DIgSILENT

PowerFactory 2017

What's New

INTEGRATED POWER SYSTEM ANALYSIS SOFTWARE FOR
TRANSMISSION / DISTRIBUTION / INDUSTRY / GENERATION / INTEGRATION OF RENEWABLES

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1 Introduction

This document highlights the new key features and enhancements available in ***PowerFactory 2017***, which continues the annual cycle of ***PowerFactory*** releases.

A range of improvements have been made to the handling and data management with a series of additional convenience functions. The new version also comes with a series of enhancements to the network diagrams and graphic representation tools. A special focus in development has been on the various analysis function capabilities of ***PowerFactory***. This includes a number of new power equipment models and extensions to existing ones. Most notably, further modelling flexibility has been provided with the inclusion of user-defined models for load flow and quasi-dynamic simulation.

Key highlights of ***PowerFactory 2017*** include the following:

- Enhanced Diagram Layout Tool for auto-drawing of feeders and branches, protection device layout, as well as auto-layout of site and substation diagrams
- Output window redesigned to be interactive, with flexible filter functionality
- Add-on Modules: new framework for user-extendable function scope including fully integrated result representation
- New Project Combination and Connection Assistant
- Various new and enhanced Power Equipment Models (harmonic filters, busbar trunking systems, voltage regulator, 4-winding transformer, power frequency control using merit order)
- New QDSL modelling language: User-definable load flow and quasi-dynamic simulation models
- Unbalanced Feeder Load Scaling
- IEC 60909 Update - 2016 edition (available in upcoming Service Pack)
- New Protection Audit validation tool for protection settings and configurations
- Connection Request Assessment according to BDEW 2008 and VDE AR-N-4105 guidelines
- New optimisation methods for Tie Open Point and Phase Balance Optimisation: genetic algorithms and simulated annealing
- Extension of failure models and power restoration strategies for Reliability Analysis
- New Outage Planning module
- Extension of simulation scan by Fault Ride Through verification
- IEC 61400-27-1 interface for external dynamic models
- CGMES interface: functional extensions and performance improvements
- New Integral export function

With its continually-updated analysis and modelling capabilities, ***PowerFactory 2017*** is perfectly suited to network planning and operation studies, from small micro grids and distribution networks with distributed generation to larger transmission systems, taking new HVDC technologies and renewable generation into account.

Also, with its flexibility for scripting and interfacing, ***PowerFactory 2017*** is perfectly suited to highly automated and integrated solutions in your business applications.

2 Handling and Data Management

2.1 Redesign of the Output Window

PowerFactory 2017 comes with a redesigned output window, making the handling of messages more intuitive and user-friendly.

In the new output window, shown in figure 2.1, the messages are not only coloured, but icons are also used to indicate the category (error, warning, info, events,...); these categories can be filtered using the predefined filtering tabs. There is also a text filter, to find specific text strings in the output messages.

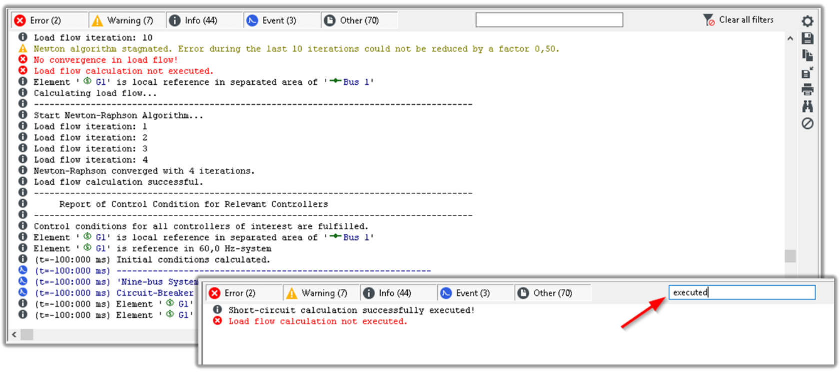


Figure 2.1: Output window

2.2 Project Combination

Responding to customer requirements for a user-friendly method for combining two or more projects, a new process has been developed in ***PowerFactory 2017***. There are two steps in the process, using these tools:

- **Project Combination Assistant:** this creates a new "combined" project from two or more source projects. Initially, after this first step, the constituent grids are separate from one other.
- **Project Connection Assistant:** this is used to connect the separate grids together, with options to identify the connection points using fictitious nodes or elements (switches) identified by their corresponding foreign keys.

Figure 2.2 below illustrates the concept when used to integrate high voltage and low voltage systems.

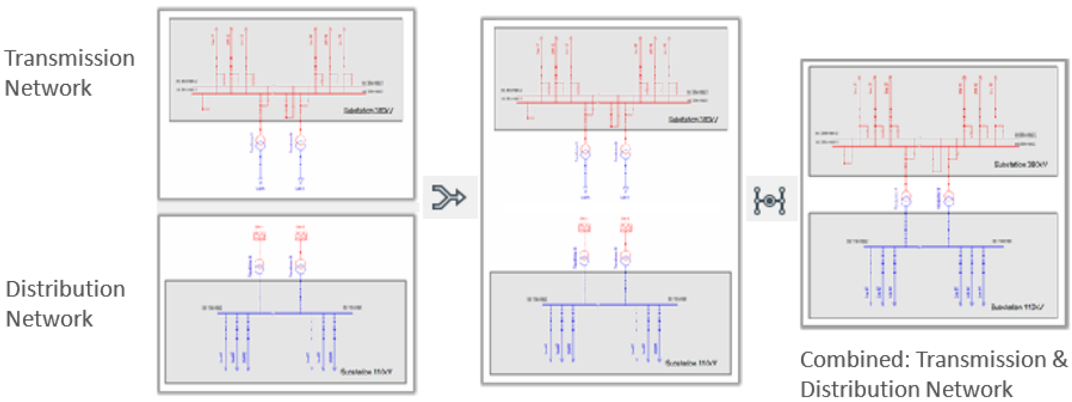


Figure 2.2: Creating a combined project from transmission and distribution networks

2.3 Snapshot Export

PowerFactory 2017 offers a new method for exporting and sharing project information. The Snapshot Export function enables the currently active status of a project to be exported, such that only the relevant objects are included. A project exported in this way is potentially a much smaller file, which nevertheless when reimported into ***PowerFactory*** can be used to reproduce analysis carried out in the original project study case.

Unlike the existing Project Export, where the project must first be deactivated, the Snapshot Export is performed on an active project. This way, ***PowerFactory*** can determine exactly which objects are active and which data are applicable as a result of an active scenario or active variations.

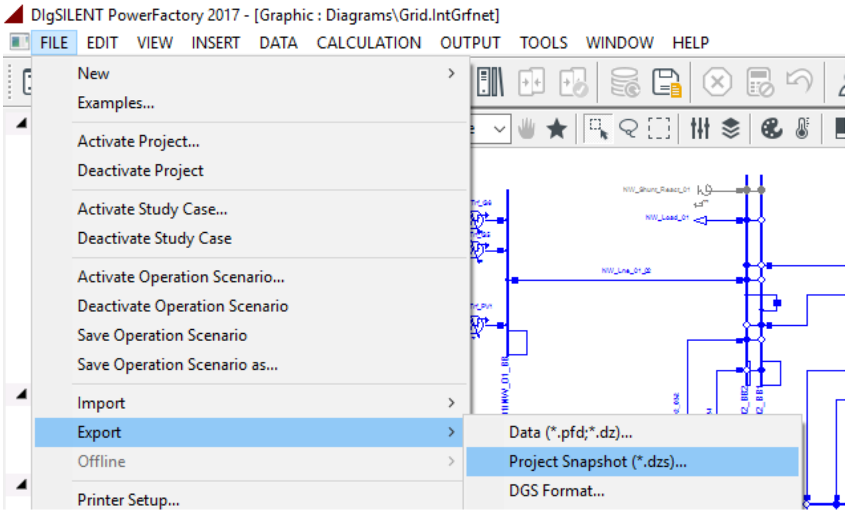


Figure 2.3: Executing a Snapshot Export

When the Snapshot Export is carried out, the resulting file outside ***PowerFactory*** has the file extension .dzs. It can be imported just like a .pfd or .dz file and when activated can be used to perform the usual calculations such as load flow or simulations. Furthermore, it is possible for merge processes to be carried out between it and the source project, for example if there is a need to include additional data from the source project.

3 Network Diagrams and Graphic Features

3.1 Diagram Layout Tool

In ***PowerFactory 2017***, the Diagram Layout Tool has been completely redesigned and extended to include additional functions as shown in figure 3.1. The additional functions are described in the following subsections.

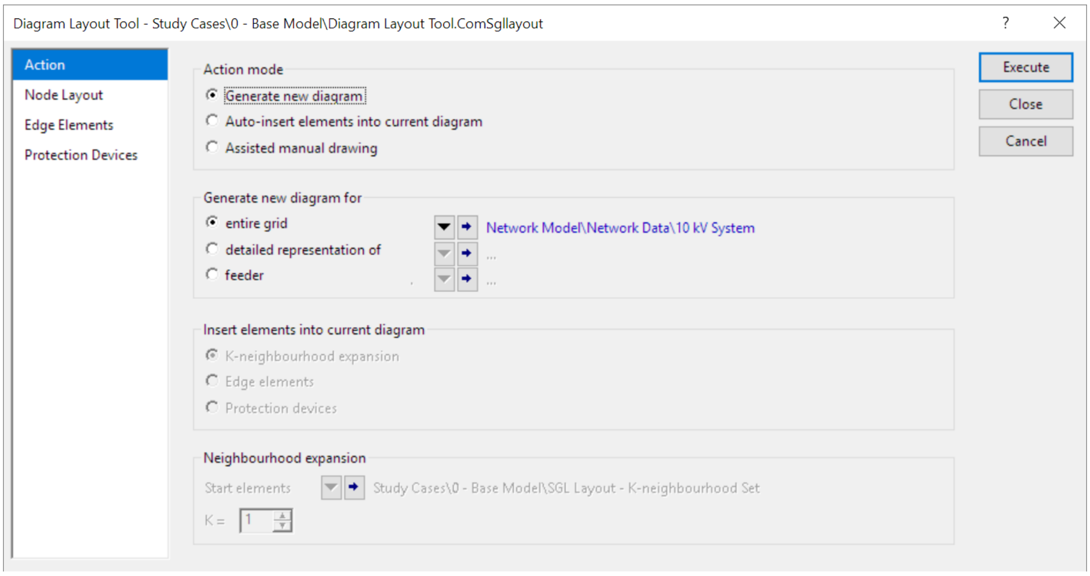


Figure 3.1: Redesign of the Diagram Layout Tool

3.1.1 Layout of Feeders

The new Diagram Layout Tool includes an option to generate complete new schematic feeder diagrams. There are several options related to the layout style and node spacing. There is also an option to consider backbones. Figure 3.2 shows a feeder diagram created using the Diagram Layout Tool.

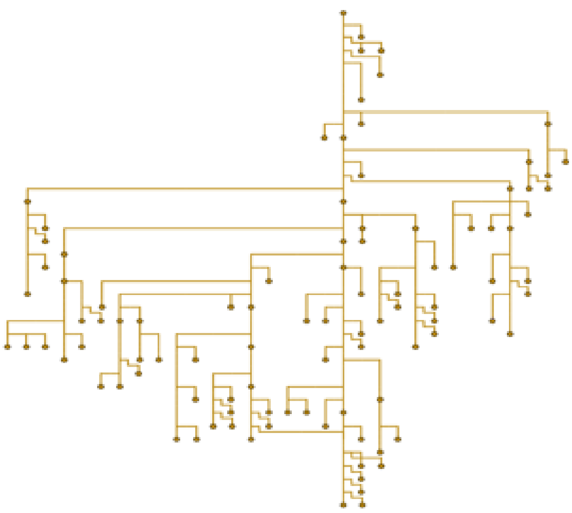


Figure 3.2: Feeder diagram

3.1.2 Drawing of Branches

With the enhanced Diagram Layout Tool it is possible to generate detailed representations of branches *ElmBranch*. Figure 3.3 shows a detailed diagram of a branch element generated using the Diagram Layout Tool.

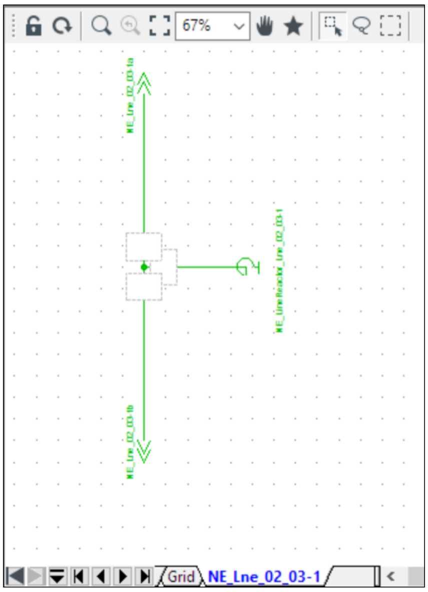


Figure 3.3: Branch diagram

3.1.3 Drawing of Protection Devices

Now the protection devices can be automatically drawn into the single line diagram by selecting the option *Auto-insert elements into current diagram* of the Diagram Layout Tool as shown in figure 3.4.

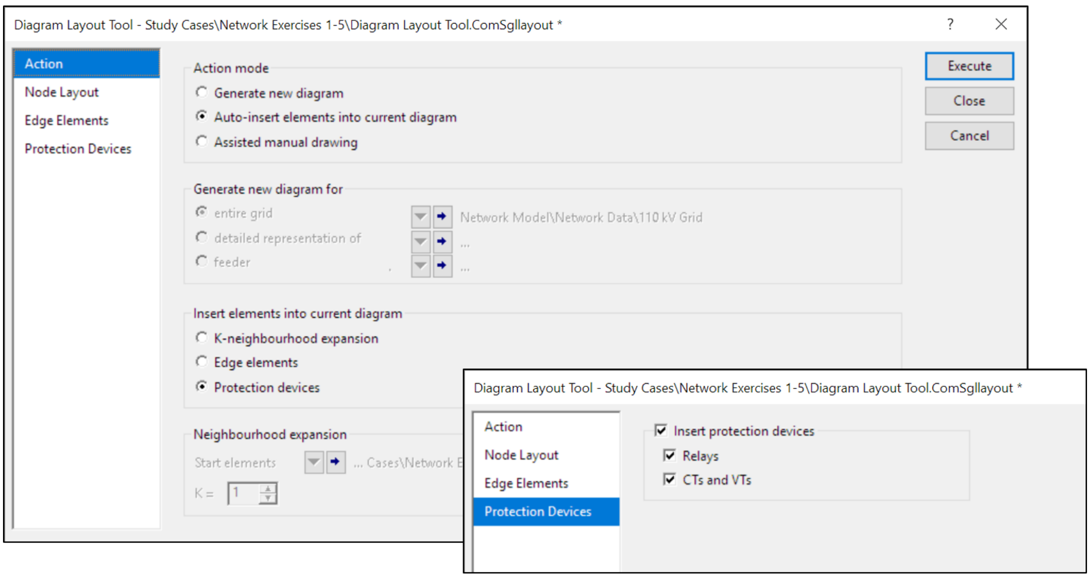


Figure 3.4: Option to insert missing protection devices

It is possible to select to draw relays and/or current and voltage transformers. An example of automatically inserted protection devices is shown in figure 3.5

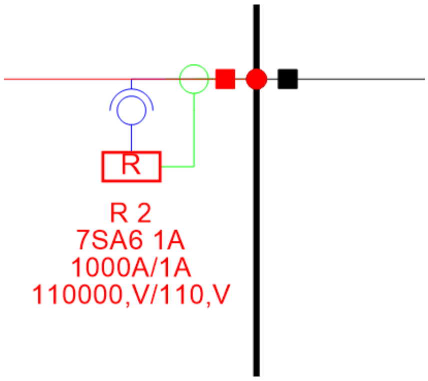


Figure 3.5: Protection devices in the single line diagram

3.2 Representation of Site Model

PowerFactory 2017 includes graphical representation of the Site element (*ElmSite*). A Site is normally used to group network components, for example, substations of different voltage levels at the same location.

The Site can be represented by a square or a circle and geographical coordinates can be defined in order to show it in the geographic diagram. Figure 3.6 shows a representation of a site element in the single line diagram and the geographic diagram.

