 and Rg1 are in series (both must be <=1.e6 and >= 0)

Rg2 = secondary earthing resistance of neutral point, ohms (for YY and DY transformers)
Xg2 = secondary earthing reactance of neutral point, ohms (for YY and DY transformers)
Xg2 and Rg2 are in series (both must be <= 1e6 and >= 0)

+30? Read: Is the phase shift between primary and secondary +30 degrees? 0 = no, 1 = yes
(For YD and DY transformers only)
That is, if 0, then phase shift = -30 degrees, if 1, then phase shift = +30 degrees
As a test other values can be used, as 2: phase shift = +60 degrees,
3: phase shift = 90 degrees, etc
Note: A phase shift of n*60 degrees (n = 1, 2, 3...) may not be physically
possible. The results may be unpredictable, especially in the case of unsymmetrical faults

tap = tap changer position
If tap > -20 and tap < 20, then tap is taken as the change in the secondary voltage in %
but if tap > 0.8 * V1, then tap is taken as a new value for the primary voltage
In all other cases tap has no effect
Note: When the tap is used, X and R are changed
by the same percentage as the voltages, because it is assumed that
the tap changer is in the primary winding

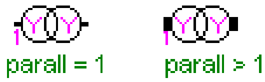
VAn = nominal apparent power, used only in the IEC-short circuit calculations

Vs1,Vs2 = primary and secondary network voltages (system voltages).
If Vs1 = 0, then V1 is used, and if Vs2 = 0, V2 is used
Used only in the IEC-short circuit calculations
That is, Vs1 or Vs2 is the voltage (Un) for which the fault current is calculated, if the fault
is at the transformer.
[The fault current is basically calculated as I" = c Un / (Z sqrt(3)]

tapmin, tapmax minimum and maximum values of the tap changer, as multipliers of V1.
That is, both must be near to one, for example 0.8 and 1.1

parall number of parallel identical transformers. The impedances are divided by "parall", and the open circuit current Io1 is multiplied by "parall"

If "parall" is larger than one, the connection lines of the transformer symbol are drawn with a bold line



Note: As a default, the secondary voltage is 30 degrees behind the primary voltage in both YD- and DY transformers.
That is, the default value of the parameter "+30?" is 0. If the parameter "+30?" = 1, then the secondary voltage leads the primary by 30 degrees.

A Trick (not recommended any more):
Turn a DY transformer upside down and you get a YD transformer, where the (new) secondary voltage leads the (new) primary voltage by 30 degrees.
But **Note:** the impedances must be transformed by the square of the voltage ratio
Note: Do not use this trick in the IEC-calculations, because the correction factors are based on the primary impedance. The results will be completely wrong, if the transformer is the wrong way around.

The winding currents

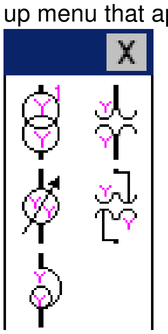
When a YD, DY, or a DD transformer is clicked after a calculation, also the winding currents are displayed in a small result box (if it is allowed to display the result box).

```
(X|xx) T6
 Delta (winding) currents
Iab1     3482,7 <  -94,4°
Ibc1     1731,4 <   86,7°
Ica1     1752,0 <   84,5°
```

The notation is:
  Iab1 = the current in the primary winding connecting the phases a and b.
  Ibc2 = the current in the secondary winding connecting the phases b and c.
  etc.

Transformer symbols

The symbol of the transformers can be changed. Right-click the transformer. Click "symbol" in the pop-up menu that appears. Select the symbol in the menu that appears.

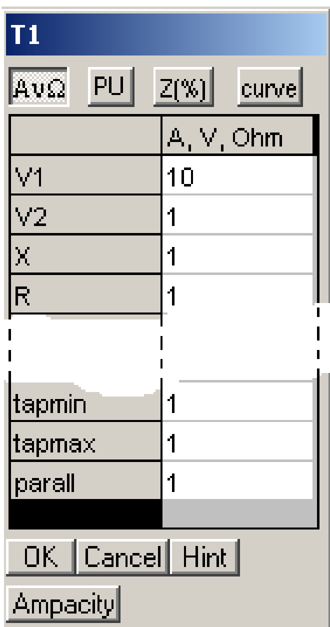


Entering transformer parameters

It may be better to enter the parameters of transformers in a table, because there are so many parameters. The table becomes visible when the transformer is clicked. The table can be kept hidden by clicking "view | parameter windows.." in the menu bar, and unchecking the "transformers 2w"-box. If this is done, then the main parameters of the transformer are displayed at the bottom of the screen.

The parameters can be entered using physical units (A, V, Ohm), or using the per-unit convention. Additionally, the impedances can be entered in percent (%), using separate, transformer base values. All parameters are saved in physical units. The conversion from pu to physical units (or back) may result in small round-off errors. When the parameters are entered in one way (AVOhm, pu, or Z(%)) they are immediately converted to the other forms, and displayed (if possible).

Note: The primary voltage V1 and the nominal apparent power VAn are used as the base values, when entering the impedances in percent (Z(%)-button down). This means that the **impedances in percent will change, when V1 or VAn is changed**. The parametes in the pu-column (pu-button down) have their own base values, see below.



The buttons on the top of the table

AvO displays the column for physical units
PU displays the column for per-unit values
Z(%) displays a table for entering the impedances in percent of the transformer base
curve displays a table for entering the parameters for the transformer damage curve (for 2-winding transformers only)

The buttons below the table

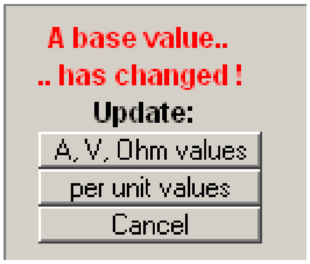
OK accepts the parameters = saves them at the component
Cancel cancels changes in the parameters
Hint displays a small help-memo
Ampacity displays a table for the ampacity parameters of the primary

The base values for the per unit parameters

When the PU-button is down and the column for the per unit parameters is displayed, a table for the base voltage (in kV) and the base power (in MVA) is displayed. The calculated base impedance is also displayed in the table, base Z = (base kV) * (base kV) / base MVA. It cannot be directly edited.

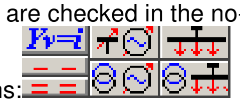
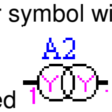
base MVA	2
base kV	1
Base Z =	0,5 Ω

When the base kV- or base MVA-values is edited, then the transformer parameters either in physical units or in the per unit notation must change. The user selects the parameters to be changed in a small panel with buttons for physical units (A, V, Ohm values) and for per unit values. The cancel button cancels the change(s) in the base values. The panel with the buttons appears, when the base values are edited.



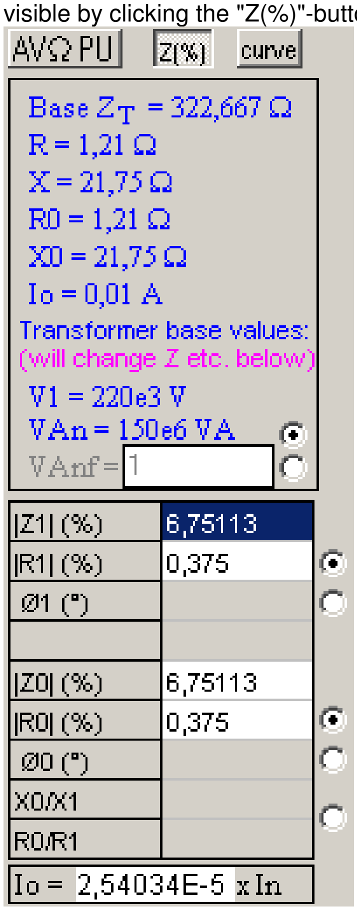
The ampacity limits

Ampacity limits [A]			
A1	A2	A3	A4
700	800	900	1000

Four different ampacity limits can be entered for the primary current, denoted by A1...A4, the smallest first. The ampacity limits are checked in the no-fault calculations, and in the cases of open line faults, started with these buttons: 
The exceeding of the ampacity limits is indicated near the transformer symbol with the identifier of the limit that was exceeded, A1...A4. Here, the limit A2 has been exceeded 

Transformer impedances in percent Z(%)

The impedances of 2-winding transformers can be entered in percent using the primary voltage and the nominal (apparent) power as the base values. The impedances are entered in a table, that becomes visible by clicking the "Z(%)"-button in the window of the transformer parameters.



The base impedance is calculated (in the usual way) as base voltage squared divided by the base power. The base voltage is the primary voltage V1 entered in the main table. The base power is either the nominal apparent power VAn entered in the main table, or the nominal fan cooled apparent power VAnf entered in this table. The base power to be used is selected using the radio buttons on the right hand side.

Note: The **impedances in percent will change, when V1, VAn, or VAnf is changed**. **It is recommended that the base values V1 and VAn or VAnf are entered first**, and the impedances in percent after that.

The buttons on the top

AVOPU used to display the parameters in physical units (A, V, Ohm) and/or using the per unit notation.
Z(%) is already down, has no effect here
curve used to display the parameters for the damage curves

Some parameters are displayed using physical units above the table for the impedances in percent. These include the base values: the primary voltage and the nominal apparent power. They can be edited in the tables that use the physical units, or the per unit notation, available by clicking the AVOPU-button.

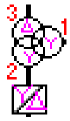
Different ways to enter the impedances

The positive and zero sequence impedances can be entered in two ways: by giving the absolute value of the total impedance [|Z1|(%) or |Z0|(%)], and either the resistance [|R1|(%), |R0|(%)] or the phase angle of the impedance [arc cos (R1/Z1) , arc cos (R0/Z0)]. The selection between these two ways is done by the radio-buttons on the right of the table.

The zero sequence impedance can in addition be given by defining the ratio of zero and positive sequence resistances (R0/R1) and reactances (X0/X1). Also this choice is selected by the radio buttons on the right of the table.

The nominal primary open circuit current **Io** can be entered as a multiple of the nominal current in the last row of the table (at Io = ... x In)

Ideal 1:1 YD transformer

The ideal 1:1 YD-transformer  can be used to model a three-winding YDD-transformer, for example, 

The parameters d1, d2, d5 are not used. They are for possible future extensions.

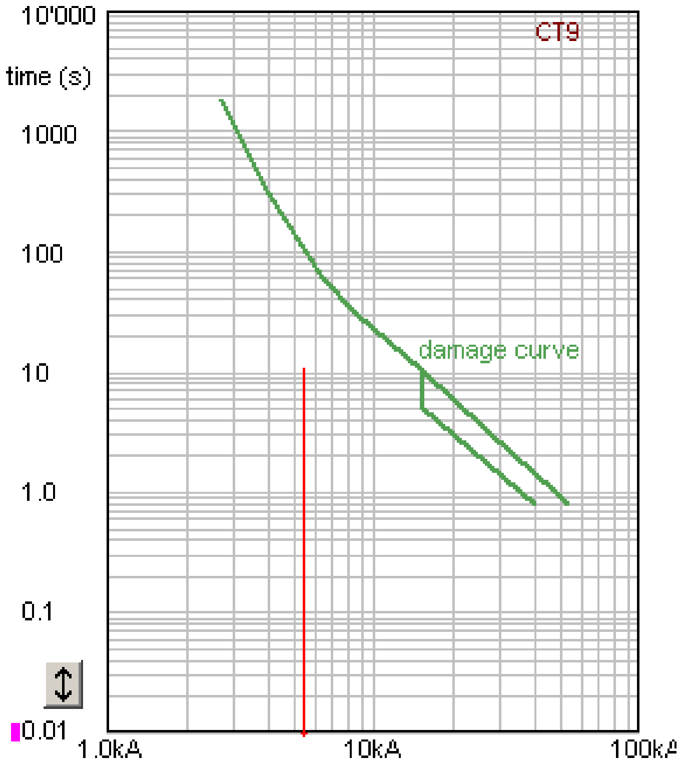
The parameter "**+30**" determines the phase shift from the Y-side to the D-side.
If the parameter is 0, the phase shift is -30degrees.
If it is 1, the phase shift is +30 degrees, 2 corresponds to a (unphysical) phase shift of 60degrees, etc.

The parameter "**grnd**" defines the earthing (grounding) of the neutral point of the Y-winding.
if grnd = 0, the neutral is not grounded, else it is grounded

In the picture above, the ideal YD-transformer is connected to the secondary Y-winding of a three-winding YYD-transformer in order to modell a YDD-transformer. If the neutral of this secondary Y-winding is grounded, either directly (solidly), of through an impedance, the neutral of the Y-winding of the ideal YD-transformer should be grounded (grnd = 1). If that is not done, the earth fault current (near the transformer) may not be correct.

Transformer damage curve

It is possible to include **the transformer damage curve** in the coordination graphics. The curve tells, how long a transformer withstands ("tolerates") a given current without a damage. The curve is given in terms of the primary current. The curve depends on the transformer type (oil-, or air cooled), size ("category"), and the parameters of the transformers. It is possible to use a standard curve, or a user defined curve. The standard curve looks like



The parameters of the damage curve are given on the "curve"-sheet in the parameter window of the transformer, that becomes visible by clicking the "curve" button.

The parameters of the damage curve

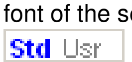
There can be at most three curves for one transformer. There is one column for each of these curves

in use yes or no: curve is/is not drawn. Cannot be edited, use the "Show"-button below the table
Oil/Air oil- or air cooled. Select by clicking the "Oil"- or "Air"-end of the button on the row. The selected cooling type is shown in blue, bold font, and the unselected in gray, normal font.

Oil cooled

Air cooled

Std/user Standard or user defined curve. Select by clicking the "Std" or "Usr" end of the button. The font of the selected curve type is shown in blue, bold font, the unselected in gray, normal font.



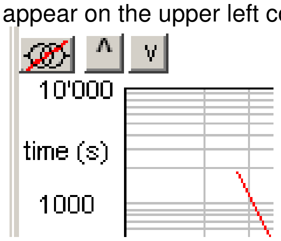
Standard curve

User defined curve

curr.factor multiplies the current values of the curve (shifts horizontally)
time.factor multiplies the time values of the curve (shifts vertically)
name name or identifier of the curve, written near the curve.
The name can be moved with the mouse in the coordination graphics, similarly as the names of markers.
color select the color of the curve from the palette
thickness thickness of the curve, 1...4

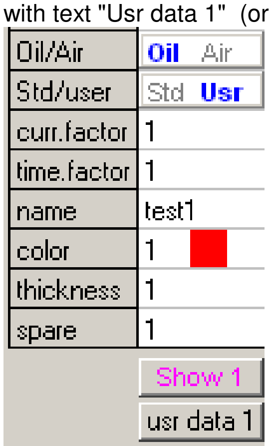
spare not used

In order to **show a curve**, push the "show1", "show2", or "show3" button. A second push will return the button to the up-position, and delete the curve. All three curves of one transformer can be visible at the same time. But only curves of one transformer can be displayed simultaneously. When one or more curves of a transformer are displayed on the graph, a small button with the transformer symbol will appear on the upper left corner of the window of the graph.



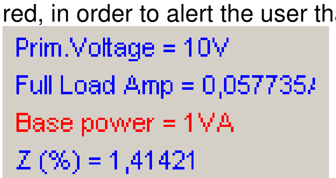
The transformer damage curves can be deleted by clicking this button.

When **the user defined curve** is selected (the Usr-end of the Std/Usr-button in bold+blue text), a button with text "Usr data 1" (or 2 or 3) appears below the table.



When this button is pressed, a new window appears with a table where the user defined curve can be entered pointwise.

Note: The primary voltage V1, the nominal (apparent) power VAn and the impedance (X and R) must be defined, because the curves depend on the size and impedance of the transformer. They are entered on the parameter "sheet" of the transformer (click the AVOPU-button). The main parameters of the transformer are displayed under the table. If the nominal power VAn is exceptionally low, it is shown in red, in order to alert the user that this parameter may not be correct.



Note: For some transformer types (delta-wye, at least) separate curves for primary side and secondary side are needed, because the fault current(s) of an unsymmetrical fault is/are distributed differently in the phases on both sides of the transformer. The additional curve is not drawn automatically. Instead, the user must define the curve and the necessary multiplier with the help of the buttons and coefficients.

Note: The "mechanical damage curve" (the broken line under the main curve), depends on the impedance of the transformer. It is quite possible to enter such an impedance, that this curve is not meaningful. It is not drawn in such a case.

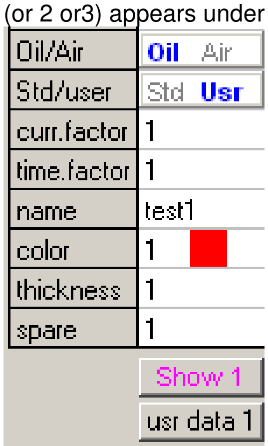
The transformer damage curves are discussed in some detail at

http://www.skm.com/Equipment%20Damage%20Curves%20Transformers.shtml and other documents accessible through that web page. (click "back to Application guides" at the bottom of the web page)

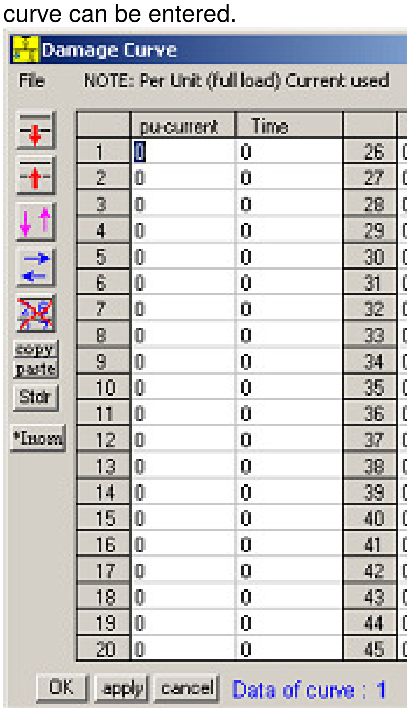
User defined transformer damage curve

The **the user defined curve** is selected by clicking the gray Usr-end of the Std/Usr-button 

. The Usr-text in the button will then be displayed in bold+blue font. A new button with text "Usr data 1" (or 2 or3) appears under the table and the "show"-button in the transformer data sheet for the curve.



When this "Usr data .." button is pressed, a new window appears with a table where the user defined curve can be entered.



The data for the curve is entered pointwise, current in the left column and time in the right column, at most 50 points. The data can be entered manually, read from a file, or copied from a LOCAL clipboard. The data can also be saved to a file and copied to a LOCAL clipboard. Most buttons and the use of the table are the same as in the user defined relay.

Note: The current must be entered as per unit, using the full load amperes (FLA, nominal current) as the base.

Note: The user defined damage curve is drawn from point to point, through all points given in the table. A two-branched curve like the "mechanical damage curve" can be drawn by entering the points for the branch two times, first down, then back up to the branching point in the opposite order.

There are two additional buttons (that do not appear in the user defined relay)

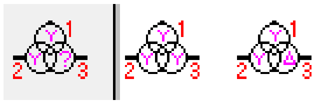
Stdr copies the points from the standard damage curve, defined for the power and voltage of the transformer. Note that "the mechanical damage curve" is not copied (the broken line under the main curve).

***Inom** temporarily multiplies the currents in the table by the nominal current (full load amperes). The multiplied values of the currents are displayed only as long as the button is pressed.

The buttons at the bottom of the page have the usual meanings

OK accept the values, save to the component
Apply use the values, but do not save
Cancel cancel the changes

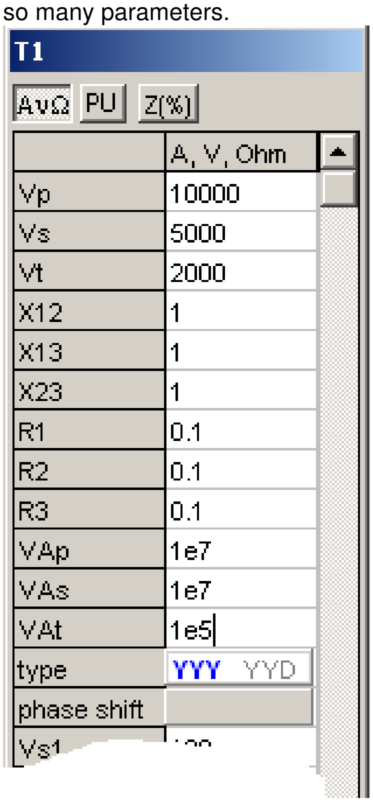
Three-winding transformer



1, 2, 3 in the symbol refer to the primary, secondary, and tertiary windings
The configuration can only be YYY or YYD. The phase shift in the D-winding is -30 or +30 degrees, depending on the parameter "phase shift".

The parameters

The parameters are entered in a table, and not on a line at the bottom of the screen, because there are so many parameters.



T1

AvΩ PU Z(%)

	A, V, Ohm
Vp	10000
Vs	5000
Vt	2000
X12	1
X13	1
X23	1
R1	0.1
R2	0.1
R3	0.1
VAp	1e7
VAs	1e7
VAt	1e5
type	YYY YYD
phase shift	
Vs1	[illegible]

The table becomes visible when the transformer is clicked. The table can be kept hidden by clicking view | parameter windows.. in the menu bar, and unchecking the "3w transformers" -box.

The parameters can be entered using physical units (A, V, Ohm), or using the per-unit convention. Additionally, when the Z(%)-button is down, the impedances can be entered in percent (%) in a separate table, using voltages and powers of the transformer as base values. All parameters are saved in physical units. The conversion from pu to physical units (or back) may result in small round-off errors. When the parameters are entered in one way (AVOhm, pu, or Z(%)) they are immediately converted to the other forms, and displayed (if possible).

Note: Some of the voltages Vp, Vs, Vt and some of the nominal apparent powers VAp, VAs, VAt may be used as the base values, when entering the impedances in percent (Z(%)-button down). This means that the **impedances in percent may change, when voltages or powers are changed**. The parametes in the pu-column (pu-button down) have their own base values, see the two-winding transformer.

The parameters are:

Vp, Vs, Vt primary, secondary, and tertiary phase-to-phase voltages

NOTE: Vs is used as the base voltage for X23 when using the per-unit notation. If Vs is edited, the per-unit value of X23 will change.

X12 the combined reactance of the primary and secondary windings, seen from the primary side
X13 the combined reactance of the primary and tertiary windings, seen from the primary side
X23 the combined reactance of the secondary and tertiary windings seen from the secondary side

Note: the sum of any two must be larger than the third (when normalized to the same voltage).
For example: $X12 < X13 + X23 (V1^2 / V2^2)$
If these conditions do not hold, i.e. if some impedance is too large, then a warning is given. If the option "3w Trafo impedances checked" is selected (under Options, in the main menu), then the largest (normalized) impedance is reduced.

The reactances can be zero (but then all must be zero).

NOTE: When the value of X23 is given using the per-unit notation, the base voltage is the secondary voltage Vs, and NOT the base voltage used for the other parameters (given at the bottom of the window)

R1, R2,R3 the resistance of the primary, secondary, and tertiary windings

Note: These are the resistances of single windings, not pairs of windings (This is different from the two-winding transformer).
If only the combined resistances are known, the resistances of the individual windings can be solved similarly as the impedances of two-winding transformers combined as one three-winding transformer. Alternatively, click the Z(%)-button, and enter the resistances in percent of the respective transformer base impedance.

VAp nominal apparent primary power (for the IEC calculations, and for impedances in %)
VAs nominal apparent secondary power
VAt nominal apparent tertiary power

type YYY or YYD, click to select

phase shift (for YYD only) the phase shift between the D-winding and the (primary) Y-winding.
select -30 or +30 by clicking

Vs1 the system voltage of the primary side
Vs2 the system voltage of the secondary side
Vs3 the system voltage of the tertiary side
these are needed for the IEC calculations only
That is, Vs1, Vs2 or Vs3 is the voltage (Un) for which the fault current is calculated, if the fault is at the transformer.
[The fault current is basically calculated as I" = c Un / (Z sqrt(3)]

Rg1, Xg1 earthing impedance of the primary winding
Rg2, Xg2 earthing impedance of the secondary winding
Rg3, Xg3 earthing impedance of the tertiary winding. This parameter is hidden in the case of a YYD-transformer.

Z0/Z1 (1-2) the ratio of the zero sequence impedance and the positive sequence impedance for the combined impedance of the primary and secondary windings.
The zero sequence reactance is thus: X120 = X12 * (Z0/Z1)
If Z0/Z1 is zero, the value one is used.
Z0/Z1 (1-3) zero seq. imped/pos.seq.imped for X13
Z0/Z1 (2-3) zero seq. imped/pos.seq.imped for X23

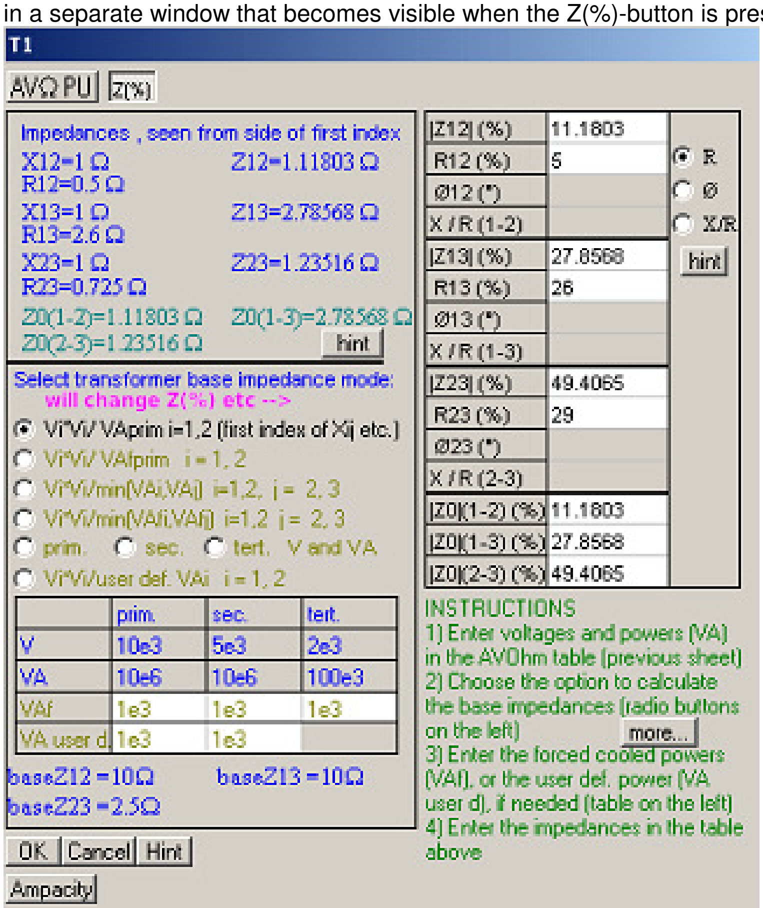
The same ratios are used for the resistances of the windings. The calculation is done so that the combined resistance of winding pairs (prim+sec, prim+tert, sec+tert) are calculated first. These are then multiplied with the ratios, and finally, the resistances of individual windings are solved.

The buttons at the bottom of the window

OK accepts the parameters (saves to the component)
Cancel cancels the editing of the parameters, old values kept
Hint opens a small help-memo (not this help-file)
Ampacity displays a table for entering ampacity limits for the primary current. See transformers for more details.

Impedances of three-winding transformer in %

It is a common practice among the transformer manufacturers to give the impedances of a three-winding transformer in per cent, using a base impedance or impedances that is or are derived from the nominal voltages and powers of the transformer itself. It is possible to enter these per cent-impedances as such in a separate window that becomes visible when the Z(%)-button is pressed down.

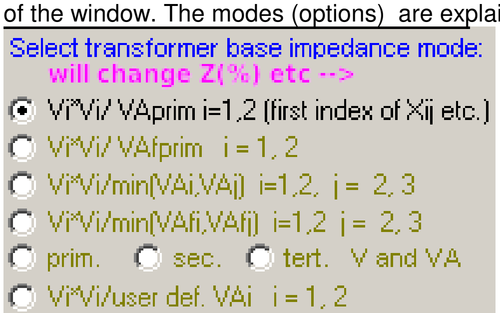


The window may look complicated or confusing. The reason for this is that there are several ways or modes in which the base variables (voltage, power, impedances) and also the transformer impedances themselves can be defined.

Proceed in the following way to enter the impedances:

1) Enter the voltages and powers in the VAOhm-table of the previous sheet (or window) where the parameters are entered in physical units or in per unit.

2) Select the mode (or option) for calculating the base impedances. Use the radio buttons in the left part of the window. The modes (options) are explained in some detail below.



NOTE that the change of the mode will change the per cent-impedances in the table on the right hand side of the window. The impedances in Ohms stay constant.

3) Enter the forced cooled powers (VAf), or the user def. power (VA user d) in the table below the radio buttons, if the corresponding mode has been selected. That is, if "Vi*Vi/VAfprim" (second radio button from top) or "Vi*Vi/min(VAfi,VAfj)" (fourth radio button from top) has been selected, then the values of the forced cooled power(s) VAf must be entered in the table. If "Vi*Vi/user def. VAi" (the last radio button) has been selected, then the user defined power(s) must be entered in the table.

4) Enter the impedances in per cent (more below...) in the table on the right hand side.

Some details on the modes (options) of the base parameters (point 2 above)

(*) Vi*Vi / VAprim :
For Z12 and Z13 the base impedance is calculated as primary voltage (Vp) squared divided by primary power (VAp)(both in the table on the VAOhm-sheet).
For Z23 the base impedance is calculated as secondary voltage (Vs) squared divided by the primary power (VAp).

(*) Vi*Vi / VAfprim: as above, but using the primary forced cooled power (power VAf prim entered in the table below the radio buttons)

(*) Vi*Vi / min(VAi, VAj) :
For Z12, the base impedance is calculated as primary voltage Vp squared divided by the minimum of primary (VAp) and secondary power (VAs) (all in the table on the VAOhm-sheet)
For Z13 : primary voltage (Vp) squared divided ty the minimum of primary (VAp) and tertiary power (VAt).
For Z23 : secondary voltage (Vs) squared divided by the minimum of secondary (VAs) and tertiary power (VAt)

(*) Vi*Vi/min(VAfi, VAfj) : as above, but using the forced cooled powers (Vaf prim, sec, tert., entered in the table under the radio buttons)

(*) prim (*) sec (*) tert : For all impedances the base is calculated either as primary voltage (Vp) squared divided by the primary power (VAp) , or secondary voltage (Vs) squared divided by the secondary power (VAs) , or tertiary voltage (Vt) squared divided by the tertiary power (VAt) , depending on which option is selected (all entered in the table on the VAOhm-sheet)

(*) Vi*Vi/user defined VAi:
For Z12 and Z13 the base impedance is calculated as primary voltage (Vp, in the table on the VAOhm-sheet) squared divided by the user defined primary power (VAuser d., prim, entered in the table under the radio buttons)
For Z23 the base impedance is calculated as secondary voltage (Vs, in the table on the VAOhm-sheet) squared divided by the user defined secondary power (VAuser d., sec., entered in the table under the radio buttons).

Some details on entering the impedances in percent (point 4 above)

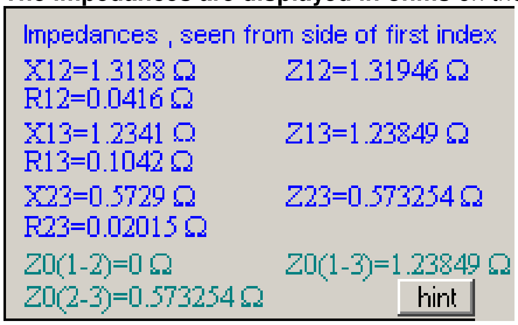
The impedanceds of the three-winding transformer are entered in % in the table on the right side of the sheet (window) using the transformer base impedance, selected with the
"radio-buttons" on the lower left part of the sheet.
NOTE: the base is not the same as the per-unit base, on the AVOhm sheet

The magnitude of the impedances (| Z12 | etc) must be always given. The components can be given in three ways, that are selected with the radio buttons on the right of the table.

(*) R enter the resistance (in per cent)
(*) Ø enter the "phase angle" of the impedance = arctan(X/R), in degrees
(*) X/R enter the ratio reactance/resistance

NOTE: It is assumed that X/R is the same for the positive and zero sequence impedances.
NOTE: the first index always gives the side from which the impedance is seen. For example, Z12 is the impedance of the primary and secondary winding pair, as seen from the primary side.

The impedances are displayed in ohms on the upper left side of the sheet.



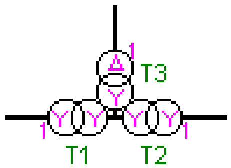
The impedances cannot be edited here, only in the tables. The values of the impedances are shown as seen from the side of the first index. Z12 is the impedance of the primary-secondary winding pair, as seen from the primary side. Similarly, Z0(1-2) is the zero sequence impedance of the primary-secondary winding pair, as seen from the primary side.

NOTE: The resistances are given for the winding pairs here (R12, R13, R23), but resistances of individual windings are entered in the table on the AVOhm-sheet (R1, R2, R3). The values of the resistances of the individual windings can be very different from the resistances of the winding pairs, depending on the transformation ratio, that is, the nominal voltages of the windings.

NOTE: It is possible that some of the resistances of the individual windings becomes negative, even when the resistances of the winding pairs have reasonable values. The program may work correctly with the negative values.

Modeling a three-winding transformer

The three-winding transformer included in the component menu is available only in the YYY and YYD configuration, without taps. Other configurations can be modeled using three pieces of two-winding transformers connected in a star. It is recommended that the primary windings point outwards, see picture.



The parameters of the two-winding transformers can be calculated in the following way. Assume that the three transformer impedances Z12, Z23, and Z13 of the three-winding transformer are given. Here Z12 = R12 + j X12 is the impedance of the transformer consisting of windings 1 and 2 of the three-winding transformer as seen from the winding 1 (of the 3-w trafo). The other impedances of the 3-w trafo are defined similarly. In addition, the nominal voltages V1, V2,and V3 of the three windings must be given, of course.

Set the primary voltage of the two-winding transformers equal to V1, V2, and V3, respectively. The secondary voltage can be selected freely. A reasonable choice is to use the smallest of the voltages V1, V2, V3 as the secondary voltage of the two-winding transformers. Assuming that the impedances can be concentrated in the primary windings of the two-winding transformers, the impedances Z12, Z23, Z31 can be written as

$$Z12 = Z1 + Z2\,(V1/V2)^2$$
$$Z23 = Z2 + Z3\,(V2/V3)^2$$
$$Z13 = Z1 + Z3\,(V1/V3)^2$$

where Z1, Z2, Z3 are the impedances of the primary windings of the two-winding transformers, Z1 = R1 + j X1, and similarly the others. Solve this set of three linear equations and set the resistance and reactance parameters of the two-winding transformers equal to the solved values, R = Ri, X = Xi, where i = 1,2,3.

In order to solve the equations, convert Z23 to voltage level V1: $Z23a = Z23 * (V1/V2)^2$
The impedances at voltage level V1 can be then calculated as

$$Z1 = (Z12 + Z13 - Z23a) / 2$$
$$Z2a = (Z12 + Z23a - Z13) / 2$$
$$Z3a = (Z13 + Z23a - Z12) / 2$$

where the index "a" refers to the voltage V1.

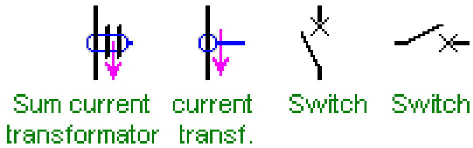
The impedances Z2a and Z3a can then be converted to the voltage levels V2 and V3, as

$$Z2 = Z2a * (V2/V1)^2$$
$$Z3 = Z3a * (V3/V1)^2$$

Note: Some of the resulting resistances and reactances may be negative. This may be an indication that some of the data may be in error. For example, some of the impedances Zij may have been taken the wrong way around. Try to avoid negative impedances especially, if there are asynchronous motors in the network. (The program may work correctly even with negative impedances.)

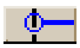
Note: The three-widing transformers use the resistances of the individual windings as parameters. If only the combined resistances R12, R13 and R23 are known, the individual resistances of the windings can be solved using the equations above. The results can be used as such for a YYY-transformer. But for a YYD-transformer, the resistance of the tertiary winding calculated with the equations above must be multiplied by three.

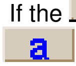
Current transformers, switches (breakers)

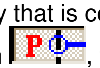


and 

The current transformer and **the sum current transformer** are actually measuring points. Actually, they have parameters, but it is not necessary to use the parameters. They are used to show the current in the branch where they sit, and to transfer the value of the current to the protection relay or distance relay. The sum current transformer "measures" the sum of the currents in the phases "a", "b" and "c". The (normal) current transformer "measures" the current in a single phase.

If the  button is in the position 

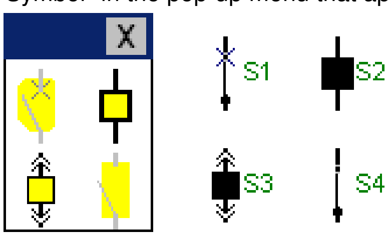
, the current of the phase or sequence determined by the 

button is displayed. The relay that is connected to the current transformer is not affected by this button. If the button is in the position 

, then the power transmitted through the point of measurement is displayed.

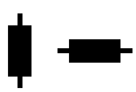
The switches (breakers) change position from open to closed and from closed to open every time they are clicked. When a switch is closed it is considered as a connection wire, without any impedance. When the switch is open, the connection is completely broken.

The symbol of the switches (breakers) can be changed by right clicking the component, and selecting "Symbol" in the pop-up menu that appears. A small window opens showing the available breaker types.

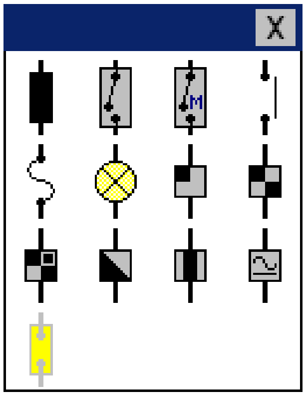


The breaker symbol can be changed by clicking one of the symbols in the small window. (The window mostly shows open breakers.The corresponding symbols for closed breakers are shown on the right hand side of the image above.)

- - - - - - - - - - - - - -

More breakers of the second kind 

Several different breaker symbols are available under the "breaker-2" component. The symbols can be selected in a menu



The menu becomes visible by right-clicking the component, and by (left-) clicking the text "Symbol" in the pop-up menu. The menu can be dragged with the mouse at the colored upper part of the menu picture. The menu can be closed by clicking the [X] in the upper right of the menu picture.

Note: The state of the breaker (open/closed) does not change, when the breaker is clicked, unlike the first breaker type (see above). Instead, the breaker is opened and closed by selecting the symbol of an open or a closed breaker in the menu.

Parameters of the current transformers

Parameters of the current transformers
(including sum current transformers, and the special current transformers)

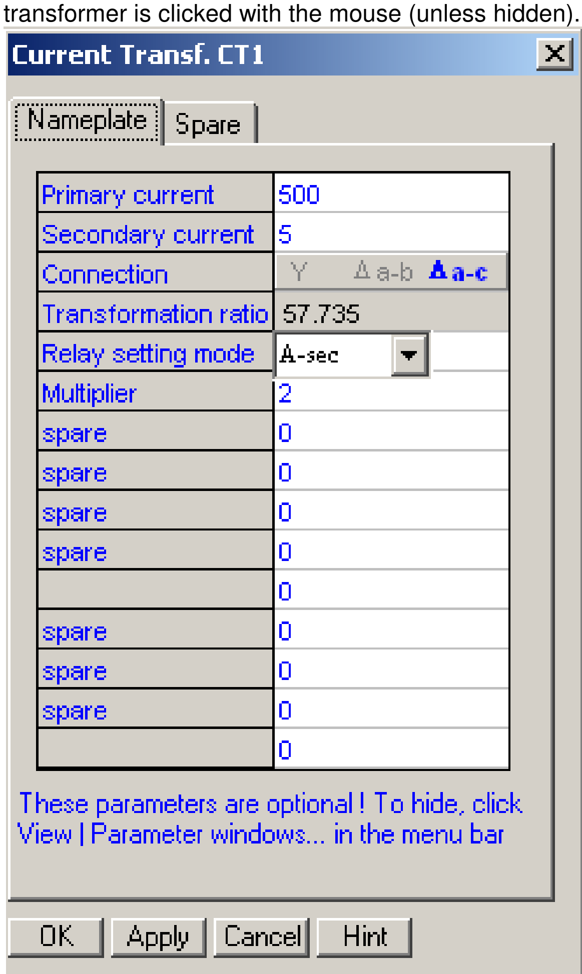
The current transformers, sum current transformers and the special current transformers have optional parameters that determine how the connected overcurrent relays (simple, PGQ, electromechanical, recloser, and user defined relays) handle the readings from the current transformers.

Note: These parameters are added for convenience only, the user can neglect the parameters. That means, that the current transformers and the sum current transformers can be used as measurement points only, without attention to any parameters. Just select "A-prim" as the relay setting mode. Even the parameter window can be kept hidden.

Note that the special current transformers have also a second set of parameters. These are the multipliers that are used when adding the contribution from other current transformers. When a special current transformer is clicked, two small windows will open, one for the multipliers and the other for the optional parameters described here (only the window for the optional parameters can be hidden.)

Note that the distance relays do not use (do not care about) these parameters of the current transformer

The parameters are edited in a small parameter window that becomes visible when the current transformer is clicked with the mouse (unless hidden).



There are two sheets for parameters. The sheets can be selected by clicking the tab of the sheet. The label on the tab gives the types of parameters.
Nameplate contains the main parameters

Spare is for future extensions.

The main parameters are

Primary current   the nominal primary current of the current transformer, in Amperes

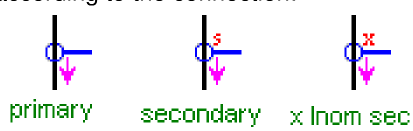
Secondary current the nominal secondary current of the current transformer, in Amperes

Connection The secondary of the current transformer can be connected in Y (wye) or in delta. If delta, the windings can be connected in two different sequences: either as a-b-c, or a-c-b. The connection can be selected by clicking the appropriate symbol on the "Connection"-row

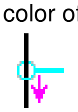
Transformation ratio nominal prim.current divided by the nominal secondary current. If the connection is "Delta", then the nominal secondary current is still multiplied by the square root of three.The ratio cannot be edited. It is calculated from the data above.

Relay setting mode determines how the current from the current transformer is used in the relay that is connected to the current trafo. There are three possibilities that can be selected in the small drop down menu that opens when the "Relay setting mode"-row is clicked. The possibilities are:
A-prim   (read: "primary current in Amperes") the relay uses the primary current, that is, the current in the network as such, in Amperes
A-sec   (read: "secondary current in Amperes") the relay uses the secondary current, in Amperes
x Inom sec (read: "times nominal secondary current") the relay uses the relative secondary current, which is defined as the secondary current divided by the nominal secondary current

The "Connection" and the "Relay setting mode" are indicated in the symbol of the current transformer with a small "s" for "secondary", and "x" for "x Inom sec", and by changing the color of the arrow according to the connection:



multiplier multiplies the current, but **only** in the coordination graphics. Might be useful in coordination (grading).
Note: if the multiplier is equal to zero, the current is not multiplied
If the multiplier is not one and not zero, the symbol of the current transformer is changed so that the color of the connecting line is light blue



The buttons on the bottom of the parameter window act in the same way as the corresponding buttons on other parameter windows.
OK accept (and store) the parameters, closes the window
Apply use the parameters, but do not store, does not close the window
Cancel cancels the changes made in the parameters, closes the window
Hint opens a small help-window (not this "proper" help-file)

Use of the parameters fo current transformers

The parameters of the current transformers are optional, for convenience only. The idea is that the user can enter the same settings to a relay of this program as are used in a real relay. The parameters have (almost) no effect on the calculations, and only little effect on the displayed results.

When a current transformer is clicked, the value of the primary current of the current transformer is displayed in the result box. This is the same current as in the network. But when the relay that is connected to the current transformer is clicked, the value of the current determined by the parameters of the current transformer is displayed. This current can be the primary current, the secondary current, or the relative secondary current. If secondary current, or relative secondary current, it can be connected in Y, delta a-b, or delta a-c, all this according to the parameters.

The coordinatin graphic displays the value of the primary current as default, i.e. the current flowing in the network. But if the "Delta"-button  is down, and the "connection" parameter of the current transformer is "delta" (either a-b, or a-c), the delta connected current is displayed, but with a transformation ratio of 1:1, independent of the proper transformation ratio of the current transformer. The purpose is to show the current that the relay "sees", so that the activation time of the relay as read in the graphics is the same as displayed in the diagram or in the result box.

Note:The "delta"-button is visible only, when the "relay connection mode" of the current transformer is "A-sec" or "x Inom Sec", that is, when the secondary current is used, and the secondary is connected in delta.

Also the current phasor diagram displays the primary current as default. But it is possible to display the secondary currents by using the "Options"-menu on the menu bar of the phasor diagram window.

The **Options-menu** on the toolbar of the phasor window can be used to select the source of the displayed current phasors. When the "Currents in Amp prim"-item is selected, the currents are read from the primaries of the current transformers (that is, directly from the network). When the "Currents in Amp sec"-item is selected the phasor diagram reads the currents from the secondaries of the current transformers, in Amperes. This will include the factor of square root of three, if the secondary of a current transformer is connected in Delta.

Note, that the "Relay setting mode"-parameter of the current transformer has no effect in the phasor display.

