INTEGRATED POWER SYSTEM ANALYSIS SOFTWARE

DIgSILENT

PowerFactory 15.2

What´s New

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1 Introduction

PowerFactory 15.2 completes the successful series of ***PowerFactory*** version 15 releases. The latest release comes with a broad range of new functions, new electrical models and extensions to the existing modelling suite. Special attention has been paid to improved calculation and simulation performance. Moreover, a variety of new features for improved result visualisation and graphical representation has been made available. With its rich analysis and modelling capabilities, ***PowerFactory*** is perfectly suited for network planning and operation studies of increasingly smart grids.

This document highlights the new key features and enhancements available in ***PowerFactory*** *15.2*.

2 Installation and Configuration

2.1 Minimal Database Migration

Upgrading to a new version of ***PowerFactory*** requires a migration of the database. In ***PowerFactory*** 15.2, this is achieved with optimal efficiency via the minimal migration feature, whereby the database is altered and users' projects are migrated on an as-needed basis.

PowerFactory will automatically start the migration when upgrading to a new version. In this process, the user can select whether to run a complete migration or a minimal migration (see Figure 2.1). For larger installations, the latter option is recommended.

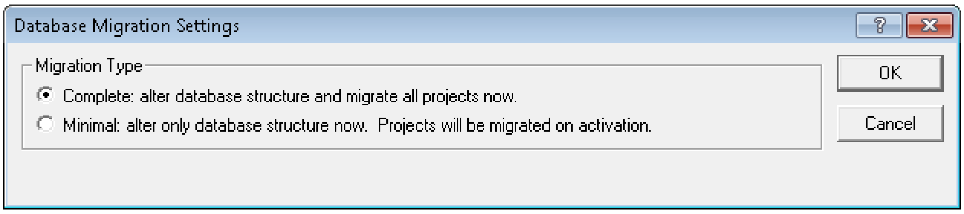


Figure 2.1: New migration dialog

3 Handling and Data Management

3.1 Network Diagrams and Graphic Features

3.1.1 Heatmaps

The new Heatmap background colouring scheme provides an instant visual overview of the status of the entire grid. As illustrated in Figure 3.1, critical parts of the grid requiring closer analysis can be seen at a glance.

The Heatmap colouring scheme is very flexible as it can be used in conjunction with *all* ***PowerFactory*** diagram colouring modes. In particular, Heatmaps are supported for:

- Alarm colouring, i.e. overloading and voltage violations, outages, etc.
- Calculation results, i.e. loading/voltages, fault clearing times, outage rates, etc.
- Primary and secondary equipment information, i.e. year of construction, cross-sections, relay/CT/VT location, etc.

- Topological information, i.e. feeders, voltage levels, substation supply, etc.
- Grouping information, i.e. zones, areas, grids, etc.

Creation of a Heatmap background image can be executed via a button on the main toolbar of the graphic window.

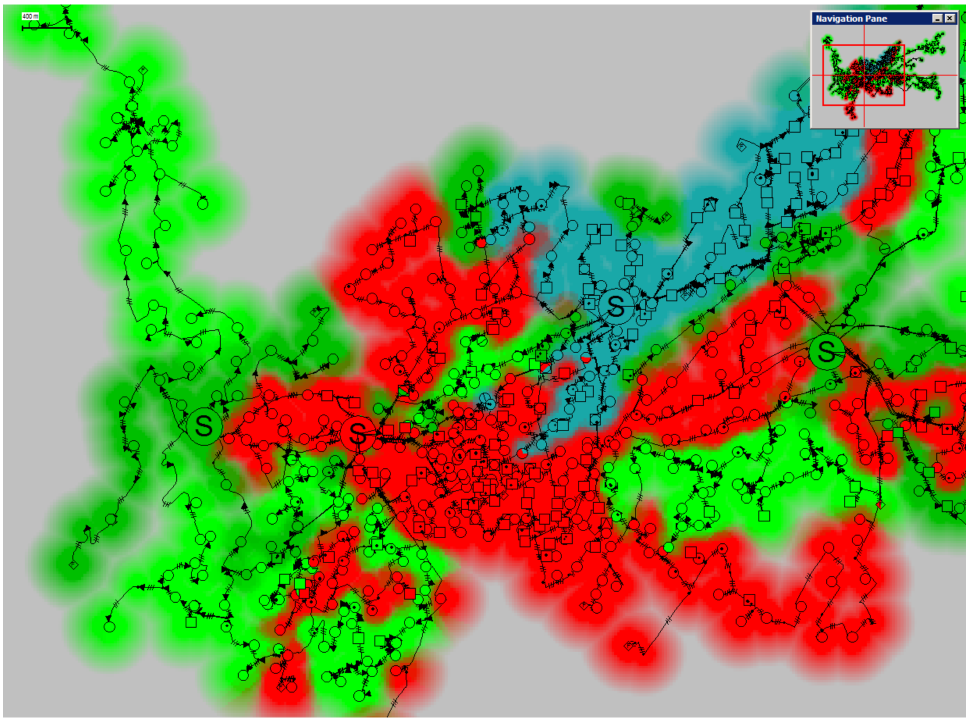


Figure 3.1: Heatmap example

3.1.2 Navigation Pane

The newly-introduced navigation pane provides the user with an overview of the whole network in a small window. When zooming-in on a part of the grid, the navigation pane continues to show an overview of the whole network and highlights which part of the network is currently being shown in the single line diagram. This is illustrated in Figure 3.2.

In addition, the navigation pane supports the relocation of the zoomed area, while maintaining the zoom level. This is achieved by either moving the red frame inside the navigation pane to the desired location, or by double-clicking on another location within the navigation pane. By resizing the red frame in the navigation pane, the zoom level used in the single line diagram can be changed accordingly.

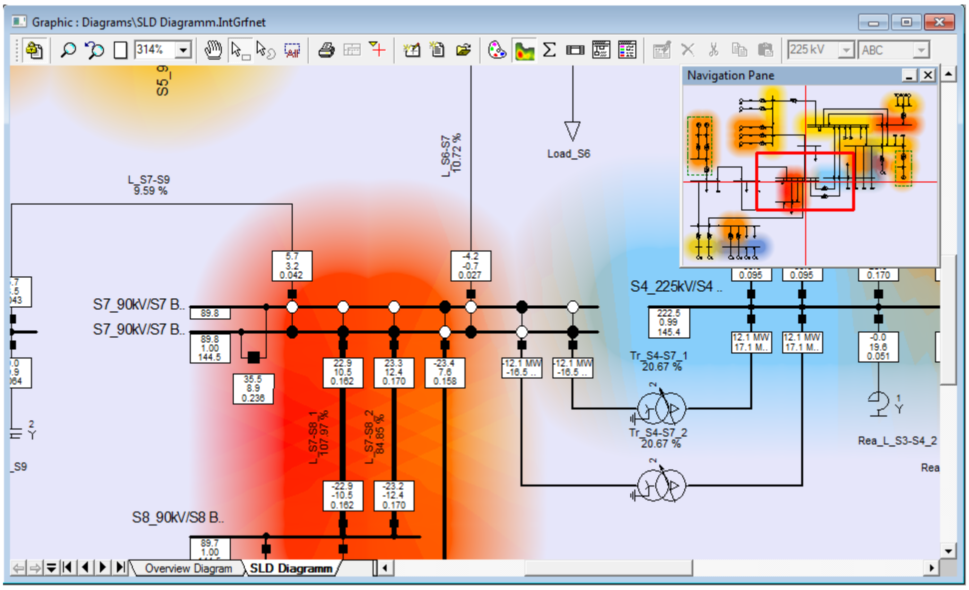


Figure 3.2: Navigation pane

3.1.3 Map Interface

PowerFactory 15.2 provides a general mapping server interface for Geographic Diagrams based on GPS data. This allows the display of geographical background maps automatically retrieved from an internet map server. The following map services are actually supported:

- OpenStreetMap (OSM), featuring free-of-charge mapnik-style maps
- Esri ArcGIS©[1], including road maps, satellite, and hybrid maps
- Google Maps©[1], including road maps, satellite/aerial, hybrid, and topographic maps

Following user input of the desired map provider as shown in Figure 3.3, ***PowerFactory*** can automatically download and visualize precise background maps using the coordinates of the grid. The corresponding settings can be found in the Graphic Layers dialog, on the Configuration page.

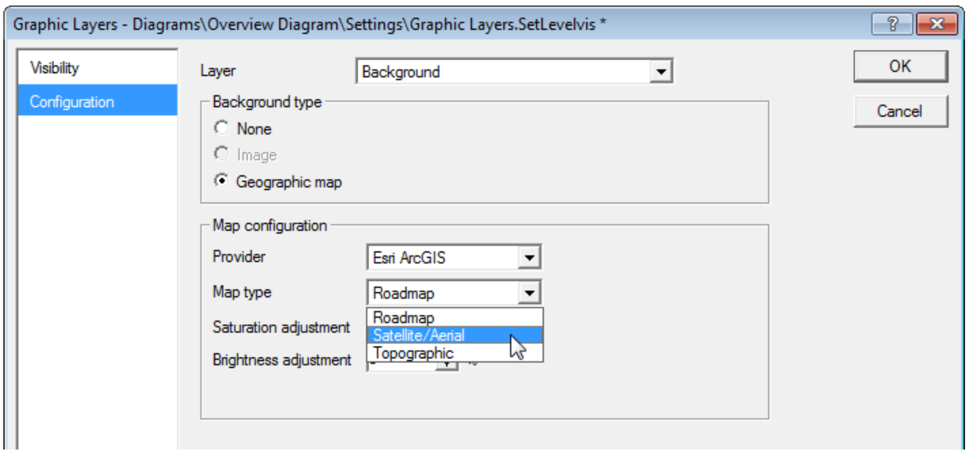


Figure 3.3: New background layer configuration

[1] upon request; additional license agreements with map service providers apply

Figures 3.4 and 3.5 illustrate small distribution grids where OpenStreetMap, and Esri ArcGIS© satellite maps, respectively, are used as the background image providers.

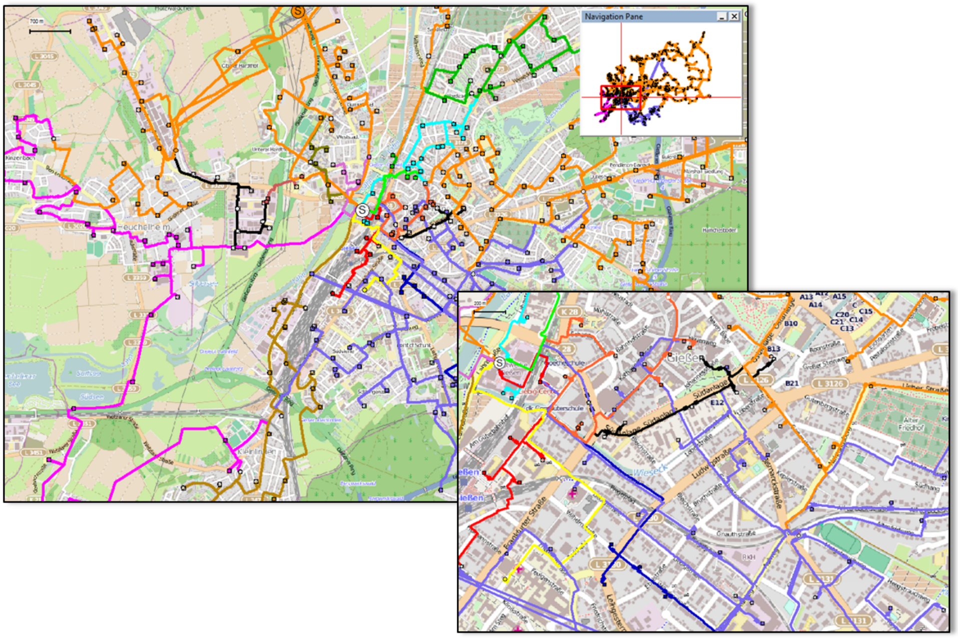


Figure 3.4: Network example with OpenStreetMap data

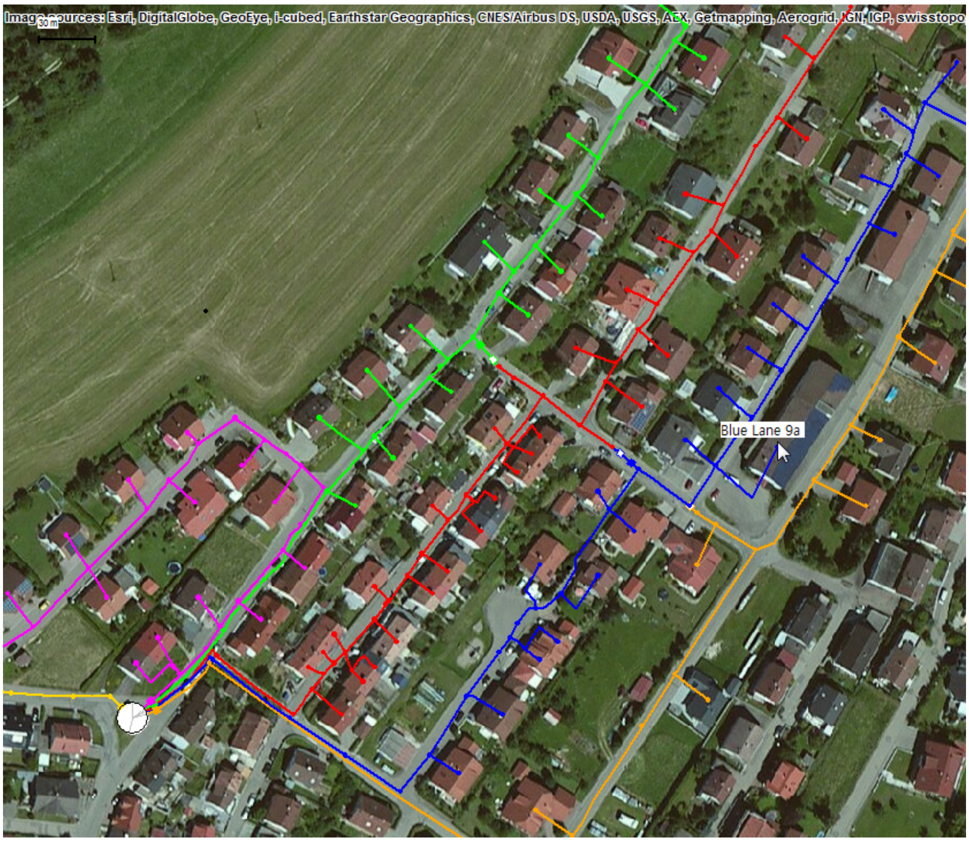


Figure 3.5: Network example with satellite background map (ESRI ArcGIS©)

3.1.4 Quick Access to Protection Plots

A protection study often contains many coordination plots, which can make finding the desired plot for a particular relay difficult. The new quick access to protection plots feature allows direct access to all existing protection plots containing the chosen relay.

