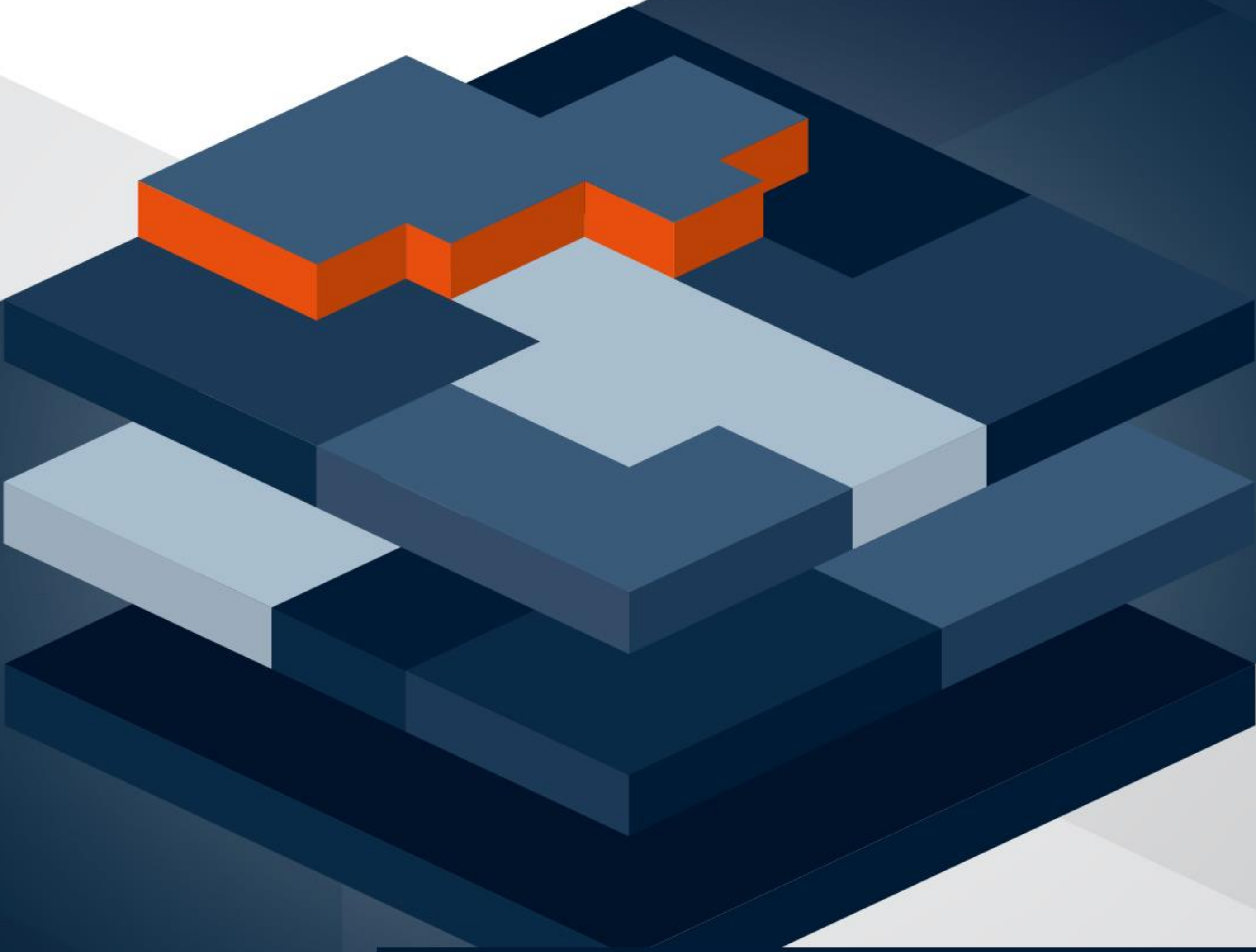

zenon manual

Automatic Line Coloring (ALC) - Topology

v.8.20

Contents

1 Welcome to COPA-DATA help

ZENON VIDEO TUTORIALS

You can find practical examples for project configuration with zenon in our YouTube channel (https://www.copadata.com/tutorial_menu). The tutorials are grouped according to topics and give an initial insight into working with different zenon modules. All tutorials are available in English.

GENERAL HELP

If you cannot find any information you require in this help chapter or can think of anything that you would like added, please send an email to documentation@copadata.com.

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LICENSES AND MODULES

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2 Automatic Line Coloring (ALC) - Topology

The topological coloring of lines allows easy automatic dynamizing of tubes in technology (for media) as well as in the energy distribution (for electricity). So process controlled coloring of topological nets can easily be realized.

Because the tube structure is designed in the screen with all its technological elements (e.g. tanks and valves, or generators, switches and consumers), it is internally emulated as a model and the media flow is displayed in the Runtime.

In order to allow screen-overlapping models the entire design and configuration is always project-wide. You therefore have one entire topological model per project, which is used for the calculation of the tube statuses and ultimately for the coloring of the tubes.

The whole topology is created automatically from the graphic design. No other engineering actions are necessary.

Information

Starting with a source, the ALC algorithm runs through each switch only once per direction.

DETAIL SCREENS

To display individual screens, a partial area can be taken from the topological network and displayed individually by means of alias. A detail screen (on page 43) can be displayed with the data from different equipment parts, for instance outputs or partial networks.

3 ALC elements

Automatic Line Coloring (ALC) makes it possible to color lines depending on the process status. The combined element is used as the process element. Automatic line coloring allows easy automatic dynamizing of tubes in technology (for media) as well as in the topological networks (for electricity).

ENGINEERING

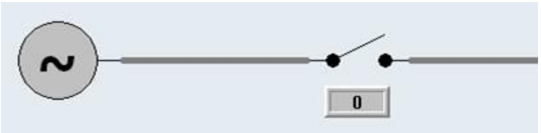
For the design two types of screen elements with different functions are distinguished. On the one hand these are procedural elements (on page 8) (source, switch/disconnector, drain, transformer or link) and on the other hand lines (on page 21).

In doing so, the technical elements have a function and a color (source and transformer). If the procedural elements are active, the connected lines take on the color of these elements at the source and transformer or they take on the color of the element's input line for the switch and the link. If the procedural elements are inactive, the color of the lines is taken from the definition in the editor.

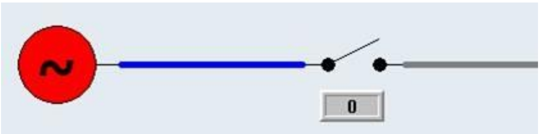
The different functions of the elements are assigned in the properties of the combined element.

EXAMPLE

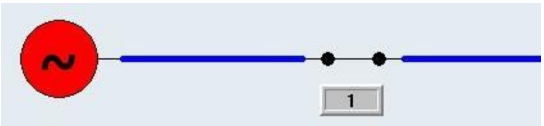
A source has a connected line. A switch is connected to the line. And a second line is connected there. If the source is active, the first line is colored with the color of the Automatic Line Coloring defined in the source up to the valve. The other line is not colored before the switch is closed.



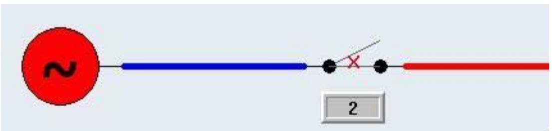
Source inactive



Source active



Switch closed



Undefined or invalid

Information

If the procedural element status is *undefined* or *malfunction*, this is automatically detected. All connected lines and all further elements are displayed in the color of the predefined source *undefined*' for both states.

NUMBER OF CLOSED SWITCHES IN A SERIES

For the correct functioning of the ALC algorithm, the number of connected switches in a series plays a role.

Recommendation: Arrange a maximum of 256 closed switches in a series between the source and the drain.

3.1 Procedural elements via Combined element

Procedural elements are created in zenon with a **combined Element**. Their state determines the coloring of the connected line.

> **Attention**
>
> When ALC is activated, the combined element has no effect on the drawing of lines. It only controls the visibility of elements.
> This means: Even invisible lines continue to forward their colors.
>
> This also applies to ALC lines whose visibility is determined by a variable. This does not include lines with **Alias**. These display the color, but do not forward it.

SETTINGS

The procedural type of the combined element is defined by the value of the **Function type** property. The available options are:

Function type	Description
No function	The element has no function in the ALC. **Note:** The "*no function*" function type is the default value.
Source	Passes on its color. If the source is active (value: *1*), all connected lines that have the **Color from ALC** option set in the **Automatic Line Coloring** properties group are allocated the color of the source. The color is defined in the project properties as the source color. (e.g. tanks or generators). A source is a single pole with a static source number assigned to it. The source is switchable over the state of its main variable. Generally, sources are considered as net-synchronous and detachable. For the *Interconnect various voltage levels* topological interlocking (on page 34), the nominal voltage of the source is taken into account. You can find details on the source in the configuration of the sources (on page 29) chapter.
Generator	A generator generally behaves like a source, but it is considered as an independent and not net-synchronous. For the *Interconnect grids* topological interlocking (on page 34), the number of the source that is linked to a generator is taken into account.
Switch	With this lines can be split. If the switch is *closed/active* (value: *1*), then the connection between the two lines is closed and the line is colored in the Runtime up to the next switch with the defined source color. In this

Function type	Description
	case a switch forwards the source color of the input line to the output line. If the status of the switch is *invalid* (value: *3*) or *undefined* (value: *2*) or the status of the main variable is INVALID, the line is colored in the *undefined* color from the ALC configuration. The parameters of the colors are configured in the **ALC configuration** property in the **Automatic Line Coloring** project properties group. A switch thus delivers source number *0* (undefined) to its output (connection *2*) instead of the incoming source number. **Example:** see **Switch example - colors from ALC** (on page 14) section. **Note**: If the **Switch input/output** property is active, the input and output of this element are reversed for the ALC.
Disconnector	A disconnector generally behaves like a *switch*. However, a disconnector in the topological model must not be switched when live - topological interlocking "**Disconnector under load**" in the command processing. As with the switch, the main variable determines the status: *On, off, intermediate position, malfunction*. **Note**: If the **Switch input/output** property is active, the input and output of this element are reversed for the ALC.
Transformer	A transformer is a drain and a source at the same time. SO with a transformer the input color (input source) can be transformed to a new output color (transformer source color). The output line is only displayed as active once the transformer has an active input line. However the output line does not get the color of the input line as with a switch, but instead the color of the transformer's own source. So a source has to be defined for each transformer. A transformer cannot be switched active or inactive, it always is active, regardless of the value of the linked variable. **Note**: If the **Switch input/output** property is active, the input and output of this element are reversed for the ALC. *Reverse-feed-compatible transformer:* To have a transformer capable of reverse feed, you must select, for **Source for reverse feed**, a different source than *UNDEFINED [0]*. This means that the transformer behaves the same for both directions - from the input to the output (forward) and also from the output to the input (backward). The only difference is that the source number of the

Function type	Description
	Source for reverse feed property and not the **Source** property is used for relaying the information (e.g. colors) in the topological model. **Note:** Faulty network statuses or missing configurations, such as a feed from the input and output at the same time or a short circuit from input and output are not specially colored. This means that the transformer capable of taking a reverse feed behaves like two transformers switched to run antiparallel that are not capable of taking a reverse feed.
Capacitor	The capacitor can only be connected as a load on one side. For the **Load flow calculation**, the capacitor serves as compensation for the reactive power.
Valve	A slider (a valve) acts in a similar manner to a *switch*, but it is used for water and gas lines. Value of the main variable: - Switch OFF: Value *0* -> Slider closed-> No forwarding - Slider ON: Value *1* -> Slider open completely-> Water flow - Slider value *2 (intermediate)* -> Slider partially open-> Water flow - Slider value *3 (error)* -> Slider malfunction **Note**: If the **Switch input/output** property is active, the input and output of this element are reversed for the ALC.
Check valve	The *check valve* only forwards information in one direction. Value of the main variable: - *Value 0*: The forwarding is not active (= the valve is closed) - *Value 1 or 2*: Forwarding is only possible in one direction. In doing so, the color of the source is only forwarded from the input to the output. Forwarding in the opposite direction is not envisaged. This also concerns the forwarding of ALC information for the color of the earth. - *Value 3*: Forwarding is undefined. This then occurs, for example if the *check valve* is faulty. In this case the status is only forwarded at the output. **Note**: If the **Switch input/output** property is active, the input and

Function type	Description
	output of this element are reversed for the ALC. The *check valve* is also taken into account by the topological interlocking (on page 34).
Drain	This defines the end of the line. The drain does not influence the coloring; it is only used so that the model can be displayed in full. If an external program (e.g. VBA) should access the model, then the drain probably is needed for further calculations, and so has to be inserted. In Energy projects, the drain is used for representing consumers. These are used to calculate the ALC - topological interlockings (in the **command processing**) '**Device would not be supplied**'.
Terminator	For bus bar ends. Blocks the error message "*Line only connected on one side*" when being compiled in the Editor.
Link	A link serves to continue a line at another place. If a link is "supplied" by a line, all other links with the same link name also are supplied by this line. Here it does not matter, whether the links are in the same screen or on different screens in the project. Topological networks can thus be designed throughout screens. More than two links with the same link name in the project are also permitted. Links are configured with the **Link name** property. Links can be supplied by several lines at the same time or can themselves supply several lines. In principle there is no difference between inputs and outputs. The ALC colors of the sources are forwarded to all connected lines. A link cannot be switched active or inactive in the event of a value change: it is always active. For this reason, it is not absolutely necessary to link the combined element to a variable. **Caution:** Two link elements cannot be connected directly to one line. In between, there has to be at least one other procedural element (switch/disconnector or transformer).

The source number given - for the source and transformer function types - is forwarded via closed switches (disconnnectors, sliders etc.) up to the devices (drains). The colors of all connected lines and process-related elements are calculated dynamic from the higher-level sum of the supplying source numbers.

SOURCE AND LINK NAME

Parameter	Description
Source	Here a source is assigned to an element. In this drop-down list all sources defined in the ALC configuration (in the project properties) are available. All source names are listed. This property is only active if the function type '*source*', '*transformer*' or '*generator*' has been selected. You can find details on the source in the configuration of the sources (on page 29) chapter. **Attention:** Use the pre-defined system sources for this (ID 0..9). Configure separate sources for this linking: - For the configuration of your own sources, click the **...** button in the **ALC configuration** property in the **Automatic Line Coloring** project properties group. - The system sources *UNDEFINED [0]*, *GROUND FAULT [1]*, *SHORT FAULT [2]* and *GROUNDED [3]* are only envisaged for the configuration of the grounding. - The pre-defined system sources *SYSSOURCE4 [4]* to *SYSSOURCE9 [9]* serve as placeholders.
Link name	The link name can be configured here for the *link* function type. All identical link names in a project correlate with each other. You can find further information about this in the *Link* function type. This property is only active, if the function type *link* has been selected.

VARIABLES OF PROCESS-RELATED ELEMENTS

In order for a switch, disconnector or slider etc. to be given the status (open, closed, invalid), a BOOL data type or integer variable must be linked in the respective combined element as the main variable.

Example:

- IEC870 driver: Variables with **Typ ID** *T01..T37*
- IEC850 driver: Variables */Pos/stVal[ST]*
- DNP3 driver: Input Variables

Pre-requisite: the **DPI/DPC mapping** has not been deactivated in the driver.

> **Information**
>
> For the position of a switch, only the first two bits of the main variable are taken into account.
>
> - The first bit is the actual switching; 0 is OFF and 1 is ON.
> - The second bit is the error bit. There is no error if it is 0.

The status of a source ("*present*" *(ON)* / "*not present*" *(OFF)*) is also evaluated using the linked main variable. For this evaluation, a BOOL data type variable of the internal driver is recommended. Then (as is usual in practice) the source can be linked to the rest of the topology via a *switch* or *disconnector*. As a result, it is possible to forward the color of the source - depending on the position of the switch.

Note: For the main variable of a source that is connected to the network via a *switch/disconnector* (ground, for example), create a variable for the **internal driver**. For this variable, configure the **Calculation** properties with the value *network* and **Initial value** with value *1* ("always present"). You can find this properties in the **Internal Variable** variable properties group. Alternatively, you can also link a *source* to the process variable directly (the *source* and its *switch* in one). As a result, you can deactivate or avoid the topological interlocking when switching the source.

STATUSES

The following applies for statuses:

- A switch and a source are switched on (closed) if the value of the linked variable is *1*.
- A switch is invalid if the value of the linked variable is >*1* or has an *INVALID* status bit.
  An invalid switch provides the source number *0* (undefined) at its exit (connection 2) instead of the source number entering. In the direction from input to output, the switch behaves as if it were open.

  Note: if the main variable has the status *INVALID*, the whole subsequent network is *INVALID*, because the status of the network is not known. The status *INVALID* is forwarded using subsequent closed switches.

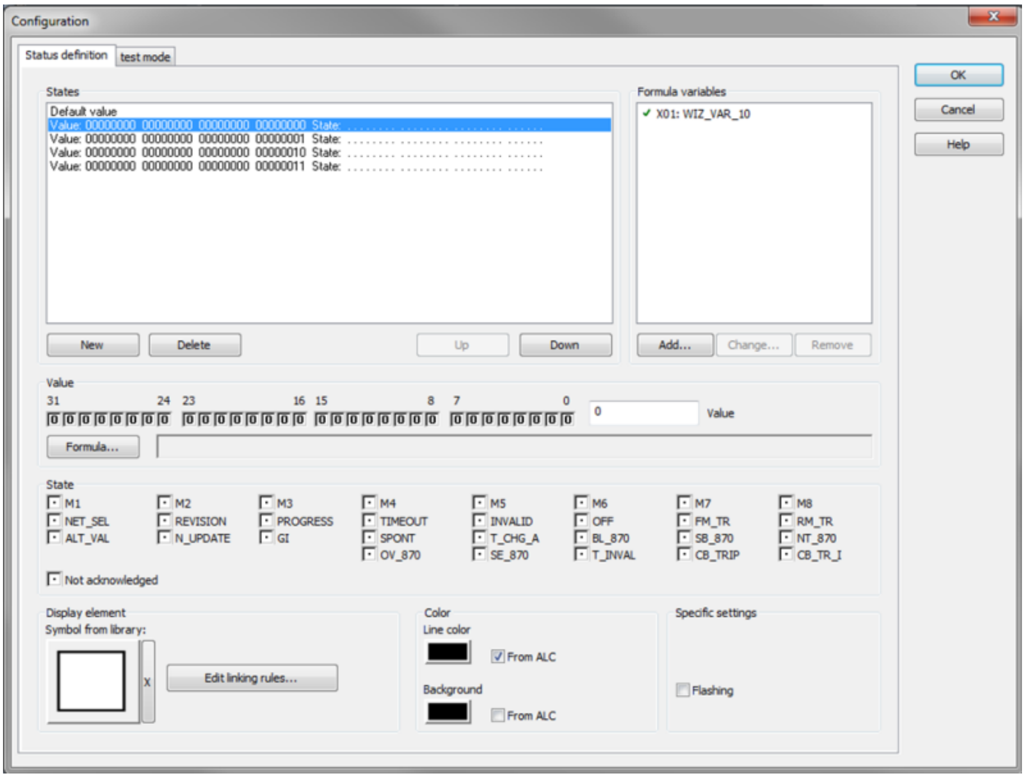
  > **Attention**
  >
  > If, in the statuses of the combined element, the color and the fill color from the **ALC** property is activated, it is not just the lines but also the procedural elements that are colored in the Runtime.