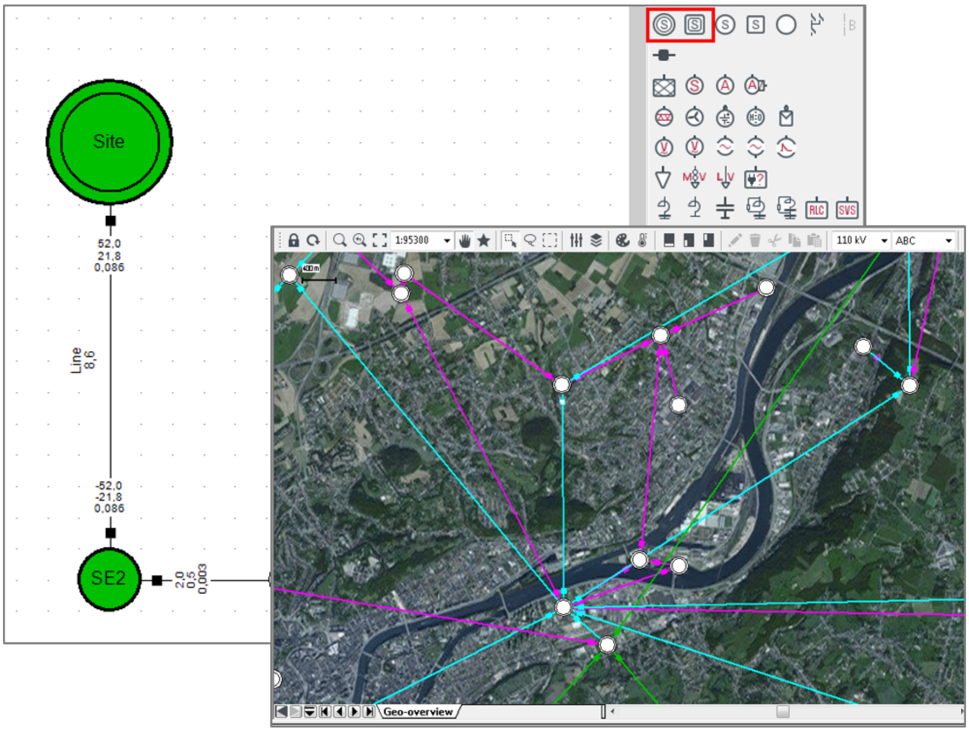


Figure 3.6: Site representation

When a Site is defined, a detailed diagram is automatically created. The user can then draw all the elements directly inside the Site diagram, using detailed substation diagram templates for drawing the site content. If the Site already exists it is possible to use the Diagram Layout Tool to automatically generate its detailed representation. Figure 3.7 shows an example of a site diagram consisting of two substation diagrams.

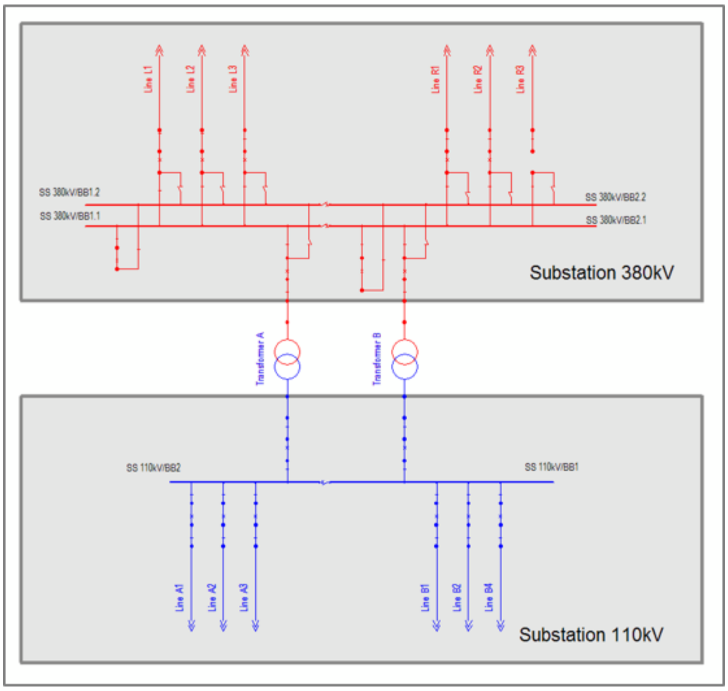


Figure 3.7: Detailed diagram of a Site

3.3 Geographic Diagrams

With ***PowerFactory 2017*** all elements can now be represented in the geographic diagram, including loads, generators and transformers.

Figure 3.8 shows an example of a geographic diagram. The Diagram Layout Tool can be used to automatically draw all the edge elements in the diagram.

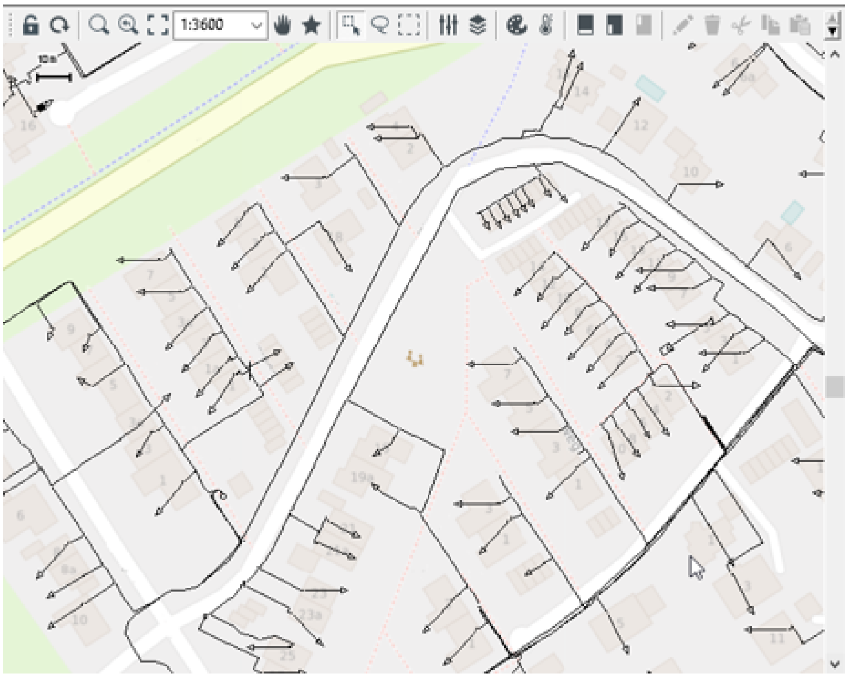


Figure 3.8: Visualisation of loads in the geographic diagram

3.4 Visualisation of Tie Open Points

PowerFactory 2017 offers the possibility to visualise tie open points in network diagrams (geographic, single line and detailed). Tie open points are dynamically determined by the software as those open breakers which separate two different feeders. An example is shown in figure 3.9.

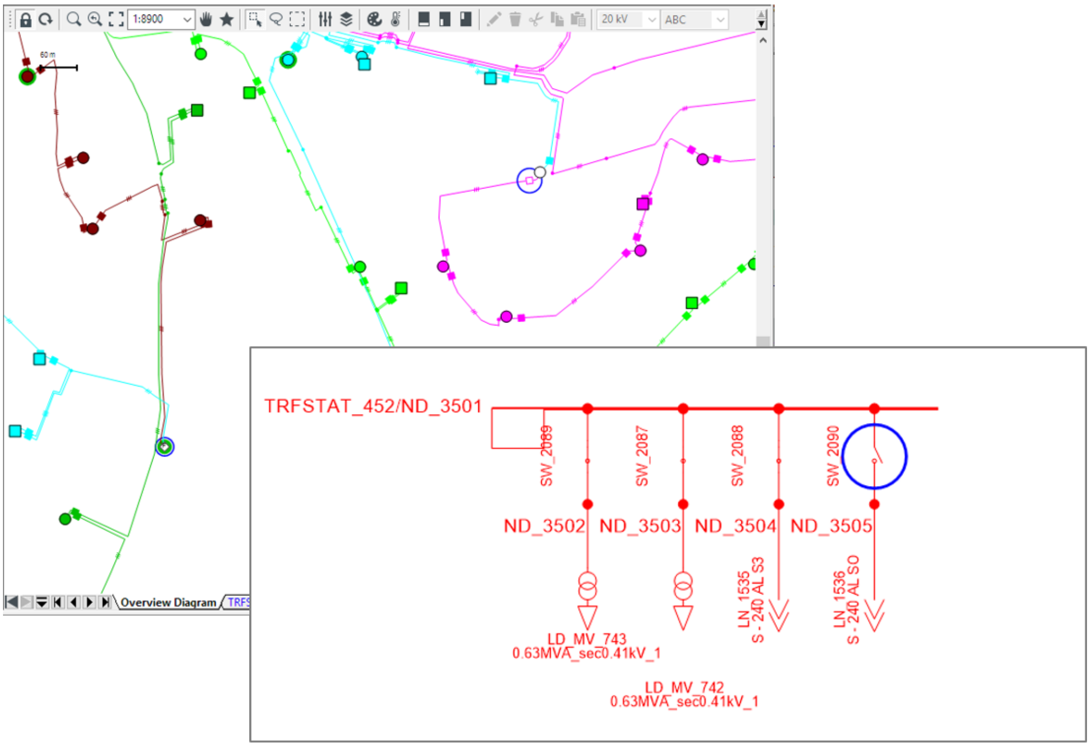


Figure 3.9: Visualisation of tie open points

The visualisation is done using a new layer called “Tie Open Points”, which is by default visible and can be configured as shown in figure 3.10.

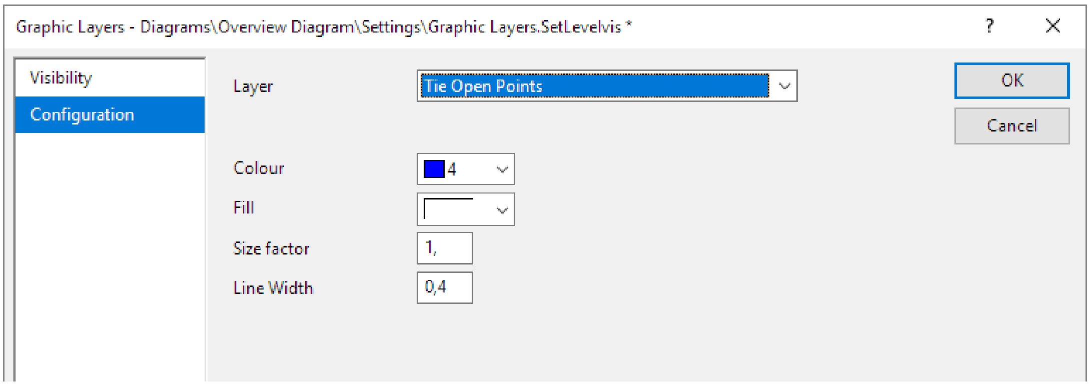


Figure 3.10: Tie Open Points Layer configuration

3.5 Background Maps

Besides usage of pre-configured built-in map services such as Google or OpenStreetmap, ***PowerFactory 2017*** supports the use of user-configured map services based on the standardised WMS/WMTS protocol, as background maps of the geographic diagram. The WMS are defined by the *Administrator* in the *Configuration* folder as shown in figure 3.11

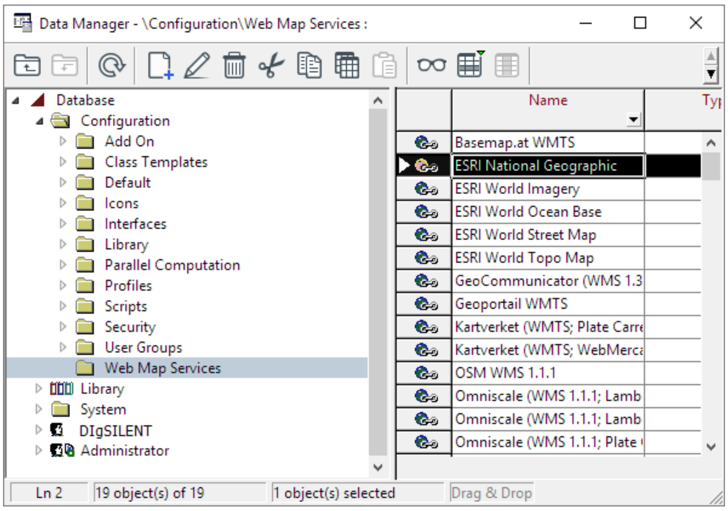


Figure 3.11: Web Map Services folder

Then the user can select the desired map by configuring the *Background* layer of the geographic diagram, as shown in figure 3.12

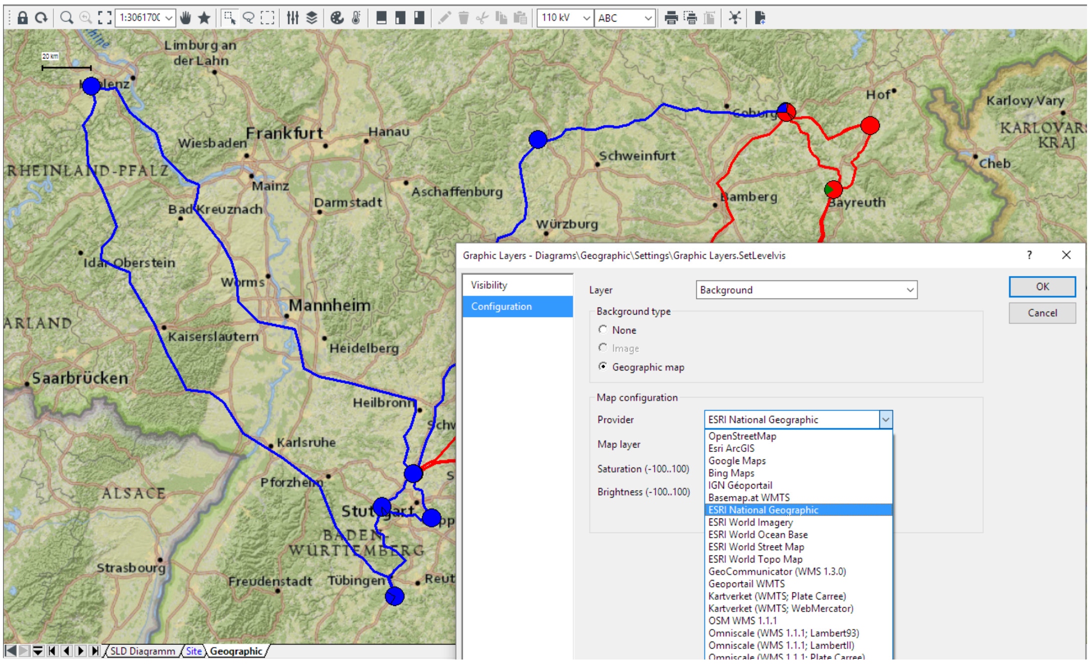
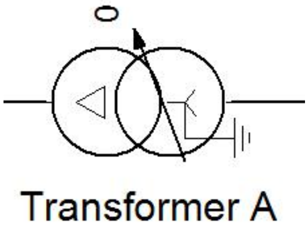


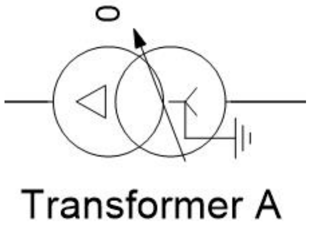
Figure 3.12: Background layer configuration

3.6 Anti-Aliasing

A new diagram setting has been provided that results in a slightly smoother and less pixelated look of the single line diagrams. This option can be activated in the User Settings, *Graphic Windows* page, via the new check-box *Enable anti-aliasing for single line diagrams*.



(a) No anti-aliasing



(b) With anti-aliasing

Figure 3.13: Example of the anti-aliasing option

It should be noted that it is not recommended to enable this setting when working on projects with large diagrams, due to potential graphic performance issues.

4 Analysis Functions

4.1 Load Flow Analysis

Several enhancements to load flow analysis have been introduced in ***PowerFactory 2017*** and the opportunity has also been taken to rationalise the Load Flow Calculation dialog, making it easier for users to locate the parameters that they are interested in.

4.1.1 Consideration of active/reactive power limits according to model type

Under the existing load flow options it was already possible to select whether active power limits and/or reactive power limits should be considered. In ***PowerFactory 2017*** more flexibility has been introduced: users are now able to have the limits considered for some models and not for others.

Figure 4.1 below shows the options available.