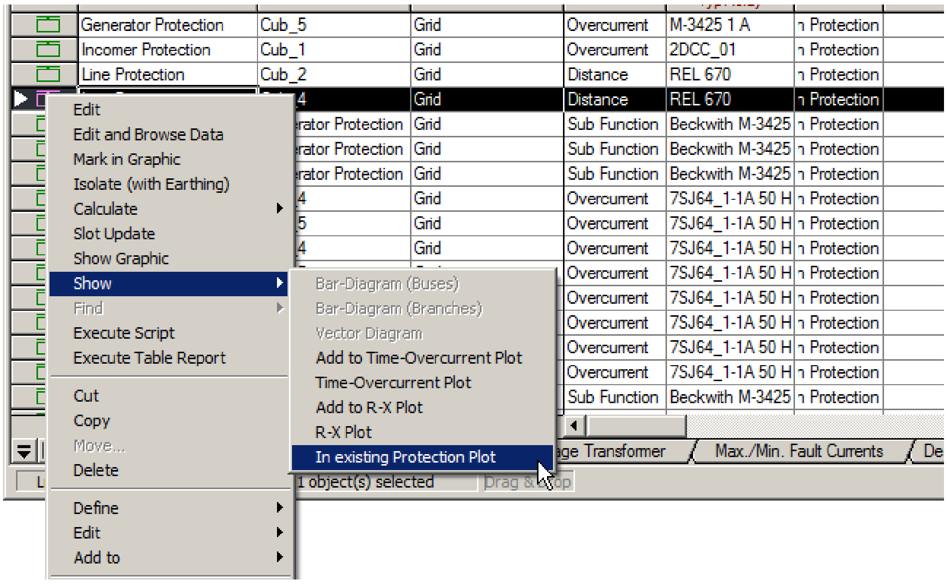


Figure 3.6: Quick access to protection plots

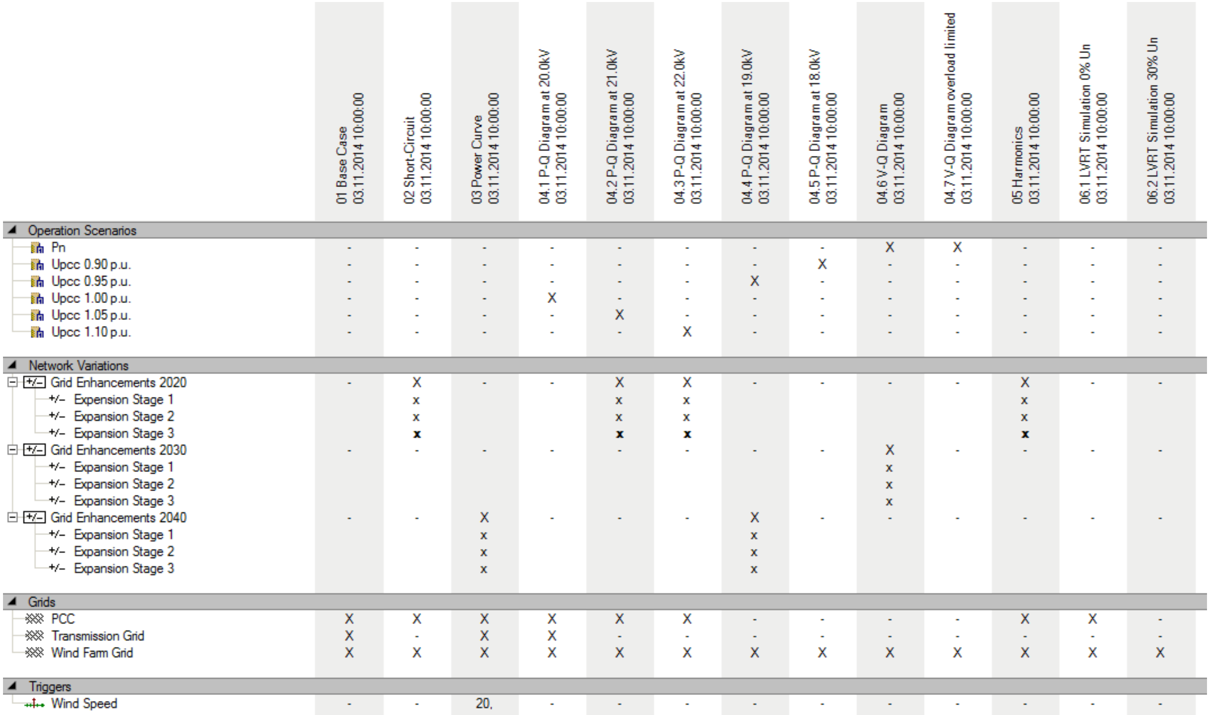
3.2 Study Case Overview

The Study Case Overview is an enhancement of the Project Overview and simplifies the management of Study Cases. It provides an overview of all existing Study Cases with all active Operation Scenarios, Variations, Grids and Triggers, as illustrated in Figure 3.7. In this representation, Study Cases are arranged in the columns of the chart, and their components are visualised row-wise. The Study Case Overview can be accessed by clicking on the arrow symbol in the upper right corner of the Project Overview window.

This overview can be used to manage the setup of the individual Study Cases, since it allows the activation/deactivation of:

- Operation Scenarios
- Variations
- Grids
- Triggers

simply by double-clicking on the cell entries - without the need to activate the Study Cases themselves.



	01 Base Case 03.11.2014 10:00:00	02 Short-Circuit 03.11.2014 10:00:00	03 Power Curve 03.11.2014 10:00:00	04.1 P-Q Diagram at 20.0kV 03.11.2014 10:00:00	04.2 P-Q Diagram at 21.0kV 03.11.2014 10:00:00	04.3 P-Q Diagram at 22.0kV 03.11.2014 10:00:00	04.4 P-Q Diagram at 19.0kV 03.11.2014 10:00:00	04.5 P-Q Diagram at 18.0kV 03.11.2014 10:00:00	04.6 V-Q Diagram 03.11.2014 10:00:00	04.7 V-Q Diagram overload limited 03.11.2014 10:00:00	05 Harmonics 03.11.2014 10:00:00	06.1 LVRT Simulation 0% Un 03.11.2014 10:00:00	06.2 LVRT Simulation 30% Un 03.11.2014 10:00:00
Operation Scenarios													
Pn	-	-	-	-	-	-	-	-	X	X	-	-	-
Upcc 0.90 p.u.	-	-	-	-	-	-	-	X	-	-	-	-	-
Upcc 0.95 p.u.	-	-	-	-	-	-	X	-	-	-	-	-	-
Upcc 1.00 p.u.	-	-	-	X	-	-	-	-	-	-	-	-	-
Upcc 1.05 p.u.	-	-	-	-	X	-	-	-	-	-	-	-	-
Upcc 1.10 p.u.	-	-	-	-	-	X	-	-	-	-	-	-	-
Network Variations													
Grid Enhancements 2020	-	X	-	-	X	X	-	-	-	-	X	-	-
Expension Stage 1		x			x	x					x		
Expension Stage 2		x			x	x					x		
Expension Stage 3		x			x	x					x		
Grid Enhancements 2030	-	-	-	-	-	-	-	-	X	-	-	-	-
Expension Stage 1									x				
Expension Stage 2									x				
Expension Stage 3									x				
Grid Enhancements 2040	-	-	X	-	-	-	X	-	-	-	-	-	-
Expension Stage 1			x				x						
Expension Stage 2			x				x						
Expension Stage 3			x				x						
Grids													
PCC	X	X	X	X	X	X	-	-	-	-	X	X	-
Transmission Grid	X	-	X	X	-	-	-	-	-	-	-	-	-
Wind Farm Grid	X	X	X	X	X	X	X	X	X	X	X	X	X
Triggers													
Wind Speed	-	-	20,	-	-	-	-	-	-	-	-	-	-

Figure 3.7: Study Case Overview

3.3 Scaling Factor Characteristics

The scaling of parameters has been improved and simplified in ***PowerFactory*** 15.2 via the new Scaling Factor characteristic.

Using this characteristic, one Scaling Factor can be assigned to multiple elements in ***PowerFactory***. It is then very simple to change the value by double-clicking on the Scaling Factor in the Project Overview window.

A typical application of the Scaling Factor Characteristic is the scaling of, e.g. load and generation, in individual network regions (see Figure 3.8).

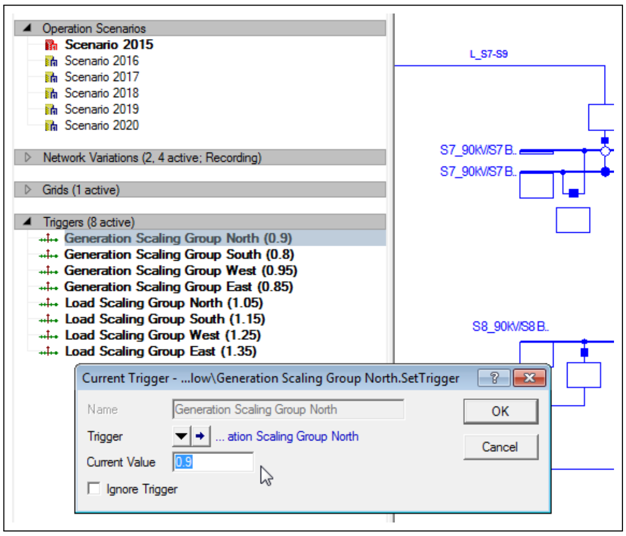


Figure 3.8: Usage of the Scaling Factor Characteristic

3.4 Reporting and Visualisation

3.4.1 New Differential Protection Diagrams

Differential protection relays are typically defined as either:

- A magnitude percentage restrained (with single or double slope) differential element with/without unrestrained differential threshold; or
- A phase comparison with restrained area differential element.

In ***PowerFactory*** 15.2, two new kinds of diagram are available for these relay types:

- A differential threshold magnitude diagram (magnitude-based differential), as shown in Figure 3.9. This diagram is a Cartesian diagram with the restraint current on the x-axis and the differential operating current on the y-axis.
- A phase comparison diagram (alpha plane), as shown in Figure 3.10. This diagram consists of an angular restraint region area with an optional minimum and maximum current magnitude limitation.