Transformation ratio of the current transformer

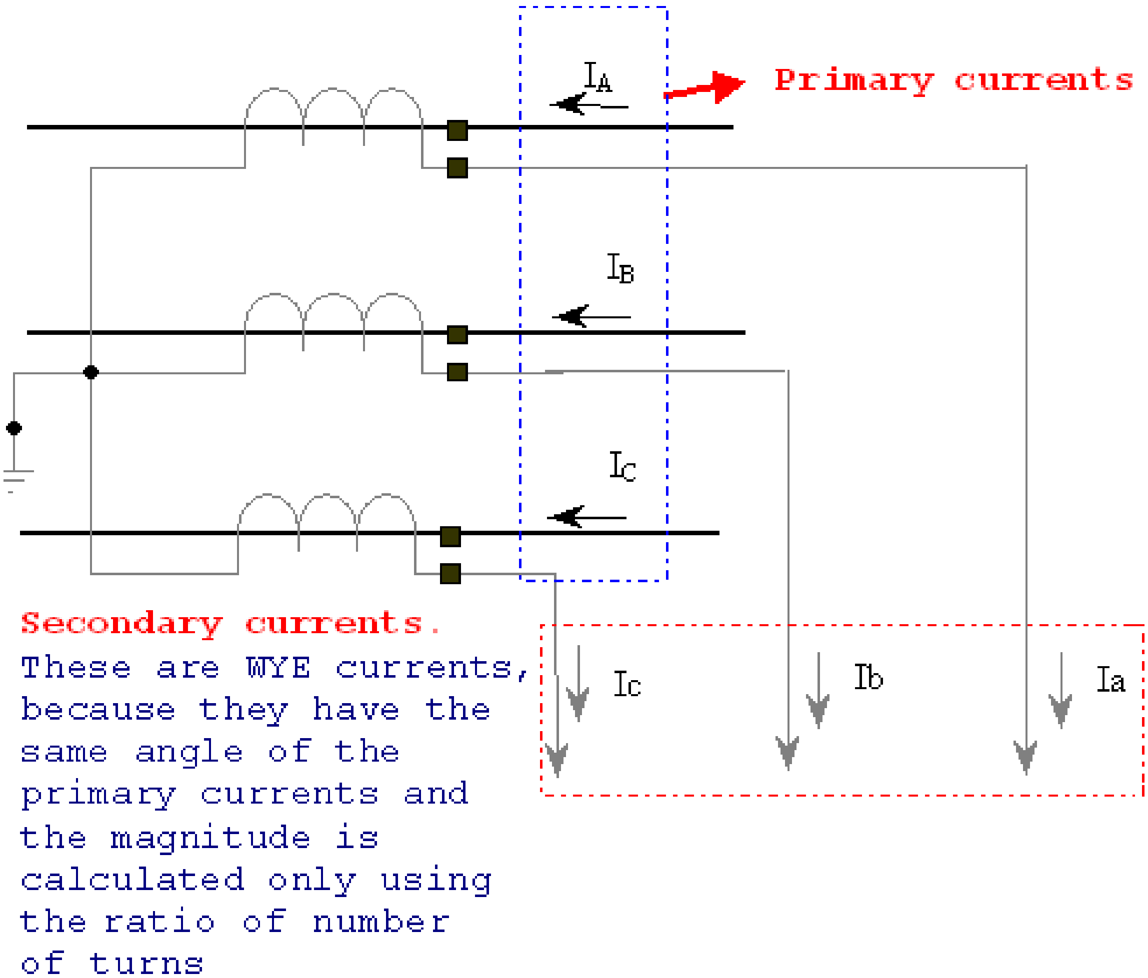
The transformation ratio of the current transformer
(Remember, the parameters of the current transformer are optional, and can be neglected)

The transformation ratio is defined here as the ratio of primary current to the secondary current.

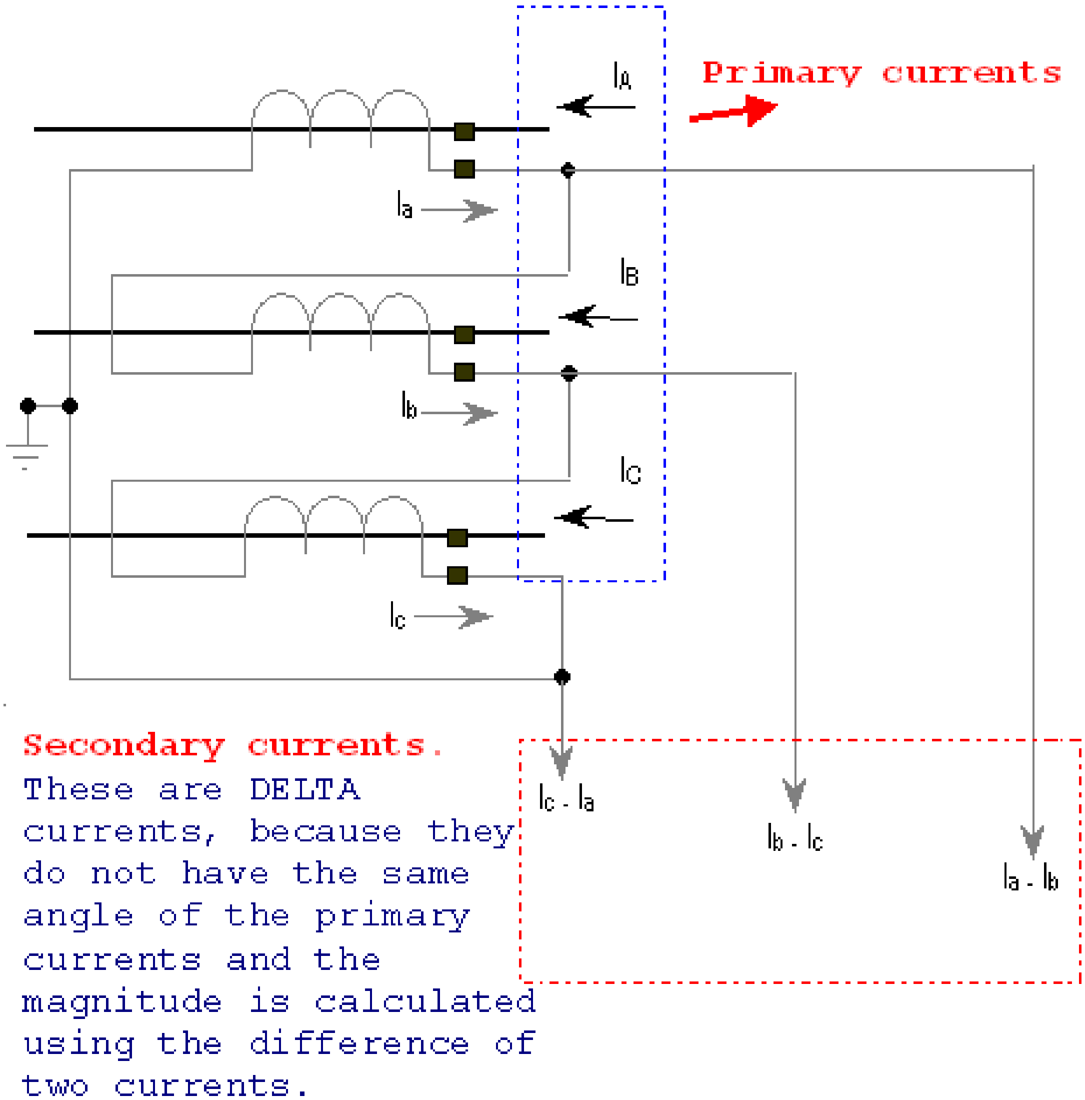
The number of turns is fixed in the binary and secondary windings, but the transformation ratio depends also on how the secondary windings are connected. This is determined by the "connection"-parameter. When connected in Y, the ratio is directly the ratio of the nominal primary and secondary currents: ratio = (Iprim,nom) : (Isec,nom) , where Iprim,nom and Isec,nom are the values of the nominal primary and secondary currents.

But if the windings are connected in Delta, either as a-b, or a-c, then the transformation ratio is: ratio = (Iprim,nom) : (Isec,nom*sqrt(3)). The type of the Delta connection, a-b, or a-c, affects only the phase shift between the primary and secondary currents.

Y (wye) connected current transformer



Delta (a-b) connected current transformer

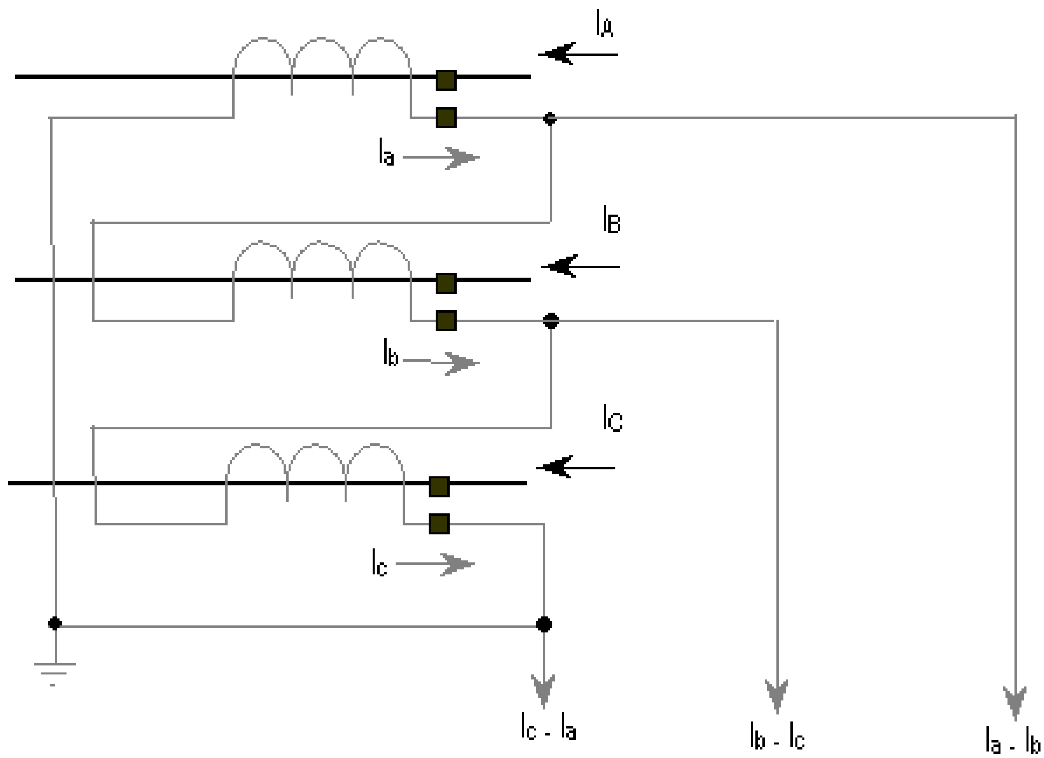


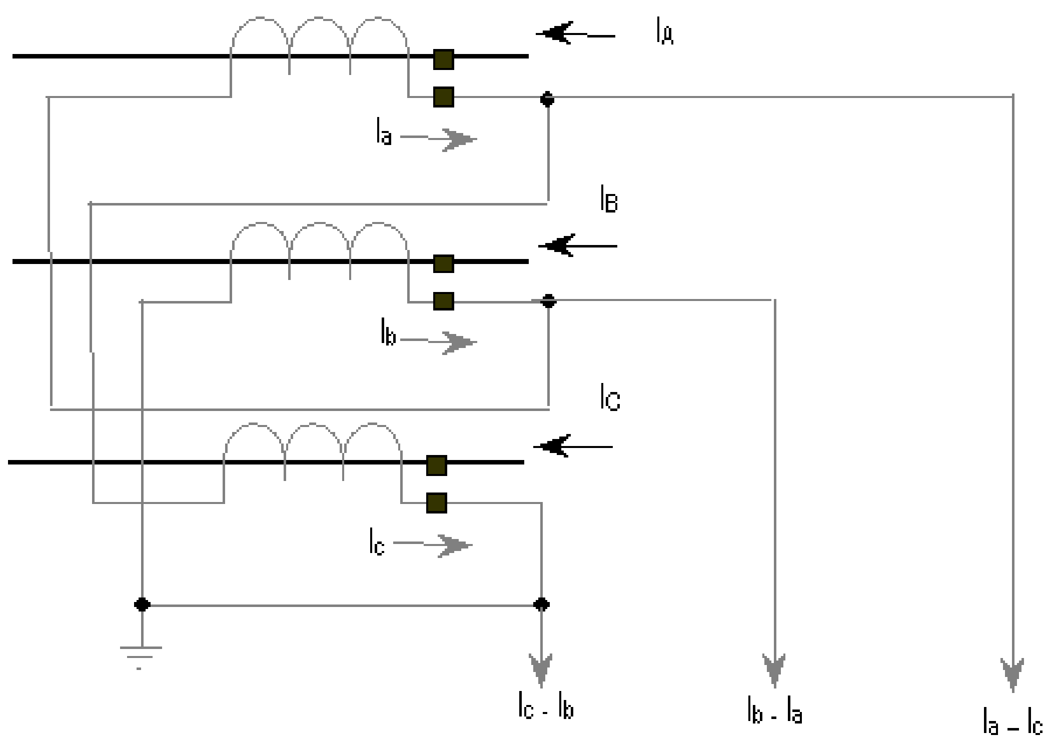
Consider a current transformer with 300 A as a primary current and the transformation ratio is 100. The secondary "wye" current would be 3 A (or A-sec), whereas the secondary "delta" current would be (3 x sqrt(3)) A = 5,166 A (or A-sec).

Delta a-b and a-c connected current transformer

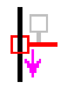
The upper picture shows a "Delta a-b" connected current transformer. The connected relay will receive the current Ia - Ib in phase a.

The lower picture shows a "Delta a-c" connected current transformer. The connected relay will receive the current Ia - Ic in phase a.


IA
Ia
IB
Ib
IC
Ic
Ic - Ia
Ib - Ic
Ia - Ib

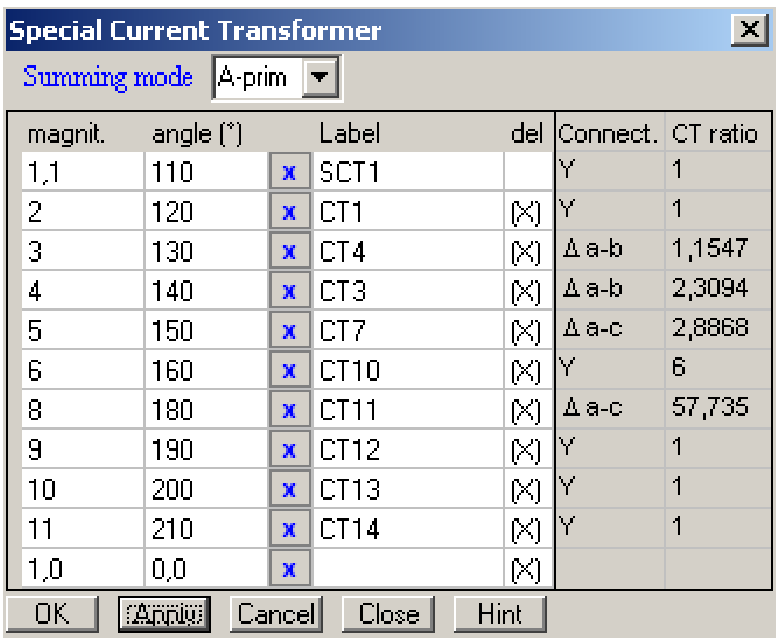

IA
Ia
IB
Ib
IC
Ic
Ic - Ib
Ib - Ia
Ia – Ic

Special, summing current transformer



The special summing current transformer calculates the weighed sum of the currents of the current transformers connected to it, including itself. That is, it reads the primary or secondary current of the current transformers connected to it, multiplies the currents with complex coefficients given in the list (see below), and sums the multiplied currents. In other respects, it behaves like an "ordinary" current transformer: It displays the (weighed sum) current, a relay can be connected to it, etc. However, it does not display the power through it, because the power related to the weighed sum current does not make sense.

When this special current transformer is clicked, two small windows will open, one for entering the coefficients for the sum and the other for entering the "ordinary" parameters (nominal currents, connection type, etc) of the special current transformer. The complex coefficients must be given as magnitude and phase, in degrees.



The selection of the primary or secondary current is done with the small drop-down menu on the top of the parameter window. If "A-prim" (read: primary current in Amperes) is selected, the weighed sum of the primary currents, i.e. the currents in the network is calculated. If "A-sec" (read: secondary current in Amperes) is selected, then the weighed sum of the secondary currents of the current transformers is calculated.

Note: The "Relay setting mode"-parameter of the current transformer is not considered, when the (weighed) sum of the secondary currents is calculated.

An ordinary current transformer can be added to the list, i.e. connected to this special current transformer by clicking it, when this window is visible. The label of the clicked current transformer appears in the column with the heading "Label".

A current transformer can be removed from the list by clicking the (X) in the column labeled with "del" on the row where the label of the current transformer is. Two buttons appear, a "Delete" button, and a "Cancel" button. The Delete-button removes the current transformer from the list. The Cancel-button cancels the deleting and hides the buttons. This special current transformer itself cannot be removed from the list. That is why there is no (X) on the first row. (Note: The small blue x's in the middle column are only decorations!)

The two last columns in the parameter window (picture above) display the connection type (Y or Delta a-b, or Delta a-c) and the transformation ratio of the connected current transformers. This data is displayed here for information only. They cannot be changed here. To change, click the (ordinary) current transformer itself.

Note: The weighed sum of the currents does not change immediately, when a new current transformer is added to the list, or when a coefficient is changed. The calculations are carried out first when the OK-button or the Apply-button on the bottom of the window is clicked. (The purpose of the yellow background is to remind of pressing either of these buttons.) But note, the effect of the Delete-button is immediate: the current transformer is removed from the list, the calculations are carried out, and the list is saved.

The buttons on the bottom of the window

OK Carries out the calculations (the weighed sum), saves the list, and closes the window.

Apply Carries out the calculations, but does not close the window.

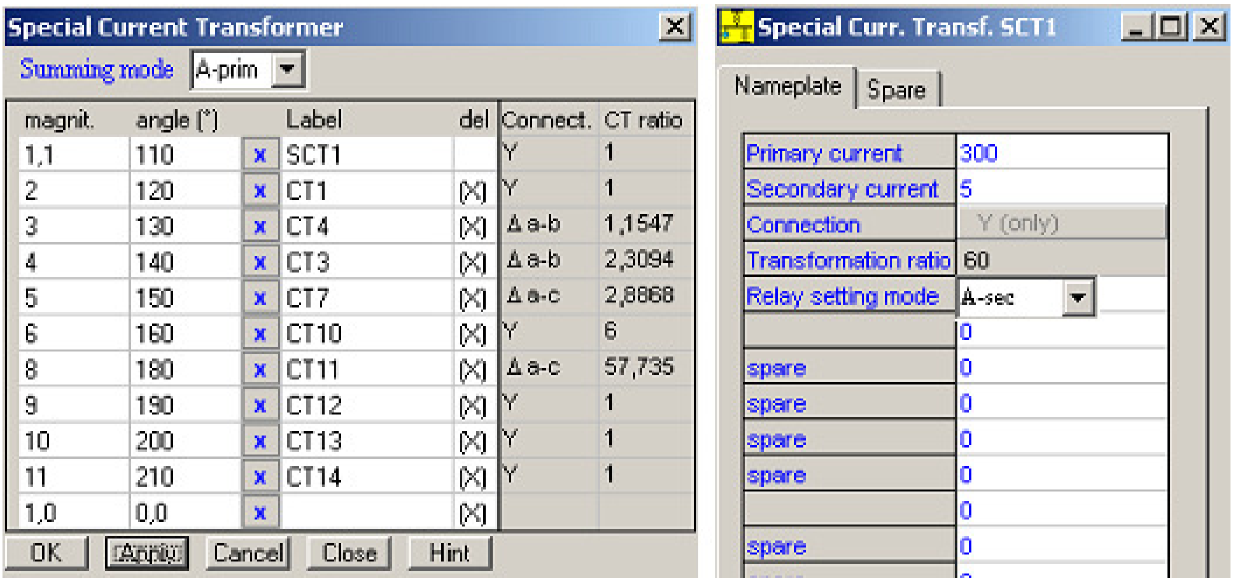
Cancel Returns the list in the state it was when the window last became visible. That is, the deletions, additions and changes in the coefficients are cancelled.

Close Closes the window. The list is saved in the state it was after the Apply- or Delete- or Cancel-button was clicked. If none has been clicked, it is saved in the state it was when the window become visible, discarding any changes.

Hint Opens a separate Help-window. The help-window can be closed by clicking the (X) in the upper left corner of the help-window.

CT parameters and the special current transformer

The special current transformer (or summing CT) calculates the weighed sum of currents in the current transformers connected to it. When a special current transformer is clicked, two small parameter windows open. One contains the list of the connected current transformers and the coefficients for the sum. The other window contains the "ordinary" parameters for the current transformer.



Let's call the first window "the sum window". The other window will be called "the ratio window".

Because the special current transformer is a little special, the use of these "ordinary" parameters of the ratio window must perhaps be explained in some more detail.

There is a small menu on the top of the sum window. **If the user selects "A-prim"** (read: primary currents in Amperes) in this menu, the special current transformer reads the primary currents of the connected current transformers (including itself), multiplies the currents with the coefficients of the sum window, and calculates the sum. The parameters of the ratio window are not used in this calculation, neither for the special CT, nor for the connected CT's. But the "relay setting mode"-parameter is still used to determine which current is read to the connected relay.

But if the user selects "A-sec" (read: secondary currents in Amperes) in this menu, the calculation of the sum becomes a bit more complicated.

- The special current transformer reads the secondary currents (in amperes) of the connected current transformers, including itself. The transformation ratio and the connection type (Y or delta) of the current transformers are taken into account. But the "relay setting mode" is not considered.

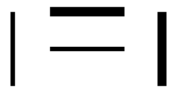
- These secondary currents are multiplied with the coefficients of the sum window, and the products are summed.

- Because the current transformers always display the primary current in the result box, and near the current transformer, the sum is still multiplied by the transformation ratio of the special current transformer before it is displayed.

- Typically, a relay is connected also to the special current transformer. The relay reads (and displays) the primary current, the secondary current, or the relative secondary current from the current transformer, depending on the value of the "relay setting mode"-parameter. When **"A-sec"** is selected in the small menu in the sum window, the sum multiplied by the transformation ratio corresponds to the primary current, the sum as such corresponds the secondary current, and the sum divided by the nominal secondary current corresponds to the relative secondary current. But if **"A-prim"** is selected, the sum as such corresponds to the primary current, and the sum divided by the transformation ratio corresponds to the secondary current.

Lines (wires and buses), Voltmeter, Text

Wires and Buses



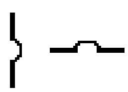
The wires and buses are actually only connecting lines, without parameters that affect the calculations (no resistance, reactance, etc.). The bus has parameters for checking only, see below. If there is a line (=wire, bus) between two components (in a reasonable way), then the components are connected. Components can be attached to both ends of the lines, and also somewhere betwen the ends .

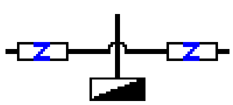
The wires and buses can be stretched. Place the cursor near to one end of the line so that the cursor changes to a double arrow. Press and keep the left mouse key down. Move the mouse (cursor) until the line has been stretched to the desired length. Note, that the line can be stretched only to a given maximum length. If a longer line is needed, two lines must be attached end to end.

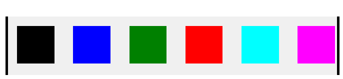
The symbol (picture) of the wire (not the bus) can be changed from a continuous line to a dashed line (- - - - - -) or a dotted line (........) by right-clicking the wire and selecting "Symbol" in the pop-up menu that appears. Default is a continuous line, one click gives a dashed line, and the second click gives a dotted line.

The parameters of the bus
Vn nominal phase-phase voltage
puVmin alarm limit for minimum voltage, in per-unit notation (not yet in use)
puVmax alarm limit for maximum voltage, in per-unit notation (not yet in use)

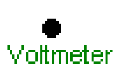
Results displayed for the bus
Voltage, either magnitude (V) and phase (fii), or real (Vr) and imaginary (Vi) components
puV per unit voltage, so far for phase a only. puV = phase-neutral voltage*sqrt(3) / Vn

The crossing lines  are intended for drawing two crossing lines that are not connected. Remember that components are (generally) connected, if they seem to be connected in a reasonable way. The crossing lines cannot be stretched.



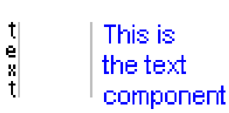


The color of wires and buses and some other components can be selected by clicking the colored squares at the bottom of the component menu. The colors can be used to indicate the nominal voltage level, for example. The color of the same components can be changed in the single line diagram by right clicking the component, and selecting the color in the menu that appears.

Voltmeter 

A voltmeter-component is actually the same as a bus, but with a different symbol.

Text



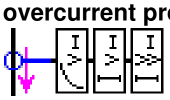
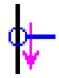
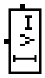
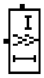
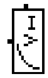
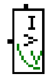
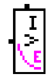
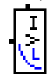
The user can add small texts in the diagram with the text-component. It behaves like a normal component, but has no parameters. When the text-component is clicked, or created, an explanation appears on the bottom of the screen: "Write text to the next row. Semiocolons (;) indicate line feed, Only two semicolons !" in the place of the paramenter names of a normal component The user can write the text under this explanation line, in the place where the parameter values of a normal component are. This text then appears on the right of the text component.The text can contain at most three rows. The font of the text cannot be changed.

Note: The vertical word "text" disappears, when the text component is dragged from the component menu to the diagram. Only the thin, grey, vertical line remains to show the position of the component.

Note: Click and drag (move) the vertical grey line, when you want to move the text component around (not the user written blue text).

Simple overcurrent protection relays

Simple overcurrent protection relays

Relays  are constructed from current transformers , definite time modules   and at most one inverse time module    . The two definite time modules are actually identical. Only the symbol is different. **Note**, that the current transformer has no parameters. It is actually only a measurement point.

The parameters of the definite time modules are

I0 = start current, Amperes
t = operate time (delay), seconds

The relay is activated, if the current through the connected current transformator is larger than I0 for a period longer than the time t. If either I0 or t is zero, the relay module is disabled.

The parameters of the inverse time modules are

Is = set current value, Amperes
k = time multiplier

The characteristic curve of the inverse time modules are defined by the equation

$$t = \frac{k\,b}{(I / Is)^{a} - 1}$$

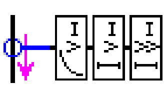
from which the operating time is calculated.

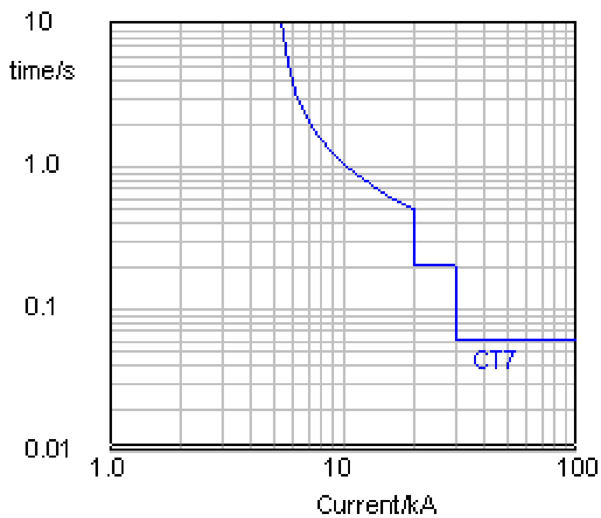
I is the current through the connected current trafo

Here a and b are constants. They have different values for the different types of the inverse time module.The user cannot change these constants.

Normal inverse : a = 0.02 and b = 0.14
Very inverse: a = 1.0 and b = 13.5
Extremely inverse : a = 2.0 and b = 80.0
Long time inverse: a = 1.0 and b = 120.0

The characteristic curve of the relay is the combination of the characteristic curves of the modules. The characteristic curve of a relay with one normal inverse time module and two definite time modules might be something like the picture below





Relay parameters and the parameters of the current transformers

The parameters of the relay and the current transformer

(Remember, the parameters of the current transformer are optional, and can be neglected)

The parameters of the current transformer (if in use) must be taken into account actually only when entering the current-related parameters (not time-parameters etc.) of the relay that is connected to the current transformer. The "if in use" above means that the relay setting mode of the current transformer is "A-sec" or "x Inom sec".

If the **relay setting mode is "A-prim"** (read: primary current in Amperes), the relay uses the primary current of the current transformer, i.e. the current in the network as such. In this case, the parameters of the current transformers have no effect, they can be neglected. The current-related parameters of the relay refer directly to the current in the network. If, for example, the set current parameter of a definite time relay is 100 A, then the relay reacts, when the current in the network exceeds 100 A.

But if the **relay setting mode is "A-sec"** (read: secondary current in Amperes), or **"x Inom sec"** (read: times nominal secondary current), then the parameters of the current transformer must be taken into account, because the secondary currents enter the relays.

Assume, for example, that the ratio of the nominal primary and secondary currents is 200:5 = 40, and the connection type is Y (wye). If the set current parameter of a definite time relay is again 100 A, and the relay setting mode is "A-sec", then the relay reacts, when the current in the network exceeds 40*100A. But if the relay setting mode is "x Inom sec", then the relay reacts, when the current in the network exceeds 40*5*100A = 20000A, because the relative secondary current is used.

But if the connection of the current transformer is Delta (a-b, or a-c), then the relay reacts, when the primary current exceeds 40*100/sqrt(3) A = 2309A in the "A-sec" case, and 40*5*100/sqrt(3) A = 11550A in the "x Inom sec"-case.

Conversely, if the current at which the relay must react is given in terms of the primary current, i.e. the current in the network, the current related parameters of the relay must be calculated by dividing by the transformation ratio, and possibly by the nominal secondary current, in the "x Inom sec"-case. Thus, if the relay must react at 11550A of network current in the last case, then the set current parameter of the definite time relay must be: Iset = 11550*sqrt(3)/(40*5) = 100 (A).

This all may sound complicated, but should not be. If the current transformer is used as a measurement point only, i.e. to connect the relays to the network, the connection mode is "A-prim", and the parameters of the current transformer can be neglected. But if the secondary currents are used, the parameters of the relay should be the same as in a real relay.

The only exception among the current related parameters is the maximum current-parameter of the combined relays. It is always given in primary currents, i.e. it corresponds to the currents in the network.

The parameter windows of the combined relays (PGQ-relays, etc) have small texts "A prim", "A sec" or "x Inom sec" to remind the user on the way the parameters must be entered.

Pickup Def 3 [A, sec]	50
Delay Def 3 [s]	0,04
Pickup Def 4 [A, sec]	30
Delay Def 4 [s]	0,05
Common	
Max current [A,prim]	700
Directional (0 = no)	1

Momentary (temporary) relay setting mode

When the relay setting mode is given, it may be of interest to see, what the current related parameters would be in some other relay setting mode. For example, if the relay setting mode is "A sec", i.e. the relay uses the secondary current from the current transformer, it may be interesting to see, what the parameters would be, if the relay used the primary current. This is possible by using the "momentary mode" buttons at the bottom of the relay parameter window

There are three buttons, one for each relay setting mode. When one button is pressed down, the current related parameters of the relay (set current, pickup def 1...4) are multiplied by a multiplier, so that the multiplied parameters correspond to the relay setting mode of the pressed button. The rules for calculating this multiplier are the following:

(In the following, "ratio" is the ratio of the nominal primary
current and the nominal secondary current of the current transformer,
and Isc is the nominal secondary current of the current transformer.)

if the relay setting mode is "primary amperes" (A-prim),
  if the "A sec"-button is down, then the multiplier = 1/ratio
  but if the "X Inom"-button is down, then the multiplier = 1/(Isc*ratio),

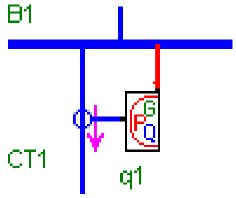
if the relay setting mode is "secondary amperes" (A sec), then
  if the "A prim"-button is down, then the multiplier = ratio
  but if the "x Inom" button is down, then the multiplier = 1/Isc

if the relay setting mode is such that the normalized (relative) secondary
current is used (mode = x Inom sec), then
  if the "A prim"-button is down, then the multiplier = ratio*Isc
  but if the "A sec"-button is down, then the multiplier = Isc

In order to avoid errors, it is not possible to edit the parameter values, when one of the buttons is down. The table for the parameters is colored light gray to emphasize this.

PGQ-Relay

The combined PGQ-relay

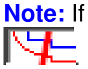


See also: The parameters The menu bar The buttons The equations for the inverse time module

The connection point on the long side of the relay symbol is connected directly to a current transformer. If the directionality function is in use (see below), the connection point on the short side of the relay (red in the figure above) must be connected to to a bus (for example) in order to get a reference voltage.

The combined PGQ-relay is an overcurrent relay, that checks the **P**hase current, the sum current (or residual- or **G**round current) and the negative se**Q**uence current (multiplied by three!). Each of these currents can be checked using a combination of at most three relay modules: For this, there are available two definite time modules and one inverse time module.

Note: The values of some of the parameters determine whether a module is in use.

Note: If the "Show char. of all clicked relay"-button is down, and a red slash is drawn over the button  , the parameter box and the graph of the relay will not appear, when the relay is clicked. This may be handy, when constructing the diagram.

The relay has also a directionality function separately for each of these currents. If the directionality is in use, and the relay considers that the fault is in the reverse direction, the relay does not react, when the current exceeds the activation value. The direction of the fault is determined similarly as is done in the distance relay.

Note: The directionality-property is not in use in the short circuit calculations according to the IEC-standard. Due to the calculation method, it is not always possible to determine the direction of the fault.

The inverse time module has several characteristics curves available. The curves are connected in groups for an easier selection.

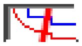
The PGQ-relay has so many parameters, that the parameters cannot be displayed on the lower part of the screen, as is done with most other components. Instead, a small parameter window opens, when the relay is clicked.

Note: Minimize the parameter window, if it is not desirable that this parameter window appears, when the relay is clicked (for example, when the single line diagram is under construction). That is, click the small button with the bar in the upper left corner of the parameter window (not the button with the cross). In this way, only a minimized parameter window appears, when the relay is clicked again.

Parameters of the PGQ-relay

See also: The menu bar The buttons The equations for the inverse time module

The parameters are entered in a parameter window, because there are too many parameters to be displayed on the bottom of the screen. The user can move from a parameter cell to a neighbouring cell using the arrow keys, or the tab-key. One can move in any direction with the arrow keys. The tab-key can be used to move right, from column to column, and from the last, rightmost column to the next row on the first column.

Note: If the "Show char. of all clicked relay"-button is down, and a red slash is drawn over the button  , the parameter window and the graph of the relay will not appear, when the relay is clicked. This may be handy, when constructing the diagram.

There are nine rows for a free description of the relays, such as name, type, for example. These rows are identified with ID P(1) ... ID Q(3). These rows become visible by pressing the "Show texts"-tiem in the menu bar. The ID P(*)-rows are for the phase relay, the ID G(*)-rows are for the sum, or residual relay, and the ID Q(*)-rows are for the negative sequence relay. Additional comments can be written in a box for notes. Click View | Notes.

The actual parameters become visible by pressing the "Show parameters" item in the menu bar. There are three columns of parameters. The leftmost column (marked with 51 P and 50 P) is for the phase current-module of the relay. The middele column (marked with 51 G and 50 G) is for the sum- or residual current-module. The rightmost column is for the negative sequence current-module. It is marked with 51 Q(3I2) and 50 Q (3I2) in order to remind that three times the negative sequence current (3 * I2) is considered.

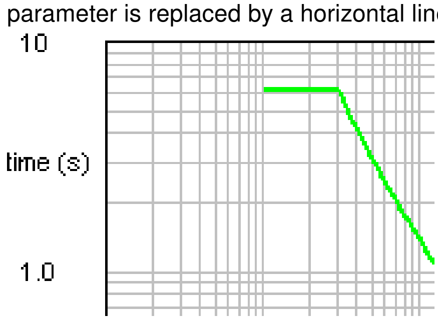
Group and Curve

The type of the inverse time module is defined by selecting the group of curves and the curve within the group. The group and the curve are selected from the small menus that appear when the group-cell and the curve-cell are clicked (or entered). The groups and curves are described on separate pages.

Set current value (Is) [A]

The current parameter of the inverse time module. It is the value of the current at which the curve starts (if the Factor (n) is equal to 1), or at which the characteristics curve goes to infinity. If the Set current value is zero, the inverse time module is not in use.

Factor OR Start time
(must be >= 1)
If the factor-parameter is less than or equal to five, then the factor-parameter determines the (minimum) current at which the inverse time curve starts: at (Factor) times (Set current value).
But if the factor-parameter is larger than five, then it gives the maximum time. The curve starts at the value of the set current-parameter, but the part of the curve where time is larger than the factor-parameter is replaced by a horizontal line. In the example below, factor = 6 and set current = 10A



Curve modifiers t'' = Bt+C modify the curve by multiplying the time or adding a constant to the time
B = Time multiplier multiplies the time

C = Time adder(s) adds a constant to the time
tx = min.response time (s) activation time cannot be smaller

The equation of the characteristic curve gives the time as a function of current. The Time multiplier (mostly) simply multiplies the value of the time. See the definitions of the curves, for an exact description.

Picup def 1, 2, 3, and 4 [A], and Delay def 1, 2, 3 and 4 [s]

The definite time modules react, if the current exceeds the Picup def-value for a time longer than the Delay def-value. In other words, these parameters define the edge (or corner) of the characteristic curves of the definite time modules. If the Picup def. or the Delay def. is zero, the definite time module is not in use.

Max. Current [A]

The characteristic curve is drawn up to this current value

Directional, | Z line| (ohms) Ø line (degrees)

If the directional-parameter is equal to one (not zero) the relay is directional, and the line impedance | Z line | and the impedance phase angle Ø (in degrees) must be given.
Note: The same value of impedance and angle is used for all three modules. The values are entered in the leftmost column, and are automatically copied to the two other columns.

Show curve and act. test

This parameter has four possible values. They are selected using the small menu that appears, when the box is clicked:
"hide" = 0: hide the characteristic curve
"show complete" = 1: show the complete curve
"only inv.time" = 2: show only the inverse time part of the curve (not the definite time part)
"only def.time" = 3: show only the definite time part of the curve (not the inverse time part)

The values 2 and 3 (only inv.time or def.time) are temporary values. They are needed (used) in test calculations, where either time or current is given, and current or time is calculated, see "Current (calculate time) and Time (calculate current), Multiple of P.U. current" below. Additionally, these parameters are used when calculating the time difference between two characteristic curve. The values 2 and 3 are reset to 1 automatically when the short circuit currents are calculated. The values can also be reset manually by selecting "Advanced | Reset relay curves" in the menubar of the main window.

The texts on the "Activation test"-row follow the value of this parameter. If the parameter is zero, so that the curve is not shown, the texts is "no test", etc.

Line thickness

Determines the thickness of the line of the characteristic curve on the coordination graphics page. If the thickness is equal to zero, a thin dashed (noncontinuous line) is shown.

Color

Determines the color of the line on the coordinantion graphics page. Select the color from the menu that appears when the color cell is selected (clicked).

Spare

Not used, for future extensions.

Current (calculate time) and Time (calculate current), Multiple of P.U. current

The three last rows are for test inputs. If a value for the current is entered, the program calculates the time at which the relay module would react when the current has the given value. If a value for the time is entered, the program calculates the current for which the activation time would be equal to the given time. Both the time and the current are calculated using the combined characteristic curve of the definite time and inverse time modules.

The last row expresses the current as multiples of the pick-up current of the inverse time module. If a value of the current or time is given as input, the value of current / pick-up current is displayed here. This line can also be used to enter the current as multiples of the pick-up current for the calculation of the activation time.

The texts on the "Activation test"-row follow the value of the "Show curve and act. test"-parameter, see above. If the parameter is zero, so that the curve is not shown, the texts is "no test", etc.

Menu-bar of the PGQ-relay parameter window

File | Save

Save the selected nonlinear curve ("inverse time curve") to file. The curve is saved pointwise, by writing the values of some tens of current-time pairs of the "normalized" curve to the file. "Normalized" means that the parameters "set current value" and "time multiplier" are equal to one in the saved curve. The first and last saved points are determined by the parameters "factor" and "max current". The saved curve can then be modified and used in the user defined relay.
Note: Only the nonlinear curve is saved, not the eventual definite time parts.

Note: The curve that has been selected last is exported. That is, if you click some parameter of the 51P-relay before clicking "file | save as", then the inverse time curve of P51 relay is exported. If you click some parameter of the 51Q-relay, then the curve of the 51Q-relay is exported, and similarly for 51G.

File | Exit

Close the parameter window. The parameter window can be closed also by clicking almost anywhere on the screen (except the parameter window and an eventual help-box), or by clicking the OK- or the Cancel-buttons. The parameters are accepted (moved to the component) when the parameter window is closed, except for when the Cancel button is closed.

View | Notes

displays a small text-box for additional notes. The notes are saved together with the other parameters of the relays, when the single line diagram is saved to file. The box is closed by clicking again view | notes. The box can be moved around by dragging with the mouse, but only within the parameter window. The same notes can be displayed in the main window, when the cursor is set on the relay, if the "show component notes" flag is set.

Options | Highlight selected cell

1) Highlight is selected (checked):
When a parameter cell is entered either by clicking the cell, or by moving with the arrow or tab-keys. the text in the cell is highlighted (has a colored background). If the user starts to edit the text in the cell directly, the old text is deleted. But if the user first clicks the cell, or presses the enter-key, the text can be edited without losing the old text.

2) Highlight is not selected (not checked)
When a parameter cell is entered, the cell is not highlighted, but the cursor is visible as a vertical bar. Editing the text in the cell does not deltete the old text.

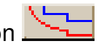
PHASE PLANE or NEGATIVE SEQUENCE PLANE

The negative sequence current (multiplied by three) is "smaller" than the phase or sum currents. When the characteristics of the relay modules for the negative sequence current are drawn on the same coordination graphics as the characteristics of the the phase and/or sum current relays , the current-related parameters of the negative sequence curves must be divided by the square root of three, or the current-related parameters of the other characteristics must by multiplied by the square root of three.

When the parameters of the negative sequence relays are taken as such (withoud the division), the coordination graphics is presented in "the negative sequence plane". When the parameters of the other relays are taken as such, the coordination graphics is presented in "the phase plane".

The selection of the plane is done by clicking "phase plane" or "negative sequence plane" in the menu, that opens when the text "PHASE PLANE" or "NEGATIVE SEQUENCE PLANE" in the menu bar is clicked.

In practice, the selection of the plane moves the characteristics to the right or left on the coordination graphics.

Note: The planes are in use and can be changed only when the "show char..."-button  is down. When the button is not down, the text "EDITION PLANE" appears in the menu bar. All curves are then shown as they are, without any multiplications or divisions.

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< Group 1 >
There are three items here. The arrows **<** and **>** are used to change the parameter group of the relay, either decrease (<) or increase (>) the group index.

The "Group 1" or group 2, group 3, etc. shows the parameter group in use. It is also a menu item for copying parameters from one group to another, and for displaying and setting conditions for the automatic change of the group.

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M or **A**
Manual or automatic mode for the change of parameter groups.

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Help
Opens a new window, where the equations of the inverse time module of the different groups are displayed. The equations are the same as in the chapter "Equations for the inverse time module" of this help-file.

Buttons of the PGQ-relay parameter window

OK
Clicking the OK-button accepts the parameters (moves the parameters to the relay) and closes the parameter window.

Cancel
Clicking the Cancel-button closes the parameter window without accepting the parameters. If the parameters have been edited, and the Apply-button has been pressed, the Cancel-button returns the original, unedited parameters.

Apply
Clicking the Apply-button moves the parameters temporarily to the relay, so that the coordination graphics curve and the activation times (may) change. The parameter window is not closed. The original values of the parameters can be returned by clicking the Cancel-button.

Hint
The clicking of the Hint-button opens a small "Help-box". (Different from this, proper help file). The Help-box can be closed by clicking the (X) in the upper left corner of the box, of by clicking somewhere on the screen, except for the Help-box itself or the parameter window.

The "Momentary mode"-buttons at the bottom of the parameter window are explained in the chapter "The parameters of the relay and the current transformer".

Equations for the inverse time module

The type of the invese time module of the PGQ-relay, i.e. the equation for the characteristic curve can be selected from several groups. Each of them have four or more curves, or equations. The groups are called by the following names:

Group 1: IEC
Group 2: IEEE C37.112
Group 3: ABB
Group 4: ANSI
Group 5: IAC
Group 6: MIC
Group 7: variant 1 of IEEE C37.122
Group 8: Basler
Group 9: Noja ANSI
Group10: variant 2 of IEEE C37.122
Group11: GE motor protection relay

The equations and parameters of the different groups are the following:

Group 1, IEC

General Equation for Group 1

$$tp = TD\left(\frac{A}{M^{P} - 1} + B\right)$$

tp = operating time in seconds
TD = time multiplier setting **(range 0,01-100 / step : 0,01)**
M = applied multiples of set current value (= I/Is)

Constants for Group 1 Time Overcurrent Characteristics

Curve	A	B	P
Standard inverse (1)	0,14	0,0	0,02
Very inverse (2)	13,5	0,0	1
Extremely inverse (3)	80,0	0,0	2,00
Long-time inverse(4)	120,0	0,0	1
Short-time inverse (5)	0,05	0,0	0,04
Inverse (6)	9,4	0,0	0,7

Group 2, IEEE C37.112

General Equation for Group 2

$$tp = TD\left(\frac{A}{M^{p}-1}+B\right)$$

tp = operating time in seconds
TD= time multiplier setting **(range 0,5-100 / step : 0,01)**
M=applied multiples of set current value (Is)

Constants for Group 2 Time Overcurrent Characteristics

Curve	A	B	P
1 Moderately inverse	0,0104	0,0226	0,02
2 Inverse	5,95	0,180	2,00
3 Very Inverse	3,88	0,0963	2,00
4 Extremely inverse	5,67	0,0352	2,00
5 Short-time inverse	0,00342	0,00262	0,02

Group 3, ABB

General Equation for Group 3

$$tp = \left(\frac{A}{M^{p} - C} + B \right) \times \left(\frac{14n - 5}{9} \right)$$

M= applied multiples of set current value (= I / Is)
n= time multiplier setting **(range 0.5-100 / step : 0,01)**

Constants for Group 3 Time Overcurrent Characteristics

Curve	A	B	C	P
1 Extremely Inverse	6,407	0,025	1	2,0
2 Very Inverse	2,855	0,0712	1	2,0
3 Inverse	0,0086	0,0185	1	0,02
4 Short Time inverse	0,00172	0,0037	1	0,02
5 Short-Time Ext. Inverse	1,281	0,005	1	2,0
6 Long Time Ext. Inverse	64,07	0,250	1	2,0
7 Long-Time Very Inverse	28,55	0,712	1	2,0
8 Long Time Inverse	0,086	0,185	1	0,02
9 Recloser Curve #8	4,211	0,013	0,35	1,8

Group 4, ANSI

General Equation for Group 4

$$T = M \times \left(A + \frac{B}{(I/Ipu) - C} + \frac{D}{((I/Ipu) - C)^2} + \frac{E}{((I/Ipu) - C)^3} \right)$$

T = trip time (seconds)
M = multiplier value range 0.01 - 100, step 0.01
I = Input current
Ipu = pickup current setpoint
A,B,C,D,E =constants

Constants for Group 4 Time Overcurrent Characteristics

Curve	A	B	C	D	E
1 Extremely Inverse	0,0399	0,2294	0,5000	3,0094	0,7222
2 Very Inverse	0,0615	0,7989	0,3400	-0,2840	4,0505
3 Normally Inverse	0,0274	2,2614	0,3000	-4,1899	9,1272
4 Moderately Inverse	0,1735	0,6791	0,8000	-0,0800	0,1271

Group 5, IAC

General Equation for Group 5

$$T = M \times \left(A + \frac{B}{(I/Ipu) - C} + \frac{D}{((I/Ipu) - C)^2} + \frac{E}{((I/Ipu) - C)^3} \right)$$

T = trip time (seconds)
M = multiplier value range 0.01 - 100, step 0.01
I = Input current
Ipu = pickup current setpoint
A,B,C,D,E =constants

Constants for Group 5 Time Overcurrent Characteristics

Curve	A	B	C	D	E
1 Extremely Inverse	0,0040	0,6379	0,6200	1,7872	0,2461
2 Very Inverse	0,0900	0,7955	0,1000	-1,2885	7,9586
3 Inverse	0,2078	0,8630	0,8000	-0,4180	0,1947
4 Short Inverse	0,0428	0,0609	0,6200	-0,0010	0,0221

Group 6, MIC

$$tp = TD\left(\frac{A}{M^{p}-1}+B\right)$$

tp = operating time in seconds
TD = time multiplier setting (range : 0,05-100 / step :0,05)
M = applied multiples of set current value (M = I / Is)

	A	B	p	
BS 142 inverse	0.14	0	0.02	
Inverse	0.005934	0.418944	0.001	for M = 1 - 4
	0.006881	-0.252552	0.001	for M = 4 - 31
Very inverse	52.953837	0.923352	2.11174	for M = 1 -
	28.447085	1.007587	1.70216	for M = 4 -
Extremely inv.	58.132137	0.166533	2.1346	

Group 7, a variant of IEEE C37.112

General Equation for Group 7

$$tp = TD\left(\frac{A}{M^{P}-1}+B\right)$$

tp = operating time in seconds
TD = time multiplier setting **(range 0,01-100 / step : 0,01)**
M = applied multiples of set current value (= I/Is)

Constants for Group 7 Time Overcurrent Characteristics

Curve	A	B	P
Moderately inverse (1)	0,0515	0,1140	0,02
Very inverse (2)	19,61	0,4910	2,00
Extremely inverse (3)	28,2	0,1217	2,00

Curve	A	B	P
Inverse (4)	0,0086	0,0185	0,02
Long-time inverse (5)	0,086	0,185	0,02
Long-time very inverse (6)	28,55	0,712	2,0
Long-time extremely inverse (7)	64,07	0,25	2,0

- -

Group 8, Basler relays

All time characteristic curves follow the relation:

$$T_T = \frac{AD}{M^N - C} + BD + K = \text{Time to trip}$$

where D is the time dial setting (time multiplier, 0.0 to 100). M is the multiple of pickup. A, B, C, N and K are constants defining the shape of the curve.

