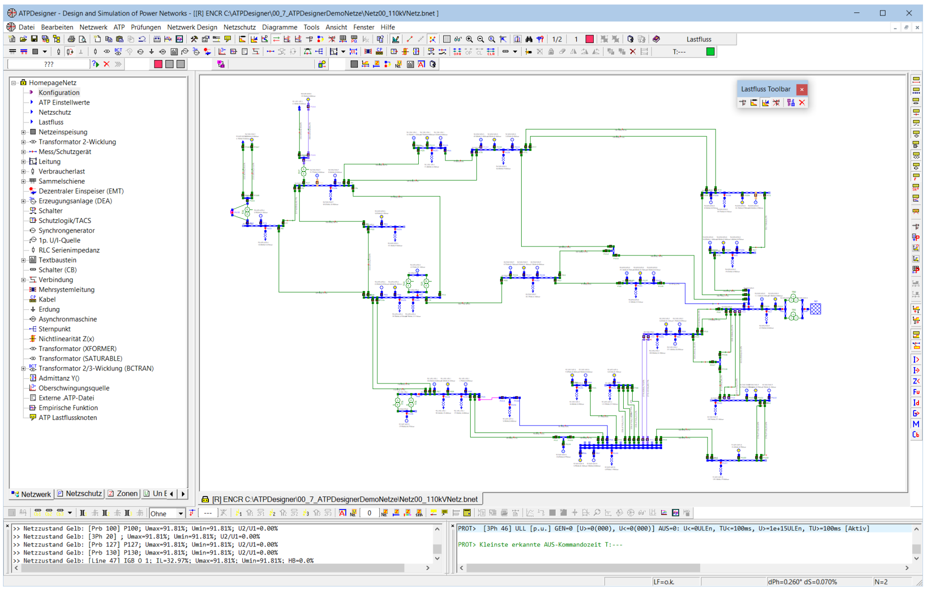
ATPDesigner
Design and Simulation of Electrical Power Networks
-
Quick Start Guide

Power Engineering Saar



Power Engineering Saar
Institute for Electrical Power Systems

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Content

1 About ATPDesigner

The grid calculation program ATPDesigner is a graphical user interface for the calculation of voltages, currents, powers and various mechanical parameters in power supply networks, which uses the grid calculation program ATP (**Alternative Transients Program**, www.eeug.org). The interface between ATPDesigner and ATP is established via text files. During the calculation, ATPDesigner generates an output file (.ATP file) that contains all the necessary data of the power supply network and can be calculated by ATP. Thus, it is not necessary to deal with the complex set of rules of the ATP grid calculation program. As a result, ATP delivers an .LST file (load flow results) and a diagram file (.PL4 file).

ATP is a worldwide used software tool for the calculation of especially 3-phase, electrical power supply networks. With the help of the ATPDesigner program as a graphical user interface, even complex and large electrical power supply networks (power grids) can be set up and calculated in a simple way. Detailed knowledge of the ATP-specific regulations is not required.

ATPDesigner contains all important electrical power supply equipment, such as transformers or lines, as templates. The physical properties of the equipment can be changed and thus adapted to the respective operating conditions. Due to the simple selection of the desired equipment and the simple connection options of the equipment to every other, even large electrical power supply networks can be quickly created and calculated. With the help of ATPDesigner, it is also possible to calculate network faults such as short circuits. The results, i.e. voltages, currents and active and reactive power, are displayed for the individual resources in tooltips or in the network graphic.

ATPDesigner can examine the power supply network with the ATP calculation kernel in its steady-state as well as in its transient behaviour. ATPDesigner is therefore particularly suitable for the analysis and evaluation of short circuits in power supply networks, but also for load flow calculation.

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1.1 Protection Relays in ATPDesigner

The grid calculation program ATPDesigner is especially suitable for the simulation of electricity grids of all voltage levels and the grid protection technology and decentralised generation systems used in them. The numerical models of protection functions implemented in ATPDesigner are generic, i.e. manufacturer-independent models.

- ⇨ Read more about Protection Relays in ATPDesigner

1.2 First Start of ATPDesigner – The Main Window

The chapter explains the first step if the setup has been successfully executed. If ATPDesigner starts automatically by the setup or by the user, the main window of ATPDesigner will be shown.

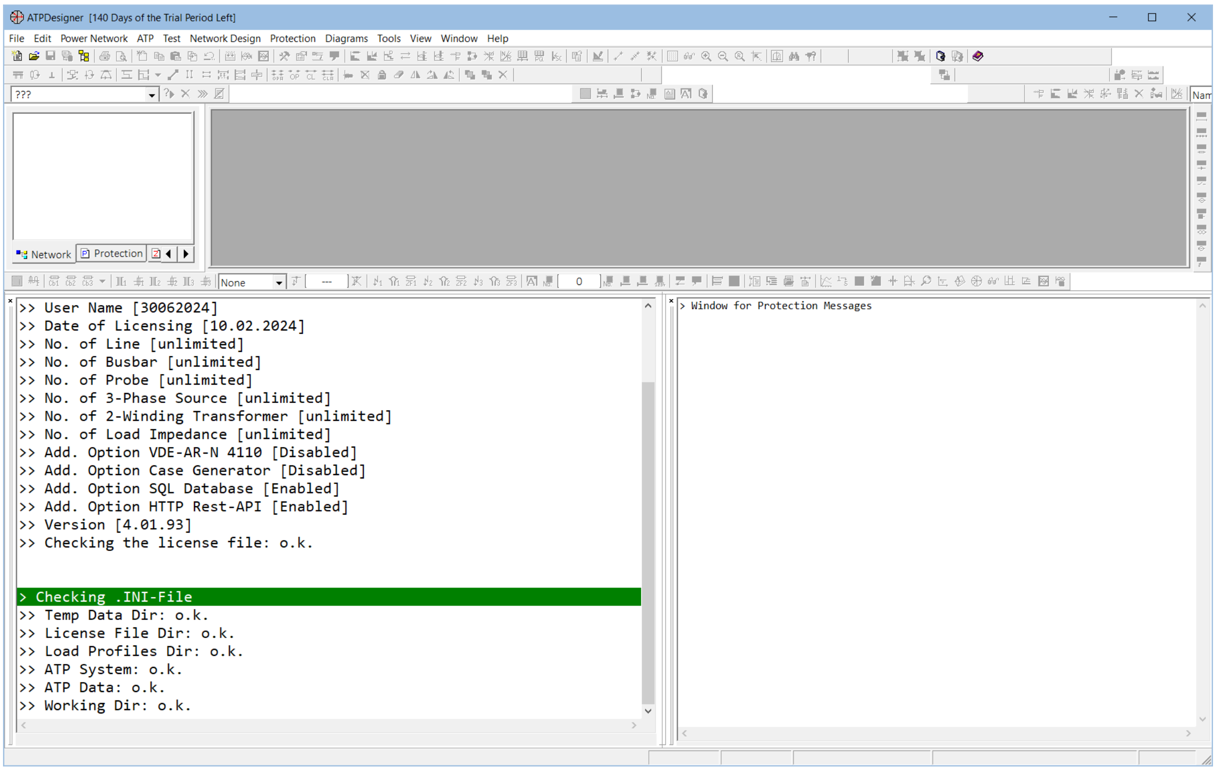


Figure 1: Main Window of ATPDesigner

ATPDesigner displays the user specific license information, which shall be checked.

- **User Name**
  If the username is a date e.g. 30062024 = ddmmyyyy, the license is time limited up to this date.

- Date of Licensing

The ATPDesigner license may have additional restrictions e.g. limitations acc. to the maximum number of power network elements.

- Number of lines
- Number of busbars
- Number of probes (measuring devices and protection relays)
- Number of 3-phase sources (e.g. decentralised generation systems)
- Number of 2-winding transformers
- Number of load impedances (e.g. consumer loads)

The next license information deals with calculation and modelling methods and algorithms and other additional options.

License Option	Description
VDE-AR-N 4110	Special features for decentralised generation systems acc. to German standards
Case Generator	Case generator for the generation of training data for AI systems (artifi-cial intelligence)

SQL Database	Using a SQL database to store results of the load flow calculation e.g. of the case generator
HTTP Rest-API	http-interface to control the ATPDesigner internal webserver using a Rest-API

⇨ The license data should be checked to ensure that all data are correct.

In the next step, the directories should be checked. If a directory exists during startup, the result **o.k.** will be shown.

Directories	Description
Temp Data Dir	Temporary directory of the windows operation system for saving temporary files and other data which can be deleted automatically

License File Dir	Directory of the license file **ATPDesignerReg.lic**
	
	If the setup has been successfully finalized, the license file has been automatically generated and stored in the folder c:\atpdesigner\exe. But nevertheless, the license file can be stored everywhere, if the license file directory has been set in the ATPDesigner settings dialog Program Settings or in the configuration file **ATPDesigner.ini**.
	
	`[ATPDesigner - Design and Simulation of Power Networks]`
	`VersionIniFile=Version INI File 4.2 - 02.08.2023`
	`VersionATPDesigner=Version 4.01.95 - 23.03.2024`
	`AtpDesignerFolder=C:\ATPDesigner\Exe`
	`AtpDataFolder=C:\ATPDesigner\Data`
	`CmEngineDllFolder=C:\`
	`AtpFolder=C:\ATPDesigner\AtpSystem`
	`AtpLoadProfilesFolder=C:\ATPDESIGNER\EXE\LoadProfiles`
	`AtpLicenseFileFolder=C:\ATPDESIGNER\EXE\`
	`AtpTempFolder=C:\Users\MICHAE~1\AppData\Local\Temp\`
	`AtpBrowserFolder=C:\ATPDesigner\Data`
	`AtpExeFilename=TPGIGI64.EXE`
	`GraphicViewerFilename=C:\ATPDesigner\AtpSystem\PLOTXY.EXE`
	`TxtEditorFilename=NOTEPAD.EXE`
	`TxtEditorFolder=C:\WINDOWS`
	
	If ATPDesigner is **NOT** running, the license directory can be changed by hand. ATPDesigner reads the configuration file during startup and writes the configuration file during shutdown.
	
	If an error is detected during licensing, a text file name **error.txt** is written to the directory c:\atpdesigner\exe.

Load Profiles Dir	Directory containing text files with load profiles to simulate a time dependent behaviour of consumer loads and decentralised generation systems
ATP System	Directory of the ATP (**A**lternative **T**ransients **P**rogram, www.eeug.org) executable software
ATP Data	Directory with sample files for the first steps with ATPDesigner
Working Dir	Default working directory of ATPDesigner The user can use any directory structure and locations to read and write the files used by ATPDesigner

⇨ The directories should be checked to ensure that all directories are available.

1.3 The *Program Settings* Dialog

The settings dialog **Program Settings** can be opened without displaying a power grid in the ATPDesigner view. The tab **Program Settings** of the settings dialog only contains settings, which are relevant for ATPDesigner itself and independent of the power grids shown in the view.

- Main Menu: **Tools**
- Menu Item: **Program Settings**

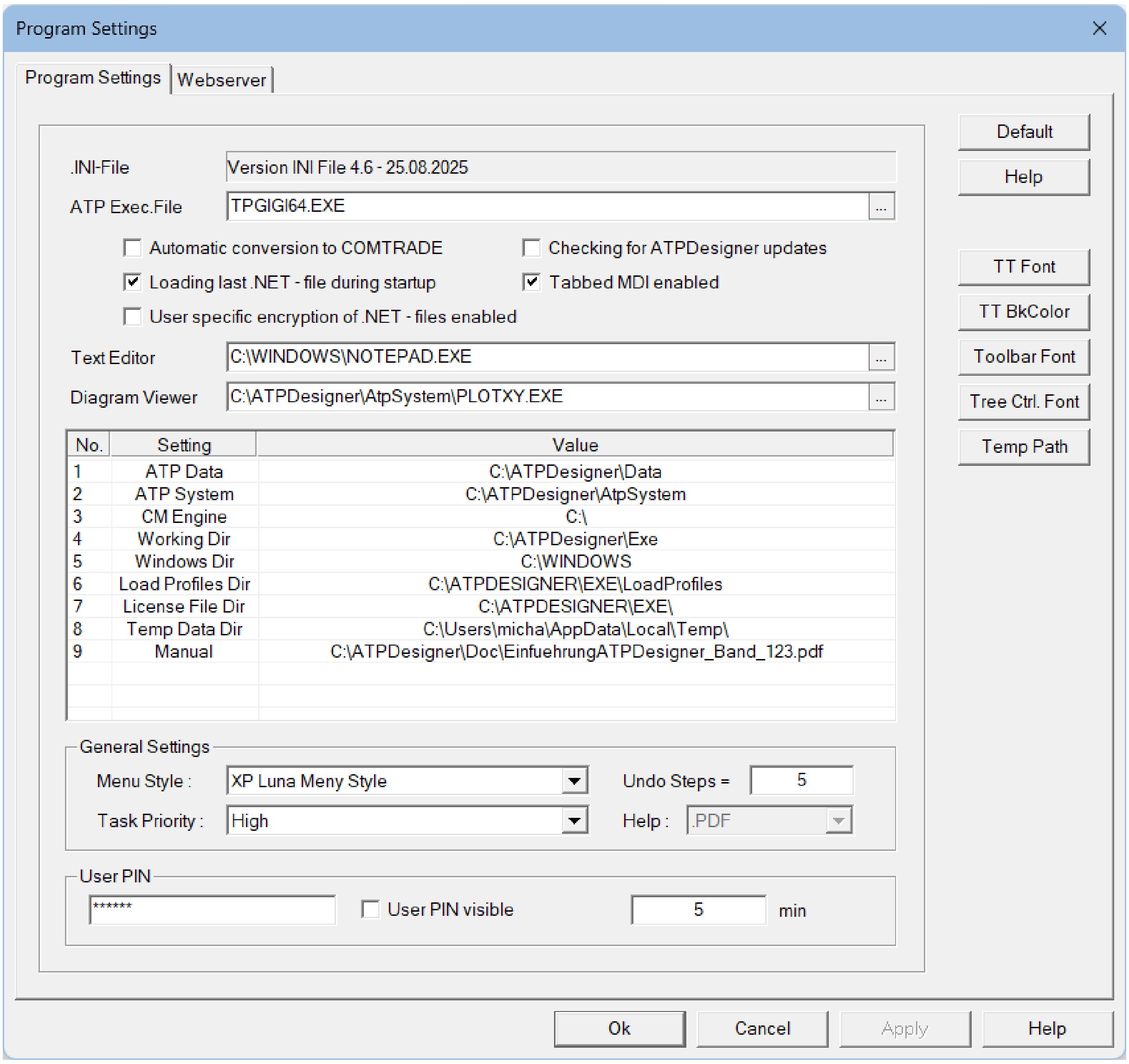


Figure 2: Settings Dialog *Program Settings*

Closing ATPDesigner the settings of the settings dialog **Program Settings** will be stored partly in a .INI-file called **ATPDesigner.ini** stored in the **Project Directory** and partly in the Windows registry.

Setting	Description
Loading Last .NET-file during startup	The filename of the .NET-file which are visible in the topmost view will be automatically opened and displayed, when ATPDesigner will be started again.
Tabbed MDI enabled	If enabled tab's will be used to organize the different power grids in the views.
TT Font	The font of the tooltips can be set, which are used to display results of the load flow calculation.

TT BkColor	The background color of the tooltips can be set, which are used to display results of the load flow calculation.
Toolbar Font	The font of the toolbar elements as part of the main frame can be selected.
Temp Path	The path of user specific Windows temporary directory can be loaded and displayed in line **8 Temp Data Dir** of the spread sheet. ATPDesigner uses the Windows temporary directory to save only temporary used files during the calculation processes. Only temporary used files will not be stored in the **Project Directory**.
Text Editor	The user can set a standard text editor which will be used to open text files. The text editor notepad++ (www.notepad-plus-plus.org) is recommended.
Diagram Viewer	The user can set a external diagram viewer.
ATP Exec. File	The filename of the ATP executable file e.g. tpgigi64.exe will be displayed and can be modified by hand, if the user takes this configuration itself. If the automatic configuration will be used, this line is disabled and empty.
User specific encryption of .NET - files enabled	ATPDesigner uses a Blowfish based algorithm to encrypt the .NET-files containing the power grid data, which is stored in the **Project Directory**. If required, the user can use a user specific password. **PLEASE CAUTION USING A USER SPECIFIC PASSWORD !!!** **If a user specific password will be used to encrypt the .NET-files, there is no possibility to decrypt such .NET-files if the user forgot his own encryption password. Caused by security reasons it is NOT possible to decrypt a user specific encrypted .NET-file by a backdoor. There is no backdoor available in ATPDesigner.**
Tree Ctrl Font	The user can choose a font for the **Project Information** tree controls on the left side of the ATPDesigner main view.

In addition, settings are available in the spread sheet. These settings can be changed by a **Left Mouse Button Double Click** on the cell of the column **value**.

No.	Setting	Description
1	**ATP Data**	Default directory (c:\ATPDesigner\Data) where ATPDesigner reads and saves .NET-files containing the power grid data.
2	**ATP System**	Directory where the ATP executable file (e.g. tpgigi64.exe) is stored. If automatic configuration is selected, the Windows temporary directory will be used. If the user takes his own configuration the directory must be set, where the ATP executable file has been stored by the user.
3	**CM Engine**	Directory where the CM Engine driver must be stored The CM Engine driver will be used to use Omicron test systems e.g. CMC 356.
4	**Working Dir**	Directory where the executable program **ATPDesigner.exe** and **ATPDesigner_DE.exe** with all DLL are stored.
5	**Windows Dir**	Directory of the Windows operating system
6	**Load Profiles Dir**	Directory where the .CSV-files containing the load profiles according VDEW [8] and BDEW [10] as well as the user specific load profiles are stored
7	**License File Dir**	Directory where the license file **ATPDesignerLic.ini** is stored During startup ATPDesigner reads first the .INI-file **ATPDesigner.ini**. After that ATPDesigner reads the license file **ATPDesignerLic.ini** using the directory **License File Dir**.

8	**Temp Data Dir**	The Windows temporary directory can easily be determined by a **Left Mouse Button Click** on the button **Temp Path**.

2 System Information and Data of ATPDesigner

2.1 Default Directory created by the Setup Software

The setup software creates as default the directories and the directory structure shown below if ATPDesigner has been installed successfully.