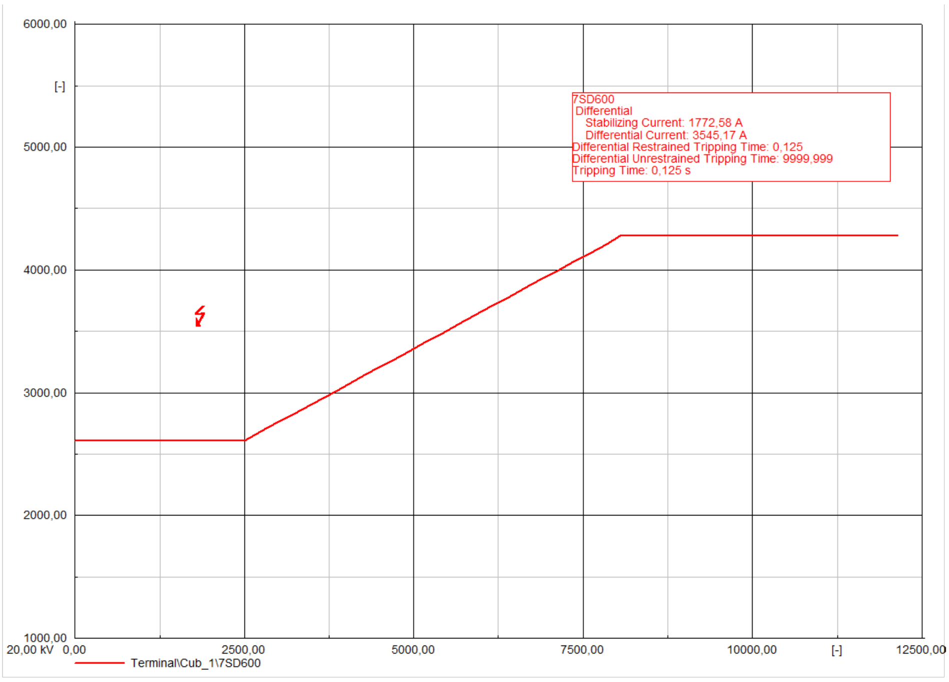


Figure 3.9: Current magnitude based differential protection diagram

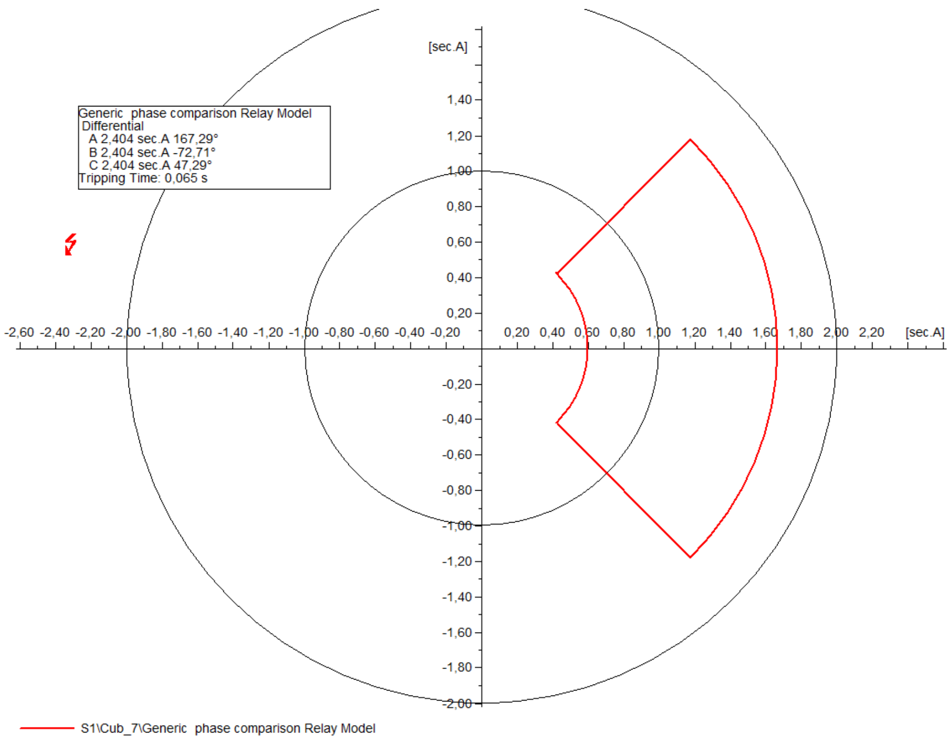
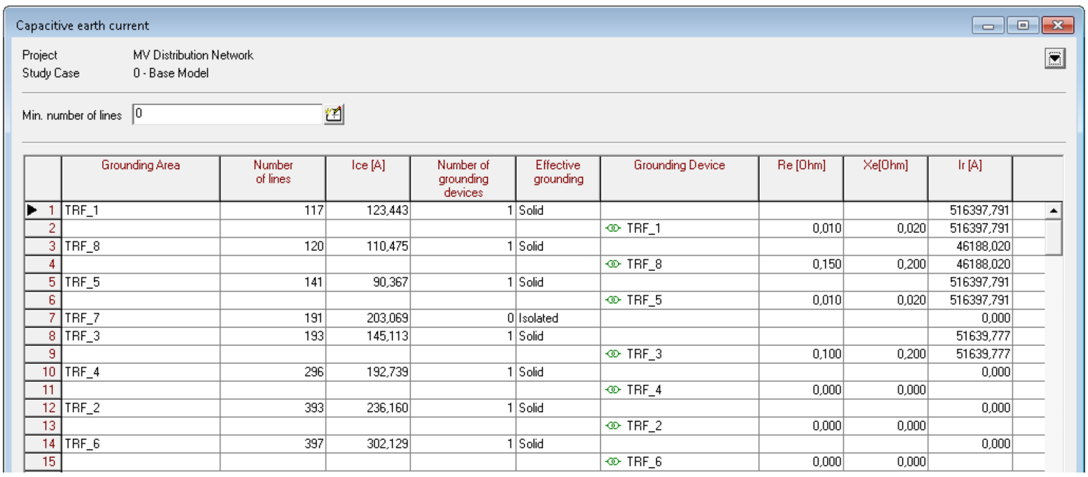


Figure 3.10: Phase angle based differential protection diagram

3.4.2 Summary Report: Capacitive Earth Fault Current

Strong capacitive coupling between phases and earth can result in high capacitive earth fault currents during single-phase faults. In order to reduce these earth fault currents, the network can be compensated (e.g. arc suppression via a Peterson coil). ***PowerFactory*** 15.2 provides a capacitive earth fault current report. This report supports the user in defining an optimal compensation system layout. It is available as a new report type via the *Tools* menu under *Network Data Assessment*.



Capacitive earth current

Project MV Distribution Network
Study Case 0 - Base Model

Min. number of lines 0

	Grounding Area	Number of lines	Ice [A]	Number of grounding devices	Effective grounding	Grounding Device	Re [Ohm]	Xe[Ohm]	Ir [A]
1	TRF_1	117	123,443	1	Solid				516397,791
2						TRF_1	0,010	0,020	516397,791
3	TRF_8	120	110,475	1	Solid				46188,020
4						TRF_8	0,150	0,200	46188,020
5	TRF_5	141	90,367	1	Solid				516397,791
6						TRF_5	0,010	0,020	516397,791
7	TRF_7	191	203,069	0	Isolated				0,000
8	TRF_3	193	145,113	1	Solid				51639,777
9						TRF_3	0,100	0,200	51639,777
10	TRF_4	296	192,739	1	Solid				0,000
11						TRF_4	0,000	0,000	
12	TRF_2	393	236,160	1	Solid				0,000
13						TRF_2	0,000	0,000	
14	TRF_6	397	302,129	1	Solid				0,000
15						TRF_6	0,000	0,000	

Figure 3.11: Example of a tabular earth fault current report

3.5 Scripting and Automation

3.5.1 Python

Several enhancements to Python scripting language support have been made. These include:

- **Python 3.4:** ***PowerFactory*** 15.2 uses the new Python 3.4 version by default. For backward compatibility, Python 3.3 can also be selected in the ***PowerFactory*** Configuration.
- **Improved handling:** the Python script GUI provides simple access to input parameters, external objects and result parameters. The script can access these parameters during execution, and set result parameters which may be used later (i.e. in reports).
- **Remote script:** ***PowerFactory*** has long supported the use of global scripts stored in its Library, and now extends this concept in version 15.2 to include Python scripts. Users can create a local Python script (which references a global Python script), allowing customisation and thereby providing maximum flexibility.
- **Execution of compiled Python scripts:** pre-compiled Python scripts can be executed. The format of the pre-compiled scripts can be *.pyc or *.pyo.

3.5.2 *StationWare* Interface

PowerFactory 15.2 has enhanced the *StationWare* Interface, making it possible to transfer calculation results from ***PowerFactory*** to *StationWare*. A new option is provided in the *StationWare* Interface command, as shown in Figure 3.12.

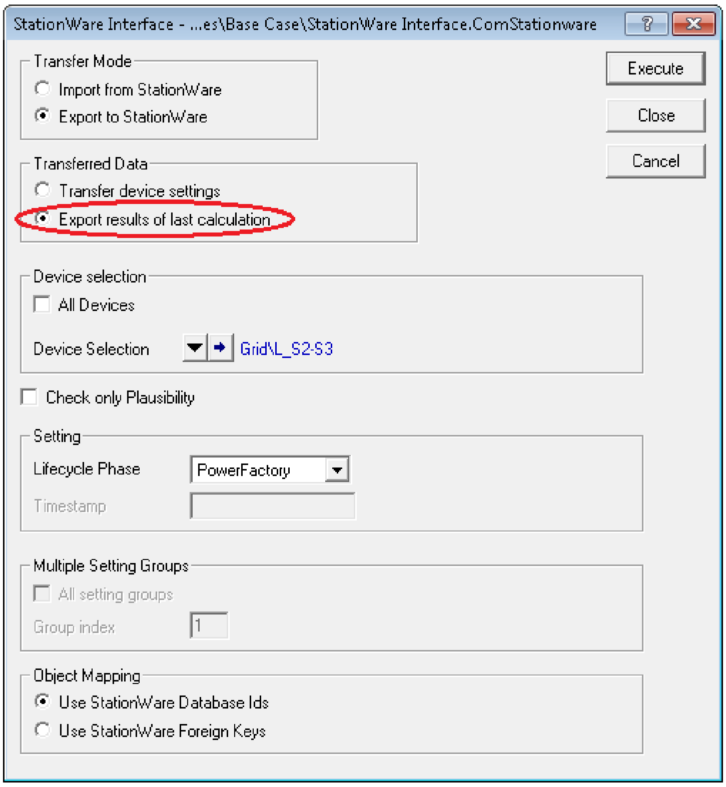


Figure 3.12: Export dialog from ***PowerFactory*** to *StationWare*

4 Analysis Functions

4.1 Transmission Network Tools

4.1.1 Power Transfer Distribution Factors

The calculation of Power Transfer Distribution Factors (PTDFs) has been introduced in ***PowerFactory*** 15.2. Knowledge of these factors assists greatly in the analysis of the impact of a power exchange between two regions. More precisely, the PTDF command evaluates the change in power flow across a set of branches, while changing production and consumption, respectively, in two predefined regions. The interchange region can be a zone, grid, area or boundary. The interconnections between these regions are called Flowgates.

This calculation requires the selection of two sets of regions: one for exporting (commonly called the "seller"), and one for importing (commonly called the "buyer"). The Flowgates can either be automatically determined according to adjacent regions, or can be user-defined (by using a set of boundaries). The scaling elements can be either loads or generators. The PTDF command is available either via the main toolbar or the *Calculation* main menu, under *Transmission Network Tools*. The *Basic Data* page of the PTDF command is shown in Figure 4.1.

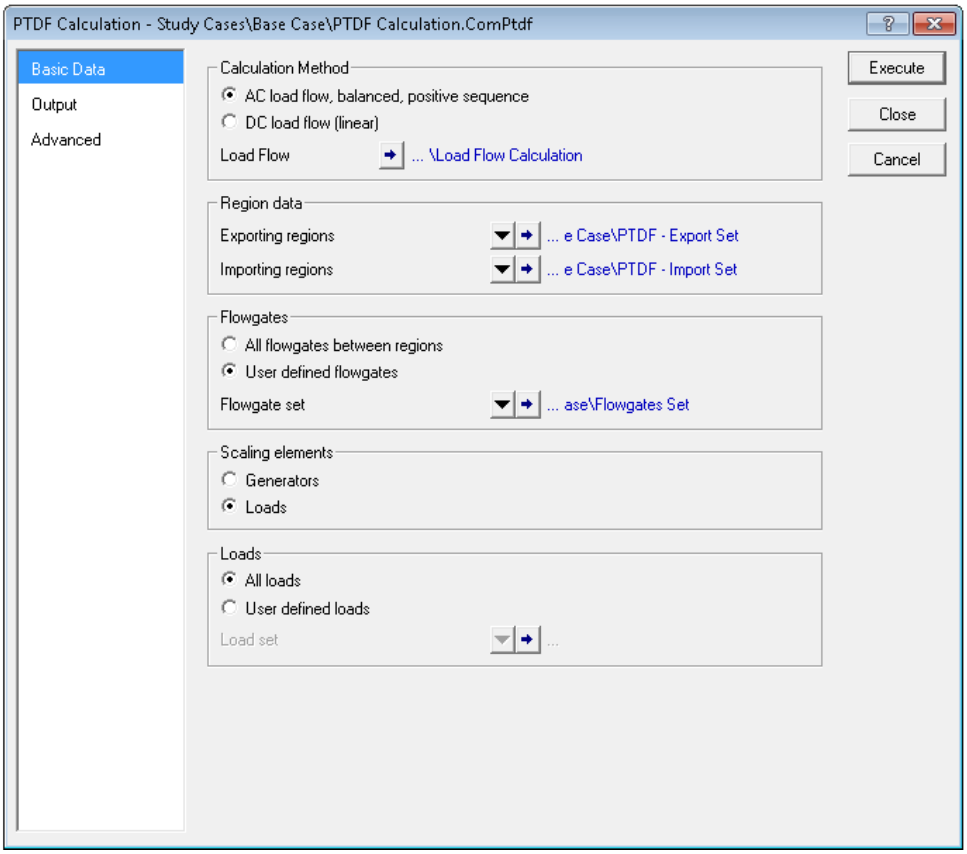
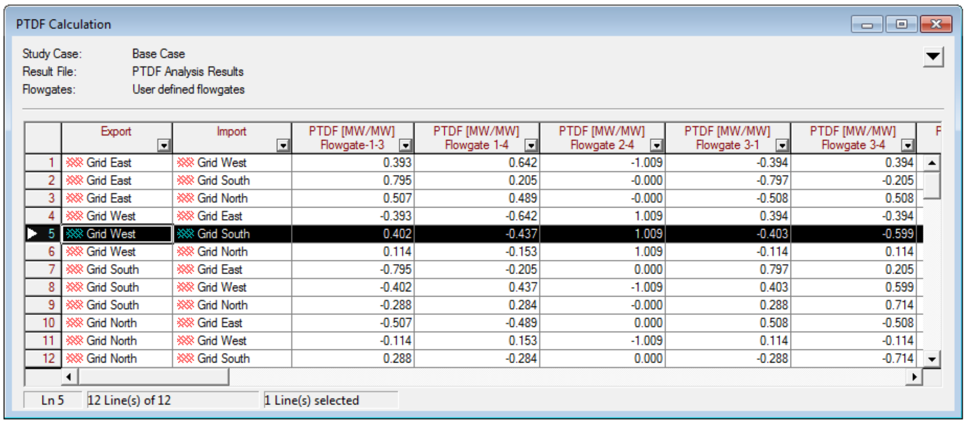


Figure 4.1: PTDF Basic Options

The result of this calculation is the increase or decrease of power flow through the Flowgates according to the change of power in both the exporting and importing regions. All possible combinations of exporting and importing regions are calculated. An example result overview can be seen in Figure 4.2. In this example, the regions are different grids and the Flowgates are user-defined boundaries. In the tabular report each row represents the transaction between the exporting and importing regions, and the PTDFs are provided in the corresponding cell of the Flowgate column.