The constants are

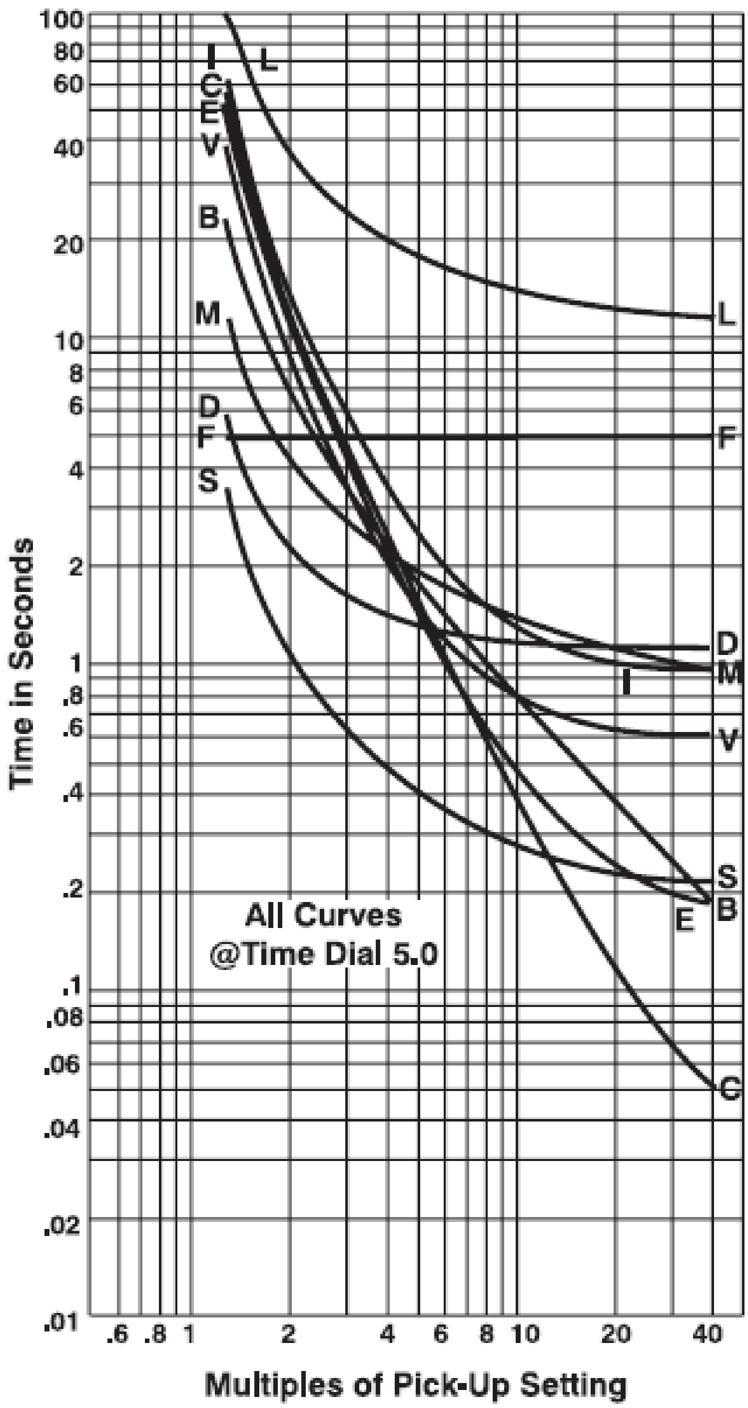
Curve Type	Constants				
	A	B	C	N	K
S	0.2663	0.03393	1.000	1.2969	0.028
L	5.6143	2.18592	1.000	1.0000	0.028
D	0.4797	0.21359	1.000	1.5625	0.028
M	0.3022	0.12840	1.000	0.5000	0.028
I	8.9341	0.17966	1.000	2.0938	0.028
V	5.4678	0.10814	1.000	2.0469	0.028
E	7.7624	0.02758	1.000	2.0938	0.028
B	1.4636	0.00000	1.000	1.0469	0.028
C	8.2506	0.00000	1.000	2.0469	0.028

where

S=Short Inverse
L=Long Inverse
D=Definite Time
M=Moderately Inverse
I=Inverse
V=Very Inverse
E=Extremely Inverse
B=BS142 Very Inverse
C=BS142 Extremely Inverse
F=Fixed Time

Note: The curve F (fixed time) is not included in the program.

The curves look like



Group 9, Noja ANSI

$$Tt = \left(\frac{A}{(I/Ip)^{p} - 1} + B \right) * TM$$

A, B, p	Constants
TM	Time multiplier
Ip	Set current (pickup)
Tt	Trip time

Tipo TCC	A	B	p
Extremely inverse	6.407	0.025	2.0
Very inverse	2.855	0.0712	2.0
Inverse	0.0086	0.0185	0.02
Short time inverse	0.00172	0.0037	0.02
Short time extremely inverse	1.281	0.005	2.0
Long time extreme inverse	64.07	0.250	2.0
Long time very inverse	28.55	0.712	2.0
Long time inverse	0.086	0.185	0.02

The range of TM is 0,01 - 100 / step: 0,01

Group 10, variant 2 of IEEE C37.122

Group 10, a variant 2 of IEEE C37.112

General equation for Group 10

$$tp = TD\left(\frac{A}{M^{P} - 1} + B\right)$$

tp = operating time in seconds
TD = time multiplier setting (**range 0,01 – 100 / step: 0,01**)
M = applied multiples of set current value (= I/Is)

Constants for Group 10 Time Overcurrent Characteristics

Curve	A	B	P
Inverse	8,9341	0,17966	2,0938
Short inverse	0,2663	0,03393	1,2969
Long inverse	5,6143	2,18592	1,0000
Definite inverse	0,4797	0,21359	1,5625
Moderately inverse	0,0103	0,0228	0,0200
Very inverse	3,922	0,0982	2,0000
Extremely inverse	5,64	0,0243	2,0000

Group 11, GE motor protection relay

Group 11 GE Motor

The standard overload curves equation is:

$$\text{Time to Trip} = \frac{\text{Curve\_Multiplier} \times 2.2116623}{0.02530337 \times (\text{Pickup} - 1)^2 + 0.05054758 \times (\text{Pickup} - 1)}$$

Above 8.0 x Pickup, the trip time for 8.0 is used.

The range of Curve_Multiplier is 1 - 100

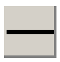
"Human readable" equations for PGQ-relay

The inverse-time part of the characteristics of a PGQ-relay can be entered in a "human readable" form using the equation editor, that consists of an "equation and curve"-window and a small equation menu-window.

The "equation and curve"-window becomes visible by clicking **Advanced** | **PGQ relay equations** in the main window. An equation can be writtten (edited) with "tools" in the **Equation menus** window, which is opened by clicking the "Edit equation"-button in the "Equation and curve"-window.

The writing of the equations and related operations (move, delete,..) are done in the same way as the drawing of the graphical elements. The equation must be written (drawn) in the upper left part of the "equation and curve"- window, labeled with "equation".

There are three buttons for writing the equations in the equation menu:

 for drawing a horizontal line, for division

for writing ordinary parts of the equation (variables, operators, parenthese, etc)

for writing the power when an expression is raised to a given power

The fourth button 

can be used to write additional texts, that are not part of the equation.

A line is drawn by pressing the line-button down, and drawing the line with the mouse to the desired location. Only horizontal lines can be drawn.

NOTE: The line is interpreted as a division operator in the program. It must be longer than the dividend or divisor above and below the line

The "ordinary" parts of the equation and the powers are written by first pressing the respective button down, then drawing a small rectangle by pulling the cursor diagonally from one corner to the opposite corner of the rectangle. The text (a term of the equation or the power) is then written in the rectangle.

NOTE: the different parts of the equation must not overlap. Thus, the equation

$(M^{P} -1)$ for example, must be written in three parts. First "(M" using the "X+Y"-button. Next, the power P with the power button, and finally the "-1)" using again the "X+Y"-button

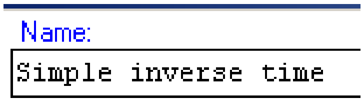
All variables of the equation must be listed in the table, with values. If the equation is like

$$Td \frac{A}{(M^{P} -1)} +C$$

then the table might look like

M	1.01
A	2
Td	1
P	0.2
C	1

An **unique** name must be given to the equation. The name is written to the box in the top left of the window



Parameters of the PGQ-relay and the "human readable" equations

There are three parameters for the inverse time characteristics in the parameter window of the PGQ-relay:

(1) The Set current (or pickup current), (2) the time multiplier (B) and (3) the time adder (C)

Set current [A, prim]	5
Factor OR Start time (if > 3)	0
Curve modifiers t" = B t+C	
B = Time multiplier	1.5
C = Time adder (s)	0.1

The set current is needed to calculate the normalized current that is used in the equations. The symbol M is often used for the normalized current. That is, the normalized current M is
M = current / Set current.

The program for the relays must know, which symbols in the "human readable" equation (and in the table) correspond to these three parameters. This is "told" to the program by dragging the three explanating texts from the small rectangle to the right side of the table. Each explanation is dragged (with the mouse) to the row of the table, where the corresponding symbol appears.

The the explanating texts are initially in the small rectangle like this

Current/Set current
Time Multiplier (B)
Time Adder (C)

The explanating texts are then dragged to the correct positions, where they turn green. The result is then something like

M	1.01	Current/Set current
A	2	
Td	1	Time Multiplier (B)
P	0.2	
C	1	Time Adder (C)

There may not always be a time adder (C) in the equation. It can then be left out, or added to the equation with the value zero. The normalized current (M) must always appear in the equation, otherwise the equation is not meaningful. Similarly, the time multiplier (B) should appear in the equation.

NOTE: The set current (or pickup current), the time multiplier (B) and the time adder (C) are parameters of the PGQ-relay, not of the "human readable equation". Their values are set in the window for the relay parameters. The values in the table for the "human readable equation" are needed only for drawing the curve (or for calculating some point(s) of the curve.)

Make a new "human readable" equation available

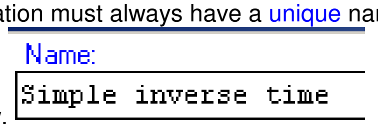
When a new equation has been edited in the equation window, it is not yet available for the PGQ-relays. The equation must be added to a list of equations maintained in the program before it can be used. In addition, the equation should be saved to a file.

The equation is saved to a file "in the usual way", that is, click "**File** | **Save as...**" in the menu bar of the equation window, and select the file and directory in the Save-dialogue that becomes visible. The extension of the saved file is "equ". Each *.equ-file must have a unique name. Each file contains only one equation.

If the equations are saved in the directory where the program Elplek is or in some directory directly under the elplek-directory, the equation-files are automatically opened and the equations read and added to the list of equations within the program, when Elplek is started. In this way, the "old" equations are automatically available for the relays.

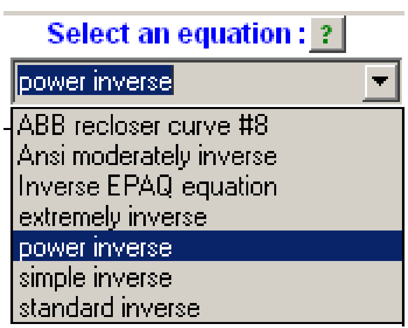
Note: A new equation is not directly available for the relays, after it has saved to file. It must still be added to the list of equations. This is done by clicking the "Add Equation to List"-button.


, or by restarting the program, as explained above

NOTE: The equation must always have a unique name. The name is written in the top left field in the equation window.


It may be desirable to study and edit existing equations. An equation can be read from file to the equation window "in the usual way": Click "**File** | **Open...**" in the menubar of the equation window, and select the equation using the "Open"-dialogue that becomes visible.

The equations that are already in the list of equations within the program can be selected for studying and editing from the drop-down list in the upper right of the window, under the text "Select an equation".



If a selected equation has been modified, it can be added to the list of equations as a new equation using the "Add Equation to List"-button, and/or saved to a file. Remember the unique name!. The modified equation can also be put back to the list, replacing the unmodified equation. In this case the name should not be changed. The replacing is done by clicking the "Save (replace) in List"-button.


NOTE/WARNING: If an existing equation is modified and put back to the list under the same name, then the modified equation will probably be used in the relays where the unmodified equation was used. Whether the modified equation is used or not depends on the way the equation is saved, and how the single line diagram with the relay is opened in the program. If the single line diagram is opened after modifying the equation, for example, then the modified equation is used. But if the modified equation or the single line diagram is not re-saved, then the modified equation is not available next time the program is started.

The buttons and fields in the equation window

The **draw curve**-button draws the equation, that is, the time-current characteristics defined by the equation as a log-log graph.

The **calculate**-buttons calculates the value of the equation using the parameter values in the table. The result is given in the lowermost field in the right hand side of the equation window.

Add Equation To List-button adds the equation to the internal list of equations

Save (replace) in List-button can be used to put an equation back to the list under the name it was read from the list

The **Edit equation**-button opens the equation-menu window, that is used to edit the equations.

Clear equation-button clears the equation in the window, including the table of parameters, name etc.

Buttons with a **question mark** [?] show short hints

NOTE-button shows one more hint

When the Curve or calculate button is clicked, the equation appears in a "computer-understandable form" in the long field on the bottom right of the window.

```
Td*[(1)/(M^p-1)]+C
```

If there are any errors, then the thext #Error appears in the lowermost field (in the results field), without any explanations (!)

The "Add Equation to List" and "Put eq. back"-buttons are described also on the Make a new equation available-page

Use of the "human readable" equations in the PGQ-relays

Before an equation can be used in the PGQ-relays, it must be in the internal list of equations that the program maintains. There are three ways to put equations in the list:

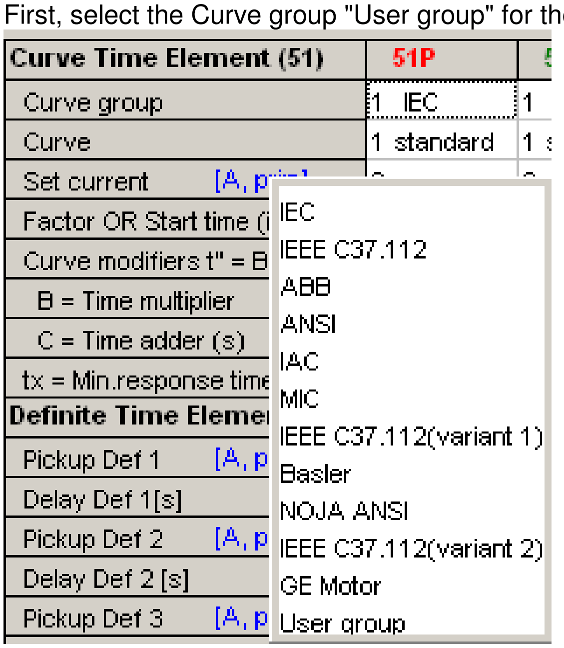
1) An equation is edited and saved to file, and the file is put in the directory where the program elplek is, or in a directory directly under it. When the program is started, the files in those directories are opened, and the equations in the files are added to the internal list.

2) A new equation is edited in the equation window, and added to the list bly clicking the "Add Equation to List"-button, as explained in the chapter "Make a new equation available"

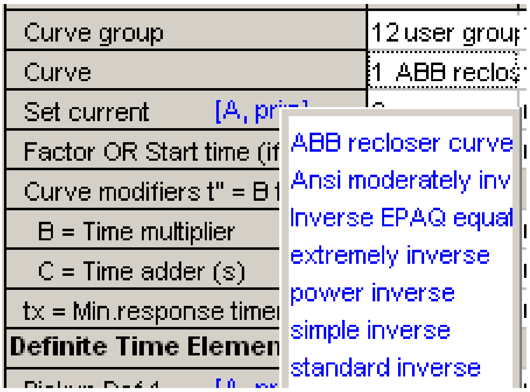
3) If a relay in a single line diagram already uses an equation discussed in these sections, and the single line diagram is saved to a file (to a *.sld-file), then also the equation is saved to the same file. When the file is opened and the single line diagram read in, then also the equation is read in and added to the internal list of equations.

The equations in the internal list are used in the same way as other equations in the PGQ-relays.

First, select the Curve group "User group" for the first parameter in the parameter table.

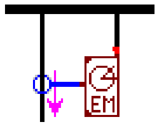


Next, select the desired equation for the Curve-parameter, i.e. the second parameter in the table. All equations from the internal list are displayed in the small panel for the curve parameter.



Finally, set the values for all other parameters in the usual way.

Electromechanical relay



The electromechanical relay, or more accurately the combined electromechanical phase, ground and sequence relay (PGQ-relay) is a overcurrent relay,where the desired current-time behaviour (characteristics) is obtained by electromechanical means. It is modeled in this program similarly as the "proper" PGQ-relay. The only difference is that the inverse time (nonlinear) characteristic curve is read from tables, whereas equations are used in the proper PGQ-relay. (The tables have been provided by elplek users in South America, which is gratefully acknowledged.)

The table of the selected curve can be saved by **File | Save As**. The values of the normalized current and time are saved in such a form that the file can be used in the user defined relay.

The use of tables sets some constraints on the characteristic curves:

1) The points of (maximum time, minimum current) and (minimum current, maximum time) on the inverse time characteristics are constrained by the data available in the tables.
2) The time-multiplier parameter can have only discrete values between given minimum and maximum values.

Note: The term "current" refers here to the normalized current. In order to get the operating current of the relay, the normalized current is multiplied by the current parameter "Is" (set current value).

The constraints for the relays are the following:

Here time m. = time multiplier
minim. = minimum value
max. = maximum value

Relays	current minim.	current max.	time m. step	time m. minim.	time m. max.
IAC,IFC	1.5	50	0.5	0.5	10.0
SFC	1.1	50	0.5	0.5	10.0
CDG11,12	2.0	20	0.05	0.1	1.0
CDG13,14	2.0	40	0.05	0.1	1.0
CO2	1.5	20	0.5	0.5	11.0
CO6	1.5	20	0.5	0.5	10.5 (I=1.5) 11.0 (I>1.5)
CO7	1.5	20	0.5	0.5	5.0 (I=1.5) 9.0 (I=2.0) 11.0 (I>2.0)
CO8	1.5	20	0.5	0.5	1.0 (I=1.5) 3.0 (I=2.0) 7.0 (I=3.0) 11.0 (I>3.0)
CO9(West)	1.5	20	0.5	0.5	2.0 (I=1.5) 5.0 (I=2.0) 10.0 (I=3.0) 11.0 (I>3.0)
CO11	1.5	20	0.5	0.5	6.0 (I=1.5) 11.0 (I>1.5)
CO9(Mits)	1.5	40	0.5	0.5	10.0

Note that the maximum value of the time multiplier depends on the current in the Westinghouse relays CO6...CO11. The current is given in parenthesis (like I=2.0).

The parameters

The parameters are the same as for the "proper" PGQ-relay. Some additonal explanations only are given here.

The first nine rows are for comments in free form. The remaining rows are for the proper parameters.

Group: Select the group, or the manufacturer of the relay from the small menu that appears when the cell for the group is selected.

Curve: Select the curve, or the relay type from the small menu that appears, when the cell for the curve is selected.

Set current value (Is) Multiplies the normalized current. That is, shifts the characteristics sideways.

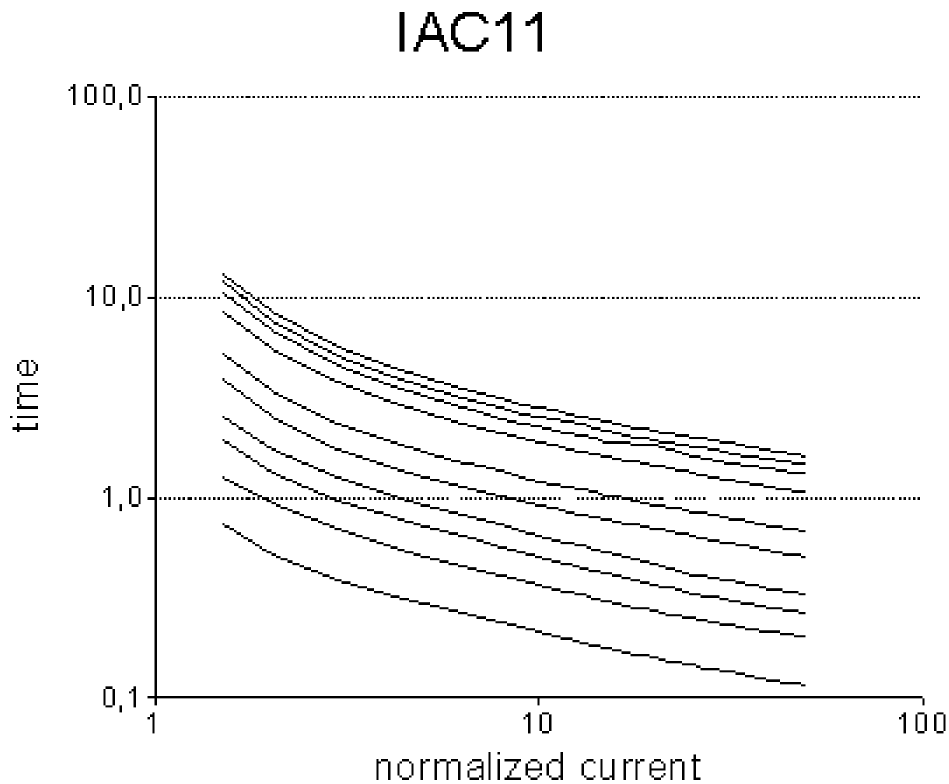
fact Determines the (proper) minimum current, i.e. the starting point of the characteristics. If fact is larger than the minimum normalized current (see table above), then the proper minimum current is equal to (fact) * (Set current value). But if the fact-parameter is smaller than the minimum normalized current, then the proper minimum current is (Set current value) * (minimum normalized current).

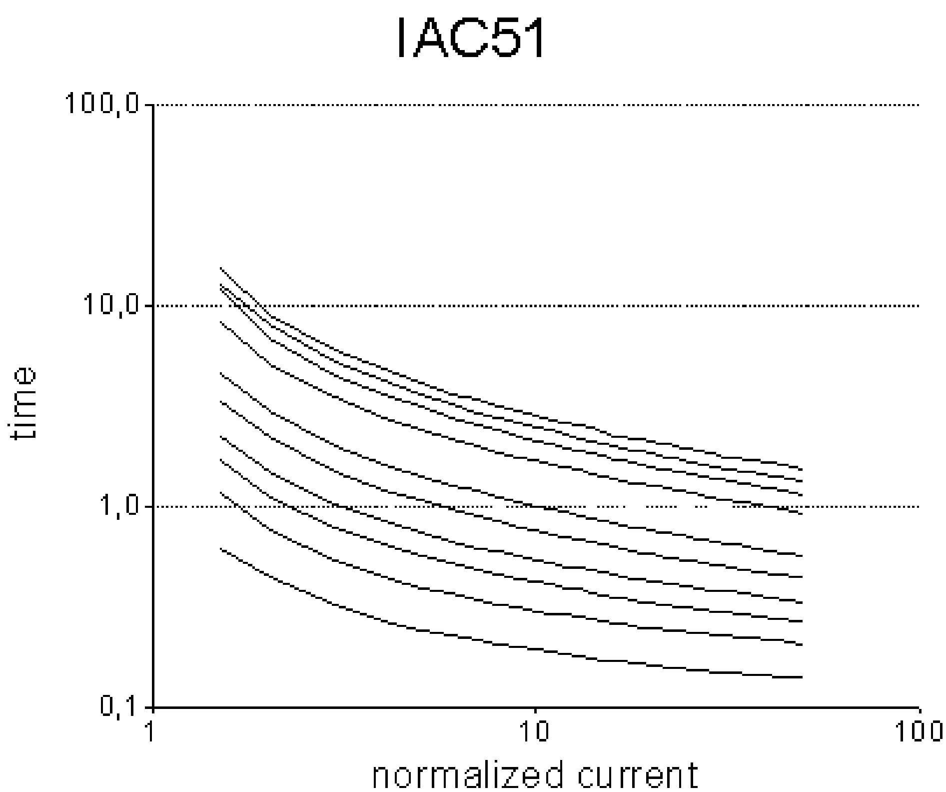
Time multiplier The characteristic curve of the relay gives time as a function of current. The Time multiplier-parameter basically multiplies the value of the time that corresponds to a given current, i.e moves the characteristic curve upwards. The shape of the curve may also change slightly. (In practice, the time multiplier parameter just selects a curve.) Because the characteristic curves are given (internally) in tabular form, the time multiplier-parameter can be changed only by discrete steps, see the table above. Use the spin buttons (the small up- and down- arrows) to change the value of the time multiplier parameter.

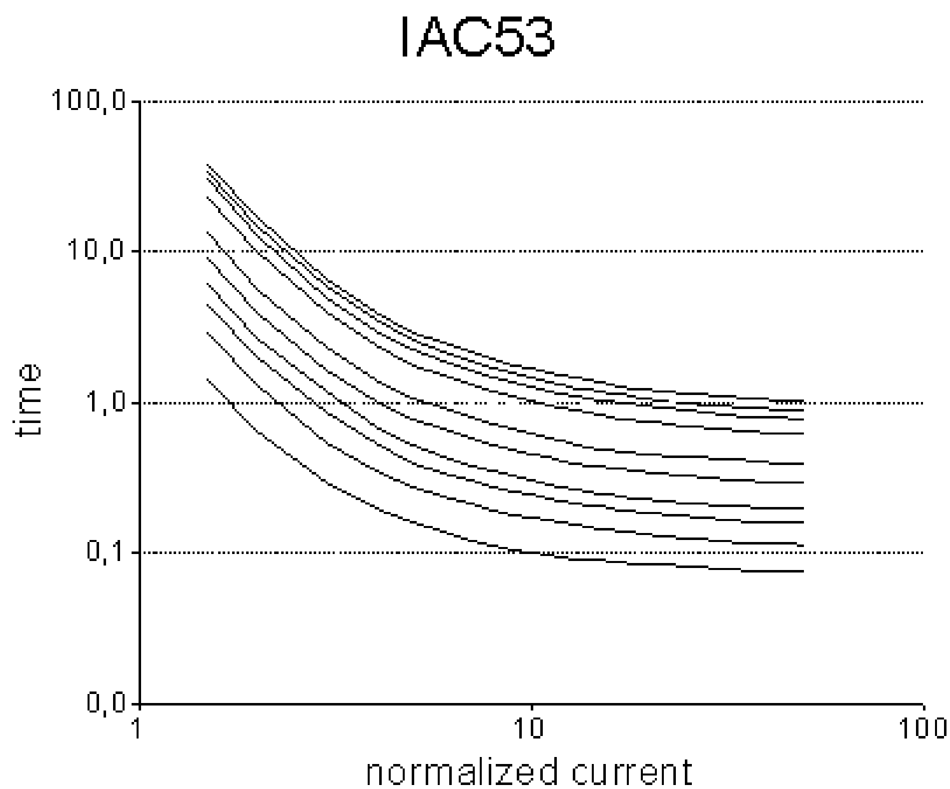
The remaining parameters are exactly the same as for the (proper) PGQ-relay, see the explanations of the parameters of that relay.
The "Momentary mode"-buttons at the bottom of the parameter window are also explained in the chapter The parameters of the relay and the current transformer.

The characteristic curves

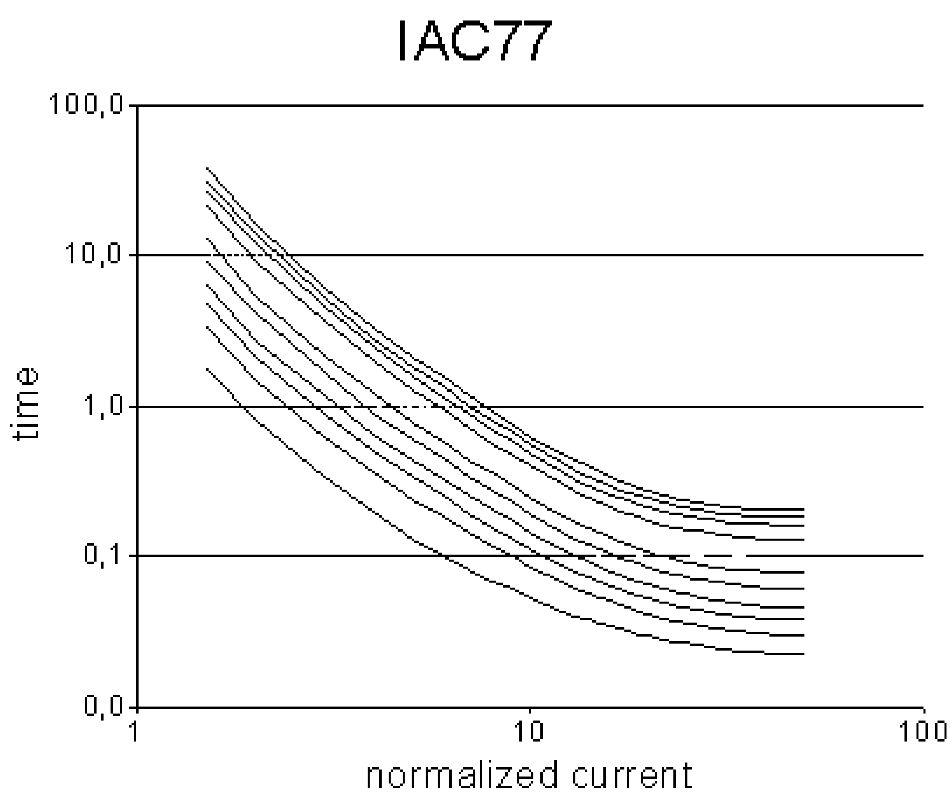
The graphs below show the nonlinear (inverse time) characteristic curves of the electromechanical relays of this program. The graphs give the value of time delay as function of the normalized current. There are several curves in each graph. The lowermost graph corresponds to the smallest value of the time multiplier-parameter (0.1 or 0.5). The uppermost curve is for the largest value of the time-parameter (1.0 or 10.0). Some curves between these have been omitted for clarity.


