POWERFACTORY

Network Model Diagrams in PowerFactory

1 Introduction

PowerFactory is a modern power system analysis software and features a wide variety of tools for graphically modeling and visualising power grids. The network model diagrams used in *PowerFactory* can be split into two different categories:

1. Single Line Diagrams (schematic and geographical network diagrams) for defining and/or visualising the topology of power grids
2. Block Diagrams for designing dynamic models and relays

This paper provides a brief overview of these diagrams and the corresponding graphical tools and features.

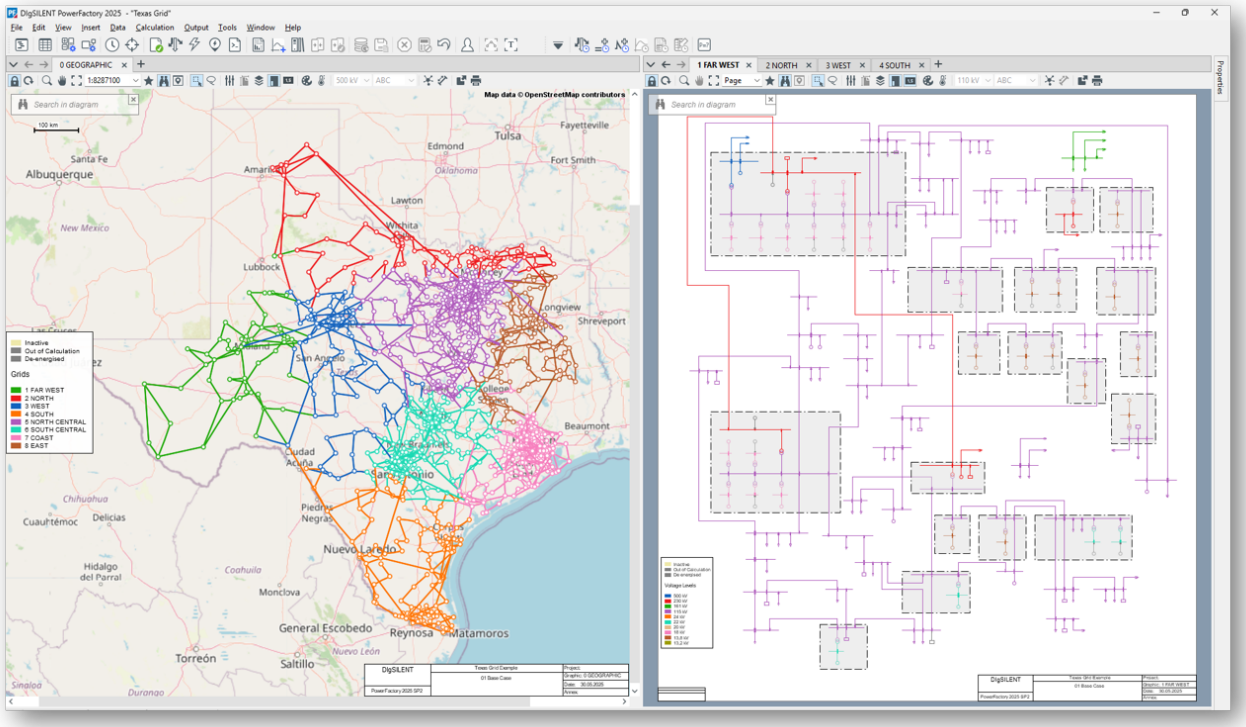


Figure 1: Geographic and schematic diagram

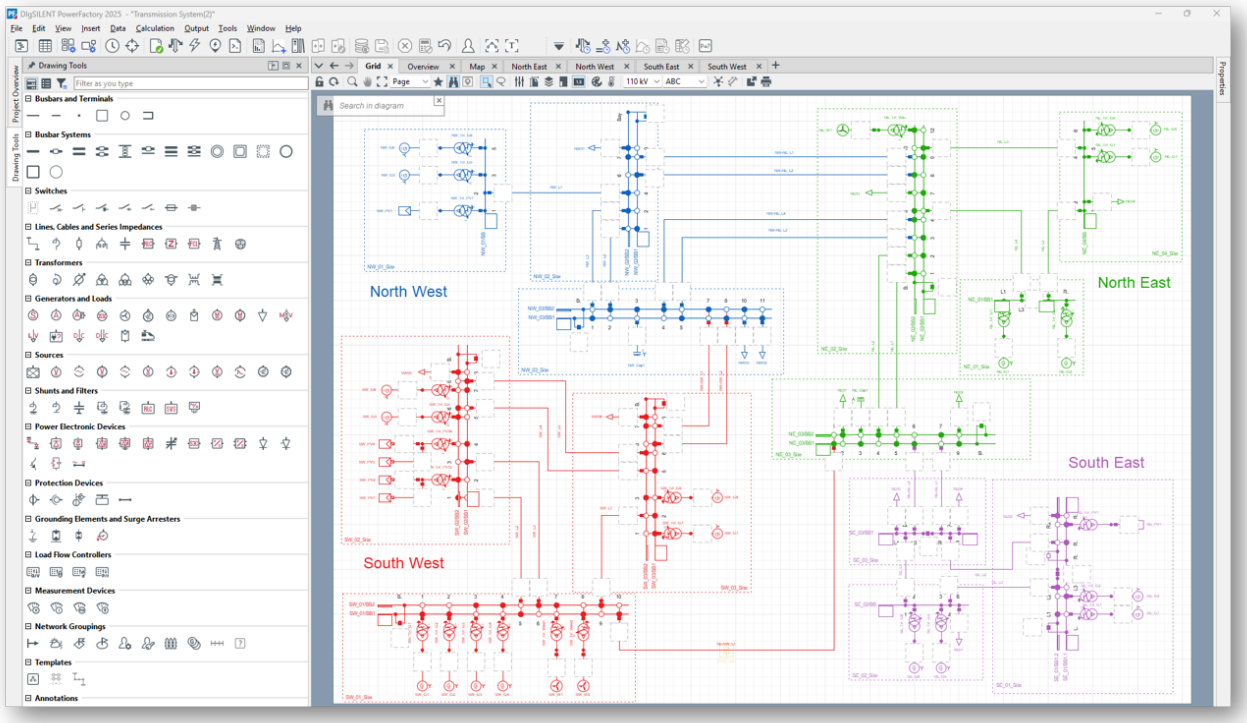


Figure 2: Schematic single line diagram and drawing toolbar

2 Single Line Diagrams

Network models can be visualized either schematically or geographically. An element can be represented in several diagrams and it's possible to easily switch between the different representations. Fruthermore, multiple diagrams can be opened at the same time and organized by means of tabs or in vertical or horizontal groups.

2.1 Schematic Diagrams

Schematic diagrams can be used to visualize the network model. Creating or updating an existing power grid model can be done graphically. A toolbox shows the symbolic representation of the various element classes, enabling the user to add selected elements to the diagram using drag and drop and then configure the new elements as required.

Grouping objects such as feeders, areas and owners can be used to group network components. They can be defined graphically and visualized in network diagrams.

2.1.1 Diagram Layout Tool

An alternative approach to creating or modifying networks graphically is to first create objects or a complete power grid in the *PowerFactory* Data Manager (either manually, via a script or via data import) and then subsequently draw these objects into one or more single line diagrams. This can be done automatically or assisted using the Diagram Layout Tool, a powerful tool for creating graphical representations of networks. In addition to generating a diagram for the entire grid, the Diagram Layout Tool offers the following options:

K-neighbourhood

With this option a new diagram will be created by starting from a selected element and extending the network representation as far as specified using the k-neighbourhood expansion, where the k-factor defines the degree of neighbourhood to be added to the diagram. This is a convenient tool if one needs to analyse just part of a network.