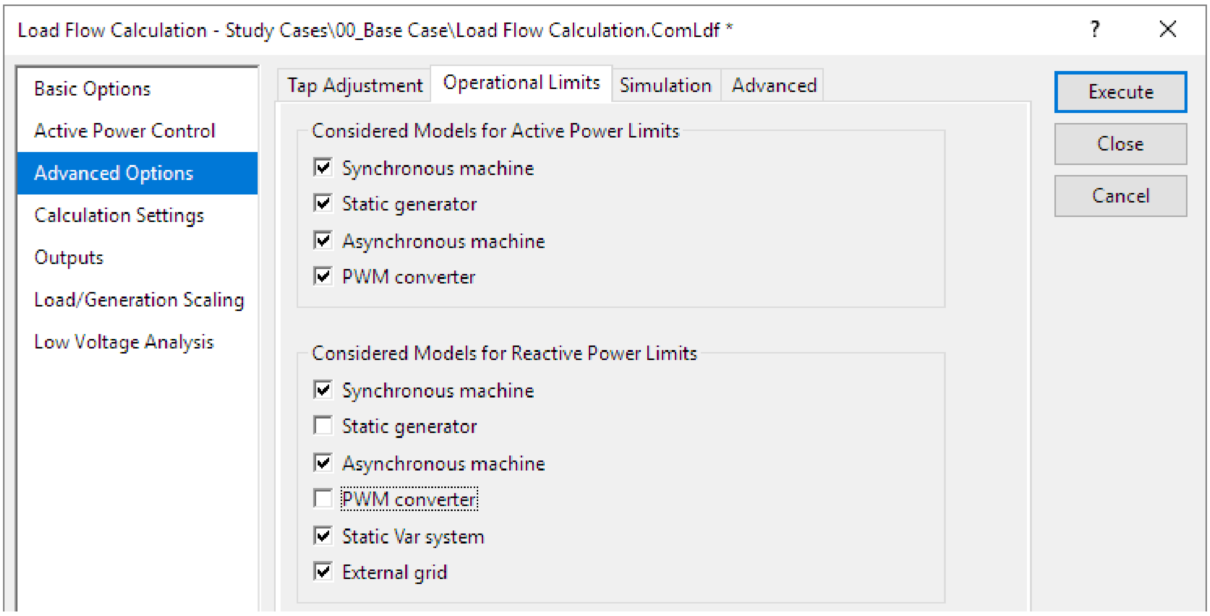


Figure 4.1: Selective consideration of active and reactive power limits

4.1.2 Unbalanced Feeder Load Scaling

With ***PowerFactory 2017*** it is now possible to use feeder load scaling to separately scale each phase of unbalanced loads. This can be useful if, for example, measurements are available at the feeding points for the individual phases.

Using an unbalanced load flow, the option *Feeder Load Scaling* is selected and each phase is then scaled according to the options selected on the relevant feeder object as shown in figure 4.2

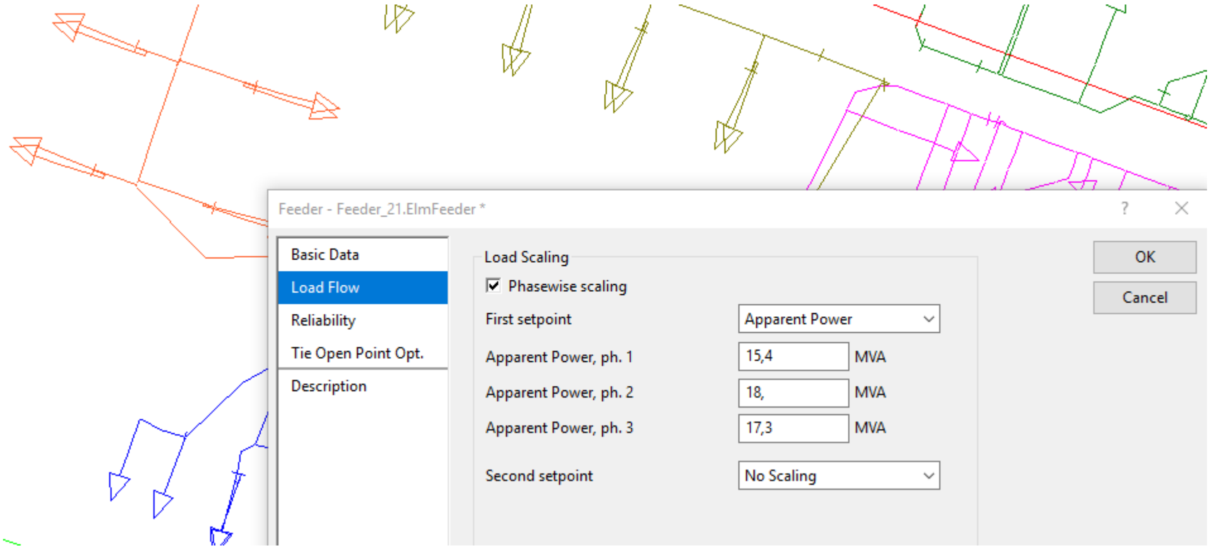


Figure 4.2: Feeder load scaling for unbalanced loads

4.1.3 Power Frequency Control using Merit Order

The existing load flow option for *Active Power Control* using a power frequency controller has been extended, to allow merit order dispatch of the group of slack generators. Generators with the highest merit order priority will be dispatched first, as far as their operational limits allow, then the generators with successively lower merit order priorities as required.

Section 5.5 gives more detail about the configuration of the controller and associated elements.

4.2 Short-Circuit Analysis

4.2.1 Provision of IEC 60909 2016 Edition

PowerFactory 2017 includes an additional option to work to the 2016 edition of the IEC 60909 (and VDE 0102) standard[1]. The principal changes in the new edition are:

- Short-circuit contributions from wind power station units are included
- Short-circuit contributions from power station units with full-size converters are included

Within ***PowerFactory***, this means that wind farms (*ElmGenstat*), solar systems (both *ElmGenstat* and *ElmPvsys*) and asynchronous generators (*ElmAsm*) will now all be supported in the short-circuit calculation, if the 2016 edition is selected.

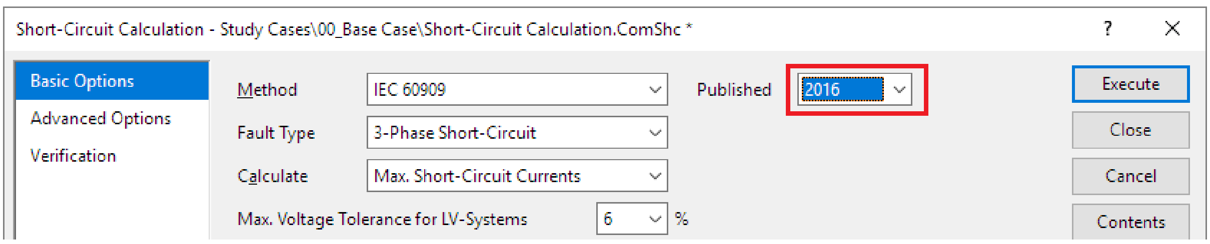


Figure 4.3: Short-Circuit Calculation command

[1] available in upcoming service pack

4.2.2 Performance Optimisation (Complete Method)

The calculation of short-circuits using the Complete Method has been considerably optimised in ***PowerFactory 2017***. This leads to improvements in the end-to-end execution times compared with ***PowerFactory 2016***. As an example, reductions in run-time of around 30 per cent have been observed when analysing over 6000 short-circuits on a large transmission network; the reduction in execution time is more significant with unbalanced than with balanced faults.

4.2.3 Option to Omit Transient Calculations (Complete Method)

By default, transient and subtransient currents and associated parameters will be calculated when short-circuit analysis is carried out using the Complete Method. However, the user now has the option to omit the transient calculations if these results are not required, leading to a shorter execution time.

4.3 Power Transfer Events

An additional event type is now available to the user when setting up events for Contingency Analysis, RMS Simulations or Planned Outages. Unlike the existing Load Event EvtLod, which is used to define real and reactive demand changes for an individual load, the Power Transfer Event EvtTransfer makes it possible to define post-fault power transfers between load objects (or static generators) on a relative basis. Figure 4.4 below shows how the Power Transfer Event is set up between loads. Only one source element is permitted per event, but the power can be distributed among several destination objects.

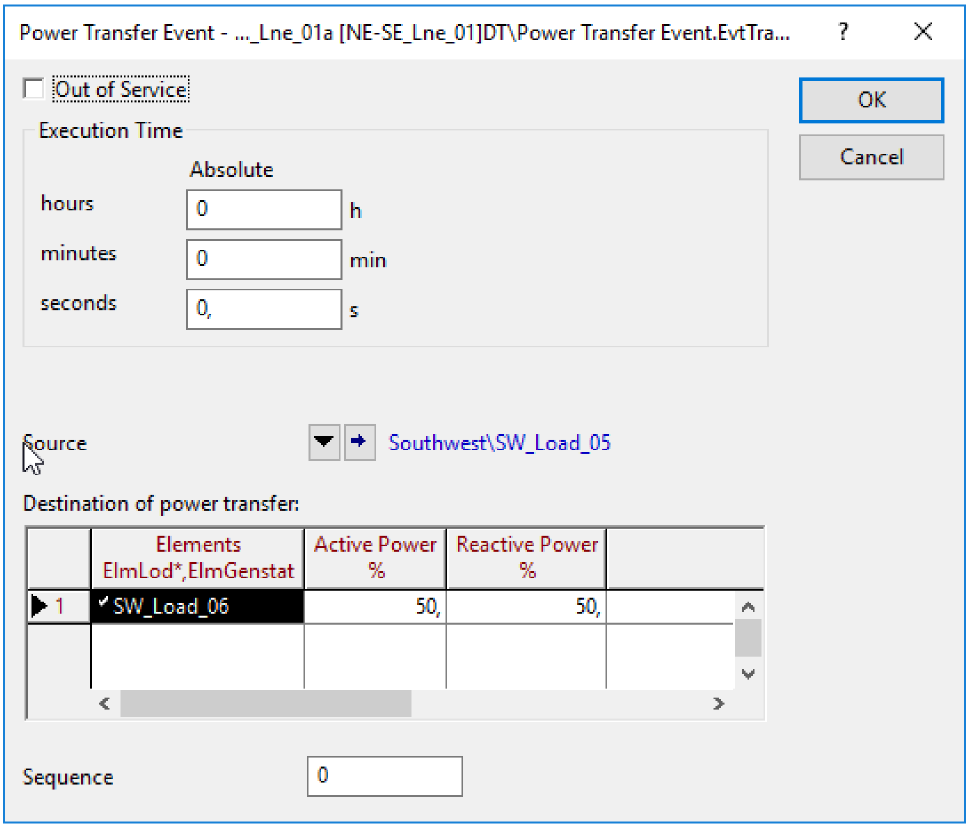


Figure 4.4: Power Transfer Event

4.4 Contingency Analysis

4.4.1 Contingency Analysis Execution from Graphic

The ability to execute a contingency directly from a graphic has been enhanced in ***PowerFactory 2017***. The underlying assumption is that if a relevant fault case already exists in the project library then this should be used for the analysis. There are two options:

- Execution of a single contingency: In this case, a single contingency representing a fault on all the elements selected will be executed via a fault case. A fault case from the library will be used if present (the user will be offered a choice if there is more than one), otherwise a temporary fault case will be created and executed, with the calculation results being visible on the graphic or via an object filter.
- Contingency Analysis: In this case, fault cases for each selected element will be used to populate the Contingency Analysis command. For any elements for which no relevant fault cases are found in the library, n-1 fault cases will be created; these fault cases will be retained after the analysis has been executed.

The first option, *Execute single contingency*, offers an ideal way to examine individual cases from a large contingency sweep, without losing the results of the full calculation. The second option, provides an easy way of selecting from the library all relevant fault cases for a particular part of the network.

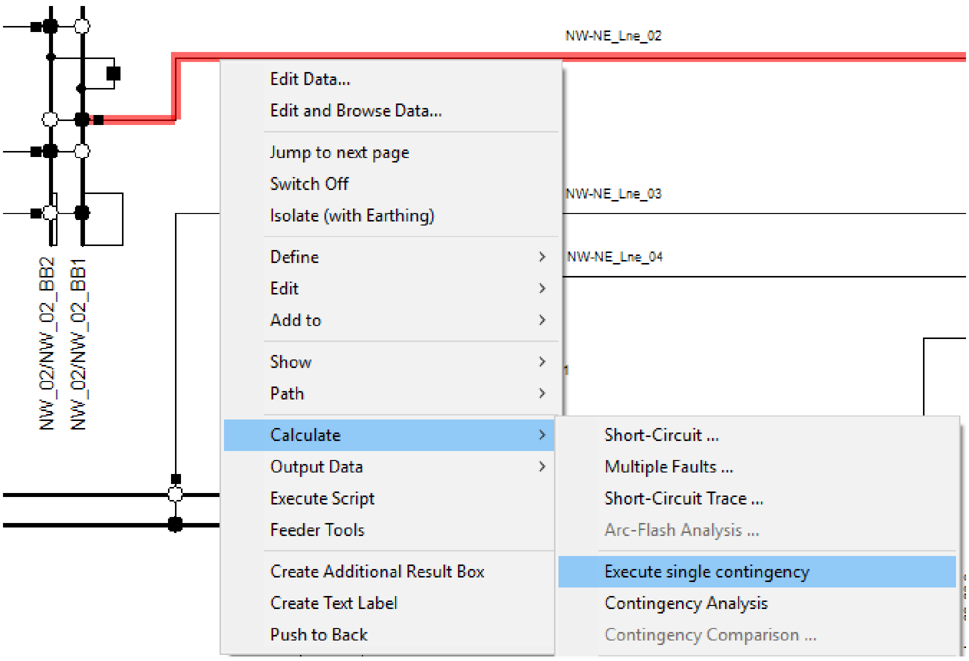


Figure 4.5: Contingency Analysis execution from graphic

4.4.2 Power Transfer Events in Contingency Analysis

Power Transfer Events (*EvtTransfer*), i.e. demand transfers defined on a relative basis, are now supported in Contingency Analysis. Section 4.3 describes the new object.

4.5 Quasi Dynamic Simulation

The Quasi-Dynamic Simulation is the optimal tool for performing medium to long term dynamic studies thereby incorporating network development and expansion defined via variations and characteristics. Previously being a pure load flow time sweep, the tool now enables the user to control the actions of network components during the simulation, based on information that is available at the respective time step.

There are several situations where the time dependency between consecutive steady states must be considered. Examples include:

- Slow reacting controllers;
- Systems which have time constants comparable to or greater than the simulation time step (e.g. Transformer/shunt tap changers, etc);
- Certain quantities might be time dependent but cannot be provided as a time characteristic, i.e. its value is not known prior to executing the simulation. Consider, e.g., the state of charge of a battery system, fuel remaining/consumed in a diesel gen-set, etc.;

PowerFactory 2017 enables the user to include these dynamics in the simulation. As one major step towards this objective, we enable the user to code his own load flow model - even more, to extend it to a dynamic model incorporating state variables. Thus, the user can create customised controllers/models which can then be used in both Load Flow and Quasi-Dynamic simulations. The governing equations are completely customisable, using standard DPL code syntax.

4.5.1 User Defined Quasi-Dynamic Simulation Models

It is now possible to develop user defined Quasi-Dynamic Simulation models (QDSL models) using two newly developed objects *TypQdsl* and *ElmQdsl*. Users are given access to the model calculation algorithm through the application of user defined equations during:

- the Load Flow iteration: customisable equations that control various load flow quantities (e.g. voltage dependent active/reactive power output of loads/static generators) can be implemented.
- the Quasi-Dynamic Simulation time step advance: support for time dependent state variables and definition of their differential equations is included.(e.g. a control algorithm that decides whether a battery should charge or not depending on its state of charge).

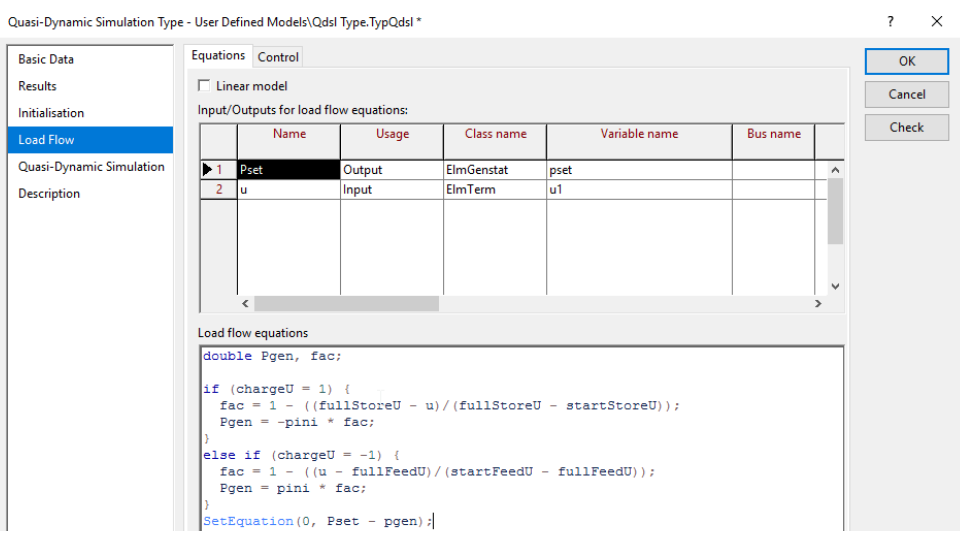


Figure 4.6: User-defined load flow equations in DPL style

Figure 4.7 shows the results of one practical example where a battery system is modelled including its charge controller, and the “state of charge” is one such state variable. As expected, the battery charges during the full sun hours (triggered by high AC terminal voltage) and discharges to a minimum afterwards.