IAC11
100,0
10,0
1,0
0,1
time
1
10
100
normalized current

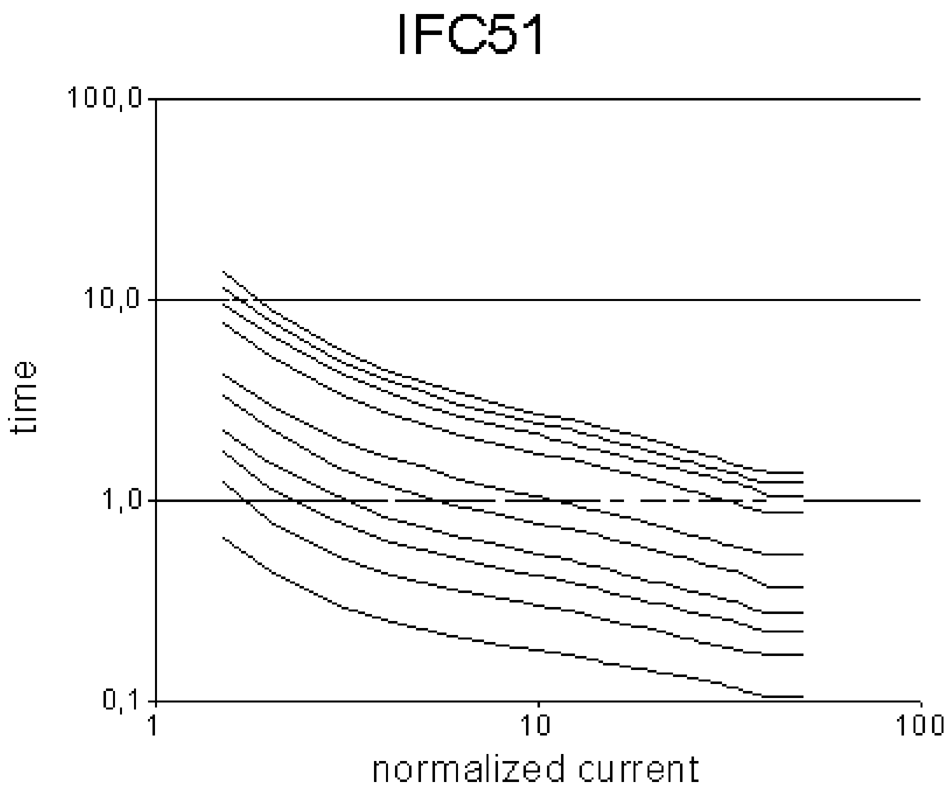

IAC51
100,0
10,0
1,0
0,1
time
1
10
100
normalized current


IAC53
100,0
10,0
1,0
0,1
0,0
time
1
10
100
normalized current

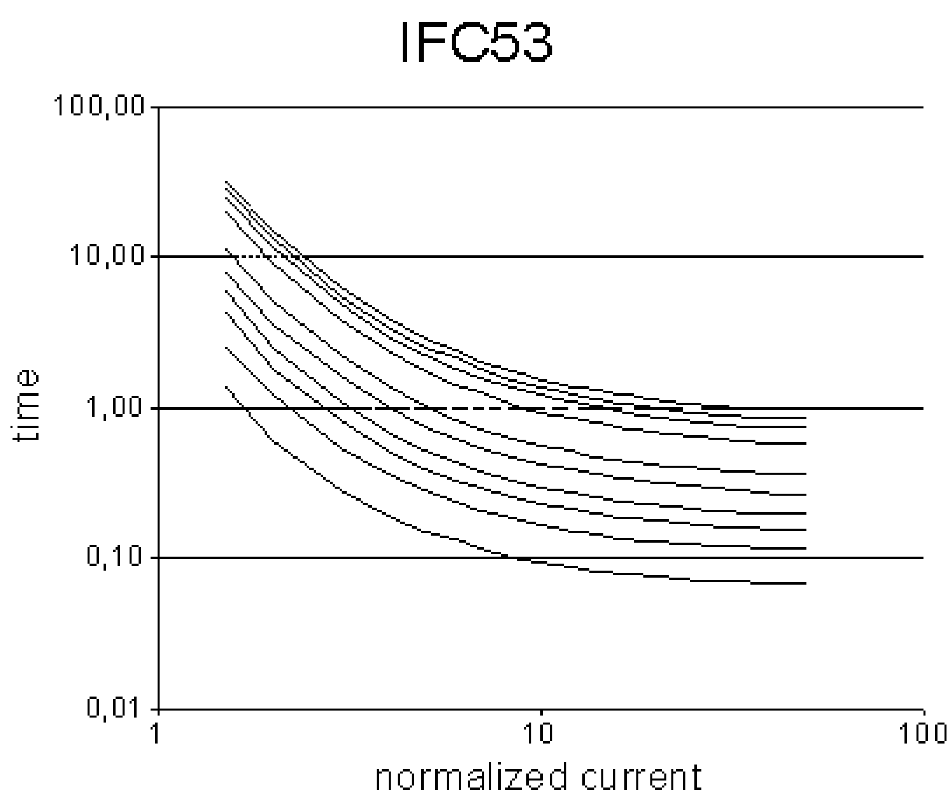
- -


IAC77
100,0
10,0
1,0
0,1
0,0
time
1
10
100
normalized current

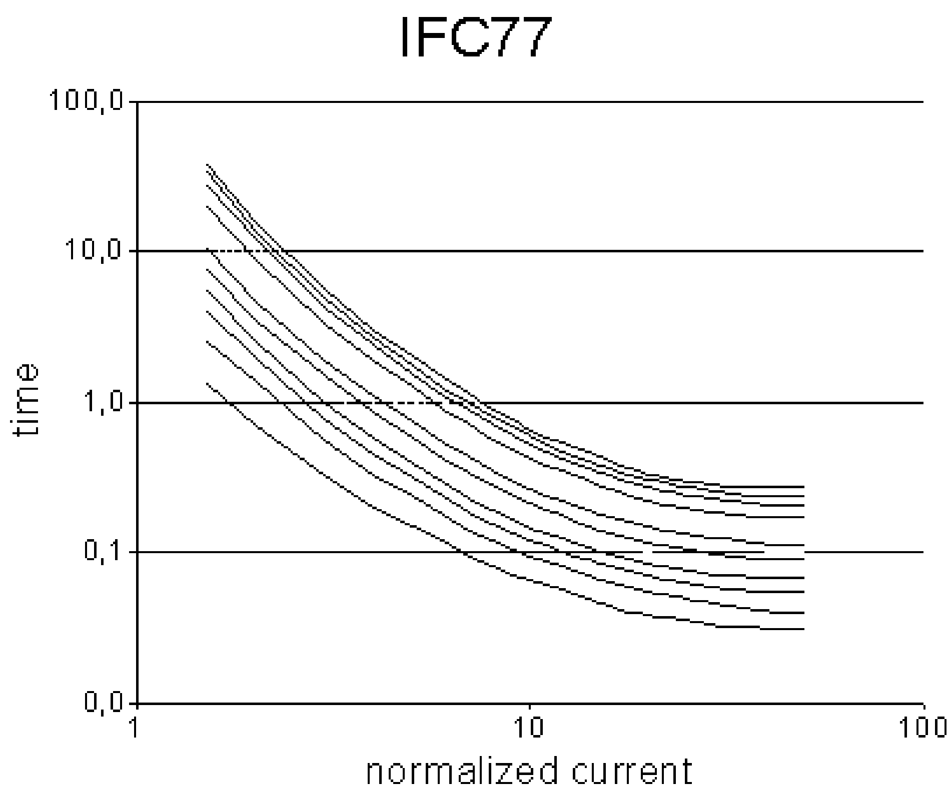
- -


IFC51
100,0
10,0
1,0
0,1
time
1
10
100
normalized current

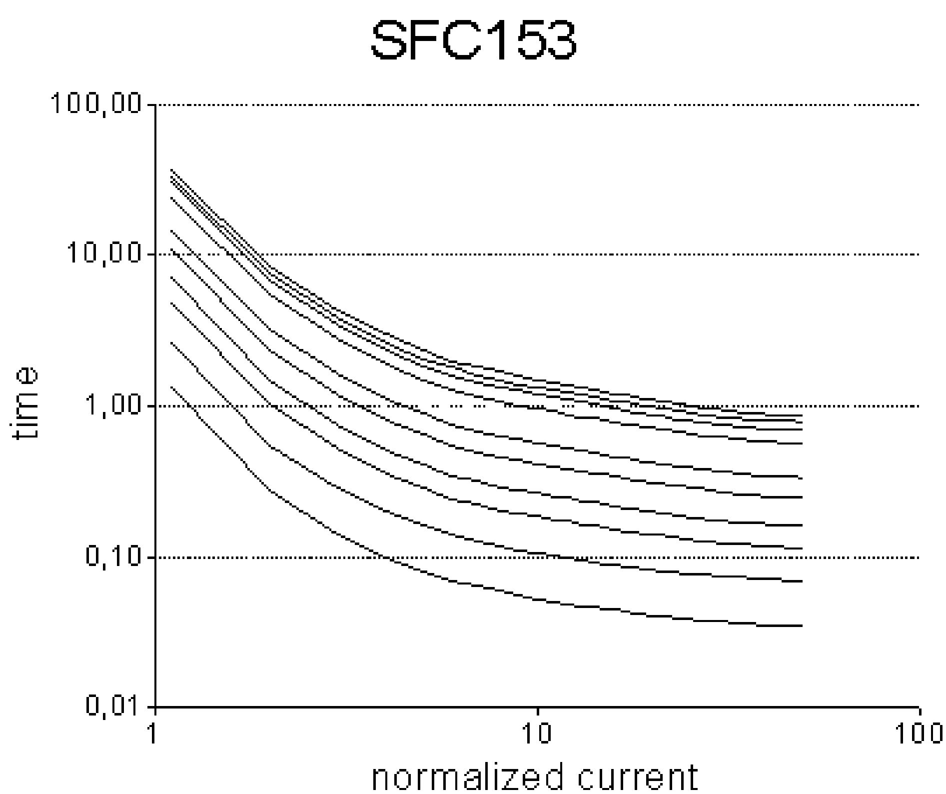
- -


IFC53
100,00
10,00
1,00
0,10
0,01
time
1
10
100
normalized current

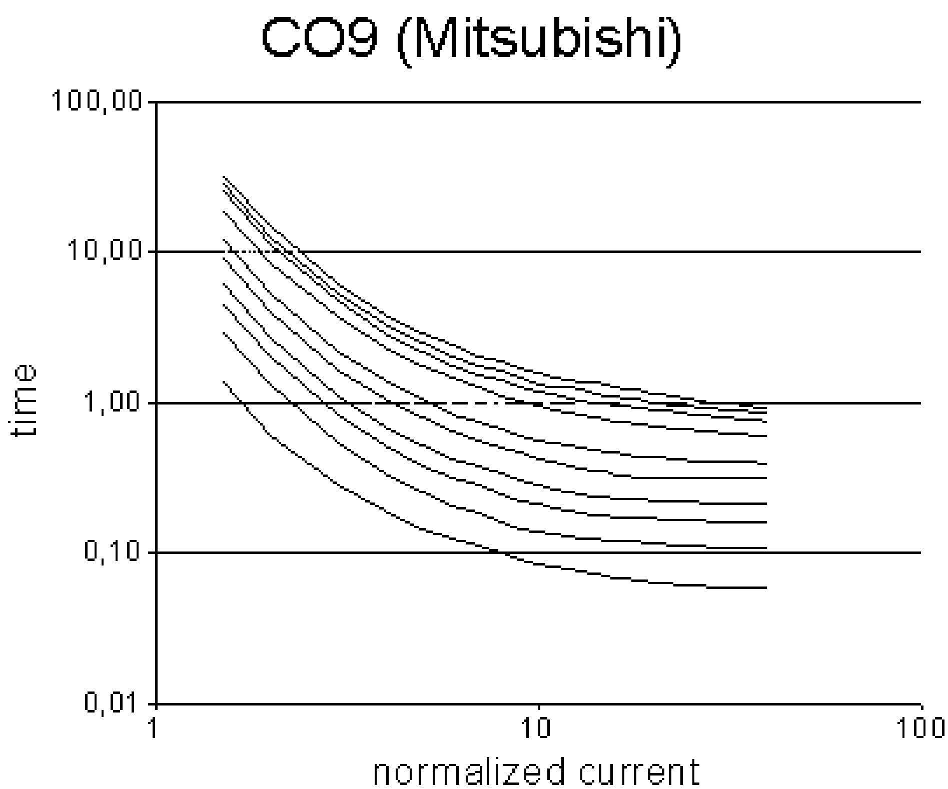
- -

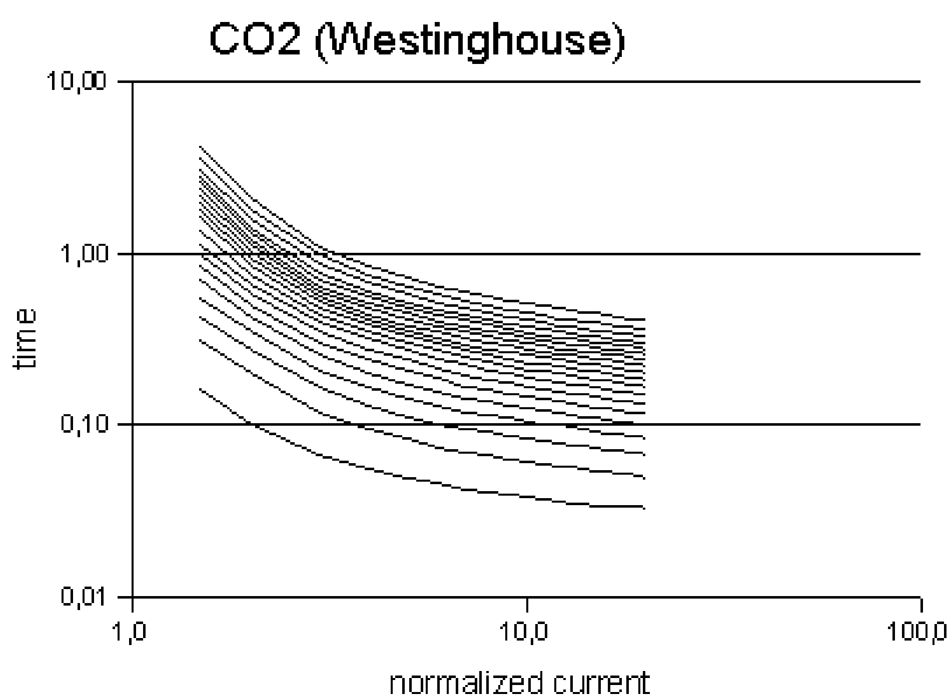

IFC77
100,0
10,0
1,0
0,1
0,0
time
1
10
100
normalized current

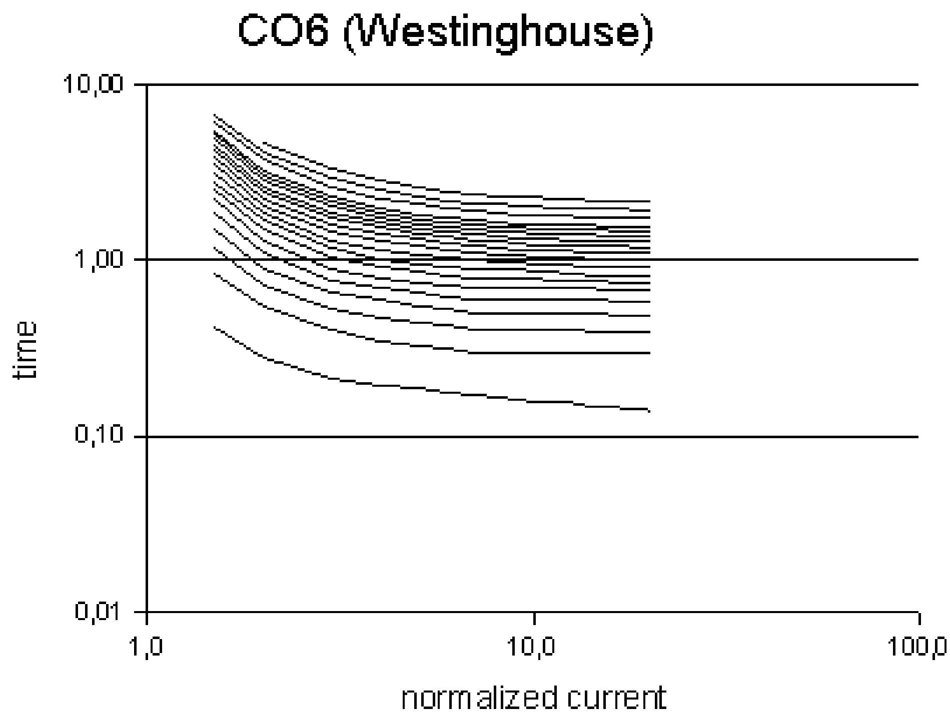
- -


SFC153
100,00
10,00
1,00
0,10
0,01
time
1
10
100
normalized current

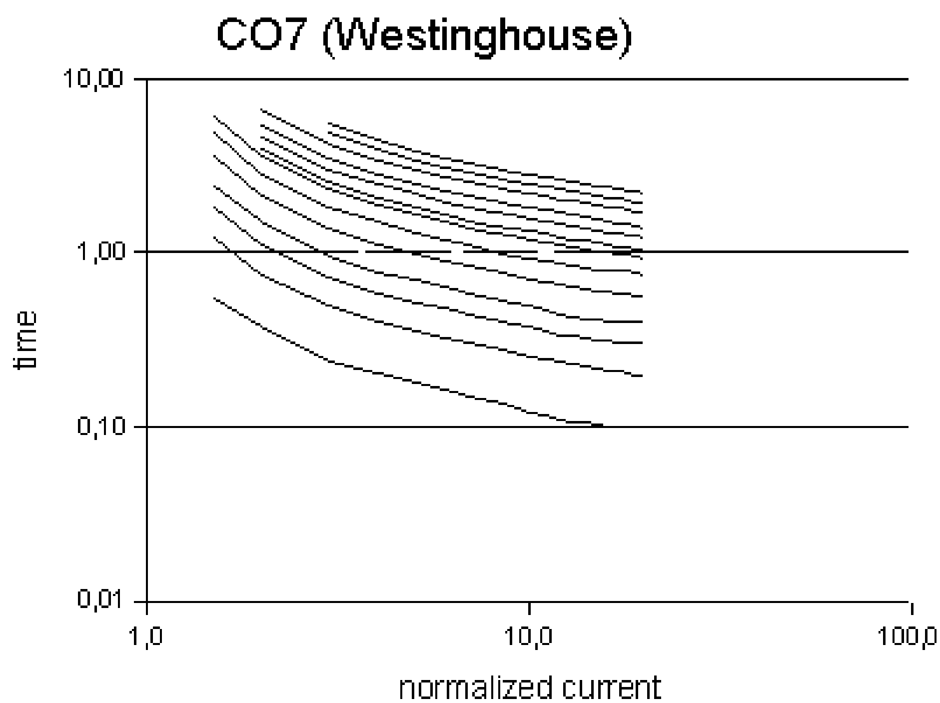
- -


CO9 (Mitsubishi)
100,00
10,00
1,00
0,10
0,01
time
1
10
100
normalized current

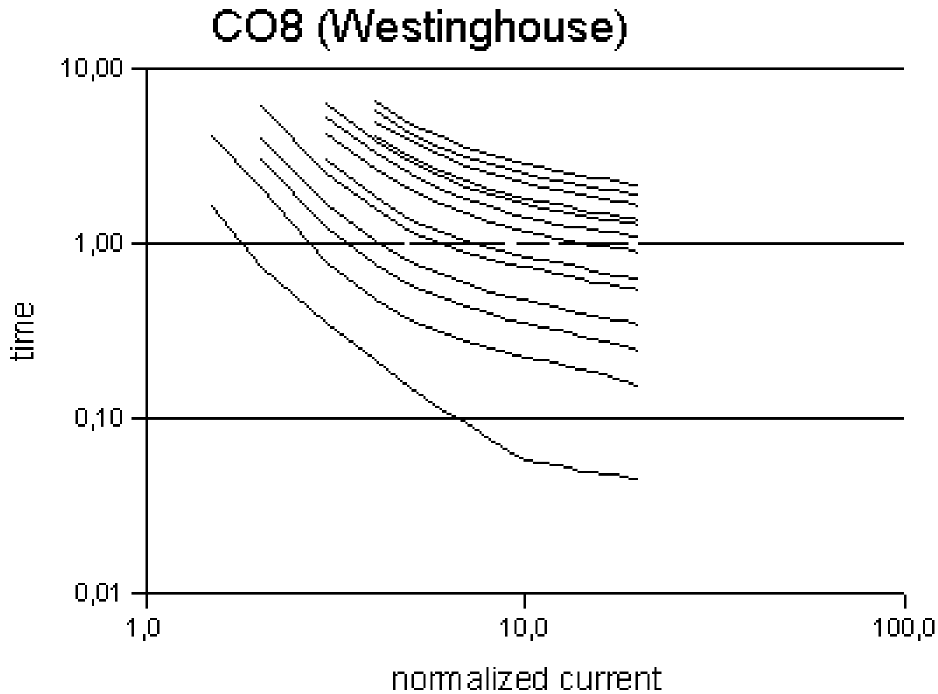

CO2 (Westinghouse)
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current


CO6 (Westinghouse)
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current

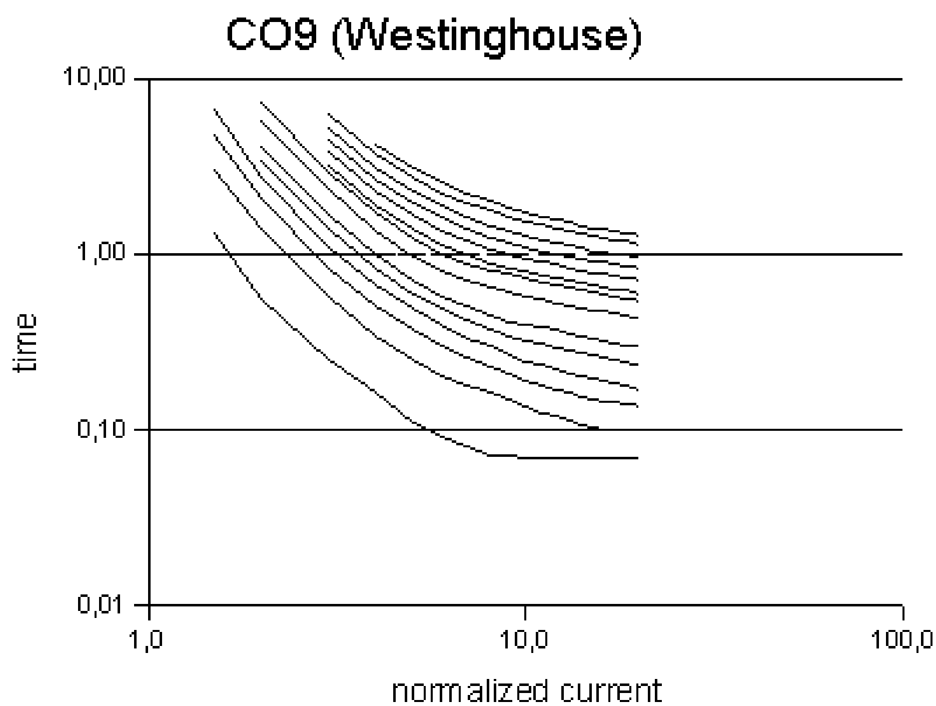
- -


CO7 (Westinghouse)
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current

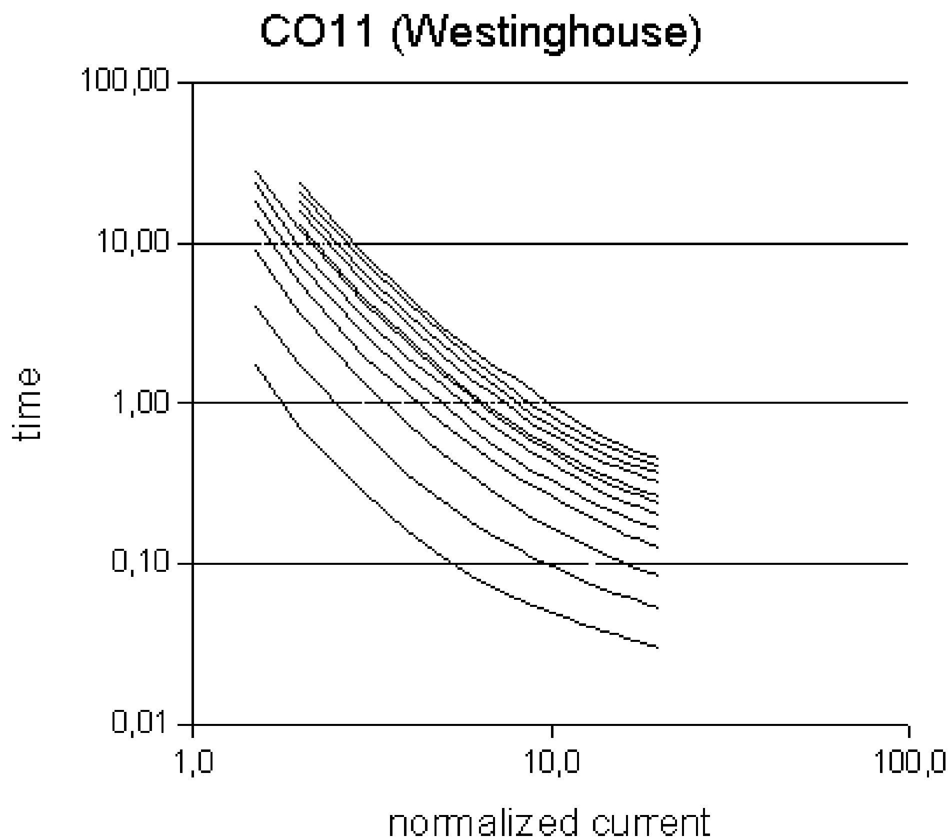
- -

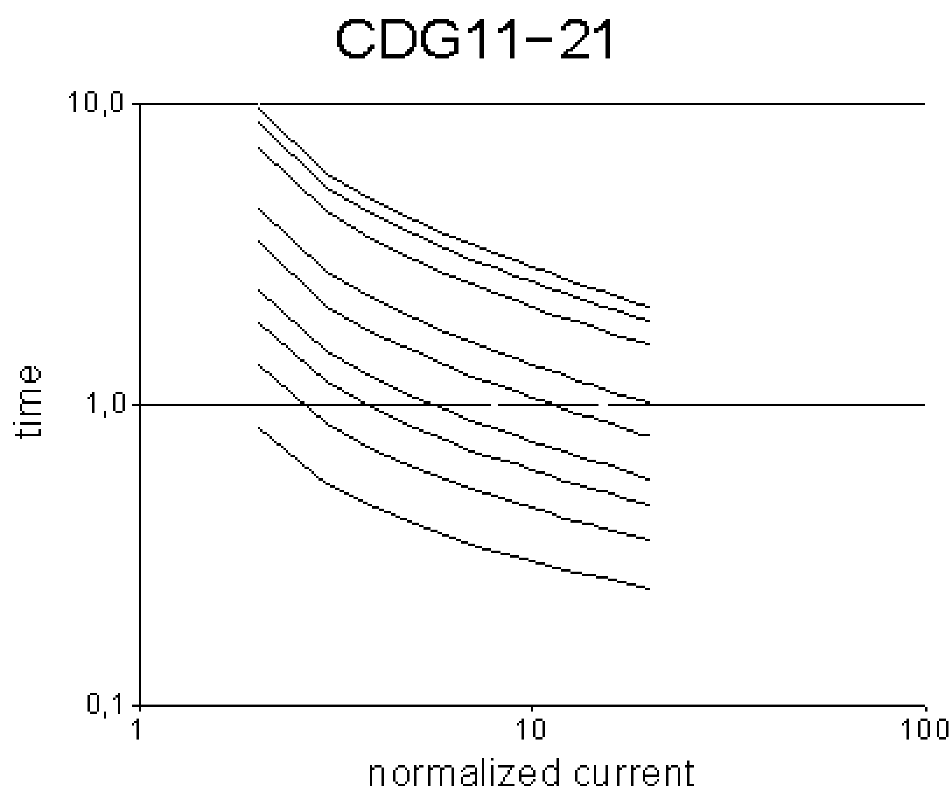

CO8 (Westinghouse)
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current

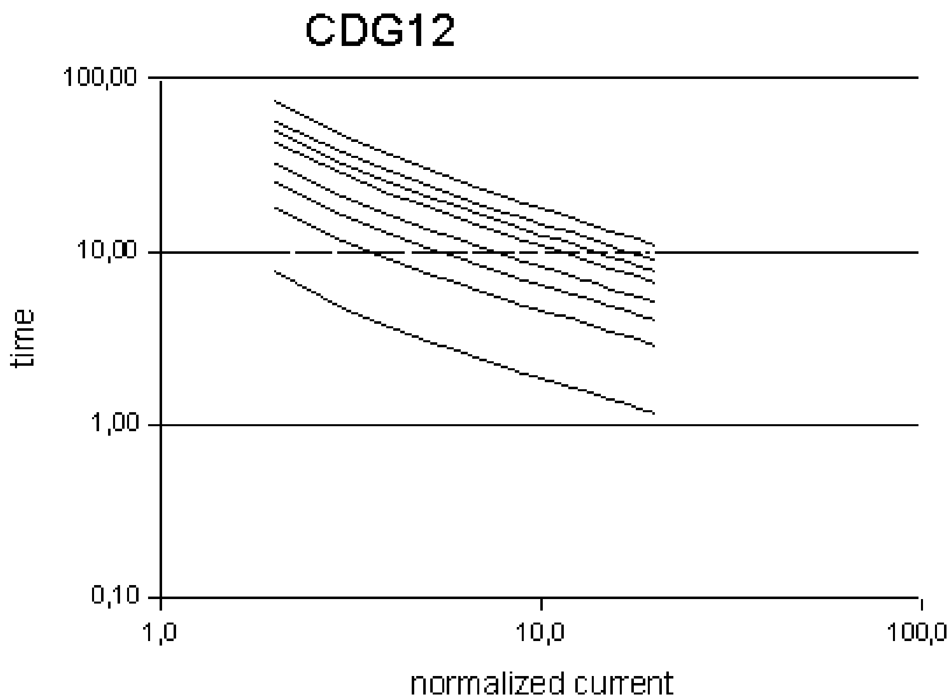
- -

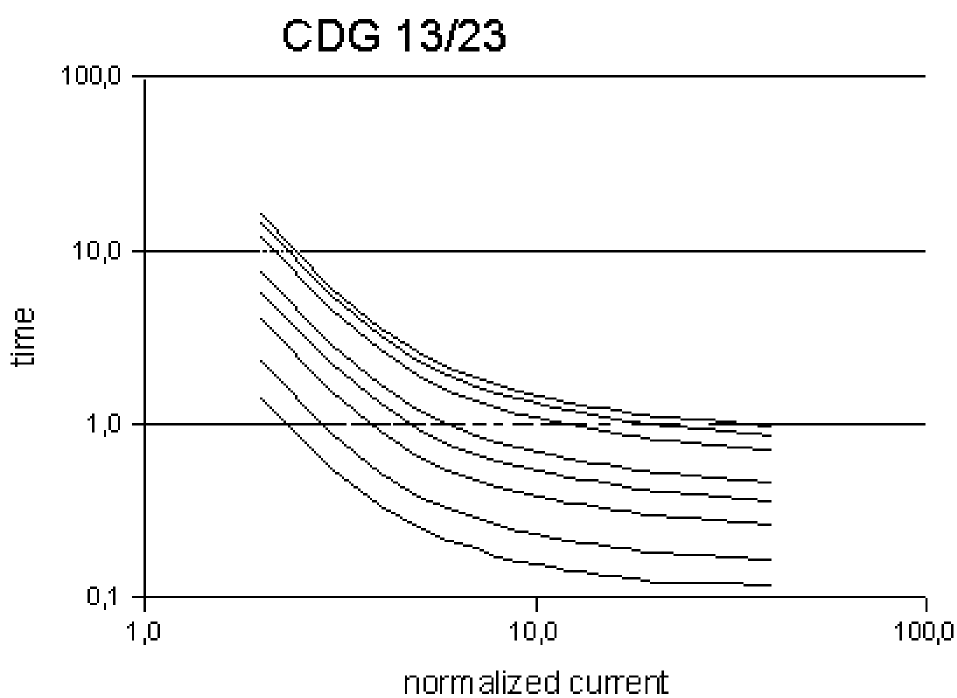

CO9 (Westinghouse)
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current

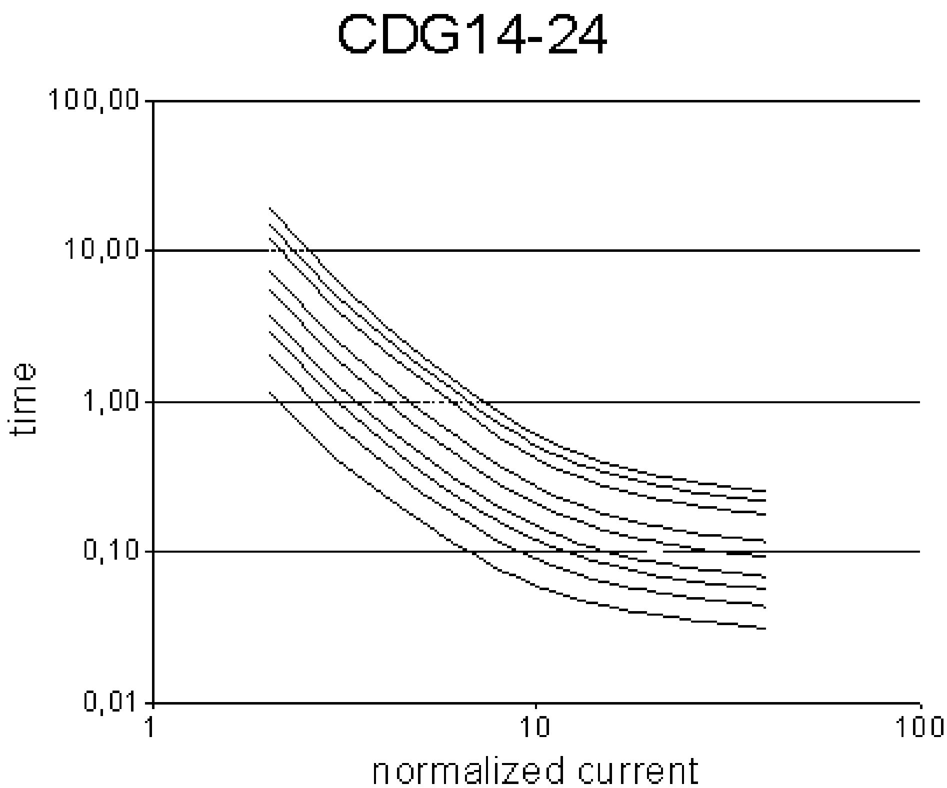
- -


CO11 (Westinghouse)
100,00
10,00
1,00
0,10
0,01
time
1,0
10,0
100,0
normalized current


CDG11-21
10,0
1,0
0,1
time
1
10
100
normalized current

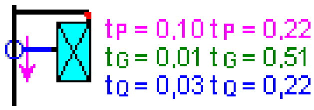

CDG12
100,00
10,00
1,00
0,10
time
1,0
10,0
100,0
normalized current


CDG 13/23
100,0
10,0
1,0
0,1
time
1,0
10,0
100,0
normalized current


CDG14-24
100,00
10,00
1,00
0,10
0,01
time
1
10
100
normalized current

- -

Recloser relay



The recloser relays are similar as the combined phase-, ground- and sequence relays (PGQ-relays), or the electromechanical relays. The only essential difference is that the recloser relays contain two sets of phase-, ground-, and sequence modules, i.e. two PGQ-relays in one package. The first set typically contains fast operating modules, and the second set contains slowly operating modules (delayed operation).

Because there are six modules in one recloser relay, six operating times can be displayed in the single line diagram. See the picture above. The operating times of the phase modules is displayed in red, the times of the ground modules in green, and the times of the sequence modules in blue.

The parameters and descriptions

There are two types of parameters available: Descriptions (notes) and actual, mainly numerical parameters.

Descriptions and notes

There are three different ways to enter descriptions and notes in the relay.

1) Click "Texts" in the menu bar of the parameter window. The parameters disappear and twelve rows for a free description of the relays appears. There are two rows available for each relay module (for both two phase, ground and sequence modules) in each parameter group. These rows are identified with C1 or C2, and ID P(1) ... ID Q(2). The C1 refers to the first, fast acting modules, and C2 to the second, slower modules. The ID P(*)-rows are for the phase relay, the ID G(*)-rows are for the sum, or residual relay, and the ID Q(*)-rows are for the negative sequence relay.

2) Click "View|Notes" and a small "notepad" will appear for free texts for the whole relay.

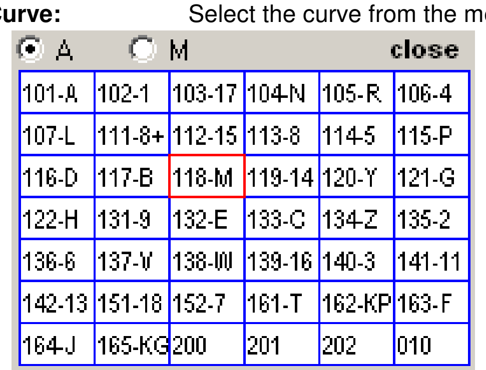
3) Click "View|info" and a smaller "notepad" will appear. This notepad is actually added fo the user defined relays, but because the recloser relays and the user defined relays use the same parameter window, this notepad is also available here. Notes for all six relay modules in all six parameter groups can be entered using this small notepad.
Note: A small symbol of an open file appears on the top of the selected column, i.e. the selected relay module for which the small "notepad" displays the information.

Both "notepads" can be moved around with the mouse.

Actual parameters

The parameters are almost the same as for the PGQ-relay. Only the first few parameters are different:

Curve: Select the curve from the menu by clicking the curve identifier



If the radio button "A" (auto) is checked, then the menu will close after selecting the curve, but if the radio button "M" (manual) is checked, the menu is not closed automatically, and must be closed either by clicking the "close"-text, or another parameter.

Set current value: Shifts the characteristics sideways
(The characteristics starts here)
Factor(n): Reduces the maximum time.
(Chops off the left part of the char. at factor*set current)

B=Time multiplier: Shifts the characteristics vertically by multiplication
C=Time adder: Shifts the characteristics vertically by addition
tx = Min. response: The activation time cannot be smaller
(Chops off the lower part of the char.)

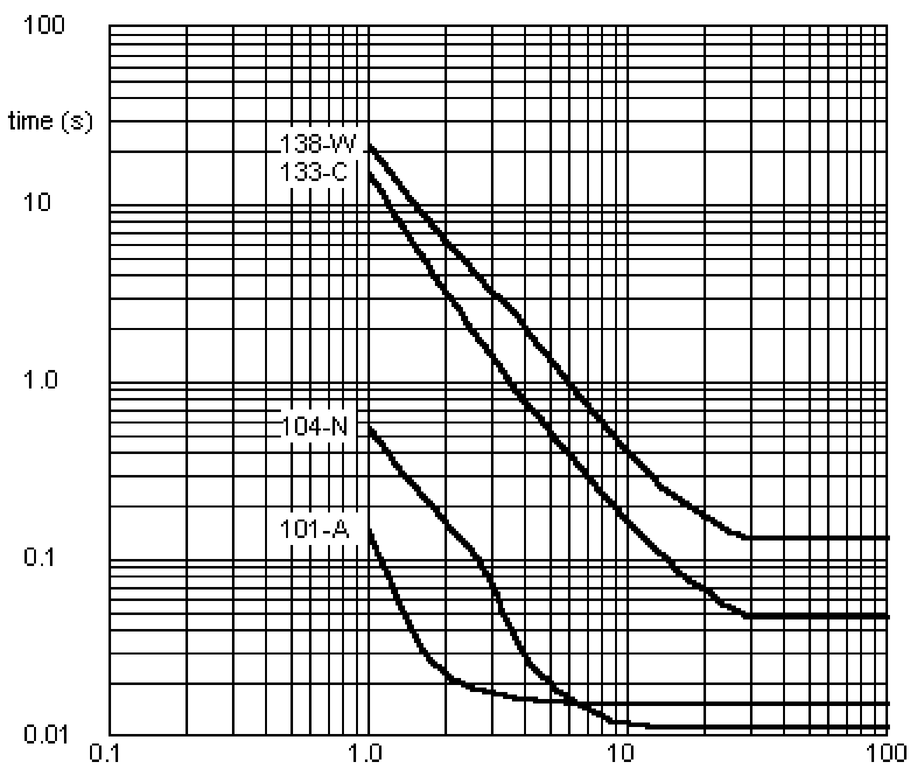
The remaining parameters are exactly the same as for the PGQ-relay.
The "Momentary mode"-buttons at the bottom of the parameter window are explained in the chapter "The parameters of the relay and the current transformer".

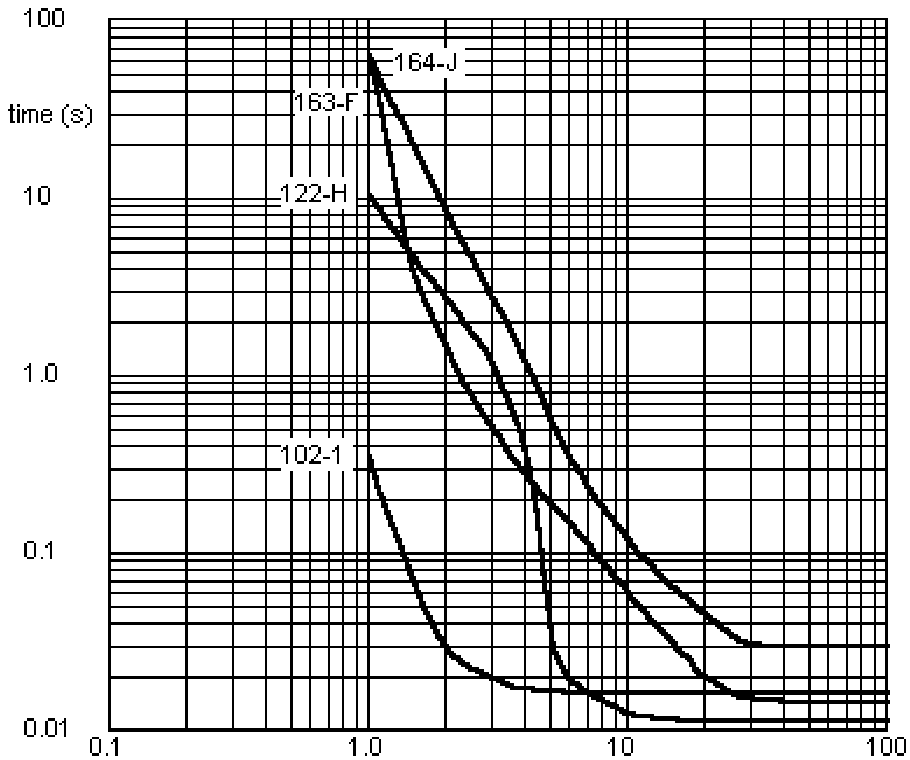
The characteristics

There are no equations for the characteristics. The curves are given in tables in the program (Thanks for the tables go again to the elplek users in South America.)

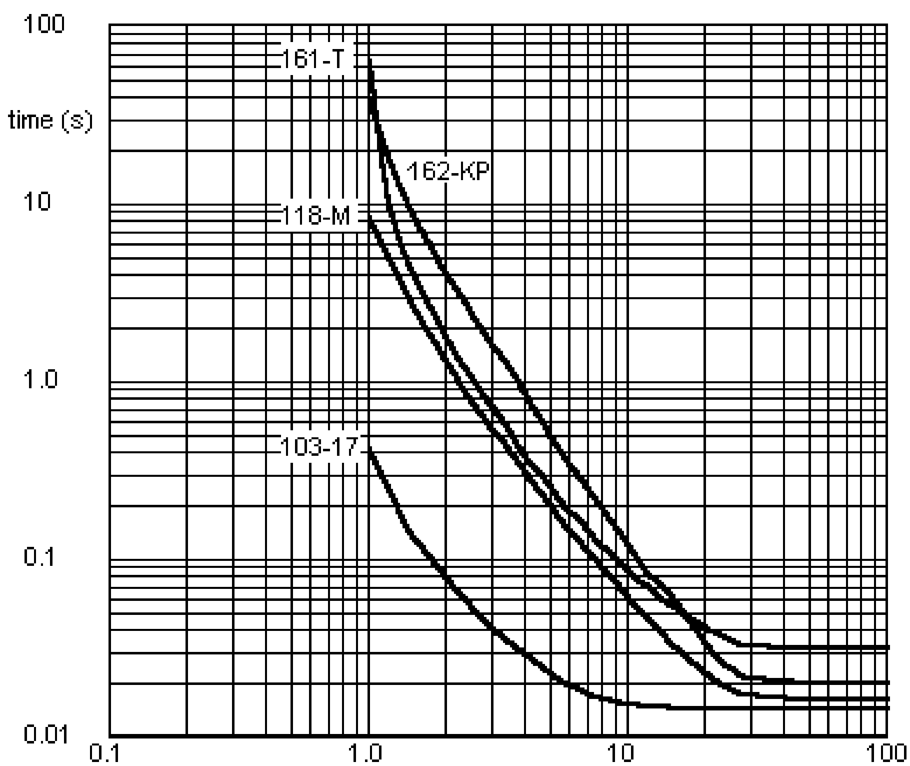
The table of the selected curve can be saved by **File | Save As**. The values of the normalized current and time are saved in such a form that the file can be used in the user defined relay.

The characteristics of the recloser relays are given in the pictures below

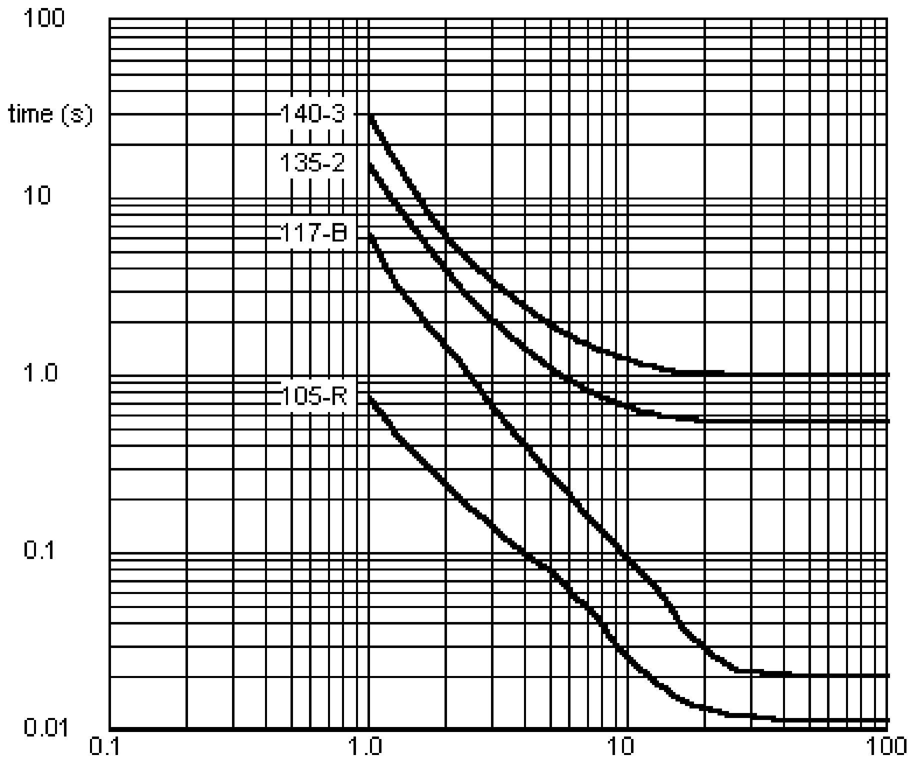


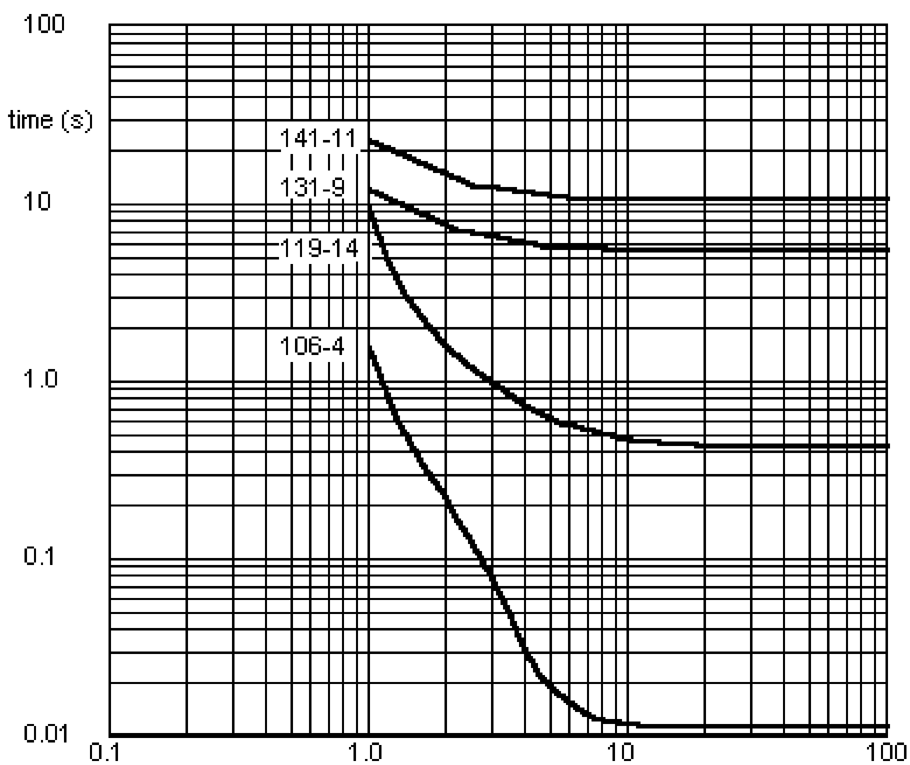


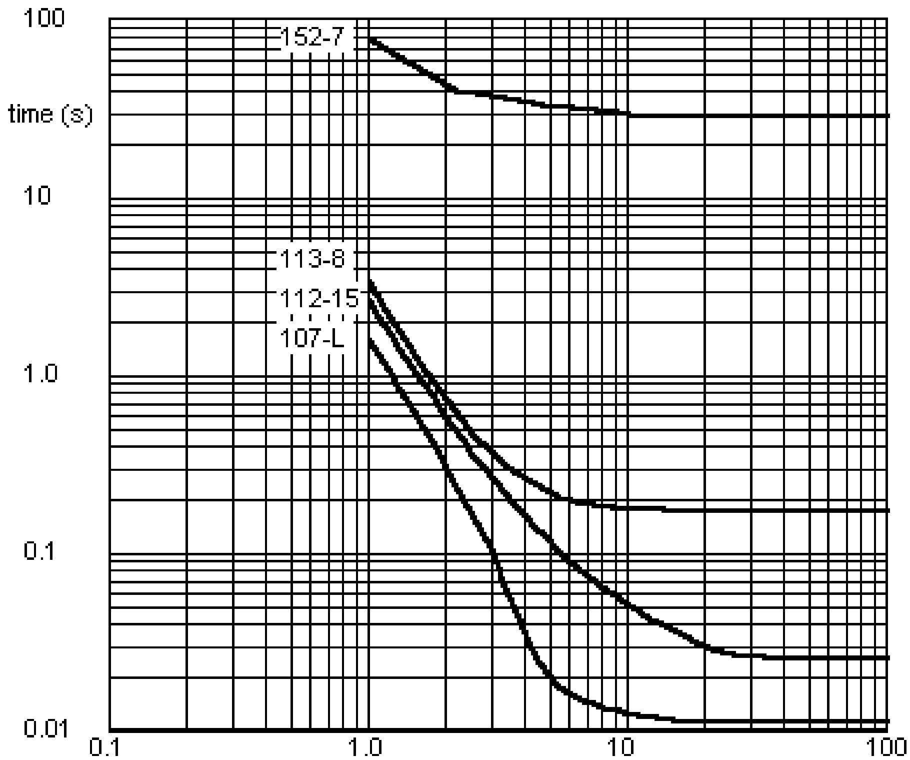
100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
164-J
163-F
122-H
102-1

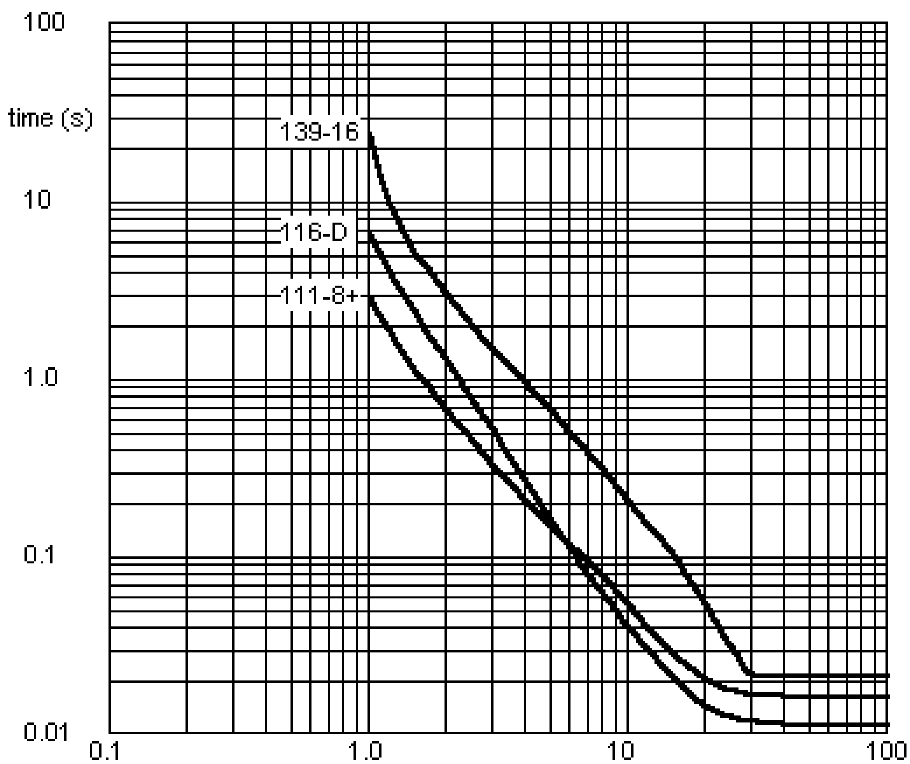


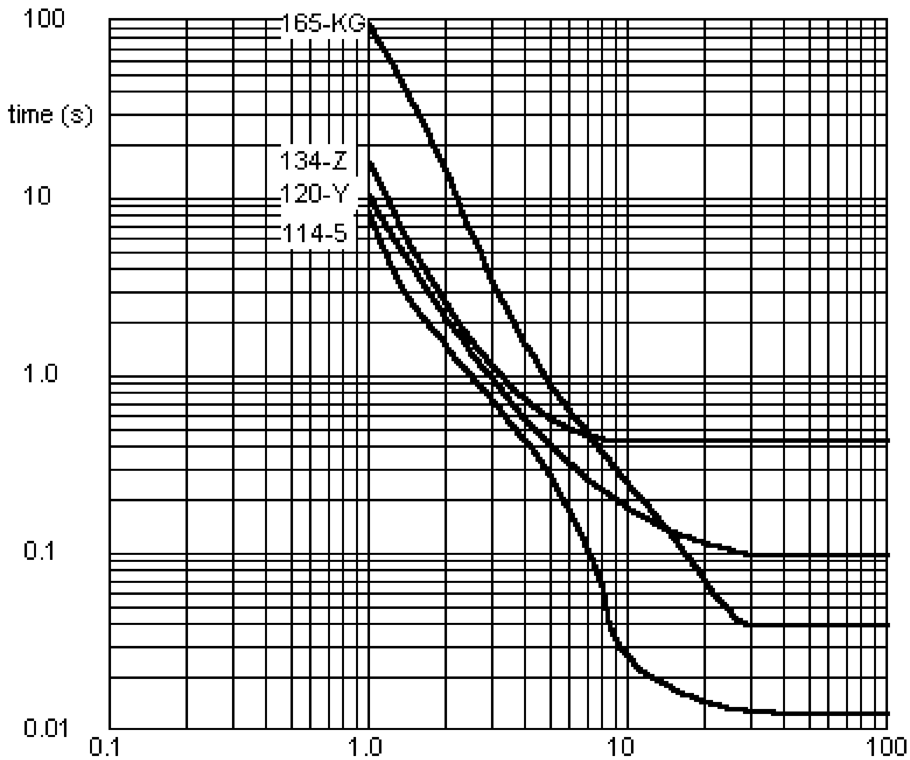
100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
161-T
162-KP
118-M
103-17

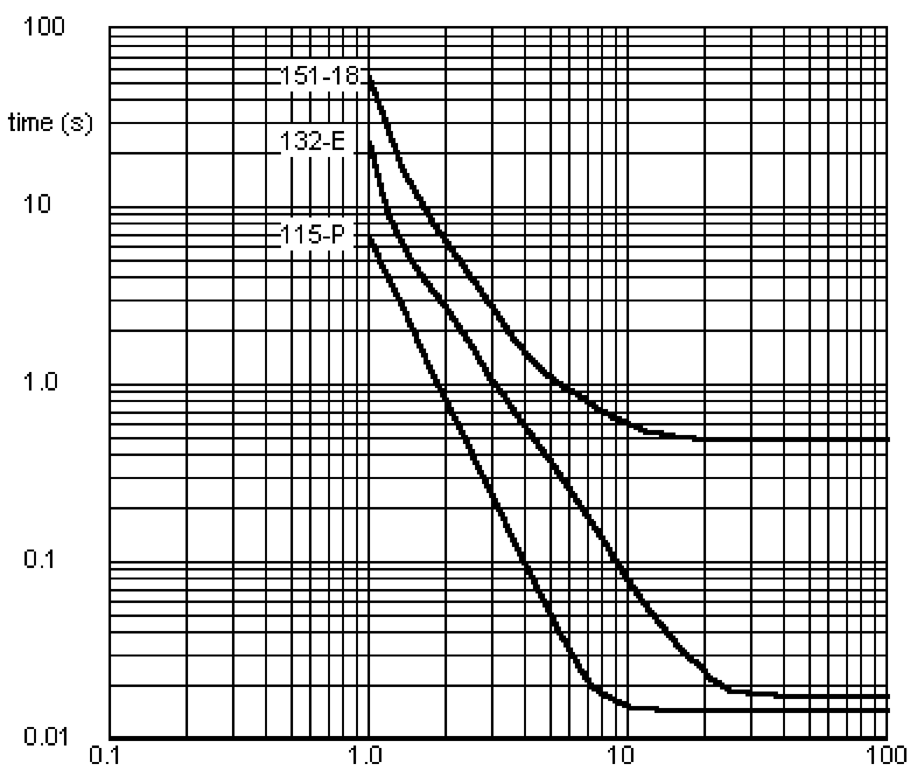

100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
140-3
135-2
117-B
105-R

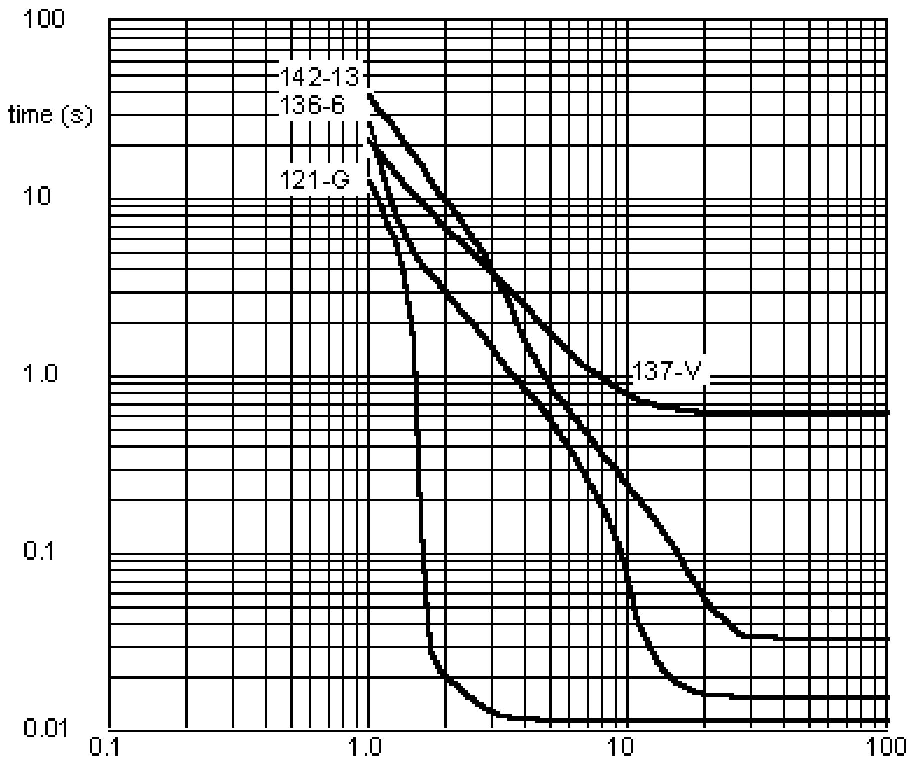

100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
141-11
131-9
119-14
106-4

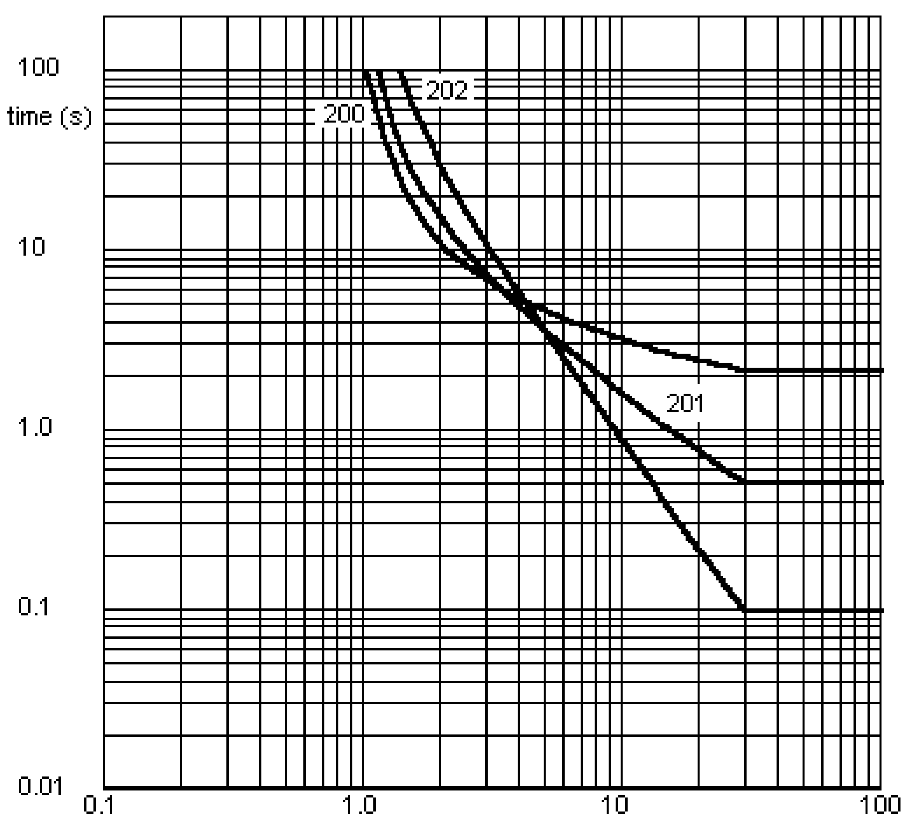

100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
152-7
113-8
112-15
107-L

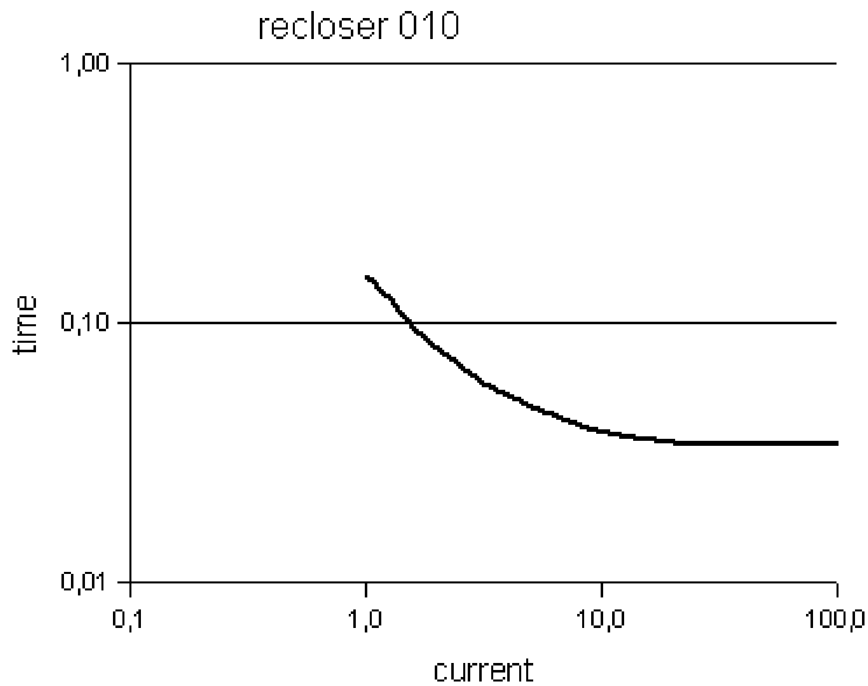

100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
139-16
116-D
111-8+


100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
165-KG
134-Z
120-Y
114-5

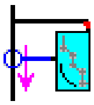

100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
151-18
132-E
115-P


100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
142-13
136-6
121-G
137-V


100
time (s)
10
1.0
0.1
0.01
0.1
1.0
10
100
202
200
201


recloser 010
1,00
0,10
0,01
time
0,1
1,0
10,0
100,0
current

User defined relay

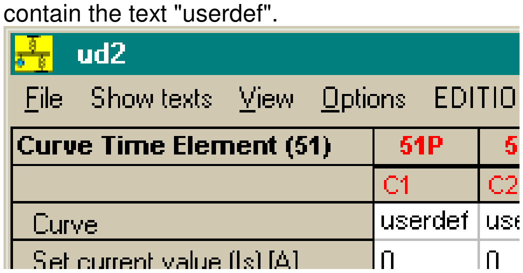


The user can define the characteristics of the user defined relay. In other respects this relay is (practically) identical with the relcoser relay.