Directoy	Description
..\atpdesigner	Root directory
..\atpdesigner\exe	Directory containing the executable files of the English and German version of ATPDesigner, configuration file **ATPDesigner.ini**, license file ATPDesignerLic.ini and required DLL's ▪ ATPDesigner in German: **ATPDesigner_DE.exe** ▪ ATPDesigner in English: **ATPDesigner.exe** DLL's ▪ libcrypto-1_1-x64.dll ▪ libcrypto-3-x64.dll ▪ libssl-1_1-x64.dll ▪ libssl-3-x64.dll ▪ msvcr120.dll ▪ mysqlcppconn-9-vs14.dll If the test equipment of Omicron e.g. CMC356 will be used, an additional file must be stored in the directory. ▪ CMEngAL.tlb
..\atpdesigner\Fuse	Directory containing the tripping characteristic files of fuses
..\atpdesigner\LoadProfiles	Directory containing the load profile files e.g. the 15min based time depended characteristic of consumer loads or photovoltaic power systems ▪ LoadProfile_AL0_S.csv ▪ LoadProfile_AL0_U.csv ▪ LoadProfile_AL0_W.csv ▪ LoadProfile_AL1_S.csv ▪ LoadProfile_AL1_U.csv ▪ LoadProfile_AL1_W.csv ▪ LoadProfile_EM0_S.csv ▪ LoadProfile_EM0_U.csv ▪ LoadProfile_EM0_W.csv ▪ LoadProfile_EM1_S.csv ▪ LoadProfile_EM1_U.csv ▪ LoadProfile_EM1_W.csv ▪ LoadProfile_EM2_S.csv ▪ LoadProfile_EM2_U.csv ▪ LoadProfile_EM2_W.csv ▪ LoadProfile_G0_S.csv ▪ LoadProfile_G0_U.csv ▪ LoadProfile_G0_W.csv ▪ LoadProfile_G1_S.csv ▪ LoadProfile_G1_U.csv ▪ LoadProfile_G1_W.csv ▪ LoadProfile_G2_S.csv ▪ LoadProfile_G2_U.csv ▪ LoadProfile_G2_W.csv

	▪ LoadProfile_G3_S.csv ▪ LoadProfile_G3_U.csv ▪ LoadProfile_G3_W.csv ▪ LoadProfile_G4_S.csv ▪ LoadProfile_G4_U.csv ▪ LoadProfile_G4_W.csv ▪ LoadProfile_G5_S.csv ▪ LoadProfile_G5_U.csv ▪ LoadProfile_G5_W.csv ▪ LoadProfile_G6_S.csv ▪ LoadProfile_G6_U.csv ▪ LoadProfile_G6_W.csv ▪ LoadProfile_H0_S.csv ▪ LoadProfile_H0_U.csv ▪ LoadProfile_H0_W.csv ▪ LoadProfile_L0_S.csv ▪ LoadProfile_L0_U.csv ▪ LoadProfile_L0_W.csv ▪ LoadProfile_L1_S.csv ▪ LoadProfile_L1_U.csv ▪ LoadProfile_L1_W.csv ▪ LoadProfile_L2_S.csv ▪ LoadProfile_L2_U.csv ▪ LoadProfile_L2_W.csv ▪ LoadProfile_PV_S.CSV ▪ LoadProfile_PV_U.CSV ▪ LoadProfile_PV_W.CSV
..\atpdesigner\Doc	Directory containing documents e.g. the manual in German language, an older help file written in English etc.
..\atpdesigner\AtpSystem	Directory containing the executable files of the ATP (**A**lternative **T**ransients **P**rogram) and the startup file of the ATP
..\atpdesigner\Project	The directory contains the default structure of the **Project Directory** used by ATPDesigner The name "project" of the directory can be used user specific. The names of the sub directories are used by ATPDesigner depending of the calculation methods implemented in ATPDesigner and cannot be changed.
..\atpdesigner\Data	Directory containing the power supply network example (.BNET-files) and examples for reports **Examples of Reports** ▪ 20220606195005309_Netz02_20kVUMZstat_PROT.xml ▪ 20220606195005452_Netz02_20kVUMZstat_LF.xml ▪ 20230430213546722_Netz18_20kVNetzNetzschutzTemplateV4_LF.xml ▪ 20240210084202402_Netz11_SimBench3_400V_laendlich_LF.XML ▪ 20240210084632074_Netz11_SimBench3_400V_laendlich_LF.XML ▪ 20240210084909587_Netz11_SimBench3_400V_laendlich_LF.XML **Examples of Power supply networks** ▪ Netz01_20kVMitWindpark.bnet ▪ Netz02_20kVUMZstat.bnet ▪ Netz03_20kVUMZdyn.bnet ▪ Netz04_20kVUMZdynMitDEA.bnet ▪ Netz05_20kVMitEMobil.bnet ▪ Netz06_20kVFlexAnalyse.bnet ▪ Netz07_20kVMessungUdiffdyn.bnet ▪ Netz08_20kVTrafoDiffSchutzPDIFF.bnet ▪ Netz09_SimBench1_400V_laendlich.bnet

	▪ Netz10_SimBench2_400V_laendlich.bnet ▪ Netz11_SimBench3_400V_laendlich.bnet ▪ Netz12_SimBench4_400V_halbstaedtisch.bnet ▪ Netz13_SimBench5_400V_halbstaedtisch.bnet ▪ Netz14_400VMitPVAnlage.bnet ▪ Netz15_Netz20kVErdschlussdyn.bnet ▪ Netz16_110kVNetzMitNetzschutzUndDEA.bnet ▪ Netz17_20kVNetzDistanzschutzUndHHSicherungen.bnet ▪ Netz18_20kVNetzNetzschutzTemplateV4.bnet ▪ Netz19_20kVLtgTrafoDiffSchutzPDIFF.bnet

2.2 ATPDesigner in German and English

Two executable files ATPDesigner.exe and ATPDesigner_DE.exe are available in the directory ..\atpdesigner\exe.

- ATPDesigner in German: **ATPDesigner_DE.exe**
- ATPDesigner in English: **ATPDesigner.exe**

3 Open a Power Network File – the .BNET-File of ATPDesigner

ATPDesigner stores all data and further information in one file, so called .BNET-file. The data in the .BNET file are encrypted. Older software versions only use .NET files with unencrypted data. The current software version of ATPDesigner can read and save .NET files and .BNET files. It is recommended to use only encrypted .BNET-files.

⇨ It is possible to use user-specific encryption keys. **It should be noted that there is no backdoor for decryption if the user-specific key is lost.**

If license data and directories have been successfully checked, the following information will be displayed after loading a power network .BNET-file.

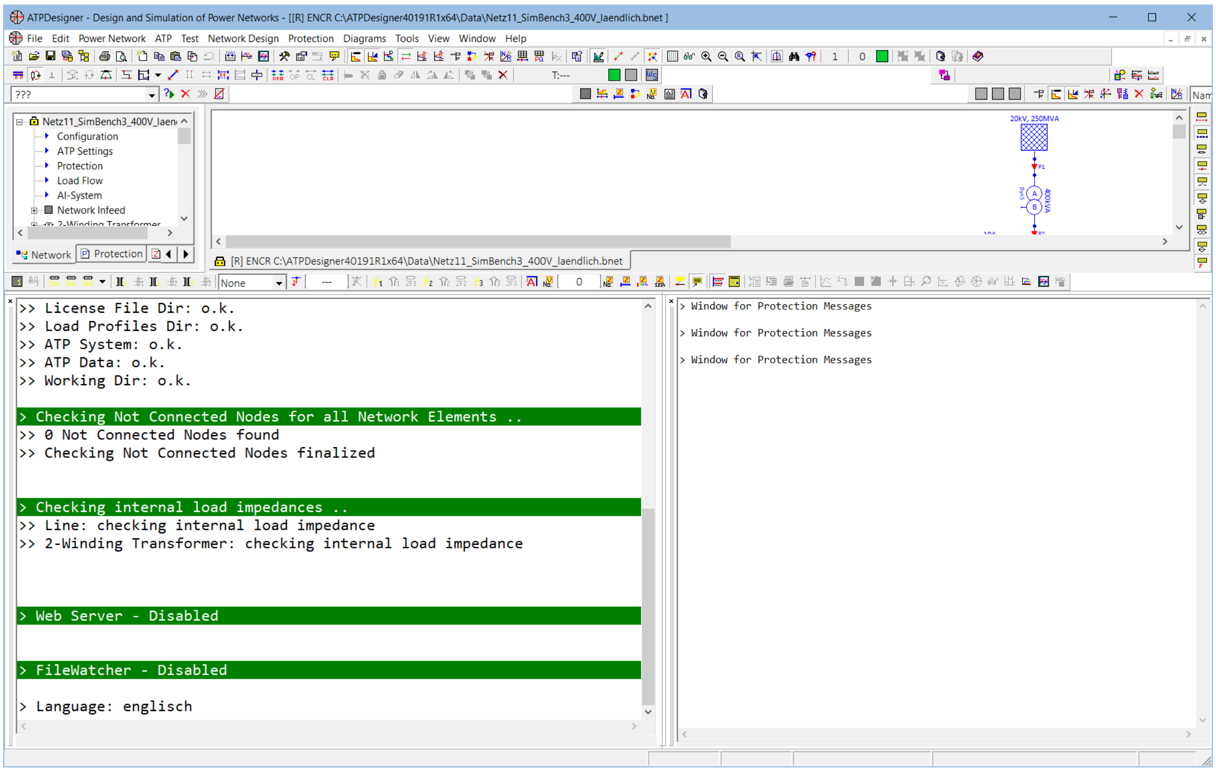


Figure 3: License Data and Directories in the *Messages Window*

The following steps explain how to open a power network .BNET-file.

- Open the main menu **File**
- Click on the menu item **Open ..** or **Ctrl + O** or open a .BNET-file with Drag&Drop from the file explorer

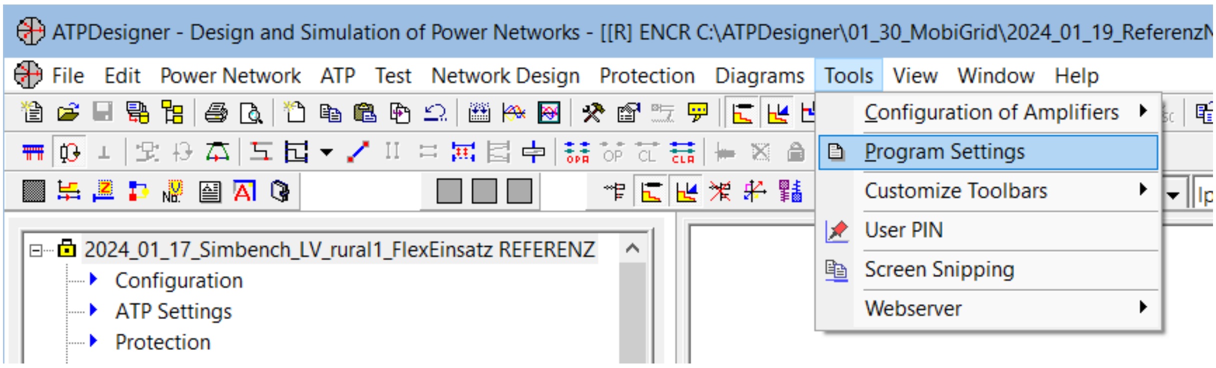
- Check if: 0 not connected nodes found.
- Check if: internal load impedance of line and 2-winding transformer are o.k.
- Check if: the web server is disabled.
- Check if: the file watcher is disabled.
- Check if: the language is English.

Now ATPDesigner is ready to be used for power network design and simulation.

4 ATPDesigner Program Settings Dialog *Program Settings*

Global settings, which are defined independent of power network related settings can be managed in the settings dialog **Program Settings**.

- Main menu **Tools**
- Menu item **Program Settings**



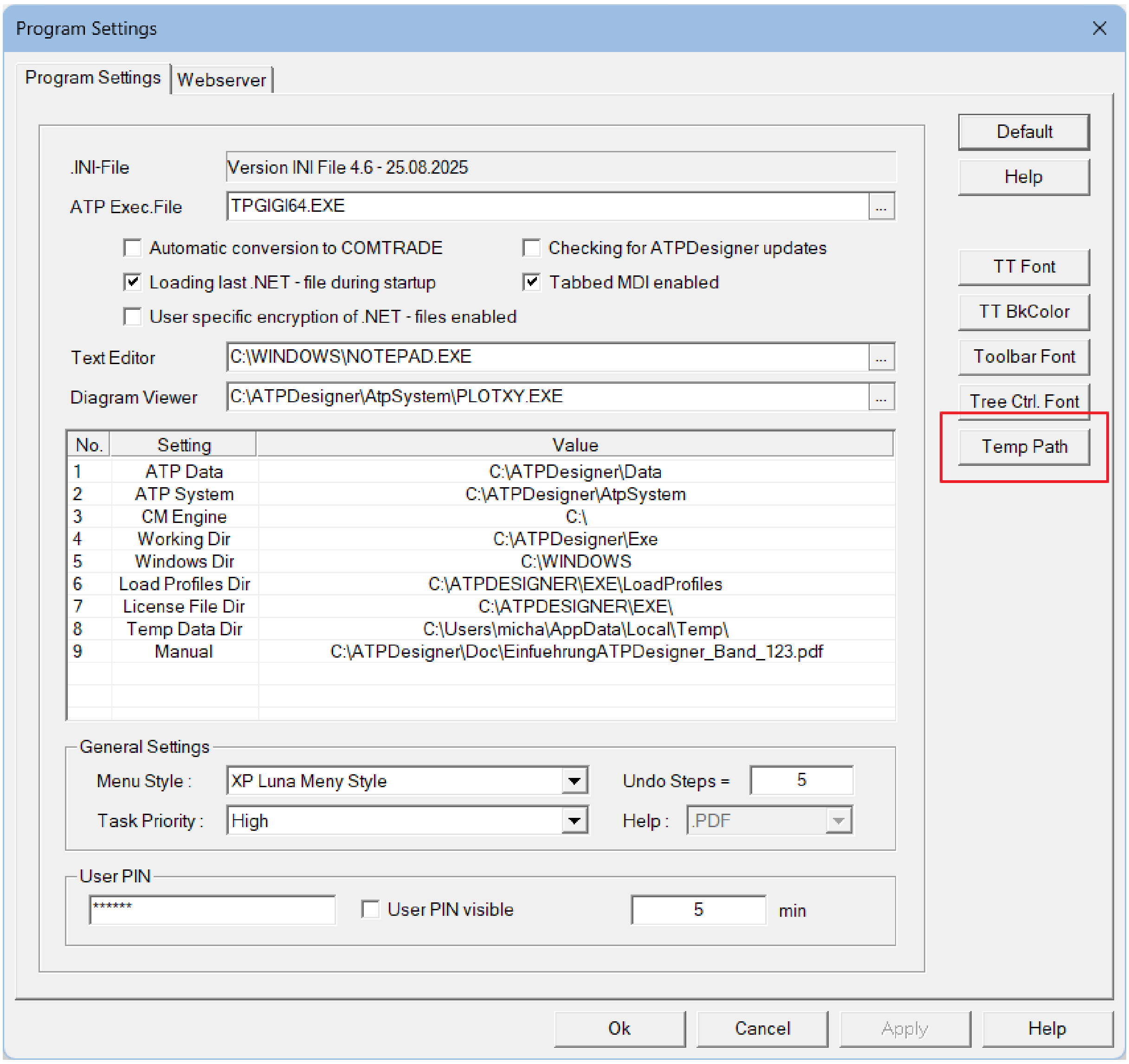


Figure 4: Settings Dialog *Program Settings*

The most important setting is the name of the temporary data directory **Temp Data Dir**. If this path is not existing power network calculations e.g. load flow calculations are not possible. With a left mouse button click on the button **Temp Path** the temporary data directory of the windows operation system can be updated easily.

- Open the settings dialog **Program Settings**
- Check if all directories are o.k.
- Update the directory of the temporary data directory of the windows operation system if necessary.

5 Start a Load Flow Calculation with ATPDesigner

A network calculation program is generally understood to be a software that enables the calculation of electrical quantities such as voltages, currents and active and reactive power in electrical power networks of all voltage levels and any topologies. The basis of the network calculation are numerical models that are derived from the physical properties of the equipment used in electricity networks, e.g. transformers or lines. For the calculation of dynamic network processes, models based on generally linear differential equations of higher order are used, which are numerically solved by integration methods. The results are time dependent curves of the physical quantities such as v(t).

If the aspect of network dynamics is dispensed with, it is sufficient to use a **load flow calculation** or extended load flow calculation with short-circuits. Starting from a physically steady-state network condition (i.e. all dynamic network processes have completely decayed), voltages, currents, etc. can be calculated at any network nodes against reference potential (usually earth) or between any two network nodes as complex pointers with the help of e.g. node potential analysis. The complex phasors indicate either the magnitude (e.g. in V or A) and the absolute phase angle in degrees or real and imaginary parts in the sense of a complex phasor. One prerequisite for a load flow calculation is a constant power network frequency, which does not necessarily have to be the nominal frequency.

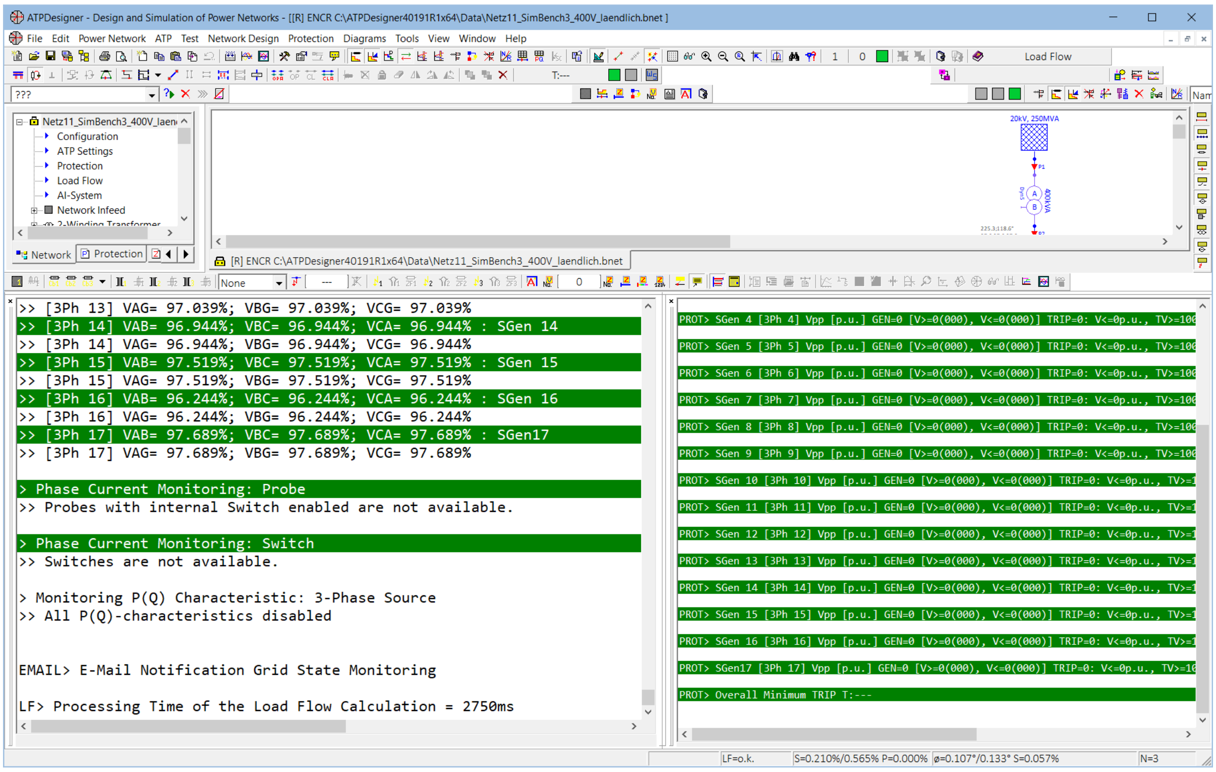
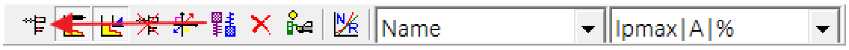


Figure 5: Load flow calculation – Displaying results in the Messages Windows

The figure above shows how ATPDesigner displays results of the **Load Flow Calculation** in messages windows: one messages window for general messages and results of the load flow calculation, a second messages window only to display the results of the **Protection Relays**. The **Load Flow Calculation** can be started with or without a short-circuit and/or protection relays as explained below.