3.1.1 Switch example - colors from ALC

EXAMPLE 1

Combined element with value status *00* and line color from ALC:

1. Configuration in the Editor:
   - Combined element with value status *00*
   - Line color from ALC active



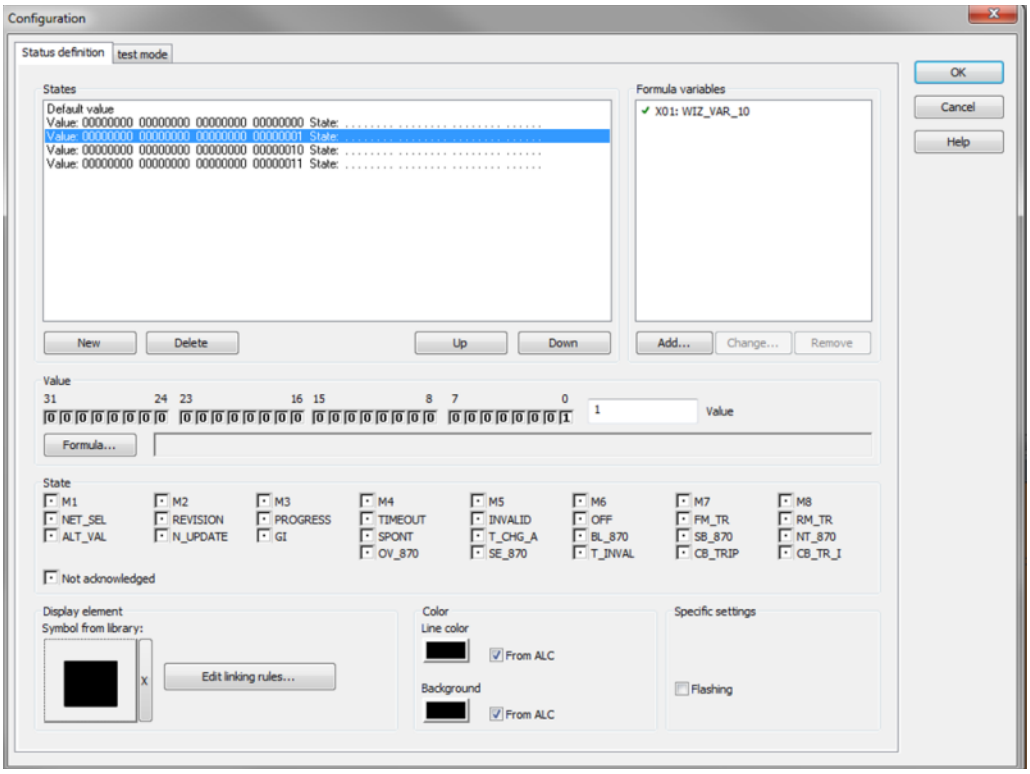
2. Produces the following in the Runtime with:
   - Source color: green
   - Color without voltage: white
   - Switching status: *off/open* (value *0*)

EXAMPLE 2

Combined element with value status *01* and colors from ALC:

1. Engineering in the Editor
   - Combined element with value status *01*

- Line color from ALC active
- Fill color from ALC active



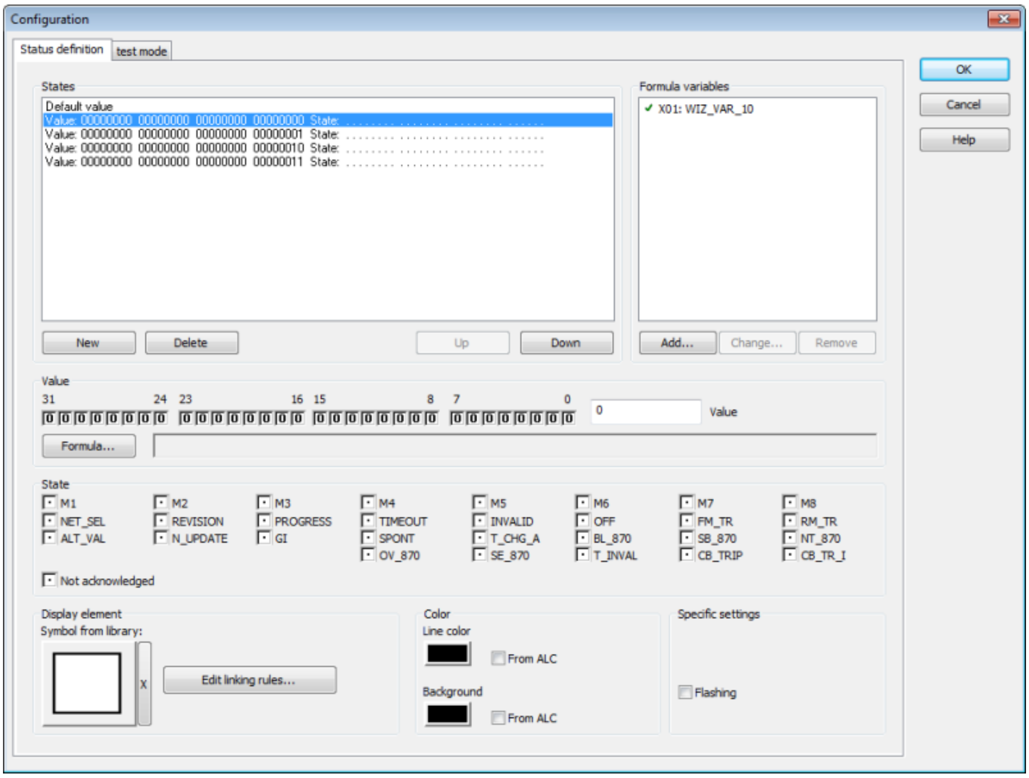
2. Produces the following in the Runtime with:
   - Source color: *green*
   - Color without voltage: *white*
   - Switching status: *on/closed* (value1)

EXAMPLE 3

Combined element with value status *00* without colors from ALC:

1. Configuration in the Editor:
   - Combined element with value status *00*

- Line color from ALC not active



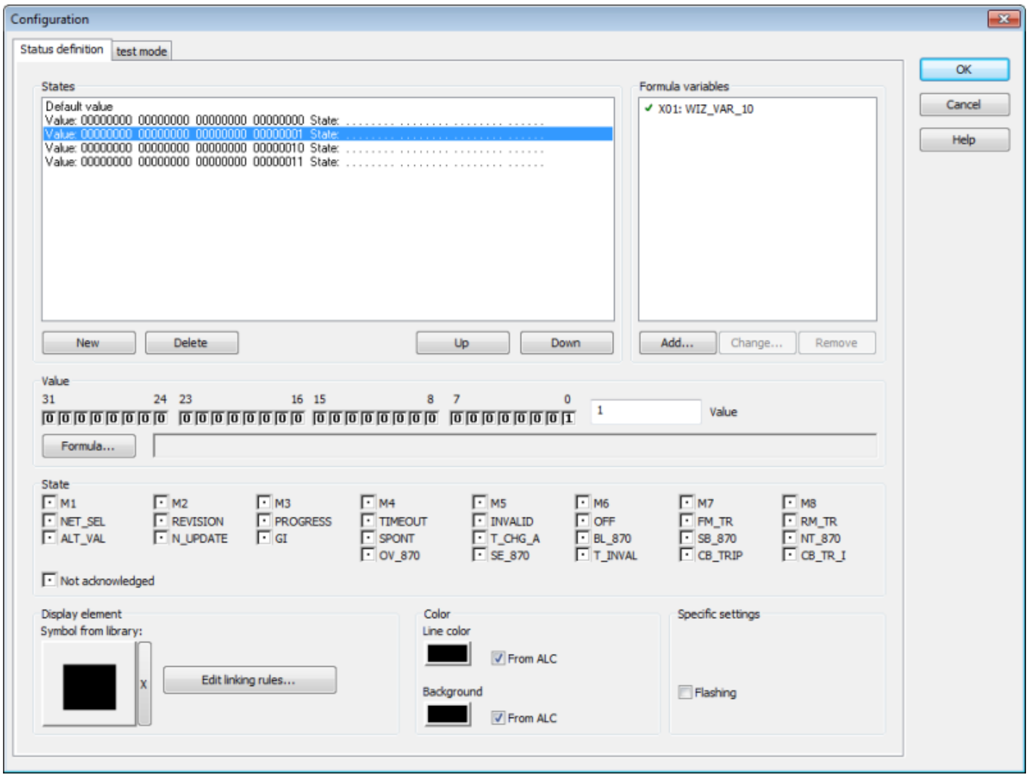
2. Produces the following in the Runtime with:
    - Source color: *green*
    - Color not energized and construction color of the line: *white*
    - Defined line and fill color of the combined element: *black*
    - Switching status: *off/open* (value *0*)

EXAMPLE 4

Combined element with value status *01* without colors from ALC:

1. Engineering in the Editor
    - Combined element with value status *01*
    - Line color from ALC inactive

- Fill color from ALC inactive



2. Produces the following in the Runtime with:
   - Source color = green
   - Color not energized and construction color of the line: *white*
   - Defined line and fill color of the combined element: *black*
   - Switching status: *on/closed* (value1)

3.1.2 Connection points of procedural elements

When configuring, a line is connected to a procedural element (combined element) by overlapping drawings in the screen at connection points of the combined element. Only one line can be connected to the same connection point at the same time. All lines that start within the area defined, are connected (Topology from the graphic).

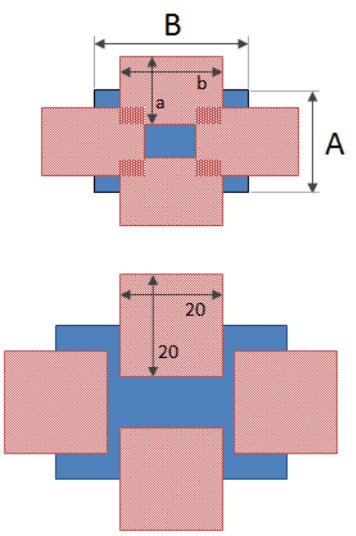
> **Attention**
>
> Use ALC elements only in un-rotated state because:
>
> The calculation for the topological model for the ALC in the Editor is based on the position of the elements in un-rotated state and without considering any dynamics.

CONNECTION POINTS AND CONNECTION AREAS

- The connection area for a connection point is in the middle of each side of the combined element. Each combined element thus has four connection points.
- The size of a connection area corresponds to 2/3 of the height and width of a combined element, but no more than 20 pixels.
- Each connection area is centered in the middle of the respective element corner and stretches symmetrically inwards and outwards, to a maximum of 10 respective pixels.

> **Attention**
>
> If the combined element is less than 30 pixels, connection areas within an element overlap. Lines that could touch can cause errors (compilation, coloring).

You can see the possible connection points for combined elements smaller and larger than 30 pixels in the illustration.



Colors:

- Blue: Combined element
- Red: Connection areas

Dimensions:

- **A**: height of the Combined element
- **B**: width of the Combined element
- **a**: Width of the connection area: 2/3 of **A**, but a maximum of 20 pixels.
- **b**: Length of the connection area: 2/3 of **B**, but a maximum of 20 pixels.

RULES

- If a line is outside the connection area, no connection is detected and there is thus no coloring of the line. So there will also be no coloring for further lines.
- With sources, drains and *Links*, all described connection points can in principle be used.
  Attention: With sources and drains, only one connection point can be used at the same time. If different connection points are used at the same time, undefined states can occur. Elements of the type *Link* can also use several connection points at the same time. The incoming color information is passed on to all lines.
- With switches/disconnectors/sliders and transformers, the connection *1* (supply) is on the left or on the top and connection *2* (output) is on the right or on the bottom. This sequence can be changed with the **Switch input/output** property.
  Attention: At switches and transformers it has to be cared, that only one input connection and one output connection is used. The simultaneous use of several input or output connection points results in inconsistencies and is therefore not reliable.
- For all procedural elements the following is true: Only one line can be connected to a connection point. Junctions cannot be realized directly on an element but must be drawn with lines.

3.1.3 Switch input/output

If a transformer, a disconnector or a switch is configured, the input and output can be swapped. To do this:

1. Select either *transformer*, *disconnector* or *switch* as a **Function type**
2. Activate the checkbox**Switch input/output**

The input is then set at the bottom right and the output at the top left.

OVERVIEW

Device configuration	Input	Output
normal	left	right
normal	top	bottom

Device configuration	Input	Output
swapped	right	left
swapped	bottom	top

3.1.4 Measuring points

Variables are linked for the visualization of ALC sources that currently supply the process-technical element or start from this element.

These variables are supplied with the current values from the ALC module. Names of the sources can be visualized by the ALC module by displaying these variables.

These properties are summarized in the **Automatic Line Coloring** properties group combined element and summarized in the **Condition** area.

Configurable properties:

- **Input active sources**
  (STRING data type)
- **Output active sources**
  (STRING data type)
- **Highest priority source input**
  (numeric data type)
- **Highest priority source output**
  (numeric data type)

DISPLAY IN RUNTIME

The linked variables are displayed with the following values in zenon Runtime:

- Number (on page 29) of the active sources (STRING data type):
  - *Active source number(s)*: The numbers of all active sources are summarized in a STRING variable.
    This is applicable for both *input* and *output*.
    Several source numbers are separated by a semicolon (;). Sorting is carried out according to the priority of the source.
    Note: With multiple sorting, the source is represented with several entries at the input.
  - <*Empty*>: not supplied
- Number of the highest priority source (numerical variable):

- *0* or greater: Number of the highest priority source. This is applicable for both *input* and *output*.
- *-1*: not supplied

3.2 Lines

Lines are represented by the vector elements Line, Polylines and Pipe.

If the **Color from ALC** property is activated for a line, the coloring is defined by the ALC configuration. Lines are automatically colored by the system depending on the status of the procedural elements and the ALC settings. The color is usually defined by the highest priority source number of the medium flowing through the line. If the status is *empty/not supplied*, the element is not colored by **Automatic Line Coloring**. In this case, the configuration of the **Line color** property (in the **Line** properties group or **Line color** in the **Line color dynamic** properties group) is used for visualization in the Runtime.

Attention

Even invisible lines that have an activated **Color from ALC** property continue to forward the colors to the linked ALC elements. This forwarding occurs regardless of whether they are visible or invisible in the Runtime.

Exception: Lines with **Alias** display the color, but do not forward it.

Note: A line can be displayed invisibly due to:

- Configurations of the properties of **Visibility**:
  The properties are located in the **Visibility/flashing** properties group
- states of the **Combined element** that do not currently apply

The ALC color will continue to be forwarded nonetheless. The value of the linked variable does not play a role. It only affects visibility, not the forwarding.

You define the display type of the line by means of drop-down lists:

- **Priority for display**
- **display multiple supplies**
- **display secured supply**

The following options are available in the properties of the lines:

Parameter	Description
Color from ALC	Activates the automatic line coloring for this vector element. That means: If the source for the line is active and all switches/valves leading from the source to the line are closed, the line is colored accordingly. If the line is fed by a single

Parameter	Description
	source, the defined source color is used for coloring the line. The line width is not changed. **Note:** If **Alias** is activated, this alters the behavior. The line then displays the color of a different element and does not forward it.
Priority for display	Defines if *multiple supply*, *secured supply* or both are displayed. Default: *Multiple supply*
Secured supply	The element is displayed according to the rules of the secured supply. A line is then considered to have a secure supply if it is supplied by at least two different switches or transformers with a non-system source. System sources do not contribute to secured supply, but do not exclude it.
Multiple supply	The element is displayed according to the rules of the multiple supply. A line is considered to have multiple supplies if it is supplied by at least two different sources. In doing do, it does not matter if they are system sources or user sources and from which side the line is supplied by the sources.
No priority	The coloring rules for *multiple supply* and for *secured supply* are applied at the same time if both criteria are met. That means: The line is displayed twice as wide and in the form of a two-colored, dashed line if the following have been configured for a line: - has *multiple supplies* and a *secured supply* - the priority is set to *No priority* - The display for multiple supply is set to *two sources with highest priority*, - the display for secured supply is set to *double width*
display multiple supplies	Multiple supply means that a line is supplied by multiple sources at the same time. Here you can define how lines with multiple supply are displayed. Default:*highest priority source*
highest priority source	The line gets the color of the source with the highest priority. **Note:** Priorities correspond to the sequence chosen in the

Parameter	Description
	ALC configuration.
two highest priority sources	Applies for lines fed by two or more different sources. The two sources with the highest priorities define the coloring. The line is displayed with these two colors (dashed). The dash length can be changed using the **Dashing length supplied multiple times** property. System sources apply for multiple supplies just as with genuine sources and color lines in two colors it they are configured accordingly.
Alternative color	The color defined in the **Alternative color** property is used.
Dashing length supplied multiple times	Defines the dash length (in pixels) of lines, polylines or tubes for the dashed ALC coloring for *two sources with the highest priority* for **display multiple supplies**. Possible values: - Minimum: *0* (automatic dash length) - Maximum: *32767* Default: *0*
Alternative color	Alternative color for the ALC coloring of lines, polylines or tubes with multiple supplies.
display secured supply	**Secured supply** means that a line gets multiple supplies from one source (parallel). Here you can define how **Secured supply** is displayed. A line is always displayed as having a *secure supply* if it is supplied by at least two switches with a genuine source (not system source). Default: *normal*
double width	Relevant for lines fed in parallel by the same source. If this is the case, the line is displayed with double the configured width. Example: A line of line width *5* is displayed with a width of *10* if it has a secure supply. If this line is fed by two or more different sources (multi-supply), the line width does not change! The color is *always* defined by the source with the highest

Parameter	Description
	priority!
double brightness	Relevant for lines fed in parallel by the same source. The line is displayed with double the original brightness. If this line is fed by two or more different sources (multi-supply), the line color does not change! If this line is multi-fed from one source (secure supply), the line is displayed with double the original brightness. Formula for the calculation of the double brightness: ▸ The defined RGB color is transformed to the HLS system. ▸ L (luminance = brightness) is recalculated by *NewLuminance = 240*3/4 + L/4* ▸ The color value is recalculated to the RGB system with the new brightness. The color is *always* defined by the source with the highest priority!
normal	The element is displayed in the color of the source and with the configured width.
Use alias	*Active*: Alias is used. The line displays the ALC color of a different ALC element. **Example:** If the line is a **Alias** of the circuit breaker, a line on a separate screen which is not connected to other elements symbolically represents the state of an entire branch of the **Topological network**.
Alias	Opens the Dialog (on page 43) for selecting an alias of an ALC element whose color is supposed to be displayed by the line.

Information

The source color and the priorities of the sources are defined in the project properties.

User-defined sources must have an ID higher than *9*. IDs up to *9* are reserved for system sources.

> **Information**
>
> The calculation of the color of a line in the Runtime is done with the following priority list:
>
> 1. Automatic Line Coloring
>   (highest priority, overrules all other settings)
> 2. Dynamic colors
> 3. Static colors

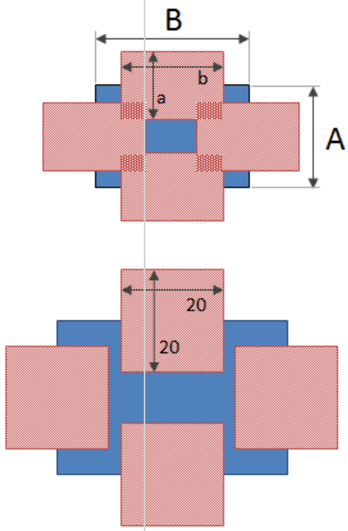
3.2.1 Example

In the following example Source 0 has the color blue and Source 1 has the color red. And Source 0 is the source with the highest priority.