Note: The meaning of the "Factor (n)" parameter is slightly different from that of the recloser relay. It still reduces the maximum time by chopping off the left part of the curve. But because the user-defined current of the first point is not necessarily equal to one, the curve starts at (First current) * (Set current value) * (Factor). Here, "First current" is the value of the user-defined current of the first point. [In the relcoser relay, the curve starts at (Set current value) * (Factor).]

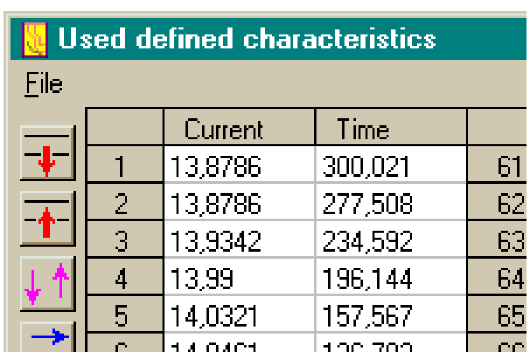
Note: For the same reason, the last parameter is called "relative current" (and not "multiples of p.u. current"). The relative current is defined as (test-) current divided by the product of the "set current value" and the "First current". In the example below, the "First current" is 13,8786. If the (test-)current is equal to 100 and the set current value is equal to 10, then the relative current = 100/(10*13,8786) = 0.72

When the user clicks the relay symbol in the single line diagram, the parameter window appears similarly as with the relcoser relay. The cells on the first parameter row, with the caption "Curve", contain the text "userdef".



When the cell with this text is clicked, a new window opens with a table for current-time pairs. The characteristic curve can be entered by writing the values of the current and the corresponding time point by point in this table. The curve ca also be read from a file, or selected from a set of saved fuse curves, see below.

Note: The points <u>must</u> be entered in increasing order of current (decreasing order of time). The first point must have the smallest value of current and the largest value of time.



Note: If you want to use the user defined curves in the form they are entered, without any multipliers etc, use the following values for the main parameters in the parameter window:

Set current value = 1
Factor(n) = 1
B = Time multiplier = 1
C = Time adder = 0
tx = min. response = 0
Pickup def 1 = 0

Delay def 1 = 0
Pickup def 2 = 0
Delay def 2 = 0
Max current = some large value
Directional = 0
|Z line| = 0
Ø line = 0
- -

The File menu

File | Open
Opens the given file and reads the current and time values for the characteristics. The data in the file must be arranged so that each line contains the values of the current and time of one point only. The value of the current must be first, then the value of time, separated by one or more spaces. The points must be in increasing order of current (decreasing order of time)

For example:

(Current Time)
13,8786 300,021
13,9342 234,592
13,9900 196,144
14,0321 157,567
...

The path and name of the file are written (and stored) in the small "notepad", that becomes visible by clicking "View | Info" both in this window for the curves of the user defined relay, and in the window for the other relay parameters.

File | Save As
Saves the values of current and time of the table in the given file. The data is saved in such a form that they can be read by file | open.

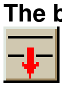
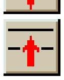
The View menu

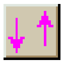
View|Info opens a small "notepad" for information of the curve of the selected relay module. The same information is displayed in the parameter window, when "View|Info" is selected there. When the user defined curve is read from a file (in either of the two ways available, see below), or a fuse curve is selected from the available curves (see below), brief information on the source of the curve is automatically written in this "notepad". The user can add or edit text in this "notepad". But note that the text is overwritten when a curve is either read in from a file, or a fuse curve is selected.

The buttons on the lower part of the window


The **OK-button** accepts the data, i.e. moves the values to the relay permanently, and closes the window.
The **Apply-button** moves the data temporarily to the relay, so that changes in the curve can be seen in the coordination graphics. The changes can be cancelled by clicking the Cancel-button.
The **Cancel-button** cancels the changes done in the values of the table, and closes the window. All changes since the opening of the window are cancelled: manual changes, data read from file, changes done by the left hand side buttons.

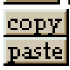
The "Momentary mode"-buttons at the bottom of the parameter window are explained in connection with the PGQ-relay.

The buttons on the left hand side of the window
 Adds cells for one current-time pair above the selected cell.
 Deletes the cells of the selected current-time pair.

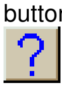
 Rearranges the data in the opposite order: first to last and last to first, etc. This can be useful if the data has been entered in the wrong order. (The right order is to have the smallest current and the largest time first.)

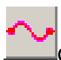
 Echanges the contents of the columns for current and time. This can be useful if the data has been entered in the wrong columns (The first column is for current and the second for time.)

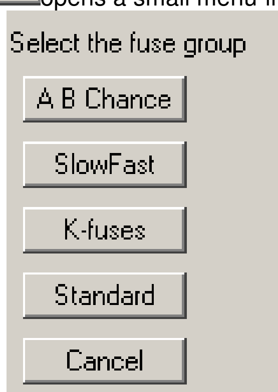
 Deletes the data in the table. Writes a '0' in each cell.



The copy-button copies the data to a <u>local</u> clipboard (not the Windows clipboard). The paste-button pastes the data from a local clipboard.

 Opens a small help-memo (not this proper help file).

opens a small menu-image (or dialog) with buttons for selecting a fuse type or group:



Several different types of fuses can be selected by clicking the buttons: A.B.Change-fuses, slow-fast-fuses, K-fuses, and standard fuses. The cancel-button closes the menu. When one of these buttons is clicked, another small menu (or dialog) opens for selecting the fuse. The menu shows the nominal currents of the fuses.

1	2	3	6
8	10	12	15
20	25	30	40
50	65	80	100
140	200		close

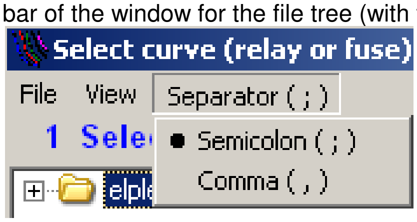
When the user clicks one of the values, the table is filled with values of current-time pairs of a fuse with the given nominal current. The example shows the menu for the fuse curves from A.B.Chance, type of the fuses is K Fast, and the nominal currents are 1...200A

opens a new window for reading the curve from an excel-generated file. This is explained in some detail in the next chapter.

User defined relay curves from excel-files

Note: Elplek cannot read "proper" excel files with the extension *.xls. It can only read the comma separated file format (*.csv) that actually is a text file. The fields (contents of the cells) are separated either by a comma (,) as the name suggests, or by a semicolon (;) depending on the language settings of the computer where the file had been saved. An excel file can be saved in the *.csv format by selecting   Save As..., and changing the file format to "CSV (comma delimited) (*.csv)" in the "save As"-dialogue of excel.

Elplek accepts both the comma (,) and the semicolon (;) as the separator, but the user must tell the program, which separator is in use. Click "Separator | Semicolon", or Separator | Comma" in the menu bar of the window for the file tree (with the caption "Select curve (relay or fuse)", see below).



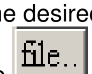
Before the file is saved in excel in the *.csv-format, the separator (comma or semicolon) can be selected in the following way in Windows XP:

Click
Start
Settings
Control panel
Regional and language options
In the tab "Regional Options", select such a language where the desired separator (comma or semicolon) is in use as default. This can be checked by clicking "Customize", and checking the item "List separator" in the tab "Numbers". For example Finnish and German use semicolon as the separator, and English uses the comma. (It is in principle possible to select the separator in some languages, but this option did not work in my computer. It is thus better to select the language itself.)
Finally, click OK

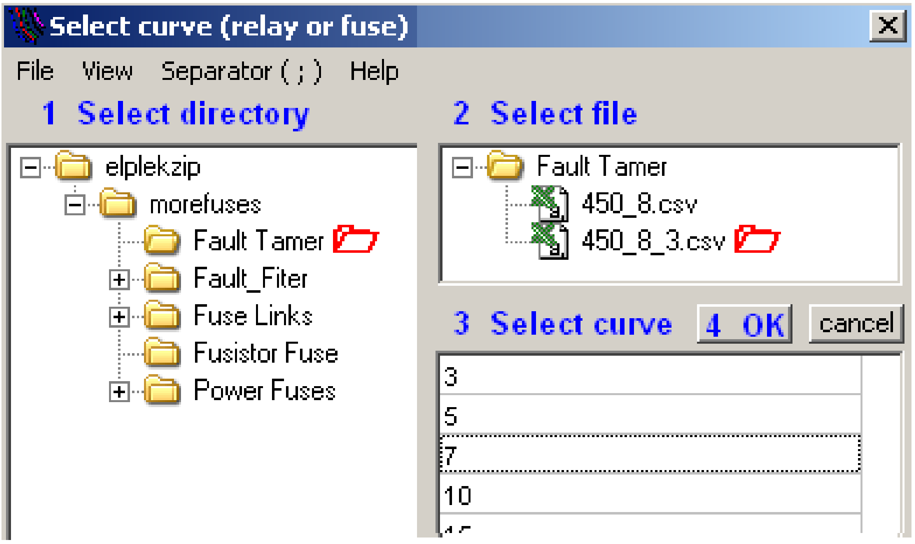
Reading the user defined curve from a *.csv excel file

Note: The *.csv files or directories containing the files must be in the same directory where the program elplek is.

Note: Because there is no "intelligence" in elplek, the data must be arranged in a given order in the excel files. More on this in the next chapter.
Suitable excel files of fuse curves are available at www.sandc.com, for example. Select "TCC curves" on the web-page.

Click the user defined relay. The window for the "ordinary" parameter will open. Click the cell on the row "Curve" and column that corresponds to the desired relay module. The window for entering the current-time points of the curve will open. Click the 

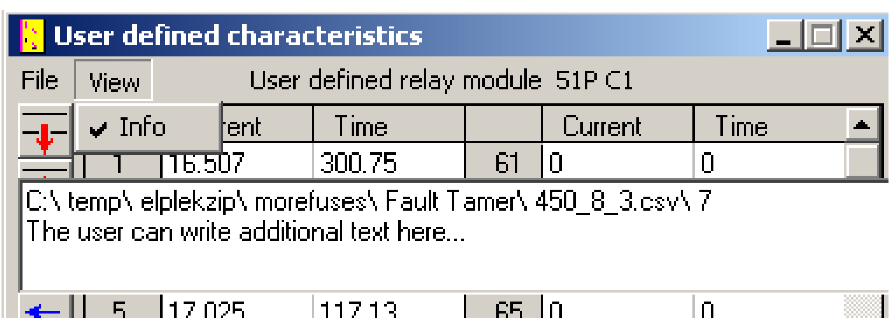
button in this window.. A new window opens, with the caption "Select curve (relay or fuse)". The window displays the "directory tree" and the "file tree" of the directories and files that are in the same directory with the program elplek. These directories should contain the *.csv-files of the curves.



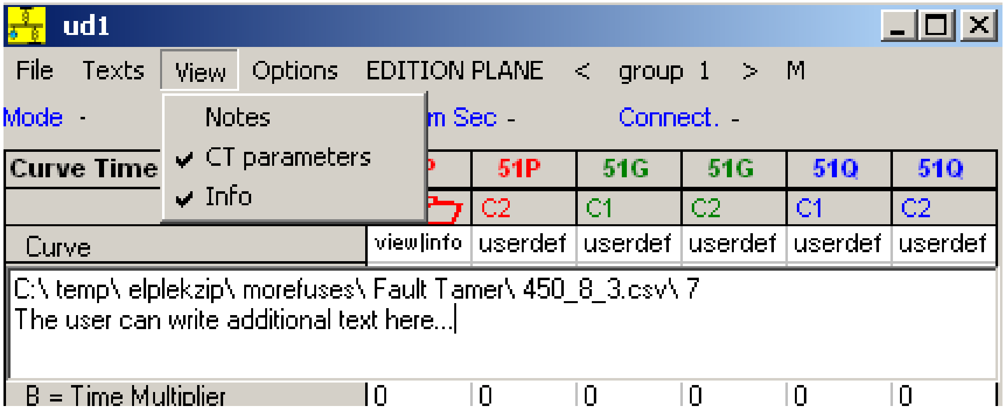
Expand the file tree in the first box by clicking the small '+' near the directory names.
1. Select the desired directory either with the mouse or using the arrow keys. The tree of files in the selected directory will be displayed in the second box. Expand the file tree in the second box. The names of the files in the selected directory will appear.
2. Select the file in the second box. The names of the time-current curves in this file will appear in the third box.
3. Select the desired curve.
4. Click OK. The current-time points are copied from the file to the window for the current time points.
Note: It is not possible click the OK-button before the curve has been selected

A simple, small symbol of an open folder appears near the selected directory and selected file in the directory tree and file tree, when the directory and file are selected. The purpose is to show, which directory and which file has been selected. It might not always be quite clear without the symbol.

The path and file name of the selected curve will be saved together with the current-time points, and other parameters of the relay. The path and file name can be displayed in a small box both in the window for the current-time points



and in the window for the "ordinary" parameters of the relay.



Click View | Info in either of the windows. The user can edit the text in the box, but the text is written over, when a new curve is selected. The boxes can be moved with the mouse.

The menu bar

File | **Exit** Close the window
View | **Show file info** opens a small box (memo) that displays the information in the selected *.csv-file, if there is any. The information must be before the curent-time values in the file, see the next chapter.
Separator (;) | **Semicolon (;)** or **Separator (;)** | **Comma (,)** selects the data separator in use in the *.csv file.
Help opens a small help box (not this, "proper" help file).

Format of the current-time data in the excel files

It is possible to read the values of the current-time points of a user defined relay from an excel file. This was explained in the previous chapter.
Note: Elplek cannot read "proper" excel files with the extension *.xls. It can only read the comma separated file format (*.csv).

The idea is that the points of several curves are entered on an excel sheet, and the sheet is saved to a file in the *csv-format.

Note: Because there is no "intelligence" in elplek, the data must be arranged in a given order in the excel files. Suitable excel files of fuse curves are available at www.sandc.com, for example. Select "TCC curves" on the web-page.

The format of the data is explained here, with the help of the picture below

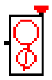
420_7MM.XLS

	A	B	C	D	E	F	G	H	I
1		S&C Fault Fiter Electronic Power Fuses							
2		Compound-Curve-Type Control Module (TCC 420-7)							
3		Minimum Tripping Time-Current Characteristic Curve Dated September 8, 1986							
4		Tolerance in Terms of Current: Plus 10%							
5									
6		Short Time Delay Band: 1							
7		Min P/U = 400A		Min P/U = 600A		Min P/U = 800A		Min P/U = 1100A	
8		Current	Time	Current	Time	Current	Current	Current	Time
9		5996,48	0,01	5996,48	0,01	5996,48	0,01	5996,48	0,01
10		5996,48	0,019523	5996,48	0,019523	5996,48	0,019523	5996,48	0,019523
11		5996,48	0,053763	5996,48	0,053763	5996,48	0,053763	5996,48	0,053763
12		5996,48	0,083395	5996,48	0,083395	5996,48	0,083395	5996,48	0,083395
13		5842,58	0,08508	5842,58	0,08508	5842,58	0,08508	5842,58	0,08508
14		4637,49	0,099643	4637,49	0,099643	4637,49	0,099643	4637,49	0,099643
15		3626,16	0,120613	3626,16	0,120613	3626,16	0,120613	3626,16	0,120613
16		2861	0,150294	2861	0,150294	2861	0,150294	2861	0,150294

1. The data must be on one sheet only
2. There may be some information lines before the values of the current-time points (rows 1..4)
   (This information is displayed, if the menu item "Show file info" is checked)
3. This information part is considered to end when an empty row is encountered (row 5),
   or two rows before a row with the text "current time current time..." is encountered (row 8)
4. There may be one empty column before the info or data (column A), but not more.
5. There may be current-time data for several curves on the sheet (columns B+C, and D+E, and ...)
6. The names of the curves must be on the row (row 7) immediately preceding the row of the Current Time captions (row 8)
7. The names of the curves must be in the same column as the caption "Current" (columns B, D,... on row 7)
8. The columns for current-time points must be identified with (preceded by) the captions Current Time, in this order (row 8)
9. The current-time points must be given with increasing time and decreasing current (largest current at smallest time first)
10. There must not be empty columns between the columns of data.

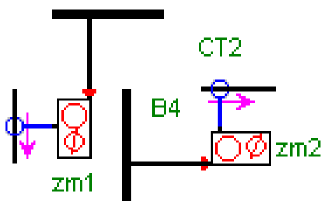
Mho distance relay

Mho distance relay (circular characteristics)

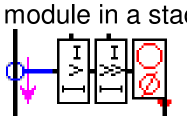


(See the corresponding chapters of the polygonal or quadrilateral relay for coordination, buttons, impedance lines, and editing and moving the graph.)

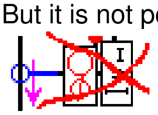
The connection point on the long side of the relay is connected directly to a current transformer. The connection point on the short side is connected to a bus, a wire, or to a network node, in order to measure the voltage in the bus, wire or node.



The distance relay should be connected to a current transformer of its own, like in the picture above. It is possible, but **not** recommended, to include a distance relay as the rightmost module in a stack of relay modules, as



But it is not possible to connect any relay modules to the right side of a distance relay, like



The distance relay calculates an impedance from the voltage and current measurements. **Note:** The impedance is calculated using the initial currents Ik" and voltages Vk". Thus, the impedance is not a function of time. (If the voltage is zero, then the prefault voltage is used, see below.)

Equations

The impedance can be calculated in two ways, either using the equation for a "type 21" relay, or using the equation for a "type 21N" relay, as

type 21: Zab = (Va - Vb) / (Ia - Ib) for phase a and similarly for the other phases.

Va and Vb are the phase to neutral voltages of phases a and b, respectively
Ia and Ib are the currents in phases a and b, respectively

type 21N: Zag = Va / (Ia + k0 * Ir) for phase a, and similarly for the other phases

Va is the phase to neutral voltage in phase a
Ia is the current in phase a
Ir is the sum current, Ir = Ia + Ib + Ic
k0 is a complex coefficient, given as input.

k0 is defined as k0 = (ZL0 - ZL1) / (3* ZL1)

ZL0 is the zero sequence impedance of the protected line (from the relay to the assumed location of the fault)
ZL1 is the positive sequence impedance of the protected line.

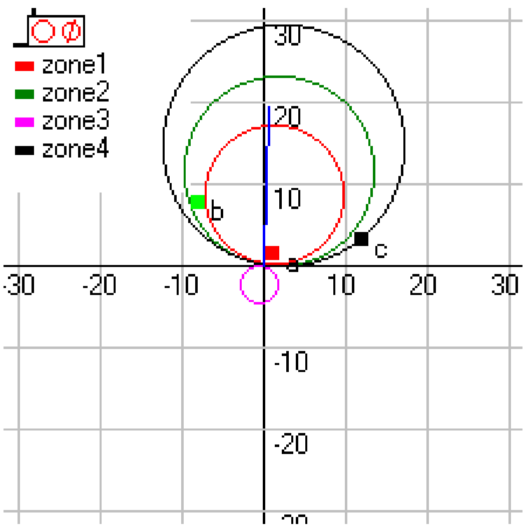
Buttons

The equation used depends on the fault type and on the position of the auto button:

When the button is in the auto position , then type 21N equation is used for the line to earth fault, and the type 21 equation for the other faults.
When the button is in the phase position, type 21 equation is used for all fault types.
When the button is in the grnd position, type 21N equation is used for all fault types.

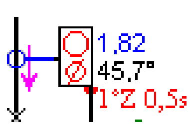
Display

The calculated impedance determines which **zone** is activated, or none. When the distance relay is clicked after a short circuit calculation, a picture is displayed showing the zones as circles and the impedances of the three phases as small rectangles.



The activated zone is the circle with the smallest diameter containing an impedance-reactangle. In the picture above the zone 1 (red) is activated. The blue line describes the line impedance. Its length is equal to the absolute value of the impedance | Z line |, and its angle with the real axis is equal to the Øline-parameter.

The impedance, the activated zone, and the time parameter of the zone are displayed near to the distance relay:



In the picture above the impedance is 1.82 ohms at 45.7 degrees (R= 1.82 cos(45.7) ohms, X = 1.82 sin(45.7) ohms). Zone 1 is activated, and the time parameter is o.5s.

Zero impedance (zero voltage)

If the fault is so near to the relay that the voltage, and thus the impedance is practically zero, the distance relay must still determine on which side of the relay the fault is, "forward", or "reverse". Normally, "forward" is in the direction to which the current transformer of the relay is pointing to, reverse is in the opposite direction. If the difference of the parameters Zangl - Øline (see below) is between 90 degrees and 270 degrees, or the Z#mag-parameter (the diameter of the circle of the zone. # = 1, 2, 3, or 4) is negative, then the forward and reverse directions are exchanged.

In the case of **a three phase fault**, a "torque" is calculated as

T = | V1 | | I1 | cos(Øv - Øc -Øz)

where
V1 is the positive sequence prefault voltage.
I1 is the positive sequence current in the faulted state
Øv is the phase angle of the voltage
Øc is the phase angle of the current
Øz is the phase angle of the impedance of the line (the parameter Ø line)

If the torque T is positive, or actually, larger that a small constant, then the fault is in the "forward" direction. If T is smaller (more negative) than a small negative constant, then the fault is in the reverse direction.

In the cases of **unsymmetrical faults**, the sequence currents and voltages are used. A negative sequence impedance Z2 is calculated, as

Z2 = Re [V2 * I2 * (cos (Øz) - j sin (Øz))] / (| I2 | | I2 |)

Øz is the phase angle of the impedance of the line (the parameter Ø line)
V2 is the negative sequence (phase to neutral) voltage
I2 is the negative sequence current

If the impedance Z2 is smaller than 0.5 * the absolute value of the line impedance (the | Zline | parameter) , then the fault is in the "forward" direction. If Z2 is larger than 0.5 * the absolute value of the line impedance + 0.1, then the fault is in the reverse direction.

An alternative way to determine the direction of the fault

When the user clicks View | Button(s), a couple of (test-)buttons become visible. The button with the default caption "+ -" can be used to select the method of determination of the fault direction, forward or reverse. When the button is in the position "+ -". then the method described above is used. When the button is in the position "Ø", an alternative method is used.

In this alternative method, the phase difference between the current and the prefault voltage is studied. If the phase difference is between +60 degrees and -120 degrees, then the fault is in the forward direction, else in the reverse direction.

The parameters

The distance relay has over twenty parameters. Because of this large number, the parameters are not displayed on a line on the lower part of the screen as is done with the parameters of other components. Instead, they are displayed in a table that appears when the relay is clicked. Below the table, there are four buttons with captions "OK", "Cancel", "Apply" and "Hint". The "OK" button accepts the parameters (enters them to the relay). The "Cancel" button cancels any changes made in the parameters. The "Apply" button temporarily accepts the parameters, i.e. shows their effect on the impedance and characterstics. The previous parameters can be recalled with the "cancel" button. The "Hint" button shows a small help-file.

Note, the parameter values are moved to the component also <u>when the user clicks almost anywhere on the screen:</u> another component, the calculation buttons, an empty place on the screen, etc.

Note: If the "Hide distance relay graphs"-button  is down, the parameter table and the graph of the relay will not appear, when the relay is clicked. This may be handy, when constructing the diagram.

The parameters are

k0mag	= absolute value of k0
k0ang	= angle of k0 (degrees)

Zang = angle of zones

if 0, then the center of the characteristics circles is on the real axis
if 90, then the center of the caracteristics circles is on the imag.axis

Z1mag(21)	= diameter of first zone (type 21)
Z2mag(21)	= diameter of second zone (type 21)
Z3mag(21)	= diameter of third zone (type 21)
Z4mag(21)	= diameter of fourth zone (type 21)
Z5mag(21)	= diameter of fifth zone (type 21)

Note: 0 = zone not in use, < 0 = reverse direction

T1(21)	= operation time of first zone (s) (type 21)
T2(21)	= operation time of second zone (s) (type 21)
T3(21)	= operation time of third zone (s) (type 21)
T4(21)	= operation time of fourth zone (s) (type 21)
T5(21)	= operation time of fifth zone (s) (type 21)

Note: type 21 = phase distance relay, used in 3-phase, line-to-line and line-to-line-to-earth faults

Z1mag(21N)	= diameter of first zone (type 21N)
Z2mag(21N)	= diameter of second zone (type 21N)
Z3mag(21N)	= diameter of third zone (type 21N)
Z4mag(21N)	= diameter of fourth zone (type 21N)
Z5mag(21N)	= diameter of fifth zone (type 21N)

Note: 0 = zone not in use, < 0 = reverse direction

T1(21)	= operation time of first zone (s) (type 21N)
T2(21)	= operation time of second zone (s) (type 21N)
T3(21)	= operation time of third zone (s) (type 21N)
T4(21)	= operation time of fourth zone (s) (type 21N)
T5(21)	= operation time of fifth zone (s) (type 21N)

Note: type 21N = ground distance relay, used in line-to-earth faults

| Z line |	= abs.value of line impedance
Ø line	= angle of line impedance (degrees)

Note: R of line = Z cos(Ø) X of line = Z sin(Ø)

thickness select the thickness of the lines (the circles) from the menu (or palette). The colors of the lines in the palette indicates the zone (the cirlce) for which the selected line thickness applies.

Parameters for the load zones
the forward zone first, then the reverse zone

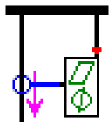
name	name (identifier) of the zone
MVA	max. apparent power (in MVA)
+ load angle	positive load angle (-90 deg...+90 deg)
- load angle	negative load angle (90 deg .. 270 deg)
line color	select the color of the line in the palette
thickn. 0..4	thickness of the line, 0 = dashed line

Parameters for the "out of step" zones.
Zone 6 first, then zone 5

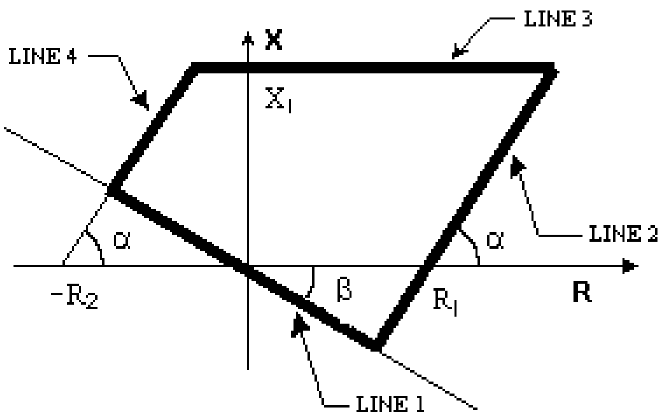
name	name (identifier)
top react.	top reactance (ohms)
bottom react	bottom reactance (ohms)
right resist	right resistance (ohms)
left resist	left resistance (ohms)
line color	color of the line
thickn. 0..4	line thickness

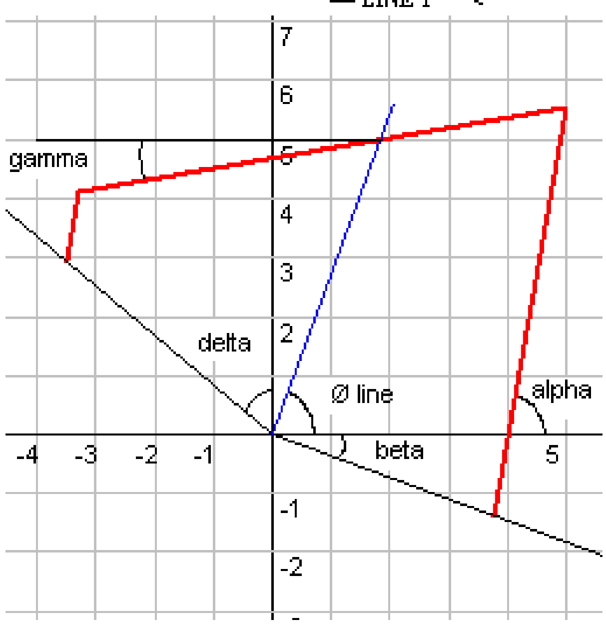
options values of options set by buttons. DO NOT EDIT

Polygonal distance relay



The polygonal distance relay (quadrilateral relay) is similar to the Mho-distance relay. The main difference is the shape of the characteristic. It is a polygon, with four or five corners, instead of a circle, see figures below. The characteristic defines the zone of the relay. There can be at most five zones, or characteristics in a relay.



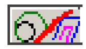


The sides of the polygon are defined by four or five lines in the impedance plane (R, X- plane). LINE 1 goes through the origo. The slope of the line on the right hand side (positive resistance R) is defined by the angle and parameter beta, and by the angle delta on the left side (negative resistance R).
Note, a positive beta means that the line slopes to the right, see the figure above.
Note, the angle delta is the angle between the LINE1 on the left side and the positive reactance axis.

LINE 2 intersects the R-axis at the resistance (and parameter) Rn, where n = 1...5 is the index of the characteristic, or zone. The slope of the line is defined by the angle alpha.

LINE 3 is horizontal if the parameter gamma = 0, else it is tilted by gamma. If gamma = 0, the line intersects the X-axis (the reactance axis) at the reactance (and parameter) Xn (n = 1...5). See below for the case where gamma is not zero. (If Xn is negative, then a fault in the reverse direction is considered.)

LINE 4 intersects the negative R-axis at a resistance that is calculated as -(R-/R+)*Rn (n = 1..5). Here (R-/R+) is the seventh parameter in the table. The slope of the line is defined by the same angle alpha as the slope of the line 2.

Note: If the "hide distance relay graphs"-button is down,  the parameter table and the graph of the relay will not appear, when the relay is clicked. This may be handy, when constructing the diagram.

The parameters are

k0mag magnitude of k0 (for "21N" or ground relays)
k0ang angle of k0 (degrees)
(See the Mho distance relay)

alpha angle of the sides of the polygon(Line2 and 4) (degrees)
10 < alpha < 170
beta angle of the bottom of the polygon (Line 1) on the positive side
-90 beta < 90
NOTE: positive beta = downwards (clockwise)
gamma angle of the top of the polygon, (Line 3)
-80 < gamma < 60

The line is rotated around the point where it intersects the impedance line of the protected line, defined by | Zline | and Ø line (see below). If the impedance of the line is not defined (Zline and Ø line are zero), then the line (line3) is rotated around the point (Xj/tan(alpha) , Xj), where Xj is the reactance (X1, ..,X5). The rotation point is the midpoint of the line 3, if the parameter R-/R+ is equal to one. Counterclockwise rotation for positive gamma.

delta angle of the bottom of the polygon on the right side, -10 < delta < 100 degrees
-10 < delta < 100
NOTE: positive delta = downwards (counter-clockwise) from the positive reactance axis
NOTE: if the parameter delta = 0, then it is set internally to 90-beta.

R-/R+ Ratio of the left and right (negative and positive) resistances (R2 and R1 in the figure above. -R2 defines the position of the left side of the polygon, line 4).

R1(21) Resistance = position of the sides of the polygon
of the first zone for "21 Phase characteristics" (> 0, ohm)
X1(21) Reactance = position of the top of the polygon
of the first zone for "21 Phase characteristics" (ohm)
If X1 < 0 : The characteristic is in the reverse direction
Note: If R1 = 0 or X1 = 0, there is no first zone characteristic

R2(21)...R5(21) as R1(21), but for the 2nd...5th zone
X2(21)...X5(21) as X1(21), but for the 2nd...5th zone

T1(21) The operation time of first zone
for "21 Phase characteristic", (seconds)

T2(21)...T4(21) As T1(21), but for the 2nd...4th zone

Note: type 21 = phase distance relay, used in
3-phase, line-to-line and line-to-line-to-earth faults

R1(21N) ... T4(21N)
as R1(21)...T4(21), but for the "21N characteristic"

Note: type 21N characteristics = ground distance relay, used in
line-to-earth faults

| **Zline** | The magnitude of the impedance of the protected line
Ø line angle of line impedance (degrees)

Note: R of line = Z cos(Ø) , X of line = Z sin(Ø)
(See the Mho distance relay)

Parameters for the load zones
the forward zone first, then the reverse zone

name	name (identifier) of the zone
MVA	max. apparent power (in MVA)
+ load angle	positive load angle (-90 deg...+90 deg)
- load angle	negative load angle (90 deg .. 270 deg)
line color	select the color of the line in the palette
thickn. 0..4	thickness of the line, 0 = dashed line

Parameters for the "out of step" zones.
Zone 6 first, then zone 7

name	name (identifier)
top react.	top reactance (ohms)
bottom react	bottom reactance (ohms)
right resist	right resistance (ohms)
left resist	left resistance (ohms)
line color	color of the line
thickn. 0..4	line thickness

Menu bar of the distance relay window

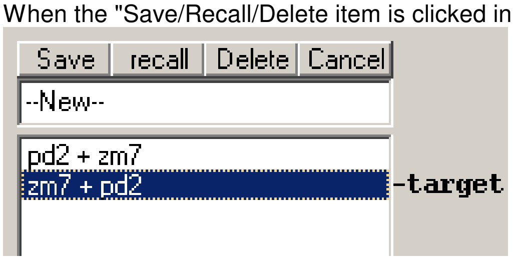
The menu-bar is the same for both Mho-distance relays and for the polygonal distance relays.

File | **Export relay diagram**
When the "export relay diagram"-item is clicked in the File-menu, a save-file dialogue opens for saving the diagram to file. The diagram can be saved either as a windows metafile format (*.wmf) , as a bitmap (*.bmp) or as a jpeg-graphics file (*.jpg). When the bitmap format or the jpeg-format is selected, the whole distance relay window is saved, including the parameters, etc. When the metafile format is selected, only the graphical part is saved.

File | **Copy to clipboard** copies the graph to the Windows clipboard as a bitmap.

Save/**Recall**/**Delete** When the characteristics of several distance relays are displayed in the graph, it is possible to save and recall and delete the list of these relays and the associated impedance lines. When a saved list is recalled, the characteristics of the relays are drawn on the graph, together with the impedance lines.

When the "Save/Recall/Delete item is clicked in the menu, a small dialogue window opens.



with buttons for saving, recalling and deleting the list of relays and impedance lines in the graph. The list to be saved or recalled or deleted is selected in the lower box. A new list can be saved by writing a suitable caption to the upper box. The text "target" points to the item in the boxes that is saved/recalled/deleted.
Note: The "Delete" deletes only the list of relays and impedance lines, not the relays and impedance themselves.

File | **Exit**
Closes the distance relay window.

____

Options | **Show buttons etc.**
This item can be used to display or hide the increase, decrease buttons, the edit box for the cursor position, etc. This feature may be useful, when the window is saved in the bitmap format

Options | **Highlight selected cell**
1) Highlight is selected (checked):
When a parameter cell is entered either by clicking the cell, or by moving with the arrow or tab-keys. the text in the cell is highlighted (has a colored background). If the user starts to edit the text in the cell directly, the old text is deleted. But if the user first clicks the cell, or presses the enter-key, the text can be edited without losing the old text.

2) Highlight is not selected (not checked)
When a parameter cell is entered, the cell is not highlighted, but the cursor is visible as a vertical bar. Editing the text in the cell does not deltete the old text.

Options | **Color of Grid**
Select the color of the grid from the palette that becomes visible, when this option is selected.

Options | **Hide Load ZONES**
Hide the graphs of the load zones (the arc of a circle, and the radial lines)

Options | **Hide Load Zone NAMES**
Hide the names (identifiers) of the load zones.

Options | Hide O.o.s ZONES
Hide the graphs of the out of step zones (the tilted rectangles)

Options | Hide out of Step NAMES
Hide the names (identifiers) of the out of step zones.

Options | Hide parameters
Hides the array of parameters and the OK-, Cancel-, etc. buttons.

Options | Hide symbol
Hides the small relay symbol in the upper left corner of the graph.

Options | Hide Title
Hides the title (caption) of the graph.

Options | Hide Impedances
Hides the small squares in the graph indicating the impedance measured (or "seen") by the relay.

View | Notes
When this item is selected (checked) a small box for notes opens at the bottom of the distance relay window. The user can write and edit text in this box. The text is saved together with the diagram.

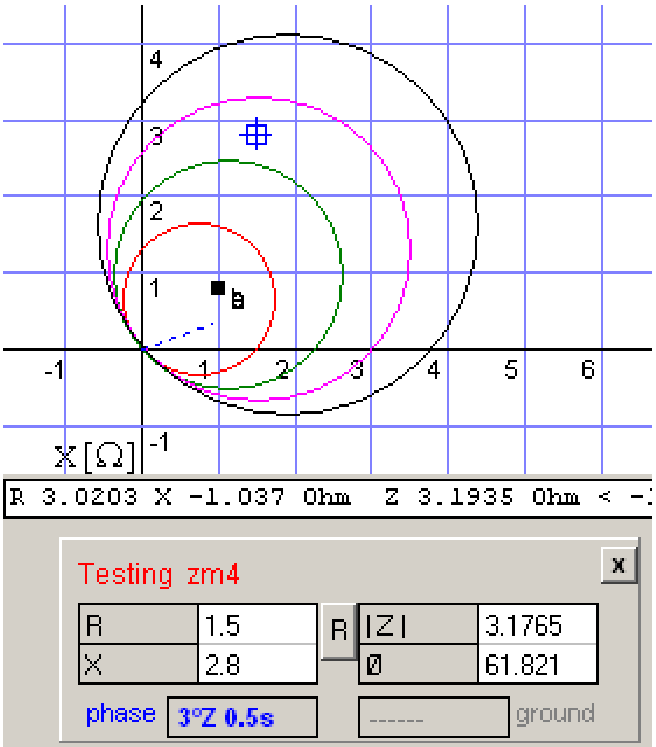
View | Zone 1, ..., View | Zone 5
This item can be used to show or hide the graph for any of the five zones in the diagram for the distance relay.

View | Z of line
This item can be used to show or hide the straight line in the diagram that describes the impedance of the line to be protected by the distance relay

View | Show Axix Units
When this item is checked, the "omega" symbols on the R- and X-axes are visible. **Note:** The omega-symbols can be moved by dragging with the mouse.

View | Keep scale
When this item is checked, the scales of the R- and X- axes do not change, when parameters are changed. When unchecked, the scales are automatically selected so that the graph fits in the available space.

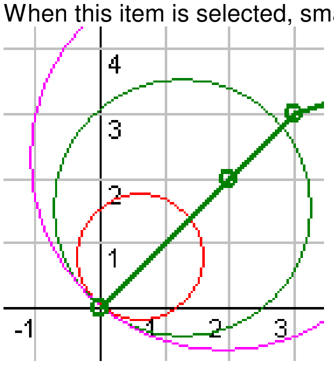
View | Activation test
The activation of the distance relay can be tested when this item is checked. Enter the value of the test-impedance in the boxes, either as resistance and reactance, or as magnitude and phase of the impedance. If the relay is activated by this impedance, the activated zone and time are displayed under the impedance boxes.



A small marker is drawn in the graph at the given impedance.

Note: If the characteristics of several relays are drawn in the graph, the activation test is always carried out with the first relay, even when the parameters of some other relay are displayed in the table.

View | Show impedance line markers
When this item is selected, small circles are drawn at the ends of the impedance lines.

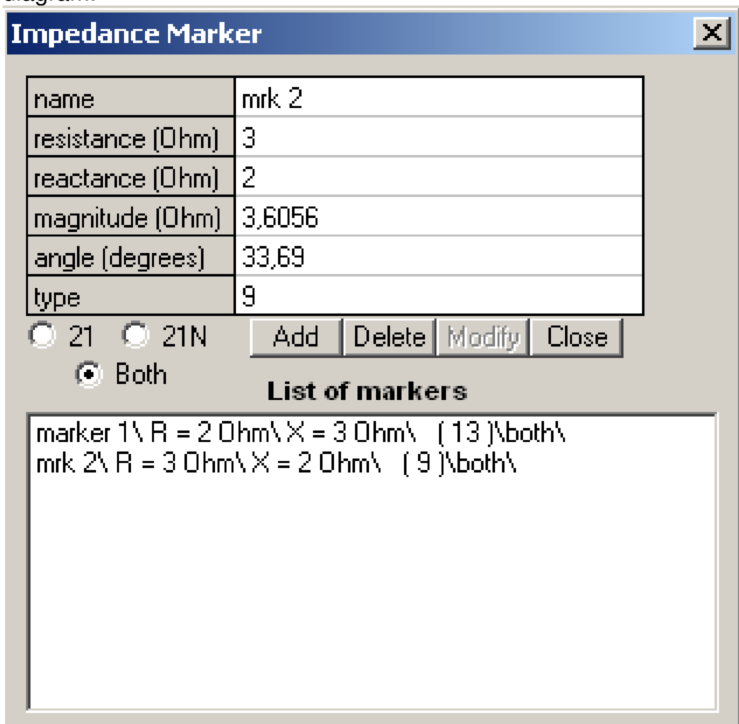


M or **A**
Manual or automatic mode for the change of parameter groups.

< Group 1 >
There are three items here. The arrows **<** and **>** are used to change the parameter group of the relay, either decrease (<) or increase (>) the group index.

The "Group 1" or group 2, group 3, etc. shows the parameter group in use. It is also a menu item for copying parameters from one group to another, and for displaying and setting conditions for the automatic change of the group.

Marker | Point
When the "Point"-item in the marker-menu is clicked, a dialog-box opens for adding a marker in the diagram.



A marker is a small symbol (circle, square, etc) that is drawn on the diagram for distance relays. The position and appearance of the marker are entered as parameters on the lines of the dialog. A title for the marker is given on the first row.

The position of the marker can be given either in terms of resistance and reactance on rows 2 and 3, or in terms of magnitude of the impedance and its angle on rows 4 and 5. When data for one pair of parameters is given, the other pair is calculated automatically.

When the last row is selected, a menu for the type, or appearance of the marker appears. The marker is selected from the menu by clicking the desired marker type.