- Main menu **ATP**
- Menu item **Short-Circuit Results** or **Ctrl + E** or using the toolbar button in the toolbar.



⇨ Caused by the history of ATPDesigner the menu item is not called **Load Flow Calculation** but **Short-Circuit Results**

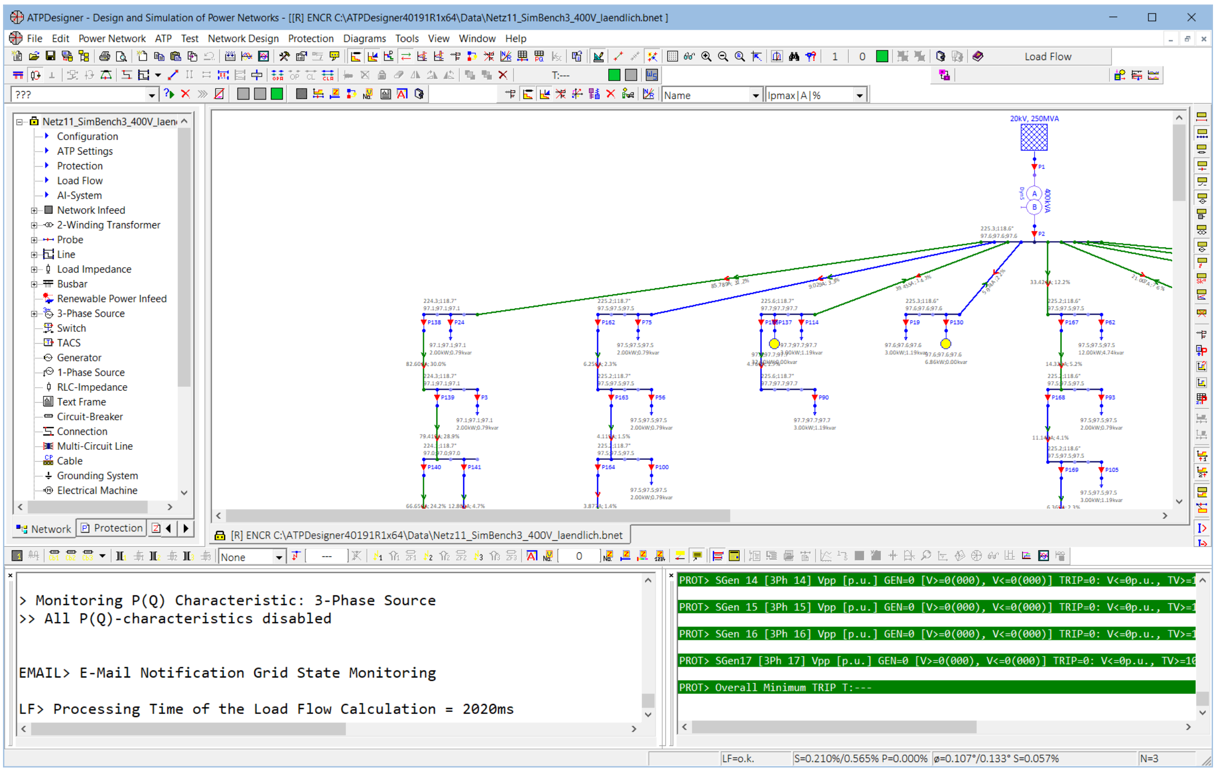


Figure 6: Load Flow Calculation (Short-Circuit Results) – Displayed in Power Network Graphic

As shown in then figure above, the main important results of the **Load Flow Calculation** (**Short-Circuit Results**) will also be displayed in the power network graphic.

Toolbar	Description
	Start the Load Flow Calculation (Short-Circuit Results)
	▪ If enabled, ATPDesigner uses an iteration algorithm as part of the load flow calculation to iterate the internal impedance Z=R+jX acc. the settings of the active and reactive power of consumer loads (network element **Load Impedance**) ▪ If disabled, the internal impedance Z=R+jX will be set to the initial values and will not be iterated by the load flow calculation algorithm **Fehler! Es ist nicht möglich, durch die Bearbeitung von Feldfunktionen Objekte zu erstellen.** ⇨ This option should be disabled if a short-circuit will be used during the load flow calculation.

	▪ If enabled, ATPDesigner uses an iteration algorithm as part of the load flow calculation to iterate the internal model of the network element **3-Phase Source** based on a current source, in order to achieve the setting values such as active power and reactive power. ⇨ This option must be enabled if a short-circuit is to be used in the load flow calculation.

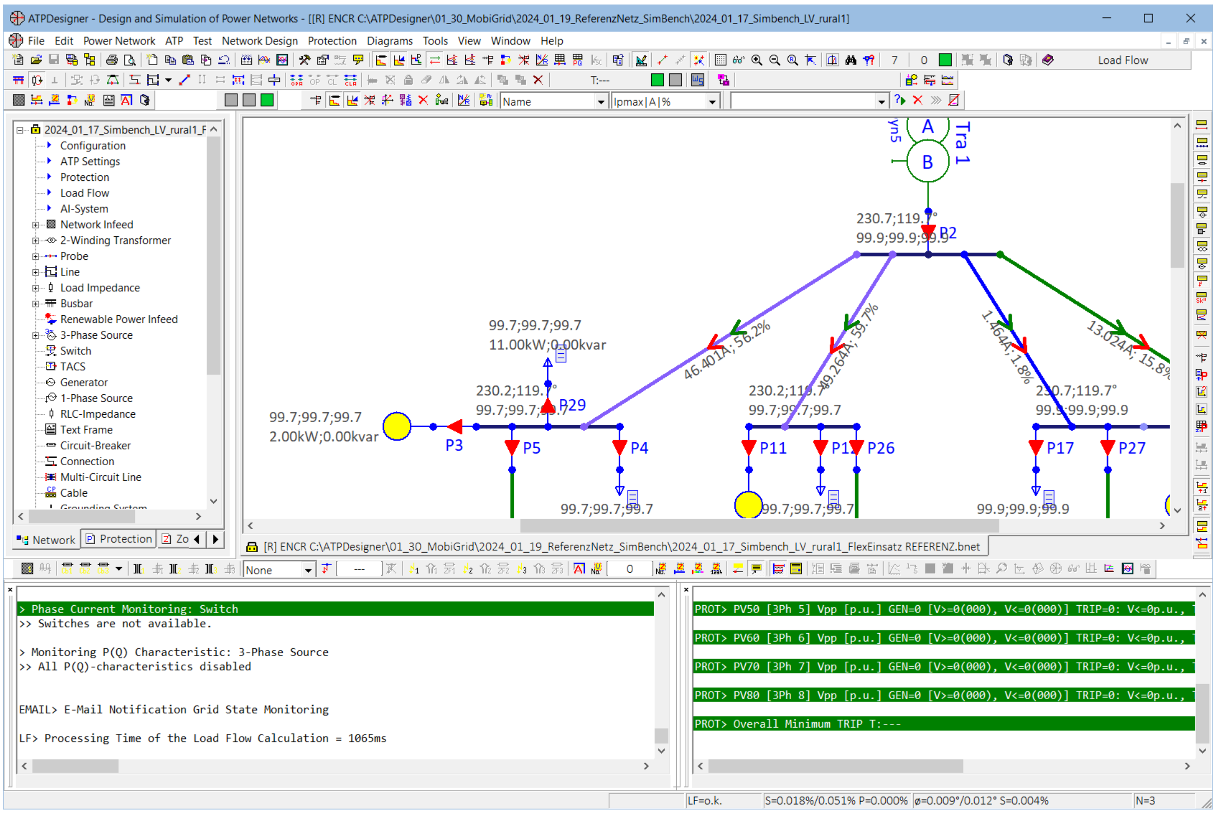


Figure 7: Load Flow Calculation (Short-Circuit Results) – Results in the Power Network

The results of the load flow calculation can be copied out of the **Messages Window**.

- Left mouse button click on the messages window.
- Ctrl + A to mark all lines in messages window.
- Ctrl + C to copy all marked lines into the clipboard.

```
> Checking the Grid State (green, amber, red) ...
>> Grid State: Grid Health fN (Line) = 100.0%
>> Grid State: Grid Health fN (Busbar) = 100.0%
>> Grid State: Grid Health fN = 100.0%
>> Grid State: Green


> Voltage Monitoring: Busbar
>> [Bb 1] VAB= 99.895%; VBC= 99.895%; VCA= 99.895% : -1-
>> [Bb 1] VAG= 99.895%; VBG= 99.895%; VCG= 99.895% : -1-
>> [Bb 1] Vpg,Vpp min= 99.895%; Vpg,Vpp max= 99.895%
>> [Bb 3] VAB= 99.662%; VBC= 99.662%; VCA= 99.662% : -3-
>> [Bb 3] VAG= 99.662%; VBG= 99.662%; VCG= 99.662% : -3-
>> [Bb 3] Vpg,Vpp min= 99.662%; Vpg,Vpp max= 99.662%
>> [Bb 4] VAB= 99.883%; VBC= 99.883%; VCA= 99.883% : -4-
>> [Bb 4] VAG= 99.883%; VBG= 99.883%; VCG= 99.883% : -4-
>> [Bb 4] Vpg,Vpp min= 99.883%; Vpg,Vpp max= 99.883%
>> [Bb 5] VAB= 99.740%; VBC= 99.740%; VCA= 99.740% : -5-
>> [Bb 5] VAG= 99.740%; VBG= 99.740%; VCG= 99.740% : -5-
>> [Bb 5] Vpg,Vpp min= 99.740%; Vpg,Vpp max= 99.740%
```

```
>> [Bb 2] VAB= 99.668%; VBC= 99.668%; VCA= 99.668% : -2-
>> [Bb 2] VAG= 99.668%; VBG= 99.668%; VCG= 99.668% : -2-
>> [Bb 2] Vpg,Vpp min= 99.668%; Vpg,Vpp max= 99.668%
>> [Bb 6] VAB= 99.614%; VBC= 99.614%; VCA= 99.614% : -6-
>> [Bb 6] VAG= 99.614%; VBG= 99.614%; VCG= 99.614% : -6-
>> [Bb 6] Vpg,Vpp min= 99.614%; Vpg,Vpp max= 99.614%
>> [Bb 7] VAB= 99.654%; VBC= 99.654%; VCA= 99.654% : -7-
>> [Bb 7] VAG= 99.654%; VBG= 99.654%; VCG= 99.654% : -7-
>> [Bb 7] Vpg,Vpp min= 99.654%; Vpg,Vpp max= 99.654%
>> [Bb 8] VAB= 99.962%; VBC= 99.962%; VCA= 99.962% : -8-
>> [Bb 8] VAG= 99.962%; VBG= 99.962%; VCG= 99.962% : -8-
>> [Bb 8] Vpg,Vpp min= 99.962%; Vpg,Vpp max= 99.962%
>> [Bb 10] VAB= 99.603%; VBC= 99.603%; VCA= 99.603% : -10-
>> [Bb 10] VAG= 99.603%; VBG= 99.603%; VCG= 99.603% : -10-
>> [Bb 10] Vpg,Vpp min= 99.603%; Vpg,Vpp max= 99.603%
>> [Bb 11] VAB= 99.552%; VBC= 99.552%; VCA= 99.552% : -11-
>> [Bb 11] VAG= 99.552%; VBG= 99.552%; VCG= 99.552% : -11-
>> [Bb 11] Vpg,Vpp min= 99.552%; Vpg,Vpp max= 99.552%
>> [Bb 12] VAB=100.056%; VBC=100.056%; VCA=100.056% : -12-
>> [Bb 12] VAG=100.056%; VBG=100.056%; VCG=100.056% : -12-
>> [Bb 12] Vpg,Vpp min=100.056%; Vpg,Vpp max=100.056%
>> [Bb 9] VAB= 99.487%; VBC= 99.487%; VCA= 99.487% : -9-
>> [Bb 9] VAG= 99.487%; VBG= 99.487%; VCG= 99.487% : -9-
>> [Bb 9] Vpg,Vpp min= 99.487%; Vpg,Vpp max= 99.487%
>> [Bb 13] VAB= 99.656%; VBC= 99.656%; VCA= 99.656% : -13-
>> [Bb 13] VAG= 99.656%; VBG= 99.656%; VCG= 99.656% : -13-
>> [Bb 13] Vpg,Vpp min= 99.656%; Vpg,Vpp max= 99.656%
>> [Bb 14] VAB= 99.489%; VBC= 99.489%; VCA= 99.489% : -14-
>> [Bb 14] VAG= 99.489%; VBG= 99.489%; VCG= 99.489% : -14-
>> [Bb 14] Vpg,Vpp min= 99.489%; Vpg,Vpp max= 99.489%
>> [Bb 15] VAB= 99.999%; VBC= 99.999%; VCA= 99.999% : -15-
>> [Bb 15] VAG= 99.999%; VBG= 99.999%; VCG= 99.999% : -15-
>> [Bb 15] Vpg,Vpp min= 99.999%; Vpg,Vpp max= 99.999%

> Voltage Monitoring: 3-Phase Source
>> [3Ph 3] VAB= 99.668%; VBC= 99.668%; VCA= 99.668% : PV30
>> [3Ph 3] VAG= 99.668%; VBG= 99.668%; VCG= 99.668%
>> [3Ph 4] VAB= 99.662%; VBC= 99.662%; VCA= 99.662% : PV40
>> [3Ph 4] VAG= 99.662%; VBG= 99.662%; VCG= 99.662%
>> [3Ph 1] VAB= 99.883%; VBC= 99.883%; VCA= 99.883% : PV10
>> [3Ph 1] VAG= 99.883%; VBG= 99.883%; VCG= 99.883%
>> [3Ph 2] VAB= 99.740%; VBC= 99.740%; VCA= 99.740% : PV20
>> [3Ph 2] VAG= 99.740%; VBG= 99.740%; VCG= 99.740%
>> [3Ph 5] VAB= 99.614%; VBC= 99.614%; VCA= 99.614% : PV50
>> [3Ph 5] VAG= 99.614%; VBG= 99.614%; VCG= 99.614%
>> [3Ph 6] VAB=100.056%; VBC=100.056%; VCA=100.056% : PV60
>> [3Ph 6] VAG=100.056%; VBG=100.056%; VCG=100.056%
>> [3Ph 7] VAB= 99.656%; VBC= 99.656%; VCA= 99.656% : PV70
>> [3Ph 7] VAG= 99.656%; VBG= 99.656%; VCG= 99.656%
>> [3Ph 8] VAB= 99.489%; VBC= 99.489%; VCA= 99.489% : PV80
>> [3Ph 8] VAG= 99.489%; VBG= 99.489%; VCG= 99.489%

> Phase Current Monitoring: Probe
>> Probes with internal Switch enabled are not available.

> Phase Current Monitoring: Switch
>> Switches are not available.

> Monitoring P(Q) Characteristic: 3-Phase Source
>> All P(Q)-characteristics disabled

EMAIL> E-Mail Notification Grid State Monitoring
LF> Processing Time of the Load Flow Calculation = 919ms
```

The example below shows how to use a 1-phase-to-ground fault at a line and the presentation of the results of the load flow calculation in the power network graphic.

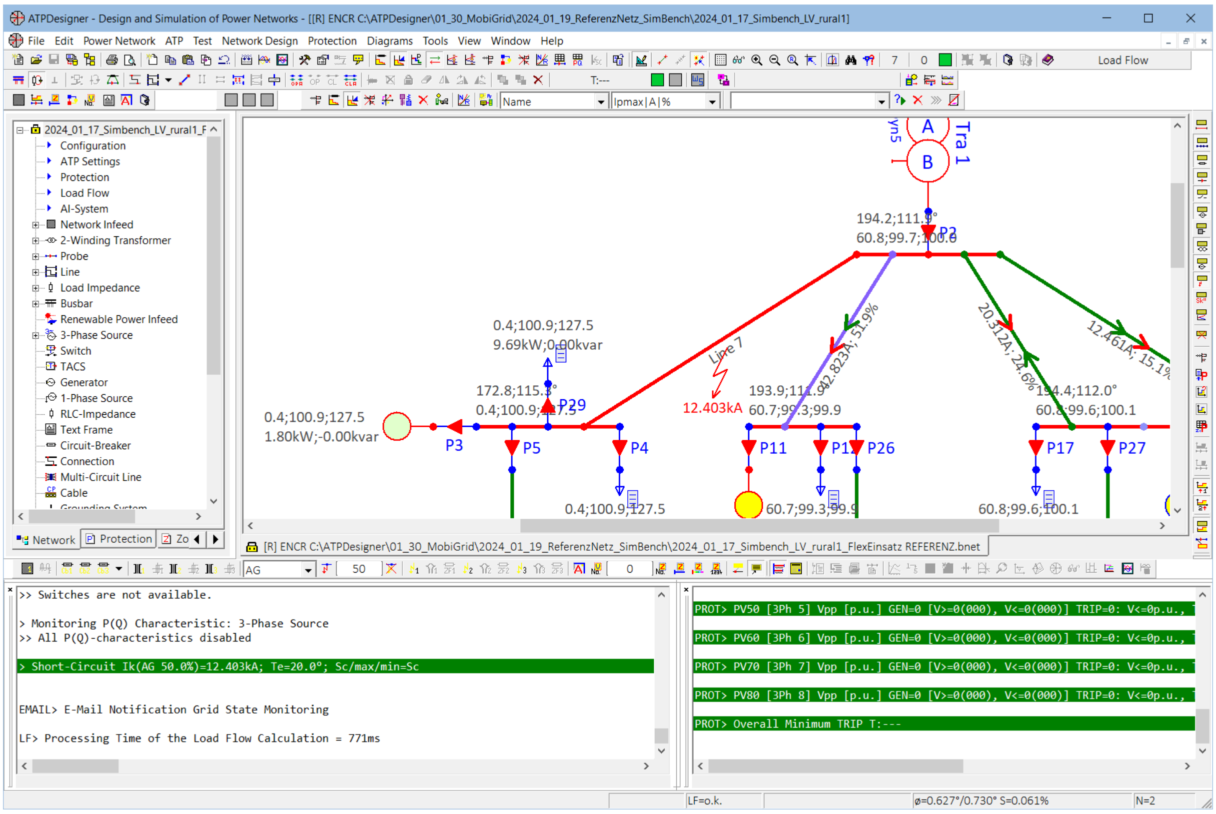


Figure 8: Load Flow Calculation with Short-Circuit – Results displayed in the Power Network

6 Reports of the Load Flow Calculation

ATPDesigner also writes reports for every load flow calculation stored in the **Project Directory** where the .BNET-file is also stored. The file format of the reports is the Office Open XML format (ECMA-376 Office Open XML File Formats, ISO/IEC 29500 Information technology – Office Open XML formats).