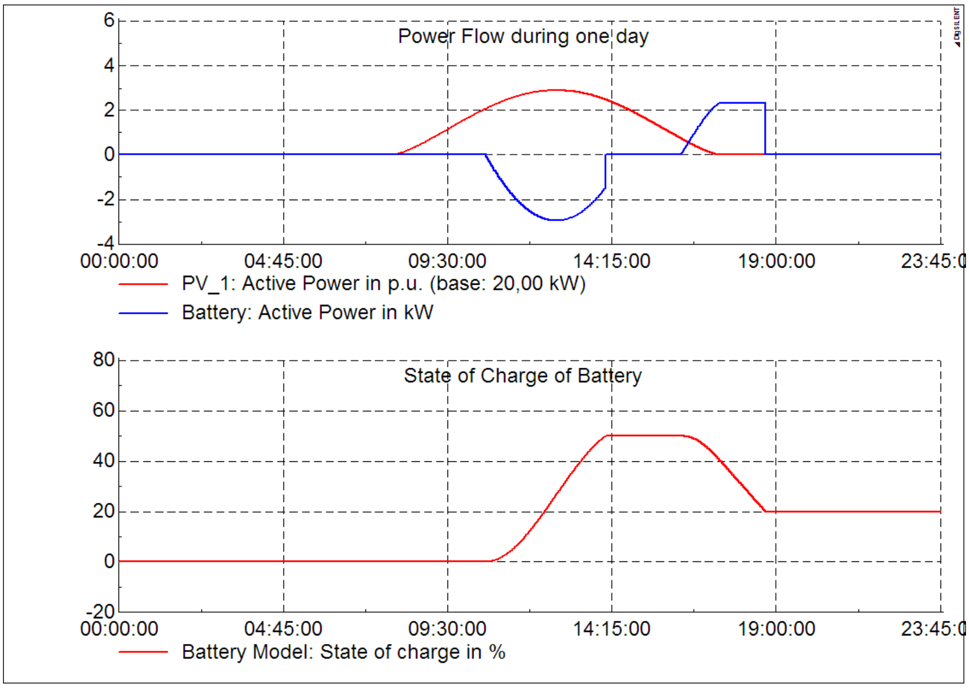


Figure 4.7: Battery state of charge during a one day cycle

4.5.2 Support of various simulation events

It is now possible to apply a multitude of user-defined simulation events in the quasi-dynamic simulation, such as switch events, dispatch events, load shedding/ramp events or parameter events. Furthermore, events can also be fired during a quasi-dynamic simulation by a QDSL model, depending on certain conditions (programmed in the model).

4.6 Network Reduction

With ***PowerFactory 2016*** a new network reduction method was introduced. This method, based on REI equivalents (Radial, Equivalent,Independent), allows elements of the network to be retained when performing a network reduction.

Until now this equivalent method was only suitable for load flow calculations. ***PowerFactory 2017*** includes the option of calculating the short-circuit equivalent of the network for both balanced and unbalanced representation, which now makes it possible to have an equivalent reduced network based not only on the load flow calculation results, but also on the short-circuit calculation (Complete Method) results.

The new Network Reduction dialog is shown below in figure 4.8

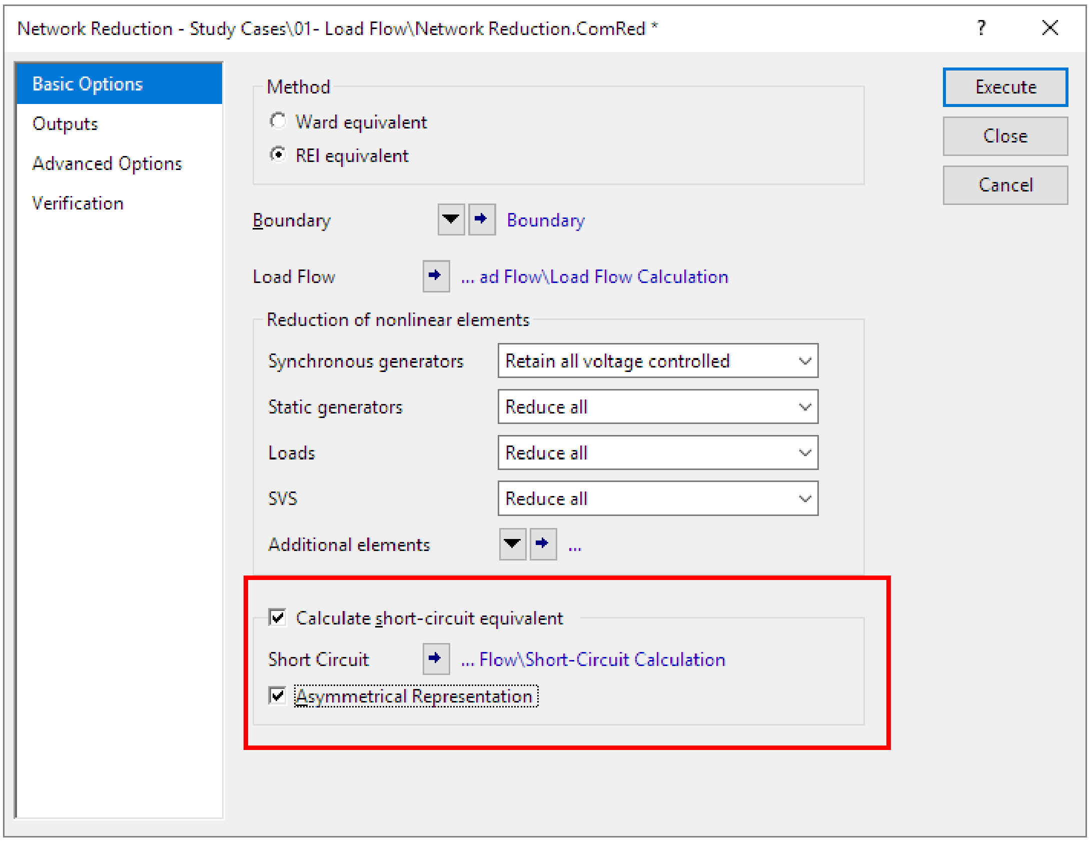


Figure 4.8: Short-circuit equivalent option for the REI method

4.7 Protection

4.7.1 Protection Audit

Detailed verification of protection system performance can be an extremely time consuming task, especially when performed for larger network areas. Most graphical coordination tools can only work with one type of protection at a time (overcurrent, distance, etc.). Verification of the scheme and settings selected during a coordination study can involve a lot of repetitive analysis where important factors can easily be missed if the engineer does not maintain a high level of concentration.

A new function has been provided that automates many of the repetitive actions carried out by the engineer when verifying the performance of a protection scheme. Further, this function presents the results in such a way that they can quickly identify weakness in their scheme. The verification process involves the application of short-circuit calculations throughout a given network area. The user specifies the network area to be examined and then configures the fault cases to be applied. The protection devices responsible for each network element are determined automatically by the feature. The fault cases specified by the user are calculated at each network element at varying locations within the selected area and the reaction of all protection devices to those faults is recorded. Verification of results with respect to various criteria is performed as a secondary step and the outcome displayed in tabular form. Colouring of the tabular output is applied to assist in the assessment of the results.

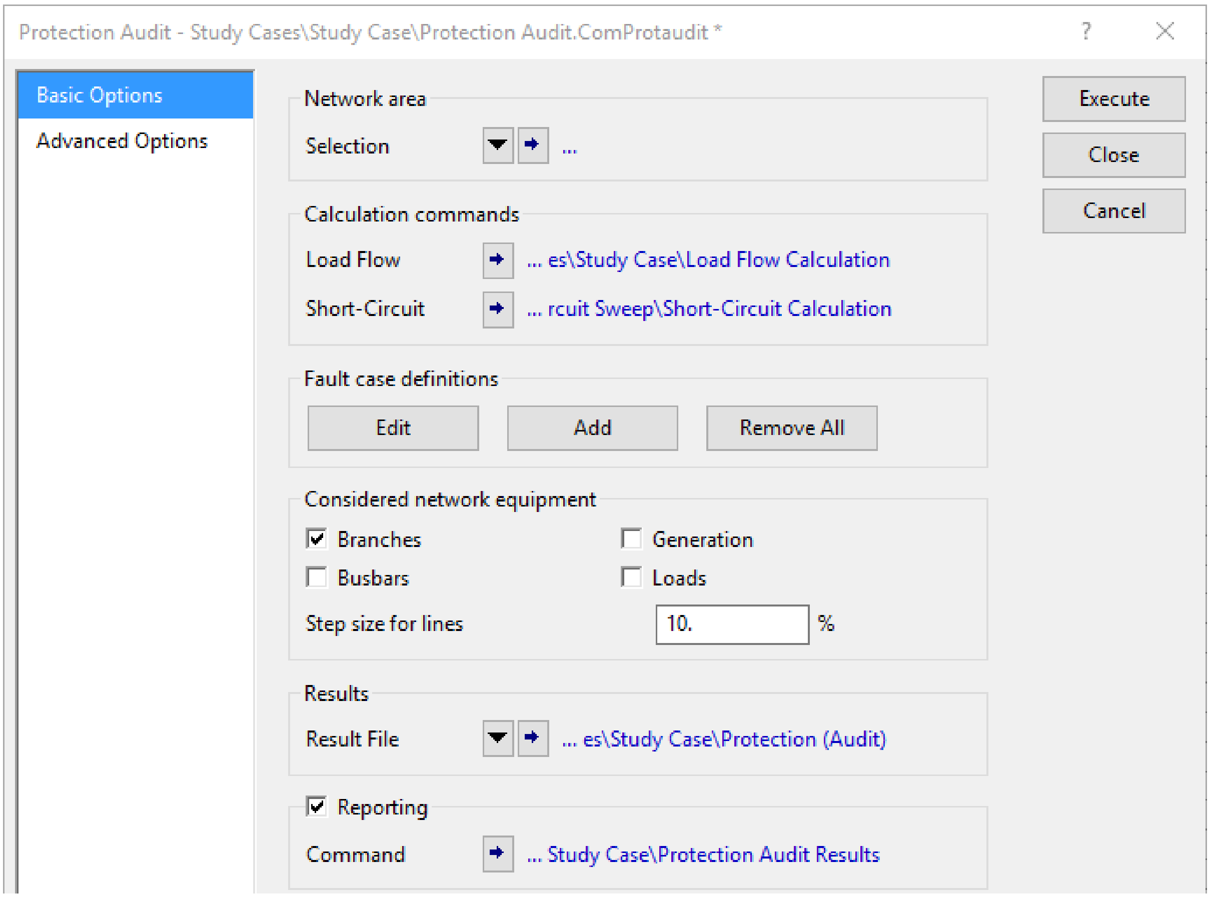


Figure 4.9: Protection Audit command dialog

The protection devices responsible for each network element are determined according to the circuit breakers they operate. The topological orientation of a circuit breaker with respect to the protected network elements is assessed to determine the next circuit breaker for consideration. Specific rules are applied to facilitate coordination over network elements requiring special consideration such as transformers.

Results can be checked against:

- Fixed coordination margin
- Coordination margin based on the downstream circuit breaker delay
- Maximum allowed device tripping time
- Maximum allowed fault clearing time

Different severities can be assigned to different conditions and locations. For example a coordination issue between main and backup protection can be considered more severe than a coordination issue between the second backup and an upstream device.

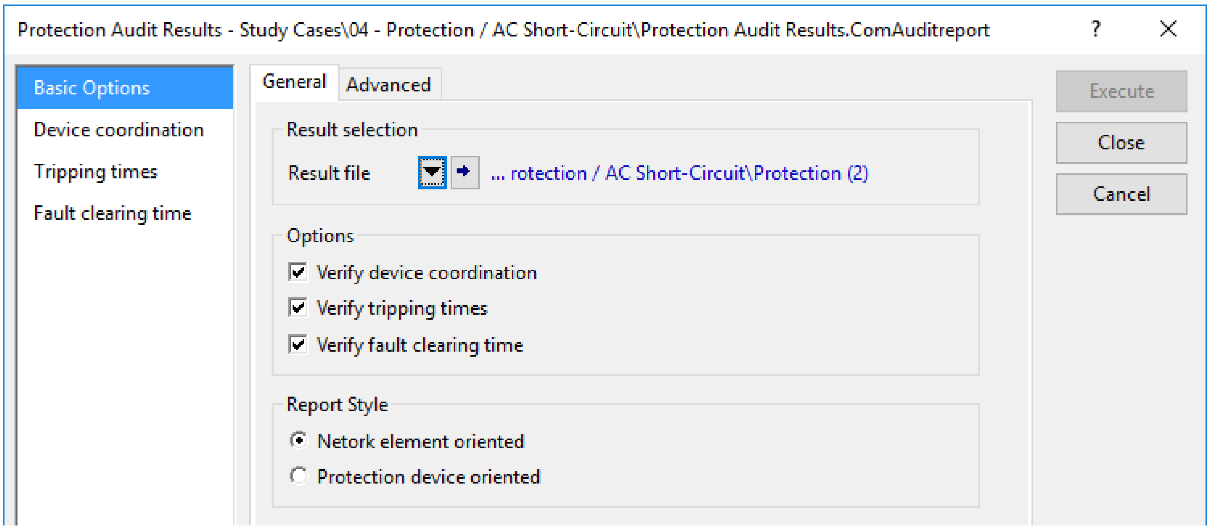


Figure 4.10: Protection Audit Results command dialog

Element	Summary	3-Phase Short-Circuit	2-Phase Short-Circuit	2-Phase to Ground	Single Phase to Ground
Line 1	Failure	OK	OK	Failure	Failure
Line 2	Warning	OK	OK	Warning	Warning
Transformer 1	Ok	OK	OK	OK	OK
Generator 1	OK	OK	OK	OK	OK
Line 3	OK	OK	OK	OK	OK

Figure 4.11: Network element oriented report

Fault Type	2-Phase to Ground			Resistance		5.0 Ohm						
Element	Line 1											
		Fault Location										
Device	Role	Bus i	10%	20%	30%	40%	50%	60%	70%	80%	90%	Bus j
R1	Main (Bus i)	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,50	0,50	0,50
R2	Main (Bus j)	0,50	0,50	0,50	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
R5	Backup (R1)	0,40	0,40	0,40	0,40	0,40	0,75	0,75	0,75	0,75	0,75	0,75
R7	Backup (R2)	NO TRIP	NO TRIP	NO TRIP	1,10	1,10	1,10	0,75	0,75	0,40	0,40	0,40
R8	Backup (R2)	NO TRIP	NO TRIP	NO TRIP	1,10	1,10	1,10	0,75	0,75	0,40	0,40	0,40

Figure 4.12: Protection device oriented report

4.8 Connection Request Assessment

4.8.1 Connection Request Assessment according to BDEW 2008 and VDE-AR-N 4105

The Connection Request Assessment has been enhanced with ***PowerFactory 2017*** to include assessments according to the guidelines BDEW 2008 (4th Supplement) and VDE-AR-N 4105. These apply to the connection of generating units at the MV and LV voltage levels, respectively. The assessments comprise: loading of network components, admissible voltage changes, sudden voltage changes and flicker, voltage unbalance, harmonics, interharmonics and audio-frequency ripple control, commutation notches and maximum short-circuit current. The use of complex load flow calculations in some of these assessments assists in providing accurate information on the effect of new installations on network conditions. The inclusion of the two new assessments makes the Connection Request Assessment in ***PowerFactory*** an invaluable tool for planners and network operators.