Feeder
The Diagram Layout Tool can automatically create schematic feeder diagrams. Feeder diagrams can help the user to better understand the topology of the network and show how the elements are supplied with power.

Detailed representation
This option creates a detailed diagram for a substations, branches, sites or terminal.

Area interchange
This option generates an interchange diagram, which shows the power flows between defined parts of the network. Interchange diagrams consist of customisable result boxes (the user can select which results to display) for those regions, and arrows showing power flows between the regions. The thickness of each power arrow indicate the relative size of the power interchange.

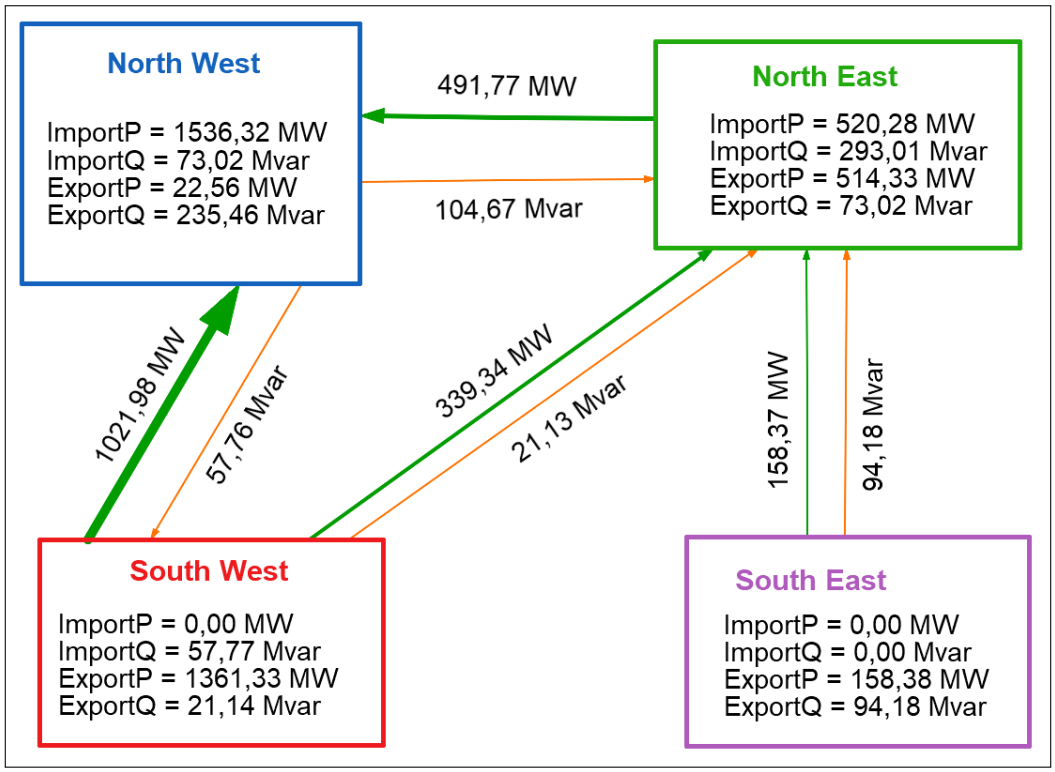
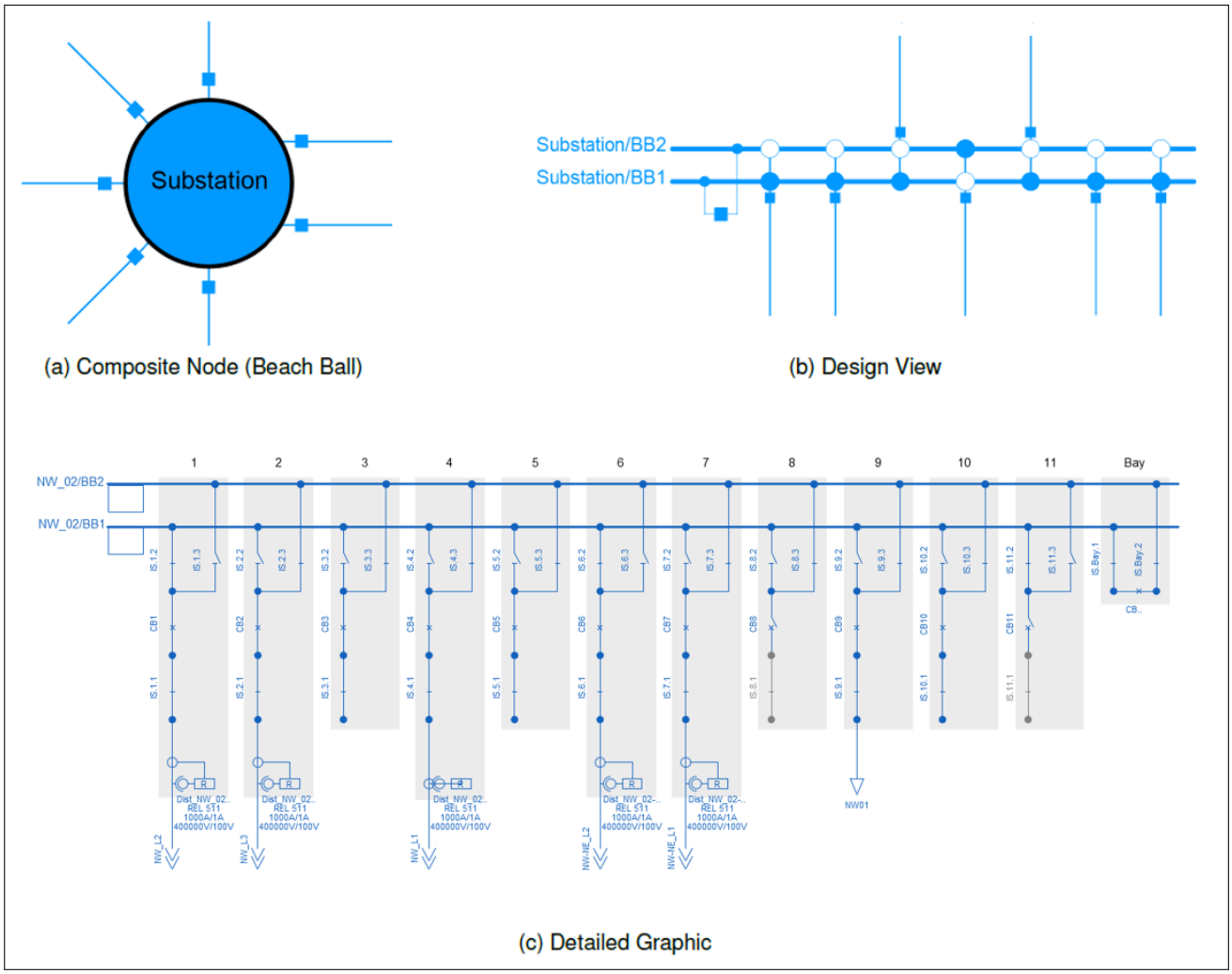