Source 0

Source 1

This results in the following displays for the different options:

	Line / Polyline	Pipe
highest priority source		
two highest priority sources		
double width		

	Line / Polyline	Pipe
double brightness		

3.2.2 Connection points of lines

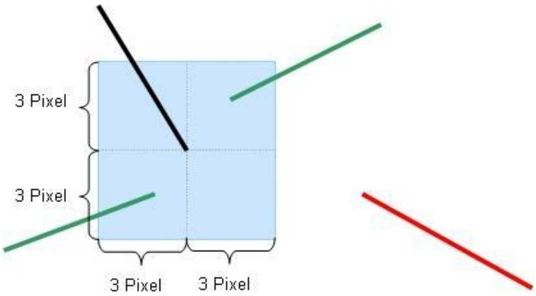
The connection of one line (line, polyline or tube) to another line is done with overlapping drawing in the screen at connection points. The connection points - either connection areas - are at the start and the end of each line and are around 3 pixels large.

Example

The start point of a line has the coordinates (start point x/start point y): 150/100 pixels.
This results in a connection area (x / y): 147 - 153 / 97 - 103 pixels.

If the line start or end of this line and that of one or more other lines is within this area, the lines are automatically connected without any further engineering. A mere overlapping of the connection areas of the single lines is not sufficient!

In the following illustration the connection area is displayed graphically (the green lines are connected to the black one, the red line not.



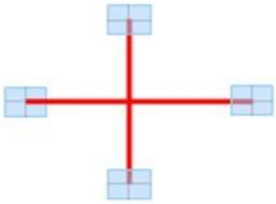
Information

Any number of lines can be connected in a connection area.

Attention

If a line is outside the connection area (e.g. the red line in the illustration), no connection is established and there is no coloring of the line. So there will also be no coloring for further lines.

Line crossings can easily be realized, if the ends of the lines are not in the connection area.



Attention

Use ALC elements only in un-rotated state because:

The calculation for the topological model for the ALC in the Editor is based on the position of the elements in un-rotated state and without considering any dynamics.

3.3 Checking the project

Engineer the desired procedural elements and lines in one or more screens and save these screens. Then you can check via **Create all Runtime files** or **Create changed Runtime files** whether there are any errors or conflicts in the screens. If error or conflicts should exist, corresponding error messages or warnings are displayed in the output window.

Information

Double click the corresponding line in the output window. The screen with the erroneous screen element will be opened automatically. If the erroneous screen element is part of a symbol, the corresponding symbol is automatically selected.

The following error message can be displayed.

- ALC: Screen '%s' - Two Link elements with different Link number or name are connected to line '%s' . (double clicking opens the screen and selects the line.)
- ALC: Screen '%s' - More than two connection points are used at element '%s'. For each element only one input and one output may be used. (double clicking opens the screen and selects the element)

The following warnings can be displayed.

- ALC: Screen '%s' - Alias line '%s' is connected to a no-alias line. (double clicking opens the screen and selects the line.)
- ALC: Screen '%s' - Alias element '%s' is connected to a no-alias line. (double clicking opens the screen and selects the element)

- ALC: Screen '%s' - No-alias element '%s' is connected to an alias line. (double clicking opens the screen and selects the element)
- ALC: Screen '%s' - Line '%s' is only connected on one side. (double clicking opens the screen and selects the line.)
- ALC: Screen '%s' - Element '%s' is not connected. (double clicking opens the screen and selects the element)
- ALC: Screen '%s' - Element '%s' is only connected on one side. (double clicking opens the screen and selects the element)

In the error messages or warnings the corresponding elements are identified using the element reference. This reference also serves as the link key for ALC aliases.

4 Configuration

To configure ALC:

1. In project properties, select **ALC configuration** the property in the **Automatic Line Coloring** group
2. Click on the **...** button.
3. The dialog for configuration is opened
4. Configure the desired properties for:
   - Sources (on page 29)

     Create a new source.
     To do this, click on the **New** button. This creates a new entry with the name *Source [serial number]* at the end of the list of the sources.
     Note: In doing so, note that the system sources (ID 0..9) have a pre-defined meaning or are reserved for future versions.

     Then configure the colors of the new source by selecting the color value with a mouse click and clicking on the ... button. This opens the drop-down menu to select the colors.

     Note also the principles for coloring for *UNDEFINED* (on page 33).
   - Interlockings (on page 34)

     Configure which **topological interlockings** the **Command Processing** module should take into account.
     Note: this tab is only available with a valid license for the optional **ALC - Topology Package** module.
   - Screen marker (on page 40)

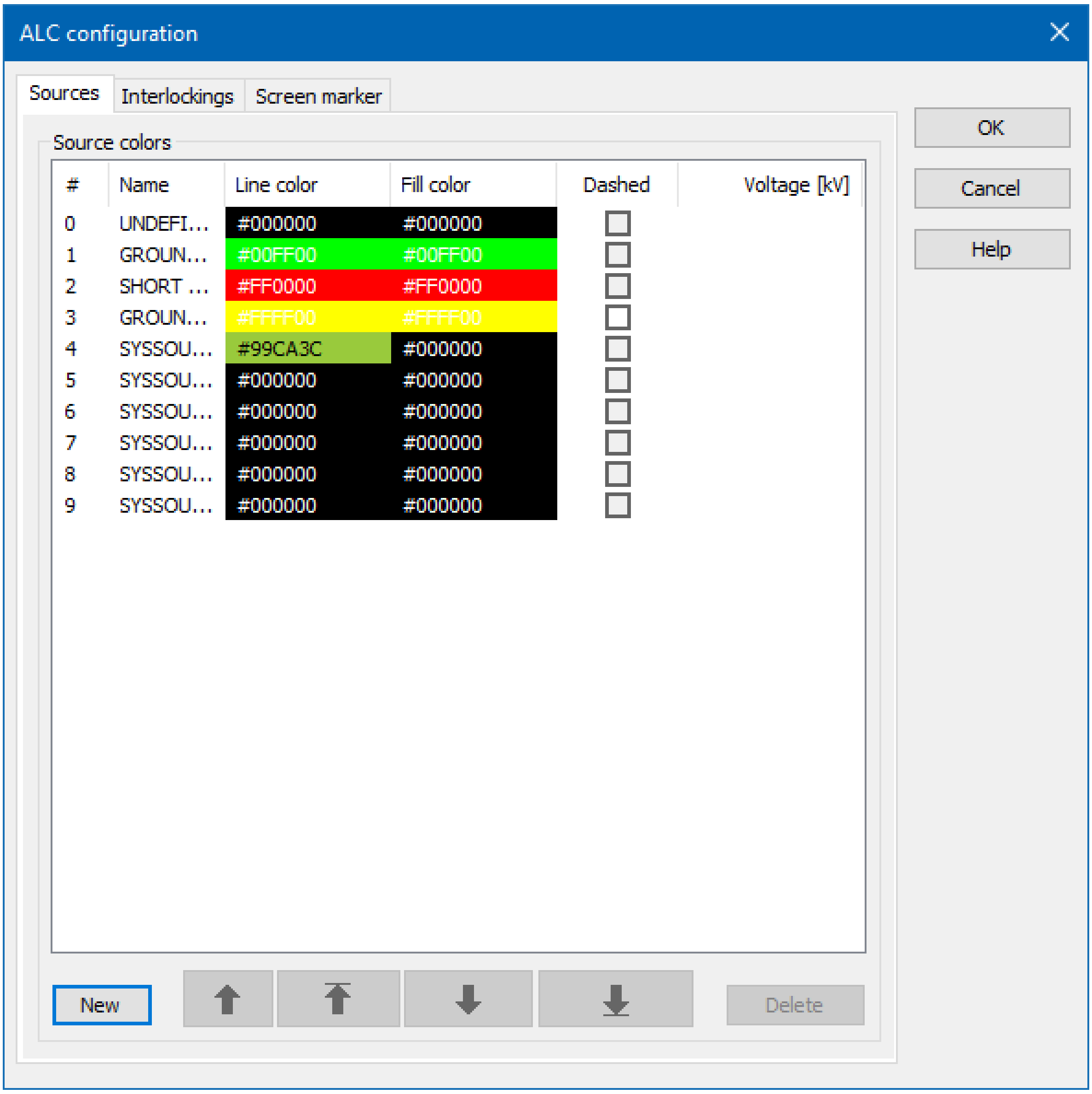
Configure the color table for the screen marker for **impedance-based fault locating**.
Note: this tab is only available with a valid license for the optional **ALC - Topology Package** module.

4.1 Configuration of the sources

The sources, e.g. their names and colors (sequence and priority), are configured project-specifically within the project properties under **ALC configuration**. Sources with ID between *0* and *9* are reserved for system sources. The configuration of those that already have a function (such as *GROUNDED* - the color of the "earth" source) may not be changed. Those that do not yet have any functionality in the current zenon version remain reserved for future versions.

The source colors from ID #10 are freely available for the process-technical elements.

Examples: Source "*Generator*" or "*110kV*". Add further colors to do this.



SOURCE COLORS

Parameter	Description
Number	Internal unique consecutive number, so that the source can be identified. This number is given by the system automatically and cannot be changed. **Attention:** The numbers *0* to *9* are reserved for the system sources and must not be used user-specific.
Name	Logical name for the source (e.g.: 'water' or 'grounded'). This name is also

Parameter	Description
	used when selecting the source number for Combined elements. You can change the name by clicking it with the left mouse button. With this edit mode is switched on. The changes are accepted with the **Enter key** or by selecting another source. **Note:** The labels are not language switchable.
Line color	Line color of the respective source. This color is used for coloring lines, polylines and as the outside color of tubes.
Fill color	
Dashed	Type of display for grounded sources. - *active*: Line for grounded source is displayed dashed in the Runtime. - *Inactive*: Line for grounded source is displayed normally in the Runtime. **Note:** This checkbox can only be activated for the system source **GROUNDED**. This check box is grayed out for all other sources.
Voltage [kV]	Nominal voltage of the source in kilovolts. This option is not available for system sources. Default: *empty* Input range: - 0 - 4000 KV - Decimal places must be separated by a (**.**). - Invalid entries are set to *0*. - Negative entries are changed to positive.
New	Adds a new color.
Delete	Deletes the selected color.
Upwards (arrow symbol)	Moves selected source up one position.
Fully upwards (arrow symbol)	Moves selected source to the start of the list.
Downwards (arrow symbol)	Moves selected variable down one position.
Fully downwards	Moves selected source to the end of the list.

Parameter	Description
(arrow symbol)	

CLOSE DIALOG

Option	Description
OK	Applies all changes in all tabs and closes the dialog.
Cancel	Discards all changes in all tabs and closes the dialog.
Help	Opens online help.

The colors can be configured directly by entering the corresponding hexadecimal code or by using a color palette.

For direct input:

1. Click on the color description with the left mouse button.

   The field is switched to editing mode.

2. Enter the code.
3. Press the **Enter key** or select another source to apply the change.

To select via a color palette:

1. highlight the desired line.
2. Click on the **...** button behind the color
   Note: The **...** button is only visible if the color entry is selected with a mouse click.

   The color palette is opened in the context menu.

3. select the desired color

The hexadecimal code describes the RGB color value and consists of the following. **#RRGGBB**.

Element	Meaning
#	Identifier to indicate that a hexadecimal color code is used.
RR	2 digits are the red value of the color in hexadecimal system. *0-255* corresponds to *0-FF*
GG	2 digits are the green value of the color in hexadecimal system. *0-255* corresponds to *0-FF*
BB	2 digits are the blue value of the color in hexadecimal system. *0-255* corresponds to *0-FF*

Information

The sequence in this list represents the priority of the sources, with the first element having the highest priority.

To change the priorities of the single sources, they can be moved upwards or downwards using the arrow buttons

Attention

Limitations when deleting the sources and resetting fault colorings:

Sources with ID between *0* and *9* are reserved for system sources. You can:

- not be deleted:
- not be reset as an erroneous color

Deleting sources

In order for sources to be able to be deleted, they must have an ID from *10*. Only the source with the highest ID can be deleted.

Resetting erroneous colorings

In order for erroneous colorings to be able to be reset once the cause has been rectified, no system source colors can be used. A color for IDs from *10* must be selected.

4.1.1 Coloring mode for UNDEFINED

Coloring in the network can be implemented in two modes with the *UNDEFINED* status:

- *Standard*
- *Input takes priority*

This setting is made using the **Automatic Line Coloring**/**Mode for coloring** project property.

STANDARD

The internal calcualtion of the topology (= graph search) starts with a source and goes through the whole network, so that each closed switch (switch variable has the value *1*) per direction is only gone through once, so no cycles occur. In doing so, each node visited (=line segment) is colored with the source color. The directly-related lines are marked as a node.

If the search finds a switch that has a switch variable with one of the following states, the UNDEFINED color is used for coloring from this point onwards:

- *INVALID* [value: any],
- is invalid [value: *3*]
- is in intermediate position [value: *2*])

The graph search is now continued in the same form. Each switch is gone through just once per direction with the *UNDEFINED* color. Therefore each switch can be gone through a maximum of four times per source:

1. with source number in forwards direction,
2. with source number in backwards direction,
3. with UNDEFINED in forwards direction,
4. with UNDEFINED in backwards direction,

INPUT TAKES PRIORITY

With the *Prior supply* setting, only lines that have a supply from at least one source but not clearly from any one source are colored as *UNDEFINED*. If a line is supplied with at least one source, it can no longer receive an *UNDEFINED* color from another source.

This search is a two-stage search:

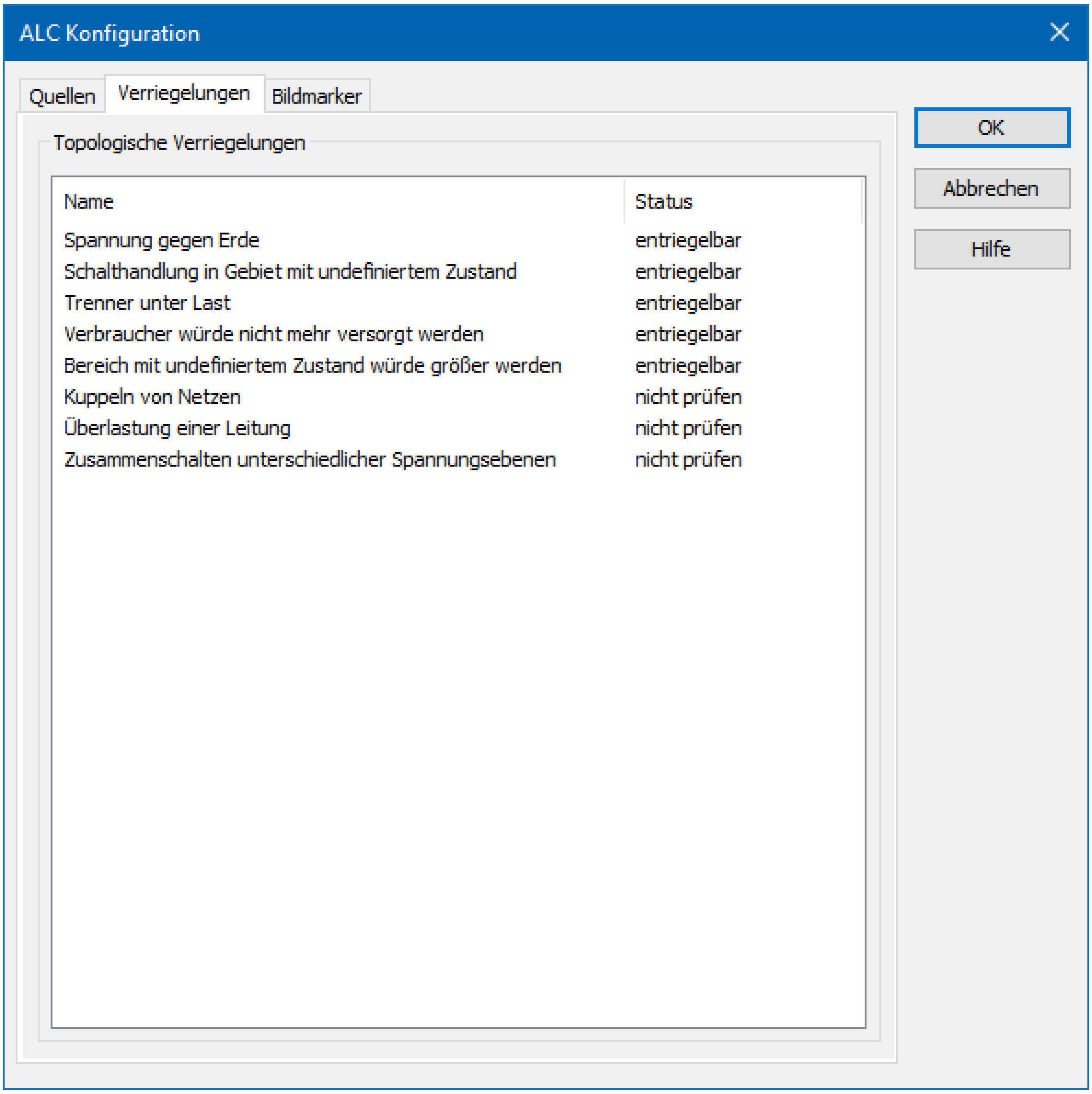
- In the first stage, as with *Standard*, the source color is distributed in the network from each switched source, as long as the next switch is closed. The search is ended if the switch is open or invalid/undefined.
- In the second stage, the search is started at each invalid/undefined switch that receives a supply from one side and the *UNDEFINED* color is distributed to the unsupplied side. This search also considers the switches that are invalid/undefined as closed and thus distributes the *UNDEFINED* color in the network until it meets a clearly open switch. In addition, a search is ended if a line element is reached that is already supplied.

4.2 Configuration of topological interlockings

The **Command Processing** module can automatically calculate the interlockings in Runtime. These interlockings are based on the dynamic status of an electricity grid. The topology of the grid is configured via **ALC**. If the Command Processing detects that the execution of a command corresponds to the interlocking condition, the execution of the command is prevented.

Example: Using the ALC configuration and the current states (*ON/OFF*) of *sources*, *Switches*, *disconnectors* etc. the **Command Processing** can automatically detect that the execution of a command would lead to the status "*Voltage towards ground*". In this case, the execution of the command will be suppressed.

The check of the topological interlockings for the **Command Processing** in the ALC Model is configured individually for each project. This configuration also determines whether a user can unlock an interlocking (provided they also have the **authorization level for unlocking** for the action).



The settings made here apply globally, for the whole Topological Model. The following conditions are available:

Parameter	Description
Voltage towards	Interlocking is active if a *switch/disconnector* is to be closed, to which

Parameter	Description
ground	grounded potential is connected to and one or more connections in the ALC model are live or undefined. This ensures that the voltage towards the ground in a line is also detected by an intermediate *transformer*. Default status: *unlockable* **Examples:** - After switching the element, one side is grounded and the other is live.
Switching operation in area with undefined status	Interlocking is active if a *switch/disconnector* is to be closed and both of its connectors are *undefined* or *invalid*. Default status: *unlockable*
Disconnector under load	Interlocking is active if certain conditions have been met for switching the *disconnector* on (= *close*) or off (= *open*). Default status: *unlockable* Conditions: see "Disconnector under load - interlocking conditions (on page 38)" section.
Device would not be supplied	Interlocking is active if a *switch/disconnector* is to be opened and a device that is switched on and supplied with voltage from a *source* (*drain*) then loses supply. Default status: *unlockable*
Area with undefined status would increase	Interlocking is active if a *switch/disconnector* is to be closed and one connector has the status *undefined* or *invalid* and the other does not. The interlocking is also reported if the *command* has been configured with the **switching direction** *none*. Default status: *unlockable*
Interconnect grids	This interlocking is to prevent unintended connection of two networks with different generator sources. Interlocking is active if two ALC network areas in which different *generators* are located are switched together. Process-technical *generator* elements with different numbers of **sources** are considered different generators. **Note:** The numbers of the sources are configured in the dialog of the

Parameter	Description
	ALC configuration project property in the **Source** tab. Process-technical elements of **Function type** *source* are not considered to be generators. The interlocking is active if: - Both sides of the element are live after switching. - One page contains a generator source that is not present in the other network. Default status: *do not check*
Line overload	The interlocking is active if switching would lead to to a current overload of a line or a transformer in the ALC network. Default status: *do not check* A name can be configured for the element with the **Transformer name** properties (for transformers) and **Line name** (for a line). This name is used in Runtime as an interlocking text if the element would be overloaded after a switching action. In addition, this interlocking is active if - A **load flow calculation** is not possible. This is the case for missing or invalid measured values, as well as in the event of a switch having an undefined status (not on or off) - The **load flow calculation** cannot achieve a conclusive result. **Note:** This interlocking is only available for the optional **load flow calculation**.
Interconnect various voltage levels	The interlocking is active if ALC sources with different nominal voltages are switched together. This check is carried out using the complete network (not just for the switch). Default status: *do not check*

STATUS

Status in the Options column allows you to configure user interaction options in the Runtime. Select the behavior in the Runtime via a drop-down list.