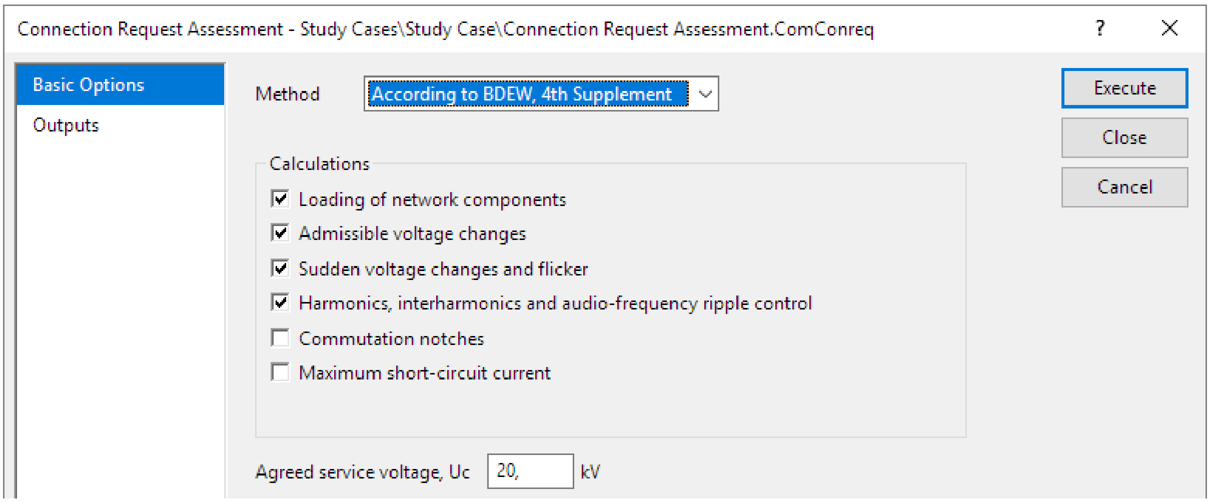


Figure 4.13: Connection Request command dialog

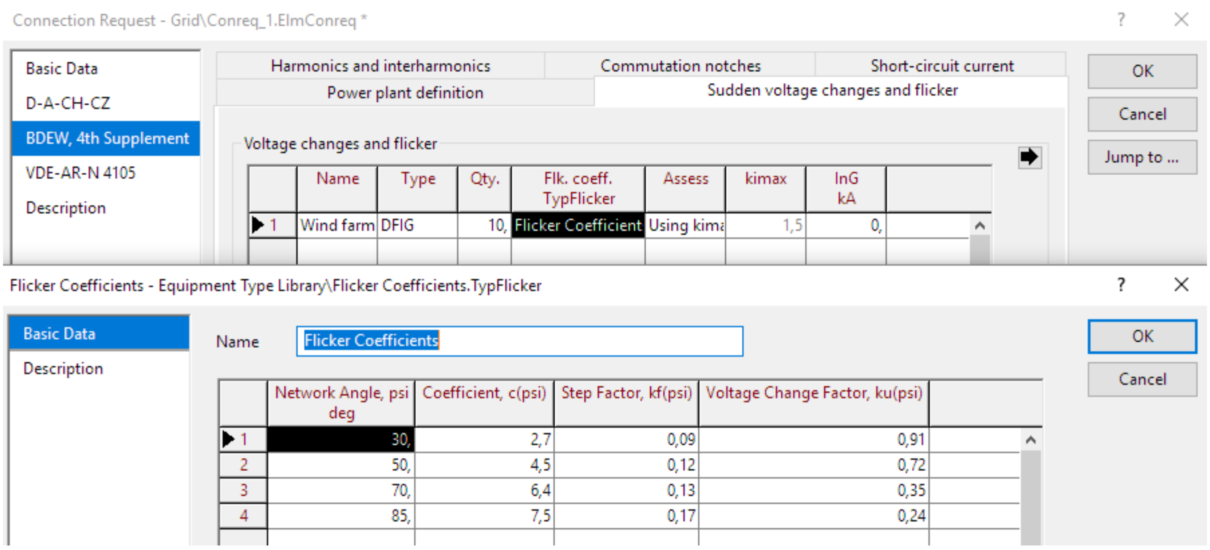


Figure 4.14: Connection Request element dialog, BDEW page

4.8.2 Connection Request Assessment according to D-A-CH-CZ: Consideration of Generation

With ***PowerFactory 2017*** the Connection Request Assessment according to D-A-CH-CZ has been enhanced to consider generating units. The connection request element now additionally allows the definition of a generating station with multiple generating units. Each type of generating unit can have individual flicker coefficients and harmonic currents defined. This enhancement allows a comprehensive assessment of network disturbances according to D-A-CH-CZ.

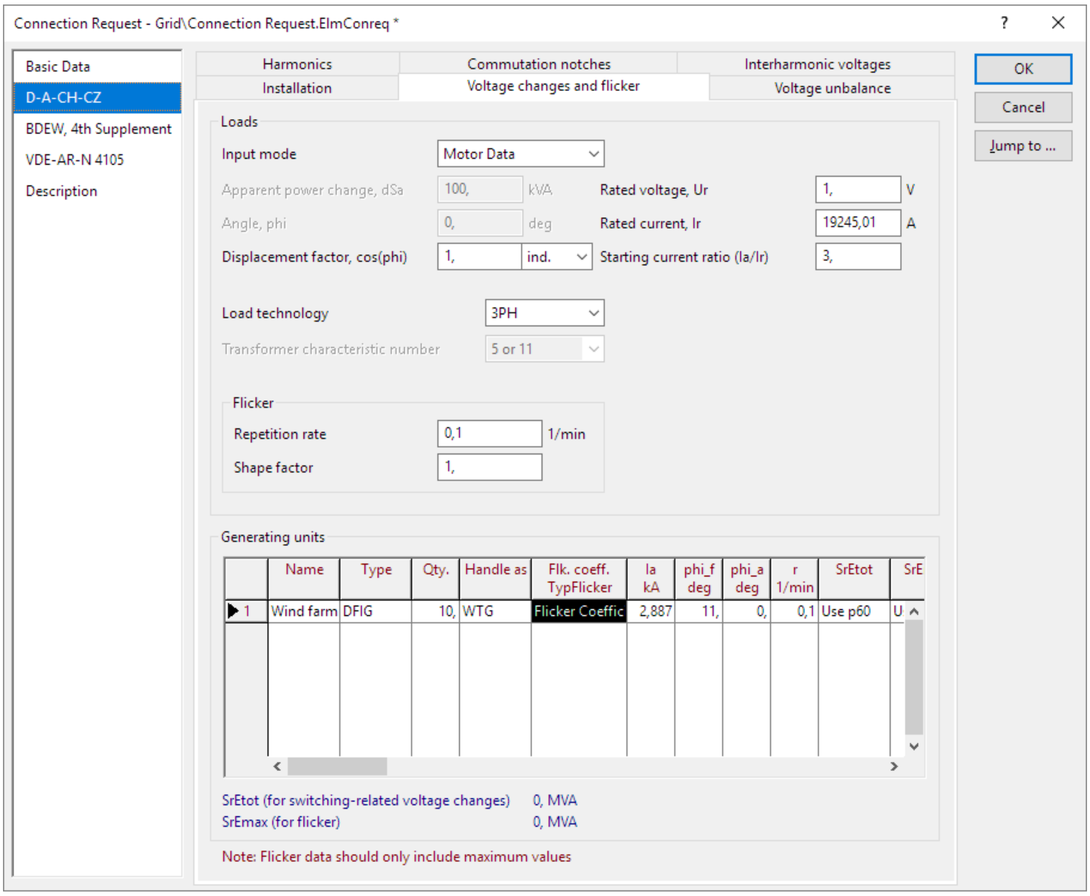


Figure 4.15: Connection Request element dialog, D-A-CH-CZ page

4.9 Distribution Network Tools

In ***PowerFactory 2017***, a Genetic Algorithm has been introduced for Tie Open Point Optimisation and Phase Balance Optimisation.

The Simulated Annealing algorithm, which was introduced in ***PowerFactory 2016*** for Phase Balance Optimisation, has now also been included as an optimisation method for Tie Open Point Optimisation.

Tie open point and phase balance optimisation problems are difficult to solve with classical methods, as they have the following properties:

- The objective function is not differentiable
- The states are “discrete”
- The objective function usually has many local minima
- The space of potential solutions is huge

For problems with such properties, metaheuristic algorithms like the Simulated Annealing or Genetic Algorithms are well suited:

- Simulated Annealing uses a random process in order to approach the optimum during a “cool down” of the system.
- Genetic Algorithms, similar to the evolutionary mechanism of nature, improve the objective by applying mutation and crossover to an evolving population of appropriately chosen individuals, which represents the specific structure of the optimisation problem.

The edit dialogs of the Tie Open Point Optimisation and Phase Balance Optimisation commands, including the new optimisation methods are shown if figure 4.16.

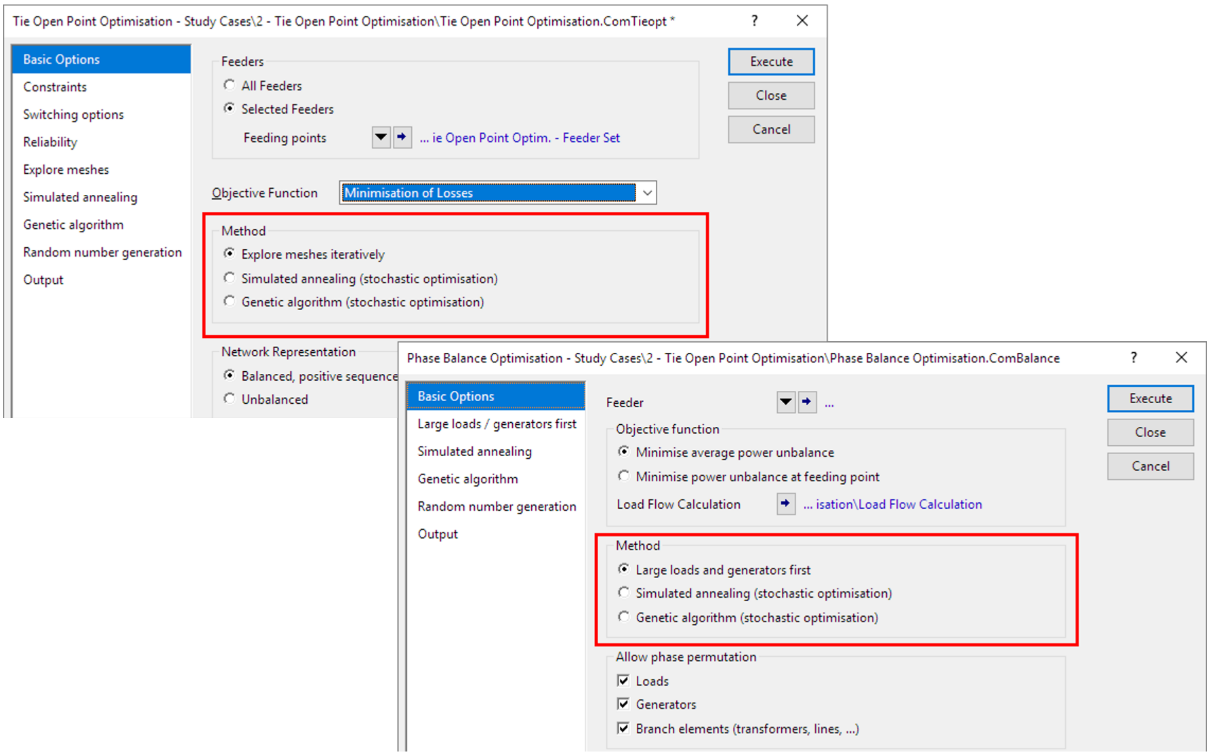


Figure 4.16: Tie Open Point Optimisation and Phase Balance Optimisation dialogs

4.10 Outage Planning

In ***PowerFactory 2017***, a new module [2] for managing and modelling of outages has been implemented.

The new methodology works on the principle that in the scenario, the network is intact. When the new Planned Outage objects (*IntPlannedout*) are applied, the network changes are just held in memory. Thus, resetting of outages becomes straightforward. All calculations will take account of applied changes such as switch positions and earths.

In addition to this, there is now the possibility to add a range of associated actions to an outage, such as additional switch actions, transformer tapping and power transfer (see section 4.3), which will subsequently be enacted whenever the outage is applied. A “record” mode is provided, which lets the user define events such as switch operations simply by carrying out the open and close actions via a diagram or filter. Figure 4.17 shows the new Planned Outage object.

[2] The module *Outage Planning* will be released as part of the *Transmission Network Tools* and the *Distribution Network Tools* packages, respectively.

The outages can be manually applied as long as a study case is active, but there is also a project setting whereby the user can opt to always automatically apply all relevant outages upon activation of a study case.

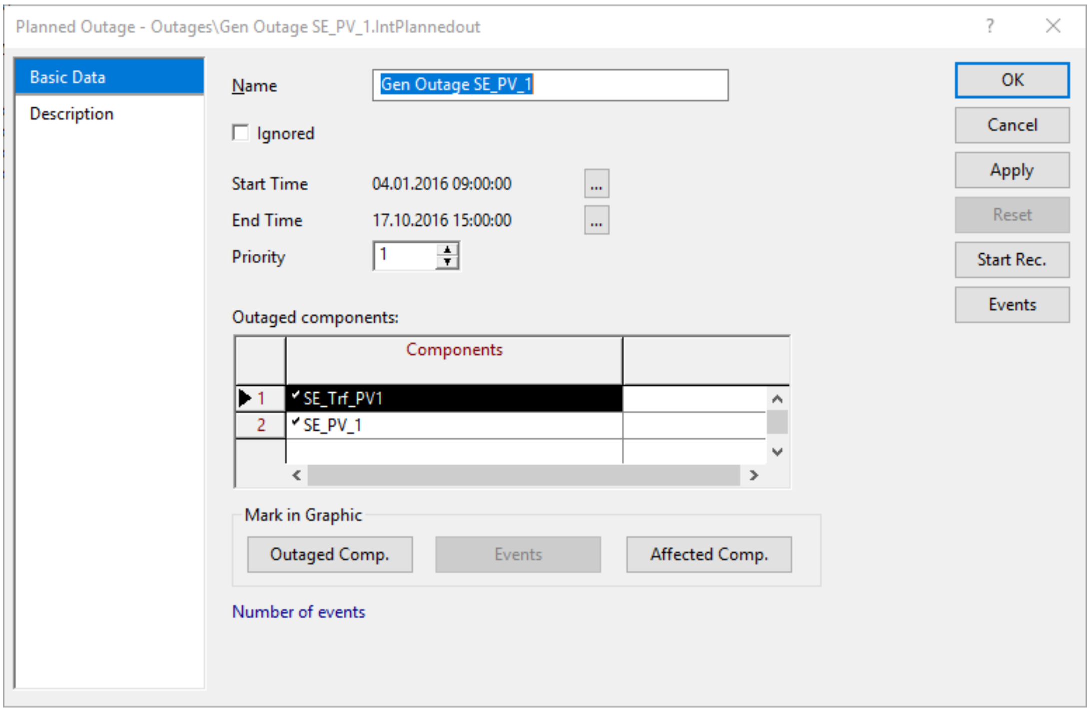


Figure 4.17: Planned Outage object

A new Outage Management toolbar has been provided (see figure 4.18), to allow the user to easily manipulate the planned outages within the project; a reporting function is also included.

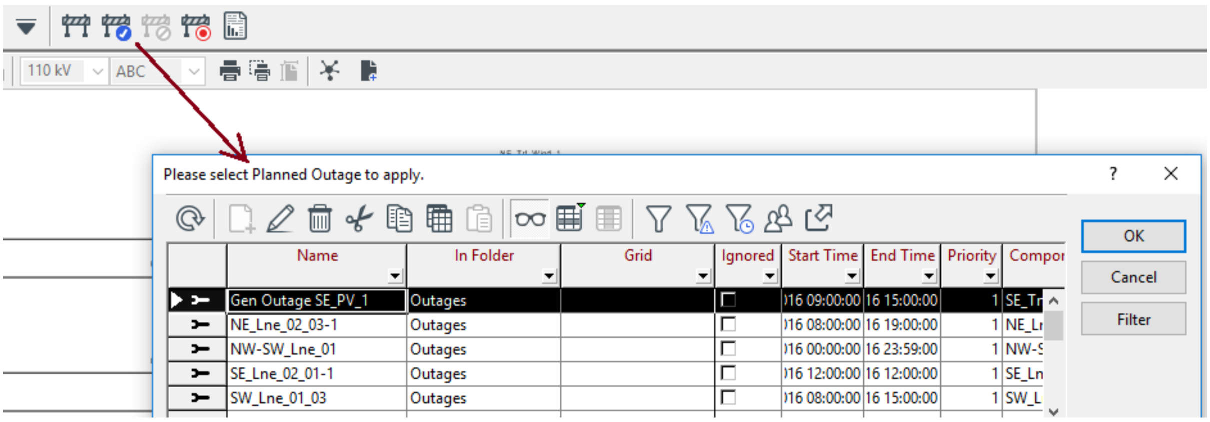


Figure 4.18: Using the Outage Planning Toolbar

The existing functionality, of Outage objects applied to a scenario, is still supported.

4.11 Reliability Analysis

Reliability Assessment now offers several new functionalities:

- Protection maloperation
- Backward Recovery of feeders in primary substations
- Reliability Assessment within meshed networks
- Enhancements in reporting
- Additional scripting functionalities for contingencies
- Option to define momentary interruption time for the SAIFI/SAIDI calculation
- Option to replace melted fuses during restoration

In the following subsections some of these new functionalities are detailed.

4.11.1 Protection Maloperation

In ***PowerFactory 2017*** two new failure modes for Reliability Analysis are added, the *spurious protection operation* and the *backup protection maloperation*.

The backup protection maloperation can occur after a short-circuit for reasons that include:

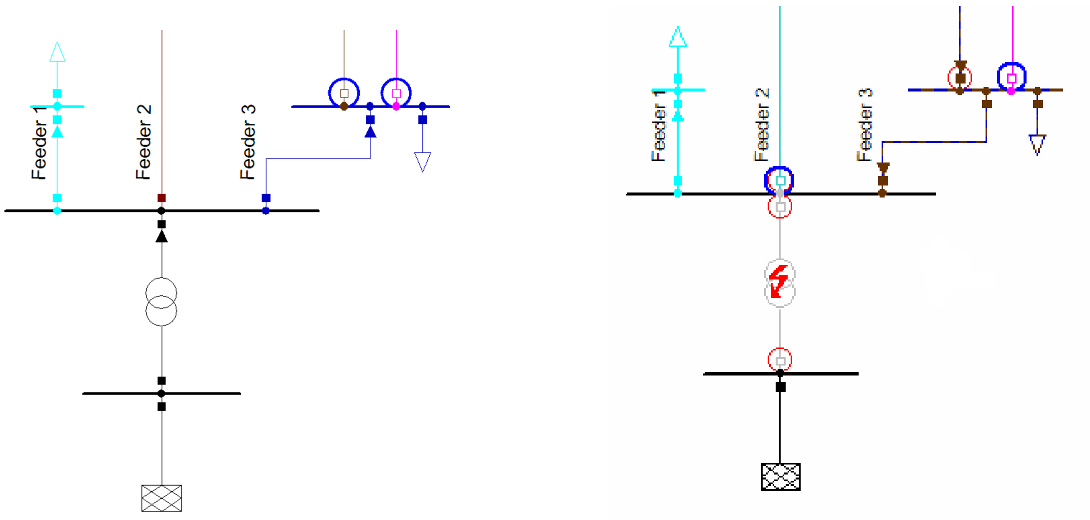
- Insufficient protection adjustment
- Measurement errors
- Wrong direction decisions
- Transformer saturation
- Damages to the protection device

The spurious protection operation models the opening event of a breaker without any preceding short-circuit.