The file name format (**LF** = load flow calculation):

- 20240324105406244_2024_01_17_Simbench_LV_rural1_FlexEinsatz REFERENZ_**LF**.xml

The following figures illustrate examples from the **Load Flow Calculation Report**, which can be opened using standard word processing software.

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Load Flow Calculation

24.03.2024, 10:54:05.335
C:\ATPDesigner\01_30_MobiGrid\2024_01_19_ReferenzNetz_SimBench\2024_01_17_Simbench_LV_rural1_FlexEinsatz REFERENZ.bnet
ATPDesigner Version 4.01.95 - 23.03.2024
Version NET File 6.3 - 22.01.2021

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Identifiers and Descriptions

VAG, VBG, VCG [V], [%]	Amount of the phase-to-ground voltages in V and %Vn/√3
VAB, VBC, VCA [V], [%]	Amount of the phase-to-phase voltages in V and %Vn
Vmin, Vmax [V], [%]	Amount of the minimum and maximum phase-to-ground and phase-to-phase voltage VABC in V and %Vnom
Vpp, Vpg [V], [%]	Amount of the phase-to-phase voltages VAB, VBC, VCA in V and %Vn Amount of the phase-to-ground voltages VAG, VBG, VCG in V and %Vn/√3
IA, IB, IC [A], [%]	Amount of the phase currents in A and %In
V1, V2, V0 [V], [%]	Amount of the positive-, negative- and zero-sequence voltage in V and %Vn/√3
I1, I2, I0 [A], [%]	Amount of the positive-, negative- and zero-sequence current in A and %In
Ipmax [A], [%]	Amount of the maximum phase current IABC in A und %In
Maximum Load [%]	Amount of the maximum phase current IABC in %In
S [VA]	Amount of the apparent power in VA
P [W]	Amount of the active power in W
Q [var]	Amount of the reactive power in var
CosPhi	Displacement factor cos phi = P / S
Load [%]	Load of winding A and B in %In
SA, SB, SC [VA]	Single-phase apparent power of phase A, B and C in VA
PA, PB, PC [W]	Single-phase active power of phase A, B and C in W
QA, QB, QC [var]	Single-phase reactive power of phase A, B and C in var
NA	Need for Action
Ipmax [%]	Maximum phase current IABC in %Inom
fN [%]	Grid Health in %
m [p.u.]	Load Level acc. VDE 0276
LF	State of Load Flow Calculation: o.k.=1, failed=0, stopped=2, invalid=-1
TRIP	Grid Protection: TRIP-Command - 0=disabled, 1=enabled
GEN	Grid Protection: General starting - 0=disabled, 1=enabled
DSZ	Grid Protection: Distance zone of the distance protection with TRIP
R1k	Grid Protection: Resistance of the short-circuit impedance of the positive sequence system
X1k	Grid Protection: Reactance of the short-circuit impedance of the positive sequence system
DST	Daylight Saving Time: Summer = S, Winter = W

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[Bb 8] -8-	0.4	99.96	99.96	99.96	90% - 110%	0	Green
[Bb 10] -10-	0.4	99.60	99.60	99.60	90% - 110%	0	Green
[Bb 11] -11-	0.4	99.55	99.55	99.55	90% - 110%	0	Green
[Bb 12] -12-	0.4	100.06	100.06	100.06	90% - 110%	0	Green
[Bb 9] -9-	0.4	99.49	99.49	99.49	90% - 110%	0	Green
[Bb 13] -13-	0.4	99.66	99.66	99.66	90% - 110%	0	Green
[Bb 14] -14-	0.4	99.49	99.49	99.49	90% - 110%	0	Green
[Bb 15] -15-	20.0	100.00	100.00	100.00	90% - 110%	0	Green

Name	Vnom [kV]	V1 [%]	V2 [%]	V0 [%]	phiV1 [°]	phiV2 [°]	phiV0 [°]	State
[Bb 1] -1-	0.4	99.89	0.00	0.00	119.70	165.52	66.87	Green
[Bb 3] -3-	0.4	99.66	0.00	0.00	119.67	159.05	46.51	Green
[Bb 4] -4-	0.4	99.88	0.00	0.00	119.69	149.16	35.78	Green
[Bb 5] -5-	0.4	99.74	0.00	0.00	119.66	157.64	31.37	Green
[Bb 2] -2-	0.4	99.67	0.00	0.00	119.68	143.39	14.18	Green
[Bb 6] -6-	0.4	99.61	0.00	0.00	119.68	135.93	8.92	Green
[Bb 7] -7-	0.4	99.65	0.00	0.00	119.67	159.50	46.33	Green
[Bb 8] -8-	0.4	99.96	0.00	0.00	119.71	141.05	29.22	Green
[Bb 10] -10-	0.4	99.60	0.00	0.00	119.68	132.54	5.71	Green
[Bb 11] -11-	0.4	99.55	0.00	0.00	119.66	151.38	35.33	Green
[Bb 12] -12-	0.4	100.06	0.00	0.00	119.73	132.24	25.71	Green
[Bb 9] -9-	0.4	99.49	0.00	0.00	119.67	137.38	22.68	Green
[Bb 13] -13-	0.4	99.66	0.00	0.00	119.70	126.28	3.44	Green
[Bb 14] -14-	0.4	99.49	0.00	0.00	119.67	135.40	22.80	Green
[Bb 15] -15-	20.0	100.00	0.00	0.00	-90.00	9.34	170.65	Green

Classification of Busbar Voltages

Classes	Vpp	Vpg	V1
<=90%	0	0	0
]90% - 92%]	0	0	0
]92% - 94%]	0	0	0
]94% - 96%]	0	0	0
]96% - 98%]	0	0	0
]98% - 100%]	14	14	14
]100% - 102%]	1	1	1
]102% - 104%]	0	0	0
]104% - 106%]	0	0	0
]106% - 108%]	0	0	0
]108% - 110%]	0	0	0
>110%	0	0	0

Voltage Monitoring: 3-Phase Source

Name	Vnom [kV]	VAB [%]	VBC [%]	VCA [%]	V<> [%]	State
[3Ph 3] PV30	0.4	99.67	99.67	99.67	V<=0%; V>=1e+17%	Green
[3Ph 4] PV40	0.4	99.66	99.66	99.66	V<=0%; V>=1e+17%	Green
[3Ph 1] PV10	0.4	99.88	99.88	99.88	V<=0%; V>=1e+17%	Green
[3Ph 2] PV20	0.4	99.74	99.74	99.74	V<=0%; V>=1e+17%	Green
[3Ph 5] PV50	0.4	99.61	99.61	99.61	V<=0%; V>=1e+17%	Green
[3Ph 6] PV60	0.4	100.06	100.06	100.06	V<=0%; V>=1e+17%	Green
[3Ph 7] PV70	0.4	99.66	99.66	99.66	V<=0%; V>=1e+17%	Green
[3Ph 8] PV80	0.4	99.49	99.49	99.49	V<=0%; V>=1e+17%	Green

Name	Vnom [kV]	VAG [%]	VBG [%]	VCG [%]	V<> [%]	State
[3Ph 3] PV30	0.4	99.67	99.67	99.67	V<=0%; V>=1e+17%	Green
[3Ph 4] PV40	0.4	99.66	99.66	99.66	V<=0%; V>=1e+17%	Green

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[3Ph 1] PV10	0.4	99.88	99.88	99.88	V<=0%; V>=1e+17%	Green
[3Ph 2] PV20	0.4	99.74	99.74	99.74	V<=0%; V>=1e+17%	Green
[3Ph 5] PV50	0.4	99.61	99.61	99.61	V<=0%; V>=1e+17%	Green
[3Ph 6] PV60	0.4	100.06	100.06	100.06	V<=0%; V>=1e+17%	Green
[3Ph 7] PV70	0.4	99.66	99.66	99.66	V<=0%; V>=1e+17%	Green
[3Ph 8] PV80	0.4	99.49	99.49	99.49	V<=0%; V>=1e+17%	Green

Power Infeed: 3-Phase Source

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi
[3Ph 3] PV30	0.002000	0.002000	0.000000	1.000
[3Ph 4] PV40	0.002000	0.002000	0.000000	1.000
[3Ph 1] PV10	0.002000	0.002000	0.000000	1.000
[3Ph 2] PV20	0.002000	0.002000	0.000000	1.000
[3Ph 5] PV50	0.002000	0.002000	0.000000	1.000
[3Ph 6] PV60	0.019000	0.019000	0.000000	1.000
[3Ph 7] PV70	0.019000	0.019000	0.000000	1.000
[3Ph 8] PV80	0.019000	0.019000	0.000000	1.000

Power Infeed: Load Impedance

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi
[Load 1] EM1	0.011001	0.011001	0.000000	1.000
[Load 2] EM2	0.011002	0.011002	0.000000	1.000
[Load 3] EM3	0.011003	0.011003	-0.000000	1.000
[Load 4] EM4	0.011000	0.011000	0.000000	1.000
[Load 5] EM5	0.010999	0.010999	0.000000	1.000
[Load 6] WP6	0.011001	0.010781	0.002189	0.980
[Load 7] WP7	0.011001	0.010781	0.002189	0.980
[Load 8] WP8	0.011001	0.010781	0.002189	0.980
[Load 9] WP9	0.011006	0.010785	0.002190	0.980
[Load 11] WP11	0.011002	0.010782	0.002189	0.980
[Load 12] WP12	0.011002	0.010782	0.002189	0.980
[Load 13] BS13	0.011006	0.011006	-0.000000	1.000
[Load 14] BS14	0.011000	0.011000	0.000000	1.000

Power Infeed: 2-Winding Transformer

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi

Power Infeed: Line

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi

Voltage Monitoring: Probe

Name	Vnom [kV]	VAB [%]	VBC [%]	VCA [%]	State
[Prb 1] P1	20.0	99.9986	99.9986	99.9986	Green
[Prb 2] P2	0.4	99.895	99.895	99.895	Green
[Prb 3] P3	0.4	99.6677	99.6677	99.6677	Green
[Prb 4] P4	0.4	99.6677	99.6677	99.6677	Green
[Prb 6] P6	0.4	99.7395	99.7395	99.7395	Green

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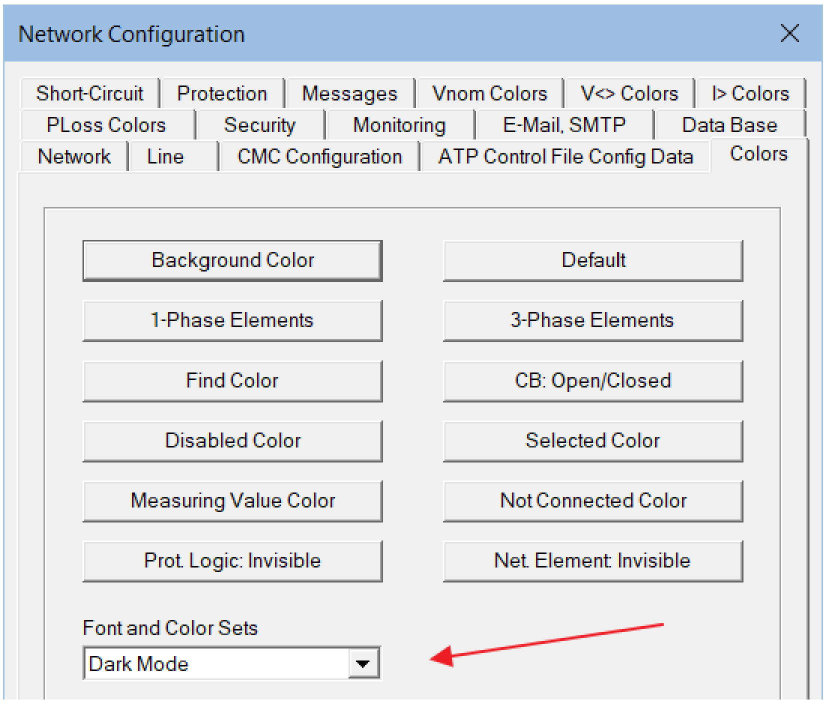
Figure 9: Report of Load Flow Calculation (Office Open XML Format)

7 ATPDesigner and Dark Mode

The power network graphic and the messages windows can be displayed in **Dark Mode**.

- Main menu **Power Network**
- Menu item **Network Configuration**
- Tab **Colors**



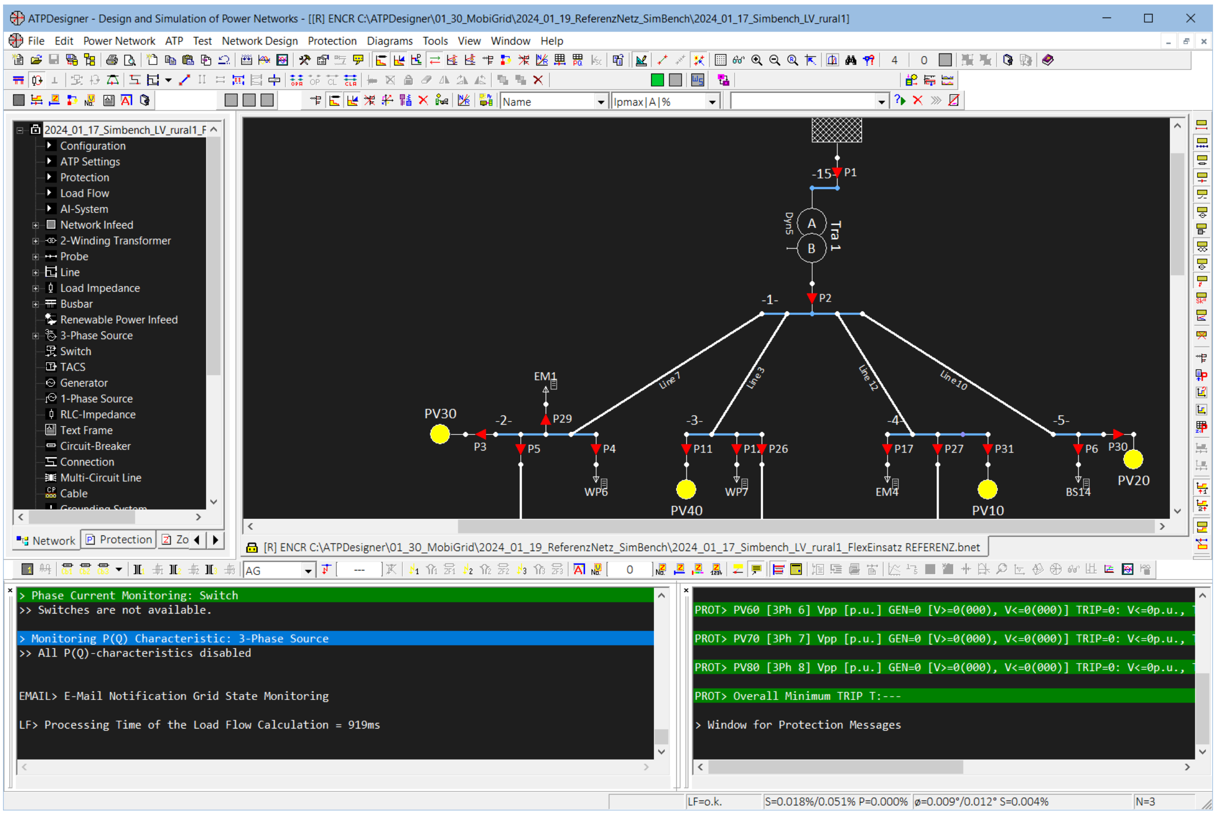


Figure 10: ATPDesigner Dark Mode Interface

8 ATPDesigner User Interface

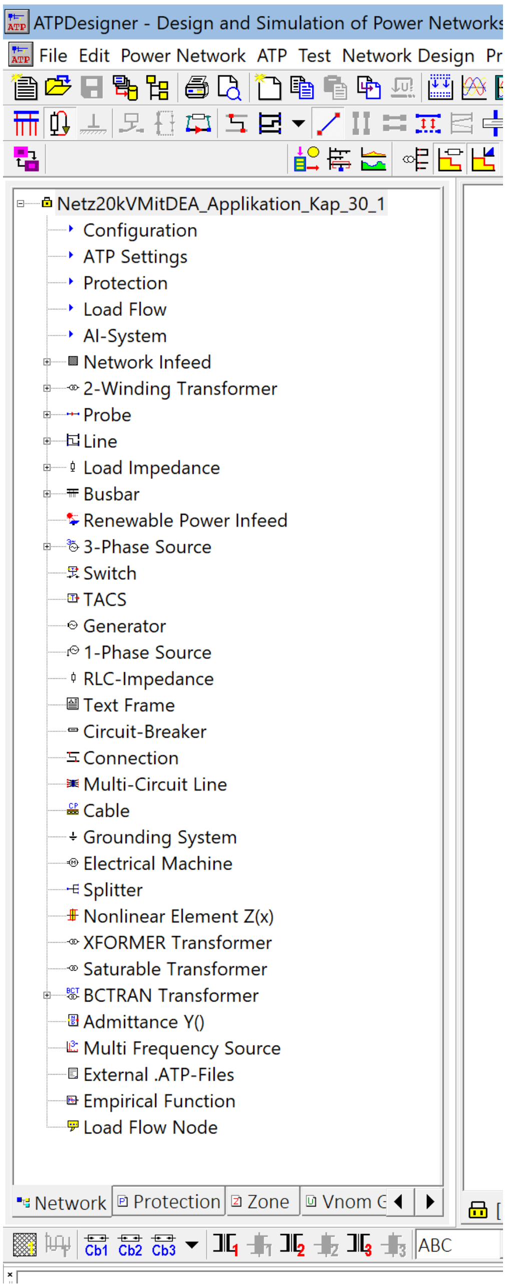
The concept and the implementation of the user interface of ATPDesigner is driven by the rules to design an intuitive user interface, which is designed for windows operating systems.