Parameter	Description
do not check	No check and interlocking is carried out for this condition.
unlockable	The interlocking conditions are checked for this condition. If the condition applies, the interlocking goes into operation. The interlocking can be unlocked by a user in the Runtime, for instance, on a **Command Processing** type screen. This unlocking action is logged in the **Chronological Event List**.
not unlockable	If the interlocking goes into operation for this condition in the Runtime, this cannot be unlocked by a user. The action (such as a *switching command*) is not carried out.

EXCEPTION TOPOLOGICAL INTERLOCKING

The topological interlocking is not carried out if:

- the variable of a switch has the state Revision
  or
- the variable is corrected manually by hand or is set to **Substitute value** and the value of the variable after the change is the same as the initial value (the value before the change).

  Example:

  - *OFF* switch position is corrected manually to or replaced by *OFF*
  - *ON* switch position is corrected manually to or replaced by *ON*

4.2.1 Disconnector under load - interlocking conditions

For the **disconnector under load** topological interlocking, a disconnector can be switched (opened or closed) if one of the following conditions is met for the line segments that connect the disconnectors:

WHEN TURNING THE DISCONNECTOR ON (CLOSING):

A check is carried out to see whether the topology before switching to *ON* is in one of the following states:

- Both line segments are supplied/grounded by the same source;
- One line segment does not receive any voltage and the other line segment is grounded;
- A line segment is not under load.

WHEN TURNING THE DISCONNECTOR OFF (OPENING):

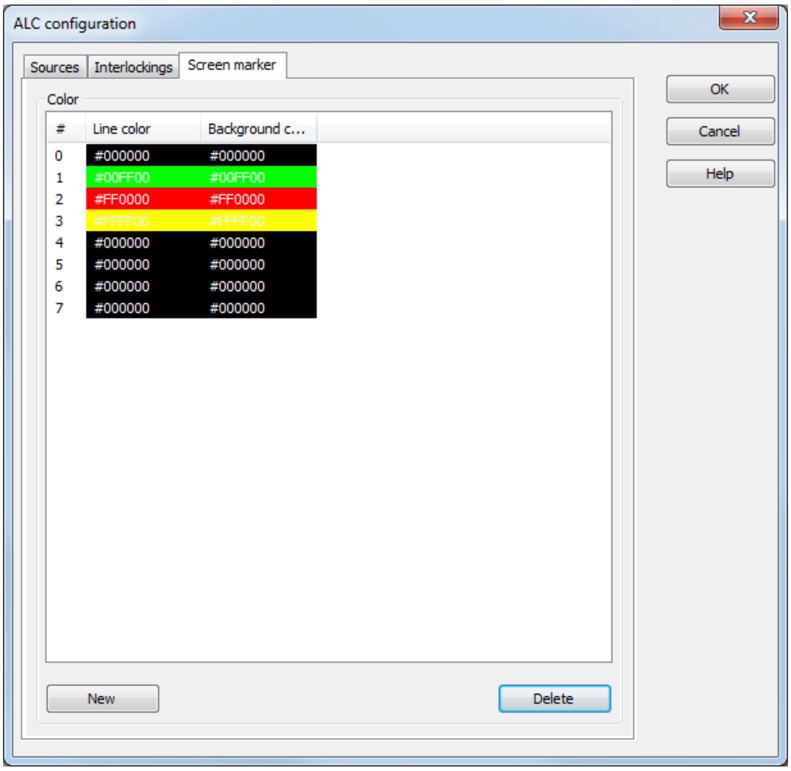
A check is carried out to see whether the topology after switching to *OFF* is in one of the following states:

- Both line segments are supplied by the same source;
- One line segment stops receiving voltage, the other line segment is grounded;
- A line segment stops being under load.

> **Information**
>
> Meaning of "not under load"
>
> The status *not under load* means:
>
> - Either:
>   All switches and disconnectors connected to the line segment are open.
> - Or:
>   Switches and disconnectors connected to the line segment are closed but only connect to a further segment that is also not under load.
>
> In addition, all of the following conditions must be met for the status of *not under load*:
>
> - All sources and consuming devices connected to the line segment are switched off.
> - No transformer may be connected to the line segment.
> - It must not be a line that is only connected to this disconnector (one open line).

4.3 Configuration of the screen marker

Here you configure the color table for the color marker for the impedance-based fault detection and calculation of load distribution (on page 64). See also: **AddMarker**.



Parameter	Description
Number	Unique internal serial number for clear assignment. This number is given by the system automatically and cannot be changed.
Line color	Line color of the screen marker.
Fill color	Fill color of the screen marker.
New	Adds a new color.
Delete	Deletes the selected color. **Note:** Only the last color in the list can be deleted. Standard colors cannot be deleted.

The colors can be configured directly by entering the corresponding hexadecimal code or by using a color palette.

For direct input:

1. Click on the color description with the left mouse button.

The field is switched to editing mode.

2. Enter the code.
3. Press the **Enter key** or select another source to apply the change.

To select via a color palette:

1. highlight the desired line.
2. Click on the **...** button behind the color
   Note: The **...** button is only visible if the color entry is selected with a mouse click.

   The color palette is opened in the context menu.
3. select the desired color

The hexadecimal code describes the RGB color value and consists of the following. **#RRGGBB**.

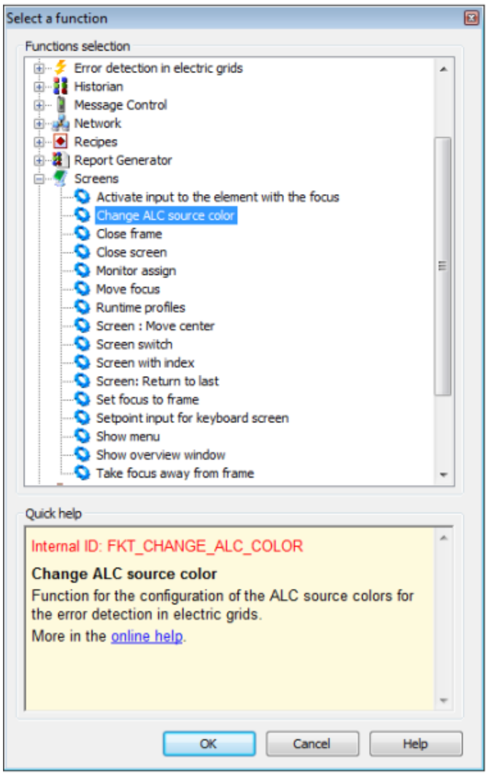
Element	Meaning
#	Identifier to indicate that a hexadecimal color code is used.
RR	2 digits are the red value of the color in hexadecimal system. *0-255* corresponds to *0-FF*
GG	2 digits are the green value of the color in hexadecimal system. *0-255* corresponds to *0-FF*
BB	2 digits are the blue value of the color in hexadecimal system. *0-255* corresponds to *0-FF*

5 Function: Change ALC source color

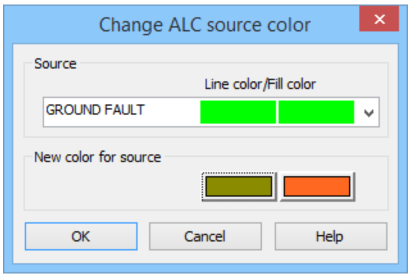
The foreground and background color of an ALC source can be temporarily changed for the coloring in the Runtime using the **Change ALC source color** function. The change remains until Runtime is ended, reloaded or the function is executed again. To create the function:

- select New Function
- Navigate to the Screens node

- Select **Change ALC source color**



- The dialog to define line colors and fill colors opens
- define the desired color



Property	Function
Source	Drop-down list to select the source and display the colors currently assigned. These colors cannot be changed here.
New color for source	Click on the color and a dialog opens to select a color.

6 Alias for detail screens

To display individual screens, a partial area can be taken from the topological network and displayed individually by means of an *Alias*. The screen elements in the detail screen are not included in the topological model, but do however get their ALC colors from the model. These screen elements relate to an alias of the screen elements from the overall screen.

> **Attention**
>
> Aliases are only valid within a project.
>
> This means that for symbols that contain elements with links to aliases:
>
> If the symbol is added to the **general symbol library** or the **library in the global project** and edited there, all ALC alias information is lost without notice!

CREATE ALIAS

Aliases can be created for the elements:

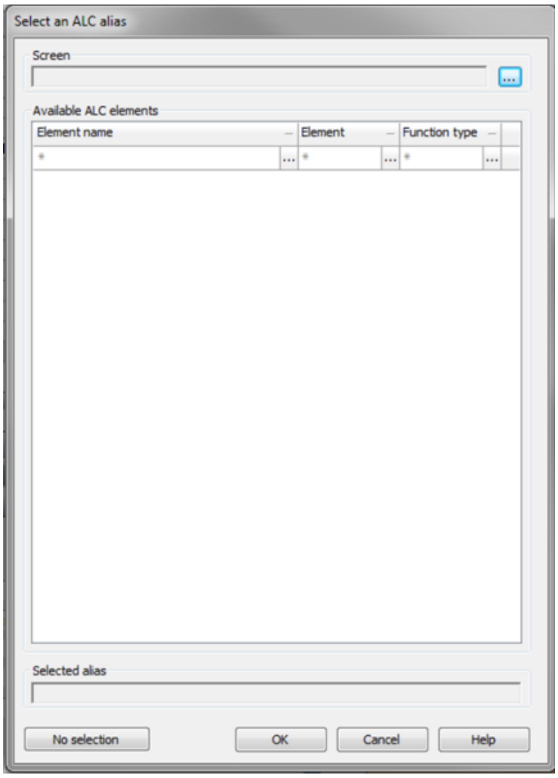
- Line
- Polyline
- Pipe
- Combined element

> **Attention**
>
> An ALC alias cannot be created if a period (**.**) is contained in the name of the selected screen.
>
> Solution: Replace the period in the screen name with a different character, such as an underscore for example (**_**).

To create a source element as an alias:

- Activate, in the **Automatic Line Coloring** properties group for the element, the **Use alias**.
  Note: To do this, the **ALC** module must be licensed and the **Color from ALC** property must be activated.
- In the **Alias** property, click on the **...** button.

- The dialog to select the element opens.



Parameter	Description
Screen	Click the **...** button and a dialog opens to select a screen.
Available ALC elements	Shows the elements that belong to a screen with the element name, type of element and function type. Clicking on an element selects an alias. **Filter** The elements can be sorted according to all columns. When setting a filter, the options offered from all other filters are reduced to values that can be sensibly combined. - **Name**: Input of a user-defined search term with wild cards (*). The last 12 search terms are offered in the list until the Editor is ended. - **Element**: Select from drop-down list. - **Function type**: Select from drop-down list. Clicking on **...** opens saved search or drop-down list.

Parameter	Description
	If a filter is active, clicking on the **X** deletes the filter.
Selected alias	Shows the selected element in the field of **Available ALC elements**.
no selection	Removes selected element.
OK	Saves selection and closes dialog.
Cancel	Discards changes and closes dialog.
Help	Opens online help.

Information

When selecting an element for a new alias, only elements and screens from the same project that the alias was defined in can be selected. Elements from subprojects or parallel projects are not available.

REPLACING ALIAS NAMES

Aliases can be changed when switching screens with Replace link. A detail screen can therefore be displayed with the data from different equipment parts, for instance lines or partial networks. Alias names are replaced along the lines of variables and functions. It is also possible to replace in elements that are used in symbols. For selecting the target the same selection dialog is opened as for the **Alias** property.

7 Fault locating in electric grids

Fault location uses special coloring via ALC to mark the parts of a network that have a ground fault or earth fault. Starting points for fault detection are called ground fault or short circuit recognition device (such as a detector of a protective device) that are assigned to a circuit breaker. It is assumed that the ground fault and short circuit reporters are always at the output of the circuit breaker element. For this reason, when configuring, the corresponding variables (with detection from the protective device) should be linked to **Function type** *switch* elements.

The detections from protective devices are displayed with special coloring with the source colors *ID 1* and *ID 2*. The coloring is only carried out if the detection is applicable for a protective device whilst the lines are live. At the same time as this, the detections are set to the additional variables for display. Faults can thus also be shown graphically in a zenon screen. This display can, for example, be carried out by the configuration of an additional combined element that is only visible if the corresponding status (= *invalid status*) is the case.

The display must be reset manually (acknowledged) once the protective devices have retracted the reports.

> **Information**
>
> This function is only available when both the "Energy Edition" and the "Automatic Line Coloring" modules are licensed.

ERROR DETECTION

Error detection runs locally on each computer in the zenon network. Each client in the network has its own independent model and can therefore search for ground faults and short circuits in different parts of the topology.

Error detection in the electrical network is divided into:

- Search for ground fault (on page 47)
- Search for short-circuit (on page 54)

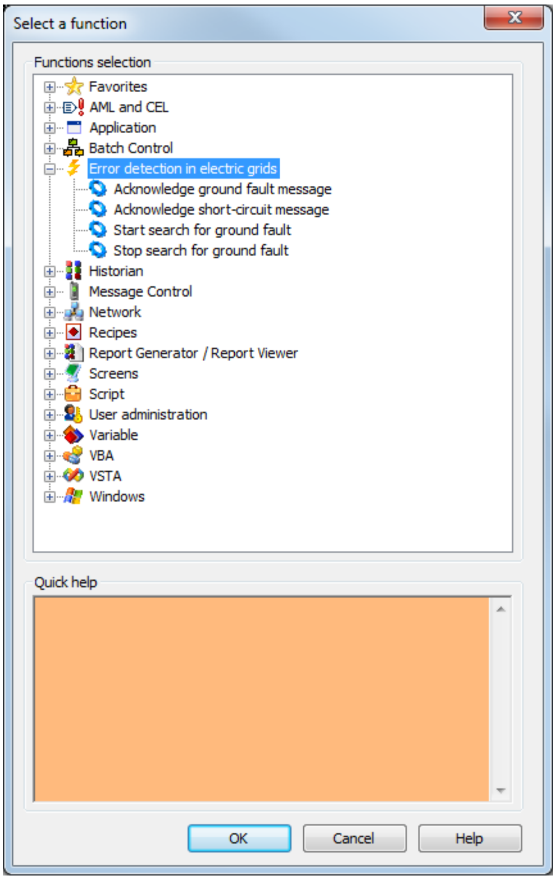
To configure error detection

- You require a license for ALC and zenon Energy Edition
- configure the appropriate screens
- Configure (on page 8) ALC to the corresponding combined elements with the *switch* function
- configure (on page 21) the lines so that they are colored by ALC

Special functions are available in the Runtime for error detection:

- Start search for ground fault (on page 52)
- acknowledge (on page 53) ground fault message (on page 53)
- Stop search for ground fault (on page 54)

- Acknowledge short-circuit message (on page 57)



COLORINGS

Errors can be displayed with special coloring of the lines in the ALC if the notifications are received whilst the lines are live. In the Runtime, the color assigned by ALC changes automatically as soon as the status of the line changes. The colorings configured can be changed in the Runtime via the Change ALC source color (on page 41) function.

Messages are processed in the order in which they arrive. In the event of conflicts

- The colors for displaying errors take priority
- short circuit messages have priority over ground fault messages

7.1 Search for ground fault

The search for a ground fault serves to highlight the network parts that may have a ground fault by coloring these. The color is taken from the engineering of ALC source colors (on page 28) for the *GROUND FAULT* (ID 1) source. At the same time as this, the notifications are set to the additional variables for graphical **display**.

The network parts that may have a ground fault are derived from the ground fault indication from ground fault detection devices (ground indicators, protective device that records ground faults). The following is applicable for ground fault indications:

- Each device can have one, two or three ground fault indications.
- This ground fault indications are handled either by permanent indication processing or by wiper indication processing.
- For directional ground fault detection devices with direction detection, the direction can be lagging or leading in relation to triggering.
  - Leading:
    Initially, the indication is determined using the direction (**forwards** and/or **backwards**) and reported, then the indication by means of **triggering**.
  - Lagging:
    First the **triggering**, then the direction is determined and reported.

> **Information**
>
> A network component that may have a ground fault is then no longer considered to have a ground fault if this has been successfully connected.

ENGINEERING

To configure a search for a ground fault:

1. assign the combined element that represents the switching element to the **Function type** switch (on page 49)
2. Define the mode of search for ground fault (on page 48), ground fault trigger (on page 51) and ground fault display (on page 50).
3. Create the functions for start search for ground fault (on page 52), acknowledge ground fault indication (on page 53) and end search for ground fault (on page 54)

> **Information**
>
> In order to also be able to limit ground faults in mixed networks, only one area with ground faults is searched per path, starting with a source.

7.1.1 Mode of the search for ground faults

The ground fault search can either:

- color the network part potentially subject to a short circuit
  or

- the whole network where the short circuit is located

The coloring mode is defined via the **Mode of the search for ground faults** property.

To configure the property:

- navigate to the **Automatic Line Coloring** node in properties
- select the desired mode in the **Mode of the search for ground faults** property drop-down list
  - Color grid part: colors only the grid parts that are potentially subject to a short circuit
  - Color entire grid: colors the entire coherent grid, in which a ground fault is located

This setting can be changed in the Runtime via the zenon API object model. In doing so, the ground fault search is recalculated once again.

7.1.2 Ground fault detection type

The direction and type of message processing for the combined element of type switch are configured by means of the **Type** property.

To do this, carry out the following steps:

1. Navigate to the **Automatic Line Coloring** property group in the combined element properties
2. Navigate to the area **Ground fault recognition**
3. Select the desired type with direction and type of indication processing from the drop-down list in the **Type** property
   - *Direction:*
     indicates if the raising edge of trigger indication or if the raising edge of a direction comes before it
   - *leading:*
     The current direction status is used for the raising edge of the trigger indication.
   - *lagging:*
     after a raising edge of the trigger indication, the first raising edge of a direction is waited on; if this does not occur within 2 seconds, the earth fault device is considered non-directional
   - *Indication processing:*
     Specifies how indications are processed.
   - *none:*
     normal switch; indications are not processed
   - *Permanent indication processing:*
     Newly received indications are considered as new ground fault trip

- *Wiper message processing:*
  Indications that are received during a current Search (on page 52) are suppressed

Note: The distinction between *permanent indication processing* and *wiper indication processing* is only how the message is processed, not its type. *Wiper indication processing* thus does not need to relate to a wiper bit.

> **Attention**
>
> To suppress intermittent ground faults, ground fault indications that occur in intervals of less than 2s are ignored.

7.1.3 Ground fault display

The variable linked at **Display** is an output variable for fault detection and displays the recorded status of the ground fault identification device. This is necessary because all indications remain saved internally until until they are acknowledged. The saved indications thus do not necessarily correspond to the current status of the message variable.