Figure 3: Area interchange diagram

2.1.2 Substations

PowerFactory offers three levels of detail for the graphical representation of substations from which the user can choose, as indicated in Figure 4.
(a) Composite Node - simplified representation; can be used for overview diagrams
(b) Design View - showing the connection of the bays to the busbar including the circuit breaker; switch actions such as busbar switchover can be performed graphically; this is the standard view
(c) Detailed Graphic - detailed representation of the bays showing all switches and additional elements such as relays and current transformers



(a) Composite Node (Beach Ball)

(b) Design View

(c) Detailed Graphic

Figure 4: Substation graphical representations

2.1.3 Graphical Symbols of Elements

The symbols used for the graphical representation of elements such as transformers, loads and generators can be changed. *PowerFactory* offers a number of symbols per element. Furthermore, the users can create their own symbols using the built-in symbol editor.

2.2 Geographical Diagrams

In *PowerFactory*, it is possible to specify GPS coordinates (latitude and longitude) of power equipment such as terminals and lines. If this data is available, the user can create a geographic diagram and a map can be displayed as a background as shown in Figure 1. *PowerFactory* supports the following map providers:

(a) OpenStreetMap (OSM), featuring free-of-charge mapnik-style maps
(b) Esri ArcGIS, including road maps, satellite, and hybrid maps
(c) Google Maps (requires Google Maps for Business account), including road maps, satellite/aerial, hybrid, and topographic maps
(d) Bing Maps, including road and satellite maps
(e) IGN Géoportail, including road maps, satellite and special maps
(f) Local map files, stored in plain text-files
(g) User-configured map services based on the standardised WMS/WMTS protocol

2.3 Colouring

It is possible to add an additional dimension of information to single line diagrams by using the colouring feature. Single line diagrams can be coloured for example according to the voltage level (schematic diagram in Figure 1), owner or grid (geographic diagram in Figure 1). Furthermore, it is also possible to colour the single line diagram according to calculation results, such as thermal loading and voltages for load flow calculations. The colouring can be enhanced by using a heatmap. It is also possible to define filters for individual colouring.

2.4 Graphical Tools and Features

PowerFactory supports various tools and features that facilitate working with single line diagrams such as:

(a) Switch markers to indicate for example tie open points and normally open switches

(b) Load and generation circles around substations - the size of the circle indicates the load and generation values

(c) Tool for measuring the distance between two or more locations in a geographic diagram

(d) Arrows to indicate the direction of the power flow

(e) Line width according to loading

3 Block Diagrams

Block Diagrams can be used to create dynamic models, for example for protection relays and control systems, using Composite Model Frames and either DSL (DIgSILENT Simulation Language) or Modelica.

3.1 Composite Model Frames

Composite Model Frames are diagrams that define the connections between dynamic models and network elements. They can be created graphically by using elements such as slots and signals from the drawing toolbox. A simple example for the high-level control system diagram of a synchronous generator is shown in Figure 5.