4.11.2 Backward Recovery of Feeders in Primary Substations

For ***PowerFactory 2017*** the restoration algorithm is enhanced with an option which allows the restoration through a substation. This function is called “Backward Recovery”. The algorithm checks for the best feeder to resupply the substation and the interrupted feeders. This can improve the restoration quality for a loss of a substation significantly.

Figure 4.19 show an example of a substation where an outage has occurred on the supply transformer. Therefore the external grid is disconnected. In this example, with the new Backward Recovery option selected, the isolated Feeder 1 is resupplied backward through Feeder 3.



(a) Initial State (b) Resupply of Feeder 1

Figure 4.19: Example of Backward Recovery

4.11.3 Reliability Assessment within Meshed Distribution Networks

This section refers to the *Distribution Mode* of the Reliability Analysis which implements the Optimal Power Restoration strategies. ***PowerFactory 2017*** meets the objective to run Reliability Assessment in weakly meshed distribution networks, with a restoration that considers thermal, as well as voltage limits. Examples of possible topologies of meshed networks that are suitable for reliability assessment are illustrated in the following figures.

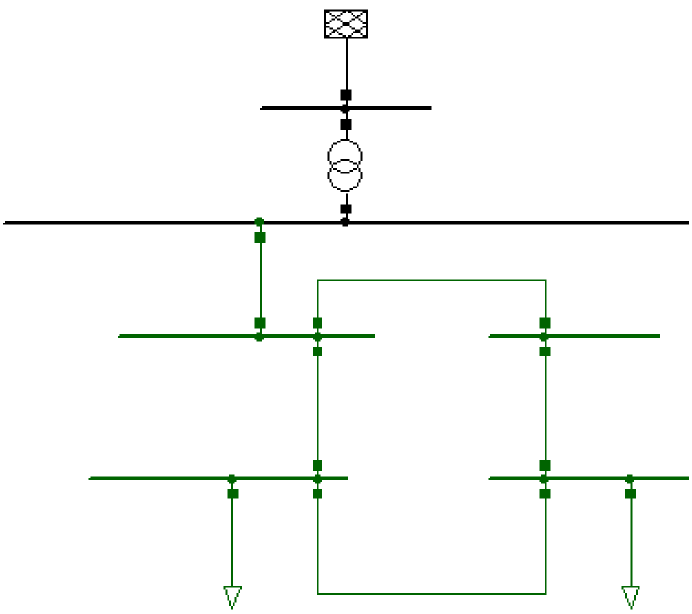


Figure 4.20: Configuration 1, mesh within feeder

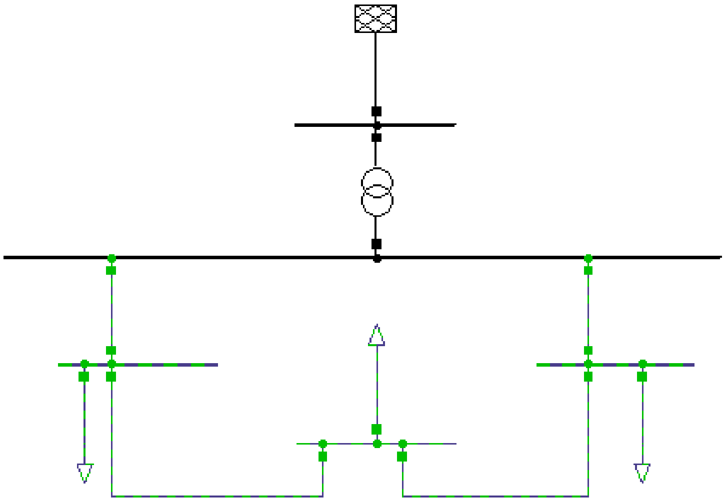


Figure 4.21: Configuration 2, mesh containing two feeders starting from the same terminal

In the case shown in figure 4.21, there are again two feeders defined from one supply point.

4.12 RMS/EMT Simulation

4.12.1 Power Transfer Events in RMS simulations

Power Transfer Events (*EvtTransfer*), i.e. demand transfers defined on a relative basis, are now supported in RMS simulations. Section 4.3 describes the new object.

4.12.2 Simulation Scan: Fault Ride Through

A new simulation scan module has been developed for ***PowerFactory 2017***. With this *Fault Ride Through* module it is possible to monitor the simulation using a user-specified curve definition. The edit dialog of the module is shown in figure 4.22

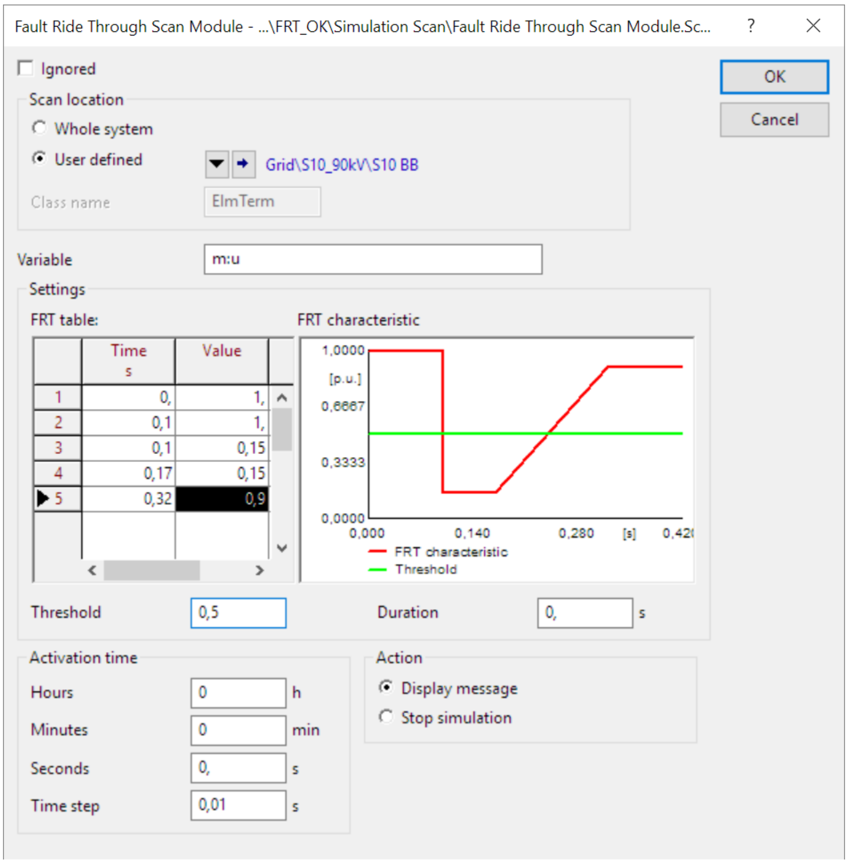


Figure 4.22: Fault Ride Through Scan Module

This module is particularly useful when verifying, for example, if the voltage of the complete system or of a specific terminal fulfils the fault ride through characteristic defined by the regulator's standards. The definition of the FRT curves is done in a simple and flexible way; different types of curves can be defined, as shown in figure 4.23.

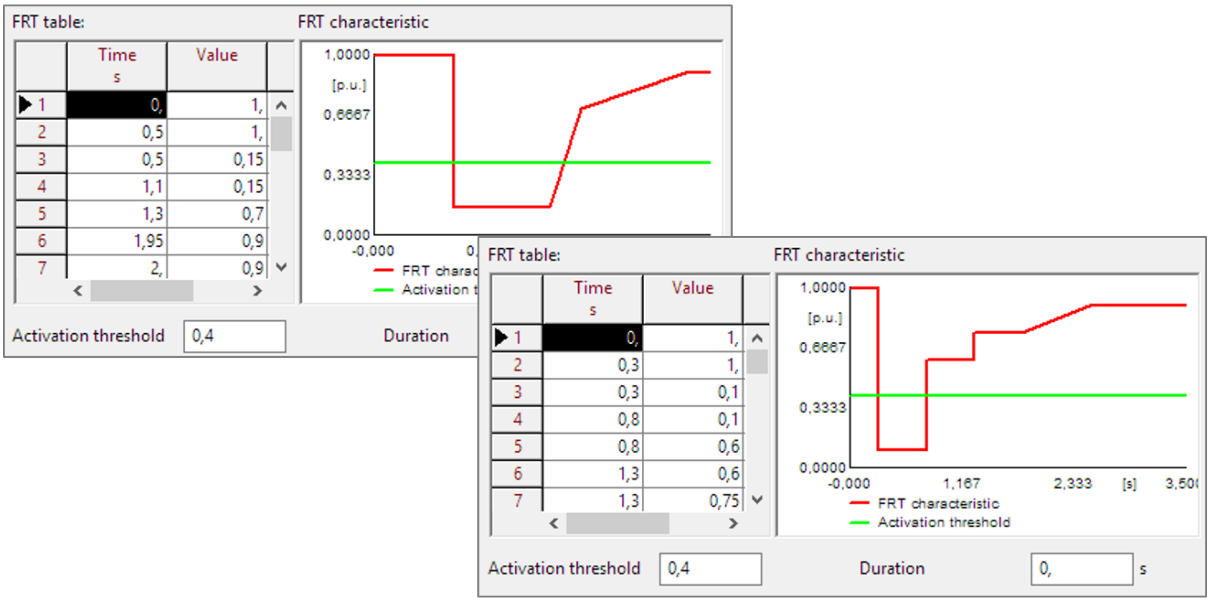


Figure 4.23: Fault Ride Through Characteristics

4.12.3 Retention of Load Flow results after Initialisation

When the Calculation of Initial Conditions is carried out at the start of a simulation, a load flow needs to be run. If many simulations are to be performed and therefore the initial conditions must be repeatedly recalculated, the repeated load flows could cause a considerable time overhead. An enhancement in ***PowerFactory 2017*** provides a performance improvement by offering an option in the Calculation of Initial Conditions to reuse the previous load flow results. If the option is selected, the load flow results from the calculation of initial conditions are retained and used in subsequent initial conditions calculations.

4.12.4 Additional DSL functions

DSL modelling has been improved with the addition of several new functions, which will streamline the DSL code :

- PI controller according to IEEE 421.5 (2005) standard
  `picontrol_const(state,min,max,prop_input)`
- Gradient limiter
  `gradlim_const(input,min,max)`
- Moving average filter
  `movingavg(input,Tdel,Tlength)`
- Return value at last valid iteration
  `lastvalue(input)`
- Return simulation type
  `rms()`
- Return balanced/unbalanced network representation mode
  `balanced()`
- Constant values of on and off expressions on the function *select*
  `select_const(...)`
- Constant values of on and off expressions on the function *selfix*
  `selfix_const(...)`
- Constant values of limits on the function *lim*
  `lim_const(...)`
- Constant values of limits on the function *limstate*
  `limstate_const(...)`
- Constant time values on the function *picdro*
  `picdro_const(...)`

4.12.5 Support of external models acc. to IEC 61400-27-1 (2015)

It is possible now to directly interface external models compliant with IEC 61400-27-1 Annex F specifications. The models can be used for both RMS and EMT type simulations (provided they are appropriately designed and intended for RMS or EMT).

PowerFactory provides the built-in DSL (*DIgSILENT* Simulation Language) model development environment which allows the creation of user defined dynamic models. Although DSL remains the recommended approach for developing models, we recognise the requirements of customers who have to develop simulation models of the same equipment in multiple simulation tools. Creating the same model in each simulation tool can be time-consuming and may also lead to slightly different implementations/results. The generic IEC interface provides an alternative solution by defining a common interface which can be interpreted by any third party software whilst using the same simulation model core equations.

Note: As with any other externally compiled model (e.g. based on digexdyn or digexfun interfaces), the IEC 61400-27-1 models are not supported by the Modal Analysis Toolbox. The only exception is made for compiled models developed based on *DIgSILENT*'s C-interface (further information on the DSL to C-interface can be found in the ***PowerFactory*** User Manual).

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5 Power Equipment Models

5.1 4-Winding Transformer Model

PowerFactory 2017 comes with a built-in model for a four-winding transformer, *ElmTr4*, which connects to four cubicles in the network.

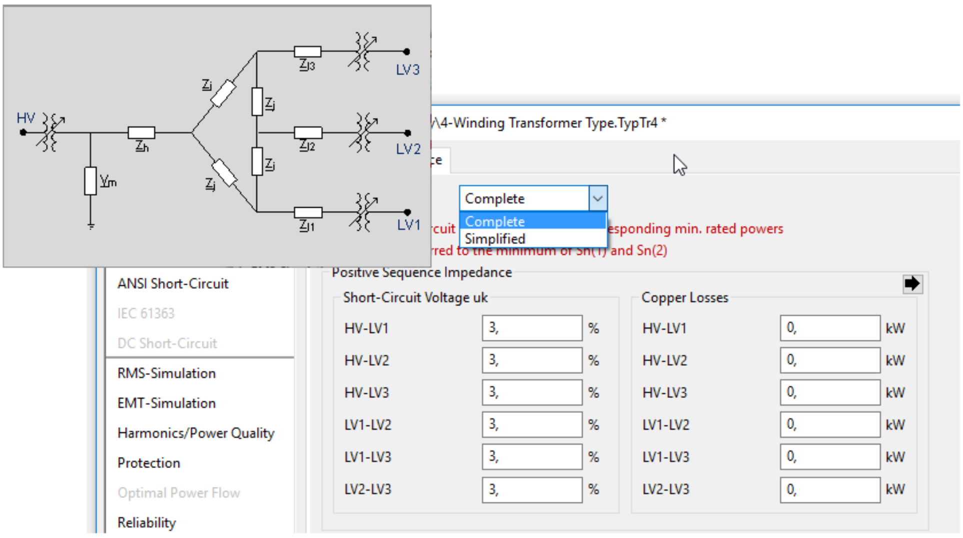

Figure 5.1: Four-winding transformer

Winding connections Y, YN, D, Z and ZN are supported, as are autotransformer configurations. There are also two options for impedance data input: complete (winding-to-winding) and simplified (per-winding).

The four-winding transformer is supported for all calculation functions.

5.2 Automatic Tap Adjustment according to Compounding

Transformer voltage control has been enhanced in ***PowerFactory 2017*** through the introduction of a Current Compounding compensation method, designed to control transformer voltages within acceptable limits by increasing the voltage set point as the load current increases. For transformers operating with automatic tap changing, set to control voltage at the local setpoint, there is an existing Compensation option. This has been extended to include the new current compounding capability, as shown in figure 5.2 below. The compounding can be based on apparent, active or reactive current or power.

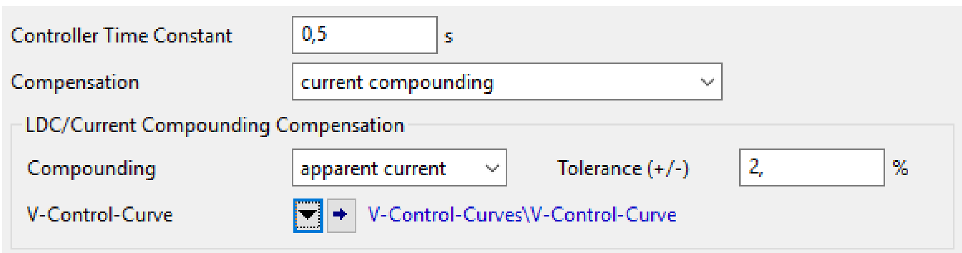

Figure 5.2: Current Compounding selection

The voltage is controlled according to a user-defined voltage control curve:

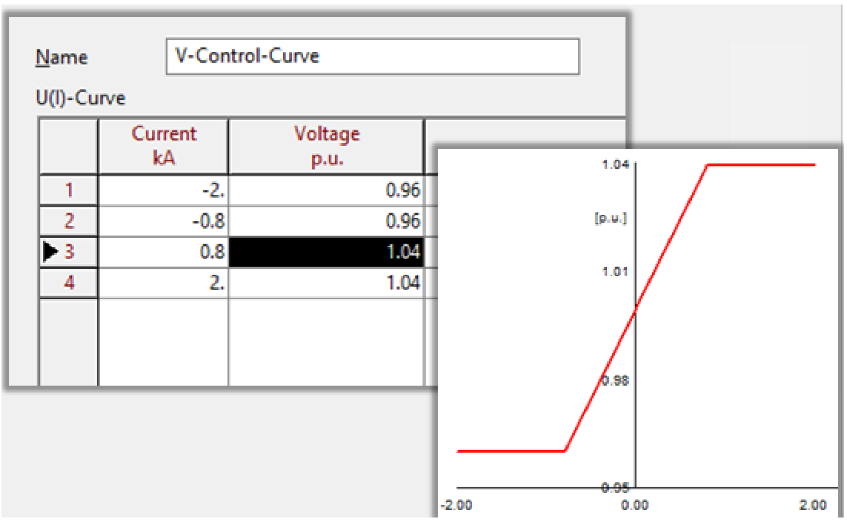

Figure 5.3: V-Control curve for Current Compounding

5.3 Harmonic Filter Element

The options for modelling harmonic filters are extended in ***PowerFactory 2017*** with the introduction of the Harmonic Filter Element *ElmFilter*.