8.1 How to open a Settings Dialog

A settings dialog of a network element can be opened with a **Left Mouse Button Double Click** on the shape[3] of the network element in the power network graphic.

8.2 How to Insert a new Network Element in the Power Network by *Drag&Drop*

The easiest way to insert a new network element is Drag&Drop the network element from the **Network** tab shown below.



- Select a network element e.g. **Load Impedance** with a **Left Mouse Button Click** on the name of the network element, the name shall be high-lighted.
- Press the left mouse bottom and move the mouse cursor to a position in the network graphic.
- Release the left mouse button.

Figure 11: *Network* Tab – *Drag&Drop* a Network Element into the Network Graphic

8.3 How to Move a Network Element in the Power Network

It will be explained below, how to move a network element which is part of a power network. The first step is always to select one or more network elements by **Left Mouse Button Click(s)** on the shape of the network element.

8.3.1 Moving only one Network Element

1. Select the network element by a **Left Mouse Button Click**
   The network element will be drawn in **grey** if selected.

2. Move the mouse cursor over the shape of the network element

3. Press the left mouse button, keep it pressed and move the network element to another position

4. Release the left mouse button

8.3.2 Moving two or more Network Elements

Two or more network elements can be selected by several methods.

The first method is to select network elements by two or more **Left Mouse Button Click** on the shape of the network elements. The selection can be removed by a **Left Mouse Button Click** on the empty area of the network graphic.

The second method uses a “rubber band” frame to select two or more network elements.

1. Open a frame to select network elements by pressing the left mouse button and keep the left mouse button pressed

2. Move the mouse cursor and select all network elements of interest
   If a network element has been fully enclosed by the frame, it will be drawn in **grey**.

3. Release the left mouse button

8.3.3 Moving the Power Grid

The whole power grid can be moved using the mouse.

1. Press the **Shift** key and hold it down

2. Click on the **Left Mouse Button** and hold it down, release the **Shift** key
   The power grid will be bordered by a frame.

3. Move the frame of the power grid to another position using the mouse

4. Release the left mouse button

8.4 How to Rotate a Network Element

It will be explained below, how to rotate a network element which is part of a power network. The first step is always to select but only one network elements by **Left Mouse Button Click** on the shape of the network element. It is important to know, that only one network element stand-alone can be rotate.

1. Select one network element by a **Left Mouse Button Click** on its shape

2. Disconnect the selected network element from all other network elements

3. Rotate the network element

    a. Using the **Right Mouse Button Menu**: **Rotate 180°**, **Rotate 90° Clockwise**, **Rotate 90° Invers**

    b. Using the toolbar 

    c. Using the keys **l** (**l**eft) and **r** (**r**ight)

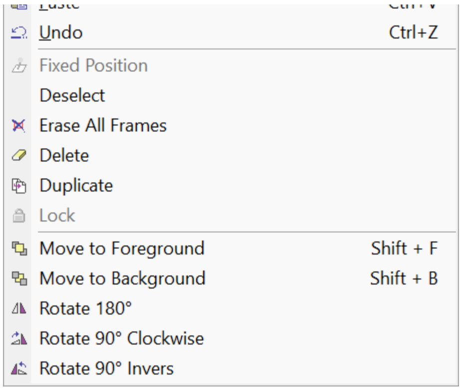


Figure 12: Right Mouse Button Menu (partly) – Menu items to rotate a network element

The figure below shows the message box with the error message, if the network element to be rotated always is connected to other network elements.

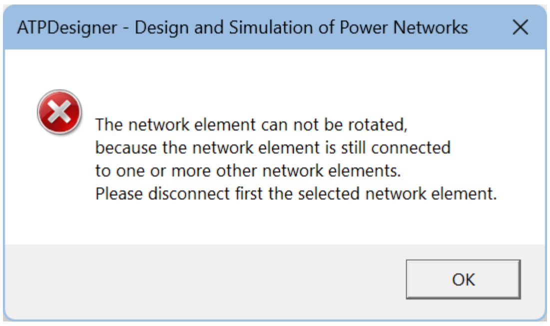


Figure 13: Error Message - Rotating Connected Network Elements

9 Design of an Electrical Power Supply Network using ATPDesigner

In this chapter, it will be explained how to design a simple power supply network in ATPDesigner. The power supply network shall consist of a 110kV-**Network Infeed**, a 110/20kV **2-Winding Transformer**, some **Probe** to measure voltages, currents, active and reactive power or to simulate a protection relay as well as a **Load Impedance** to simulate a consumer load and a **3-Phase Source** to simulate a decentralised generation system.

⇨ ATPDesigner offers two ways to build a power supply network from an empty drawing area, but it is recommended to build the power supply network by Drag&Drop the network elements from the tree structure of the **Network** tab of the **Project Information**.

9.1 Open a new Drawing Area for a Power Supply Network

The first step is to open a new empty drawing area before starting the design of the power network, now also called power grid.

1. Start the network calculation program ATPDesigner.

2. Open a new empty drawing area with the menu item **New** in the main menu **File** or by a **Left Mouse Button Click** on the toolbar button or with **CTRL + N**.

Network elements can now be added by Drag&Drop.

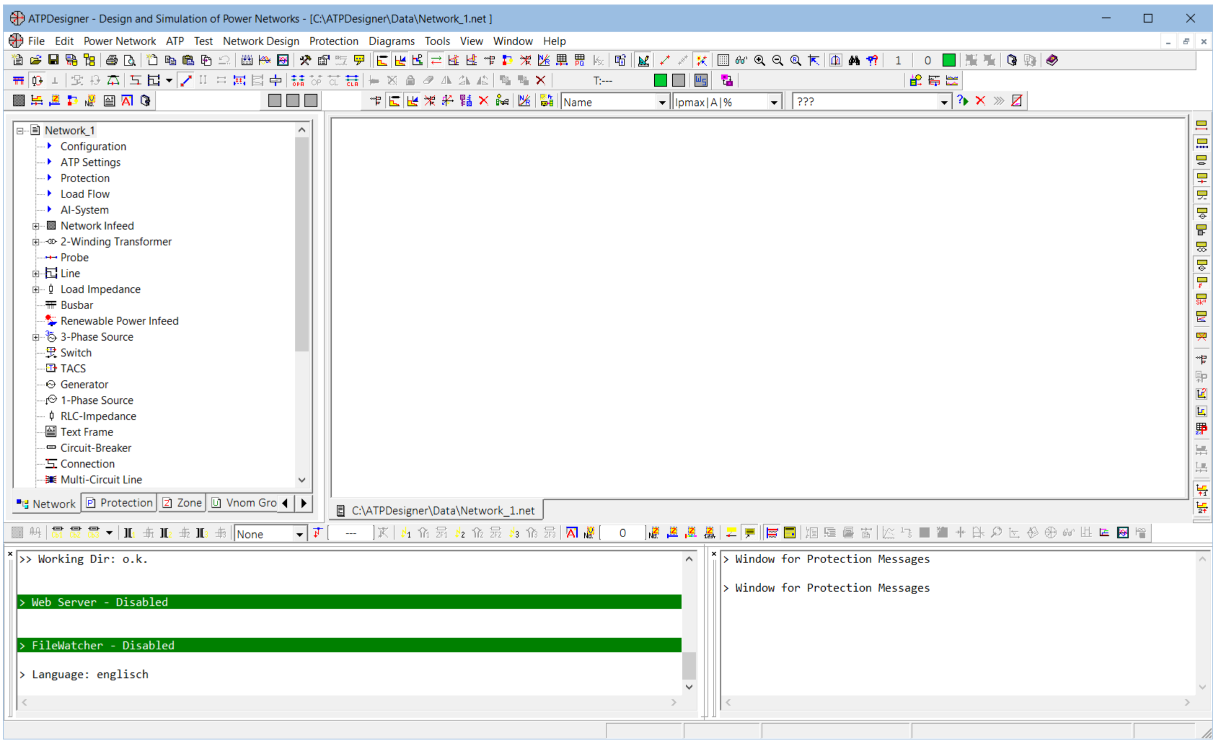


Figure 14: Open an empty drawing area to design a new power supply network

9.2 Design a new Power Grid in an empty Drawing Area

After opening an empty drawing area, a new power network can be designed. New network elements can now be added using the menu items in the **Network Design** main menu or the **toolbar buttons** in the top toolbar or by Drag&Drop with the items of the tree structure of the **Network** tab of the **Project Information** window.

9.2.1 Connecting a new Network Element to an existing Network Element

A new network element can be inserted from the tree structure in the **Network** tab of the **Project Information** (chapter 8.2) window using Drag&Drop.

- ⇨ It is recommended to start with the network element **Network Infeed** **Network 1**. The nominal network frequency f_n can be set in the settings dialog of **Network Infeed** **Network 1**.

1. Insert a new network element by Drag&Drop.

2. Move the mouse cursor over a “free” not connected node of the new network element, press the left mouse cursor and keep it pressed.

3. Move the mouse cursor over a “free” not connected node of another network element.

4. Release the left mouse button. The both nodes will be now automatically connected.

After inserting a new network element, the settings dialog of the new network element will not be automatically opened, but can be opened manually using a **Left Mouse Button Double Click** on the shape of the network element.

10 Automatic Identification of the Nominal Voltage V_{nom}

The network calculation program ATPDesigner offers the capability to automatically identify the nominal voltage V_{nom} of the electrical power grids and assign it to the equipment. The function **Electrical Power Grid: V_n Level** is demonstrated with the power grid shown in the figure below as an example.

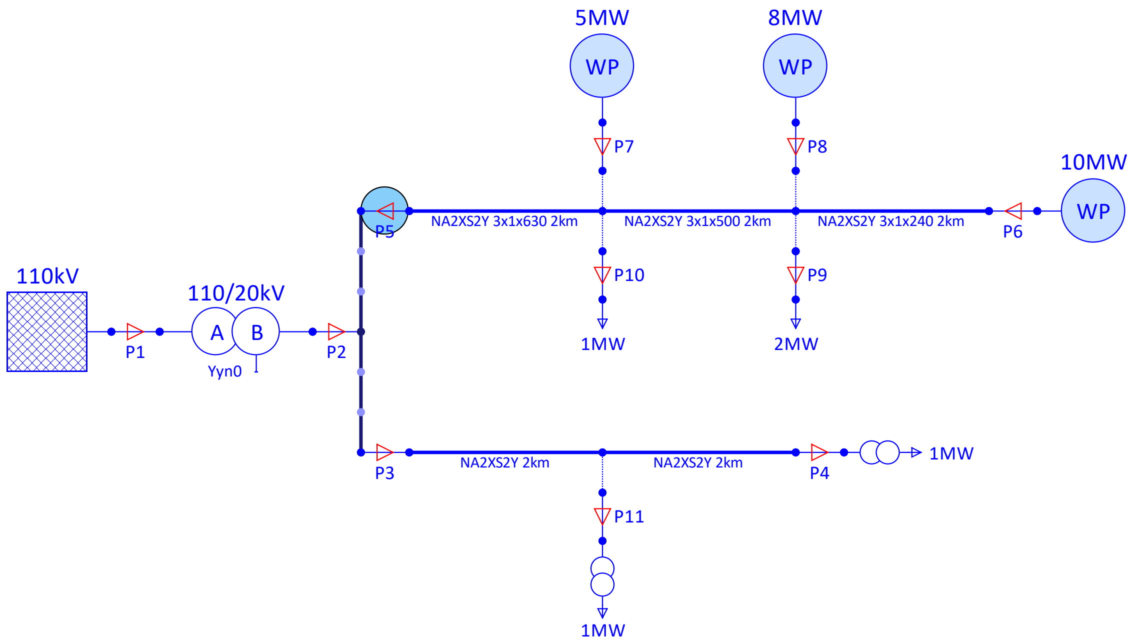


Figure 15: Automated identification of the nominal voltage of power grids

The function **Electrical Power Grid: V_n Level** is started as follows:

- Main menu: **Test**
- Menu item: **Electrical Power Grid: V_n Level**

Alternatively, the **Right Mouse Button Menu** can be opened, and the function **Electrical Power Grid: V_n Level** can be started with a **Left Mouse Button Click**.

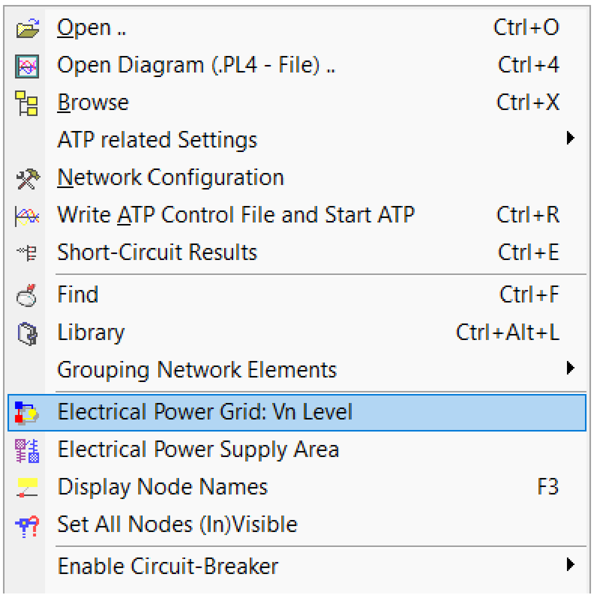


Figure 16: Starting the function *Electrical Power Grid: V_n Level* to identify nominal voltages of the grid

Some rules are important to know.

1. The algorithm to identify the nominal voltages always starts at every winding A, B or C of every transformer in the power grid. Therefore, the algorithm cannot be executed in a power grid without any transformer.

2. It will always be assumed that the V_n or V_{nom} settings of every transformer are correct and well defined.

3. The state opened or closed of switches, circuit-breaker, etc. will be ignored. The algorithm always assumes, that switches, circuit-breaker, etc. are closed.

As shown in the example in the following figure, the algorithm starts the identification of the nominal voltages from winding A of the transformer **110kV/20kV [Tra 1]** with V_n = 110kV. Only two network elements are identified and assigned to the nominal voltage V_n = 110kV: **P1 [Prb 1]** and **110kV [Network 1]**. The algorithm then continues at winding B of the transformer with V_n = 20kV. This procedure will be repeated starting from the windings of every transformer until all windings of the transformers in the power grid have been processed. The identified network elements are displayed in the **Message Window**

In the first step the algorithm only identifies the nominal voltages but doesn't change the settings of the network elements.

- **P1 [Prb 1] – V_n=110kV**
  The **Probe** was assigned to the nominal voltage V_n = 110kV because the network element was found starting from winding A of the transformer with nominal voltage V_n = 110kV. The setting value of the network element was not changed.

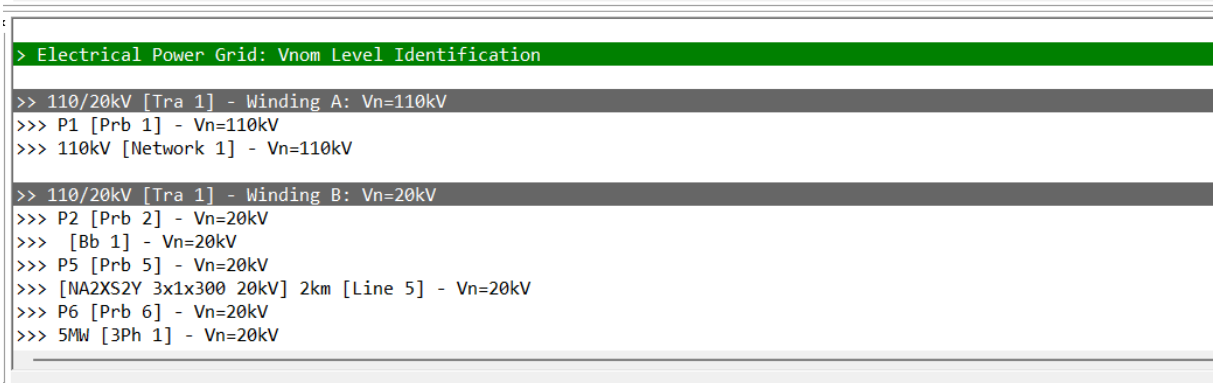


Figure 17: Search starting from the windings of the transformers

Before changing the setting values of the nominal voltages of the network elements, the user will be asked to proceed or to cancel.

- Ja = Yes, Nein = No

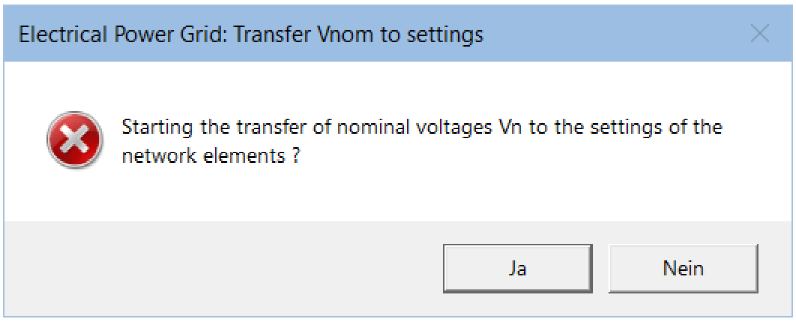


Figure 18: Question before changing the setting values

After confirmation by the user, in the second step, the setting values of the nominal voltage V_{nom} or V_n of the network elements are changed.

- **110/20kV [Tra 1] – Winding A: Vn=110kV**
  The V_{nom} identification routine starts at winding A of the transformer.

- **P1 [Prb 1] – 110kV → 110kV**
  The setting value for the nominal voltage has been set to V_n = 110kV for this network element by the algorithm.

```
> Electrical Power Grid: Vnom Level Identification

>> 110/20kV [Tra 1] - Winding A: Vn=110kV
>>> P1 [Prb 1] - Vn=110kV
>>> 110kV [Network 1] - Vn=110kV

>> 110/20kV [Tra 1] - Winding B: Vn=20kV
>>> P2 [Prb 2] - Vn=20kV
>>>  [Bb 1] - Vn=20kV
>>> P5 [Prb 5] - Vn=20kV
>>> [NA2XS2Y 3x1x300 20kV] 2km [Line 5] - Vn=20kV
>>> P6 [Prb 6] - Vn=20kV
>>> 5MW [3Ph 1] - Vn=20kV
>>> P3 [Prb 3] - Vn=20kV
>>> [NA2XS2Y 3x1x300 20kV] 2km [Line 4] - Vn=20kV
>>>  [Bb 2] - Vn=20kV
>>> P4 [Prb 4] - Vn=20kV
>>> 5MW [Load 1] - Vn=20kV
>>> [NA2XS2Y 3x1x300 20kV] 2km [Line 6] - Vn=20kV
>>> P7 [Prb 7] - Vn=20kV
>>> 5MW [3Ph 2] - Vn=20kV
```

Figure 19: Message window - Identification of nominal voltages V_n

The figure below shows the power grid after the function has been successfully finalized. The color of the equipment depends on the identified nominal voltages assigned to the equipment. Additionally, the nominal voltages are displayed in the **V_n Level tab** of the **Project Information** tab, organized in a tree structure and corresponding to the relevant equipment.