The marker can be visible in the phase plane (21), the residual plane (21N), or in both planes. The plane where the marker is visible, is selected with the radio buttons. (The plane itself depends on the fault type, and on the position of the auto-phase-ground-button, see the Mho distance relay.)

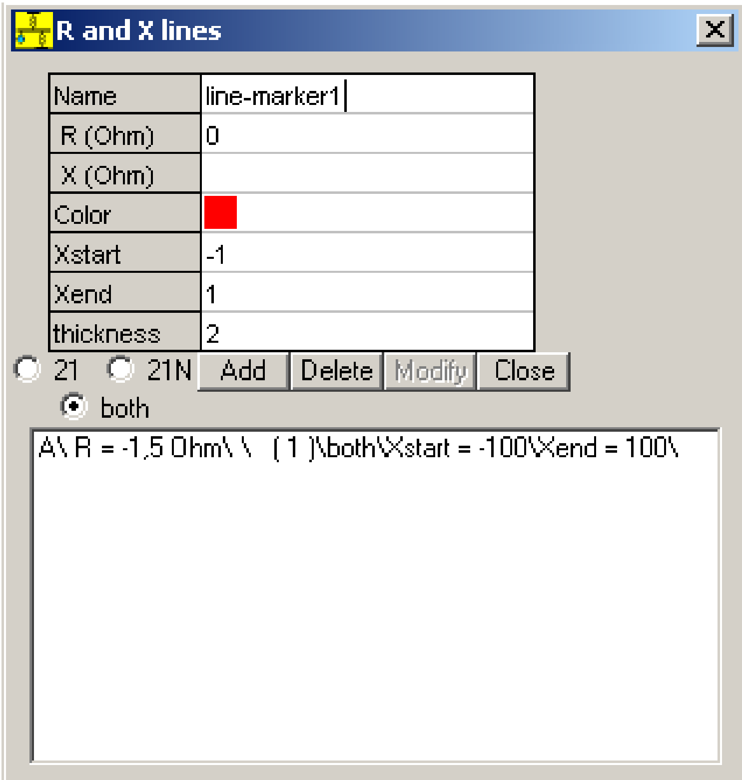
The marker is added to the diagram, when the Add-button is clicked. The marker itself appears in the graph, and the parameters appear in the box below the buttons. A marker can be deleted by first selecting it with the mouse in the list (below the buttons) and clicking the Delete-button. The Close-button closes the dialog.

An existing marker can be modified (edited) in the following way: Select the marker in the list (below the buttons) by clicking the row with the marker data. The data is copied from the line to the table (above the buttons). Edit the data, and click the Modify-button.

The names of the markers can be moved with the mouse: Put the cursor on the first character of the name. Press and keep the left mouse button down. A small square appears around the first character. Keep the mouse button pressed and move the square to the desired location. When the mouse button is released, the name moves to the position of the square.

Marker | Line

When the "Line"-item in the marker-menu is clicked, a dialog-box opens for adding a horizontal or a vertical line in the diagram.



The parameters of the line are entered in the lines of the dialog. The name of the line is written to the first line. >The position of a vertical line is given as a resistance (R) on the second line. The position of a horizontal line is given as a reactance (X) on the third line. **Note:** It is only possible to write either the resistance, or the reactance, but not both. When one of them is entered, the other is wiped out. The start- and endpoints in terms of reactance or resistance are given by the parameters Xstart and Xend, or Rstart and Rend.

The color of the line is selected from a palette, that appears, when the last row is clicked. The thickness of the line can be selected in the range 1..5.

The marker can be visible in the phase plane (21), the residual plane (21N), or in both planes. The plane where the marker is visible, is selected with the radio buttons. (The plane itself depends on the fault type, and on the position of the auto-phase-ground-button, see the Mho distance relay.)

The line is added to the diagram, when the Add-button is clicked. The line itself appears in the graph, and the parameters appear in the box below the buttons. A line can be deleted by first selecting it with the mouse in the list (below the buttons) and clicking the Delete-button. The Close-button closes the dialog.

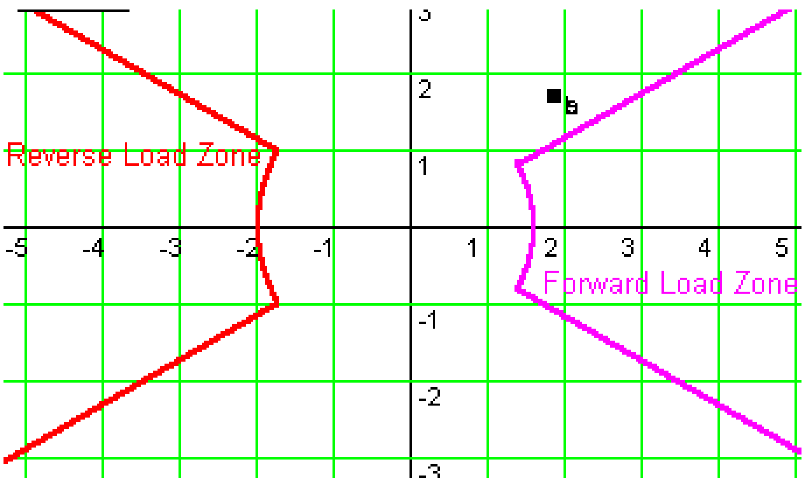
An existing marker can be modified (edited) in the following way: Select the marker in the list (below the buttons) by clicking the row with the marker data. The data is copied from the line to the table (above the buttons). Edit the data, and click the Modify-button.

The names of the lines can be moved with the mouse. See above for moving the names of the markers.

Load Zones and Out of step zones of distance relays

Note: The load zones and the out of step zones are only drawn on the graph of the distance relay. They do not have any effect on the operation of the relay in this program.

The load zones are sectors defined by an arc and two radial lines in the graph of the distance relays. One can define "a forward load zone" and "a reverse load zone".



The load zones are defined so that the impedance corresponding to the (maximum) load is within the zones. If a load zone overlaps an impedance zone (a circle for the Mho distance relays and a polygon for the polygon-distance relays), and the impedance seen by the distance relay is in the overlapping area, the distance relay should not react. In this case, the (small) impedance seen by the relay does not indicate a fault, but a large load.

The radius of the arc defining the left or right boundary of the load zone is an impedance that is calculated from

$$Z_{forward} = V^2 / S_{forward}$$
$$Z_{reverse} = V^2 / S_{reverse}$$

where:

V = bus voltage

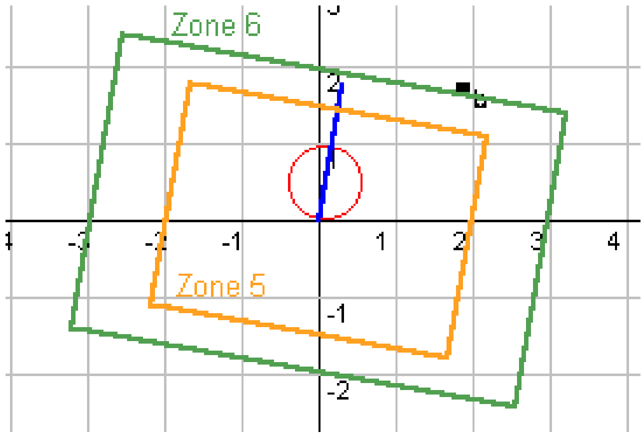
$S_{forward}$ = the maximum apparent power expected to flow in forward direction

$S_{reverse}$ = the maximum apparent power expected to flow in reverse direction

The voltage V is not given as an input. It is the nominal voltage of the bus or other point which the relay is connected to.

The angles or the lines defining the load zone are given by the user. The angles for the forward load zone must be between -90 degrees and +90 degrees. The angles for the reverse zone must be between 90 degrees and 270 degrees.

The out of step zones are tilted rectangles. They can be used to study the out of step blocking and tripping behavior of the relay during power swings.



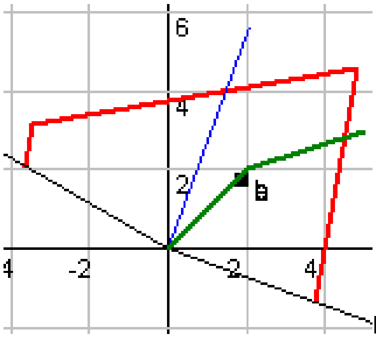
The rectangle is defined by the points where the sides of the rectangle intersect the resistance and reactance axies. (The "right resist"-parameter is the point where the right side of the rectangle intersects the resistance axis, for example.) The tilting angle is the same as the angle of the line impedance (the "Ø angle" parameter).

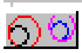
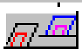
Coordination of distance relays

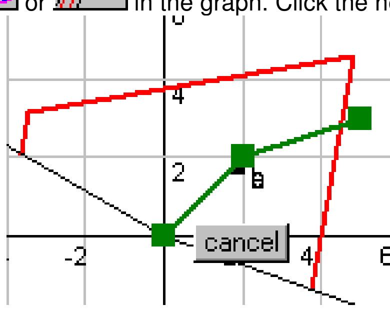
It is possible to display the characteristics of up to five distance relays in the same graph. This may be useful when coordinating distance relays.

The characteristics of distance relays can be added to the graph in the following way:

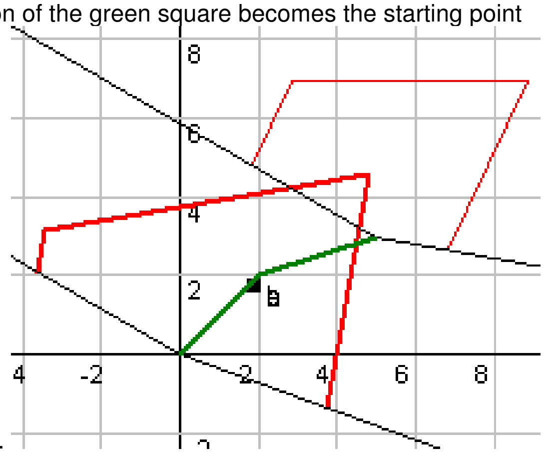
The characteristics of one relay are already (automatically) on the graph. (Becomes visible when a distance relay is clicked after a short circuit calculation.) The impedance lines of the related transformers or transmission lines must also be on the graph (the green lines in the picture).



Press down the "Show zones of all clicked distance relays" button  or  in the graph. Click the next relay. Green squares appear at the ends of the impedance

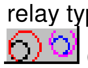


lines. When a green square is clicked, the characteristics of the newly clicked relay will be drawn so that the position of the green square becomes the starting point

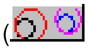
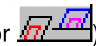


(the "local origo") of the characteristics of the relay.

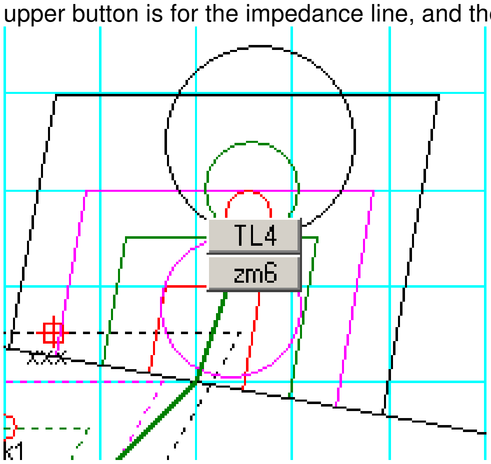
Parameters of coordinated distance relays

There are two types of distance relays in elplek: relays with circular characteristics (Mho-relays) and relays with polygonal characteristics. When the user clicks a distance relay after a short circuit calculation, the parameters and the characteristics of the relay are displayed (unless forbidden) in a window for the clicked relay type, either Mho or polygonal relay. But if the "show zones of all clicked distance relay"-button  (for Mho relays) or  (for the polygonal relays) is down, the characteristics of the clicked relay can be added to the graph where the button is down, independent of the type of the clicked relay or the graph.

However, the parameters of a clicked relay are always displayed in the window of the clicked relay type, in the Mho window for Mho relays, and in the polygonal window for the polygonal relays.

If the user wants to see the parameters of a relay whose characteristics are displayed in a window where the "show zones of all clicked distance relay"-button ( or ) is down, one has to proceed in the following way. If the user just clicks the relay in the single line diagram, the program will/may understand the clicking as a signal to add the relay to the graph, and does not (necessarily) display the parameters.

Move the cursor (the mouse) to the "local origo" of the characteristics, that is, to the end of the impedance line where the characteristics of the relay is attached. Two (or three) buttons will appear, the upper button is for the impedance line, and the lower button(s) is/are for the relay.



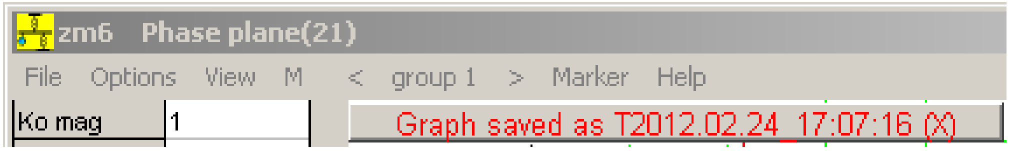
When the button for the relay is clicked (zm6 in this example), the parameters of the relay are displayed in the window of the relay. There are several possibilities:

- If the relay is of the same type as the graph (Mho relay in a Mho graph, or polygonal relay in a polygonal graph), the parameters are simply displayed in the left part of the window.

- If the relay is not of the same type as the graph (Mho relay in a polygonal window, or vice versa), the parameters and the characteristics of the relay are displayed in the window for the clicked relay type.

If the "show zones of all clicked distance relay"-button is not down in that window, nothing special happens, the parameters and characteristics are displayed, and that's it. But if the "show zones of all clicked distance relay"-button is down also in that window (for displaying the characteristics of several relays in the graph), then the following happens:

The existing characteristics in the graph disappear, and the parameters and characteristics of the clicked relay are displayed instead, as if the relay had been directly clicked. But in addition, the characteristics that were in the graph are saved in the way explained on the menu bar-page, under save/recall/delete. A message also appears telling the name under which the graph was saved.

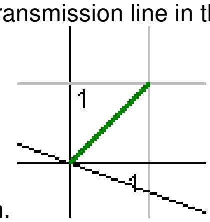


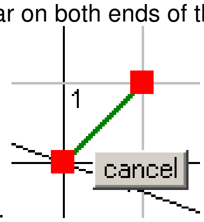
(The message disappears by clicking it.) The name consists simply of the date and time of the saving moment. The saved graph can be recalled and/or deleted later, as explained on the menu bar-page, under save/recall/delete.

Impedance lines of distance relays

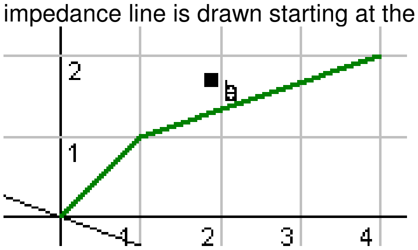
The impedances of transmission lines and transformers can be displayed on the graph of distance relays as lines. The length of the line corresponds to the magnitude of the impedance. The angle of the line is the same as the phase angle of the impedance. That is tan(angle) = X / R

The impedance lines are added to the graph in the following way:

Press the  button down. Click a transformer or a transmission line in the single line diagram. The first impedance line is drawn starting at origo in the graph. 

Click a second transformer or transmission line. Red squares appear on both ends of the impedance line on the graph (or of all impedance lines, if there are several). 

Click one of the squares, and the new impedance line is drawn starting at the position of the clicked square.



Buttons and the box in the graph of distance relays

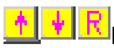
 Impedance lines can be added to the graph, when this button is down. Click a transmission line or a transformer to add the line to the graph.

Clear the impedance lines from the graph

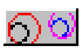
Reverses the polarization of the characteristics = upside down, as if the reactance parameters (X) were negative

An arrow points to the characteristics whose parameters are displayed in the table on the left. (Useful, if the char. of several relays are displayed)

When this button is down, the impedance-parametes of the relay are displayed as magnitude (Z) and resistance (R). A negative magnitude indicates a negative reactance (X < 0)



Increase, decrease, and reset the scale of the graph. (Increase = reduce the size of the polygons]

 in graph of circular (Mho) characteristics, and

 in graph of polygonal characteristics:

When this button is down, the graphs of the clicked distance relays can be added to the graph.

The box under the graph shows the position of the cursor in terms of impedance.

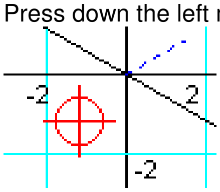
R 5.026 X 9.7989 Ohm Z 11.013 Ohm < 62.846°

Resistance is given on the horizontal axis, and reactance on the vertical axis. The position is also given in terms of magnitude of the impedance and its angle.

The buttons and the box for the cursor position can be hidden by unchecking Options | Show buttons etc in the menu bar.

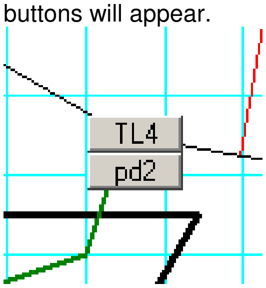
Editing the coordination graph of distance relays

The whole graph can be moved by dragging with the mouse:

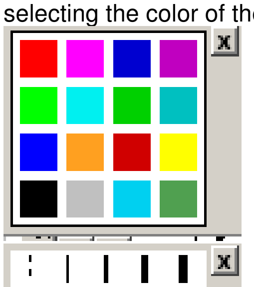
Press down the left mouse button and keep it down. A red "crosshair" appears in the origo


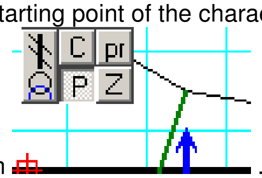
(here the crosshair has been moved, for clarity)
When the mouse is moved while keeping the left button down, the crosshair moves along. When the mouse button is released, the whole graph moves so that the origo moves to the position of the crosshair (which disappears).

Some other changes can be done to the graph:

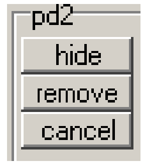
When the cursor is moved (with the mouse) near either end of an impedance line, one, two or three buttons will appear.


The upper button is for the impedance line, that ends at the position of the button (i.e. the position of the cursor). The lower buttons, if any, is/are for the distance relay, whose characteristics start at the position of the button (i.e. at the position of the cursor). The label of the impedance line is copied to the caption of the upper button, and the label of the relay to the lower button.

When the button of the impedance line is clicked (the upper button), two menus will apprear, one for selecting the color of the impedance line, and the other for selecting the thickness of the line.

The menus disappear, when the small "x" is clicked in the upper right corner of the menus.

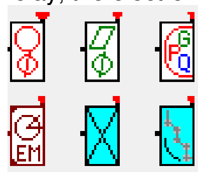
When the button of the distance relay is clicked (the lower button), several things will (or may) happen.
- The parameters of the relay will be displayed on the left of the graph.
- The blue arrow will now point to the starting point of the characteristics (the "local origo") of the selected relay, if the "P"-button is down 

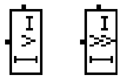
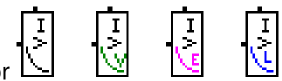
. This should remind the user that the parameter of just this relay are displayed.
- In addition, a " hide", a "remove" and a "cancel" button will appear in the upper left corner of the graph,

together with the label of the relay. 

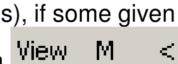
When the "hide"-button is clicked, the characteristics of the selected relay will be hidden. The characteristics become visible by clicking the button once more. When the "remove"-button is clicked, the characteristics of the selected relay are removed permanently from the graph. (The characteristics can be re-added to the graph in the "usual" way). The "cancel"-button just hides the buttons.

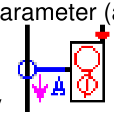
Parameter groups of relays

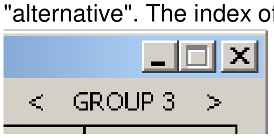
Principle
A microprocessor based relay can have several groups (or sets) of parameters, of which one can be selected for use. The combined PGQ-relay, the electromechanical relay, the recloser relay, the user defined relay, and the distance relays  can have six different groups of parameters in this program.

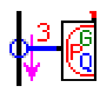
Note: the single relay modules  or  do not have parameter groups.

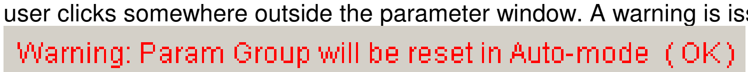
Ghanging groups manually
The group can be changed manually by clicking the right (increase) or left (decrease) arrows on both sides of the group indicator 

in the menu bar. The group may also be changed automatically by opening or closing breaker(s), if some given conditions are satisfied. The mode, auto or manual is selected by clicking the A/M item 

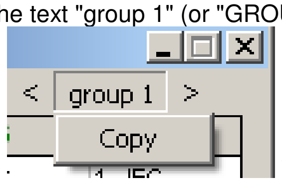
in the menu bar of the parameter (and graph) window. When a relay is in automatic mode, a small "A" appears near the relay 

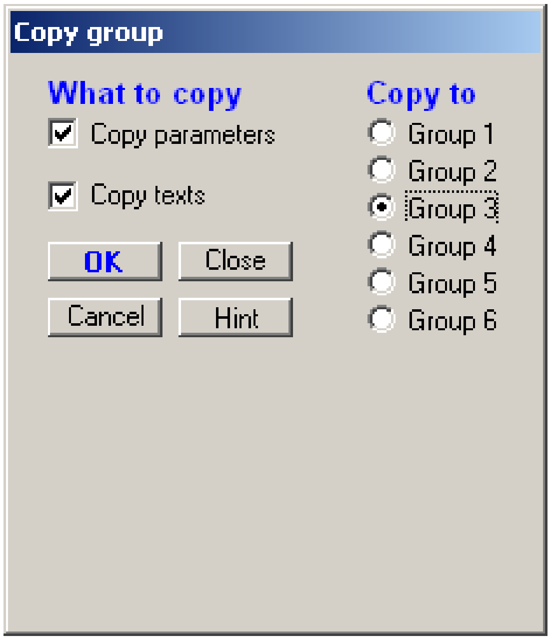
One parameter group is "active", that is, the parameters of that group are in use. The other groups are "alternative". The index of the active group is shown in the menu bar of the parameter window. 

as texts "group 1", "GROUP 2", etc. Upper case characters are used for groups 2 to 6, in order to emphasize that some other group than the default group number 1 is in use. The active group can be changed by clicking the right and left arrows on both sides of the "group X"-text. If some other parameter group than group 1 is active, then the active group is indicated also near the relay symbol in the diagram with a small number 

Note: When a relay is in automatic mode, the parameter group can be changed temporarily, for editing the parameters, for example, but the group is reset when the parameter window is closed, or when the user clicks somewhere outside the parameter window. A warning is issued 

, when the group is changed manually in automatic mode.

Copying groups
When the text "group 1" (or "GROUP 2", etc) is clicked in the menu bar, a button with the text "Copy" will appear. 

When the button is clicked a dialog for the copying of parameters to an another group appears. 

. When the tick-box "Copy parameters" is checked, the parameters will be copied, and when the tick-box "Copy texts" the descriptions (texts) of the relay will be copied. This does not apply to the distance relays, because there are no descriptions in the distance relays. The destination group is selected with the "Copy to" radio buttons. The parameters and texts to be copied are always the visible parameters and texts.

The purpose of the buttons in the dialogue is the following
OK carries out the copying
Close closes the dialog
Cancel closes the dialog, if copying has not been carried out, or cancels ("undoes") the copying, if copying has been carried out.
Hint opens a small help memo (not this "proper" help file)

Automatic change of relay parameter groups

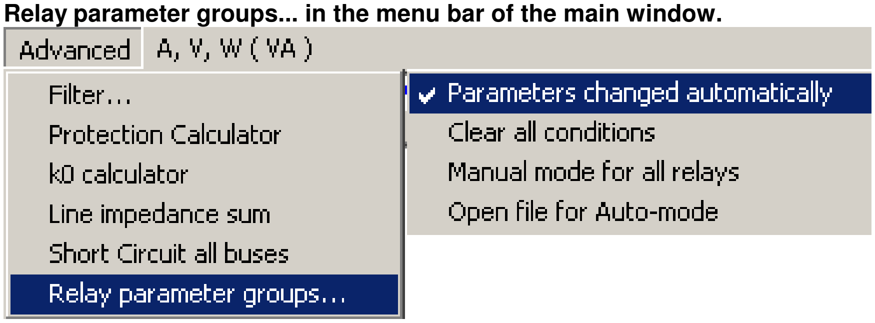
The distance relays and the overcurrent relays (PGQ-relays, electromechanical relays, recloser relays, user defined relays) have six groups (sets) of parameters. Different parameter groups are used in different configurations of the net. The configurations are obtained by opening and closing breakers. The parameter group can be changed in the relay either manually or automatically. The group is changed manually by clicking the items marked with a left (decrease) or a right arrow (increase) in the menu bar 

of the relay parameter window on both sides of the group indicator.

The check for an automatic change of parameter groups is done always when a breaker state (open or closed) is changed, IF
- the "Parameters changed automatically"-item is checked (a submenu in the main window, see below)
- the relay is in automatic mode
- a set of conditions on breaker positions, open or closed, are satisfied.

The check is also done, when the relay is switched from manual to automatic mode (with respect to the parameter groups), usind the M-item in menu bar, and when the conditions are changed.

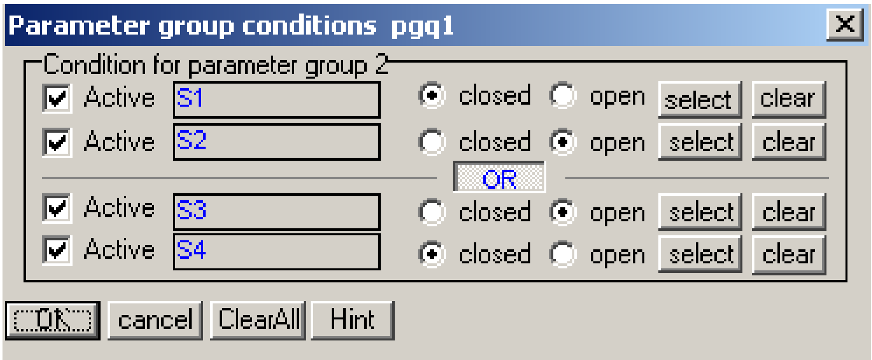
The "Parameters changed automatically"-item is in a submenu that is found under Advanced | Relay parameter groups... in the menu bar of the main window.



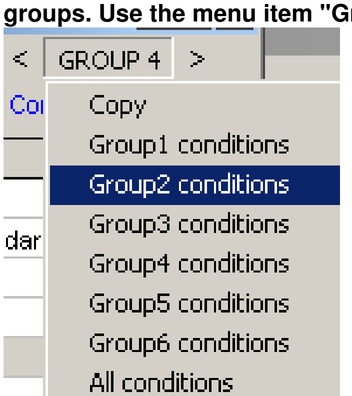
The mode of the relay, automatic or manual, is changed with a A/M menu item 

in the menu bar in the parameter window of the relay.

The submenu **under Advanced | Relay parameter groups... in the menu bar of the main window**
Parameters changed automatically, explained above
Clear all conditions clears all conditions for automatic change of the parameter groups, for all relays
Manual mode for all relays sets all relays to manual mode (with respect to the change of the parameter groups)
Open file for auto-mode opens an "open-file" dialogue, for reading from a file the labels of relays to be set in auto mode
The file can be generated with the "search" function of the component menu. The file should list the labels of the relays to be set in auto mode, as
Relay_1
relay_2
etc.
If a row in the file starts with a special character, it is considered as a comment.
- - - - - - -
The conditions for changing the parameter groups can be defined for each relay and each parameter group in a "Parameter group conditions"-window



The "Parameter group conditions" window can display the conditions for one group, or for all groups. Use the menu item "Group x" and the submenu for displaying the window.



A condition of a group can contain the position (open or closed) of at most four breakers. The conditions of the two first breakers are "AND"-ed, and the condtions of the two last breakers are AND-ed. The results of these two "AND"-operations are then either "AND"-ed, or "OR"-ed, depending on the position of the button in the middle, AND or OR. In the picture above, the condition for group 4 is

[(S1 closed) AND (S2 open)] OR [(S3 open) AND (S4 closed)]

If this condition is satisfied, then the parameters of group 2 are used in the relay.

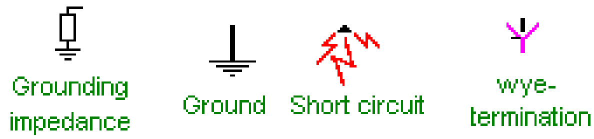
The conditions of the groups are checked starting from the first parameter group. If the conditions are satisfied, the first parameter group is selected. If the conditions are not satisfied, then the conditions of the second group are checked, and, if satisfied, then the second group is selected. If not satisfied, then the next parameter group is checked, etc. up to the sixth group, if necessary. If the conditions of any group are not satisfied, then the first parameter group is selected.

If the "active"-box is not checked, the corresponding breaker is not considered.

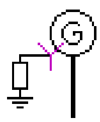
The breakers for the conditions are selected by clicking first the "select"-button, and, when the select-button is down, by clicking the breaker to be selected. The condition, open or closed, is selected with the corresponding radio-buttons. In addition, the condition can be set active by checking the "active"-box. The condition can be cleared with the "clear"-button.

Note: **When a relay is in automatic mode, the parameter group can be changed temporarily, for editing the parameters, for example, but the group is reset when the user clicks somewhere outside the parameter window, or when the parameter window is closed. In addition, a warning is issued :**

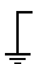
Grounding impedance, Ground, Short circuit, Wye



The grounding impedance is used to connect the neutral point of a generator or a wye-termination-component to ground. It is connected to the "Y" of the generator symbol in the lower left corner of the symbol, or to the center of the wye-component. It can be used only for the generator and the wye-termination, not for other components.



The parameters are the resistance R and reactance X of the impedance, in ohms. R and X are in series. If both are zero, then the symbol changes to a line connected to the ground.



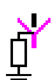
The Ground-component connects the network to ground in the point where the "ground" component is located. It keeps the voltage at zero at that point.

The short circuit indicates the location of the fault (short circuit).

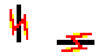
Note: The fault is neglected in the normal solution of the network. It is used only in the calculations that are initialized by pressing one of the four "fault" buttons.

Note, There can be many or no short circuits in the network in the case of the three phase fault. In the other cases, there must be exactly one short circuit in the network.

The **wye-termination-component** connects the phases in a wye (star). The star point can be connected to the ground, either directly, or through an impedance by using the grounding impedance.

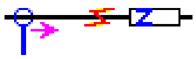


Open line fault



When one of the "open line fault"-buttons  is pressed, the steady state currents are calculated in the network with one phase (c) open, or two phases (b and c) open at the location indicated by the "open line fault"-component.

The fault must be inserted between two components, like



The prefault state can be selected by the long, narrow button 

below the fault buttons, similarly as in the case of the different short circuits.

Note: There must be exactly one open line fault-component in the network for a successful calculation.

Note: The currents in the open phases may not always be exactly zero, mostly due to numerical round off, but sometimes also due to some circulating currents.

Note: The open line fault is neglected in other calculations (solve the net, load flow, faults).

Entering parameters

Every time a component is clicked, the parameter values and the parameter symbols appear on two lines of text in the lower part of the screen, like

Vn	Pn	sn	pf	eff	IsIn	P
621,8	644022	0,012	0,9121	0,9732	5,32	0,05

The values can be edited like a line in a text editor. That includes copying and pasting. Thus, it is easy to copy the parameter values from one component to another.

Note: This does not apply to the distance relays, PGQ-, electromechanical-, recloser- or user defined relays, transmission lines, 2-winding- and 3-winding transformers and current transformers. Because these components have many parameters, a table is used to enter the parameters.

When the line with the parameter values is clicked with the mouse, four buttons appear:

the OK Cancel Hint PU calc buttons.

When the **OK** button is pressed, the parameter values are moved to the component (accepted). But **note**, the parameter values are moved to the component also when the user clicks almost anywhere on the screen: another component, the calculation buttons, an empty place on the screen, etc. If there is some error in the line with the parameter values (too few parameters, a non numerical value, for example) the parameter values are not accepted and the old parameter values are kept.

Note: If the user clicks a component, but does not click the line of the parameter values, the OK-, Cancel, and Hint-buttons do not appear. The lines with the parameter values and symbols disappear without any special action, just a click almost anywhere on the screen suffices.

If the **Cancel** button is pressed, the eventual changes in the parameter values are not accepted and the old parameter values are kept.

When the **Hint** button is pressed, a box appear where the parameters are explained. The explanation for the clicked component is essential the same as in this Help file. The box disappears either when the (X) in the upper left corner of the box is clicked, or when the parameter lines disappear.

When the **PU Calc** button is pressed, the PU calculator appears. It can be used to convert impedances from the per unit notation to ohms. It can also be called from the View-menu.

When the line with the parameter values of a relay module is clicked, the PU Calc-button does not appear. Instead the Apply -button appears. When the line with the parameter values has been edited, and the **apply** button is pressed, the lines with the parameter symbols and values do not disappear, and the parameter values are not yet moved to the relay (accepted). Instead, the changed characteristic curve of the relay is shown (if visible), corresponding to the new parameter values. The user can test the effect of different parameter values in this way.

Copy parameters

Copying parameters of components

There are different ways to copy parameters from a component to another similar component. The simplest way is to copy the whole component: Select the component by clicking it with the mouse, click the copy and paste buttons on the toolbar (or use the keyboard with ctrl-c and ctrl-v).

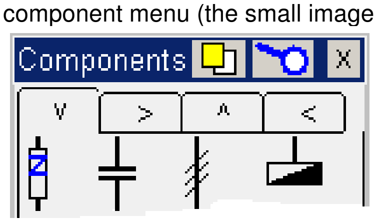
It is sometimes useful or even necessary to copy the parameters from a component to another. This is the case for example when the two components have different orientations, because it is not possible to rotate the components.

Components with not too many parameters

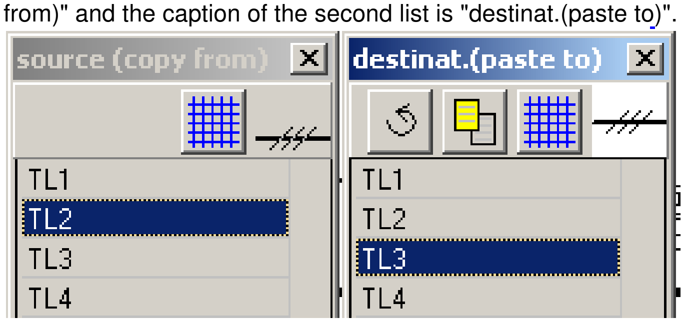
Most components display the parameters as a text line on the lower part of the screen. Exceptions are components with many parameters, for example some relays. This text line can be copied similarly as a line in a text editor: Highlight the line from which the parameters are to be copied, press ctrl-c on the keyboard to copy the line to the clipboard. Click the component to which the parameters are to be copied, so that the parameter line of this component appears. Clear the line (delete) and press ctrl_v on the keyboard. to paste the line from the clipboard.
Note: Do not use the copy and paste buttons in the toolbar. They are used only to copy components.

All components

It is possible to copy the parameters using lists of components. Click the "copy" symbol on the top of the component menu (the small image with the two overlapping rectangles).



An empty list appears, and the background color of the component menu is changed. Next, click the component type in the component menu (not in the single line diagram) for which the copying of the parameters is to be carried out. Another list appears, and both lists are filled with the labels of the components of the given type in the single line diagram. The caption of the first list is "source (copy from)" and the caption of the second list is "destinat.(paste to)".



In the first list, select the component from which the parameters are to be copied, and in the second list, select the component to which the parameters are to be copied. The components can be selected either by clicking with the mouse, or by using the arrow keys in the keyboard. When both components have been selected, click the "copy" button (with the two small overlapping rectangles), and the copying of the parameters is carried out.

The copying can be "undone" by clicking the "undo" button with the image of a semicircle with an arrowhead. The list(s) of components can be made shorter by filtering, i.e. by clicking the "filter" button with the image of a mesh (or a net).

Copying using the Windows clipboard

It is also possible to copy parameters into the windows clipboard, and paste parameters from the clipboard by right clicking the component(s) and selecting "copy.." or "paste.." (or "undo"..), as explained in the chapter for the pop-up menu of the components.

Move items around the screen

Almost all items (components, result boxes, labels, etc) on the screen can be moved around by dragging with the mouse. Put the cursor on the item to be moved, press the left mouse button and drag the item to the desired location with the mouse, and release the mouse button. This simple method applies to:

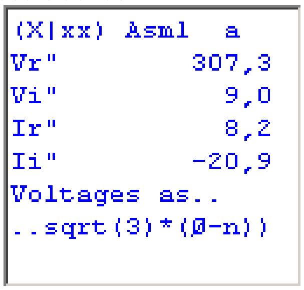
the components in the single line diagram

the labels of the components 

(click afterwards somewhere to close the edit box 

)

the result boxes



the network title

The component menu can be moved similarly by dragging, but only at the coloured title bar in the top of the menu.

A group of components or the whole single line diagram can be moved similarly by dragging. But first the user has to draw a rectangle around the group to be moved. Put the cursor in one corner of the planned rectangle, press the left mouse button and move the cursor diagonally over the group to the opposite corner of the planned rectangle, and release the mouse button. (A rectangle can be drawn around the whole diagram also by pushing the "select all" button. ) A grey rectangle appears around the group, and around every component in the group. (If the diagram is larger than the screen, the grey rectangles are drawn only around the components in an area that is slightly larger than the screen. All components are seclected, however.) Now the rectangle can be moved by dragging. The components within the rectangle move to the new location, when the mouse button is released.

If the grey marking (or actually the cursor) is moved outside the elplek-window, the whole diagram starts to move in the opposite direction. When the mouse button is released, the selected components move to where the marking is.

Several groups of components, or several separate components can be selected by keeping the ctrl-key pressed down while clicking components, or drawing the two or more rectangles with the mouse

The single line diagram may be so large that only a part of it is visible on the screen. In such a case there are two methods to select both components that are visible on the screen, and components that are outside the screen.
1) If the cursor is moved at the boundary of the elplek-window, or outside of the elplek-window, when drawing the rectangle, the diagram starts to move in the opposite direction. One edge of the rectangle is moved with the diagram, while the opposite edge remains at the boundary. In this way, the size of the rectangle increases.
2) First, select a group of components by drawing the rectangle around the components. Next, (optionally) move the diagram with the arrow keys so that the other components become visible. Now, draw a new rectangle around the other components, while keeping the ctrl-key down. In this way, the components in the first group remain selected, and the components inside the new rectangle are added to the selected components. This operation can be repeated.

The lines with the parameter symbols and values

Vn Pn sn pf eff IsIn P

When a component is clicked, the parameter symbols and values appear on the lower part of the screen. These lines can also be moved, but only sideways. Move the line with the red symbols (sideways) by dragging with the mouse. When the line with the symbols has been moved to the desired location, and the left mouse button is released, the line with the parameter values is automatically moved below the line of the symbols.

The whole single line diagram can also be moved using the **arrow keys** on the keyboard (but in the opposite direction !). A longer step is taken, if the shift-key is kept down while pressing the arrow-keys. Alternatively, the "page up", "Page down", "home" and "end" keys can be used to move the diagram using larger steps. A large diagram (larger than the screen) can be moved with the help of the Diagram window.

A group of components can be moved with the **arrow keys** in the following way: First, select the components, for example by drawing a rectangle around the components. Press the Alt-key down and use the arrow keys to move the markings in the direction of the arrows. When the Alt-key is released the selected components move to where the markings were moved.

- - - - - - - - - - - - - - -

A (small?) disadvantage of this property of moving the network title and the result boxes by the mouse is that the text in the title and in the boxes can be selected or marked (for copying) only by using the shift- and arrow keys on the keyboard. An attempt to select the text by using the mouse results in moving of the whole title or result box.

Display of the results

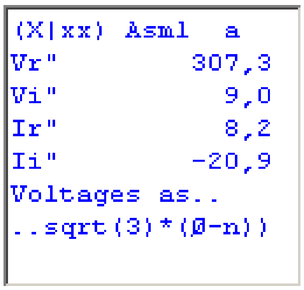
Note: After a calculation, no results are visible, unless some of the display method described below is "activated".

Note: The voltages displayed are either phase to phase voltages, or phase to ground voltages (more below). (Phase to ground voltages are equal to phase to neutral voltages, except for the cases of a line to earth or line to line to earth faults, of course.)

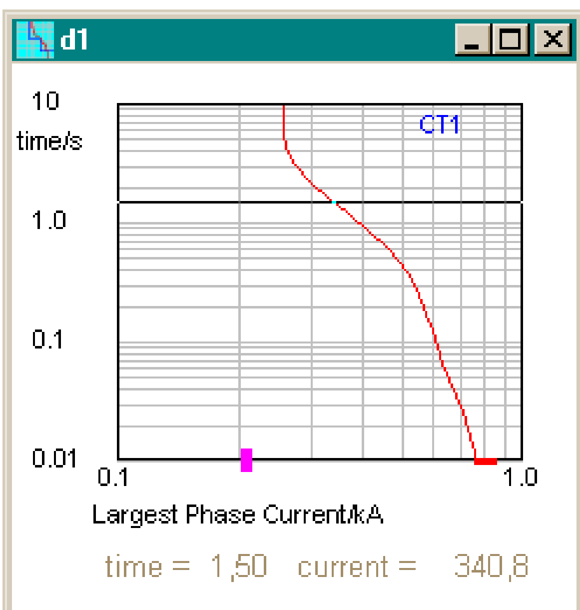
The results of the calculations can be displayed in the following ways

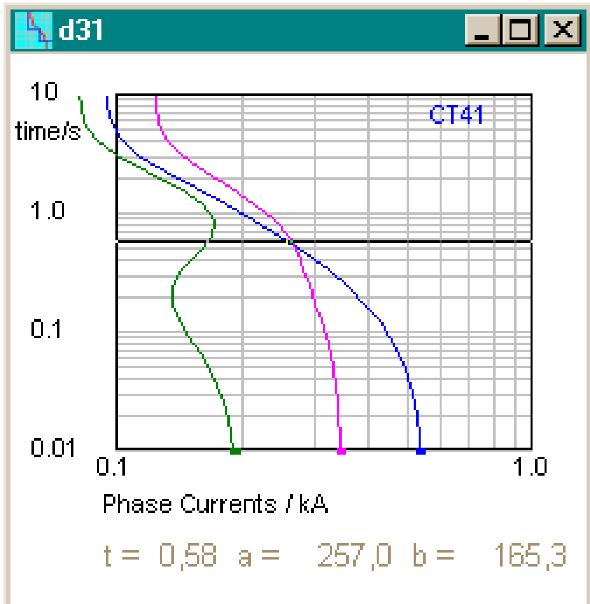
1) values of the current can be shown near to the current transformers, as explained in connection with the toolbar

2) values of currents and voltages (and the power of the load) are shown in **the result boxes** (more below)



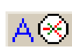
3) values of currents are shown in **"a current-time form"** (window), as a function of time (more below)

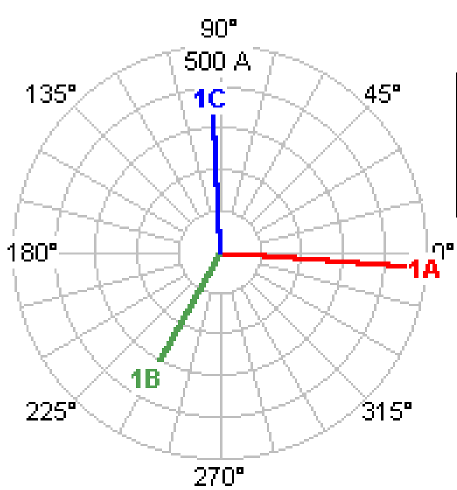




The transformation ratio of the current transformer connected to the relay is displayed in the upper left hand corner as (nominal primary current) : (nominal secondary current), possibly multiplied by square root of three (not shown in the pictures above). The ratio can be changed by changing the parameters of the current transformer. The sqrt(3) appears, if the secondary of the current transformer is connected in delta.

A delta button  will be visible on the form after short circuit calculation, if the secondary of the current transformer of the relay is connected in Delta. When this button is pushed down, the delta connected currents are displayed.
Note: The display of the delta-connected currents is only temporary. The button pops back up, when the user clicks somewhere on the screen, outside the window of the graph.

4) When the current-phasor button  is down, currents of current transformers are displayed in phasor form in the current-phasor window, when the current transformer component is clicked. Similarly, when the voltage-phasor button  is down, the voltages of buses are displayed in phasor form, when the buses are clicked.

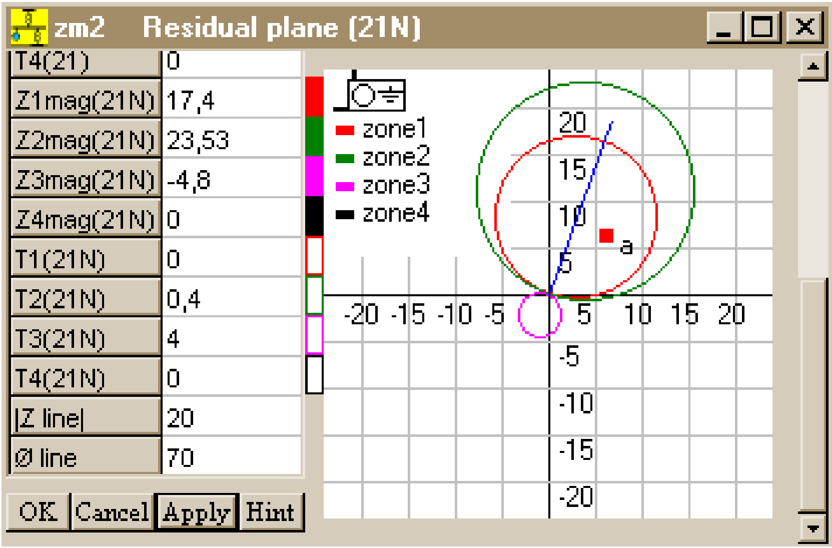


Current phase components

	(X)		CT1
	1	1A	445,2 A < -4,1 °
	1	1B	308,4 A < -119,5 °
	1	1C	332,2 A < 93,2 °

5) The impedance measured by a distance relay is shown together with the characteristics and

parameters, when a distance relay is clicked after a fault calculation.



The result box

When a component is clicked, a result box appears showing the results for that component from the latest calculation, unless the "do not show the result box"-button is down. **Note** that the result boxes that already are on the screen do not disappear, when the "do not show the result box"-button is pressed down. When that button is down, it only prevents new result boxes from becoming visible.

There is a (X|xx) "symbol" at the upper left corner of the result box. If the X -part of the symbol is clicked, the result box disappears. If the xx -part of the symbol is clicked, all result boxes will disappear.