	Export	Import	PTDF [MW/MW] Flowgate-1-3	PTDF [MW/MW] Flowgate 1-4	PTDF [MW/MW] Flowgate 2-4	PTDF [MW/MW] Flowgate 3-1	PTDF [MW/MW] Flowgate 3-4
1	Grid East	Grid West	0.393	0.642	-1.009	-0.394	0.394
2	Grid East	Grid South	0.795	0.205	-0.000	-0.797	-0.205
3	Grid East	Grid North	0.507	0.489	-0.000	-0.508	0.508
4	Grid West	Grid East	-0.393	-0.642	1.009	0.394	-0.394
5	Grid West	Grid South	0.402	-0.437	1.009	-0.403	-0.599
6	Grid West	Grid North	0.114	-0.153	1.009	-0.114	0.114
7	Grid South	Grid East	-0.795	-0.205	0.000	0.797	0.205
8	Grid South	Grid West	-0.402	0.437	-1.009	0.403	0.599
9	Grid South	Grid North	-0.288	0.284	-0.000	0.288	0.714
10	Grid North	Grid East	-0.507	-0.489	0.000	0.508	-0.508
11	Grid North	Grid West	-0.114	0.153	-1.009	0.114	-0.114
12	Grid North	Grid South	0.288	-0.284	0.000	-0.288	-0.714

Figure 4.2: PTDF result table

4.1.2 Transfer Capacity Analysis

The Transfer Capacity Analysis command determines the maximum power transfer capacity between two regions. To run the analysis, two regions must be specified: one which exports power and one which imports power. The region can be a zone, grid, area or boundary. The scaling elements can be either loads or generators.

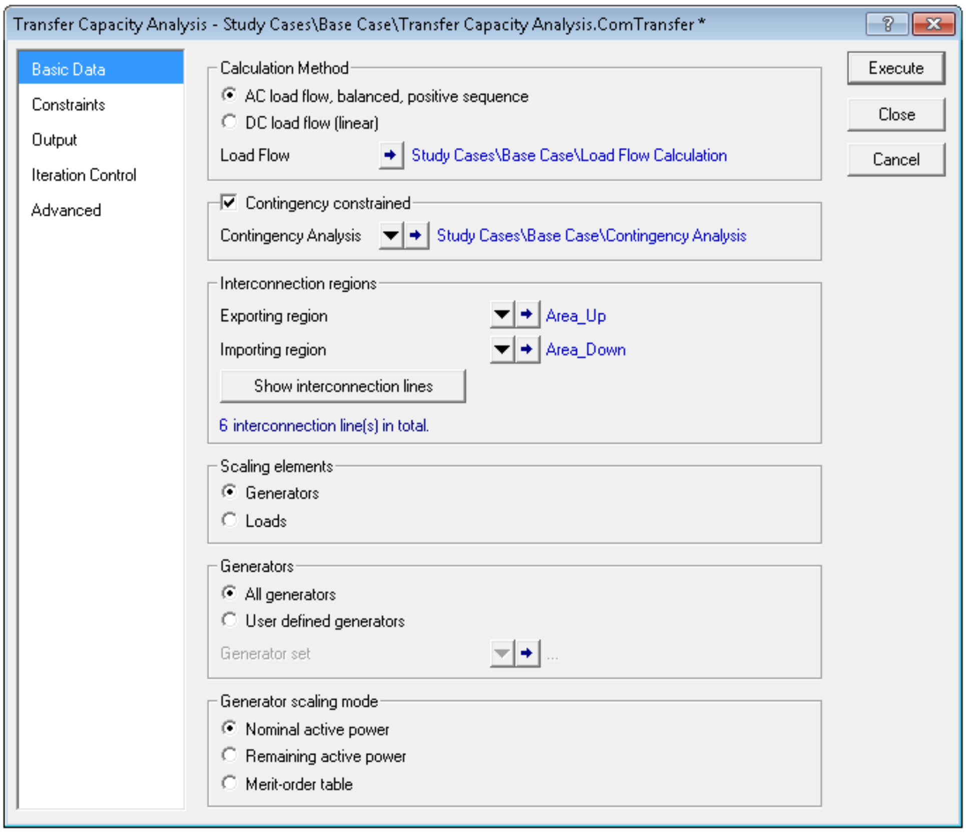


Figure 4.3: Transfer Capacity Analysis dialog

In addition, it is possible to determine the transfer capacity under consideration of contingency-, voltage- and thermal constraints. The results are provided in a window as shown in Figure 4.4. In the example shown, the scaling mode was selected for generators. ***PowerFactory*** generates a status report for each iteration while the power scaling process is running. The Transfer Capacity Analysis command is available either via the main toolbar or the *Calculation* main menu, under *Transmission Network Tools*.

```
DIgSI/info - Transfer capacity analysis started...
DIgSI/info - ...from Net4 to Net2.
DIgSI/wrng - Generator SG1 with active power set to zero is treated as the synchronous compensator and cannot be scaled.
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -    Iteration    Exporting Region          Importing Region          Transfer        Iteration
DIgSI/info -       No.       Generation (MW)           Generation (MW)           Capacity (MW)    status
DIgSI/info -                 Net4                      Net2
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -       0         3741,00                   1900,77                   921,28           OK
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/wrng -       1         3928,05                   1713,72                   921,28           thermal violation
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -       2         3834,52                   1807,24                   1018,03          OK
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -       3         3881,29                   1760,48                   1066,54          OK
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -       4         3904,67                   1737,10                   1090,83          OK
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/wrng -       5         3904,67                   1737,10                   1090,83          generation minimum breached (import)
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info -       6         3910,51                   1731,26                   1096,91          OK
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info - The total transfer capacity for the last feasible solution is 1096,91 (MW).
DIgSI/info - ---------------------------------------------------------------------------------------------------------
DIgSI/info - Transfer capacity successfully calculated.
```

Figure 4.4: Transfer Capacity Analysis output

4.1.3 PV Curves Calculation

PV curves are essential for analysing the voltage stability of power systems. The PV Curves Calculation finds the critical point of voltage instability by increasing the power demand of user-selected loads until the load flow calculation no longer converges; i.e. until the stability limit is reached. The critical demand is reported in the output window, and the voltage drop (V), and increasing power (P), can then be plotted in a PV curve.

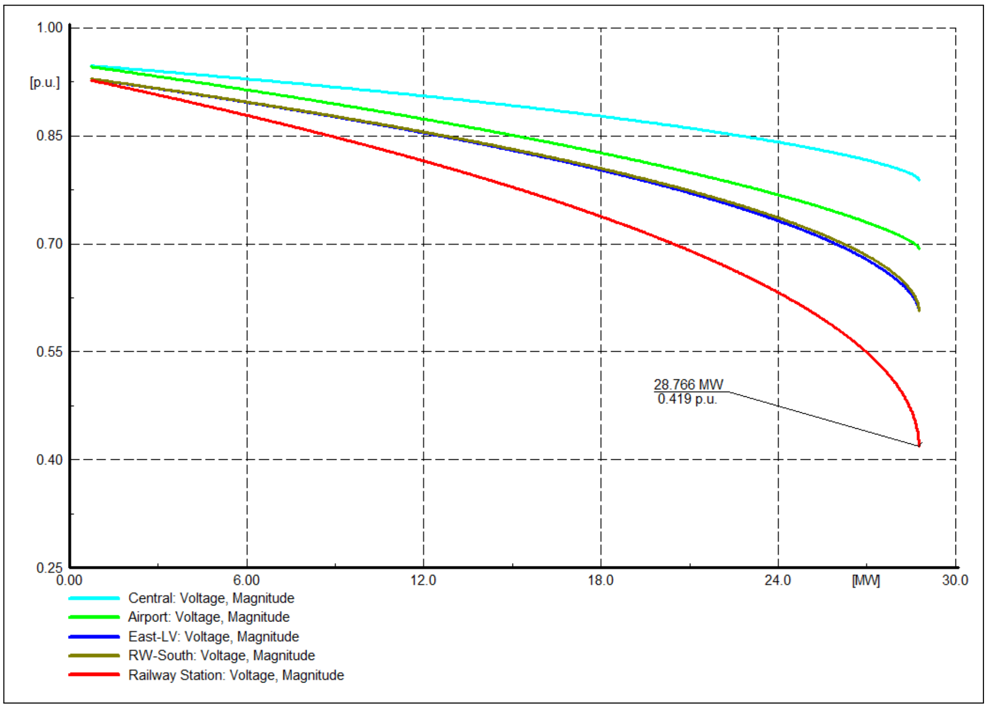


Figure 4.5: Network PV curve

In ***PowerFactory*** 15.2, the calculation and the corresponding plots are made available via two separate commands, both of which are available either via the main toolbar or the *Calculation* main menu, under *Transmission Network Tools*:

- PV Curves Calculation (calculates the critical demand)
- PV Curves Plot (plots the PV curve)

The PV Curves Calculation can be executed using default settings, but can also be configured to consider contingencies.

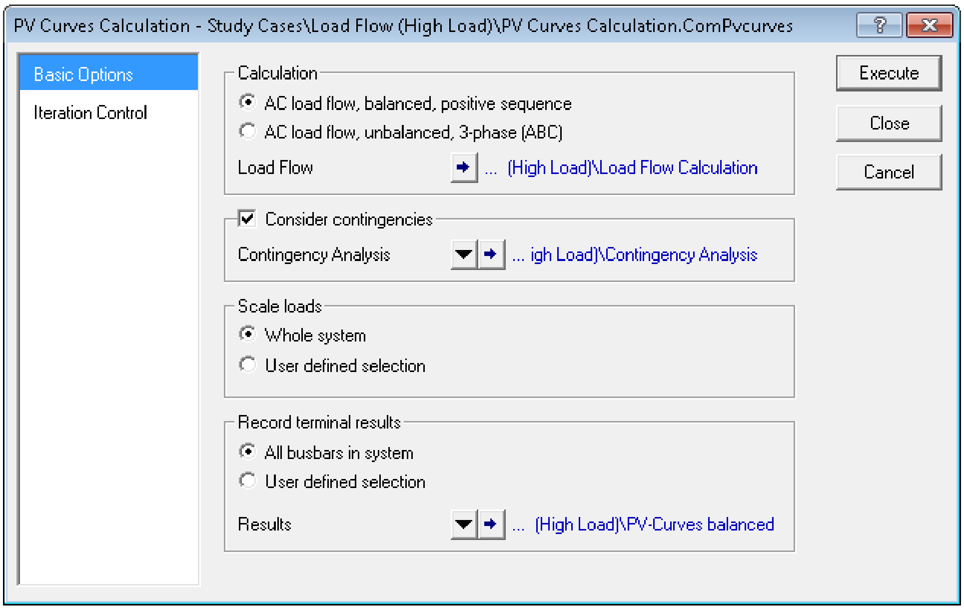


Figure 4.6: PV Curves Calculation dialog

The PV Curves Plot offers the following options:

- If the PV Curves Calculation has been executed without considering contingencies, the user can choose to plot the critical busbar, or select the busbar/s to be plotted.
- If the PV Curves Calculation has been executed with consideration of contingencies, the user can either choose to plot the busbar of the critical contingency, or may select the busbar/s to be plotted from a list of defined contingencies. By default, the critical busbar of each contingency is used.

4.2 Distribution Network Tools

4.2.1 Voltage Profile Optimisation

Voltage Profile Optimisation in ***PowerFactory*** 15.2 offers the following new features:

- **Independent Consideration of Production and Consumption Case:** Definition of a calculation case, on which it is possible to perform Voltage Profile Optimisation according to predefined settings for the production case or consumption case individually. This results in a clearer graphical representation, as illustrated in Figure 4.7.
- **New objective functions:** Optimisation of transformer tap positions by maximisation of either generation or production. In this case, the voltages will be taken either to the lower limit (production case) or to the upper limit (consumption case) within the user-defined voltage range.
- **Verification Mode:** With this mode, it is possible to check current transformer tap positions. Any violations of the predefined voltage limits of the transformer will be shown.