Each time a recording is made, a set value is sent to this variable. In doing so, the values are as follows:

Value	Meaning
0	no ground fault
1	ground fault forwards
2	Ground fault backwards
3	non-directional ground fault
4	Fault status - > both directions have activated

> **Information**
>
> To reduce problems in network operation, the variable linked here should be a local variable.

7.1.4 Earth fault triggering

The variable for the earth fault detection device indication is defined via the **Triggering** property. It can contain information on the presence of an ground fault and the direction of the ground fault from the point of view of the ground fault recognition device. In doing so, a distinction is made between:

- Non-directional ground fault recognition devices
- directed ground fault recognition devices with a trip alarm
- directed ground fault recognition devices without a trip alarm

To configure the variable for the **Triggering**:

1. navigate to the **Automatic Line Coloring** node in the combined element properties
2. open the node **Ground fault recognition**
   a) For non-directional ground fault recognition devices:

      Click on the ... button in the **Triggering** property

      select the variable you wish to import in the dialog that opens

      The properties for the direction remain empty

   b) for directional ground fault recognition devices with a trip alarm

      link the variable with **Triggering** and add the appropriate direction:

      Forward:
      link a variable to the **Forwards** property

      Backward:
      link a variable to the **Backwards** property

   c) for directional ground fault recognition devices without a trigger indication

      Link the variable with the corresponding direction:

      Forward:
      link a variable to the **Forwards** property

      Backward:
      link a variable to the **Backwards** property

      The **Triggering** property remains empty

Note: If you address a directional ground fault recognition devices with **Forwards** in both directions, this is then considered erroneous and ignored.

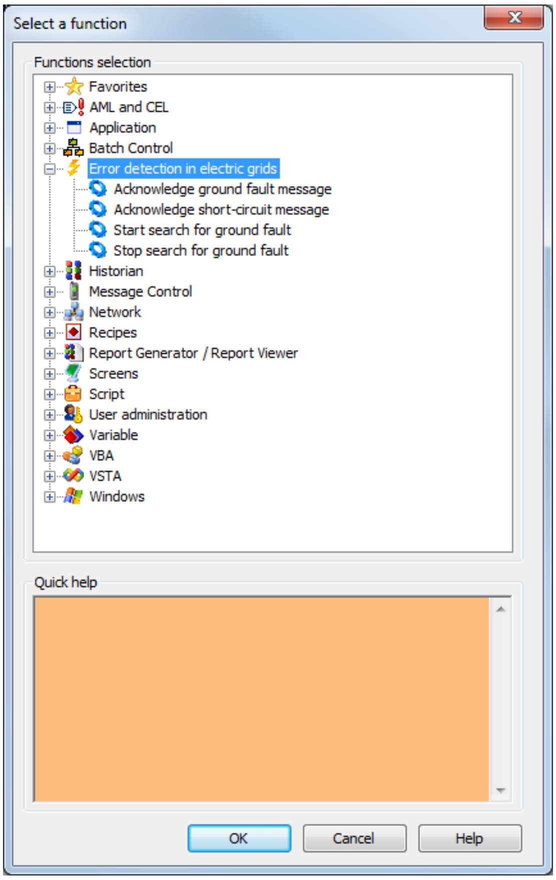
7.1.5 Start search for ground fault

The function **Start search for ground fault** serves to localize a ground fault and has two effects in the Runtime:

1. Fault reports from all ground fault identification devices that were configured with wiper message processing are ignored.
2. The search algorithm is changed: Switch actions can only reduce the area subject to a ground fault further. Newly received messages do not therefore increase the area potentially subject to a ground fault.

To configure the **Start search for ground fault** function:

- create a new function
- navigate to the fault detection node in the electrical network
- Select the **Start search for ground fault** function



- link the function to a button

7.1.6 Acknowledge ground fault indication

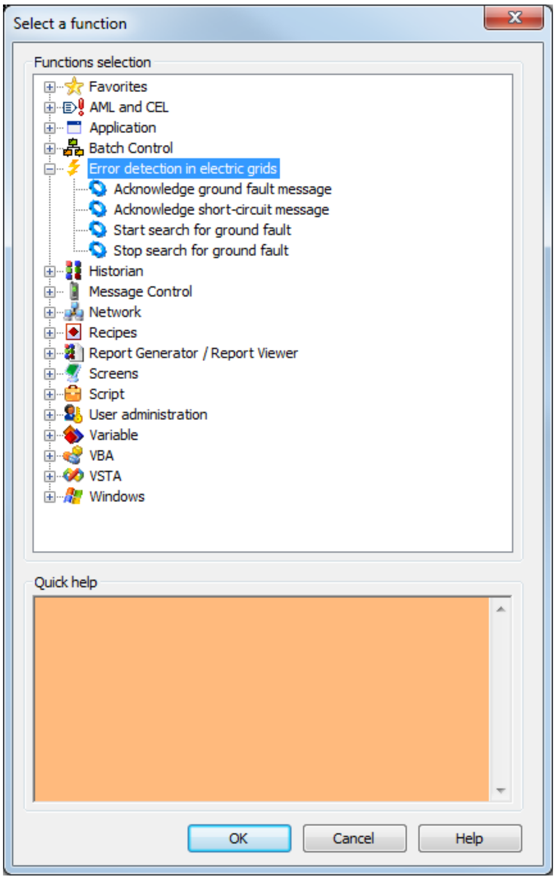
With the **Acknowledge ground fault message** function, an internally recorded ground fault from a ground fault indication device can be acknowledged in the Runtime. In doing so, the internally-latched ground fault status is reset if the status is still pending, or highlighted as acknowledged. A recorded ground fault message is only deleted internally if this has been acknowledged and is no longer pending.

Rules when acknowledging:

- If a variable that corresponds to a triggering or direction variable of a ground fault recognition device is linked, this special ground fault indication is acknowledged.
- If no variable has been linked, all ground fault indications are acknowledged.
- Acknowledgment can also take place via the zenon API object model.

To configure the **Acknowledge ground fault message** function:

- create a new function
- navigate to the fault detection node in the electrical network
- Select the **Acknowledge ground fault message** function



- the dialog to select a variable opens

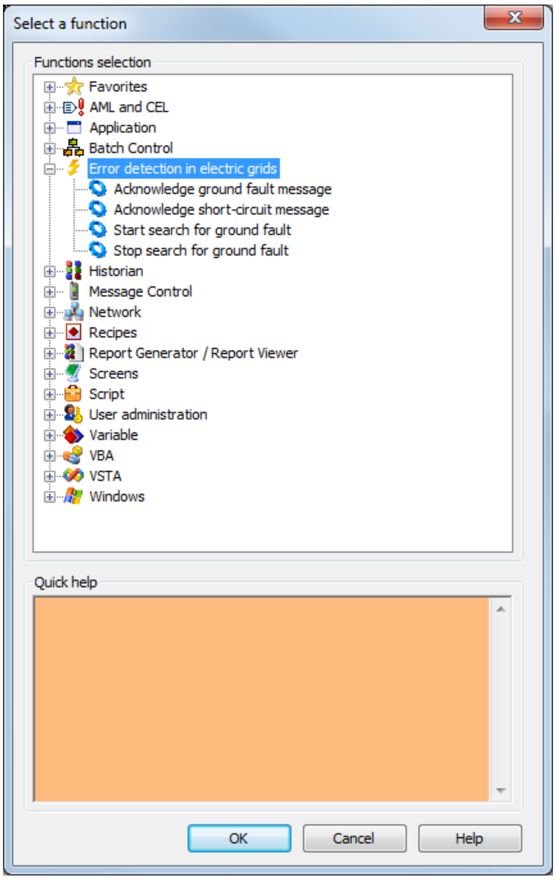
- link the desired variable to the function
- link the function to a button

7.1.7 Stop search for ground fault

You end the ground fault search with the **Stop search for ground fault** function in the Runtime.

To configure the function:

- create a new function
- navigate to the fault detection node in the electrical network
- Select the **Stop search for ground fault** function



- link the function to a button

7.2 Short circuit search

The short circuit search serves to highlight the network parts that potentially have a short circuit by coloring these. The color is taken from the configuration of ALC source colors for the *SHORT FAULT* source.

The network parts that are potentially subject to short circuits are deduced from short circuit reports. A short circuit identification device (short circuit indicator, protective device) can have one to three short circuit messages. For directional short circuit indication devices, the direction can be lagging or leading in relation to triggering. A network component that potentially has a short circuit is then no longer considered to have a ground fault if this has been successfully connected.

ENGINEERING

To configure the short circuit search:

1. assign the combined element that represents the switching element to the **Function type** switch (on page 55)
2. Define ground fault display (on page 56) andtriggering of ground fault detection (on page 56)
3. Set up the function for acknowledgment of ground fault message (on page 57)

7.2.1 Short-circuit recognition type

The direction and type of message processing for the combined element are determined by means of the **Type** setting. For project configuration:

1. navigate to the **Automatic Line Coloring** node in the combined element properties
2. open the node **Short-circuit detection**
3. Select the desired type in the **Type** property
   - *Direction:*
     indicates if the raising edge of trigger indication or if the raising edge of a direction comes before it
   - *leading:*
     With rising edge of the trigger indication, the current status of the direction is used.
   - *lagging:*
     After a rising edge of the trigger indication, the first rising edge of a direction is waited for,; if this does not occur within 2 seconds, the short circuit identification device is considered non-directional
   - *Indication processing:*
     states which indication can be processed
   - *None:*
     normal switch; indications are not processed
   - *Permanent indication processing:*
     Newly received indications are considered as new ground fault trip

7.2.2 Ground fault display

The variable linked for **Display** is an output variable for error detection and displays the recorded status of the ground fault detection device. This is necessary because all messages remain saved internally until they are acknowledged, i.e. they do not necessarily conform to the current status of the message variables.

Each time a recording is made, a set value is sent to this variable. In doing so, the values are as follows:

Value	Meaning
0	No short circuit
1	Short circuit forwards
2	Short circuit backwards
3	Non-directional short circuit

7.2.3 Ground fault detection triggering

The variable for the message from the short circuit identification device is defined by the **Triggering** variable It can contain information on the presence of a short circuit and the direction of the short circuit from the point of view of the ground fault recognition device. In doing so, a distinction is made between:

- non-directional short circuit reporters
- directional short circuit reporters with a trip alarm
- directional short circuit alarms with a trip alarm

To configure the variables for:

1. navigate to the **Automatic Line Coloring** node in the combined element properties
2. open the **Short-circuit detection** node
   a) for non-directional short circuit detection devices
      Click on the ... button in the **Triggering** property
      select the variable you wish to import in the dialog that opens
      The properties for the direction remain empty
   b) for directional short circuit detection devices with a trip alarm
      link the variable with **Triggering** and add the appropriate direction:
      Forwards: link a variable to the **Forwards** property

Backwards: link a variable to the **Backwards** property

c) for directional short circuit detection devices without a trip alarm

Link the variable with the corresponding direction:

Forwards: link a variable to the **Forwards** property

Backwards: link a variable to the **Backwards** property

The **Triggering** property remains empty

7.2.4 Acknowledge short-circuit message

With the **Acknowledge short-circuit message** function, an internally recorded short circuit from a short circuit indication device can be acknowledged in the Runtime. In doing so, the internally-latched ground fault status is reset if the status is still pending, or highlighted as acknowledged. A recorded short circuit message is only deleted internally if this has been acknowledged and is no longer pending.

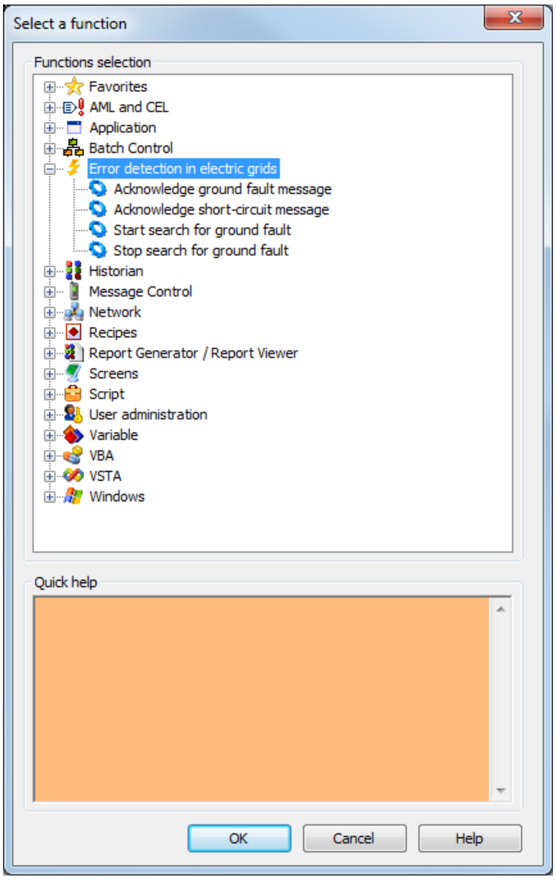
Rules when acknowledging:

- If a variable that corresponds to a triggering or direction variable of a short circuit recognition device is linked, this special short circuit message is acknowledged.
- If no variable has been linked, all short circuit messages are acknowledged.
- Acknowledgment can also take place via the zenon API object model.

TO CONFIGURE THE ACKNOWLEDGE SHORT-CIRCUIT MESSAGE FUNCTION:

- create a new function
- navigate to the fault detection node in the electrical network

- Select the **Acknowledge short-circuit message** function



- select the variable you wish to import in the dialog that opens
- link the function to a button

7.3 Curb

With curbing activated, corresponding ALC elements are visualized in Runtime with an additional border if a *ground fault* or *short circuit* is present on the line. The coloring is visualized with the configured ground fault or short circuit color.

Supported ALC elements

- *Electric line*
- *Line*
- *Polyline*

If there is both a ground fault and short circuit on the ALC element, the color is displayed according to the configured priority. Neither ground fault nor short circuit is displayed. Configured **Effects** are also supported for the display in zenon Runtime.

ENGINEERING IN THE EDITOR

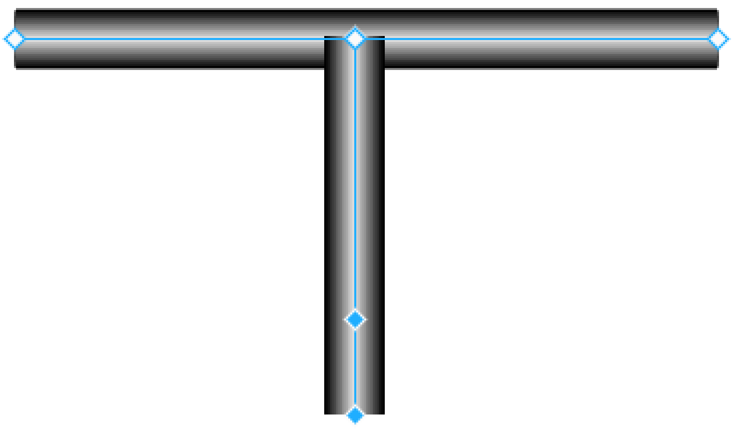
Carry out the following steps to configure curbing:

- Configure the colors for ground fault and short circuit.
  - To do this, click on the **...** button in the **ALC configuration** property in the **Automatic Line Coloring** project properties group.
    The **ALC configuration** dialog is opened.
  - Amend the colors for the pre-existing *GROUND FAULT* and *SHORT FAULT* entries.
    To do this, click on the **...** button in the line color column. The color is selected from a drop-down list.
- Create or selected a zenon screen in the Editor.
- Draw a line, polyline or pipeline or select an existing element.
- Activate, in the **Automatic Line Coloring** project properties group, the **Color from ALC** property.
- Activate the **Use curb** property and configure the width of the curbing in the **Curb width [px]** property.

NOTE ON CONFIGURATION

The following configuration is recommended for a clean graphic display of the curbing in Runtime:

- Draw ALC line elements.
  As a result, it is possible that the display of one line protrudes into another.



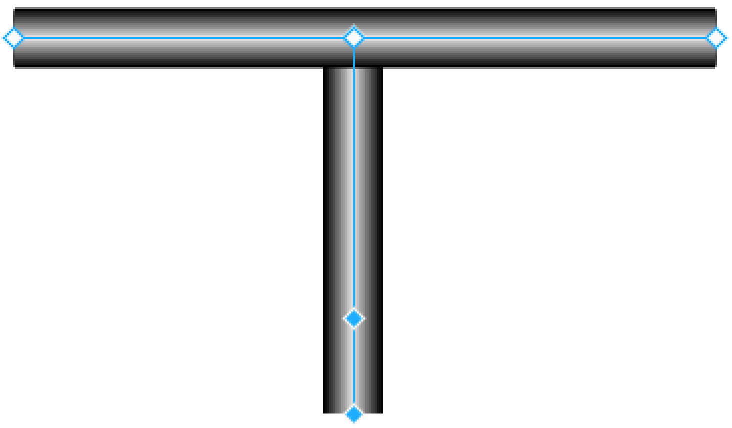
- To clean a graphics defect:

  a) Highlight the element that overlaps due to the configuration.

  b) Select the **Element position** entry in the context menu.

c) Select the **Background** entry.

The selected element is moved to the background. As a result, the correct display of the line elements is guaranteed.



8 Impedance-based fault locating and load distribution calculation

Impedance based fault detection and *calculation of load distribution* extend the ALC module.

Whereas the ALC base model identifies nodes and beams, this special model also detects lines and their parameters.

Fault locating from protection is possible by means of configuration in the zenon Editor. Therefore, for example, the location of the error can be visualized in a zenon screen with a marker.

In addition, this ALC model provides properties and methods for external evaluation of the fault location and load distribution via API.

PROPERTIES FOR ALC AND THE EXTENDED TOPOLOGICAL MODEL

The ALC elements **Combined element** and **Line** (*line*, *polyline*, *pipe*) have special properties for *impedance-based fault locating* and to *calculate the load distribution*. The properties for the *load distribution calculation* is configured in the Editor. The evaluation is not carried out in zenon however, but is available via the zenon API as algorithms to be created by users.

FILE FOR EXPANDED TOPOLOGICAL MODEL

The simple topological model of the ALC base module for the coloring is supplemented by an expanded topological model that includes all lines as separate beams. The extended topological model is stored as **ALC.xml** and can be read by external applications this way. **ALC.xml** contains two sections:

- **GraphElements**:
  contains the extended topological model without aliases
- **GraphAliases**:
  contains only the aliases

8.1 Impedance-based fault locating of the short circuit

With impedance-based fault locating, an error marker is set at the location of the failure in the topology. The impedance values measured by protective devices are evaluated by the **ALC** module. Based on the topology, the fault markers are positioned in the screen correctly in a zenon screen.

If a short circuit occurs and the reactance is not equal to zero, the search for the location of the short circuit starts:

- *Short circuit*:
  Reported by a linked variable for the **Triggering** property (**Short-circuit detection** properties group of the element).
- *Reactance*:
  Value of the variable (from the REAL data type), that is linked to the **Reactance value from protection** property (**Topological properties** properties group of the element) .

> **Information**
>
> Impedance-based causes of error can no longer be applied to mash networks in this topology.

POSITION OF THE MARKER

All lines are run through in the corresponding direction. The direction results from negative or positive reactancy. The respective reactancy of the line run through is deducted and the search continues until the residual reactancy is less than the reactancy of the next line. A marker is drawn in the line. The position of the marker corresponds to the residual reactancy.

If there is no reactancy value, no marker is set in the event of a short circuit indication. In order for the marker to be drawn correctly, the area must not be under load during the short circuit indication. With lagging short-circuit indications, the reactancy is only evaluated if the notification of direction has been received or the timeout of 2 seconds has expired.

The search is canceled if an open shift element or another ALC element has been found. Each part of the network and each individual line therein must only run once per trigger, there are thus less markers that occur in the line network than would be possible.