Note

The result boxes display the symbol of the variable and its value. The symbols are the following

Vr,Vi real and imaginary components of the voltage

V1r, V1i real and imaginary components of the upstream voltage,
or the primary voltage of a transformer
or the internal voltage of a generator or feeder

V2r, V2i real and imaginary components of the downstream voltage,
or the secondary voltage of a transformer
or the output voltage of a generator or feeder

Vnr, Vni, Vn1r, Vn1i, Vn2r, Vn2i real and imaginary components of the voltage at the neutral point

Ir,Ii real and imaginary components of the current through the component

I1r,I1i real and imaginary components of the primary current of a transformer

I1r,I1i real and imaginary components of the secondary current of a transformer

I, I1, I2 the absolute value of the current through the component

V, V1, V2 the absolute value of the phase to phase voltage

Vn, Vn1, Vn2 the absolute value of the voltage at the neutral point

fii, fii1, fii2 the phase of the current through the component, or the voltage of the component, in degrees

fiin, fiin1,fiin2 the phase of the voltage at the neutral point

P,Q the real and reactive power taken or produced by the component

S the total power taken or produced by the component.

Z an impedance calculated by a distance relay

When a voltage is displayed in the result box, the type of the displayed voltage can be selected by the "sqrt(3)-button" . The type is indicated on the top or the bottom of the box.
Top:
- sqrt(3) Van (and Vbn, Vcn): Square root 3 times the phase to ground voltage is displayed
- Van, Vbn,Vcn : Phase to ground voltage is displayed
-Vab,Vbc,Vca : Phase to phase voltage is displayed

Bottom:
- Voltages as sqrt(3)*(Ø-n)): Square root 3 times the phase to ground voltages are shown
- (Ø-n) voltages shown : The phase to ground voltages are shown
- (Ø-Ø) voltages shown: The phase to phase voltages are shown.

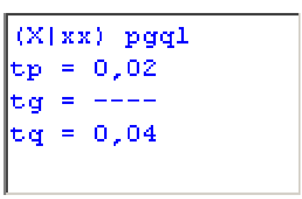
After a short circuit calculation, a quotation mark (") is added to the symbols (like I1r" or V1r") to indicate that the results shown are the initial currents and voltages.

The result boxes generally display either the real and imaginary components of the voltages and currents, depending on the position of the "r + i / Ø"-button. In the position the real and imaginary components are shown. In the position, the absolute value and the phase angle are shown. Note: The result boxes of the relay modules display the absolute value of the current and its phase through the connected current relay, independent on the position of the button.

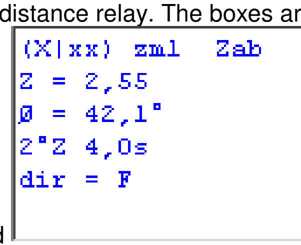
Note The phase to be displayed (a, b, or c) is determined by the phase button

Note, the phase button does not affect the "current-time form". The form displays the absolute value of the largest phase current, or the currents of all phases. In the case of the sum current transformer, the absolute value of the sum current is always displayed.

When **a relay** is clicked after a short circuit calculation, an additional box appears that shows the (eventual) activation time of the relay, and the zone for a distance relay. The boxes are like

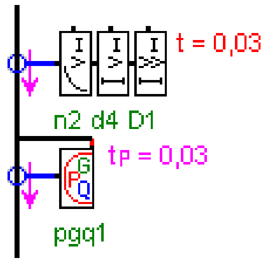


for an overcurrent relay, and



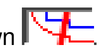
for a distance relay. These boxes do not appear, if the "Do not show the activation time"-button (for overcurrent relays) is down, or the "Hide distance relay impedance"-button (for distance relays) is down. The "dir = R" or "dir = F" in the additional result box of the distance relays gives the direction of the impedance (or of the fault, mostly), Reverse or Forward.

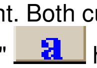
The activation times of relays are shown on the right hand side of the relay after a short circuit calculation. The shortest activation time is written in red.



Also these activation times are hidden, if the "Do not show the activation time"-button  is down.

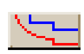
When **an overcurrent relay module** is clicked after a short circuit calculation, **the current-time form** (or window) becomes visible with a graph of the maximum phase current or currents of all phases. The prefault current is shown with a small colored rectangle on the current axis. The form is not displayed after a normal solution of the network. Its size can be changed, and it can be minimized and maximized. **Note:** If the Alt-key is pressed, when the relay module is clicked, graphs of the current of all three phases are shown in different colors.

Note: If the "Show char. of all clicked relays"-button is down  , and there is a red slash over the button (the button has been clicked twice), the current-time window and the parameters of relays do not appear. (The parameters of the single relay modules will appear at the bottom of the screen.)

The curve of the absolute value of the largest phase current (or the sum current) as a function of time is drawn with red color. It is not indicated in any way, which of the tree phases (a, b, or c) is shown in the curve. It can even be so that the current of (say) phase a is shown in one part of the curve, and the current of (say) phase b is shown in an other phase of the current. Both current and time use logarithmic scales. Because the largest current is shown, the "phase button"  has no effect on the displayed curve.

When the cursor is moved across the form, a horizontal line appears over the picture. The corresponding time and the value of the current at that time are displayed on the lower part of the picture.

The characteristic of the relay of which the clicked module is a part is also shown on the picture, if the characteristic is defined. The characteristic is (nromally) drawn with blue color.

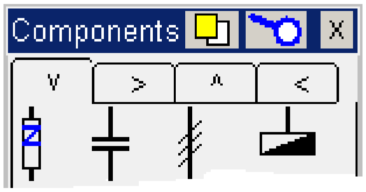
If the "show the char. of all clicked relays"-button  is down, the simple graph changes to "a coordination graphics". That is, the characteristics of all clicked relays (up to ten relays) are shown in the same picture using different colors. The characteristics are normalized to the voltage level of the clicked relay. The current of the relay clicked last is shown in the graph as a function of time. This feature (button) may be useful in relay coordination studies.

When **a distance relay** is clicked after a short circuit calculation, a form (or window) appeares displaying the characteristics of the relay. The impedances calculated by the relay are displayed as small rectangles. See distance relays.

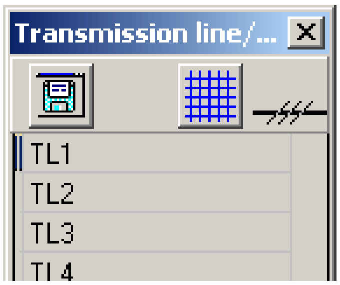
Find a component

A given component can be found in the following way in the diagram:

Click the magnifying glass-symbol in the top of the component menu.



The component menu changes color, and a small window with an empty list appears. In the component menu, click the symbol of the component to be found. The list is filled with the labels (identifiers) of all the components of the desired type.



(If a component can have two different symbols, like a breaker, a second list will appear, so that there is a list for both symbols.) Finally, in the list of the component labels, click the label of the component to be found. The diagram moves so on the screen, that the component to be found is in the middle, surrounded with a red square.If the component is already near the middle of the screen, the diagram does not move. The red square appears in any case around the component. The red square disappears, when it is pointed with the mouse.

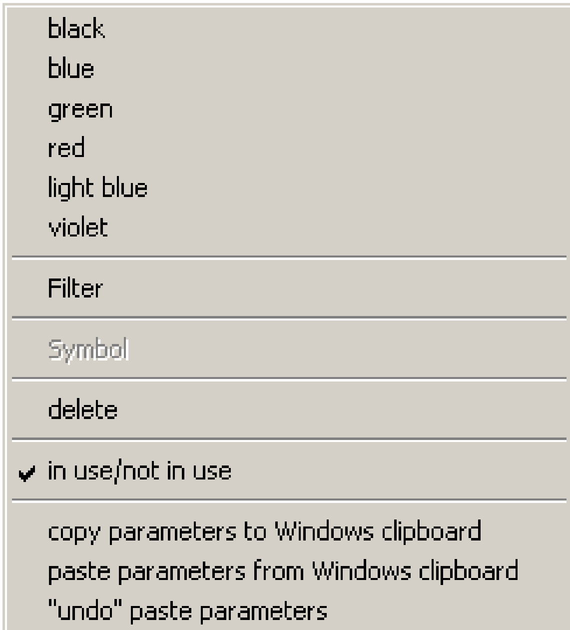
The list of the component labels can be saved to a file by clicking the "save" button on the top left of the small window. The list will contain only filtered (selected) components, when the "filter" button on the top of the small window is clicked. The filtering can be removed by clicking again the component in the component menu.

The color of the component menu returns to normal and the list of components disappears, when the symbol of the magnifying glass is clicked, or the window(s) with the list(s) is/are closed by clicking the 'X' in the upper right corner.

Note: The same lists are used to display lists of open breakers. Thus, it is not possible to locate components and display lists of open breakers at the same time.

Pop-up menu of components

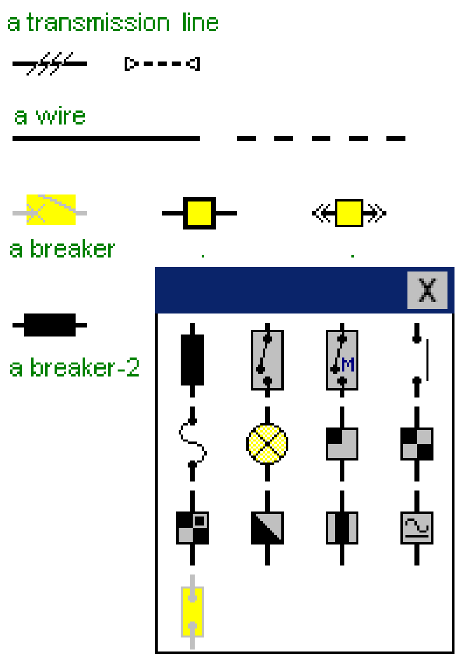
When a component is clicked with **the right button** of the mouse in the single line diagram, a pop-up menu appears,



black ... violet change the color of the component (black, blue, geen, etc.)
Note: The color of only some components can be changed. The names of the colors are greyed out in the pop-up menu for those components that cannot change color.

Filter selects, i.e. "filters" the component for reports.
Note: Only components with labels can be selected, or filtered for reports. The word "Filter" is greyed out for those components that cannot be selected. The filtered/not -status of a component can also be changed by right-clicking the label of the component.
The last character in the label of a filtered component is a " ¤ ".

Symbol changes the symbol (picture) of the component.
Note: Only a few components can have different symbols:



The transmission line and the wire interchange the symbols between the normal and dashed symbol at every click of the symbol-item in the pop-up menu. The breaker changes from the "breakerlike", to the "squarelike", and to the "squarelike" with the "arrowlike" connectors, and back to the "breakerlike" symbol at successive clicks of the symbol-item in the pop-up menu.

The symbol of the second type of breakers (breaker-2) can be selected from the menu that appears when the symbol-item is clicked in the pop-up menu.
Note: This menu is also used to open the breaker by selecting the yellow, open symbol for the breaker. To close, select the closed symbol.

delete
deletes the component

in use/not in use
Initially, all components are "in use". This is indicated by the tick-mark on the left of the "in use/not in use"-text. The "in use" means that the component is included in calculations. Every time this "in use/not in use"-text is clicked, the state of the component changes from "in use" to "not in use", and again to "in use", etc. When the component is not in use, it appears in grey in the diagram, and it is not included in the calculations. However, it is possible to edit the parameters, move the component, etc, when the component is not in use. (The editing of the parameters of relays is not possible)

copy parameters to Windows clipboard

As the caption tells, the clicking of this item copies the parameters of the component to the Windows clipboard. The parameters can then be pasted from the clipboard to another component of the same type. This another component may be in a separate elplek-program.
Note: Only parameters are copied, not the component itself.
Note: Only parameters are copied, not possible texts, as for example in relays.

paste parameters from Windows clipboard
Parameters copied to the clipboard will be pasted to this component, but only if the components are of the same type. The components may be in different elplek-programs.

"undo" paste parameters
Returns the parameters that were previously overwritten by clicking the "paste parameters fwom Widows clipboard"-item in the popup-menu.

Component library, sort of

--There is no proper component library in Elplek. But the "copy parameters to Windows clipboard"- and "paste parameters from Windows clipboard"-items of the pop-up menu can be used to the same effect.

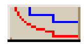
Prepare a *.sld file (a single line diagram) that contains the components of the library in question, with the proper parameters. Open the file in one Elplek-program. The parameters of the components can be copied from this program to a component of the same type in another elplek-program using the pop-up menu.

Note: Only parameters can be copied, no texts, no components.

Coordination graphics

see also the menu bar, the buttons, Floating labels, Time difference between characteristic curves

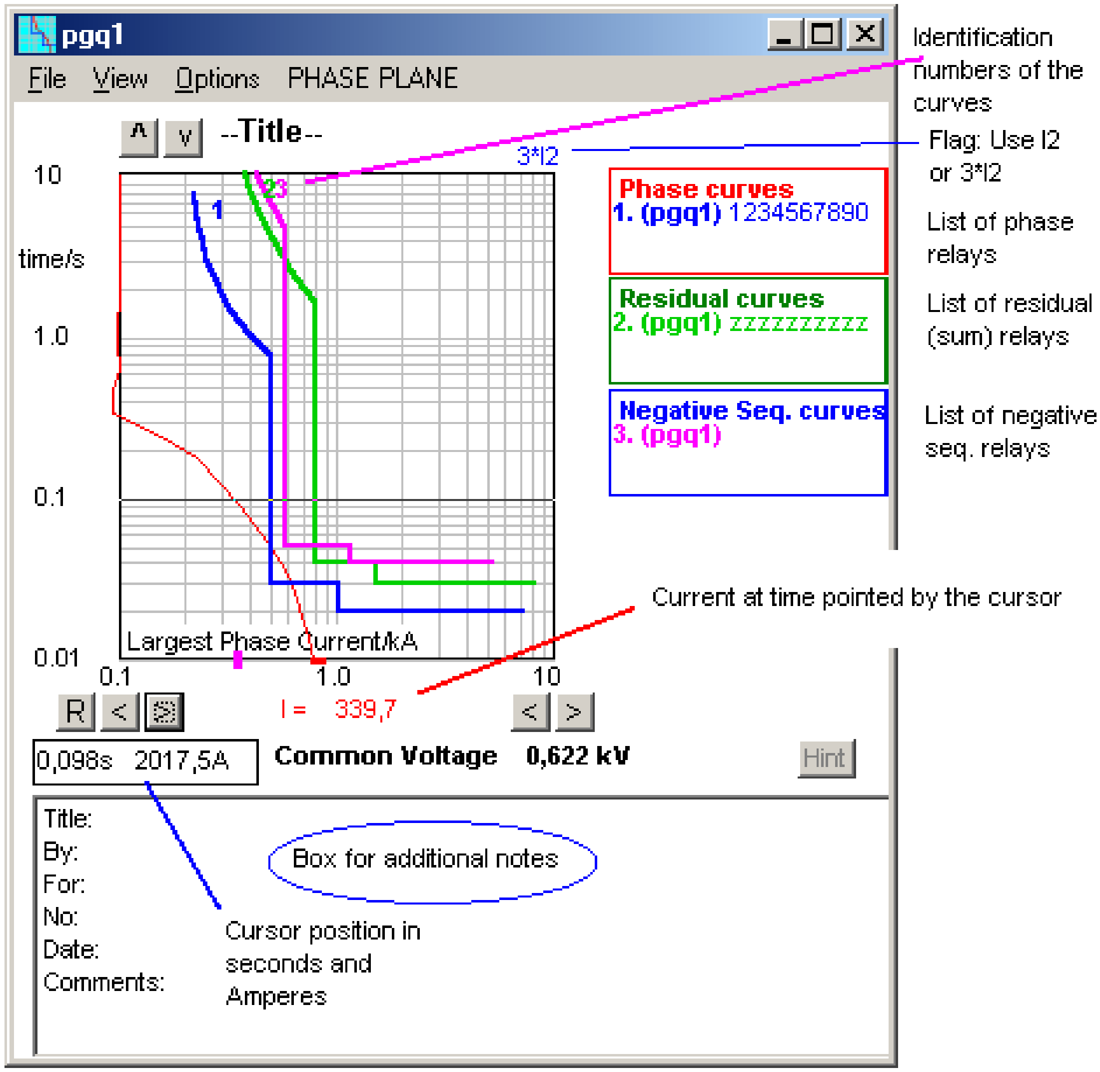
When a relay is clicked after a short circuit calculation, a window with a graph opens. The graph shows the current at the relay as a function of time, and the characteristic curve of the relay, if it is defined. When the next relay is clicked, then , as a default, the current and characteristics of the previously clicked relay disappear, and the current and characteristics of the newly clicked relay are displayed.

But if the "show char. of all clicked relays"-button  is down, the graph "changes" to a relay coordination graphics. That is, the characteristics of all the relays are shown that have been clicked since the button was pressed down. (Actually, the characteristics of maximum sixteen relays are shown). The current at the last clicked relay is shown. The characteristics are adjusted for possible different voltage levels at the relays.

Note: The adjustment does not take the transformer tap positions into accout.

A curve can be deleted from the graph in the following way:
Click the identifier (the number) of the curve. A "delete curve" and a "cancel" button will appear. To delete, click the "delete curve" button. To cancel, click the "cancel" button.
Note: All curves of the _selected_ relay will be deleted. That is, if the curve belongs to a relay that has several curves on the graph, then all these curves will be deleted.
Note: If there is only one curve left (or curves of only one relay) then this last curve cannot be deleted.

The coordination graphics contains also other information in addition to the graph itself.



On the top of the graph, there is room for a title, or caption of one line. The title can be edited directly in the place.

The coordination graphics window may also contain an indication of the transformation ratio (as 1:100, for example) of the current transformer and an "Delta" button  for the display of delta-connected currents from the current transformer. These items are in the upper left corner of the window (not shown in the picture above).

There is a text "3*I2" or "I2" above the upper right corner of the graph. The text is a flag that tells, is the negative sequence current used as such (I2) or as multiplied by three (3*I2) in the graph and when checking the activation of relays (but not elsewhere). The status of this flag can be changed by checking/unchecking "Options | Use I2 (not 3*I2) in relays" in the toolbar of the main window. The state of the flag is saved to file together with the single line diagram.

On the right hand side, there are lists of the relays that have characteristics shown in the graph. If the relay is an ordinary relay (not a PGQ-relay), only its label appears in the list for phase relays. If the relay is a PGQ-relay, the phase, residual- and negative sequence parts of the relay are included in the respective lists. In this case, the lists contain the label of the relay, and the free description of the relay copied from the parameter window (contents of the first nine rows of the parameter window). The parameter window of the PGQ-relays can be opened by clicking this free description in the relay list. (The parameter window appears also when the relay itself is clicked, of course.)

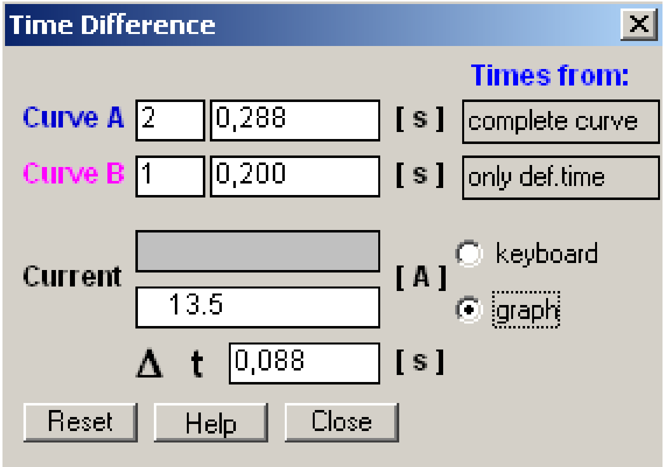
The characteristic curves are identified with numbers that are shown both in the graph and in the relay lists.
Note: The numbers can be moved by dragging with the mouse.

Below the graph, on the left hand side, there is a box that shows the position of the cursor in terms of time (s) and current (A). The value(s) of the current(s) of the relay at the time indicated by the position of the cursor is/are shown on the right of the mentioned box.

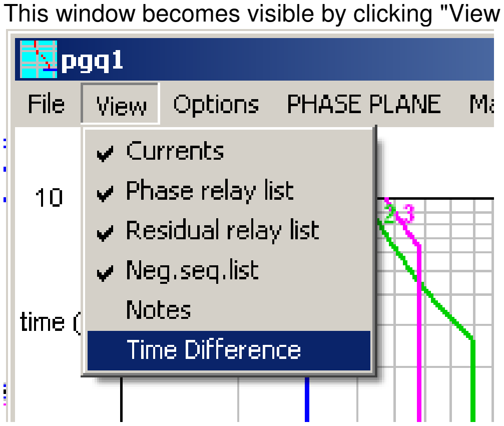
On the bottom of the window, there is a box for free comments. The default texts "Title:", "By:", "For:", etc. can be deleted.

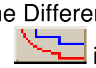
Time difference between characteristic curves

The difference between the activation times of two characteristic curves at a given current can be calculated in the "Time difference" window.



This window becomes visible by clicking "View | Time difference" in the coordination graphics window.



Note: The Time Difference-item in the view menu is enabled only when the button "Show the char. of all clicked relays"  is down.

Enter the numbers (identifiers) of the characteristic curves in the two boxes labeled "Curve A" and "Curve B". The numbers (identifiers) are displayed near the characteristic curves in the coordination graphics window. The texts "Curve A" and "Curve B" assume the colors of the curves for easier identification.

Note: The identifier of the curves may contain also the index of the parameter group. In such a case, enter only the number of the identifier. If the identifier is 2-G3, for example, indicating that the parameter group number three is in use, enter only 2 in the box.

The source of the value of the current is selected with the radio-buttons "keyboard" and "graph". If "keyboard" is selected, the user may type the value of the current in the upper box using the keyboard. If "graph" is selected, the value of the current is taken from the mouse position and entered in the lower box, when the mouse moves over the coordination graph.

The activation time difference between the two characteristic curves at the given current appear in the lowermost box every time the value in some of the input boxes changes. The activation times of the individual curves will appear in the two uppermost boxes on the right hand side. If the characteristic curve is not defined at the given current, the text "out of range" appears in the box, and stars (***) appear in the box for the time difference.

The texts in the upper right corner of the time difference window tell, which parts of the curves are used to calculate the difference. There are three possibilities: "complete curve", "only def. time", and "only inv. time", meaning that either the complete curve is used to calculate the time difference, or only the definite time- or inverse time part of the curve, respectively, is used. The parameter that defines the part of the curve that is used (and shown), and the corresponding texts is set in the relay parameter window.

The buttons

Reset clears all input and output boxes

Help opens a small help-menu (not this, "proper" help window)

Close closes the time difference window.

Menu bar of the coordination graphics

The File menu

Export diagram (*.wmf, *.bmp, *.jpg)
The contents of the coordination graphics page can be saved to a file as a bitmap (*.bmp), as a jpeg-graphic file (*.jpg), or in the Windows metafile (*.wmf) format, by clicking this "Export diagram" item. The format is selected in the save-dialog, that opens when the "Export diagram" item is clicked. The bitmap and jpeg-file can be processed and printed with an image processing program, for example with the Paint of Windows.

Copy to clipboard copies the graph to the Windows clipboard.

Save Relay List, Recall Relay List, and Delete Relay List

The lists of the relays displayed on the coordination graphics together with the additional notes can be saved by clicking the "Save Relay List"-item. The clicking opens a small dialogue, where the text "-New-" and the titles of previously saved relay lists are shown. If the text "New" and the Save-button are clicked, the relay list and the comments are saved as a new item. If one of the titles of the previously saved lists (and the Save button) are clicked, the list is saved on a previously saved list.

Note: The relay lists are here saved to internal variables only. The lists are saved to the file of the single line diagram first when the whole diagram is saved (by file | save, or by the save button on the main window).

Recall Relay List recalls a previously saved list and reconstructs the coordination graphics.
Note: It is possible that some relays or their current transformers have been deleted between the saving and recalling of the list. In this case, a warning icon becomes visible in the main window. In addition, there may be spurious numbers or other strange phenomena on the coordination graphics. In such a case, it is best to reconstruct the graphics, at least in some degree.

Delete Relay List deletes a previously saved list.

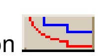
The View menu

Currents
If the "Currents"-item is selected (checked) in the View menu, then the current(s) of the last clicked relay is/are displayed graphically as a function of time. After a symmetrical fault calculation, only the phase current is shown. After a line-to-line fault calculation both the phase current and three times the negative sequence current are shown. After a fault calculation containing the earth, the sum (or residual) current is shown in addition of the two other currents.

If the "Currents"-item is not selected (not checked) the currents are not shown as a function of time. Only the initial values of the currents are indicated with small rectangles on the current axis. When the cursor is moved on one of these rectangles, the numerical value of the initial current is shown below the graph.

Phase relay List, Residual relay list, and Neg.seq. list

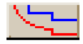
If these items are selected (checked) the lists of the corresponding relay types are shown on the right of the graph.

Note: These items are enabled only when the "Show char. of all clicked relays"-button  is down.

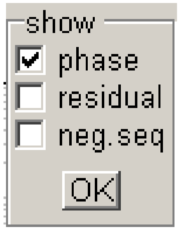
Notes

If the "Notes" item is selected (checked) the box for additional notes is displayed on the bottom of the window.

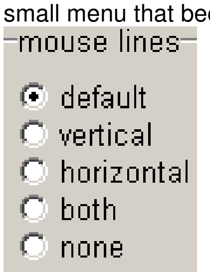
Time difference

When the "Time difference" item is selected, a new window opens for the calculation of the time difference between two characteristic curves at a given current. Can be used only when the "show char. of all clicked relays"-button  is down in the main menu.

Relay curves...
is used to select the characteristic curves of the relays to be shown. When the "relay curves"-tiem is selected, as small menu opens for selecting the curves to be shown



Mouse lines... When the cursor (the mouse) is moved over the window of the curves, a marker, that is, a moving horizontal or vertical line is attached to the cursor. The type of the line can be selected in a small menu that becomes visible by clicking the "Mouse lines..." item.



"Default" displays normally a horizontal line, but a vertical one, if the time difference window is visible.
"vertical" and "horizontal" display a vertical or a horizontal line, respectively
"both" displays both a horizontal and a vertical line
"none" hides the lines.

The Options menu

Draw full curve
When selected, the characteristic curve of the inverse time module is drawn up to the maximum current, independent of the (eventual) definite time modules. This feature may be useful when designing the protection

Show buttons etc.
When checked, the buttons of the coordination graphics (buttons with arrows, the "R"-button, the Hint-button, etc.) are visible

Show note
When checked a small note (Note:I*√3,3I0*√3 or Note:3*I2/√3) is visible on the lower part of the graphics, but only when the "Show char..." button is down.

Show prefault current etc.
When checked, small rectangles indicating the value(s) of the prefault current and (eventually) other currents are shown.

Color of grid
When this item is clicked, a small color menu, or color palette appears. This menu can be used to select the color of the logarithmic grid (the vertical and horizontal lines) in the coordination graphics.
Note: The color is stored, or attached to the current transformer. If the characteristics of several relays are displayed, the grid has the color of the last clicked relay.

Hide numbers
When checked, the the identification numbers of the relay curves are hidden.

Hide Title
When checked, the title of the graph is hidden.

Show Ampers
The unit on the current axis is Ampers (A), not kA, or MA.

Show Param. Group
The group of the relay parameters is displayed with the identification numbers of the curvers, as G and the number of the group. For example: "2 G4" tells that the identification number of the group is 2, and the parameters are taken from group 4.

Floating Label
When checked, the floating labels are displayed on the coordination graphics.

floating label dialogue
Opens a small dialogue (or window) for editing the floating labels.

Transform current param. with voltage

Draw vertical line (def. time only)
Only for definite time relays. If this item is not selected, the first vertical line (from large time to Delay def.1) is not drawn.

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PHASE PLANE, or NEGATIVE SEQUENCE PLANE and **EDITION PLANE**

see the explanation of the menu bar of the PGQ-relays

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The Markers-menu

Points

The Points-item can be used to add a small marker (a square, circle, etc) in a given position of the graph. When the points-item is clicked, a small dialogue opens, wtih the following entries:

Name:	The name of the marker. It is written above the marker in the graph
Current (A):	The position of the marker on the current axis
Time (s) :	The position of hte marker on the time-axis
Voltage:	The reference voltage of the current of the marker (see below).
Type:	The appearance of the marker.

The default voltage of the marker is the common voltage of the graph. It is the same as the nominal voltage level of the relay that was clicked last. When the common voltage of the graph is equal to the voltage of the marker, the marker is in the position given by the current- and time-parameters. If the common voltage is different, the position of the marker is calculated using the ratio of the voltages: Position of the marker on the current axis = marker current * (marker voltage / common voltage).

A list of the defined markers is below the parameters. A marker can be deleted by selecting it with a mouse click, and pressing the "delete"-button.

An existing marker can be modified (edited) in the following way: Select the marker in the list (below the buttons) by clicking the row with the marker data. The data is copied from the line to the table (above the buttons). Edit the data, and click the Modify-button.

The identifier or name of the marker can be moved with the mouse: Put the cursor on the first charcter of the identifier. Press and keep the left mouse button down. A small rectangle appears (approximately) around the first character. Drag the rectangle to the desired position. When the mouse button is released, the identifier moves to the position of the rectangle.

Lines

The Lines-item can be used to add a vertical, constant current line or a horizontal, constant time line on the graph. When the lines-item is clicked, a small window opens, with a dialogue containing the following entries:

Name : The name of the marker. It is written above or on the right of the line.
Current (A) or **Time (s)**: The position of the line in terms of current or time.
Color: Select the color of the line using the palette that opens when the color-line is selected.
Start (s) or **Start (A)** Start-point of the line, either in seconds, if vertical, or Amperes, if horizontal.
End (s) or **End (A)** end-point of the line, either in seconds, if vertical, or Amperes, if horizontal.
If Start or End is empty or zero, the line is drawn across the whole graph.
Thickness Thickness of the line, in the range 1..5.

The type of the line (current or time, that is, vertical or horizontal) is selected by clicking one of the radio buttons marked with "Current" or "Time" below the dialogue.

The line is added by clicking the Add-button. A line can be deleted by selecting (highlihting) the corresponding line in the list of lines, and pressing the "Delete"-button. The window can be closed by clicking the "close"-button, or the "X" in the upper right corner of the line.

An existing marker can be modified (edited) in the following way: Select the marker in the list (below the buttons) by clicking the row with the marker data. The data is copied from the line to the table (above the buttons). Edit the data, and click the Modify-button.

The identifier or name of the marker can be moved with the mouse, see above.

Buttons on the coordination graphics

The "arrow buttons" (< > V ^)
The buttons with the arrows on the coordination graphics can be used to change the scales of the graph. Both the starting value and the end value of the current scale can be changed by the buttons at the start and end of the current axis. Each click of the buttons with a right- or left-pointing arrow changes the start or end of the scale by one decade.

The end-value of the time scale can be changed by the buttons with up- and down pointing arrows. The start-value of the time scale can be changed alternatively between 0.001s and 0.01 s by clicking the button with the vertical double-arrow.

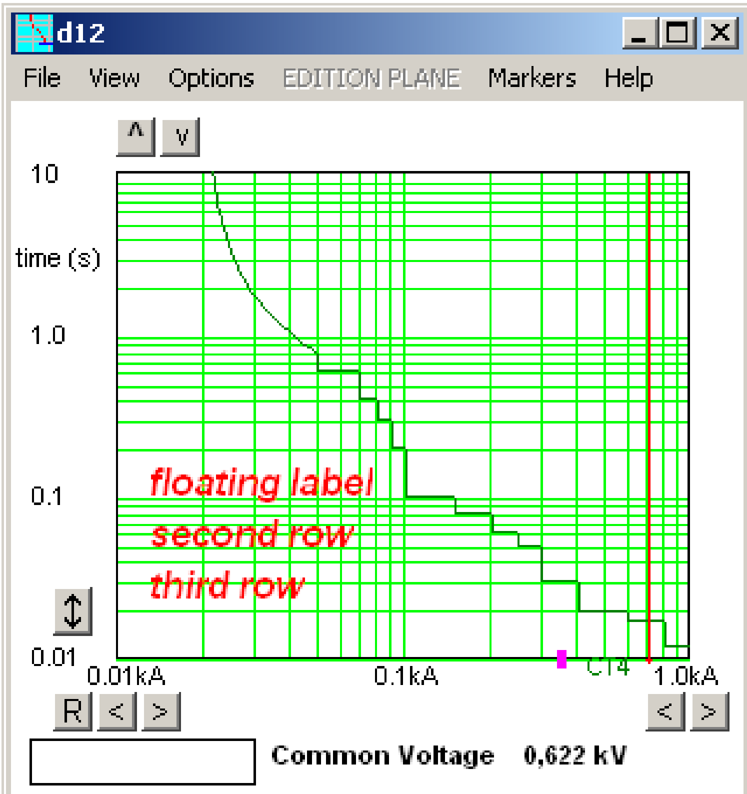
The "R-button"
The button with an "R" resets the scales to the default values.

The "Hint-button"

When the hint-button is clicked, a small help-memo with some advices appears.
Note: The help-memo can be moved by dragging it with the mouse. But, for some reason, the first attempt to move the memo always fails !?

Floating Labels

The floating labels are short texts that "float" on the coordination graphics. There are at most three rows of text.



The labels can be dragged with the mouse. The labels hidden or displayed by clicking "Options | Floating Label" in the menu bar of the coordination graphics window.

The labels are written and the font is selected in a dialogue (a small window), that will appear by clicking "Options | floating label dialogue" in the menu bar of the coordination graphics window.

The three labels are edited in the three boxes. A dialogue for the font will appear when the font-button is clikced. The OK-button accepts the changes and moves the labels to the graph. The cancel-button cancels (undoes) the changes, and closes the dialogue. Individual labels (rows) can be displayed/hidden by checking/unchecking the small tick-boxes on the left of the edit boxes.

When the floating labels are written for the first time in the coordination graphics and the OK-button is clicked, the labels are saved to the relay that was clicked last. (Or, to be exact, to the parameter space of the current transformer connected to the last-clicked relay.) When the single line diagram is saved, opened again later, and a short circuit calculation carried out, the floating labels will appear again, when the relay is clicked. If the labels are edited, they are saved back to the same relay (or CT). If, for some reason, two or more relays in a coordination graphics contain (different) labels, then the labels of the last-clicked relay will be shown. The labels will also be shown, if a previously saved relay list containing the relay with the labels is recalled, as "File | Recall Relay List" in the menu bar of the coordination graphics window.

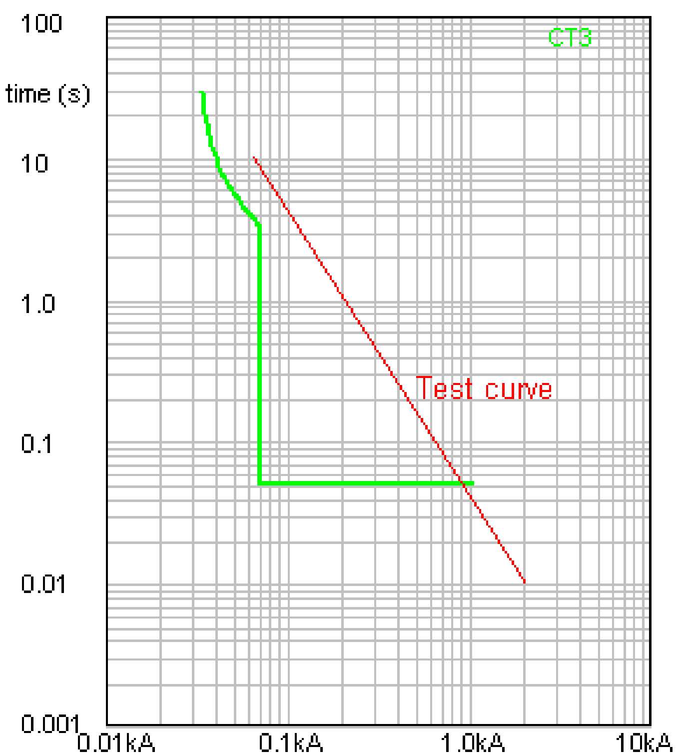
Cable damage curve

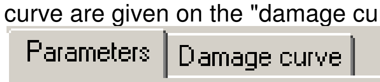
It is possible to include **the cable damage curve** in the coordination graphics. The curve tells, how long a cable withstands ("tolerates") a given current without a damage. The withstand time is determined by the heating effect of the current. Thus, it is inversely proportional to the square of the current, as:

t = K / (I * I),

where t is the withstand time, I is the current and K is a coefficient. The coefficient depends on the cable, and can in principle be calculated using some characteristic temperatures, material constants etc. Here, however, the curve is determined by giving one point: the withstand current at a given time (for example at 1s).

The curve becomes a straight line on a log-log graph. Typically, the curve (or line) is drawn only from 0.01s to 10 s.



The parameters of the damage curve are given on the "damage curve"-sheet (or -tab) in the parameter window of the transmission line 

. (The "parameters" sheet contains the impedances etc. of the transmission line.)

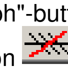
The parameters of the damage curve are

Damage curr. (A)	the current at the point defining the curve
Damage time (s)	the time at the point defining the curve
Min time	The curve is drawn between ...
Max time	....the minimum and maximum times
Name	name of the curve, to be written near the curve
Color	select the color of the curve from the palette
Line thickness	the thickness (0..4) of the line. 0 = dashed line
Voltage	the nominal voltage of the transmission line

(cannot be edited, deduced from the diagram)
In use flag telling, is the curve displayed or not

Send damage curve to graph

The damage curve of this transmission line is "sent" to the coordination graphics by clicking the "Send damage curve to graph" button on the bottom of the parameter window. If the coordination graphics is not visible, when the button is clicked, the damage curve is drawn on the graph when the graph becomes visible.
Note: Only one damage curve can be displayed. When a new curve is selected, the previous curve is deleted.

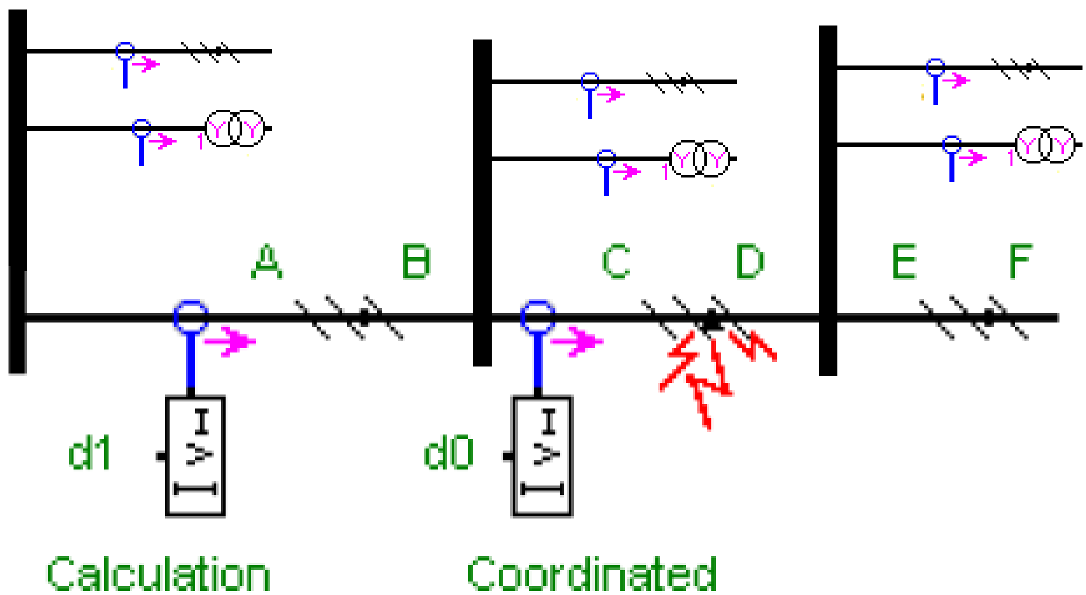
The damage curve can be deleted either by returning the"Send damage curve to graph"-button to the normal, up position by clicking it again, or by clicking the small transmission line-button  on the upper left corner of the coordination graph.

Coordination of protection of transmission lines

Pinciple

The relays that protect a transmission line must be coordinated. The coordination can be carried out (in some extent) with the program Elpek. Unfortunately, the coordination, and the window used for the coordination are complicated. But let's try to take it piece by piece.

The starting point is the coordination of the definite time relays in this simple circuit



There are two transmission line segments AB and CD and two current transformers with their definite time relays d0 and d1 in this (sub)circuit. The relay d0 is protecting the line CD and the relay d1 is protgecting the line AB. (Other types of relays can also be coordinated.)

It is assumed that the tripping current (and tripping time) of the relay d0 are known. The task is to set the tripping current of the relay d1 in such a way that it is coordinated with relay d0. The principle of the coordination is the following:

When the fault is in the section CD, the relay d0 should trip with time t0. The relay d1 must have a tripping time t1 = t0 + dt. (The exact value of dt is beyond the scope of this program, and must be selected by the user. Typically dt = 0.02 - 0.5sec, depending on the inaccuracies of the relays, and including some margin.) The "coordination" done with this program (elplek) reduces in practice to the determination of the tripping current of relay d1.

It is assumed that the network is such that the current measured by the current transformer of the relay d0 gets smaller, when the fault moves away from the relay, from C towards D. With this assumption, the coordination is done in the following way:

The position of the fault in the line CD is moved from the near end (at C) towards the far end (at D) , until the point is reached where the relay d0 is just about to trip. This happens when the current measured by the current transformer of d0 is equal to the tripping current, i.e the set-current parameter of the relay d0. The current measured by the CT of the relay d1 in this case is observed and used to set the parameter(s) of the relay d1.

Special cases

There are some special cases in the procedure described above that must be considered.

1) The tripping current (set-current parameter) of the relay d0 is so large, that the relay d0 does not trip, even when the fault is at the near end of the transmission line, at point C.
The program gives the warning: "current setting too large". In this case, the method of coordination of this program cannot be used. (There may be some special reason for this value of d0.)

2) The tripping current (set current parameter) of the relay d0 is so small, that the relay d0 trips even when the fault is at the far end of the line, at point D. In this case, the program gives the warning message: "end of zone not found (Ikz > Isz). Try multi Z-button (or next zone)" .

The current transformers display the current corresponding to the far-end position of the fault, at point D.

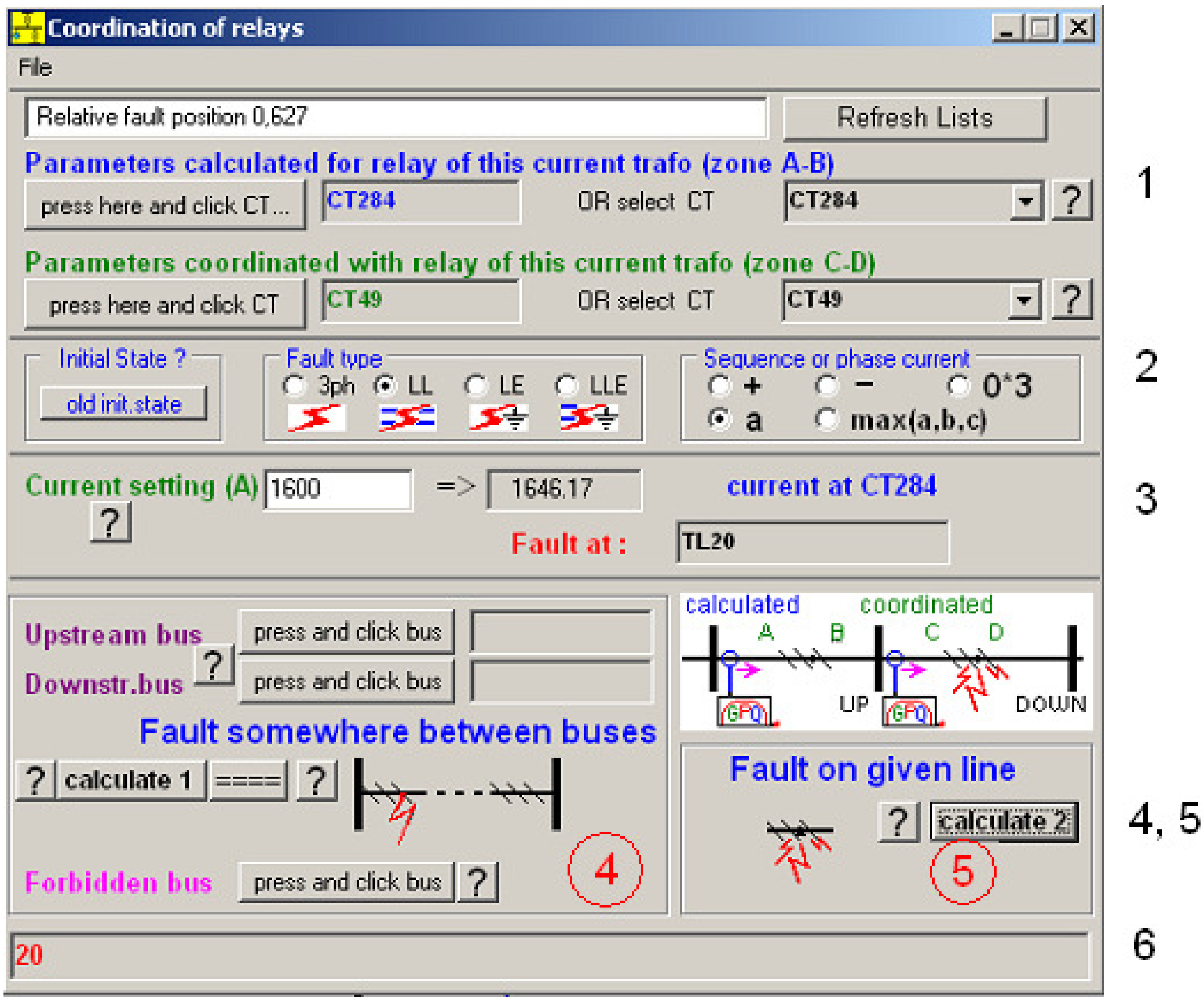
The user can continue the coordination in two different ways:
- either -
A) click the "multi Z"-button. The fault impedance is increased until the relay d0 does not trip, that is, until the current at the current transformer of d0 is equal to the current setting. The fault is kept at the far end of the line (at point D in the picture). The fault impedance is displayed on the top of the coordination window.
- or -
B) move the fault to the next line if there is any (line EF in the picture), and carry out a new calculation.

3) The network may also be such that the current measured at the relay d1 increases, although the current measured at d0 decreases, when the fault is moved farther away from point C towards point D. In this case, the coordination described above is not possible, and the program gives the warning "Warning: Current increases in *** and decreases in *** ", where *** are the labels (identifiers) of the current transformers.
The maximum current measured at d1 is given as the result. The user may use this current in the coordination.

There may be also other special cases, but they are not considered in the program.

The window for the coordination

The coordination is started by selecting "Advanced | Relay coordination calculator" in the menu bar of the main window. A new window opens. It is used to select the components needed in the coordination (current transformers, and the transmission line(s) where the fault is, etc) and to carry out the calculations for the coordination.