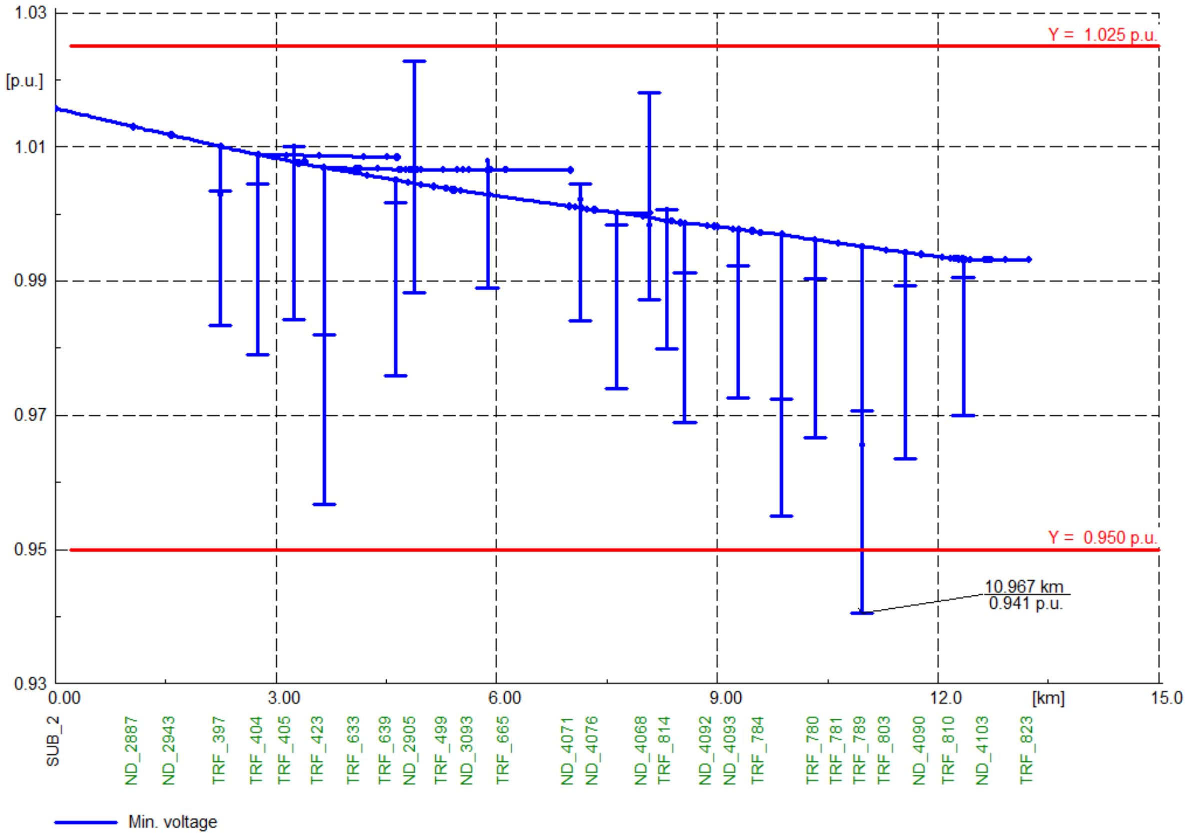


Figure 4.7: Voltage Profile Optimisation according to production case for maximisation of generation

4.3 Arc-Flash Analysis

4.3.1 Iterative Arcing-Current Calculation

PowerFactory 15.2 provides an enhancement to the Arc-Flash Analysis. A new option is available which calculates the arcing-current energy by using the actual current for each step of the arc-flash calculation (according to IEEE-1584 and NFPA 70E standards). To make use of this feature, the fault clearing time must be set to be used from the relays iteratively.

4.4 Power Quality and Harmonic Analysis

4.4.1 Harmonic Distortion and Harmonic Factor

This enhancement increases the flexibility of the Harmonic Load Flow command. To this end, the *Advanced Options* page of the Harmonic Load Flow command has changed as follows:

- HD and THD options have been simplified;
- The maximum harmonic order can be set according to:
  - Various standards
  - Unlimited
  - User-defined
- Optional calculation of HF.

In addition to the commonly-used harmonics indices:

- Harmonic Distortion (HD)
- Total Harmonic Distortion (THD)

there are new calculation variables available for buses and branch elements:

- Harmonic Factor (HF)
- Total Harmonic Factor (THF)

Further, the naming of various power quality quantities has been standardised and unified across ***PowerFactory***.

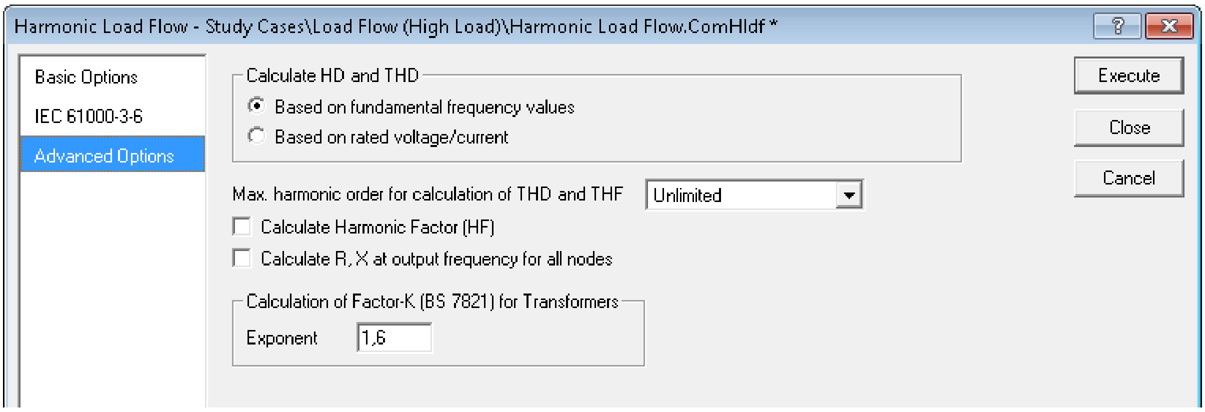


Figure 4.8: Redesigned Harmonic Load Flow command

4.4.2 K-Factor Transformers

The Harmonic Load Flow command has been enhanced to be able to calculate K-Factors for 2-winding transformers. These kinds of transformers allow operation up to nameplate capacity without de-rating and are designed to minimise harmonic current losses.

The following new calculation variables for 2-winding transformers are available:

- K-Factor (UL 1562)
- Factor-K (BS 7821)
- Harmonic Loss Factor (FHL) (IEEE C.57.110-1998)

This new feature can be used by setting an appropriate value on the *Harmonics/Power Quality* page of the 2-winding transformer type. For the calculation of Factor-K, the exponent can be entered on the *Advanced Options* page of the Harmonic Load Flow command. Knowledge of the relevant factor can assist the user in the selection of an appropriately rated transformer.

4.5 Connection Request Assessment

4.5.1 D-A-CH-CZ: HV Resonances

This ***PowerFactory*** 15.2 enhancement was introduced in accordance with the D-A-CH-CZ (HV extension document) recommendation to consider resonances in HV networks. Resonances are undesirable because they exacerbate harmonic source currents and voltages, thereby possibly resulting in equipment damage.

The *Harmonics* page of the Connection Request Assessment command has been changed as shown in Figure 4.9, and the Connection Request element has been enhanced to include additional Harmonics options (relevant to HV networks only). According to these new options, the Connection Request Assessment report (according to D-A-CH-CZ) will additionally print the following quantities:

- First parallel resonance point
- Automatically-detected supply transformers
- Emission limits

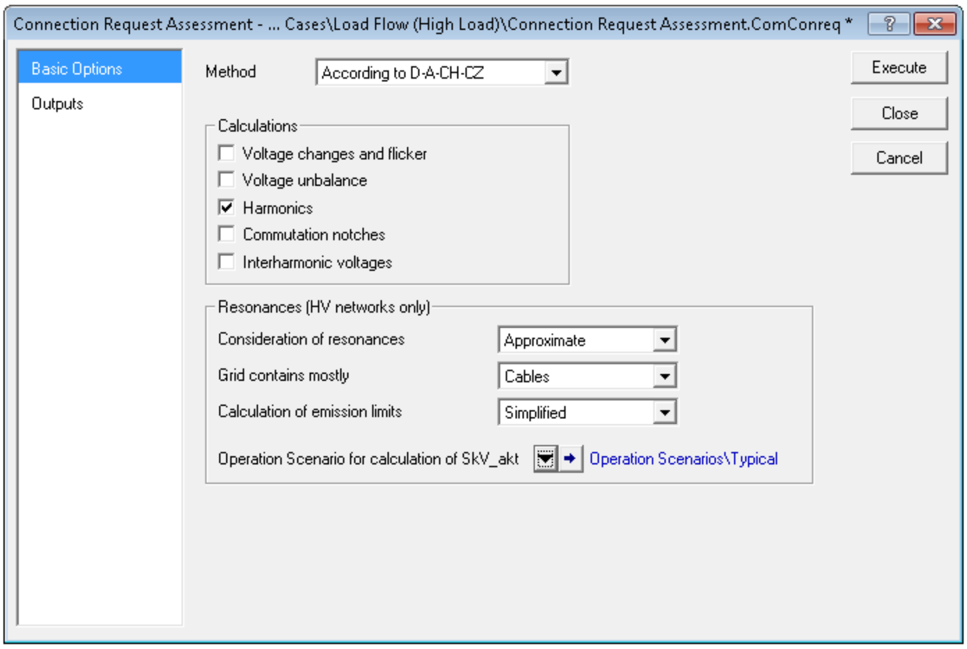


Figure 4.9: New Basic Options page of the Connection Request Assessment command

4.6 Reliability Analysis Functions

4.6.1 Optimisation of Power Restoration

When calculating Reliability Assessment for distribution systems in ***PowerFactory*** 15.2, partial restoration occurs by default to solve violations of constraints.

After the isolation of failures, parts of the network may be unsupplied. However, the network can be reconfigured by moving the tie open point in order to restore as much power as possible. For each sectionalising stage of switches, the new optimisation method offers three power restoration modes:

- Disabled (no movement of tie open points)
- Enabled without load transfer (tie open points can only be moved between the feeder and a directly-bordering feeder)
- Enabled with load transfer (tie open points can be moved between a bordering feeder and a second-level bordering feeder)

These new modes are available on the *FEA* page of the Reliability Assessment command, as shown in Figure 4.10.

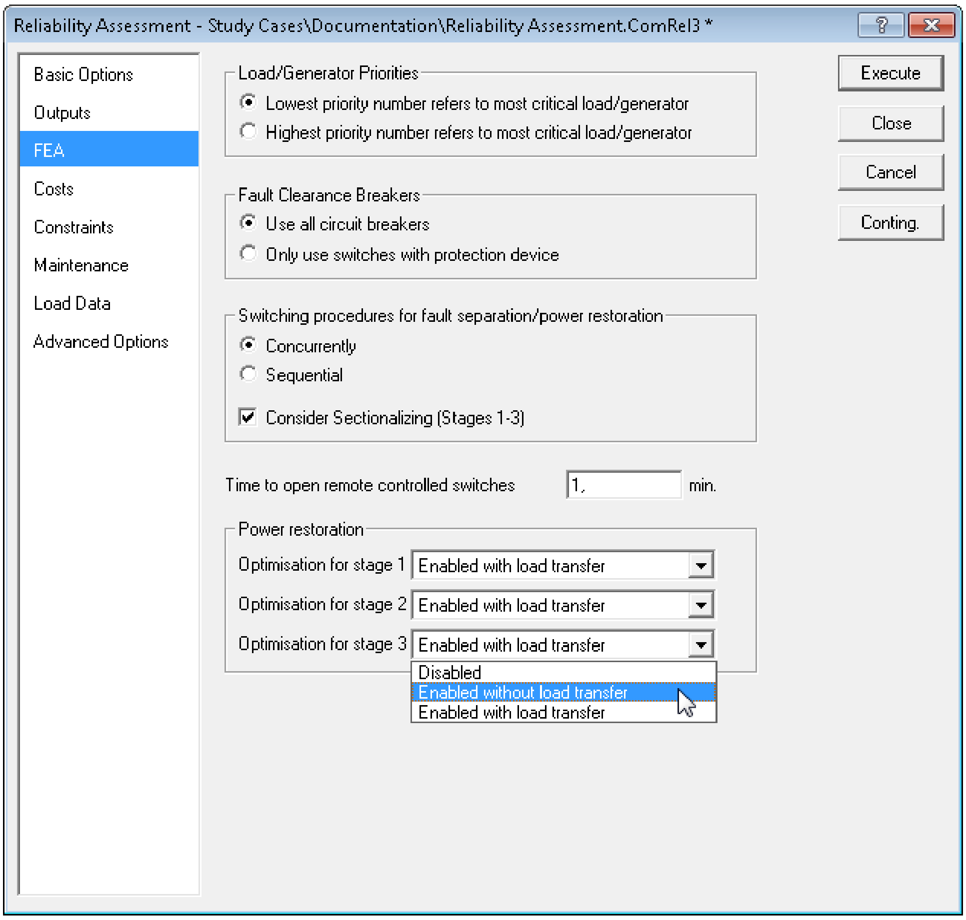


Figure 4.10: FEA dialog with new load transfer optimisation methods

4.6.2 Distribution Transformer Failure Model

Distribution transformer types can be used in the modelling of MV loads, and provide the functionality of a built-in transformer. ***PowerFactory*** 15.2 supports the definition of stochastic failure models for the distribution transformer type. The fault behaviour of the distribution transformer can then be modelled and analysed in Reliability Assessment. This is done in the same manner as for other transformers, except for the fact that the load connected behind the transformer is not supplied until the end of the repair duration. As for other transformer types in ***PowerFactory***, the transformer failure model is defined on the *Reliability* page of the distribution transformer type, as shown in Figure 4.11, and is then displayed on the *Reliability* page of the associated element.