Various technologies are supported dependent upon the number of phases:

Single Phase	Two Phase	Three Phase
PH-PH	'Y'	'D'
PH-N	'YN'	'Y'
PH-E		'YN'

Table 5.1: Winding configurations

The figure below shows the filter types available. Although it was possible in earlier versions of ***PowerFactory*** to model filters using the shunt object, the introduction of the Harmonic Filter element now also makes it possible to represent double-tuned filters.

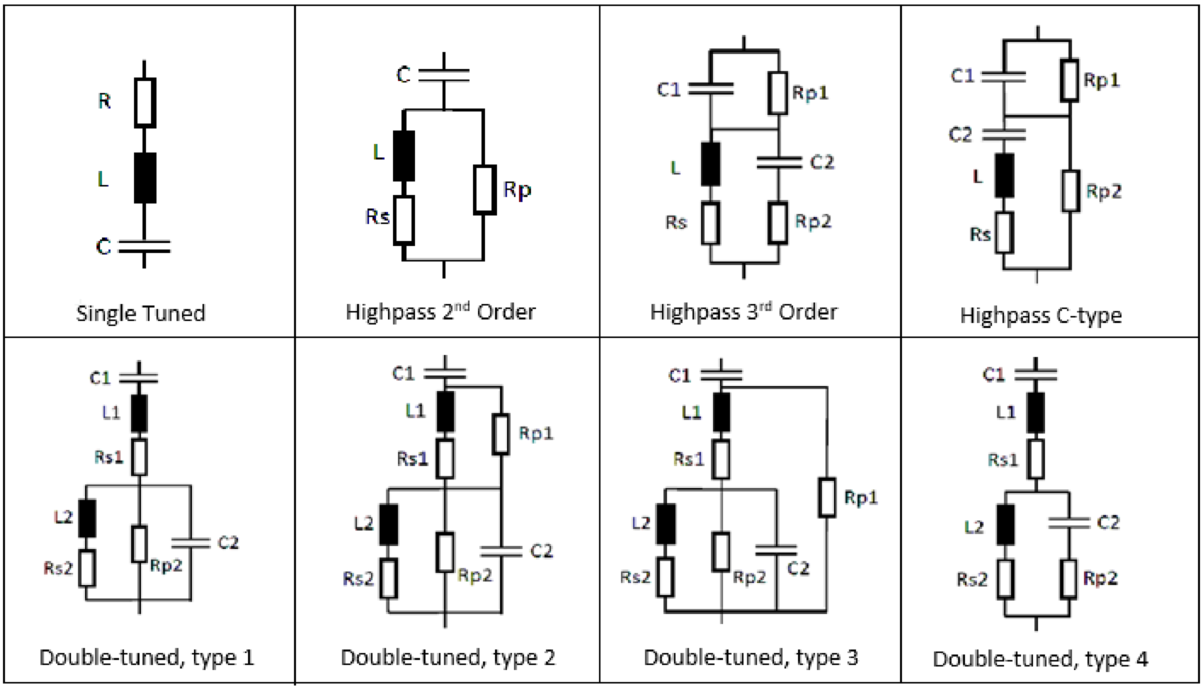

Figure 5.4: Harmonic Filter Configuration Options

Existing modelling using the shunt object *ElmShnt* will of course continue to be supported.

5.4 Step-Voltage Regulator

A new Step-Voltage Regulator element *ElmVoltreg* has now been made available, to provide automatic tap control with line drop compensation. Type A and Type B step-voltage regulators (i.e. with the tap on the Load side and Source side respectively) are supported, and the following configurations are available:

- Star, 3-phase (one tap-controller)
- Star, 3 x 1-phase (three independent tap controllers)
- Closed delta (three single-phase regulators)
- Open delta (two single-phase regulators)

The technology is supported for Load Flow and RMS/EMT simulations, and includes, for forward power flow only, voltage limiting protection. There are also several control modes supported for reverse power operation (these are not available for EMT simulations):

- Locked-forward
- Bi-directional
- Co-generation
- Reactive Bi-directional

5.5 Power Frequency Controller - Merit Order Mode

As described above in section 4.1.3, the existing load flow option for Active Power control using a Power Frequency Controller has been extended, to allow merit order dispatch of the group of slack generators. This makes it possible for example to model interarea power exchanges based on merit order schemes.

This function will be available for the following elements: synchronous machines (*ElmSym*), static generators (*ElmGenstat*) and PWM-converters (*ElmVscmono* and *ElmVsc*), where the merit order of each machine can be defined as shown in figure 5.5. A number of generators may have the same merit order.

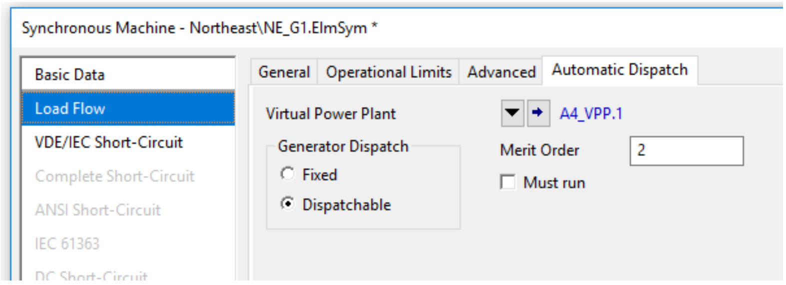

Figure 5.5: Generator Merit Order

A new setting in the Power Frequency Controller can then be selected to enable the merit order dispatch.

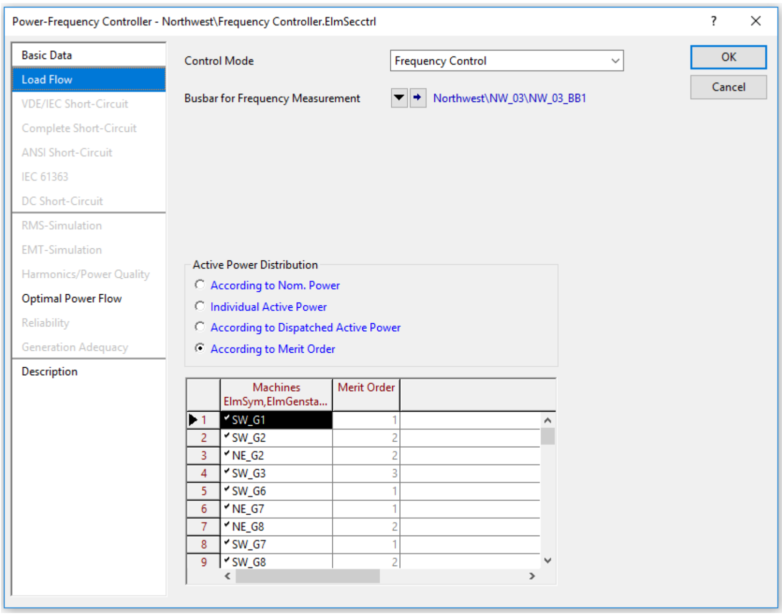

Figure 5.6: Selecting Merit Order power distribution in the Power Frequency Controller

Generators with the highest merit order priority (lowest number) will be dispatched first, as far as their operational limits allow, then the generators with successively lower merit order priorities as required.

5.6 Line Types for Busbar Trunking Systems

For industry applications with multiple power offtakes from a busbar trunking system, a set of line types is now provided in order to represent a number of standard 3-phase-N-PE busbar trunking systems using 3-phase-N line models.

5.7 PWM Converter - Third Harmonic Injection

In ***PowerFactory 2017*** the PWM Converter element (*ElmVsc*) supports modulation with third harmonic injection. Three types of third harmonic injection modulation techniques are available. Modulation techniques with third harmonic injection extend the linear range of operation, resulting in a better utilisation of the DC-link voltage. Reference signals for the PWM converter with and without third harmonic injection are shown in figure 5.7.

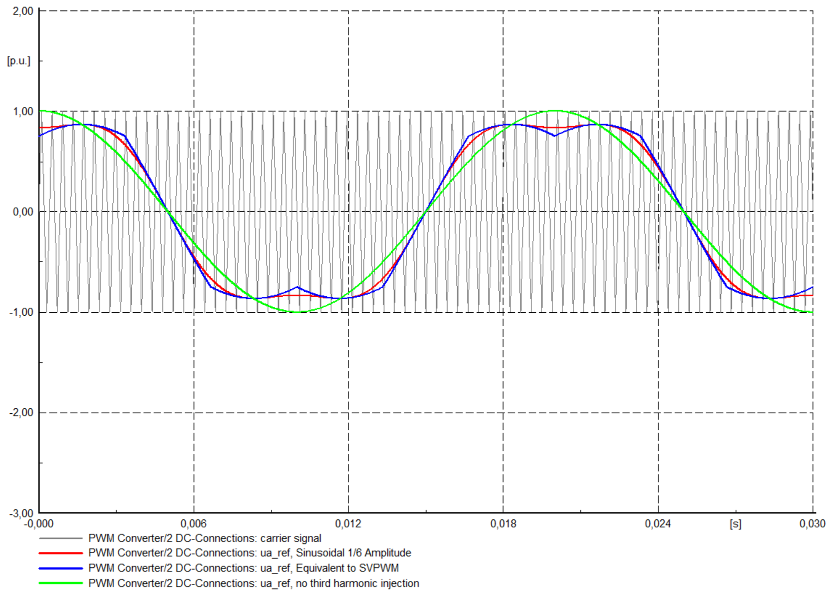

Figure 5.7: PWM Converter reference signal. Pulse width modulation index is equal to 1

5.8 Fuse with Neutral has Option to Interrupt Neutral

A fuse model with neutral now has the option to interrupt the neutral upon operation, as shown below:

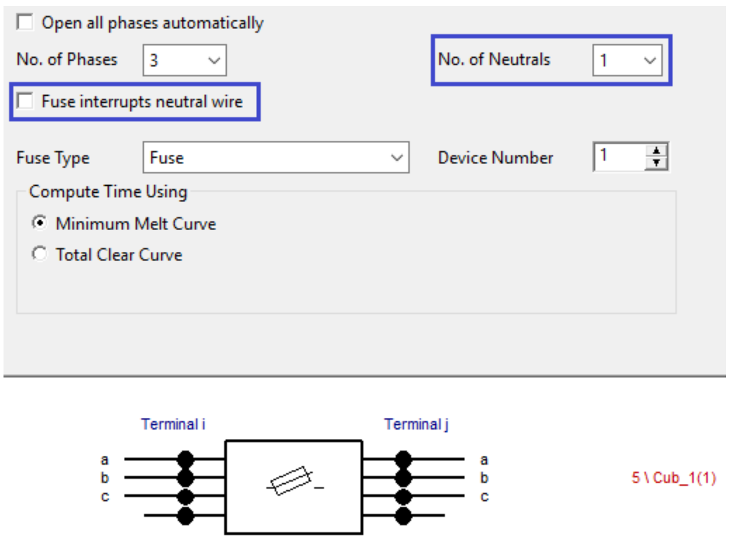

Figure 5.8: Fuse Option for interrupting neutral

6 Scripting and Automation

6.1 Text Editor

PowerFactory 2017 comes with a new text editor. This editor, besides improving usability, introduces new features that simplify the script-writing process.

The many new features include, bracket match checking and automatic bracket insertion, zoom-in and zoom-out, highlighting selected words throughout the script, changing font styles and definition of bookmarks within the code.

Additionally an **auto-completion** function has been introduced; this function shows all the possible options when a word is written, which is particulary helpful considering the number of functions/methods available.

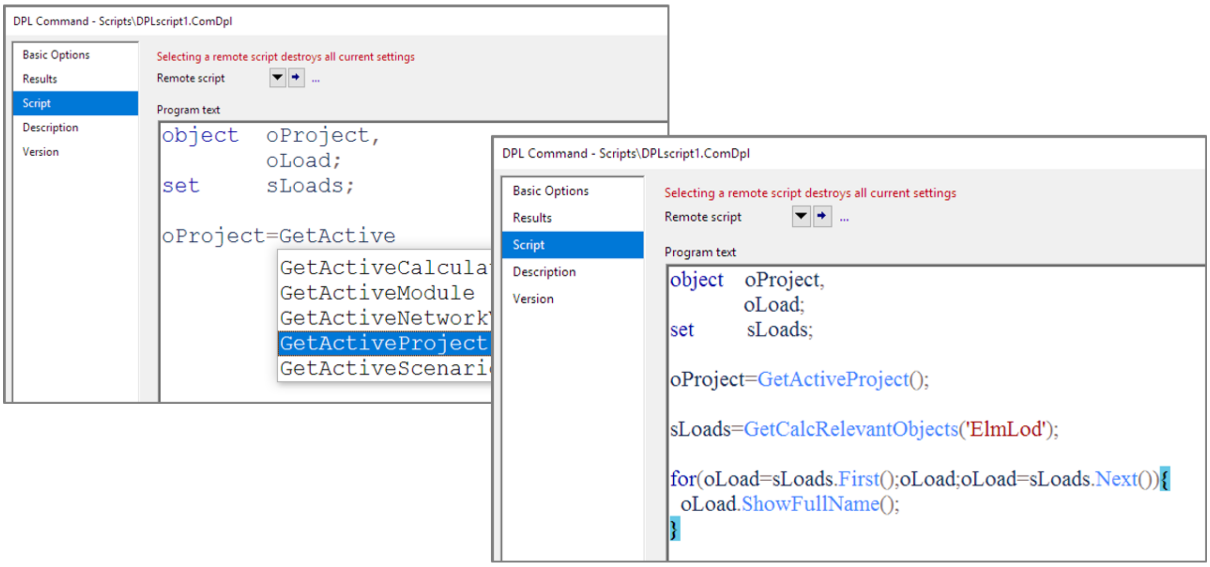

Figure 6.1: Text Editor examples

The text editor is available for DPL, DSL and QDSL; it can also be used for writing Python scripts.

6.2 Add-On Modules

In response to user requests for more flexible calculation options, ***PowerFactory 2017*** offers a new concept of Add-On Modules.

With this framework, it is possible for users to implement their own functions which are then integrated smoothly into ***PowerFactory*** as if they were built-in modules.

More precisely, an Add-On Module (*ComAddon*) consists of a calculation script (DPL or Python), together with a set of (user-definable) result variables, plus (optionally) a default result box configuration and a potential default colouring mode. See figure 6.2 for such a setup.

The user-definable result variables can be associated per class with the elements. Variables are defined by name, including data type, unit, and description. Supported data types include integer, double, string, object (reference), arrays and matrices — for branch elements, each of which can be defined as per phase and/or per connection quantities. Technically, a series of new DPL and Python methods are provided that allow to instantiate and assign these variables in the corresponding calculation script.