When reloading, markers that already exist are drawn at the same point as before reloading. Changes to the configuration of the fault locating are only evaluated after another short circuit.

If a short circuit indication is removed and acknowledged, all markers of this short circuit trigger are deleted.

Note: Depending on the order of the rectification of the short circuit and switching on again, marker can remain drawn in, although the line is no longer colored as a short circuit.

8.2 Load distribution calculation

With impedance-based fault locating, an error marker is set at the location of the failure in the topology. The location is calculated from impedance, on the basis of the expanded topology.

To configure the impedance-based fault location in the zenon Editor, carry out the following steps:

1. Activate impedance-based fault location:
   a) To do this, click on the project in your **Workspace**.
   a) Click on the **Automatic Line Coloring** project property group.
   b) Activate property **Fault location based on impedance**.

   Optional:

   Configure the **Maximum acceptable current overload [%]** of the line.

   Configure the setting for the *line overload* interlocking in the **ALC configuration** property. This interlocking is not activated by default.
2. Configure the display of the screen markers with the project properties:
   a) **Screen marker size**

   b) **Line width of the screen marker**
   c) **Display type of the screen marker**

3. Create a zenon screen.
4. Position the **combined element** on the zenon screen.
   The variable selection dialog is opened.
5. Configure the ALC settings for the combined element:
   a) Ensure that the combined element has been selected.
   b) Switch to the **Automatic Line Coloring** property group.
   c) In the **Function type** property, select the *Switch* entry from the drop-down list.
   d) Link the **Reactance value from protection** property (in the **Topological properties** properties section) to a *REAL* data type variable with the value of the measured impedance.
   e) Select the type of **Short-circuit detection** in the drop-down list of the **Type** property.
   f) Configure the color of the marker in the **Marker color** property.

8.3 Expanded topological model

Each object has a unique ID, via which it is referenced in the file. The attributes correspond to a subset of the zenon screen elements that have created the elements.

GRAPHELEMENT

ID	Description
Picture	Screen name
ElementID	Screen element ID
ElementRef	Screen element reference
Type	Screen element -type (see "element")
SourceID	Source number
ReverseSourceID	Source name in reverse direction
Variable	Status variable
VarProtReact	Reactance variable
MaxIType	Type of maximum current
MaxIVal	Maximum current constant value

ID	Description
VarMaxI	Maximum current variable
VarCurI	Instantaneous current variable
VarCalcI	Calculated current variable
VarCurP	Instantaneous power variable
LoadType	Type of load
LoadVal	Load constant value
VarLoad	Load variable
React	Reactance
Resist	Resistance
Length	Line length
Node1IDs	List of all element IDs connected with Node1
Node2IDs	List of all element IDs connected with Node2

GRAPHALIAS

ID	Description
Picture	Screen name
ElementID	Screen element ID
ElementRef	Screen element reference
Type	Screen element -type (see "element")
OrigElemRef	Screen element - reference to the original screen element
OrigGraphElemID	ID of the original elements in "GraphElements"

8.4 API

In the object model of the zenon API, the objects `ALCGraphElement` and `ALCGraphAlias` are available for the model. These contain the same information as the XML file. These objects can be accessed in the ALC engine via:

- `GraphElemCount()`

- `GraphAliasCount()`
- `GraphElemItem()`
- `GraphAliasItem()`

USER-SPECIFIC TOPOLOGICAL INTERLOCKINGS

If a topological interlocking is checked, the following event is called up at the ALC engine:

- `void CheckInterlocking(IALCEdge* pALCEdge, long nNewState, tpLockResult* LockResult, BSTR* bsText, VARIANT_BOOL* bUnlockable);`

The switch/disconnector to be switched and the new status is transferred. The event can fill `LockResult`, `bUnlockable` and `bsText` in order to display a violated interlocking condition. If the event handler returns `tpBusy` in `LockResult`, the event handler is queried until it no longer provides `tpBusy`, however for a maximum of *10 seconds*. The interlocking is active after *10 seconds*. The interlocking text and unlockability are reported back in `bsText` and `bUnlockable`.

SCREEN MARKER

Marker elements can be inserted into screens via the zenon API. These marker elements are available for the following elements:

- Line
- Polyline
- Pipe

These are added or deleted via the API functions in `DynPictures`:

- `BSTR AddMarker(BSTR bsScreenName, long nElementID, short nPosition, short nLineColorIndex, short nFillColorIndex);`
- `VARIANT_BOOL DelMarker(BSTR bsID);`

The GUID of the marker, which is supplied by AddMarker(), identifies the marker uniquely and serves as both the element name (with the prefix "**$MARKER_**") as well as the key for deletion via DelMarker(). The markers inserted via API are saved in the project according to the screen. **Attention:** Saving is not remanant, i.e. only until Runtime is restarted.

The markers set there are displayed regardless of the monitor on which the screen is opened. The markers are treated internally as normally operable screen elements. Mouse events are called up for this.

The appearance of the markers is set using the project settings in the **Automatic Line Coloring** area of the project configuration:

- **Display type of the screen marker**: Triangle, circle, square, cross
- **Screen marker size**: Size in pixels:
- **Line width of the screen marker**: Width in pixels

- Marker color: is defined via the index in the marker color table (on page 40), that is located in the properties of the screen elements in the **Automatic Line Coloring** group

9 Load flow calculation

The **Load Flow Calculation** module implements the following functionality:

- Calculation for 3-phase, high-performance energy networks.
- Derivation of the load flow model from screens with ALC elements (active elements, closed switches etc.)
- Calculation of the load flow for the current model status (from the values of the ALC elements).
- Topological interlockings, based on advance calculation of the ALC model.
- (n-1) calculation.
  Visualization of a possible network overload, for example in the event of a failure of a line.

The configuration is carried out in the zenon Editor by setting the parameters of ALC properties for the corresponding screen elements (*combined elements*, *line*, ...). The parameters for these configurations of the **load flow calculation** are set in the corresponding properties for ALC screen elements (on page 68) in zenon Editor.

In zenon Runtime, the calculation (on page 87) is carried out on the basis of the Newton-Raphson method for iterative and approximative solution of non-linear equation systems. The problem is set with complex values: applicable for N bars, of which G with generators, is 2N - G - 1 real unknown (voltage on the load bars, phase of the bars). The nominal voltage without phase moving is assumed as a starting value.

The results of the load flow calculation are output to the variables that are linked at the respective ALC element. This configuration continues to serve as a basis for subsequent (n-1) calculations. The result of this calculation can be visualized with the "*load flow (n-1) calculation*" screen type in Runtime.

9.1 General

The topological network was displayed with the help of ALC elements.

A requirement for the **load flow calculation** is that the topological network is configured with the help of ALC elements. A zenon screen (single-phase or three-phase ALC single line screen) with combined elements and lines must be present. The properties relevant for **load flow calculation** must be configured correctly for these screen elements.

The load flow calculation determines:

- For consuming devices (loads)
  The voltage and the phase.
- For generators
  The reactive power and the phase.
- For lines
  - Current (average value)
  - Power factor
  - Voltage at the input and output
  - Active power at the input and output
  - Reactive power at the input and output
- For transformers:
  - Current at the input and output
  - Voltage at the input and output
  - Active power at the input and output
  - Reactive power at the input and output

The values calculated this way can be output to variables that are linked to ALC elements.

The current can also be given as an alternative to power: $I = S/U$. This is not necessary if the current is already available via linked variables.

The load flow is calculated using the connection branches between the busbars. to do this, the generators, transformers and loads are assigned to the bars and the branches (also parallel) are formed from the lines and switches. Lines with zero impedance are integrated into the busbars.

REQUIRED MEASURED VALUES

The following measured values are necessary for the input of the load flow calculation:

- For generators and sources:
  The active power and the voltage.
  A generator is the reference for the phase; the active power is also calculated for it.
  Note: Sources do not have output values that can be calculated.
- For consuming device (loads)
  The active power and reactive power.
- For transformers:
  The coil ratio and the phase shift.
  The parameters for nominal power [MW], power loss, magnetization losses, stepped switches and phase shift can be set in the Editor.

- For lines:
  The complex impedance (resistance and reactance).
- For capacitors:
  Increment (s), interconnection (v) and position (i).
  This results in the applied reactive power as a measured value: *Q = s*v[i]*.

Note: Only active elements are taken into account.

9.2 Requirements

It is recommended that the load flow calculation is carried out on a powerful computer with a 64-bit operating system.

With the ALC elements, there must be sufficient variables linked to measured values.

9.3 Engineering in the Editor

Configuration steps for the **Load Flow Calculation** module:

1. Activate the Load flow calculation.
   a) Go to the **Automatic Line Coloring** property group in the project properties.
   a) In the **Activate load flow calculation** property, select the *Load Flow* entry from the drop-down menu.
2. Set the parameters for existing ALC screen elements.
   The setting of the parameters for the load flow calculation is configured in the following properties of the ALC screen elements for the **Automatic Line Coloring** properties group.
   Note also the information in the property help for the respective properties.
   The availability depends on the configured **Function type** of the ALC element.

   ### ALC screen element Combined element

   - **Function type** *Source*:
     Load flow calculation - input

   a) **Function type** *Generator*:

      Load flow calculation - input

      Load flow calculation output

   b) **Function type** *Drain*:

      Load flow calculation - input

      Load flow calculation output

c) **Function type** *Transformer*:

Load flow calculation transformer input

Load flow calculation transformer output

Note also the configuration notes in chapter **three-coil transformer** (on page 70).

d) **Function type** *Capacitor*:

Capacitor

ALC screen element Line or pipe:

Load flow line parameter

Load flow line result

3. Link the ALC screen element to variables that provide measured values from the process.
Example: A PLC provides the current value of the active power of a generator. You link the variables for this measured value in the combined element with which you display this generator in the topological network. You configure this linking in the **Load flow calculation - input** properties group for the **Active power dynamic [MW]** property.
4. Link the ALC screen element to variables in which the result of the load flow calculation is written.
You can use **internal driver** variables to do this. You can use these variables in zenon screens to display the output values.
Note: Note the **Configuration of the output parameters** (on page 73) chapter.

CONFIGURATION STEPS FOR (N-1) CALCULATION

1. Carry out the configuration steps for the **Load flow calculation**.
2. Activate the (n-1) calculation.
   a) Go to the **Automatic Line Coloring** property group in the project properties.
   b) Activate property **Activate (n-1) calculation**.
3. Configure a zenon *Load flow (n-1) calculation* screen.
You can find further information on this in the Screen of type Load flow (n-1) calculation (on page 74) chapter.
4. Configure a function **Screen switch**.

> **Information**
>
> If **command input** is used in the project, a *line overload* (on page 34) topological interlocking can also be configured.

9.3.1 Transformers

The ratio of the coil numbers of a transformer correspond to the ratio of the primary voltage to secondary voltage. The information about **voltage** is gained from the **ALC configuration** of the **source colors** and the parameters for this do not also need to be set up separately.

Attention

A transformer must be configured for **load-flow calculation** with:

- **Nominal output [MW]** > *0*
- **Loss reactive power [MVar]** > *0*

If the transformer does not have tap changing, the properties **minimum tap change** = **maximum tap change** = **nominal tap change** = *1* should be configured; the **tap change increment** can be *0%*. The transformer thus remains configured to 100% nominal output.

Note: If there are voltages due to deviations from the ratio as a result of the construction type, the difference can be given as **increment**. You can thus set the parameters of the transformer in such a way that it always remains at one stage next to the nominal.

TRANSFORMER WITH TAP CHANGE

Tap changer of the power transformers are for dynamic changes to the transmission ratios. In order to take the tap change into account, the following settings should be set for **load flow calculation**:

- **Minimum tap change -** the lowest level.
- **Maximum tap change** - the highest level.
- **Nominal** - the level at which the transformer provides the secondary nominal voltage. It is the level at which the voltage ratio is equal primary voltage and secondary voltage; and equal to 100%.
- **Tap-change increment [%]** - percentage indication of the increment per level, based on nominal = 100% - upwards and downwards.
- **Current position tap change** - a variable that provides the current position of the tap change from the process; for example, a '*step position information*' of the **IEC870** driver or */TapChg/stVal[ST]* of the **IEC850**.

Example:

A transformer with *380* kV primary voltage and *110* kV secondary voltage:

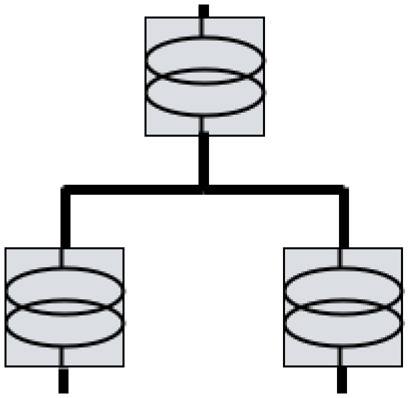
- *200* MW nominal output
- Minimum tap change = *1*

- Maximum tap change = *10*
  - A total of 10 dynamic positions are possible;
- Nominal tap change = *5*
  - At medium level, the transformer thus provides 100% of the secondary nominal voltage;
- Tap change increment [%] = *10*
  - Level 1 is thus 60%, level 5 is 100% (because it is nominal), level 10 => 150%.
  - Primary side with tap change: the levels correspond to a primary voltage of 228 kV ... 570 kV, the secondary voltage thus remains constant.
  - Secondary side with tap change: the levels correspond to a secondary voltage of 66 kV ... 166 kV, the primary voltage thus remains constant.

Note: in practical operation, the fluctuating primary voltage is the trigger for an amendment of the tap change, in order for the secondary voltage to stay close to the nominal value (after deduction of the voltage loss in the transformer itself, due to impedance and transferred power).

THREE-COIL TRANSFORMER

To configure a three-coil transformer for the **load flow calculation**, create three **combined elements** with the ALC **Function type** *Transformer*.



In zenon Editor, a check is carried out to see whether a transformer that has been defined as a three-coil primary transformer has been connected correctly: to the output of two further transformers that are not three-coil - primary transformers. An error message is shown in the output window if there is an error.

Attention: For correct calculation, it is important that all transformers of a three-coil transformer have the same **nominal output**.

ELEMENT 1 FOR THE PRIMARY COIL:

- It is important for the primary coil that the **Primary coil for three-coil transformer** property is activated.

- Link the variables for the result of the **load flow calculation** in the **Load flow calculation transformer output** properties group in the properties for the inputs:
  - **Current Input [A]**
  - **Voltage input [kV]**
  - **Active power input [MW]**
  - **Reactive power input [MVar]**

Note: The primary transformer should also have a source color for ALC.

ELEMENT 2 AND 3 FOR THE SECONDARY AND TERTIARY COIL:

- When configuring the secondary and tertiary coil, it is important that the **Primary coil for three-coil transformer** property is not activated.
- Link the variables for the result of the **load flow calculation** in the **Load flow calculation transformer output** properties group in the properties for the outputs:
  - **Current Output [A]**
  - **Voltage output [kV]**
  - **Active power output [MW]**
  - **Reactive power output [MVar]**

INTERACTION OF THE CONFIGURED PARAMETERS FOR A THREE-COIL TRANSFORMER

The three-coil transformer only uses increments from the primary transformer (and ignores them for the secondary transformers). The phase shift is only evaluated by the secondary transformers. The losses correspond to the transformer's data sheet or the following calculation: *Nominal voltage multiplied by the short circuit voltage [%] / 100*.

With secondary transformers, power losses are stated in relation to the primary coil. The losses between the secondary and the tertiary coil are taken into account when calculating the triangle with the primary transformer.

Magnetization losses are only taken into account by the primary coil.

For correct calculation, it is important that all transformers of a three-coil transformer have the same nominal output.

CONFIGURATION OF OUTPUT PARAMETERS

The result of the **load flow calculation** can be transferred to the output parameters for a transformer with linked variables.

In doing so, the following applies:

- The current is always positive.
- The prefix of the active power and reactive power is positive if it flows from the input (source = reverse feed) to the output (source).
- The fact that input and output can be interchanged with **combined elements** is also taken into account.
- The phase or the power factor at the transformer (input or output) is not given.

The following is applicable for three-coil transformers:

- For **Primary coil for three-coil transformer**, variables for the output of the calculation are linked via the inputs.
- For secondary or tertiary coils, variables for the output of the calculation are linked via the outputs.

9.3.2 Configuration of the load flow output parameters

The results of the **load flow calculation** can be written to linked variables.

The setting of the parameters for the **load flow calculation** is configured in the following properties of the ALC screen elements in the **Automatic Line Coloring** project properties group .

- Transformer

  The configuration for this is carried out for process-technology elements in the combined element with ALC**Function type** *transformer* in the **Load flow calculation transformer output** properties group
- Electric line

  The configuration for this is carried out for lines (lines, polylines etc)with the **Color from ALC** property activated in the **Load flow line result** properties group.

The following is applicable for the individual properties:

Name	Unit	Range of values	Formula
Current	Amperes	$I \geq 0,0$	$I = (VOn - VOff) / Z / \sqrt{3}$
Power factor	None	$0,0 \leq \cos \varphi \leq 1,0$	$\cos \varphi = P / S = P / \sqrt{(P^2+Q^2)}$
Voltage input	kV	$U \geq 0,0$	VOn
Voltage output	kV	$U \geq 0,0$	$VOff$
Active power input	MW		$POff + jQOn = VOn * \Delta V / Z$
Reactive power input	MVar		
Active power output	MW		$POff + jQOff = VOff * \Delta V / Z$
Reactive power output	MVar		

OUTPUT OF VALUES

All calculated values are output at each component (line or transformer) on a path.

The following is applicable for this:

- The input is at the top-left (if the line is exactly diagonal, the input is at the top right).
- The power is positive if the flow is from the input to the output.
- Active power or reactive power at the input and output have the same prefix.
- The loss as *POn - POff* or *QOn - QOff* is therefore always ≥ 0.0.
- Active and reactive power of a line can have a different prefix.
- Current, voltage and power factor are always positive.
- The current along a path (with overall impedance Z) is constant.
- The power factor is always determined at the output.
- If a line has no impedance, the values at the input and output are the same.
- If a line is part of a busbar, only the current voltage at the input and output is given.

9.4 Screen type Load flow (n-1) calculation

The new *Load flow (n-1) calculation* screen type visualizes the calculated "N-1" scenario in Runtime, for example a possible network overload in the event of a failure of a line.

A line or a transformer is removed from the network for the (n-1) calculation. The **Load Flow Calculation** module calculates the resultant load for the other components (lines and transformers) in this network and visualizes the consequences. This is determined for all lines and transformers.

The list in the screen can serve to find the part of a path that is under most load (line or transformer, **line load** column) after a component is taken from the network (**line failure**). The load from **line failure** that is displayed is in relation to the probability with which the component could fail. A switching (or failure) in the area of **line failure** would lead to a transfer of the load flow to **line load**.

ENGINEERING

Two procedures are available to create a screen:

- The use of the screen creation dialog
- The creation of a screen using the properties

Steps to create the screen using the properties if the screen creation dialog has been deactivated in the menu bar under **Tools**, **Settings** and **Use assistant**:

1. Create a new screen.

   To do this, select the **New screen** command in the tool bar or in the context menu of the **Screens** node.
2. Change the properties of the screen:
   a) Name the screen in the **Name** property.
   b) Select *load flow (n-1) calculation* in the **Screen type** property.
   c) Select the desired frame in the **Frame** property.
3. Configure the content of the screen:
   a) Select the **Elements (screen type)** menu item from the menu bar.
   b) Select *Insert template* in the drop-down list.
   The dialog to select pre-defined layouts is opened. Certain control elements are inserted into the screen at predefined positions.
   c) Remove elements that are not required from the screen.
   d) If necessary, select additional elements in the **Elements** drop-down list. Place these at the desired position in the screen.
4. Create a screen switch function.