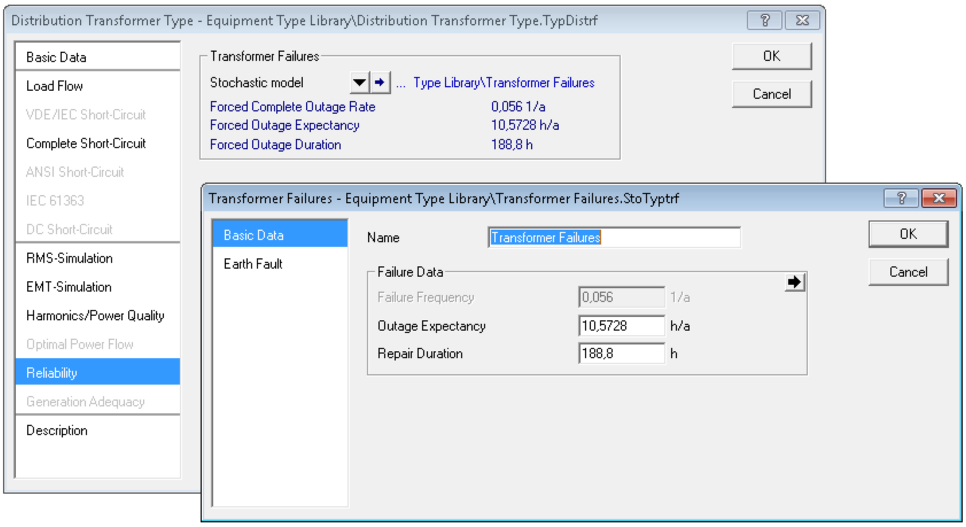


Figure 4.11: Distribution transformer type and transformer failure definition

4.6.3 Generator Failure Model

In addition to existing failure models, ***PowerFactory*** 15.2 allows the definition of stochastic failure models for generators (synchronous machines, static generators, PV systems, etc.). The failure model can contain any number of load level states; each state representing the availability of the generator over a year. Hence, complete and/or partial outages can be modelled. States can be defined using the following parameters:

- Name of State
- Availability [%]
- Probability [%]
- Duration [h]
- Frequency per year [1/a]
- Total Duration [h/a]

Upon execution of Reliability Assessment, ***PowerFactory*** creates a separate contingency for each defined state. A load flow is calculated considering the reduced availability (including 0%) of the generator, and depending on constraint violations, load shedding and/or re-dispatch of alternative generators may result. The generator failure model is defined in the generator element on the *Reliability* page, as shown for the case of a synchronous machine in Figure 4.12.

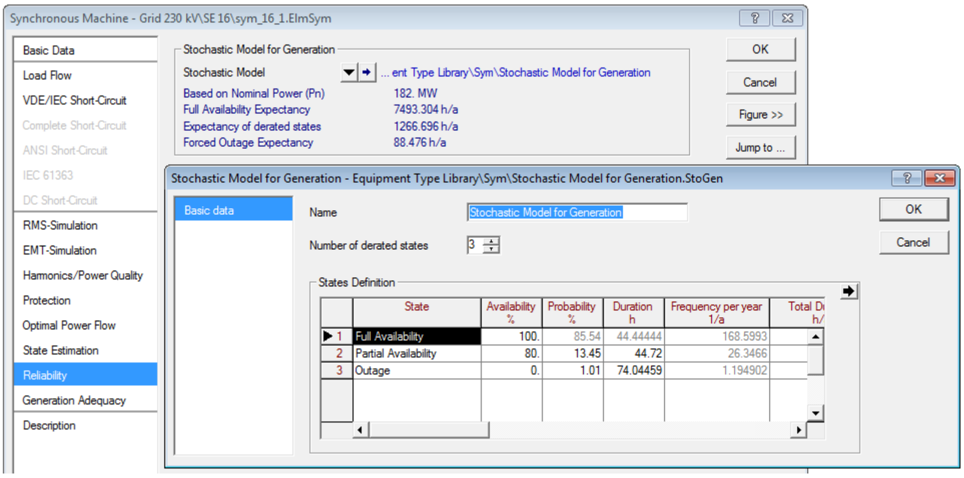


Figure 4.12: Generator element and stochastic model for generation

4.7 Stability Analysis Functions (RMS- and EMT-Simulation)

4.7.1 C Interface for Dynamic Models

The newly-developed C Interface lets the user program virtually *any* model using the C language. The advantage with respect to the existing DSL models or MATLAB interface models is that the model is then compiled and may run as fast as a standard ***PowerFactory*** element.

4.7.2 Fast DSL Functions

DSL has been enhanced via the introduction of the following fast functions: selfix(), limfix() and outfix(). These functions are analogous to the existing functions select(), limits() and output(), with the notable difference that they are evaluated only at initialisation, which provides significant speed-up depending on their frequency of use. The introduction of the new functions exploits the fact that a great proportion of the above-mentioned, existing functions were called on constant parameters in dynamic models, e.g. to select a switch or to warn about a parameter lying outside its allowable range, and thus need not be evaluated at each step.

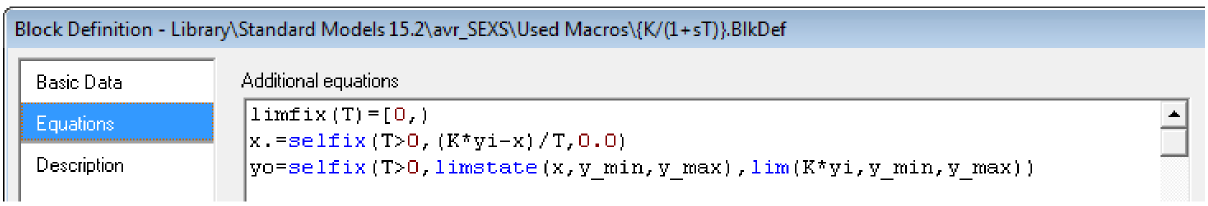


Figure 4.13: Usage of new, fast DSL functions

4.7.3 Compiled Improved Standard Libraries

The standard models provided by ***PowerFactory*** have been enhanced with the use of new, fast DSL functions and are delivered in a compiled form to achieve greater speed-up.

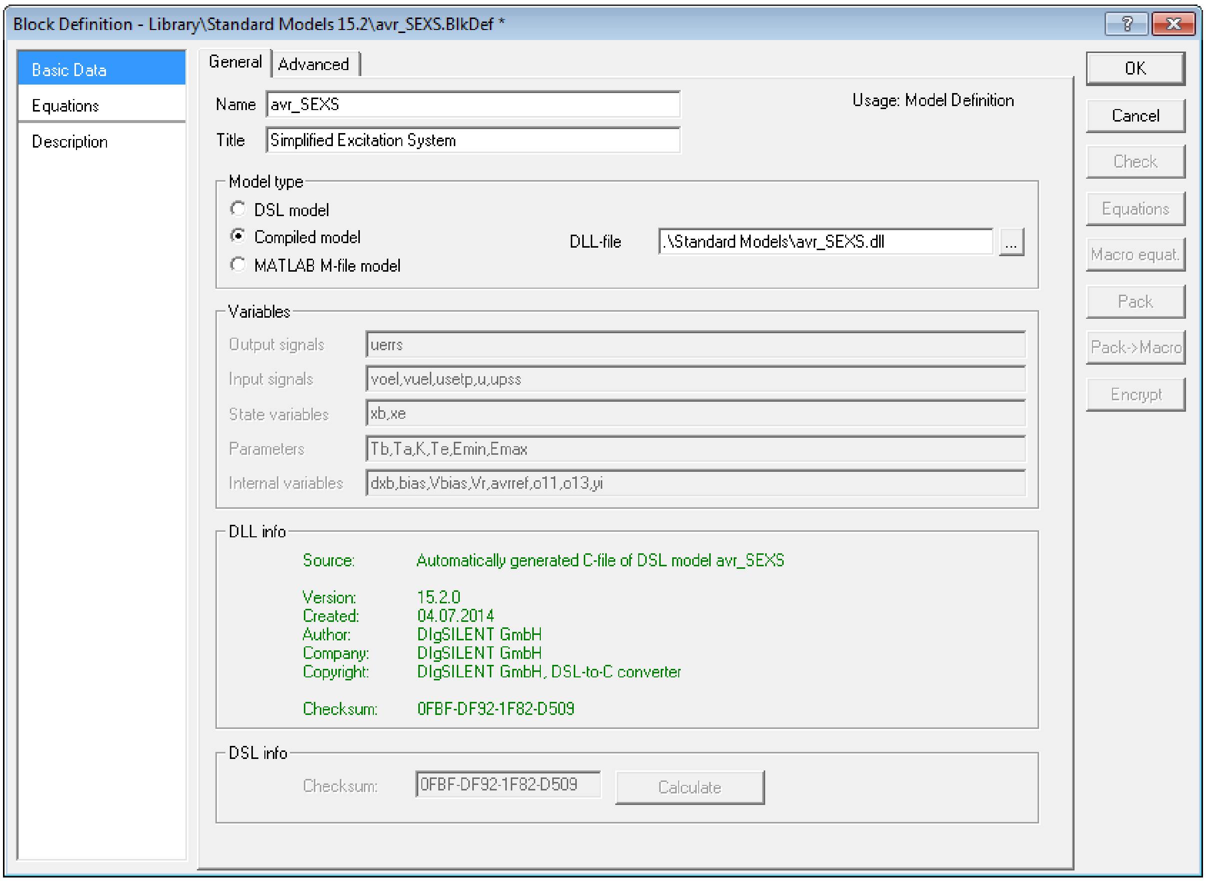


Figure 4.14: Compiled standard model avr_SEXS

4.7.4 Automatic DSL-to-C Interface Converter

The speed-up provided by the C Interface extends beyond models coded directly in the C language, and models within the standard library. In addition, the user can create or modify an existing DSL model, run the automatic DSL-to-C Interface Converter and simulate the customised model as fast as a standard ***PowerFactory*** element.

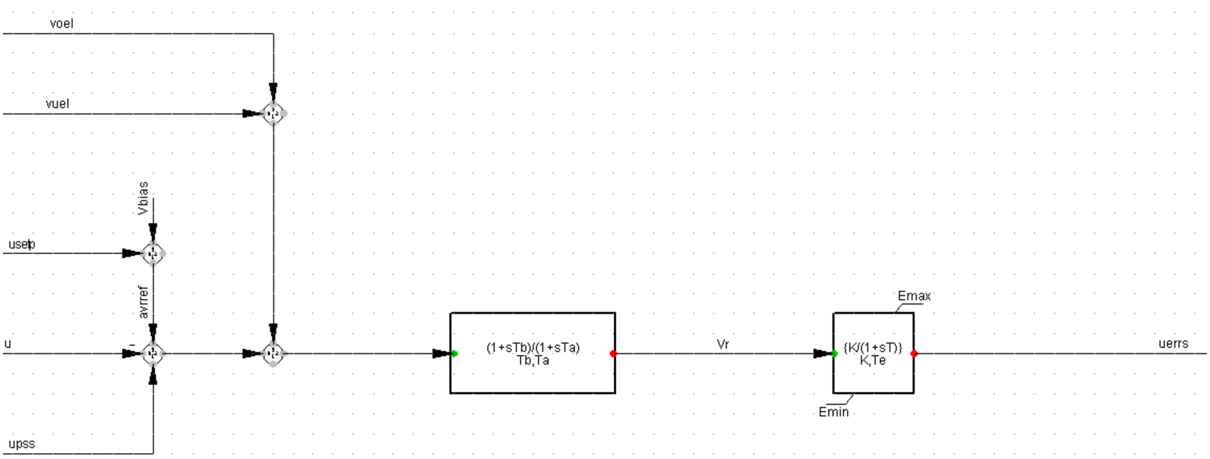


Figure 4.15: Modified model avr_SEXS

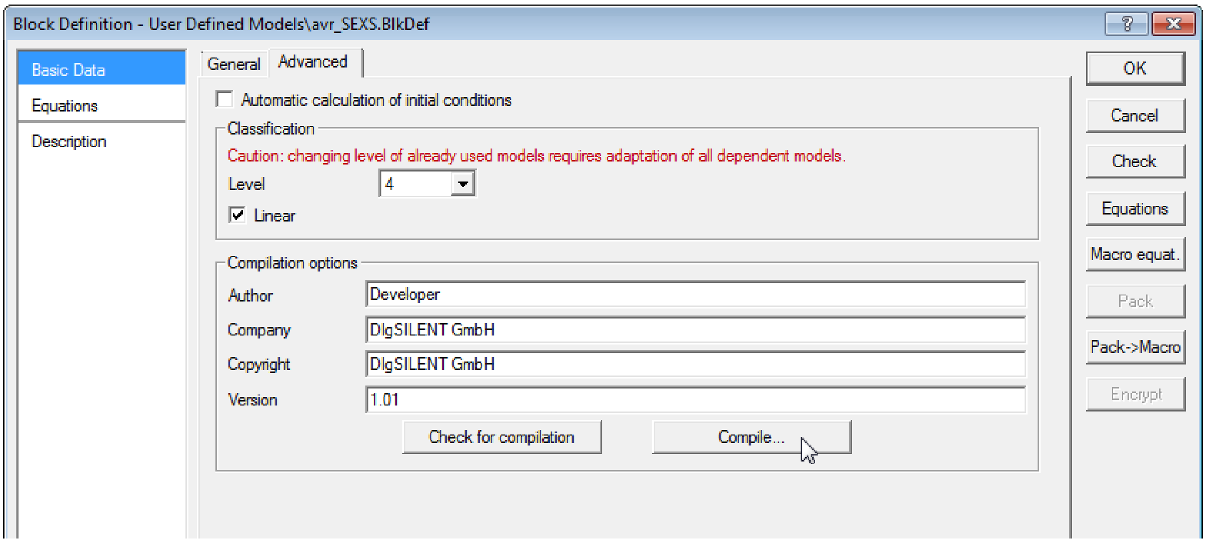


Figure 4.16: Compilation options for modified model avr_SEXS

4.7.5 Algorithmic Enhancements and Additional Options

Further performance improvements are made possible via the use of the following algorithm options:

- **Fast convergence check**
  If this option is enabled, ***PowerFactory*** 15.2 will run faster because it determines convergence via advanced heuristics instead of checking each equation.
- **Fast computation of outputs**
  PowerFactory 15.2 will run faster because it will use the last available output from the solution process instead of recomputing each single quantity.
- **Fast independent solution of network and dynamic models**
  This option determines convergence sequentially and independently on network and dynamic models rather than simultaneously. ***PowerFactory*** 15.2 may run significantly faster with this option enabled in case of systems exhibiting convergence difficulties.
- **Apply DSL events directly**
  This option enables internal DSL events stemming from the select(), lim() and limstate() functions to be applied directly within one step which, depending on the number of transitions occurring, may be significantly faster than scheduling and applying each transition singularly.