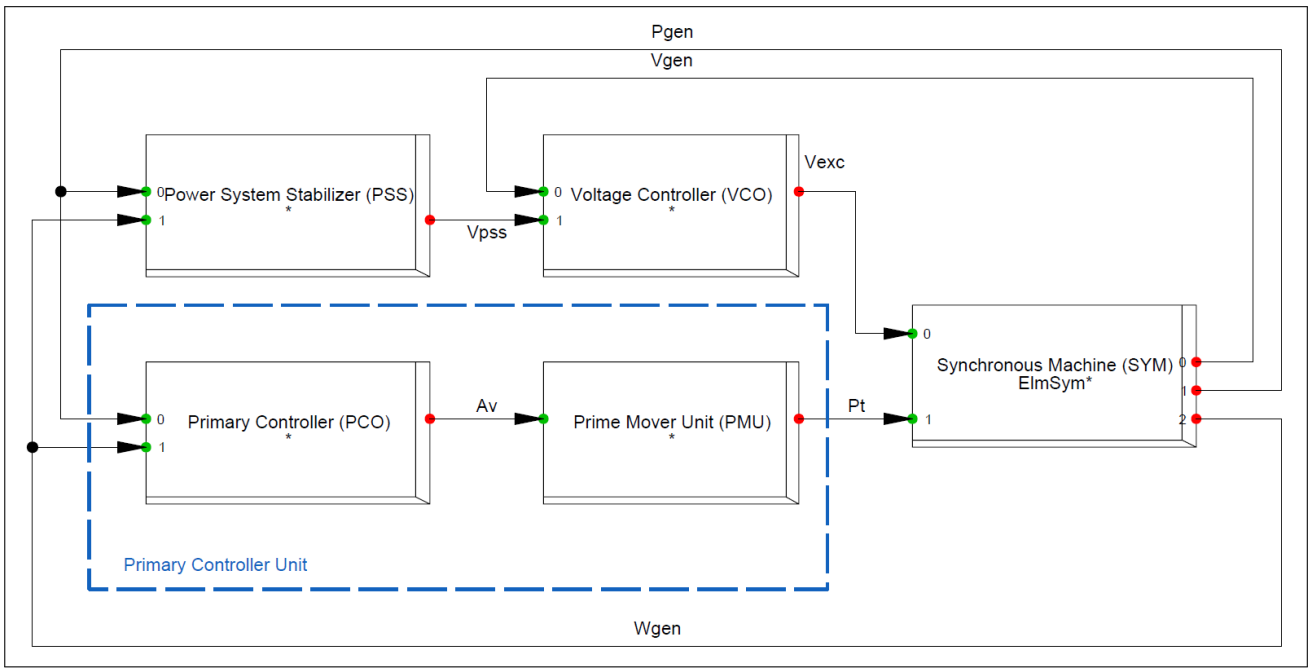


Figure 5: Example of a simple Composite Model Frame of the control system of a generator

3.2 DSL

Non-linear time-continuous control models can be created either text-based by entering DSL code or graphically using block diagrams. *PowerFactory* includes a large set of DSL macros useful for most common controller elements, e.g. PID-controllers and dead-bands.