(N-1) LIST

Breakdown actual [%]	Breakdown actual [A]	Breakdown line/trafo	Breakdown line/trafo load capacity	Load (n-1) [%]	Load (n-1) [A]	Load actual [%]	Load actual [A]	Load line
0.000	83.4	Trafo_Bus3	0.0	181.359	1517.5	85.172	712.7	Trafo 1
0.000	83.4	Trafo_Bus3	0.0	181.359	1517.5	85.172	712.7	Trafo 2
0.000	41.6	Trafo_Bus3	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	41.6	Trafo_Bus3	0.0	85.172	712.7	85.172	712.7	Trafo 2
85.172	712.7	Trafo 2	836.7	181.359	1517.5	85.172	712.7	Trafo 1
41.468	347.0	Trafo 2	836.7	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0	Trafo 1	836.7	0.000	0.0	0.000	0.0	Primary
44.831	375.1	Trafo 1	836.7	85.172	712.7	85.172	712.7	Trafo 2
85.172	712.7	Trafo 1	836.7	181.359	1517.5	85.172	712.7	Trafo 2
0.000	0.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	51.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	51.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	6.0	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	6.0	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	98.6	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	98.6	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
16.518	691.1	Primary 2	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.336	14.1	Primary 2	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.336	14.1	Primary 1	4183.7	85.172	712.7	85.172	712.7	Trafo 2
16.518	691.1	Primary 1	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.000	0.0	Primary	4183.7	0.000	0.0	0.000	0.0	Primary
0.000	375.1	Bus1_Trafo	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	347.0	Bus1_Trafo	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	712.7	Bus1_Trafo	0.0	181.359	1517.5	85.172	712.7	Trafo 2
0.000	0.0	Bus1_Trafo	0.0	0.000	0.0	0.000	0.0	Primary
0.000	712.7	Bus1_Trafo	0.0	181.359	1517.5	85.172	712.7	Trafo 1
0.000	0.0	Bus1_Bus2_2	0.0	0.000	0.0	0.000	0.0	Primary
0.000	691.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0		0.0	0.000	0.0	0.000	0.0	Primary
0.000	0.0		0.0	0.000	0.0	0.000	0.0	Primary

Parameter	Description
Breakdown actual [%]	Current load of the component (line or transformer) in percent, which is taken from the network as a calculation for the calculation of the (n-1) scenario.
Breakdown actual [A]	Current load of the components (in amperes) that has been taken from the grid for the calculation.
Failure line/transformer	Name of the components (line or transformer) that has been taken from the grid for the calculation.
Failure line load capacity	Capacity of the component that has been taken from the network to calculate the load (calculated diversion of the load flow).
Load (n-1) [%]	Calculated load (in percent) of the component (line or transformer) that is placed under the most load when another component fails (**line failure**). This entry shows the calculated load, i.e. the value after another line is taken from the network. **Note:** The name of the component is shown in the **line load** column.
Load (n-1) [A]	Calculated load (in amperes) of the component that is placed under the most load when another component (line or

Parameter	Description
	transformer) is loaded most. This entry shows the calculated load, i.e. the value after another component is taken from the network. **Note:** The name of the component is shown in the **line load** column.
Load actual [%]	Current load of the component that would be placed under the most load (in percent) after another component (line or transformer) has been removed from the network. **Note:** This entry shows the current load without taking a new loading into account, i.e. the value before another component is taken from the network.
Load actual [A]	Current load of the component that would be placed under the most load (in amperes) after another component (line or transformer) has been removed from the network. **Note:** This entry shows the current load without taking a new loading into account, i.e. the value before another component is taken from the network.
Load line/transformer	Name of the component (line or transformer) that would be placed under the most load after another component is removed from the network (**line failure**).

TRANSFORMER

The following is applicable for the (n-1) calculation of transformers:

- The two-coil transformers (also switched in parallel) are incorporated into the calculation for both loaded as well as possibly failed components. The voltage on the input side is output; the nominal current is compared to the nominal power: / √3 * nominal input voltage.
- A three-coil transformer is only considered as a component for the calculation. Load current and nominal current are taken on by the primary transformer. If the transformer forms a bridge, up to three non-connected parts of the network can occur if the transformer fails. If parts of the network continue to be supplied with energy, these are then searched through for the highest-loaded components after the failure.

9.4.1 Engineering in the Editor

The *load flow N-1 calculation* screen is to visualize current loads of a component (line or transformer) as well as calculated loads on components (line or transformer). The calculated loads show the values of a component with the assumption that another component of the mesh network is no longer present.

ENGINEERING

Two procedures are available to create a screen:

- The use of the screen creation dialog
- The creation of a screen using the properties

Steps to create the screen using the properties if the screen creation dialog has been deactivated in the menu bar under **Tools**, **Settings** and **Use assistant**:

1. Create a new screen.

   To do this, select the **New screen** command in the tool bar or in the context menu of the **Screens** node.
2. Change the properties of the screen:
   a) Name the screen in the **Name** property.
   b) Select *load flow (n-1) calculation* in the **Screen type** property.
   c) Select the desired frame in the **Frame** property.
3. Configure the content of the screen:
   a) Select the **Elements (screen type)** menu item from the menu bar.
   b) Select *Insert template* in the drop-down list.
   The dialog to select pre-defined layouts is opened. Certain control elements are inserted into the screen at predefined positions.
   c) Remove elements that are not required from the screen.
   d) If necessary, select additional elements in the **Elements** drop-down list. Place these at the desired position in the screen.
4. Create a screen switch function.

9.5 Screen switching for the load flow (n-1) calculation

To open a *Load flow (n-1) calculation* screen in the Runtime:

1. Configure a screen of type *Load flow (n-1) calculation* (on page 74).

2. Create a function Screen switch for this screen.
3. Define the desired column settings.

CREATE A SCREEN SWITCH FUNCTION

A **Screen switch** function is for calling up screens in the Runtime. You can configure the graphical appearance of the list for screen switching to a *load flow (n-1) calculation* screen.

ENGINEERING

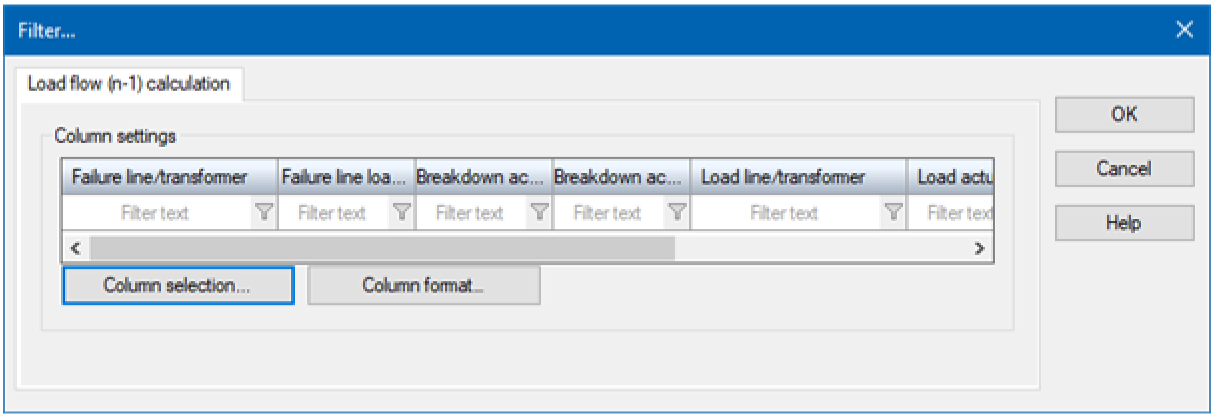
Steps to create the function:

1. Create a new function:

   In the toolbar or in the context menu of the Functions node, select **New function**.
   The dialog to select a function is opened.
2. Navigate to node **Screens**
3. Select the *Screen switching* function

   The dialog for selecting a screen is opened.
4. Select the desired screen.
   Note: If you select a screen from another project, ensure that the project is running in the Runtime.
5. Confirm your selection by clicking on the **OK** button.
   The **Filter** dialog to configure the graphical appearance of the display in Runtime is opened.
6. Click on the column selection (on page 81) button and configure the content that you want to display in Runtime.
7. Click on the column format (on page 82) button and configure the appearance of the list in the Runtime.
8. Name the function in the **Name** property.

9.5.1 Load flow calculation screen switching filter



In this dialog, you configure the content of the *load flow (n-1) calculation* for the view in zenon Runtime.

COLUMN SETTINGS

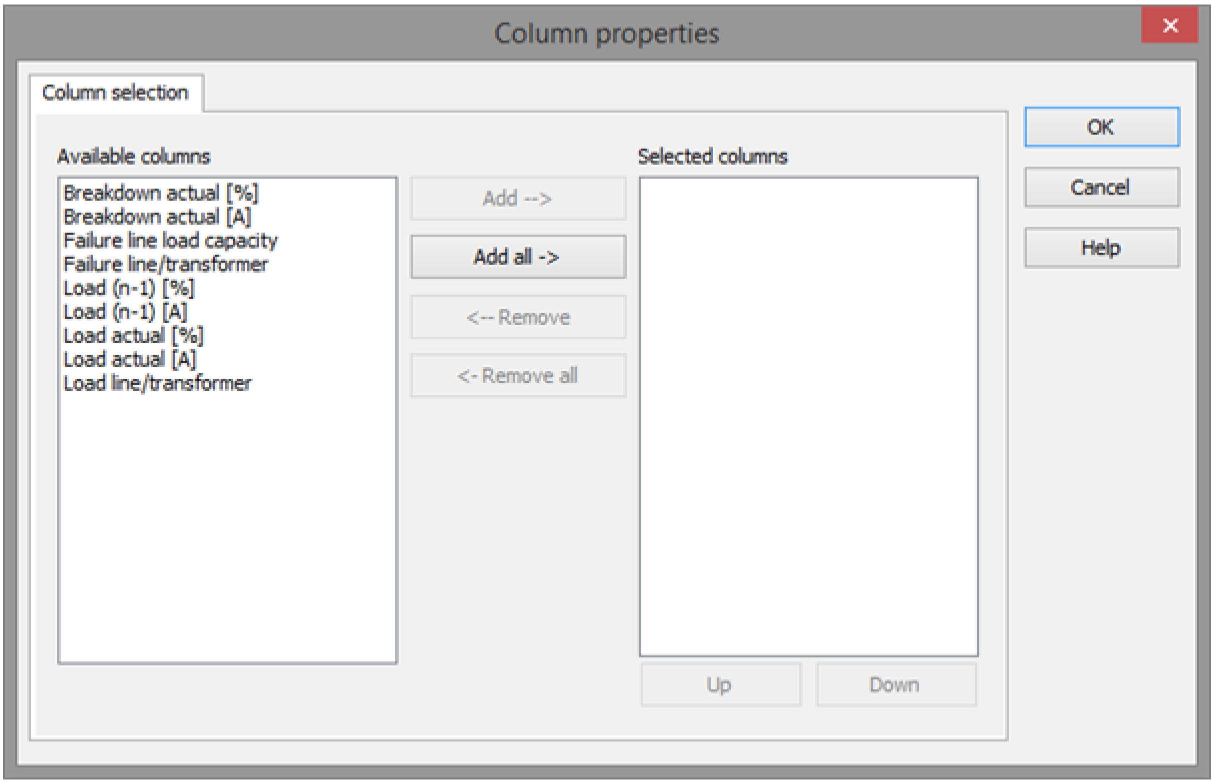
Parameter	Description
[column preview]	Preview of the columns that are configured for display in Runtime.
Column selection...	Clicking on the button opens the dialog to select and arrange the columns (on page 81) for the (n-1) list.
Column format...	Clicking on the button opens a dialog to format (on page 82) the (n-1) list.

CLOSE DIALOG

Options	Description
OK	Applies settings and closes the dialog.
Cancel	Discards all changes and closes the dialog.
Help	Opens online help.

9.5.2 Column selection

Here, you configure the columns in which the display is visualized in zenon Runtime.



Option	Function
Available columns	List of columns that can be displayed in the table.
Selected columns	Columns that are displayed in the table.
Add ->	Moves the selected column from the available ones to the selected items. After you confirm the dialog with OK, they are shown in the detail view.
Add all ->	Moves all available columns to the selected columns.
<- Remove	Removes the marked columns from the selected items and shows them in the list of available columns. After you confirm the dialog with OK, they are removed from the detail view.
<- Remove all	All columns are removed from the list of the selected columns.
Up	Moves the selected entry upward. This function is only available for unique entries, multiple selection is not

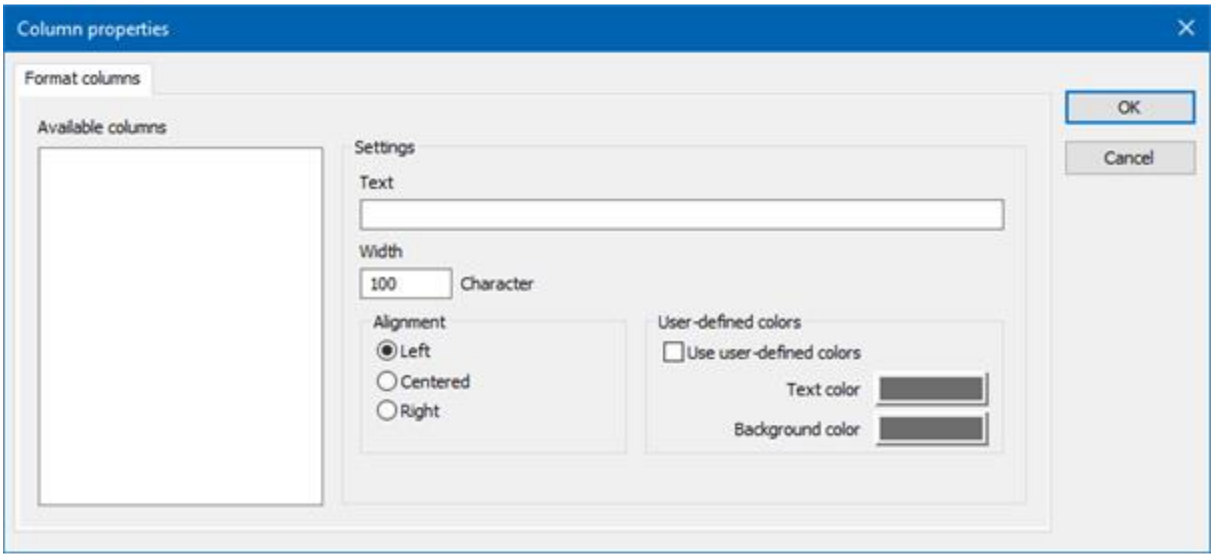
Option	Function
	possible.
Down	Moves the selected entry downward. This function is only available for unique entries, multiple selection is not possible.

CLOSE DIALOG

Options	Description
OK	Applies settings and closes the dialog.
Cancel	Discards all changes and closes the dialog.
Help	Opens online help.

9.5.3 Column format

Configuration of the properties of the columns for configurable lists. The settings have an effect on the respective list in the Editor or - when configuring screen switching - in Runtime.



AVAILABLE COLUMNS

Option	Description
Available columns	List of the available columns via **Column selection**. The highlighted column is configured via the options in the **Settings** area.

SETTINGS

Option	Description
Settings	Settings for selected column.
Labeling	Name for column title. The column title is online language switchable. To do this, the **@** character must be entered in front of the name.
Width	Width of the column in characters. Calculation: Number time average character width of the selected font.
Alignment	Alignment. Selection by means of radio buttons. Possible settings: - **Left**: Text is justified on the left edge of the column. - **Centered**: Text is displayed centered in the column. - **Right**: Text is justified on the right edge of the column.
User-defined colors	Properties in order to define user-defined colors for text and background. The settings have an effect on the Editor and Runtime. **Note:** - These settings are only available for configurable lists. - In addition, the respective focus in the list can be signalized in the Runtime by means of different text and background colors. These are configured using the project properties.
User defined colors	*Active*: User-defined colors are used.
Text color	Color for text display. Clicking on the color opens the color palette to select a color.
Background color	Color for the display of the cell background. Clicking on the color opens the color palette to select a color.
Lock column filter in the Runtime	- *Active*: The filter for this column cannot be changed in the Runtime.

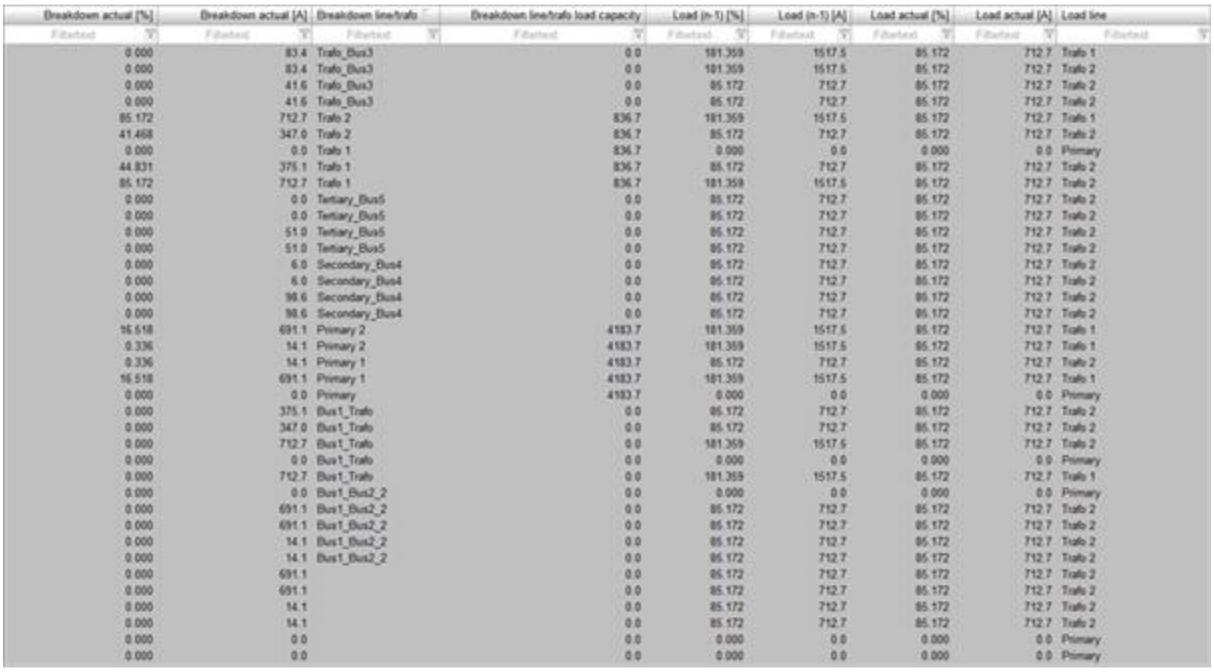
Option	Description
	Note: Only available for: - Batch Control - Extended Trend - Filter screens - Message Control - Recipegroup Manager - Shift Management - Context List

CLOSE DIALOG

Option	Description
OK	Applies all changes in all tabs and closes the dialog.
Cancel	Discards all changes in all tabs and closes the dialog.
Help	Opens online help.

9.6 Operation in Runtime

If you want to edit the list directly using the monitor, activate the Multi-Touch functionality. You can find detailed information in relation to this in the Configure interactions chapter.