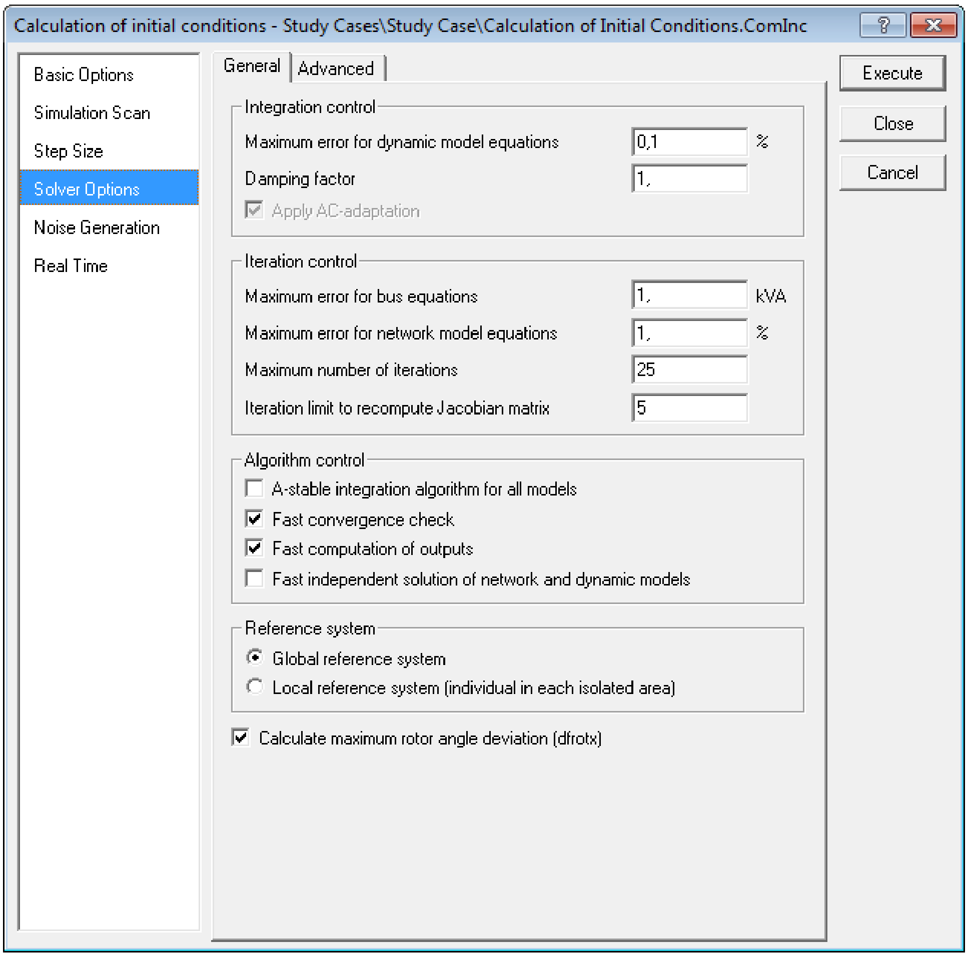


Figure 4.17: New solver options in calculation of initial conditions command

4.7.6 Simulation Scan

The Simulation Scan modules have been enhanced by a user-selectable scan location. This location can be the whole system, a set of elements or a single element. Additionally, ***PowerFactory*** 15.2 introduces the new Synchronous Machine Speed Scan module.

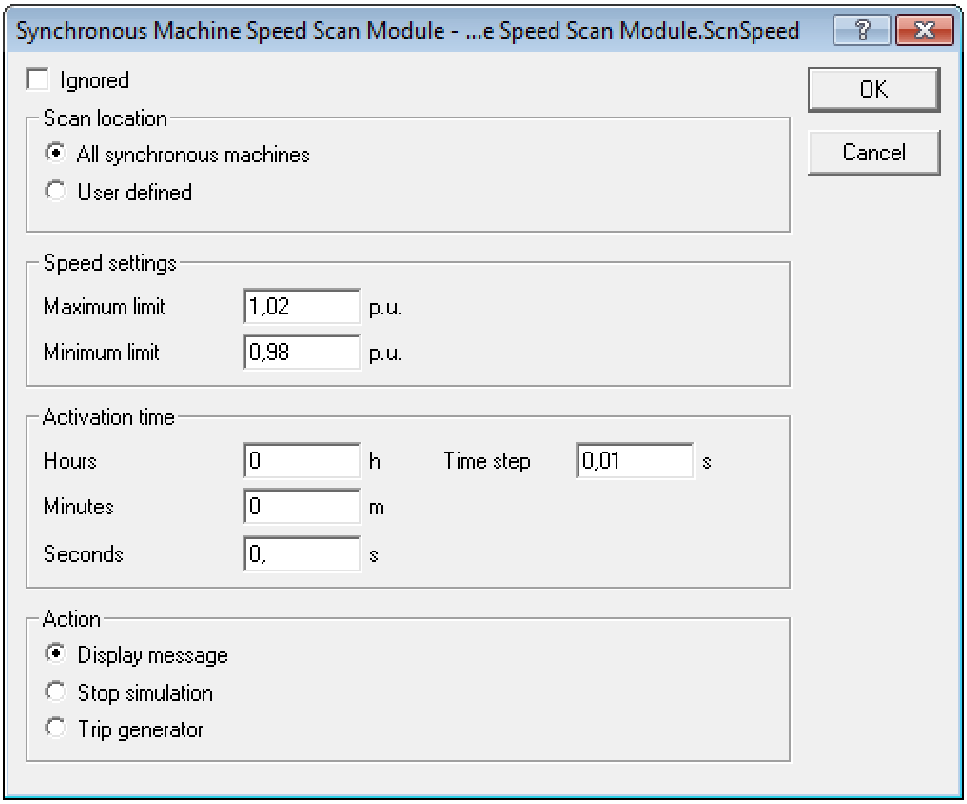


Figure 4.18: New Synchronous Machine Speed Scan module showing the new Scan location option

5 Models

5.1 New Models

5.1.1 Asynchronous Machine

A new asynchronous machine type (saturable) is available in ***PowerFactory*** 15.2. This type allows the following parameters to be defined for single-cage rotor asynchronous machines:

- Iron losses
- Main flux saturation
- Slip- and current-dependent stator reactance
- Slip- and current-dependent rotor reactance
- Slip-dependent rotor resistance

Figure 5.1 shows the equivalent circuit for the new asynchronous machine type.

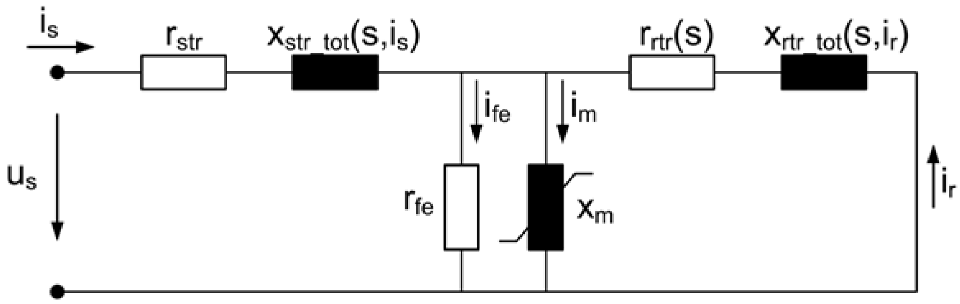


Figure 5.1: Dynamic model of the new saturable asynchronous machine type

where:
r_{str}: Stator resistance
r_{fe}: Iron losses
r_{rtr}: Rotor resistance
x_{str_tot}: Total stator reactance (including dependencies)
x_{rtr_tot}: Total rotor reactance (including dependencies)
x_m: Magnetising reactance

5.1.2 AC Current Source with Two Connections

A new AC current source with two connections has been introduced in ***PowerFactory*** 15.2.

The new element is load-oriented and extends the functionality of the existing AC current source by being able to be connected between different voltage levels.

Figure 5.2: New AC current source with two connections

5.1.3 Extended Fuse Library

PowerFactory 15.2 provides new Siemens fuse types in the relay library, which can be found in the download area of the DIgSILENT website.

5.2 Model Enhancements

5.2.1 LV and MV Loads: Input of Yearly Energy Consumption Value

The low voltage load and medium voltage load elements have been enhanced to allow the input of the annual energy consumption. This new input mode is called “E, cosphi”. This enhancement allows the use of load profiles which are normalised to the annual energy consumption. Using the yearly consumption and the assigned load profile, ***PowerFactory*** automatically calculates the active power value at the given study time. This new input mode can also be utilised when running the Quasi-Dynamic Simulation over a user-specified time period.

5.2.2 Unbalanced MV Load

The medium voltage load element has been enhanced to be able to use different phase technologies. With this enhancement, a more detailed consideration of unbalanced network conditions is possible. The following phase technologies are now supported:

- Three-phase technology:
  - Delta connection (D)
  - Connected to neutral (YN)
  - Connected to earth (PH-E)
- Two-phase technology:
  - Connected to neutral (YN)
  - Connected to earth (PH-E)
- Single-phase technology:

- Phase to phase connection (PH-PH)
- Connected to neutral (YN)
- Connected to earth (PH-E)

In addition, a new parameter “Generation Scaling Factor” has been introduced for load flow analysis, which scales the generation value of the load.

5.2.3 Synchronous Machine

The synchronous machine element has been enhanced in ***PowerFactory*** 15.2 to allow the configuration of the excitation system.

It is now possible to define the Efd base ratio, which is the ratio between the exciter rated voltage and the machine excitation rated voltage. Additionally, the following options are available on the *RMS-* and *EMT-Simulation* page of the synchronous machine element:

- **Air gap line** The excitation voltage (ve) and current (ie) is 1 p.u. for a machine without saturation at rated machine voltage under no load (P,Q = 0);
- **No load with saturation** The excitation voltage (ve) and current (ie) is 1 p.u. for a machine with saturation at rated machine voltage under no load (P,Q = 0);
- **Full load with saturation** The excitation voltage and current is 1 p.u. for a machine with saturation at rated machine voltage under full load.

$$P = S_n \cdot \cos(\varphi_n) \tag{1}$$

and

$$Q = S_n \cdot \sin(\varphi_n) \tag{2}$$

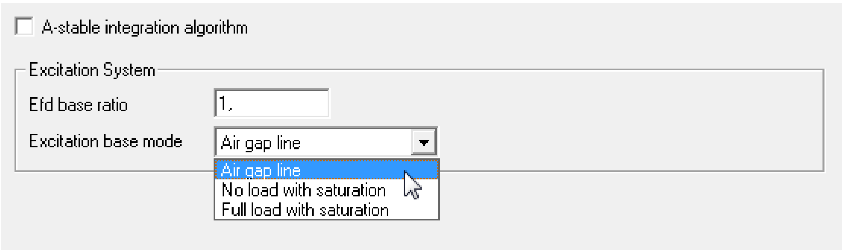


Figure 5.3: Excitation system of synchronous generator

The synchronous machine model has been enhanced for the RMS-Simulation with support of the “Classical Model”. This is a simplified model of an AC voltage source behind a transient impedance.