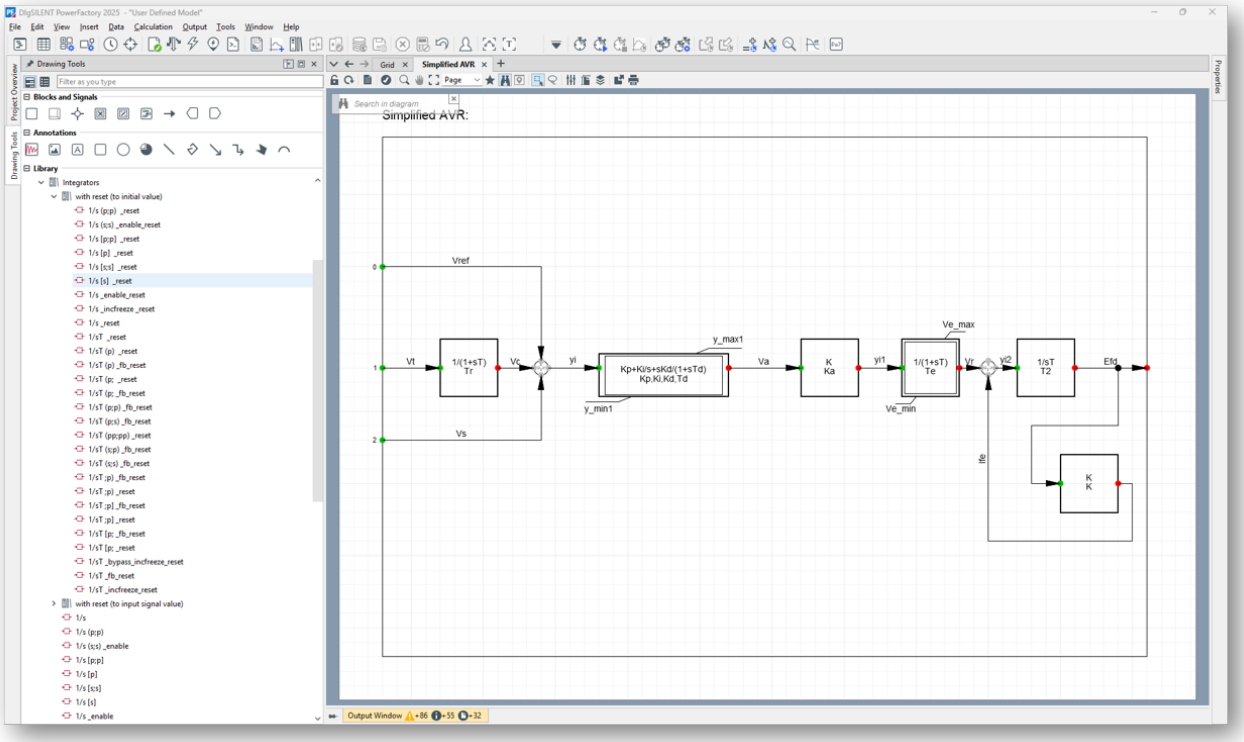


Figure 6: Example of a DSL model using block diagrams

3.3 Modelica

Modelica is an object-oriented language for modelling cyber-physical systems and is developed by the Modelica Association. In *PowerFactory*, time-continuous, time-discrete and hybrid systems can be modelled using Modelica either by entering the model's equations or by creating a block diagram.

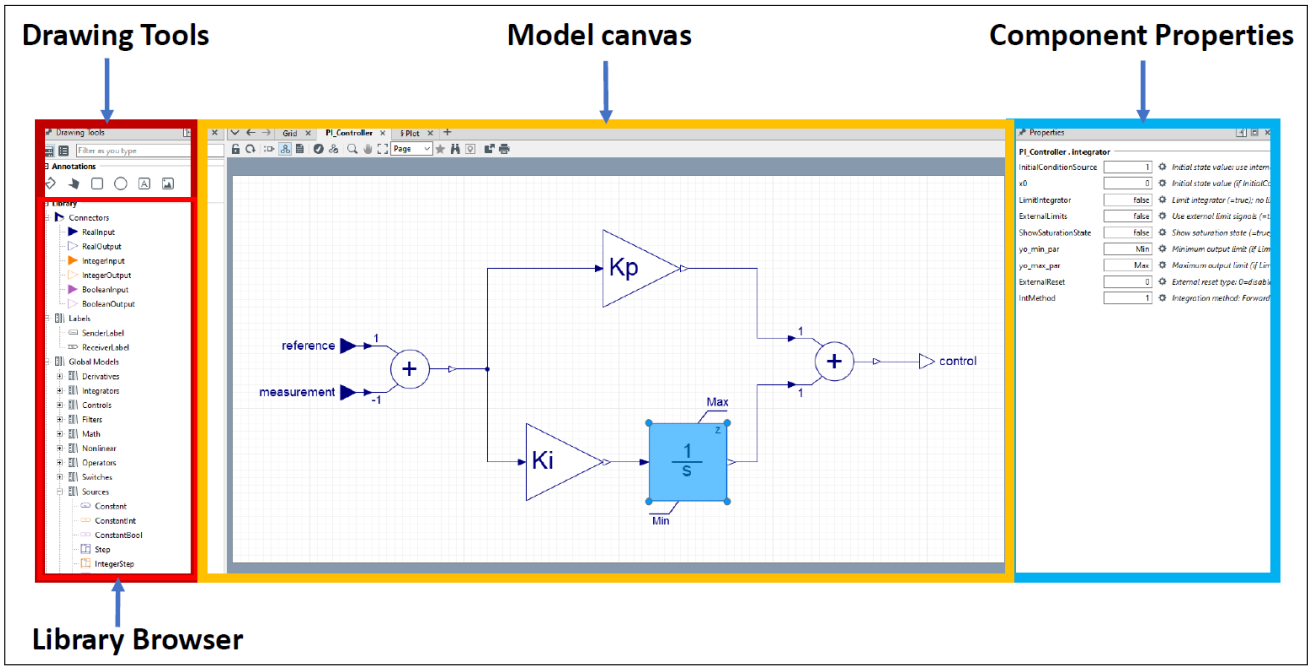


Figure 7: Overview of the Modelica models graphical environment

4 Executive Summary

PowerFactory includes a wide variety of tools for creating and visualising both the model of a power network using single line diagrams and dynamic models using block diagrams.

5 Licence Configuration

The functions described in this paper are all included in the Base Package. In order to test and use dynamic models, the Stability Analysis Functions (RMS) or Electromagnetic Transients (EMT) module is required. In order to test and use relays, the Time-Overcurrent Protection and/or Distance Protection modules are required.