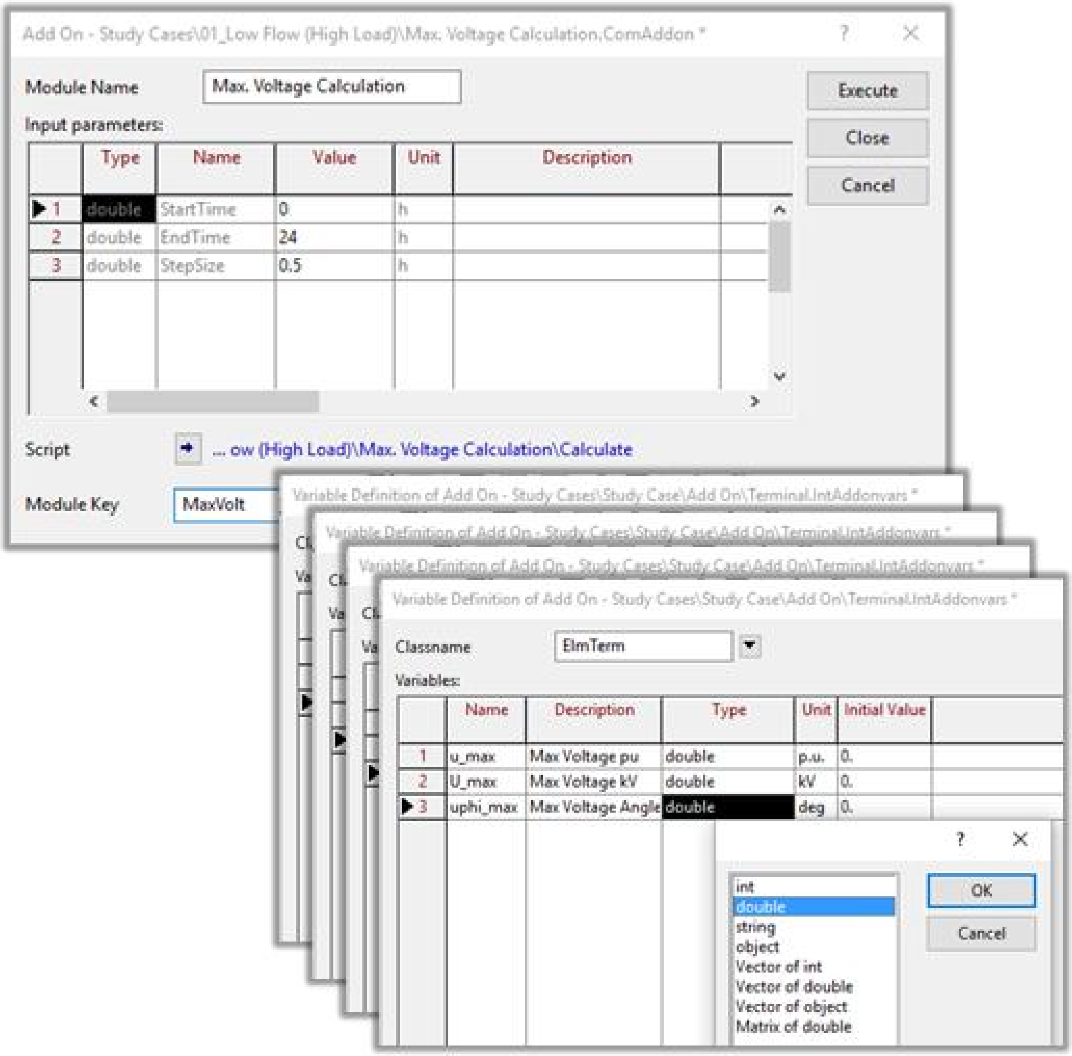

Figure 6.2: Add-On Module with a set of user-defined variables

The function defined by an Add-On Module is smoothly integrated into ***PowerFactory***, in the sense that the result variables can be accessed via flexible data pages, single line diagram result boxes, or via scripting languages, interfaces, etc... The extended quantities are accessible with a prefix *x:* (see figure 6.3 below).

This flexible tool can be used for a range of different applications, for example:

- Simultaneous calculation and viewing of, for example, load flow and short-circuit calculation results together
- Sweeps across time and cases in order to, for example, determine maxima or minima
- Post-processing of calculation results

Customised Add-On Modules can be stored and deployed centrally and accessed via the User-Defined Tools toolbar.

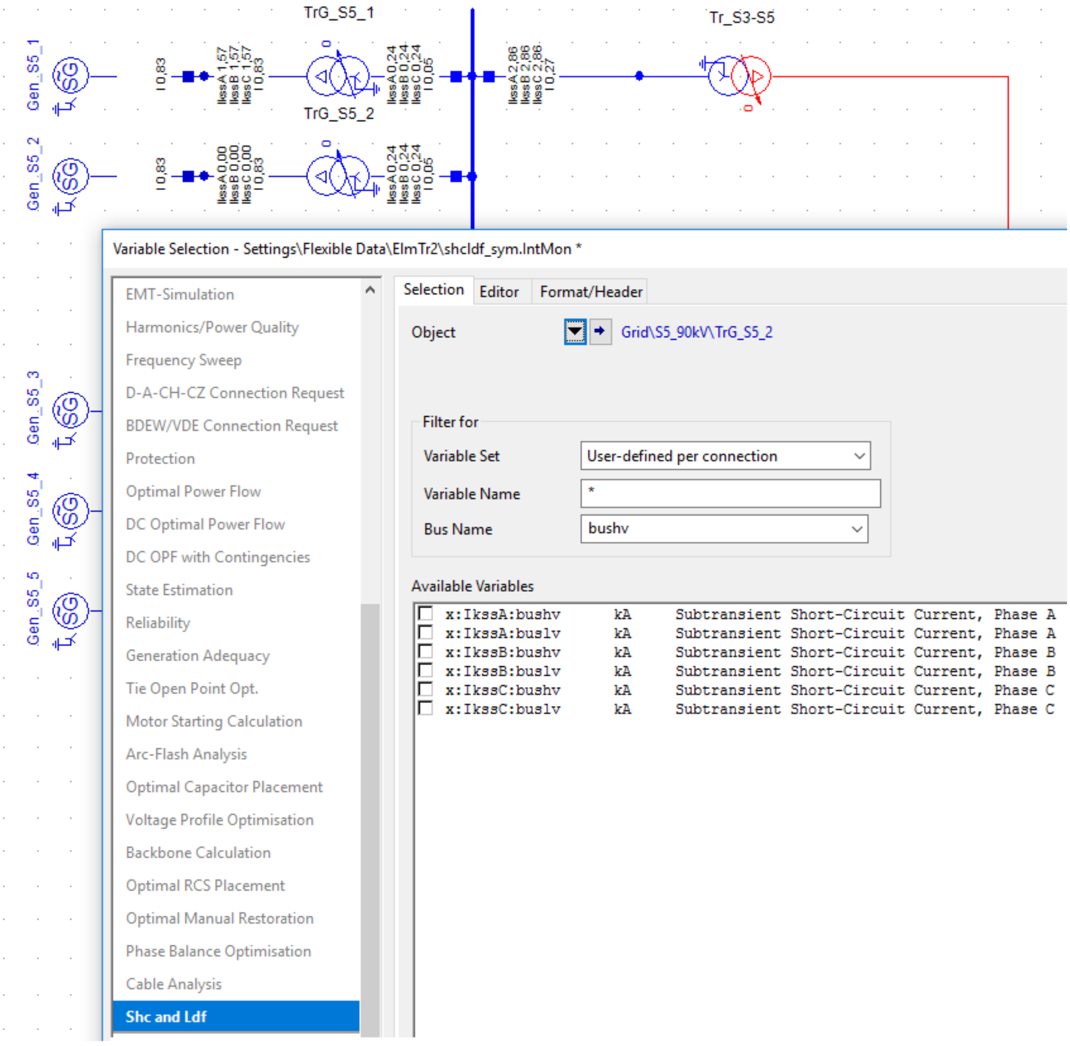

Figure 6.3: Access to calculation quantities of an Add-On module

7 Interfaces

7.1 CGMES Converter

7.1.1 CGMES Conversion Performance Improvements

With ***PowerFactory 2017*** general improvements for the CIM to Grid and Grid to CIM Conversion have been introduced. These improvements are particularly evident in complex networks and automatic model conversions. Furthermore the duration of the Grid to CIM conversion can be greatly reduced by executing a memory only export, as described in section 7.1.3.

7.1.2 Incremental Load of CIM data

In order to guarantee persistent IDs in CGMES, a reference model must be available in the ***PowerFactory*** master model in the database. This reference CIM data significantly increases the size of the project, but is not needed by most of the ***PowerFactory*** users.

Therefore ***PowerFactory 2017*** no longer loads the CIM data when activating the project. Instead this data is only loaded upon the first access of the CIM data. This way the activation time of a network model is improved.

7.1.3 Memory Only Export

The CGMES export is split into two steps:

- Grid to CIM conversion - this creates CIM data on the database
- CIM data export - this exports the CIM data to the hard drive

However, in automated processes, like DACF and IDCF, the CIM data is not needed on the database and would be deleted after the export. Therefore a new scripting command has been introduced for the Grid to CIM conversion, which does not create the database objects, but exports the data directly to the hard drive.

This way delays due to database synchronisation can be prevented. As a result the total time needed can decrease markedly. This effect increases the bigger the network and the slower the connection to the database is.

7.1.4 Automatic Handling of Equivalent Boundary Network Injections

One of the main purposes of CGMES is to use merged networks. An exported model is typically calculated while being connected to surrounding networks. Since the exported grid model does not include the connected networks, an equivalent boundary flow must be modelled. Therefore EquivalentInjection objects are used in CGMES.

PowerFactory 2017 automatically detects such injections on the boundary and creates the CIM data accordingly as shown in figure 7.1.

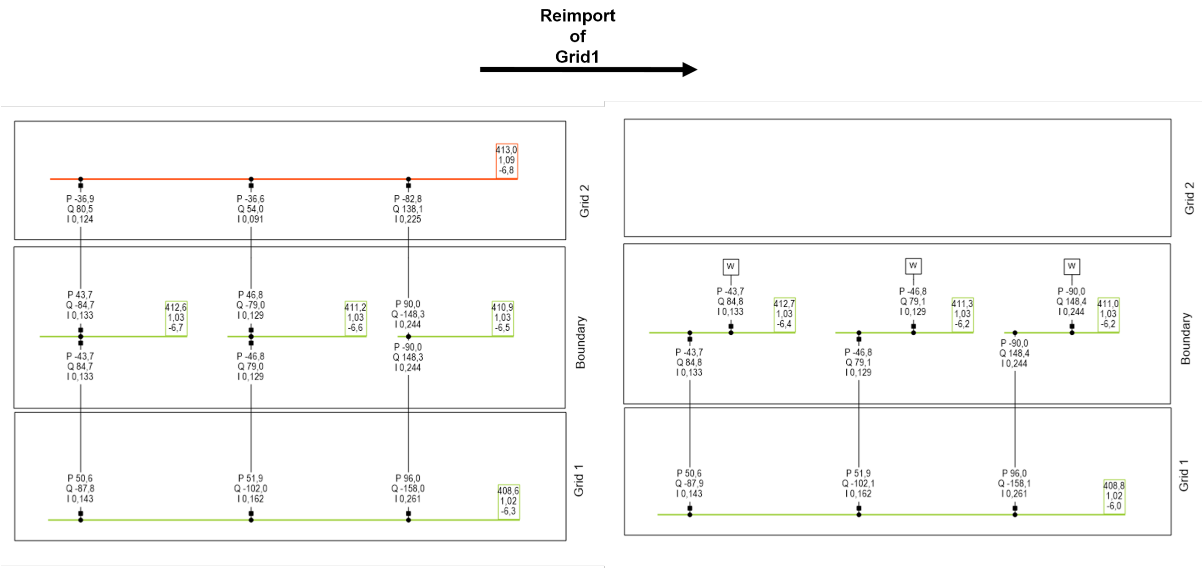

Figure 7.1: Reimport of a network model with equivalent injections

These network injections of course are only to be used when the corresponding foreign network is not available. Therefore another mechanism has been introduced, which will automatically set the equivalent network injections of both networks out of service. This way after the CGMES conversion only networks not explicitly modelled are represented by the equivalent injections.

7.2 Integral Export Converter

With ***PowerFactory 2017*** projects can be exported in *Integral 7* xml format. *Integral* is a network calculation software provided by *FGH* and is commonly used by German Transmission System Operators in long-term network planning. For more flexibility in the data exchange between neighbouring TSOs as well as connected DNOs the existing *Integral* Import converter is now complemented by an *Integral* Export Converter.

The *Integral* Export comprises the most frequently used network devices with their load flow and short circuit settings. Schematic network diagrams are converted in addition to the electrical data.

With regard to the structural and modelling differences between ***PowerFactory*** and *Integral* projects, a number of options are available so that the user's ***PowerFactory*** network model data can be converted in the most appropriate way:

- Should several networks be combined to one aggregated network?
- Should graphical or topological representation be preferred when converting substation topology?
- Should actual or input values be converted for the active and reactive power of generation or demand objects?
- A scaling factor can be entered for graphical representation.

The quality of the exported *Integral* network model and its graphical representation in *Integral* strongly depends on the set-up of the original network model in ***PowerFactory***, in particular with regard to the topology of substations and bays. ***PowerFactory*** allows for very flexible topology configuration while *Integral* applies fixed sets of admissible configurations. The user should obey certain modelling rules to achieve properly matching export results. *DIgSILENT* will provide a set of recommended rules.

7.3 OPC Unified Architecture

The communication between ***PowerFactory*** and external devices or applications is an important part in the area of automation. The OPC Data Access interface, often used for this purpose, is hard to administer and based on deprecated windows components. In order to provide an up-to-date communication interface, a new connection object based on the OPC Unified Architecture standard has been developed for ***PowerFactory 2017***. This new implementation offers several benefits compared with the old OPC Data Access protocol, especially in terms of security, setup and maintenance. The configuration of such a connection is similar to the setup of an *OPC Data Access* connection in previous ***PowerFactory*** versions. Hence, the user can easily switch between the protocols if necessary. The new features are provided by the introduced *External OPC Link* object (*ComOpc*) shown in figure 7.2.

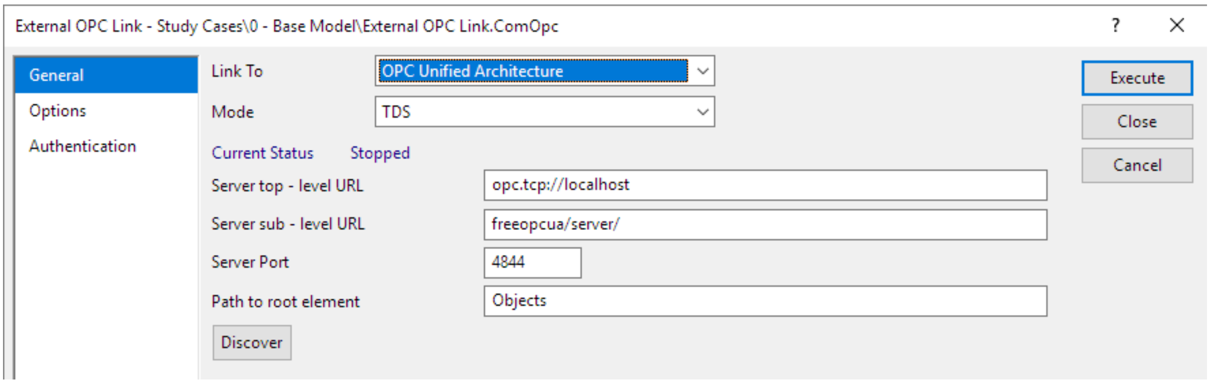

Figure 7.2: External OPC Link edit dialog

8 Installation and Licensing

8.1 Support of Floating Licences

With ***PowerFactory 2016*** new licensing technology was introduced. Initially, floating licences were not supported in ***PowerFactory 2016*** due to constraints in this technology. However, this problem was resolved in Service Pack 4 of ***PowerFactory 2016*** and floating licences are also available in ***PowerFactory 2017***. The Floating Licence function allows the user to continue working without access to a licence server by 'checking out' a temporary licence which is then stored on the user's computer and may be used for up to 30 days, after which it is destroyed and the licence restored in the licence server. It should be noted that the Floating Licence capability is itself a separately licensed feature and so will not be available by default when ***PowerFactory 2017*** is installed.

DIgSILENT

Company Profile

DIgSILENT is a consulting and software company providing engineering services in the field of electrical power systems for transmission, distribution, generation and industrial plants.

DIgSILENT was founded in 1985 and is a fully independent, privately owned company located in Gomaringen/Tübingen, Germany. DIgSILENT continued expansion by establishing offices in Australia, South Africa, Italy, Chile, Spain, France and the USA, thereby facilitating improved service following the world-wide increase in usage of its software products and services. DIgSILENT has established a strong partner network in many countries such as Mexico, Malaysia, UK, Switzerland, Colombia, Brazil, Peru, China and India. DIgSILENT services and software installations have been conducted in more than 140 countries.

DIgSILENT PowerFactory

DIgSILENT develops the leading integrated power system analysis software PowerFactory, which covers the full range of functionality from standard features to highly sophisticated and advanced applications including wind power, distributed generation, real-time simulation and performance monitoring for system testing and supervision. For wind power applications, PowerFactory has become the power industry's de-facto standard tool, due to PowerFactory models and algorithms providing unrivalled accuracy and performance.

DIgSILENT StationWare is a reliable central protection settings database and management system, based on the latest .NET technology. StationWare stores and records all settings in a central database, allows modelling of relevant workflow sequences, provides quick access to relay manuals, interfaces with manufacturer-specific relay settings and integrates with PowerFactory software, allowing powerful and easy-to-use settings coordination studies.

PowerFactory Monitor is a flexible performance recording and monitoring system that copes easily and efficiently with the special requirements for system test implementation, system performance supervision and the determination and supervision of connection characteristics. Numerous monitoring systems installed at various grid locations can be integrated into a Wide-Area-Measurement-System (WAMS). PowerFactory Monitor can be fully integrated with PowerFactory software.

DIgSILENT Consulting

DIgSILENT GmbH is staffed with experts of various disciplines relevant for performing consulting services, research activities, user training, educational programs and software development. Highly specialised expertise is available in many fields of electrical engineering applicable to liberalised power markets and to the latest developments in power generation technologies such as wind power and distributed generation. DIgSILENT has provided expert consulting services to several prominent PV and wind grid integration studies.

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