5.2.4 PWM Converter

In ***PowerFactory*** 15.2, the PWM converter has two new control modes for load flow analysis:

- P-cos(phi): Specifies P and cos(phi) on the AC side
- Vdc-cos(phi): Specifies the DC voltage setpoint and power factor on the AC side

An additional enhancement is the consideration of droop, which is the preferred control mode when building meshed HVDC systems. In ***PowerFactory*** 15.2, this is carried out according to the following equations:

For control modes according to active power:

$$P = P_{set} + 1/k \cdot (V_{dc} - V_{dc\_set}) \tag{3}$$

For control modes according to DC voltage:

$$V_{dc} = V_{dc\_set} + k \cdot (P - P_{set}) \tag{4}$$

5.2.5 DC Pole Losses for Rectifier and PWM

The rectifier and PWM elements can now have their losses defined. As such, three new input fields have been introduced:

- No Load Losses (kW);
- Switching Loss Factor (kW/A);
- Resistive Loss Factor (Ohm).

DC pole losses are reported in MW following a successful calculation.

5.2.6 Standardisation of Generator Dialogs

To provide a more intuitive handling of generator dialogs, enhancements have been made to the *Load Flow* pages of the following elements:

- Synchronous machine
- Asynchronous machine
- Static generator
- PV system
- Station control

For improved accessibility the Operational Limits settings have been moved to a separate tab.

Additionally, a new frame “Actual Dispatch” on the General tab shows the actual values (P, Q, S, cos(phi)) calculated depending on the selected Local Controller and Input Mode. This is shown in Figure 5.4.

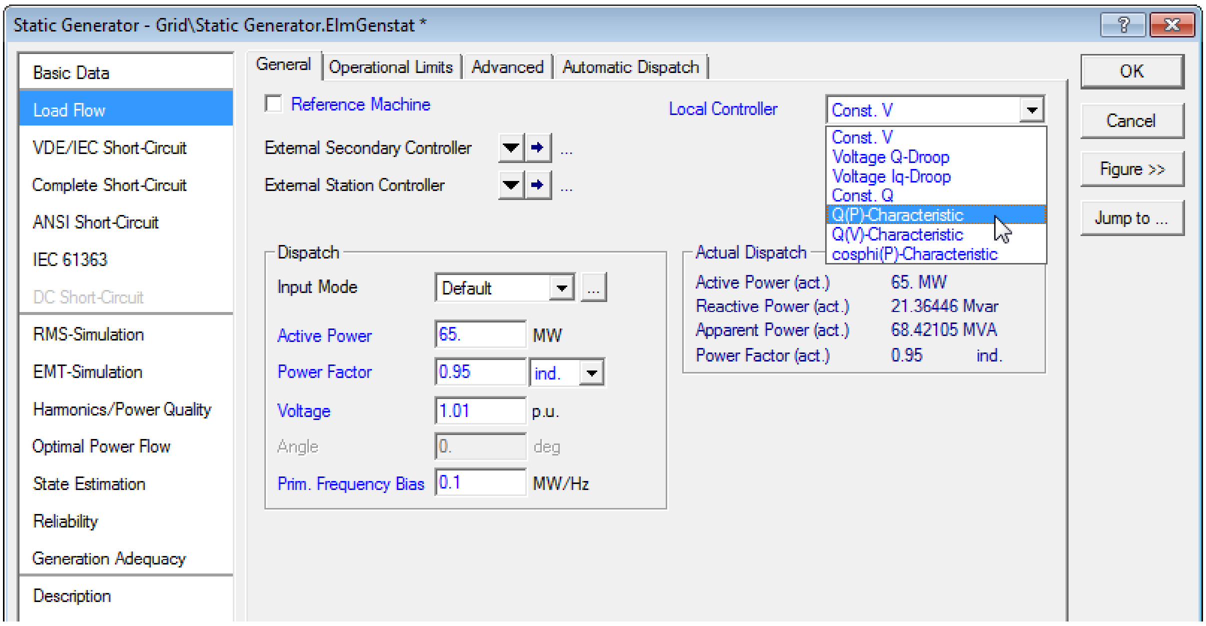


Figure 5.4: Static generator dialog

5.2.7 Local Controller Options

Various generator models have been enhanced with additional controller options. These are available in the upper right corner of the *Load Flow* page of the element dialog, as shown in the case of a static generator in Figure 5.4. New and improved Local Controller options include:

Q(P)-Characteristic: The new Q(P)-Characteristic is freely-definable either as a p.u. curve or a MW/Mvar curve, as shown in Figure 5.5. Analogous to ***PowerFactory*** types, these characteristics can be managed via the Operational Library and are available for synchronous machines, static generators, PV systems, asynchronous machines (DFIG), and station controllers.

cosphi(P)-Characteristic: The cosphi(P)-Characteristic has been extended to include curves in which the overexcited power factor limit corresponds to the higher active power value. The improved characteristic is available for PV systems, and station controllers, and is now also available for static generators.

Q(V)-Characteristic: In this control mode the reactive power setpoint follows a specified voltage characteristic. This control mode is now also available for static generators.

Voltage - Reactive Current (Iq) Droop: This new control mode is modelled according to:

$$du_{droop} = \frac{I_q - I_{q_{set}}}{K_{droop} \cdot I_{p_{nom}}} [\text{p.u.}], \quad (5)$$

where I_q, and $I_{p_{nom}}$ are the reactive current and the active nominal current, respectively. It has been introduced for static generators, PV systems, and asynchronous machines (DFIG).

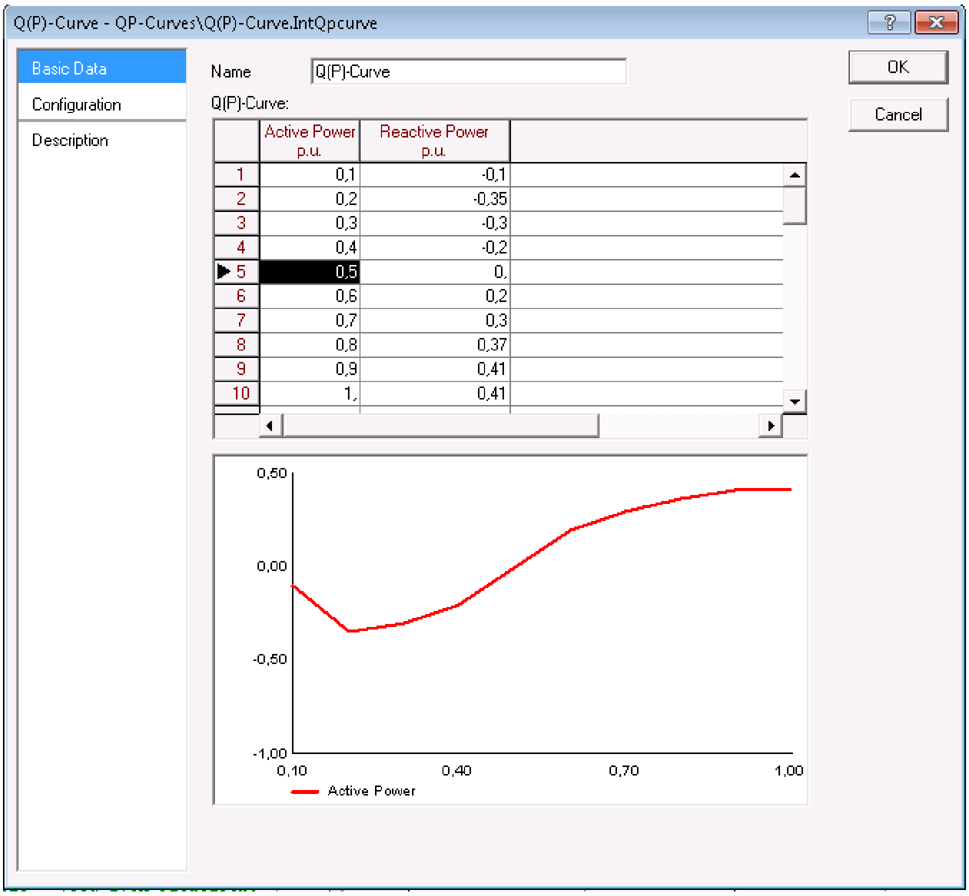


Figure 5.5: Q(P)-Curve dialog

5.2.8 Tower Model

The defined geometry of a tower type is now represented graphically in the type dialog. It is displayed next to the tower circuit coordinates table, as shown in Figure 5.6. In this diagram, the positions of the multiple three phase systems mounted on the tower can be seen. As a reference, a rectangular object in the lower left corner of the diagram symbolises a person of average height (1.8 meters).

In order to see this graphical representation of the tower, the user must first define the positions of the different phase conductors and the earth conductor in terms of X and Y coordinates in the table provided.

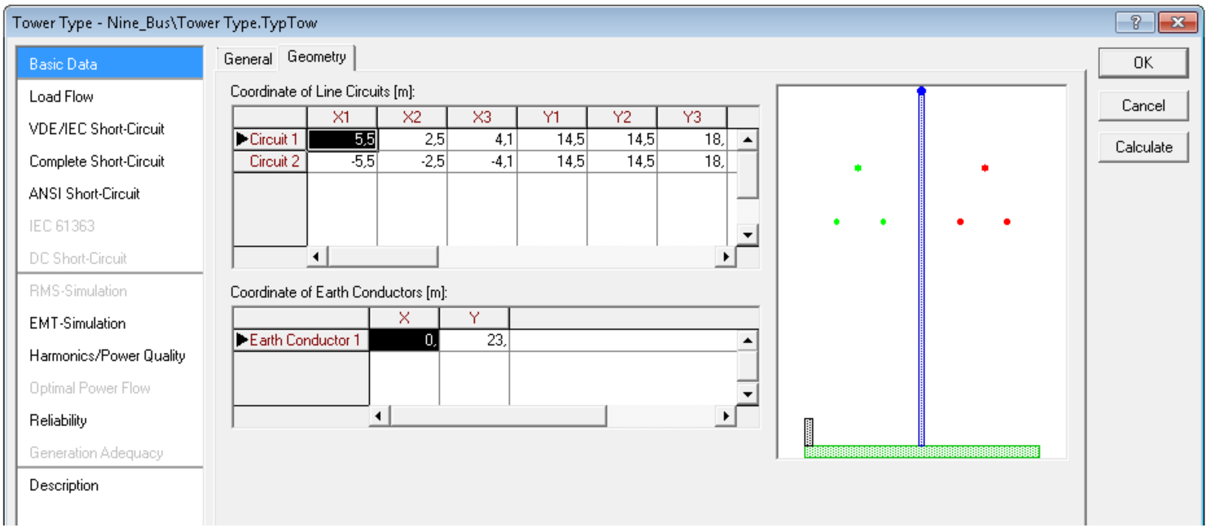


Figure 5.6: Tower geometry

5.2.9 3-Winding Auto Transformer

The 3-winding transformer can now be modelled with an auto transformer between the medium- and low voltage sides.

5.2.10 Support of AC-DC Intercircuit Fault Events in EMT Simulations

For EMT simulations it is now possible to define intercircuit fault events between DC and AC nodes, and a fault impedance. This event type may also be used to create a current path between AC and DC nodes in normal operation.

6 Performance

6.1 General Improvements

PowerFactory 15.2 provides significant general improvements via the use of new calculation algorithms. Some highlights include:

- **Performance** Various standard power system analysis functions exhibit significantly enhanced performance due to the use of algorithm optimisation and new data structures. Major performance improvements can be seen in:
  - Complete Short-Circuit calculation considering all buses
  - RMS- and EMT-Simulation for large networks (see 6.2)
  - Network Reduction
  - Effectiveness calculation under consideration of large numbers of contingencies
- **Large-scale systems** Solution of large systems with controlled precision using a state-of-the-art iterative linear solver.

The Study Case graphical user interface has been redesigned. It provides access to the new iterative linear solver and to further calculation options.

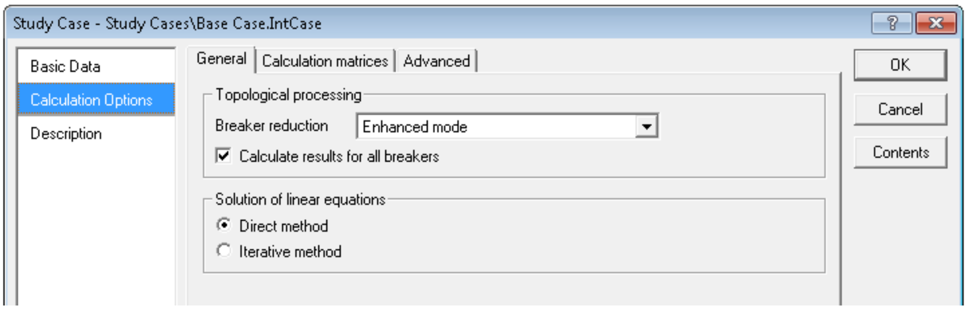


Figure 6.1: New Study Case dialog

6.2 Stability Analysis Functions (RMS- and EMT-Simulation)

PowerFactory 15.2 provides considerable performance improvement for both RMS and EMT simulation. Section 4.7 describes various enhancements which significantly increase the simulation speed, depending on the specific dynamic model. In summary, these are:

- The newly-developed C Interface, which offers the possibility to include any customised dynamic model in a compiled file which will run as fast as a standard ***PowerFactory*** element (see 4.7.1);
- New, fast DSL functions which can speed-up the simulation of DSL models considerably (see 4.7.2);
- Compiled models in the standard library for major performance improvement (see 4.7.3);
- The possibility to compile user-defined models using the new automatic DSL-to-C converter, which allows the user to run a customised DSL model as fast as a standard ***PowerFactory*** element (see 4.7.4);
- Advanced algorithmic options which offer additional speed-ups (see 4.7.5).

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 and France, 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 120 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 wind-grid integration studies.

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