Breakdown actual [%]	Breakdown actual [A]	Breakdown line/trafo	Breakdown line/trafo load capacity	Load (n-1) [%]	Load (n-1) [A]	Load actual [%]	Load actual [A]	Load line
Filtertext	Filtertext	Filtertext	Filtertext	Filtertext	Filtertext	Filtertext	Filtertext	Filtertext
0.000	83.4	Trafo_Bus3	0.0	181.359	1517.5	85.172	712.7	Trafo 1
0.000	83.4	Trafo_Bus3	0.0	181.359	1517.5	85.172	712.7	Trafo 2
0.000	41.6	Trafo_Bus3	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	41.6	Trafo_Bus3	0.0	85.172	712.7	85.172	712.7	Trafo 2
85.172	712.7	Trafo 2	836.7	181.359	1517.5	85.172	712.7	Trafo 1
41.468	347.0	Trafo 2	836.7	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0	Trafo 1	836.7	0.000	0.0	0.000	0.0	Primary
44.831	375.1	Trafo 1	836.7	85.172	712.7	85.172	712.7	Trafo 2
85.172	712.7	Trafo 1	836.7	181.359	1517.5	85.172	712.7	Trafo 2
0.000	0.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	51.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	51.0	Tertiary_Bus5	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	6.0	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	6.0	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	98.6	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	98.6	Secondary_Bus4	0.0	85.172	712.7	85.172	712.7	Trafo 2
16.518	691.1	Primary 2	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.336	14.1	Primary 2	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.336	14.1	Primary 1	4183.7	85.172	712.7	85.172	712.7	Trafo 2
16.518	691.1	Primary 1	4183.7	181.359	1517.5	85.172	712.7	Trafo 1
0.000	0.0	Primary	4183.7	0.000	0.0	0.000	0.0	Primary
0.000	375.1	Bus1_Trafo	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	347.0	Bus1_Trafo	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	712.7	Bus1_Trafo	0.0	181.359	1517.5	85.172	712.7	Trafo 2
0.000	0.0	Bus1_Trafo	0.0	0.000	0.0	0.000	0.0	Primary
0.000	712.7	Bus1_Trafo	0.0	181.359	1517.5	85.172	712.7	Trafo 1
0.000	0.0	Bus1_Bus2_2	0.0	0.000	0.0	0.000	0.0	Primary
0.000	691.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1	Bus1_Bus2_2	0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	691.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	14.1		0.0	85.172	712.7	85.172	712.7	Trafo 2
0.000	0.0		0.0	0.000	0.0	0.000	0.0	Primary
0.000	0.0		0.0	0.000	0.0	0.000	0.0	Primary

The following is applicable for the operation of the *load flow (n-1) calculation* screen in zenon Runtime:

- The list can be sorted
  - Click for the sorting on the column heading.
  - The sorting sequence is visualized with an arrow symbol next to the column heading:
    Arrow upwards: ascending sorting
    Arrow downwards: descending sorting
  - Another click on the column heading reverses the sorting order.
- The list can be filtered
  To filter the list:
  - Enter the desired filter term in the input field below the heading. The default description of an empty field is *filter text* (shown in gray font).

DISPLAY OF LONGER TEXTS IN THE LIST

Longer texts can also be displayed in the Runtime over several lines using the **Automatic word wrap** property.

In the Editor, go to **Representation** in the properties of the respective list properties and activate the checkbox of the **Automatic word wrap** property.

The line height must be amended manually.

9.6.1 Topologic interlockings

The **load flow calculation** provides the following topologic interlockings (on page 34):

LINE OVERLOAD

The interlocking is active if switching would lead to to a current overload of a line or a transformer in the ALC network.

If several components are overloaded, only the name of the component with the highest overload is displayed as an interlocking text.

Example:

Limit value current carrying capacity [A]	Calculated value [A]	Maximum acceptable current overload [%]	Load [%]	Exceedance of permitted limit value [%]	Interlocking
5	7.51	10	150.2	40.2	Yes
2	7.51	10	375.5	265.5	Yes
5	4.51	-10	90.2	0.2	Yes
5	5	0	100	0	No

Interlocking text: *The line [component name] will be overloaded by [40.20]% more than permitted*

Depending on whether a line or a transformer is overloaded, the interlocking text is amended accordingly.

In addition, this interlocking is active if

- A **load flow calculation** is not possible.
  This is the case for missing or invalid measured values, as well as in the event of a switch having an undefined status (not on or off)
- The **load flow calculation** cannot achieve a conclusive result.

In both cases, the interlocking is active and the following interlocking text is displayed:

The load flow calculation could not reach a conclusive result.

INTERCONNECT VARIOUS VOLTAGE LEVELS

The interlocking is active if switching actions lead to an interconnection of two ALC network areas with different nominal voltages of the ALC sources.

INTERCONNECT GRIDS

The interlocking is active if switching actions lead to an interconnection of two ALC network areas with different *generators*. Process-technical *generator* elements with different numbers of **sources** are considered different generators.

The interlocking is active under the following preconditions:

- Both sides of the element are live after switching.
- One page contains a generator source that is not present in the other network.

> **Information**
>
> You can find further details on topologic interlockings in the **Configuration of the topologic interlocking** (on page 34) in this manual.

9.6.2 View in zenon Runtime

9.7 Calculation

The calculation is carried out on the basis of the Newton-Raphson method for iterative and approximative solution of non-linear equation systems. The problem is set with complex values: applicable for N bars, of which G with generators, is 2N - G - 1 real unknown (voltage on the load bars, phase of the bars). The nominal voltage without phase moving is assumed as a starting value.

The iterative calculations of the Jacobian matrix and results are repeated until the L2 norm of the correction vector is less than one thousandth.

VALIDATION

When compiling the Runtime files in zenon Editor, a consistency check of the ALC configuration is carried out. Error notices are displayed in the Editor's output window.

The analysis is carried out in several steps:

- First the network, starting form the sources and generators, is searched through.
  - The search is continued for a switch, disconnector, valve and check valve.

  - The search is ended with end elements (consuming device, capacitor, end element) and transformer.
- All sources that are found in the process are in the same network segment. With a transformer - depending on the side - the source or the source for reverse feed is taken into account.
- All transformers that have only been taken into account on one side during the first stage of the search are the starting point for renewed network investigation on the side that has not been taken into account.
- In doing so, the search takes the defined voltage into account, not the source ID.
- System sources are not taken into account during this search.

Note that this output is always applicable for the last zenon screen. The sequence of the screens results from the basis of the topological model. After correction of this configuration error, it is recommended that the messages in the output window are heeded once again. You can find further information on the output messages in the **Warning messages and LOG entries** (on page 91) chapter.

9.7.1 Busbars and branches

IDENTIFICATION AND VALIDATION OF THE BUSBARS

At the start of the load flow calculation, the busbar model is built up from the current topological model and the switch positions or conditions and loads of sources.

After identification of the busbars, a check is carried out to see whether they meet the minimum requirements for the load flow. If the requirements are not met, these busbars are removed from the model.

Minimum requirements:

- The busbar determined for a generator must provide a positive net power: Power of the generator less power of the loads.
- Active busbars must have an outgoing connection for sources and generators.
  There must be an incoming connection for drains.
- Passive busbars must have at least two connections.

If a busbar is removed, this is logged in the LOG file.

VERIFICATION OF JUNCTIONS

The strongest bar of the busbars with generators is selected as a reference bar (slack-bus). All busbars connected to the reference bar are combined into a partial network. The network is subdivided into zones with the same voltage by transformers. The partial networks are numbered consecutively. As a result, all generator bars are assigned to a network.

In doing so, the voltage requirement must be met (by the source, generator, transformer or line) without contradictions. The network cannot be calculated if this is not the case. In the event of a fault, a warning message is generated in the LOG file for each busbar.

TRANSFER INTO THE CALCULATION MATRIX

For each partial network that contains at least one load bus, the per-unit system is created, arranged according to voltage and output of the reference bar. The complex admittance values of the existing connections are incorporated into the calculation matrix. In addition, the known values for **PQ** or **PV** are also applied. All unknown values are considered as *0*.

9.7.2 Calculation of the electrical sizes

The reactive power of all generator bars and the active power of the reference bar are calculated. The calculated phase of the bars is distributed to all *source* or *drain* **Function type** ALC elements. The calculated voltage is only distributed to *drain* **Function type** ALC elements. The reactive power on the generator bar that does not come from the loads is distributed to the *Generators*, in proportion to the active power generated.

The current that flows through two bars corresponds to voltage multiplied by admittance; the transferred power is calculated from the product of the voltage and the voltage difference, taking into account the phases, as a complex value, multiplied by the admittance. The difference between the power fed-in and the power received in a branch is the power loss. Current and power are output to all ALC line elements between the bars. There is a power loss on each ALC line element with impedance, corresponding to the proportion of the total impedance. With a serial connection of several impedance-loaded lines, the fed-in power is output at the first element. The power taken is output at the last line element. Because only one power output or the current (input or output) can be output, the fed-in power is output at the first ALC line element. The power taken is output at the last ALC line element.

All calculated values are written to the linked variables. Existing values of a previous calculation are overwritten by the most recent result of calculation or set to the value 0 if the element is no longer under load.

9.7.3 Parallel lines

Parallel connection paths are only permitted between two busbars if they are connected to one another in series. **Attention:** Intermeshing between two line paths is not supported.

- A line can have impedance (resistance from actual resistance and reactance).
- Admittance is the inverse of this complex resistance (impedance).
- The impedance of a line path is the sum of the impedances of the individual parts of the line.

- A current flows through each line path, according to the difference in voltage, multiplied by the admittance of the path.
- The fed-in power per path is calculated from the initial voltage, multiplied by current.
- The power loss on the line path is distributed to the lines proportionally.

9.7.4 Transformers

A transformer forms a connection between two busbars, the same as a line. A line with impedence can be directly connected to a transformer.

A transformer calculates its admittance from power loss, nominal voltage and nominal power. The admittance is used in the same way as the impedance of a line. The load-independent magnetization losses are treated as a shunt with transformers. Increment and phase shift are taken into account as a complex factor when creating the admittance matrix. If several transformers are switched in parallel between two busbars, the inputs and outputs (primary an secondary side) must be on the same side. Transformers switched in parallel must have the same output.
Note: In doing so, increment and phase shift must correlate.

Each three-coil transformer has a busbar on the secondary side, to which to transformers must be connected with their primary side in a star shape. Together, these three transformers generate entries in the admittance matrix (from the triangle to the star).

The three-coil transformer only uses increments from the primary transformer (and ignores them for the secondary transformers). The phase shift is only evaluated by the secondary transformers. The losses correspond to the transformer's data sheet or the following calculation: *Nominal voltage multiplied by the short circuit voltage [%] / 100*.

With secondary transformers, power losses are stated in relation to the primary coil. The losses between the secondary and the tertiary coil are taken into account when calculating the triangle with the primary transformer.

Magnetization losses are only taken into account by the primary coil.

For correct calculation, it is important that all transformers of a three-coil transformer have the same nominal output.

The following is applicable in general for three-phase systems: *Apparent power MVA = √(MW^2 + MVar^2) = √3 * kV * A / 1000*
With transformers, the reverse feed is also taken into account (load flow of secondary or tertiary coils to other coils).

Note: For a load-flow calculation, the transformer must have these parameters:

- **Nominal output [MW]**: > *0*

- **Loss reactive power [MVar]**: > *0*

9.7.5 Capacitors

The following is applicable for the calculation with capacitors:

- When creating the model, a capacitor is treated the same as a load: it is connected to a busbar – alone or with other loads or sources.
- The increment is the nominal power: the interconnection and position result from the multiplier and the current power as a product.
- The load flow calculation determines the equivalent admittance from nominal power, multiplier and nominal voltage. The admittance results in the actual voltage as well as the fed-in reactive power.

9.8 Warning messages and LOG entries

ENGINEERING

The following warning messages are displayed in the output window of zenon Editor when compiling.

Warning message	Description
ALC: Screen 'screen01' - The transformer 'trafo01' is defined as a three-coil transformer but has faulty engineering.	Configuration error for a three-coil transformer. There must be precisely two further transformers (that are not themselves 3-coil primary transformers) connected You can find further information on this in the "**Three-coil transformer** (on page 70)" chapter.
ALC: No voltages defined for the sources in the project.	Configuration errors due to missing voltage levels of the user-defined sources with the ALC source configuration. No source is configured with a voltage in the current configuration of the **ALC configuration**. The consistency check is terminated.
ALC: The following sources with different voltages are in the same network segment:	Configuration errors due to different voltage levels in ALC screens.

Warning message	Description
%s	The current configuration of the **ALC configuration** contains several sources with different voltage levels in the same network segment.
ALC: At least one of the sources must define the voltage of the area: %s	Configuration error with missing voltage levels in the ALC source configuration. The current configuration of the **ALC configuration** contains several related sources but none of these sources has a voltage configured.
ALC: Elements without connection to a source: %s	Configuration error for incorrect positioning of an ALC element on a zenon screen. The current configuration contains at least one element that is not supplied by a voltage source.

CALCULATION

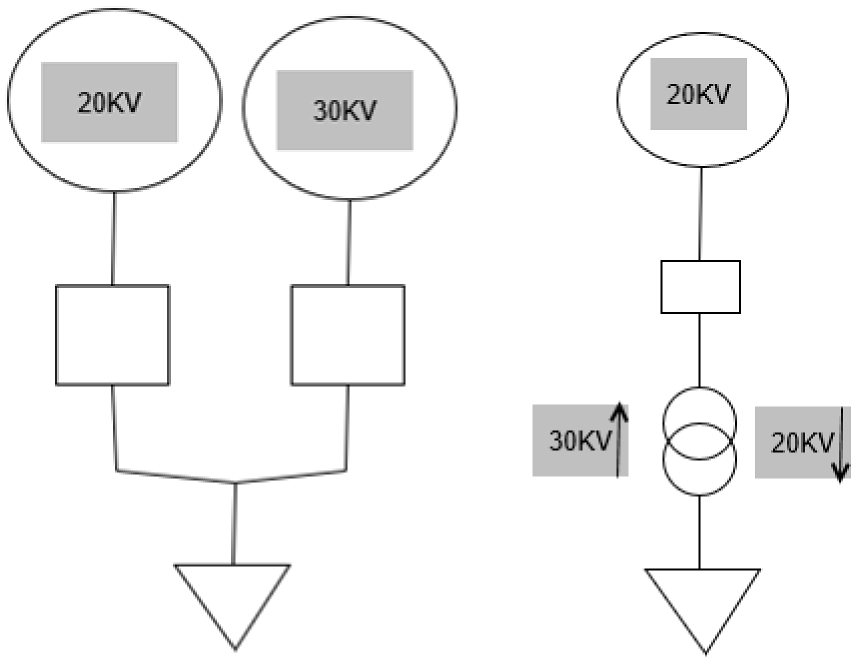
The following warning and error messages are logged in the LOG file and can be evaluated with the **Diagnosis Viewer**.

Warning message	Level	Description
Power Flow Bus voltage missing or different at[source var: gen138kV] [transformer var: trans30/110kV]	**Warning**	No voltage or no unique voltage is defined for the sources used at a busbar. The linked variables serves as identification.
Power Flow Bus voltage missing	**Warning**	A busbar does not have its own source and is not connected to any busbar that has a uniquely defined voltage.
Cannot calculate load flow due to invalid switch positions or measured values	**Error**	The **load flow calculation** cannot be carried out. Possible reasons: ▸ Missing or invalid measured values ▸ Undefined status of a switch (not on or off)
Calculation of load flow did not converge to a result.	**Error**	The **load flow calculation** could not achieve a conclusive result.

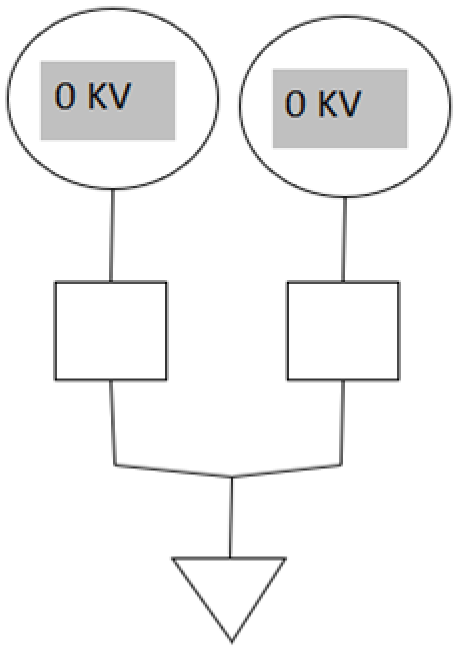
ZENON EDITOR WARNING MESSAGES

Example display of incorrect configuration for ALC elements:

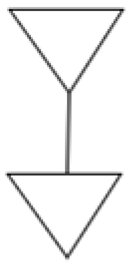
- *ALC: The following sources with different voltages are in the same network segment:*



- *ALC: At least one of the sources must define the voltage of the area:*



- *ALC: Elements without connection to a source:*



10 State Estimator

The **State Estimator** module is an additional module to the **Load Flow Calculation** module.

If, at the nodes in the topological network, not all power in or out is known for a load flow calculation, the **State Estimator** can reconstruct this from several measured values in the network.

Electrical parameters (power outputs) are estimated by the **State Estimator**. To do this, the **State Estimator** measures the values of all measuring points on lines.

- The measured values are configured in the properties of the functional ALC elements. These elements include the **combined element** as well as all **lines**. Variables that display the measured values for the calculation of the **state estimator** are linked in these properties.
- These measured values are the basis for the calculation of the load flow in the topological network.
- The result of the **State Estimator** is written to the same variables as the result of a load flow calculation. This result is also used for a topological interlocking check, as well as the (n-1) calculation.

Starting from a given Jacobian matrix of the **Load Flow Calculation** module, the voltages and phase differences of the individual busbars are calculated.

The **State Estimator** determines approximated values for voltage and phases. These calculated values are compared to the measured values. The calculation is repeated recursively until the precision required for the **State Estimator** has been achieved. This precision is 0.0001.

The **state estimator** can only detect whether the precision has been achieved if an over-determined network that is fully observable has been configured. Over-determined means that the **state estimator** has received more relevant measured values than the result values (voltage and phase per bus) that it must calculate. A network is thus observable if each line has meaningful measured values or both buses - without measured values of this line - are known or can be calculated.

The **state estimator** starts calculations - like the **load-flow calculation**- with an assumed phase 0 on each bus and a known voltage; or the nominal voltage as an estimated value. Because a current does not provide information on the phase or the direction of the power, the entry of the measured value of the current is not sufficient for calculation. The effective power or reactive power to lines is needed for the calculation.

Attention: The circumstances of the measured values of the voltage, current and power factor (cos phi) being known cannot be used to calculate effective power and reactive power from them: this is because the direction of the resultant load flow remains unknown, the prefix of the power is not known.

Only once the power is measured for all sources and drains on a bus are measured can this net power continue to be used in the calculation. This is the case regardless of active power or reactive power. The power can thus only be determined at a bus directly if only one line or only the net power is unknown. Otherwise there is a recursive estimate.

10.1 Engineering in the Editor

Configuration steps for the **State Estimator** module:

1. Activate the State Estimaotr.
   a) Go to the **Automatic Line Coloring** property group in the project properties.
   a) In the **Activate load flow calculation** property, select the *Load flow with State Estimator* entry from the drop-down menu.
2. Set the parameters for ALC screen elements that represent lines in the topological network.

Information

The **State Estimator** module builds on the configuration for the Load Flow Calculation (on page 66) module.

The **State Estimator** needs entry of measured values of the **effective power** or **reactive power** to lines.

Note: Because a current does not provide information on the phase or the direction of the power, the entry of the measured value of the current is not sufficient for calculation.

Configure the measured value of the power factor (**cos phi**) if either effective power or reactive power at the same point are known (i.e. if not both). The **state estimator** will then calculate the other power (with the same prefix) and use it for further calculations (no longer the power factor).

Even if the **voltage**, **current** and power factor (**cos phi**) are known for a line, it is not sufficient in order to calculate the measured values of the **effective power** and **reactive power** - the prefix of the power remains unknown. The voltage and the current are taken into account in further calculations.