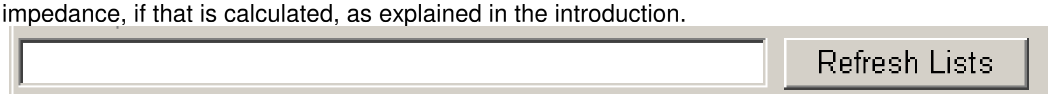


The fields and boxes in the coordination window

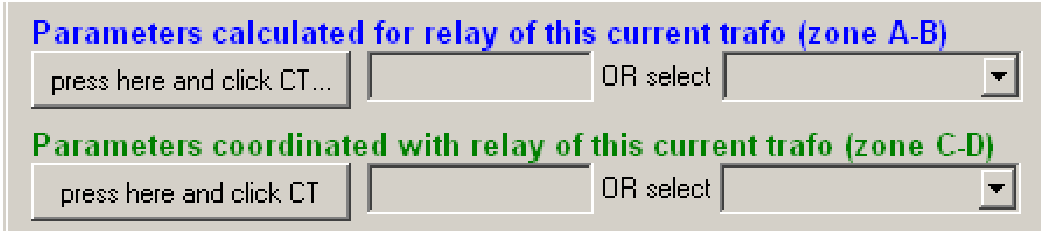
There are several fields and boxes in the coordination window. These are numbered in the picture above.

Field 1

The long field on the top is for displaying some results: The relative position of the fault, and the fault impedance, if that is calculated, as explained in the introduction.



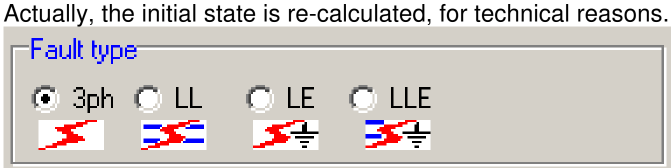
The "Refresh" button on the right is used to refresh lists of current transformers and transmission lines. These lists can be used to select the current transformers for the calculations, as explained in the chapter for current transformers . The button should be pressed, if components have been added or removed.



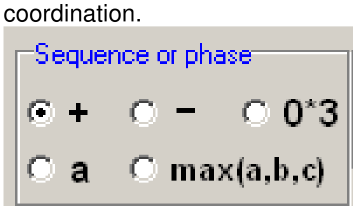
These fields and buttons and lists are used to select the current transformers. One (blue text) for which the parameters are calcualted, and the other (green text) to be coordinated with .

Field 2

This field is used for selecting the initial state, and the fault type. If the "old init.state" button is down, the results of the previous calculations (for example, a load flow calculation) are used as the intial state. Actually, the initial state is re-calculated, for technical reasons.



The type of the fault used in the calculations is selected with radio buttons. The fault can be 3-phase fault (3ph), line-line fault (LL), line-earth fault (LE), or a line-line-earth fault (LLE).
If an unsymmetrical fault (LL, LE, LLE) is selected, the user can also select the current type used in the coordination.



The user can select positive (+), negative (-) or three times zero sequence (3*0) current, or current in phase **a** (a), or maximum of the phase currents (max(a,b,c)) to be used in the coordination.

Field 3

The "current setting" parameter is written in the box on the right of the "current setting" text. It is (should be) the "set current"-parameter (pick up current) of the relay with the known parameters, near point C in the picture. The box in the middle displays the current of the current transformer/relay for which the parameters are calculated.

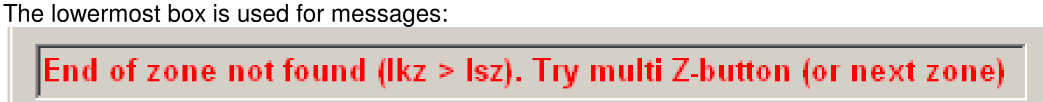
To recite: The problem solved in this coordination window is to find the position of the fault, so that the current at C (in the picture) is equal to the "current setting" parameter. The box in the middle displays the current at A (in the picture), when the position of the fault has been found.

Fields 4 and 5

The button "calculate 1" in field 4, and the button "calculate 2" in field 5 initialize the same calculations, but with a slightly different scope. The "calculate 2" button in field 5 should be used, when it is known in which transmission line (component) the fault is. The "calculate 1" button of field 4 is used when there are several transmission lines (components) in series between two buses, and it is only known that the fault is on some line between these buses.

Field 6

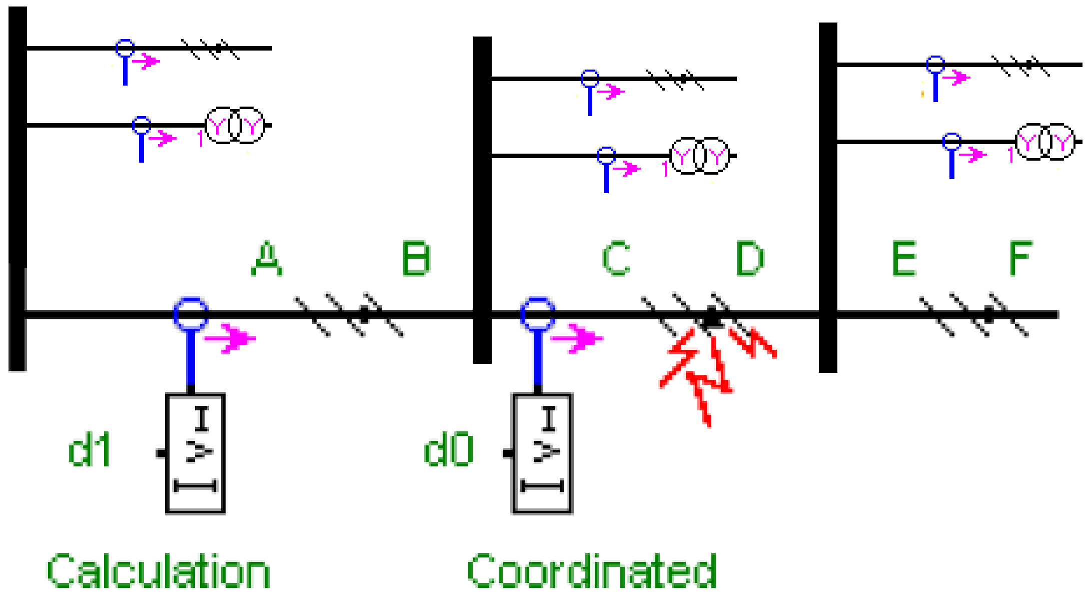
The lowermost box is used for messages:



The picture, or a small portion of a single line diagram is for illustration only. I hope that it will clarify the calculations of the coordination window.

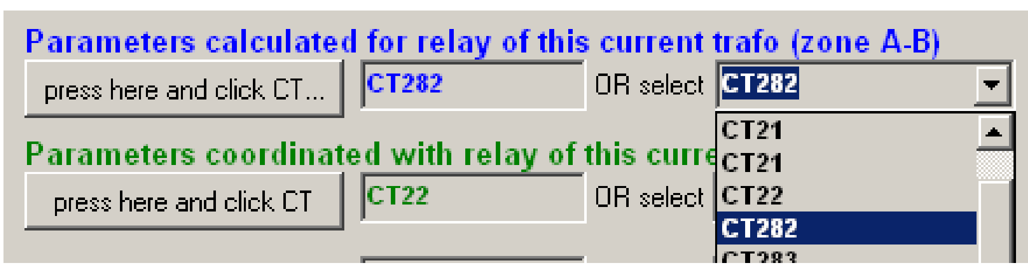
The buttons with question marks ("?") are for help-texts.

Selection of current transformers



The user must identify and tell the program the two current transformers connected to the relays: First, the relay with the known parameters to be coordinated with (near C in the picture) and, secondly, the relay with the parameters to be calculated (near A in the picture).

The current transformers can be selected in two ways:



- either -

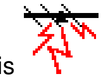
A) First, press down (click) the button labeled with "press here and click CT...", and next, click the current transformer in the single line diagram

- or -

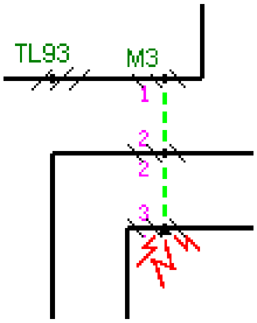
B) Select the current transformer in the drop-down list on the right hand side of the window. The list becomes visible by clicking the small arrow (triangle) in the box for the list.

The "refresh" button on top of the window should be clicked for updating, if components have been added to or removed from the single line diagram. (Click the referesh-button also, if the list does not become visible from the small arrow)

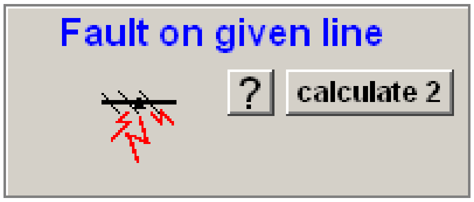
If it is known, on which transmission line (component) the fault must be, the user must move (drag with the mouse) the fault to the middle of the known line. When the fault is in the correct position (in the middle of the line), the "calculate 2" button can be pressed.

NOTE: The short circuit must be connected directly to the transmission line, like this  .There **must not** be any components or wires between the short circuit and the transmission line.

The fault can also be on a transmission line with mutual impedances,

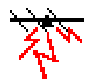


Fault on given line

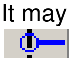


There are two calculate-buttons in the window for coordination. The "calculate 2"-button is used, when it is known, on which transmission line the fault must be (for a successful coordination). The exact position of the fault on the line is not known, and must be calculated by the program.

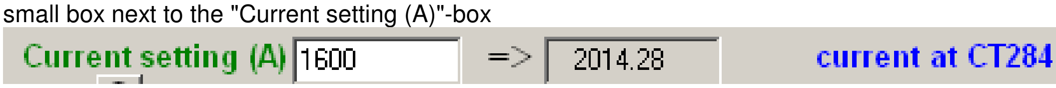
Before starting the calculations, the user must:

- move the fault to the middle of the given transmission line  by dragging with the mouse
- determine the "calculated" and "coordinated (with)" current transformers, as explained in the chapter for the principle
- determine, is a previously calculated initial state used, and select the fault type
- enter the value of the "Current setting (A)", that is, the set-current parameter of the relay with known parameters, to be coordinated with.

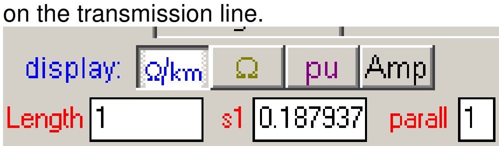
If some of the data listed above is missing, the error message "not complete input", or "input error" will be displayed in the box at the bottom of the coordination window.

It may be useful to press down the "show currents or powers"-button in the toolbar of the main window , in order to display the currents at the current transformers.

When the "calculate 2"-button is clicked, and if all parameters are correctly entered, the program searches iteratively the position of the fault on the given transmission line, so that the current at the current transformer "to be coordinated with" near the fault is (nearly) equal to the value of "Current setting (A)". The current at the current transformer of the relay "to be calculated" is displayed in the small box next to the "Current setting (A)"-box



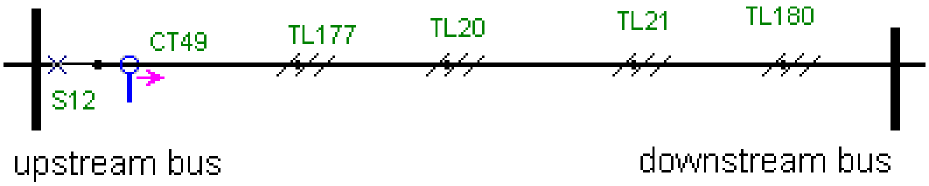
Technically, the program carries out the iteration by changing the parameter s1 of the selected transmission line, until a solution is found. The parameter s1 tells the relative position of the middle node on the transmission line.



The program carries out a complete short circuit calculation with the superposition method at each iteration.The progress of the iterations can be followed in the box at the bottom of the coordination window.

Fault somewhere between buses

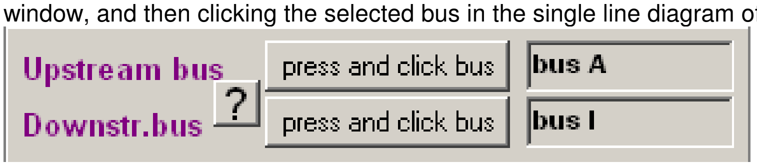
It is possible that a long transmission line is modeled with several transmission line-components, for example when the line consists of several sections with different parameters.



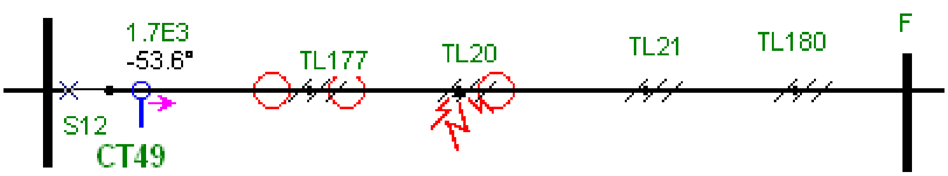
In this case it is generally not known, on which transmission line-component the fault must be, so that the relay is just about tripping. It is only known that the fault is somewhere between two buses, the upstream bus, and the downstream bus. Up- and downstream buses are defined so that the current measured near the upstream bus (CT 49 in the picture) decreases, when the fault moves towards the downstream bus.

The program must determine first, on which transmission line section, or component the fault is. When that is known, the exact position of the fault on that component is determined iteratively.

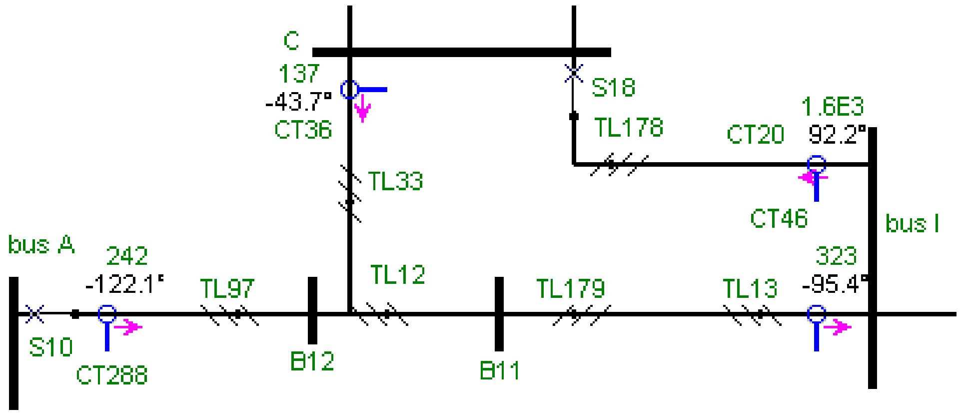
The user must define the current transformers, the value of the set current, the possible use of an old initial state, and the fault type, before starting the calculations, similarly as when the faulted line is known. Instead of moving the fault to the desired position, the user must define the upstream and downstream buses. This is done by pressing down the "press and click bus"-button in the coordination window, and then clicking the selected bus in the single line diagram of the main window.



The calculations are started by clicking the "calculate 1" button. The program moves the fault from node to node between the up- and downstream buses, until it finds the transmission line, where the fault must be. The nodes that have been checked in this way are marked with red circles.



The circles can be removed by clicking the  button. The circles may be a useful indication of the selected path, if there are **parallel paths** between the buses. "Parallel paths" refer to the case when the up- and downstream buses are connected either directly or indirectly through more than one chain of transmission lines. (Such a chain is here called "a path".)



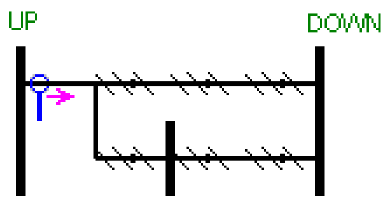
In this picture, bus A and bus I are connected through two paths: One goes through buses B12 and B11. The other goes through buses B12 and C. The problem of the parallel paths may be difficult, and requires some attention from the user. The parallel paths are discussed in the next chapter.

Parallel paths

Parallel paths

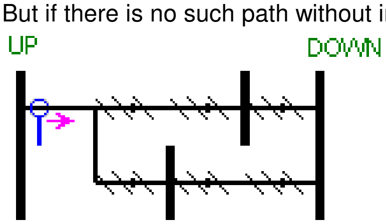
It is possible that there are more than one path, that is, more than one chain of transmission lines between the up- and downstream buses. Generally, the user must define which one of these "parallel paths" is considered in the coordination, i.e. on which transmission lines the fault can be, and where it cannot be. Probably several pahts must be studied in the course of coordination.

If there is only one path among the parallel paths that has no intermediate buses, then the program assumes, or guesses that this one is the path to be considered in the coordination. However, this selection can be overridden by the user, see below

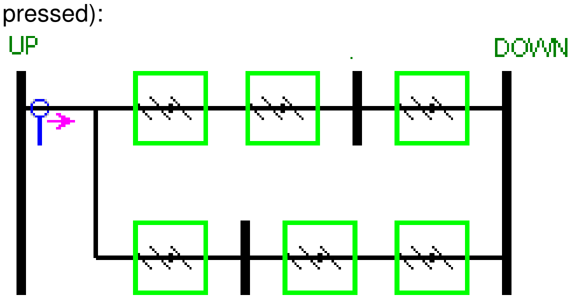


In the picture above, the program automatically selects the upper path.

But if there is no such path without intermediate buses, like



then the user must define the path. The program informs the user of these parallel paths by drawing green squares around all transmission lines on the parallel paths (after the "calculate 1"-button has been pressed):



The green squares can be removed by clicking the green "reset"-button.

Selecting a path for coordination

The user can select one of the parallel paths in two different ways:

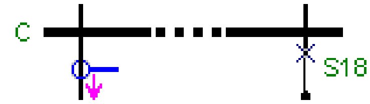
-either-

A) By clicking one or more of the green squares the user tells that the path(s) through the transmission line(s) under the clicked green square(s) are excluced, i.e. are NOT selected. (It is easier to exclude a transmission line than to tell which lines are included in the path.)

- or -

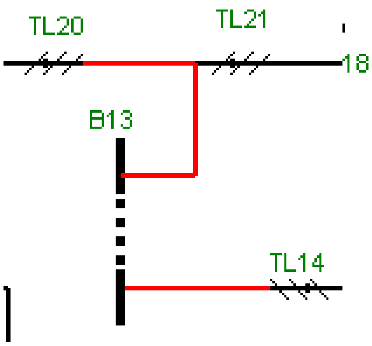
B) The user can also exclude a path by telling which bus(es) is/are NOT included in the selected path. First, press down the button next to the text "Forbidden bus".

Next, click the bus to be forbidden. Repeat for more buses, if necessary.
A "forbidden" bus is marked with a dashed line



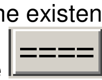
The "forbidden"-status of a bus can be removed by clicking the magenta "reset"-button.

Warning
The program "thinks" differently than a human being when considered these "forbidden" buses. Any path that touches a forbidden bus is NOT selected, even when a human being might think that the path does not go through the forbidden bus.



For example, the paths including lines TL20, TL21, and TL14 are excluded, because they touch the forbidden bus B13 (as indicated by the red lines)

Find parallel paths

It may be useful to check the existence of parallel paths before carrying out the calculations. This can be done by pressing down the -button, and clicking the "Calculate 1" button. If there are parallel paths, the program marks them with green squares, as explained above. If there are not parallel paths, then the program carries out a normal coordination calculation.

A parallel path can be excluded either by clicking one or more of the green squares, or by excluding a bus, as explained above. The user can exclude also a path with no intermediate buses in this way, i.e. to override the "guess" made by the program.

Per Unit Calculator

The Per Unit calculator converts an impedance (or resistance or reactance) from per-unit notation to ohms. The calculation is done automatically every time some of the inputs changes: the base voltage, the base power or the impedance itself. The conversion is

Z(ohms) = Z(%)*(base voltage)*(base voltage) / (100 * base power).

The unit of the base voltage is kV and the unit of the base power is MVA (or V and VA, respectively). The impedance is entered in per cent (%). The result is in ohms.

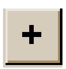
The per-unit calculator can be called either from the view menu or by pressing the PU calc. button, that appears when the parameters of a component are edited.

When the PU calc button is pressed, the values of the base voltage and base power of the edited component are fetched similarly as the other parameters. They are also saved together with the other parameters, when the user presses the OK-button (or elsewhere on the screen) and the line with the parameter values disappears. They are not saved, if the user presses the "Cancel"-button, or exits the PU calculator by pressing the X in the upper right corner of the calculator form.

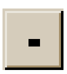
The 

button fetches the value of the base voltage or base power, respectively, that was last used. This feature may save some typing, if the same base values are used for several components.

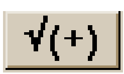
There are four buttons for some simple calculations at the lower part of the calculator form. The calculations are carred out using the values the two impedances (or resistances or reactances) Z1 and Z2 in ohms.

The 

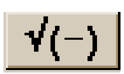
button simply adds the impedances (in ohms).

The 

button subtracts the impedances (in ohms).

The 

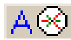
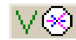
button calculates the geometric sum of the impedances, that is sqrt (Z1 * Z1 + Z2 * Z2), in ohms. If Z1 and Z2 are in series, and Z1 is a resistance and Z2 is a reactance, then this means that the absolute value of the impedance is calculated (of course)

The 

button calculates the geometric difference of the impedances, that is sqrt (Z1 * Z1 - Z2 * Z2). This is useful for transformers, if the total impedance and the resistance are given. The result is then the reactance of the transformer (in ohms).

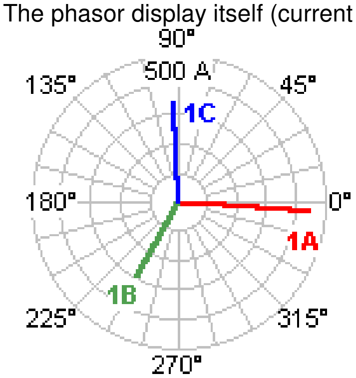
Note: The results of the calculations (any calculations) are not transferred automatically to the line of parameter values. That must be done manually (with *copy* and *paste*, for example.)

Current- and voltage-phasor windows

The currents of a current transformer are displayed as phasors in the current-phasor window, when the current-phasor button  is down and the current transformer is clicked. Similarly, the voltage of a bus is displayed as a phasor, when the voltage-phasor button  is down, and the bus is clicked.

The phasor windows contain two main items:

The phasor display itself (current phasors shown here)



and an array with some parameters and the values of the currents or voltages:

	(X)		CT1
	1	1A	445,2 A < -4,1 °
	1	1B	308,4 A < -119,5 °
	1	1C	332,2 A < 93,2 °

In addition, there is an **edit-box** on the lower part of the window. It shows the position of the cursor in terms of current or voltage, both as the real and imaginary parts, and as the magnitude and the phase angle.

The identifiers of the phasors (1A, 1B, 1C in t he figure above) can be moved with the mouse. Put the cursor on the identifier (on the two first characters) , press the left mouse button down. A small rectangle appears. Keep the mouse button pressed and drag the rectangle to the desired position. Release the mouse button and the identifier moves to the position of the rectangle.

The scale of the phasors can be changed with the R-button and the arrow-buttons . The right-arrow-button increases the scale (shortens the phasor). The left-arrow-button decreases the scale, and the R-button resets the scale to the default value.

The array contains four rows and four columns for each current transformer or bus. The first row contains the identifier of the current transformer or the bus, and an '(X)'.

The phasors of this current transformer or bus can be **deleted** from the phasor display by clicking the X and and the "delete"-button that appears.

The current phasor diagram **displays the current in the network** at the current transformer, i.e. the primary current of the current transformer as default. It is possible to display the Y (wye) or delta connected secondary currents of the current transformer by clicking "Options | Currents in Amp sec" in the menu bar, as described in connection of the parameters of the current transformers.

The colors of the phasors can be selected by clicking the colored squared of the first column, and clicking the desired color in the "color menu" that appears.

A single phasor can be **hidden** or displayed by clicking the 1 or 0 of the second column, and by unchecking or checking the box that appears.

The third column shows the **identifiers** of the phasors. They cannot be changed.

- -

The "File"-menu in the menu bar

Export diagram saves the phasor window either as as a bitmap (*.bmp), a graphic jpeg file (*.jpg), or in the Windows metafile format (*.wmf). The bitmap and jpeg formats save the whole phasor window, but the windows metafile only the graphics.

Note: If the phasors of both phase and sequence variables are shown, then the diagram can be exported only as a bitmap or as a jpeg file, not as a windows metafile.
Copy to clipboard.. The phasor is copied to the (windows) clipboard, either as a bitmap or as a windows metafile. The form (bitmap or metafile) is selected in a small pop-up menu.
Exit closes the phasor window.

The "View"-menu in the menu bar

Buttons (etc)
hides or shows the R-buttons and the arrow buttons, and the edit-box on the lower part of the window.

Phase components
Sequence components
Phase and sequence
Only one of these three items can be selected at any time. When the "Phase components" is selected, the phasors are shown as such. When the "Sequece components" is selected, the phasors of the symmetrical components (positive, negative and zero sequence) are shown. When the "Phase and sequence" is selected, the phasors of the currents or voltages and the symmetrical components are shown.

The "Options"-menu in the menu bar if the current phasor window

When **Ineg, Izero** is selected, the phasors of the negative and zero sequence components are displayed as such.
When **3*Ineg, 3*Izero** is selected, the phasors of the negative and zero sequence components are multiplied by three.
Note: In both cases, the positive sequence component is shown as such.

When "**Currents in Amp-pri**" is selected, the phasor displays the primary currents of the current transformers, that is, the currents in the network at the location of the current transformers as such, but when
"**Currents in Amp-sec**" is selected, the secondary currents of the current transformers are displayed.

The "Options"-menu in the menu bar if the voltage phasor window
When **Phase - ground voltages** is selected, the phasors of the phase-ground voltages are shown.
When **Phase - Phase voltages** is selected, the phasors of the phase-phase voltages are shown.

Phasors of currents in transformers

It is possible to show the currents in transformers in a phasor display. The display works in the same way as the display for currents in current transformers, or for voltages in buses. First, press the "show phasors of transformer currents" -button  down in the toolbar. Next, click the transformer in order to show the currents.

The display works mainly in the same way as the phasor displays for currents and voltages. There are two additional buttons:

Normalize: The secondary and tertiary currents are displayed as normalized to the primary voltage. That is, the currents are multiplied by V2/V1 or V3/V1, where V1, V2, and V3 are the primary, secondary and tertiary voltages, respectively.

winding currents: The currents in the delta windings are displayed instead of the currents to the transformers, if there are delta windings in the transformer.

Report for results

The Result report is a so called tabbed notebook, where the results of the calculations are written. The result report can be shown or hidden by clicking the "report" item in the View menu of the main form..

The report becomes visible by clicking the "Report" in the View menu, or alternatively, by pressing the alt and V keys simultaneously, followed by an R-key.

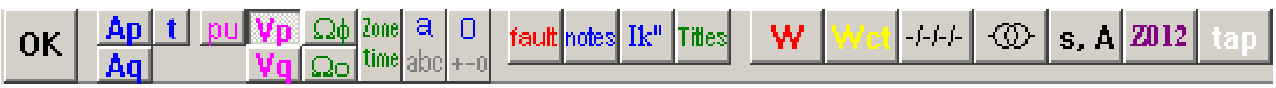
The date and title of the network are written on the top of a new page. These are followed by one line for comments and a description of last calculation carried out. This introductory part ends with a list of open breakers.

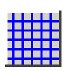
The actual results written to the report depend on the calculation type and the positions (down or up) of the buttons on the toolbar of the report window. The buttons of the left part of the toolbar are enabled after a solution of the network (straightforward solution, load flow, etc), and a short circuit calculation with one (or a few) explicit fault(s). The buttons on the right part of the toolbar (and some on the left part) are enabled after short circuit calculations with faults in all buses and voltmeters in turn.

Note: The units for the results (A or kA, W or MW, etc) are selected in the main window using the A V W dialog.
- -

Report after the solution of the network, or a calculation with an explicit fault

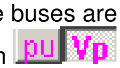
The actual results to be written depend on the positions (down or up) of the "Ap", "Aq", "Vp", "Vq" etc. buttons.

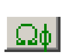
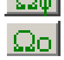


If the "filter" (or select) button  is **not down**, then data for all components corresponding to the buttons in the "down" position are written, but if the"filter" button is **down**, then only data for the selected ("filtered") components are written. The method of selection (filtering) is described below.

The OK-button on the left is used to write the new report page.

When the **"Ap"** button is down, phase currents of the current transformers are written.
If, in addition, the **"t"** button is down, the activation times of the relays are written. The relays are written in the order of increasing activation time. (Note that elsewhere the relays are written in a somewhat arbitrary order = the order the relays were added in the single line diagram.)
When the **"Aq"** button is down, sequence currents of the current transformers are written, but only after an unsymmetrical fault.

When the **"Vp"** button is down, phase voltages of the buses are written.
When the Vp-button is pressed down, the pu-button  becomes visible, but only after calculations without fault(s), that is, after a load flow calculation, or a normal solution of the network. When the pu-button is down, the per unit voltage is included in the report. If the per unit voltage is too high or too low, a "!?" is written as a warning after the voltage. The limits for the "too high" and "too low" per unit voltage are set with the puVmax- and puVmin-parameters of the bus.
When the **"Vq"** button is down, sequence voltages of the buses are written, but only after an unsymmetrical fault.

When the  button is down, phase impedances calculated by the distance relays are written.
When the  button is down, ground impedances calculated by the distance relays are written.
If, in addition the "Zone time" button is down, then the zone times (activation times) of the distance relays are written.

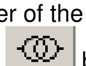
If the **" a abc"** button is down, and the **"Ap"**, the **"Vp"**, or the Ωϕ or the Ωo button is down, then currents, voltages, or impedances, respectively, of all three phases are written, else only for the phase a.
If the **" 0 +-0"** button is down, and the **"Ap"** or **"Vp"** button is down, then currents or voltages of all three sequences are written, else only current or voltage of the zero sequence is written.

When the **"fault"** button is down, the location of the fault is written (for example "Fault at bus B1").
When the **"notes"** button is down, then different "Notes" are included. For example: "NOTE: abs.value and phase shown, because the Ø/i button is down".

When the **Ik"** button is down, the initial fault current Ik" is written. After an unnsymmetrical fault both the phase and sequence currents are written, else only the phase current(s). After a calculation according to the IEC-standard, the also values of the peak and breaking currents (at 0.1s) at the location of the fault are written, when the Ik"-button is down.

The titles or captions written before some data depend on the position of the **"Titles"** button (check the effect yourself!).

When the **"W"** button is down, powers of generators, feeders, loads and motors are written, but only after a normal solution of the network, not after a fault calculation.
When the **"Wct"** button is down, powers through current transformers are written, but not after a fault calculation.

When the **"-/-/-/-"** button is down, the currents and powers through transmission lines are written, but not after a fault calculation. Additionally, the exceeding of ampacity limits is indicated with an "A" followed by the number of the limit, for example "A3"
When the  button is down, the currents and powers through 2-winding transformers are written, but not after a fault calculation. Additionally, the exceeding of ampacity limits is indicated with an "A" followed by the number of the limit, for example "A3"

When the **"s, A"** button is down, the activation times and the corresponding currents of the overcurrent relays are written after a fault calculation. The relays are listed in increasing order of the activation times, smallest time first. But **note:**, the fast and slow modules of recloser and user defined relays are always listed together.

When the **"Z012"** button is down, the Thevenin sequence impedances at the location of the fault are written.
When the **"tap"** button is down, the tap positions of the transformers are written to the report, but only after a calculation of the tap positions, see the calculation buttons.

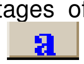
When the Ωϕ or Ωo button is down, the direction (F = forward, or R = reverse) of the current in the distance relay is also written to the report. The logics for the direction of the current is the same as for the impedance of the distance relay. If the current, or the value of the negative sequence component is too small, a "-" is written to indicate that the direction cannot be defined. The caption of the column with the directions of the current is "dir".

Several buttons can be up or down simultaneously.

The format of the data to be written depends on the Ø/i and √3 buttons in the main window.
If the Ø/i button is in the position r + i then the real and imaginary components are written. If the button is in the position Ø then the absolute value and phase are written.

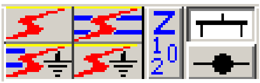
If the **"sqrt(3)"** button is in the position √3 then square root 3 times the phase to ground voltages are written. If the button is in the position Ø n then the phase to ground voltages are written as such. In the position Ø Ø the phase to phase voltages are written.

After a fault calculation, the initial currents Ik" of the current transformers and the fault are written if the **"Ap"** and **"t"** buttons are down. The last column of the current transformers (with the caption act. time) shows the activation times of the overcurrent protection relays. If a relay is not activated, a '-' is written.

In the cases of asymmetrical faults, the positive, negative and zero sequence currents of the fault and the current transformers and voltages of buses are written if the **"Aq"** or **"Vq"** button, respectively, is down. If the **"a b c + - 0"**-button  in the main window is in the "special mode", showing a, b, c, +, -*3, or 0*3, then three times negative and zero sequence currents are written, instead of the plain negative and zero sequence currents. (The "mode" of the a b etc. button can be changed from "normal" to "special" or back by keeping the alt-key down while clicking the button, or by selecting Options | show 3*Ineg,3*Izero in the menu bar of the main window.
- -

The report after faults in all voltmeters and buses

The results written to the report depend on the position (down or up) of the buttons on the right part of the toolbar, and on some buttons on the left part of the toolbar. The buttons on the left part were discussed above. The buttons on the right part are



When a button of a given fault type is down, the currents for that fault type are written. If the "bus"-button is down, the results are written for all buses, and similarly for the voltmeter button. The buttons that can be used (are enabled) depend on the calculation that has been carried out, as defined in the window for the faults in all buses and voltmeters. If, for example, only the currents for three phase faults in all buses (but not in voltmeters) have been calculated, then only the three-phase-fault-button, and the bus-button are enabled.

In addition, the fault impedance is written to the report.
- -

The File menu in the report form

New page generates a new page in the report. and writes the results of the last calculation, as determined by the "Ap", "Aq", "Vp", etc. buttons. There can be at most twenty pages in the report. The same can be done with the OK-button in the toolbar.

Print active sheet prints the page of the report that is visible ("the current page")

Save file as ... opens a save file dialogue, that can be used to save the complete report as a text file.

The Edit menu in the report form

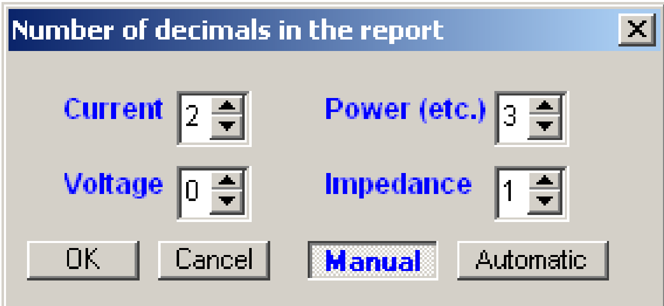
Edit tab caption opens a small box, where the caption in the tab of the active sheet (current page) can be edited. After editing, click the white report area to close the box, or hit the enter key on the keyboard. The caption can be at most twelve characters long.

Delete active page deletes the visible, or active sheet (current page). The first page cannot be deleted, however.

Delete all pages deletes all pages, except for the first one.

The options menu in the report form

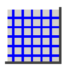
Decimals opens a small dialogue box for selecting the number of decimals for the results



The number of decimals can be selected for current, voltage, power and impedance, when the Manual-button is down. If the Automatic-button is down, the number of decimals are determined in the program. The OK-button accepts the (new) numbers of decimals. The Cancel-button rejects any changes in the number of decimals.

- -
Note The user can edit all pages in the report.
- -

Filtering i.e. selecting components for the report

If the "filter" (or select) button  is **down**, then only data for components with the "filter flag" ¤ at the end of the label are written. For example: The label CT10 tells that the component is not filtered (selected), but a component with the label CT10¤ is filtered. The filter flag can be added and removed in different ways:

- Right click the component and click the Filter-item in the pop-up menu
- Right click the label
- Click the label and edit the ¤ at the end of the label in the box that appears.

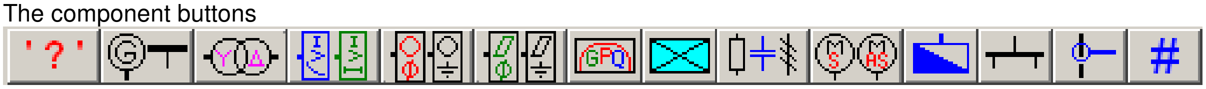
Note: Only components with a label can be filtered. Actually, this is no limitation, because almost all components have labels, that is, all components that can display calculated results.

The "**Advanced**" item in the menu bar can be used to remove the filter flag, or to display the filtered components. Clicking **Advanced** | **Filter** | **Reset filter selection** will remove the filter flag from the labels of all filtered components. Clicking **Advanced** | **Filter** | **Show filter selection** will highlight the filtered components, i.e draw a gray background for the filtered components. The highlighting disappears when any empty point on the window is clicked.

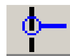
Parameter report

The Parameter report is a so called tabbed notebook, where the parameters of the network are written. It can be shown or hidden by clicking the "Parameter report" item in the View menu of the main form. See the Report for results-page for some more explanations.

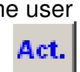
The component buttons

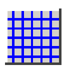


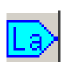
can be used to select the component types for which the parametes are written. Several buttons can be down at the same time.

When the current transformer button  is down, only the labels (identifiers) of the current transformers are shown, because these transformers do not have any parameters.
When the "bus" button is down, the nominal voltages of the buses are written.
When the " # " button is down, the numbers of the components are written.
If the **' ? '** button is down, the explanations of the parameters are also written to the report.

The other buttons are self-explanatory, I hope

The relays can have several groups (or sets) of parameters. The user can select to write only the present "active" parameters, or parameters of all groups. If the  button is in the position "Act", then the "active" parameters are written in the normal way, but if the button is in the position "All", then parameters of all groups are written. (The button works only with the relays, it has no effect on other components.)

If the "filter" (or select) button  is **not down**, then data for all components corresponding to the component buttons are written, but if the filter button is **down**, then only data for the selected ("filtered") components are written. The method of selection (filtering) is described in the report for results-page.

If the label-button  is down, then only labels of the components are written, no data.

The file and edit menus are the same as for the result report.

The parameters of relay modules

The parameters of most components are written in a straightforward way into the report. The parameters of relays, or relay modules may need some explanation. . The parameters of all relay modules that are connected to the same current transformer are written in one column. The title of the column is the label, or identifier of the current transformer. The labels of the relay modules are not shown.

The two first entries in the column are the parameters of the eventual inverse time relay module that is connected to the current transformer. If there is no inverse time module connected to the current transformer, then only slashes (-) are written. The type of the inverse time module is indicated with a letter that follows the parameter values. The letters are n for normal-, v for very-, x for extremely- and t for long time inverse.

The parameters of eventual definite time modules are writen below the parameters of the inverse time module (or the slashes). The order of the parameters (from top to bottom) of the definite time modules is the same as the order of the modules in the single line diagram (from left to right).

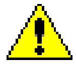
An example:

curr. trafo	CT1	CT4	CT3
inv.time Is:	400n	90v	-
inv.time k:	0,1n	0,1v	-
def.time I0:	0	-	300
def.time t:	0,1	-	0,05

In the example above, a normal inverse time module and a definite time module are connected to current transformer CT1. A very inverse module only is connected to current transformer CT 4 and only a definite time module to current transformer CT3.

Warning messages

Warnings

A warning sign  may appear in some cases. The warning-texts can be seen by clicking the warning sign. After clicking, the text will disappear, when the (X) in the text is clicked. If the cursor is kept on the warning sign, the label(s) of the component(s) with warning(s) can be seen.

NOTE: Only one warning of each type can be displayed, even when several similar warnings have been issued in the program.

There are not many warnings (yet):

"Forward/Reverse check not in use" will be issued at an IEC-chort circuit calculation, if there are directional relays in the network. Due to the calculation method, it is not (always) possible to determine the fault direction (forward or reverse) for the directional relays (PGQ-relays, electromechanical relays, reclosers, user defined relays).

" X, X', or X" not correct, default values used" will be issued at a short circuit calculation, if the d-axis reactances of a generator or a synchronous motor are not reasonable. The reactances must satisfy $0 < X'' < X' < X$.

" Xq', or Xq" not correct" will be issued at a short circuit calculation, if the q-axis reactances of a generator or a synchronous motor are not reasonable. The reactances must satisfy $0 < Xq'' < Xq' < X$ where X is the d-axis reactance;

" d-axis time constants not correct" or "q-axis time constant not correct" will be issued at a short circuit calculation, if the d-axis or q-axis time constants of a generator or a synchronous motor are not reasonable. The time constants must satisfy $T_{min} < T'' < T'$, where T" and T' are the subtransient and transient time constants. Tmin is the smallest allowed time constant = 0.01s.

" Tq' or Tq" not correct" will be issued at a short circuit calculation, if the q-axis time constants of a generator or a synchronous motor are not reasonable. The time constants must satisfy $T_{min} < Tq'' < Tq'$. Tmin is the smallest allowed time constant = 0.01s.

"Did not find all relays or current trafos for the graph!" will be issued, when recalling coordination graphics, and not all relays or current transformers are found.

"phase shift not physically possible" is issued if the phase shift parameter of YD or DY transformers is even (zero is allowed, because zero is interpreted as a phase shift of -30 degrees). That is, if the phase shift is 60 deg., 120 deg ,etc. The results of the calculations may or may not be correct in that case.

Error messages

System errors
The error messages listed below are the programmed, or planned error messages. The user should not get any system error messages, such as "illegal floating point operation", "access violation", etc, but, unfortunately, this is still quite possible. A capacitive impedance in the connection line of an asynchronous motor is a good candidate for producing floating point errors, for example. If you get a system error message, report it please. If possible, include the single line diagram file (the *.sld) file, where the error occurred. Explain also in detail the operations you did, when you got the error message. Send the report to ilkka.leikkonen@pp.kpnet.fi, please.

Asynchr. motor xxx: no solution for power
the power parameter (P) is incompatible with the other parameters. Probably it is too large

Asynchr. motor xxx: parameters ?
Cannot solve the internal model parameters from the input parameters. Check using Help or Hint that all parameters are reasonable

Asynchr. motor xxx: some error message
The error message should tell, what is wrong. Probably a wrong parameter.

Asynchr. motor xxx: strange parameters (power ?)
Cannot solve the internal model parameters from the input parameters. Probably the power parameter is not reasonable

capacitive impedance
An asyncronous motor sees a capacitive impedance, for example in a transmission line. The program cannot necessarily handle this. May also be a numerical problem due to some large impedance that the asynchronous motor "sees". Check that there are no capacitive or large impedances in the lines feeding the asynchronous machines. The results may be correct, however, if the currents settle to some (reasonable) steady state value.

error in load flow: coeff. matrix
Cannot solve the load flow problem. This is a difficult one, something is seriously wrong. Check the parameters of loads, generators (and of all other components).

fii (phase angle) must be between -90 and 90 degrees
Erroneous input. The phase angle (fii) of a synchronous motor must be between -90 and 90 degrees.

The generating PQ bus xx cannot be used in this calculation
A load with negative power is modeled as a generating PQ-bus in a load flow calculation, but it cannot be used in other calculations (for example short circuit). More...

Help file not found
Program works normally, but help is not available. Put the .hlp and .cnt files in the same directory with this program.

inconsistent voltages in node xxx
The program deduces the nominal voltage level of each node (each component) from the nominal voltages of generators, feeders and transformers. This information is needed for scaling, when the characteristic curves of several relays are drawn in the same picture on the current-time form. It is also needed as the system voltage Un in the IEC-short circuit calculations. (The IEC short circuit current is basically calculated as I" = c Un/(Z sqrt(3)) The program has detected that some node (or component) is connected to two (or more) different nominal voltage levels. This can easily happen, when one node (or component) is connected to two or more transformers. The program works normally, all calculations can be carried out. But the relay characteristic displayed in the same picture may be wrongly scaled. Check the compatibility of the nominal voltages of generators, feeders, and especially of transformers.
Note: In the IEC-calculations, the voltage levels of transformers are determined using the system voltages Vs1, Vs2, (and Vs3). In all other calculations, the "normal" voltages V1, V2 (and V3) of transformers are used.
Note: When a component is clicked, the node numbers of that component appear on the lower left of

the screen (among other test-information). A given node (node number) can be searched by clicking Edit | Find node in the menu bar.

load flow did not converge
For some reason, the program did not find a solution to the load flow problem. There can be several reasons for this: Too large power demand in the loads, too large impedances between the sources and the loads, too small an impedance between the feeder and other parts of the network, etc.

Load with nonpositive nominal voltage
Load with nonpositive power
The nominal power and voltage-parameters of a load component must be positive.

negative resistance
An asyncronous motor sees a negative resistance. The program cannot handle this. It is probably a numerical problem due to some large impedance or eventually some capacitance that the asynchronous motor "sees". Check that there are no capacitive or large impedances in the lines feeding the asynchronous machines. The results may be correct, however, if the currents settle to some (reasonable) steady state value.

negative resistance and capacitive impedance
See the error messages "negative resistance" and "capacitive impedance"

no gen
Some error in the program itself. (The user should not get this !)

No generator or no load, thus no calculation
There are either no generator(s) or no load(s) in the network. Thus, the load flow calculation cannot be carried out. Try som other calculation.

No short circuit
There must be exactly one short circuit in the network in the cases of the line to earth, the line to line, and the line to line to earth faults.

no slack bus
There should be one feeder in the network in the load flow calculation. The first feeder found acts as the slack bus.

nonpositive desired power (load)
The power-parameter of the load component must be greater than zero.

nonpositive desired power in some generator(s)
The power parameter of the generators should be greater than zero in the load flow calculation. It is not uncommon to get this error message, because the power-parameter is needed only in the load flow calculation.

not reasonable load
some parameter of a load component is not reasonable

parameter xxx is not a number + some error code + the text causing the error
There is some non-numerical character in the line of parameter values. The parameter values on the line are not accepted. Enter the parameter values again.

R1 or I1o in trafo xxx is not correct
The primary resistance and the open circuit primary current of a transformer are not compatible. Check the parameters.

too many short circuits
There must be exactly one short circuit in the network in the cases of the line to earth, the line to line, and the line to line to earth faults.

unknown component
Something wrong with the program itself. The user should not get this message

Unsuccessful! Solve the network first ! A short circuit calculation will not do!
Unsuccessful ! Solve the network first

The network must be solved before saving the *.dat file for the EMTP or ATP simulation program. A short circuit calculation is not sufficient.

wrong number of parameters

There are too many or too few parameter values on the line of parameter values. The parameters are not accepted. Enter the parameter values again.

X or I1o in trafo xxx is not correct

The transformer impedance and the open circuit current are not compatible. Check the transformer parameter values

You surely solved the network first

The network must be solved before saving the *.dat file for the EMTP or ATP simulation program. The program is not quite sure of, if you have solved the network (probably you have).

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