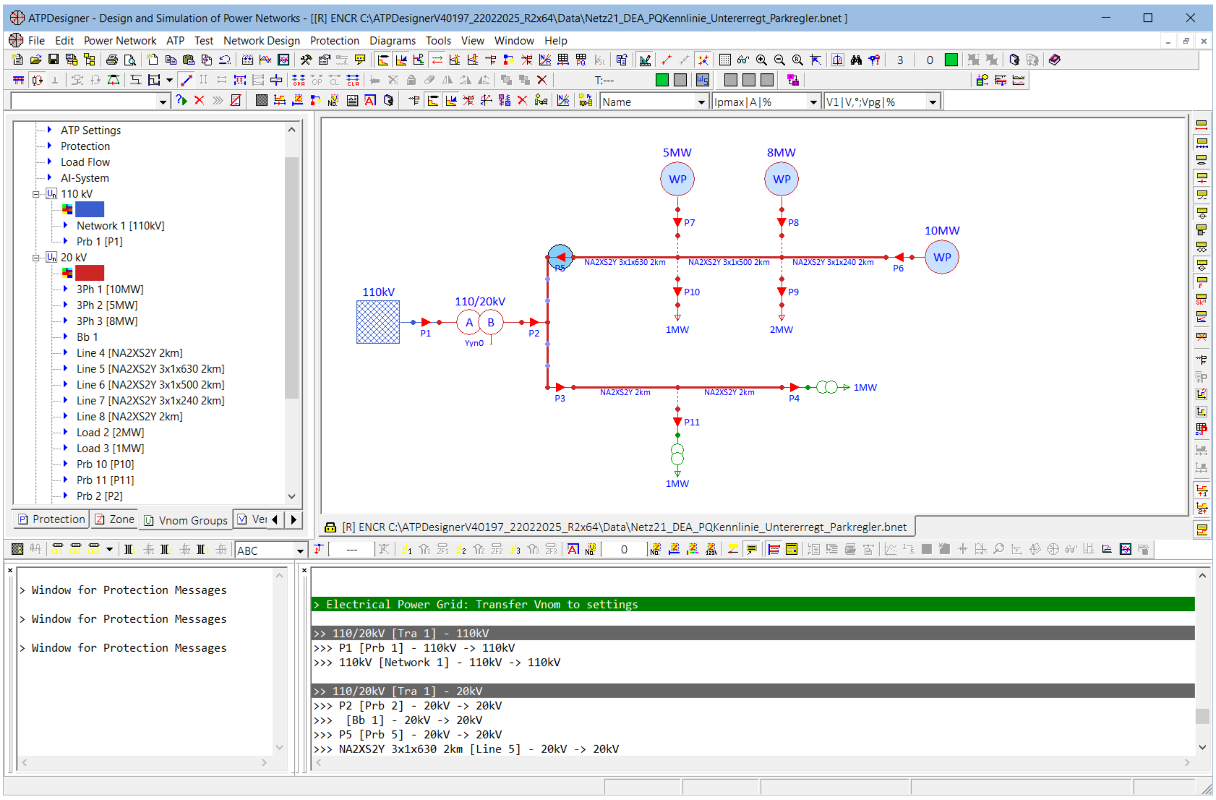


Figure 20: Coloring of voltage levels, output in the message window

The color of the nominal voltages can be set in the settings dialog **Levels V_n.**

- Main menu: **Power Network**
- Menu item: **Network Configuration**
- Tab: **Vnom Colors**

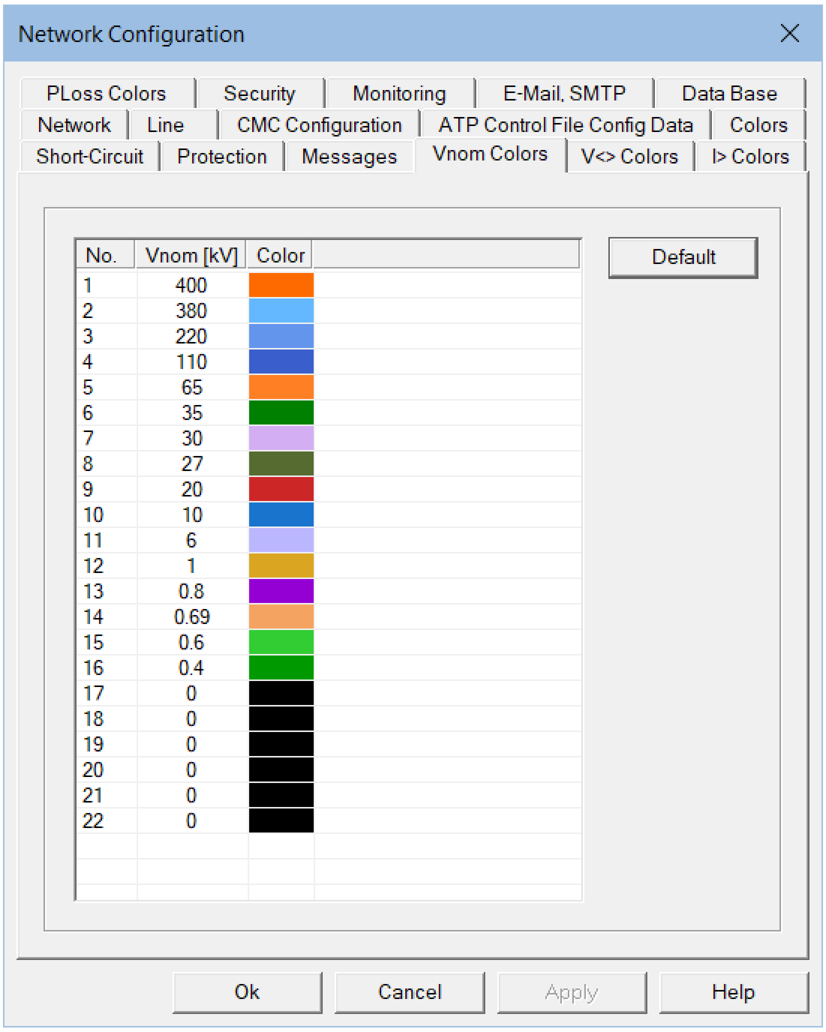


Figure 21: Settings dialog *Vnom Colors* - drawing color for the nominal voltages V_{nom}

11 Load Flow Calculation with Decentralised Generation Systems

Decentralised generation systems such as solar and wind power plants are using 1, 2 or 3 1-phase grid converters or one 3-phase symmetrical grid converter. In ATPDesigner, decentralised generation systems are simulated based on a model using 1, 2, or 3 current sources to feed in active power P and/or reactive power Q. ATPDesigner uses the network element **3-Phase Source** to simulate decentralised generation systems in a power grid.

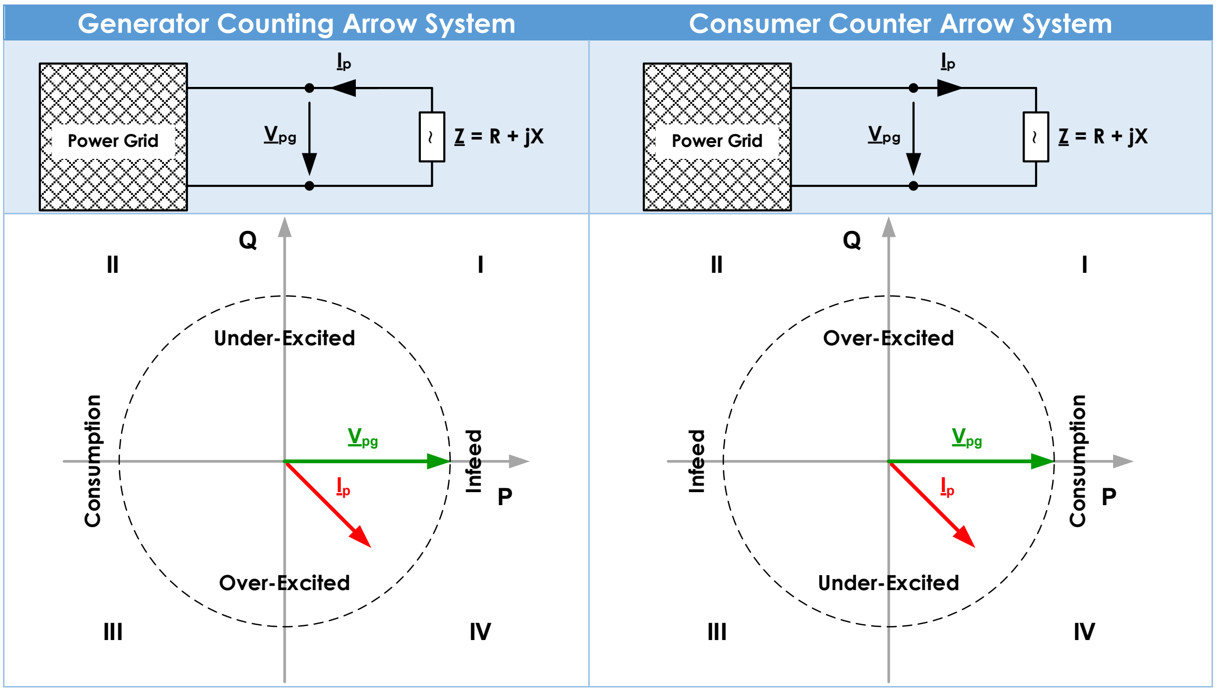
⇨ The network element **3-Phase Source** can be used as a 1-, 2- or 3-phase grid converter or as a 3-phase symmetrical grid converter.

The decentralised generation systems are typically set for normal grid operation by the active power **Pnom**. The reactive power Q will be set e.g. by the displacement factor **cos φ = const.** or a reactive power characteristic **Q(P)** or **Q(V)** according to the German standard VDE-AR-N 4110 [4] and VDE-AR-N 4120 [5].

⇨ The network element **3-Phase Source** is a **PQ node** from the point of view of the load flow calculation. The electrical behaviour of the **PQ-Node** is mainly defined by feeding in a constant active power and a constant reactive power.

⇨ A **PQ node** can feed in or consume active power P and/or reactive power Q (4-quadrant operation mode). The metering arrow system must be considered: Generator counting arrow system or consumer counting arrow system.

⇨ The network element **3-Phase Source** uses the generator counting arrow system.



In order to use a clear nomenclature, the terms

Term	Description
Under-Excited	**Consumption of reactive power Q**
Over-Excited	**Feed in of reactive power Q**

shall be used. These terms are independent of the metering arrow systems.

The following table contains network elements frequently used in ATPDesigner with the assignment as to whether the currents and powers, displayed in the network graphic or the tooltips for these network elements are calculated in the generator counter arrow system or consumer counter arrow system.

Generator Counting Arrow System	Consumer Counter Arrow System
▪ **3-Phase Source**	▪ **Load Impedance**
▪ **Renewable Power Infeed**	▪ **Probe**
▪ **Network Infeed**	▪ **Line**
▪ **Generator**	▪ **2-Winding Transformer**
	▪ **BCTRAN Transformer (2/3-Winding)**

⇨ In case of a 3-phase symmetrical power grid operation simulated by the network element **3-Phase Source**, the load flow calculation will be processed only in the positive-sequence system using the positive-sequence voltage $\underline{V}_1$ and the positive-sequence current $\underline{I}_1$.

⇨ In case of a 1-, 2- or 3-phase possibly asymmetrical power grid operation simulated by the network element **3-Phase Source**, a load flow calculation is processed using the phase-to-ground voltages $\underline{V}_{ABCG}$ and the corresponding phase currents $\underline{I}_{ABC}$.

The network element **3-Phase Source** also offers the option of simulating the behaviour in case of a short-circuit (**LVRT**-operation, **L**ow **V**oltage **R**ide **T**hrough) according to the German standards VDE-AR-N 4110 [4] or VDE-AR-N 4120 [5].

The load flow calculation will be executed iteratively as a multi-step calculation process, so called iteration process. The iteration process will be terminated in case of convergence, if the user defined accuracy has been achieved. If the maximum number of permissible iteration steps has been reached without achieving the user defined accuracy, the load flow calculation will be aborted with divergence.

⇨ If the load flow calculation is convergent, the calculation results will be displayed in the network graphic and in tooltips of the network elements. In addition, a **Report** is generated in Office Open XML format [6]. The report will be automatically saved in the **Project Directory**. The report can be read with a word processing programme such as Word.

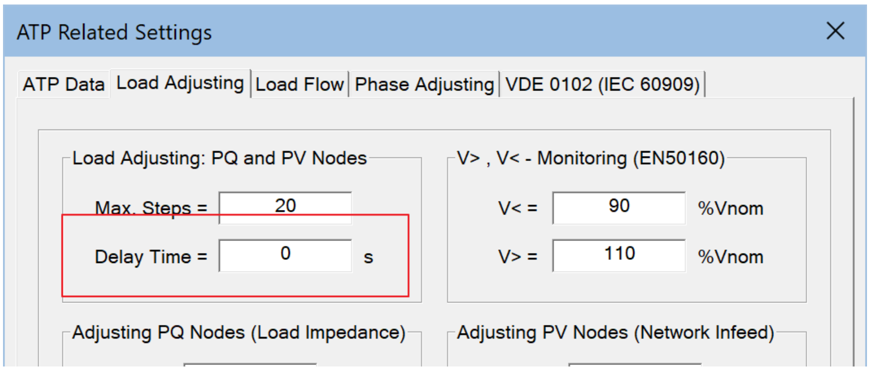


Figure 1: Setting a delay time for computer systems with low performance

In computer systems with a lower performance, problems to access files stored in the temporary directory of the operating system can occur during the load flow calculation. The **Delay Time** setting value can be used to set a delay time between two calculation steps of the iteration process.

The load flow calculation uses two independent algorithms to simulate the electrical behaviour of **PQ nodes** e.g. of the network elements **Load Impedance** and **3-Phase Source**. The two algorithms can be enabled or disabled independent of each other.

- Main menu **ATP**
  - **Load Adjusting** Enabled or Disabled
  - **Phase Adjusting** Enabled or Disabled

The **Load Adjusting** and **Phase Adjusting** options can be enabled or disabled using two toolbar buttons or in the **ATP Data** settings dialog, **ATP Data** tab.

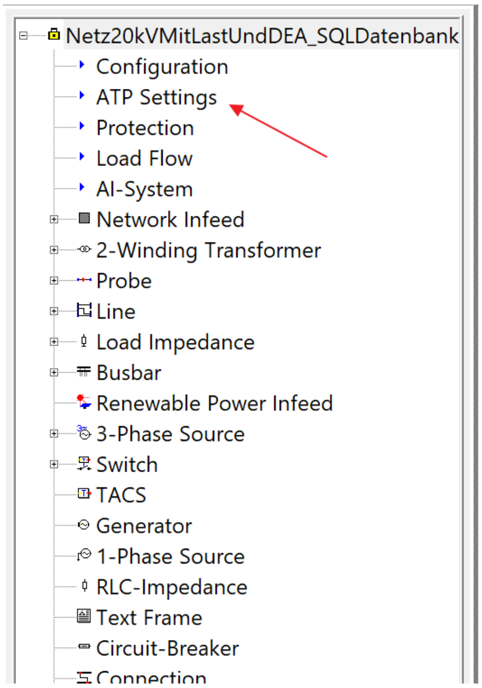


Figure 2: Open the *ATP Settings (ATP Data)* dialog by Left Mouse Button Double Click

The power grid shown in the figure below shows a simple, medium-voltage grid with a nominal voltage V_{nom} = 20kV, which consists of two parallel **Line** NA2XS2Y 3x1x240mm². The power is supplied from a 110kV **Network Infeed** via a 110/20kV **2-Winding Transformer** with S_{rT} = 31.5MVA. The measurement of phase currents, phase-to-ground voltages, active and reactive power is carried out using several network elements **Probe** **Px**.

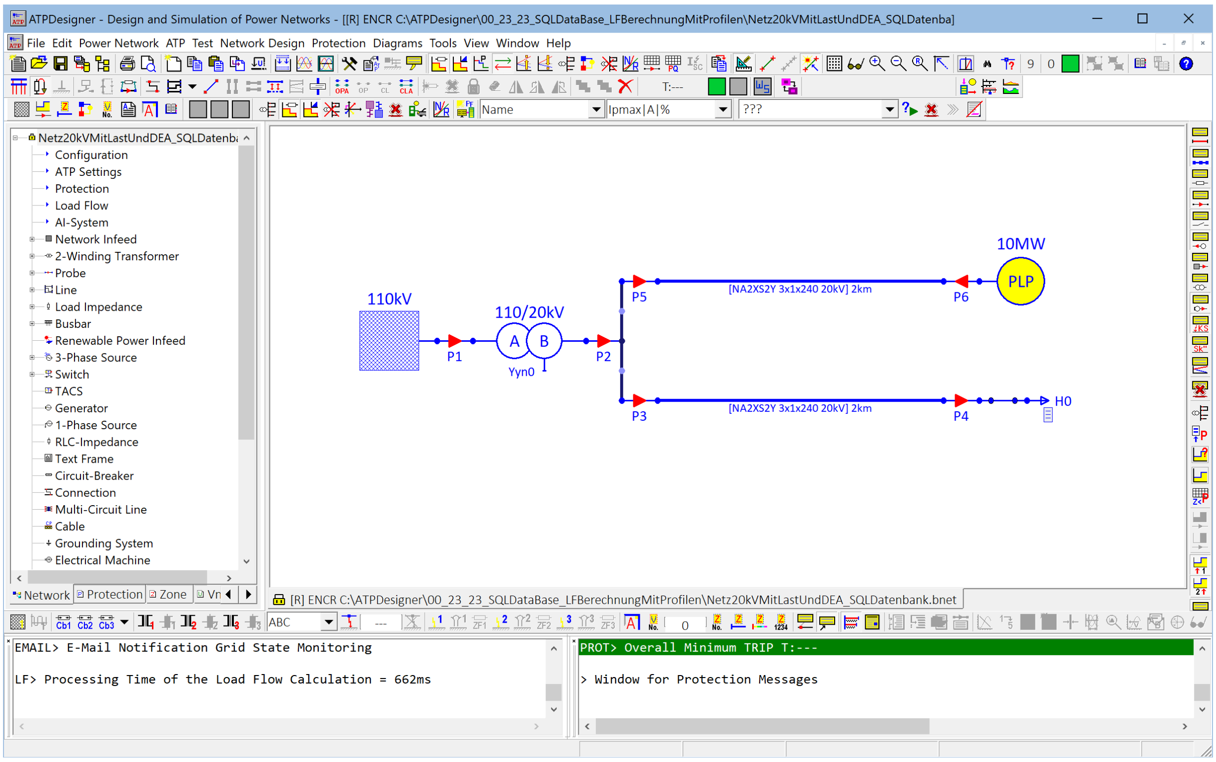


Figure 22: 20kV-Power Grid with Distributed Generation System

It will be recommended to check, that the **Load Adjusting** and **Phase Adjusting** options are both enabled in the **Load Flow Calculation** group of the **ATP Data** tab. If enabled, the load flow calculation for the network elements **Load Impedance** and **3-Phase Source** will be considered.

⇨ If the options **Load Adjusting** and **Phase Adjusting** are enabled, the network elements **Load Impedance** and **3-Phase Source** will be considered as **PQ-Nodes**.

- Main menu **Power Network**
- Menu item **ATP Data**, Tab **ATP Data**

Setting	Enabling Load Flow Calculation for …
Load Adjusting	▪ **Load Impedance** ▪ **Network Infeed** ▪ **2- Winding Transformer** (tap changer with voltage regulation)
Phase Adjusting	▪ **3-Phase Source**

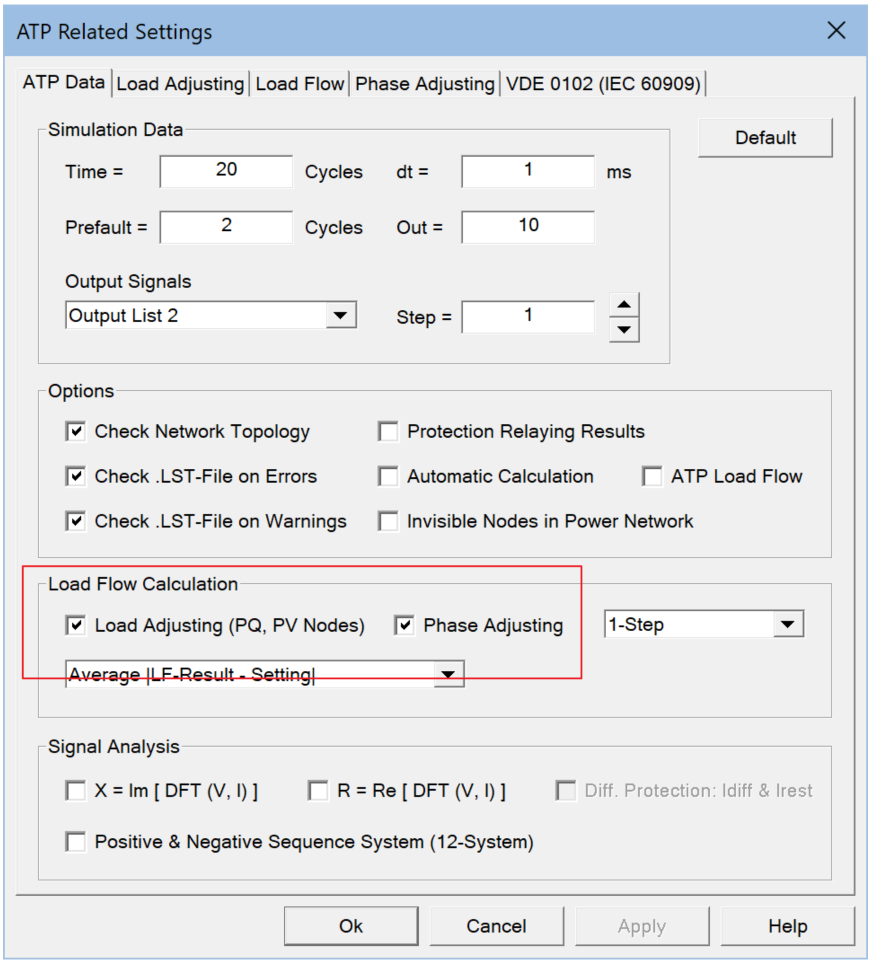
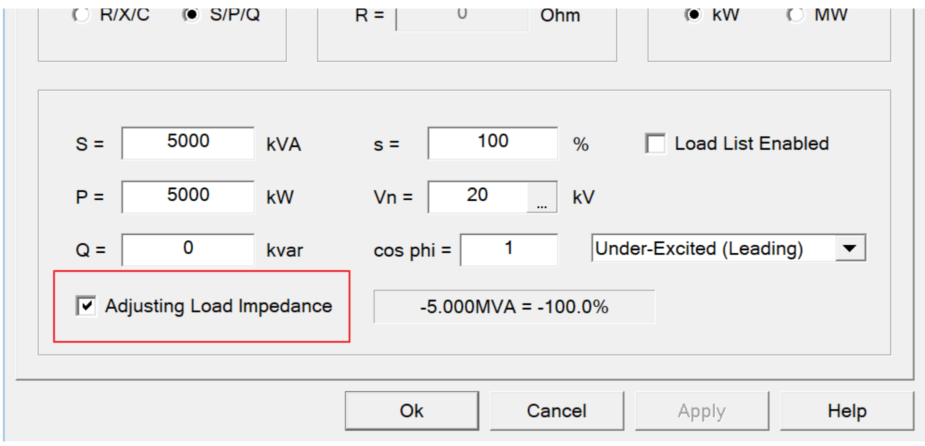


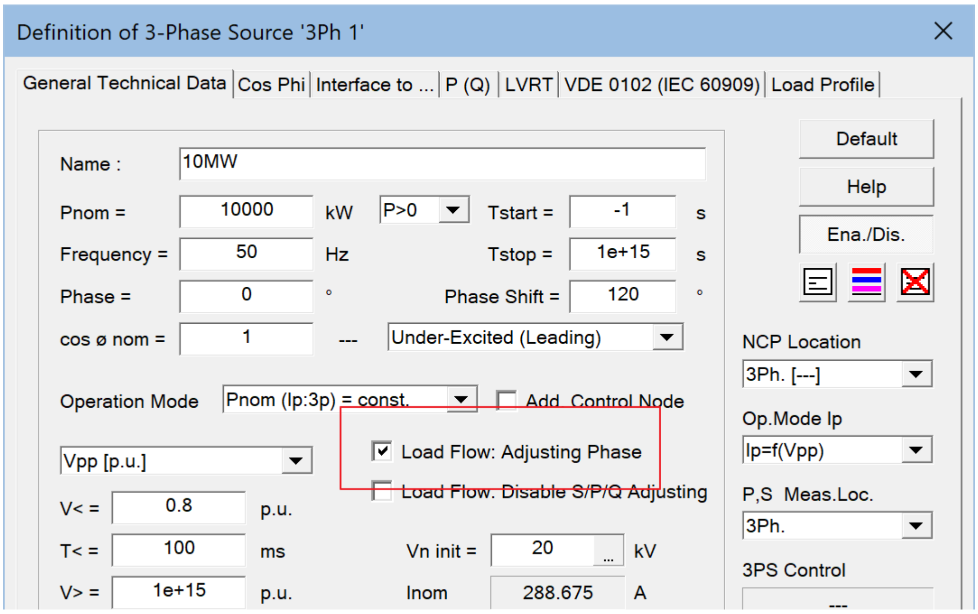
Figure 3: Enabling the Load Flow Calculation for *Load Impedance* and 3-*Phase Source*

Additional settings must be considered in the settings dialogs of the network elements e.g. the network element **Load Impedance**.

- **Network Element Load Impedance**
  The **Adjusting Load Impedance** option must be enabled.



- **Network Element** **3-Phase Source**
  The **Load Flow: Adjusting Phase** option must be enabled.



A load flow calculation can be stopped with the **ESC** button. To do this, the **ESC** button may need to be pressed for several seconds. In this case, the number of iteration steps **N = 20** and **LF = failed** are displayed in the status bar.

⇨ Load flow calculation: Divergence, **LF=failed**

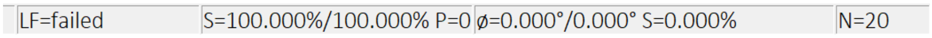


Figure 4: Termination of the Load Flow Calculation *LF=failed*

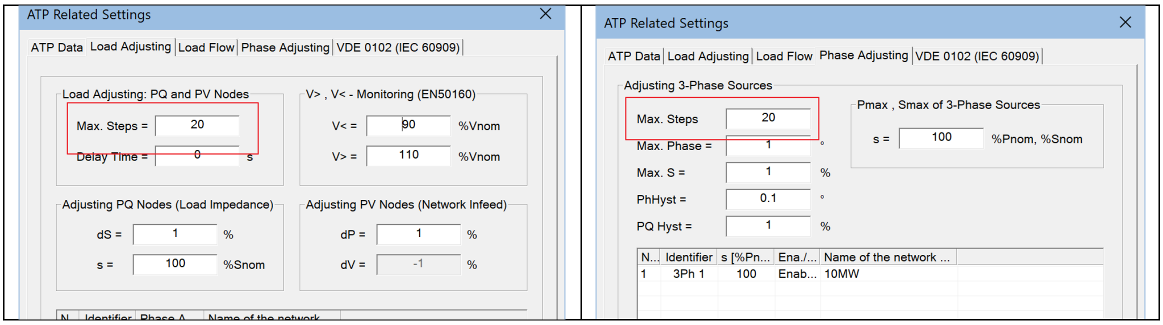
⇨ Load flow calculation: Convergence, **LF=o.k.**

Figure 5: Finalized Load Flow Calculation

ATPDesigner iteratively recalculates the data of the internal models of the network elements **Load Impedance**, **Network Infeed**, **3-Phase Source** and the tap changers of the network element **2-Winding Transformer**. After every recalculation, a calculation of the steady-state grid status is processed using the ATP (**A**lternative **T**ransients **P**rogram) [7]. ATPDesigner uses user specific accuracy settings to control the load flow calculation. In addition, a maximum number of recalculation steps (iteration steps) will be monitored by the load flow calculation algorithm.

The maximum number of iteration steps (recalculation steps) can be set separately for the network elements **Load**, **Network Infeed** and **Transformer 2-Winding** in the **Load Adjusting** and **3-Phase Source** in the **Phase Adjusting** tab.

- Main menu **Power Network**
- Menu item **ATP Data**, Tab **Load Adjusting**, **Phase Adjusting**



Setting	Description
Max. Steps	**Load Adjusting** and **Phase Adjusting:** Maximum number of iteration steps (recalculation steps)
dS	**Load Adjusting**: Accuracy of the apparent power
Max. Phase	**Phase Adjusting**: Accuracy of the phase angle
Max. S	**Phase Adjusting**: Accuracy of the apparent power

The accuracies will be monitored for every network element separately. Only if the accuracy will be achieved for all network elements, the load flow calculation will be finalised by convergence.

11.1 Steps to Design a New Power grid

The steps described below may be carry out to design a new power grid in ATPDesigner.

1. Open a new empty drawing area
   - Main menu **File,** menu item **New**
   - **Left Mouse Button Click** on the toolbar-button
   - **CTRL + N**

2. Insert new network elements using Drag&Drop into the drawing area

   - Network element **Network Infeed**
   - Network element **2-Winding Transformer**
   - Network element **Probe**[1]
   - Network element **Busbar**
   - Network element **Line**
   - Network element **3-Phase Source**[2]

The following figure shows the electrical power grid.

[1] Measuring device and protection relay
[2] Distributed generation system

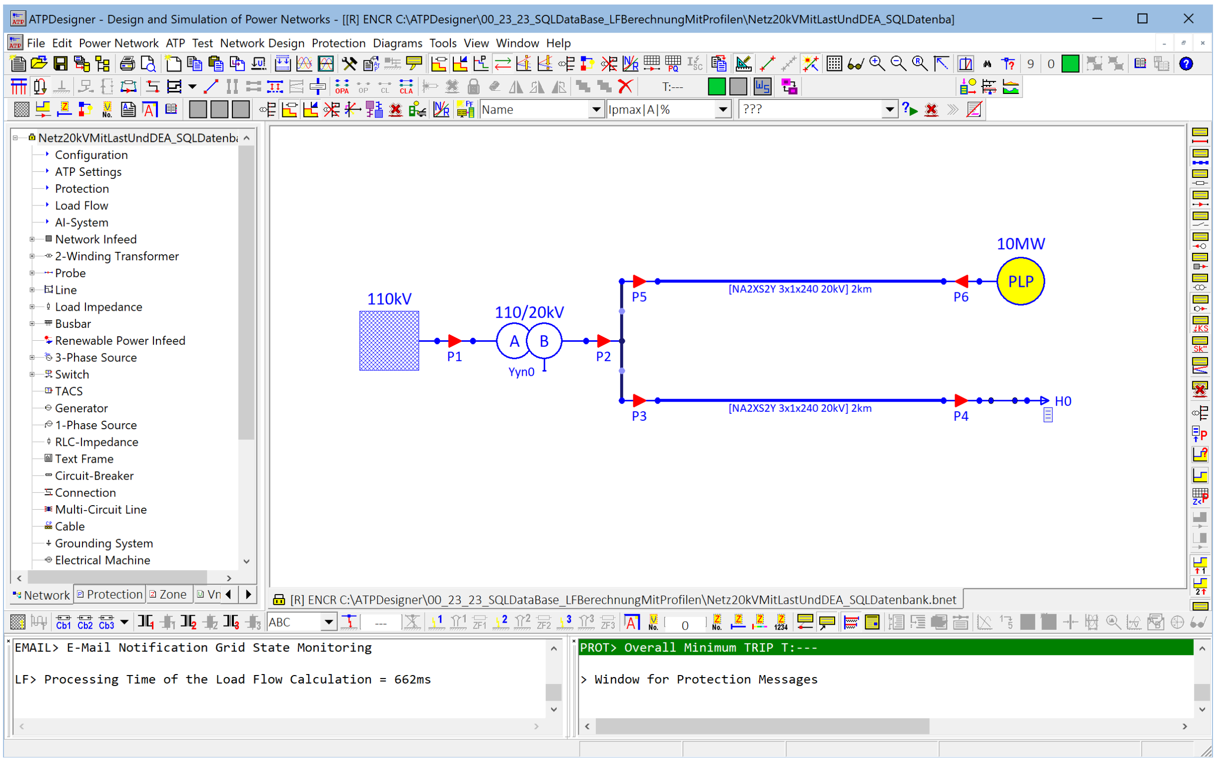


Figure 6: 20kV-Power Grid with Distributed Generation System

The topology of the 20kV power grid and the adjustment of the equipment e.g. the definition of the settings are explained step by step below.

⇨ Only settings needed to be changed based on the default settings are explained.

⇨ The default setting can be loaded by a **Left Mouse Button Click** on the **Default** button in the settings dialog. If there are several tabs in a settings dialog, the **Default** button of the 1st tab must always be used.

11.2 Design of the Power Grid in the Drawing Area

Equipment can be added into the drawing area using Drag&Drop e.g. the network elements **Network Infeed** and **Probe**[1].

1. Move the mouse cursor over the name of the network element **Network Infeed** or **Probe** in the **Network** tab of the **Project Information**

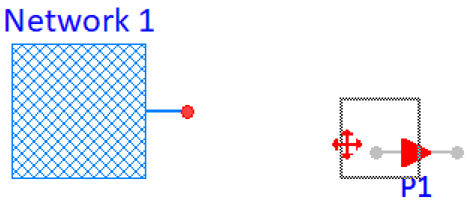
2. Move a network element into the drawing area with the left mouse button pressed down, release the left mouse button

3. The **red nodes** indicate that these nodes are not connected and therefore can be connected to nodes of another network element.

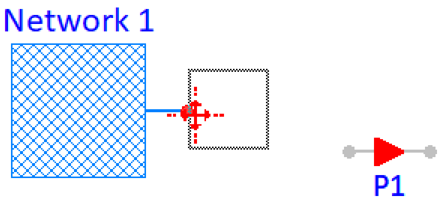
In the next step, the two network elements can be connected.

4. Select the network element **Probe P1** with a **Left Mouse Button Click** on its shape[3] ➔ **Grey Drawing Color**

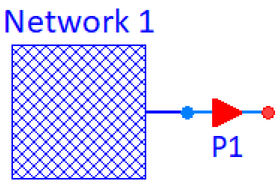
5. Move the mouse cursor over the left **red node** of the **Probe**, press the left mouse button and keep it pressed. A **red target optic** becomes visible when the mouse will be moved.



6. Move the mouse cursor while holding down the left mouse button until the **red target optic** enlarges as shown in the following figure and is positioned over the not connected node of the network element **Network Infeed**.



7. Release the left mouse button. ATPDesigner automatically "snaps" the two nodes and connects the nodes of the network elements electrically.

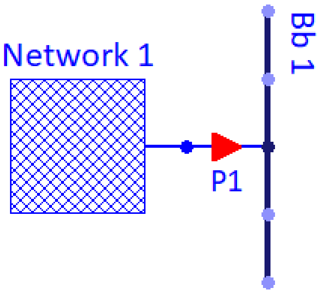


The procedure described must be continued for all network elements and the power grid can be designed up step by step. Please note the following hints.

- A node of a network element can only be connected once to another node of another network element.

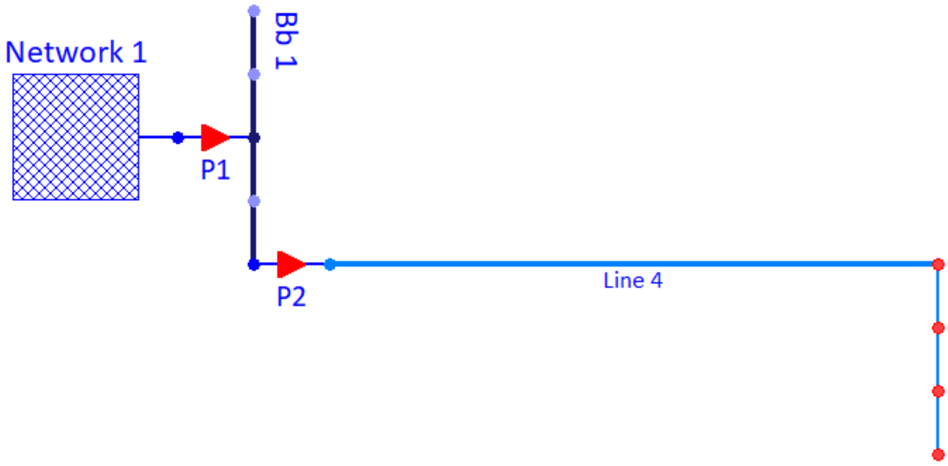
- If a node of a network element needs to be connected to several other nodes, the network element **Busbar** can be used as a 0Ω - connector.

- The network element **Busbar** represents only one electrical node (0Ω - connector). In the network graphic, this one electrical node can be represented by up to 20 graphical nodes. It is therefore possible to connect nodes from up to 20 different network elements using one **Busbar**. Single and double **Busbars** with disconnectors in the feeder and between the busbars can be used.



- Select the network element **Probe** with a left mouse button click (**Grey Drawing Color**). Press **CTRL + C** to copy the network element to the clipboard and press **CTRL + P** to insert a copy of the network element into the network graphic. The reference name of the new network element (shown in the header of the settings dialogue in '...') and the user-specific name will be changed, all other setting values will be copied and therefore unchanged.

- The network element **Line** can be set with up to 3 additional nodes at both ends of the **Line**. Together with the main node, these additional nodes represent an internal busbar with up to 4 nodes.



- Network elements can be rotated by 90° to the right and left. To do this, the network element must first be disconnected at all nodes.
  - Disconnect the network element at all nodes from all other network elements ➔ Network element is fully not connected.
  - Mark the network element with a left mouse button click (**Grey Drawing Color**)
  - Key **r** or ➔ rotate to the **right**
  - Key **l** or ➔ rotate tot he **left**

11.3 Network Element *Line* – Shape locked or unlocked , ,

The shape of the network element **Line** can be **locked** or **unlocked** using the toolbar button . In addition, the shape type can be switched between a diagonal form or a z-form.

⇨ The line must be marked first, before the shape can be locked or unlocked, or before the shape type can be changed.

- The shape can be locked or unlocked with a **Left Mouse Button Click** on the toolbar button
- The shape type can be switched between **diagonal form** or **z-form**.

It will be recommended to use lines in a power grid as explained below.

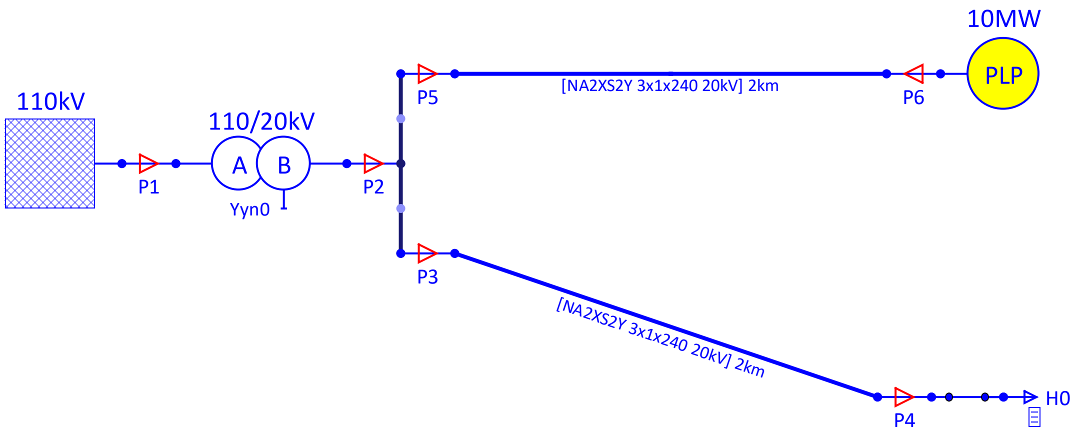
1. Enable the **diagonal form** of the network element **Line** with a **Left Mouse Button Click** on the toolbar button before Drag&Drop a network element **Line** into the drawing area

2. Add a network element **Line** via Drag&Drop into the drawing area

3. **Unlock** the shape of the network element **Line** with a **Left Mouse Button Click** on the toolbar button 

4. Move the cursor over the node of the line at the right, press the left mouse button and move the mouse to another position ➔ the shape of the line can be used as a "rubber band"

5. Release the left mouse button to setup the position of the node and to fix the new shape of the line



11.4 Opening the Settings dialog of a Network Element

The settings dialog can be opened by a **Left Mouse Button Click** on the shape (graphic symbol) of the network element.

11.5 Network Infeed 110kV

The 110kV high-voltage network is modelled with the network element **Network Infeed**. The network element can be set with Drag&Drop into the drawing area using the left mouse button. The network element is labelled with the user-specific name **Network 1** (reference name **Network 1**) in the network graphic.

- ⇨ Identifier of the reference name: **Network** x, x = 1…999
- ⇨ The identifier of a network element can be set user-specifically with the **Name** setting value.
- ⇨ The reference name of a network element cannot be changed by the user. The reference name will be shown in the header **'…'** of the settings dialog.

Figure 7: User-specific name and reference name of a network element

Setting	Description
Vnom	Nominal voltage V_{nom} = 110kV
fn	Nominal frequency f_n = 50Hz
Ssc	Short-circuit apparent power S_{sc} = 500MVA
Ssc min	Minimum short-circuit S_{scmin}
Ssc max	Maximum short-circuit S_{scmax}
Z0 = 2 Z1	Zero-sequence impedance $\underline{Z}_0 = 2 \cdot \underline{Z}_1$
Isc3	3-phase short-circuit current I_{sc3} = 2,62kA

ATPDesigner simulates the **Network Infeed** acc. the standard VDE 0102 (IEC 60909) with a 3-phase symmetrical voltage source and a short-circuit impedance as inductively coupled RL series impedances. If the **Phi (Zk).** option is disabled, the impedance angle **phi (Zk)** can be set manually. Impedance angles about 60°...80° are common for 110kV high-voltage networks.

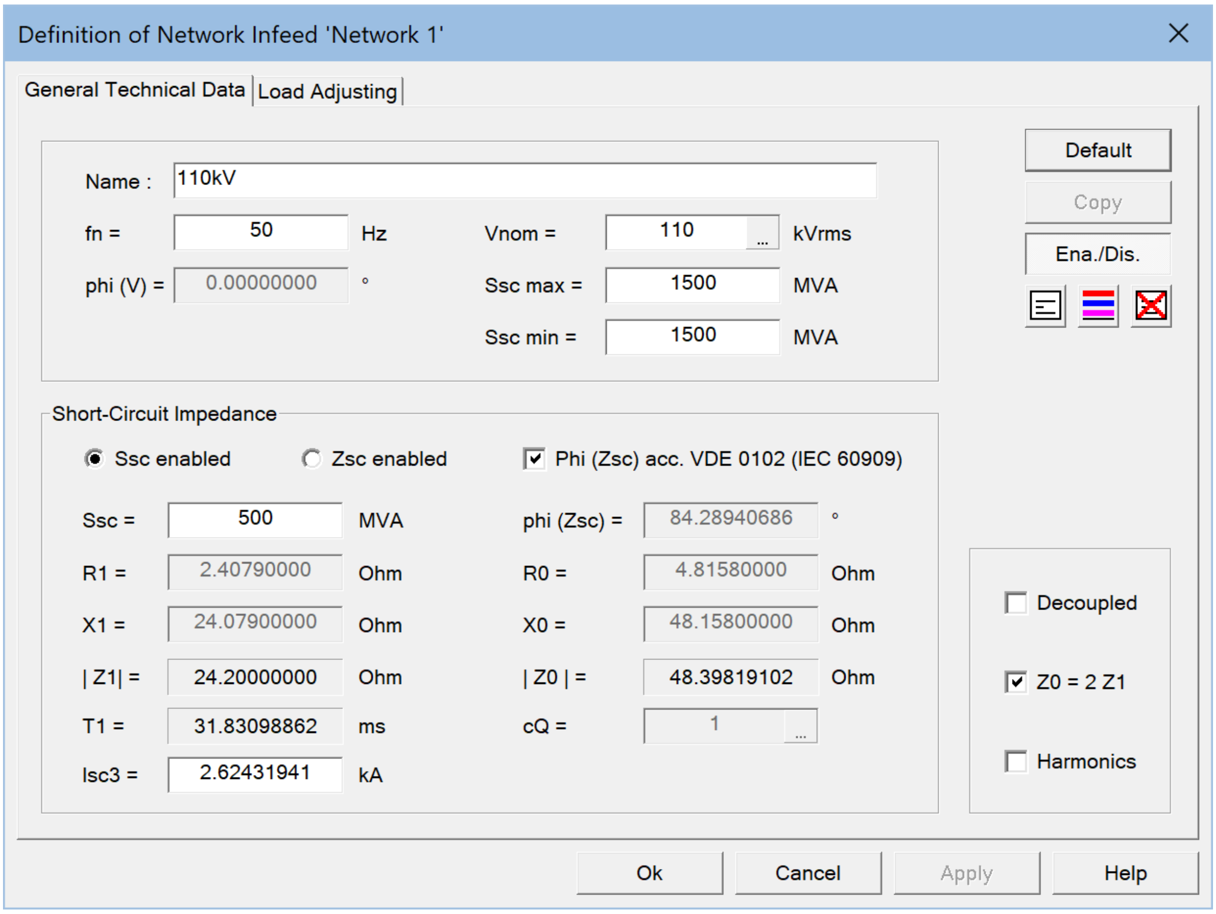


Figure 8: Setting dialog of the 110 kV high-voltage network infeed

11.6 2-Winding Transformer 110/20kV

The 110/20kV transformer is modelled by the **Transformer 2-Winding** network element. The network element can be set using Drag&Drop into the drawing area.

Setting	Description
Sr	Rated apparent power S_r = 31,5MVA
VrA, VrB	Rated nominal voltage V_{rA} = 110 and V_{rB} = 20kV
uk	Short-circuit voltage U_k = 12%
Pk	Short-circuit active power losses P_k = 130kW
Vector Group	Vector group Yyn0
Neutral Point	Vector group solid grounded

X01	Zero-sequence reactance / positive-sequence reactance X_0 / X_1= 5
IL	Excitation current I_L = 9,09A
iL	Excitation current i_L = 1%
PL	Excitation losses P_L = 20kW

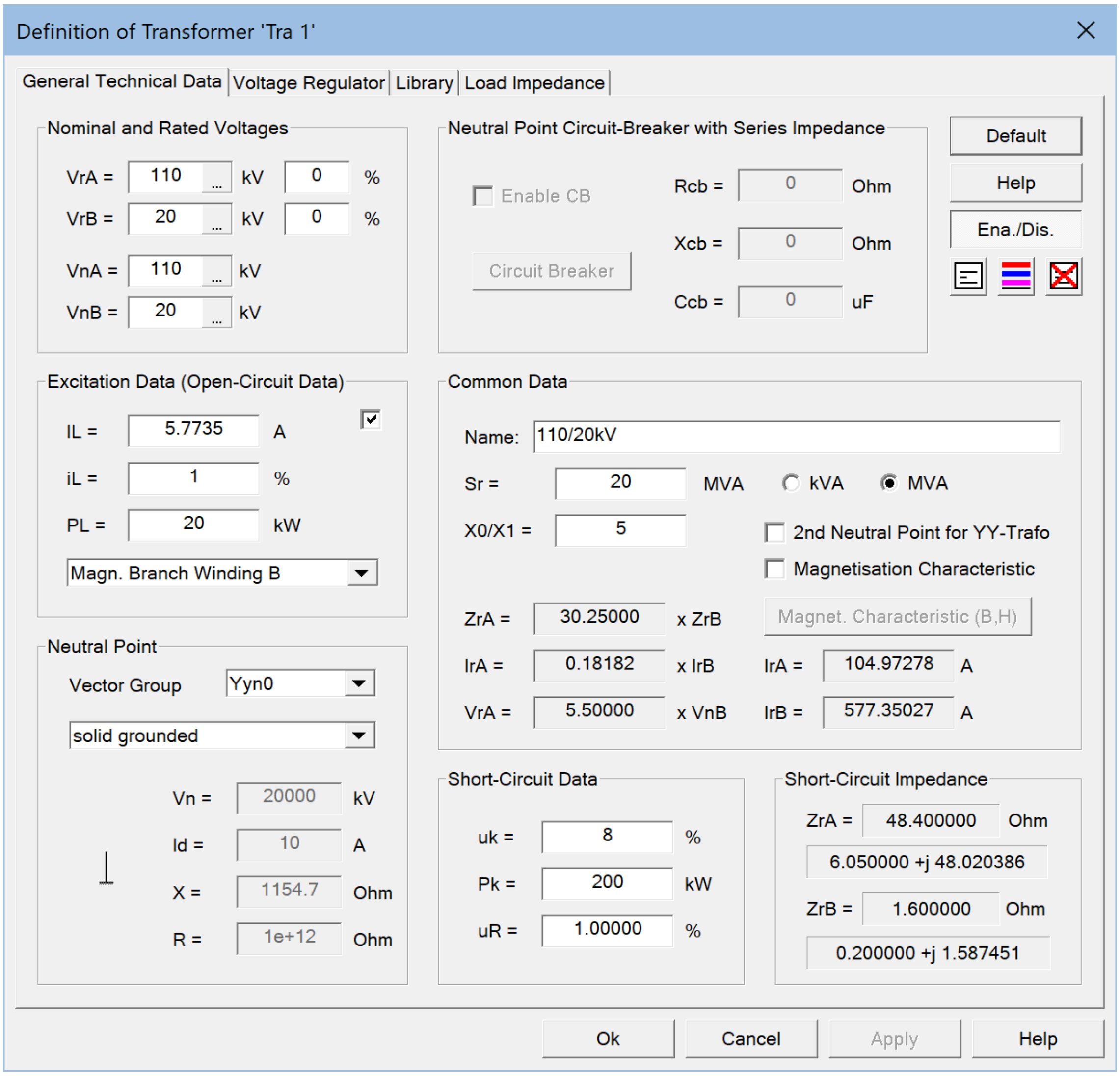
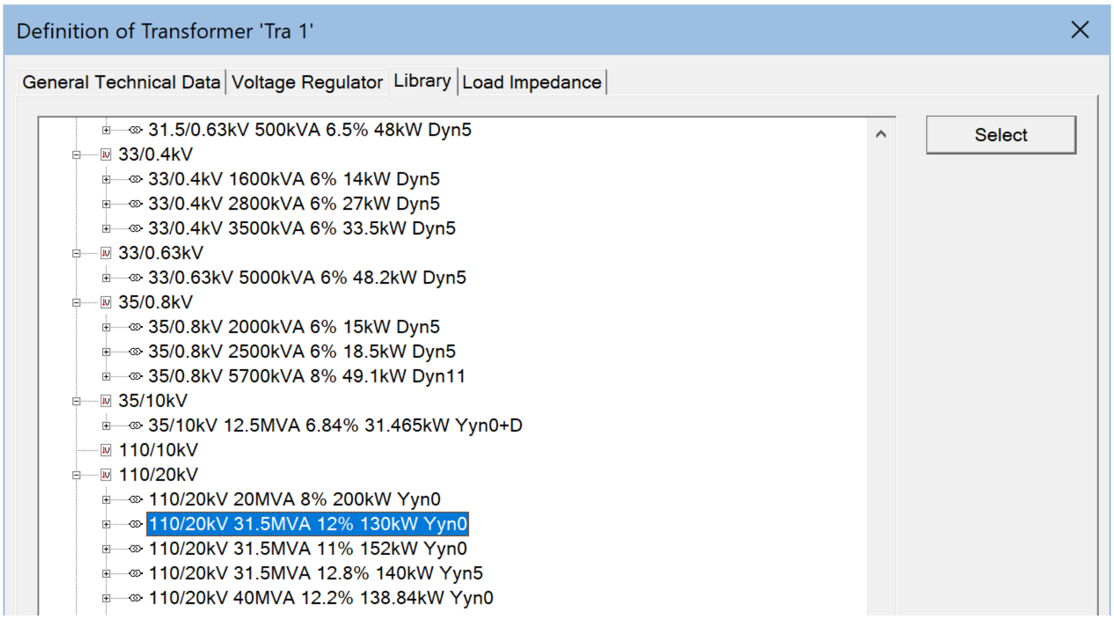


Figure 9: Einspeisetransformator 110/20kV, S_r = 31,5MVA, u_k = 12%, P_k = 130kW

The network element **Transformer 2-Winding** is labelled with the user-specific name **Tra 1** (reference name **Tra 1**) in the network graphic.

⇨ Identifier of the reference name: **Tra** x, x = 1…9999

- A transformer type can be selected in the **Library** tab of the settings dialog.



A transformer type can be selected with a **Left Mouse Button Click** in the tree structure. The selection must be confirmed with a **Left Mouse Button Click** on the **Select** button.

- The tap changer with voltage regulator can be enabled and set in the **Voltage Regulator** tab.
- An internal **Load Impedance** connected to the low-voltage winding (**Winding B**) of the transformer can be enabled and set in the **Load** tab. The network element **Load Impedance** will be used as internal part of the transformer model.

11.7 Measuring Devices and Protection Relays

In the next step, the high-voltage and medium-voltage power grids are equipped with several measuring devices or protection relays so called network element **Probe**. The network element **Probe** can be set using Drag&Drop into the drawing area. It is also possible to **copy a network element** with **CTRL + C** and paste it into the drawing area with **CTRL + V**.

The network element **Probe** is labelled with the identifier **Px** (reference name **Prb x**) in the network graphic. The network element can be used to measure voltages, currents, active and reactive power and more and display the values in a tooltip.

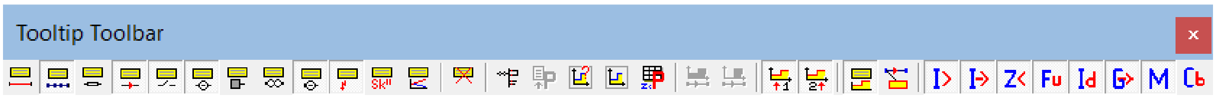
⇨ Identifier of the reference name: **Prb** x, x = 1…9999

⇨ The tooltip of a network element will only be displayed, if a convergent load flow calculation has been processed.

⇨ The mouse cursor must be moved over the shape[3] of the network element to display the tooltip.

⇨ The tooltip displays the measured values and some important settings.

⇨ The tooltips can be enabled or disabled using the tooltip buttons of the toolbar shown below.



Button	Description
	Display tooltip of the network element **Line**
	Display tooltip of the network element **Busbar**
	Display tooltip of the network element **Load Impedance**
	Display tooltip of the network element **Probe**
	Display tooltip of the network elements **Switch** and **Circuit-Breaker (CB)**
	Display tooltip of the network element **3-Phase Source**
	Display tooltip of the network element **Network Infeed**
	Display tooltip of the network element **2-Winding-Transformer** und **BCTRAN Transformer**
	Display tooltip of the network element **Generator**
	Display tooltip of the network element **Short-Circuit**
	Tooltip to display **Short-circuit apparent power S_{sc}** and **Short-circuit current I_k**
	Tooltip to display **Voltage Drop-Down** of **Busbars**
	Enable or disable all tooltips in one step

It is important to set the nominal voltage V_{nom} correctly, so that the percentage value of the calculated voltages is displayed correctly in the tooltip. In addition, a nominal current I_{nom} should also be set.

Setting	Description
Vnom	Nominal Voltage V_{nom} = 20kV
Inom	Nominal Current I_{nom} = 600A or I_n = 200A
Enable	Enable or disable the network element If disabled, the network element will not be considered for the load flow calculation

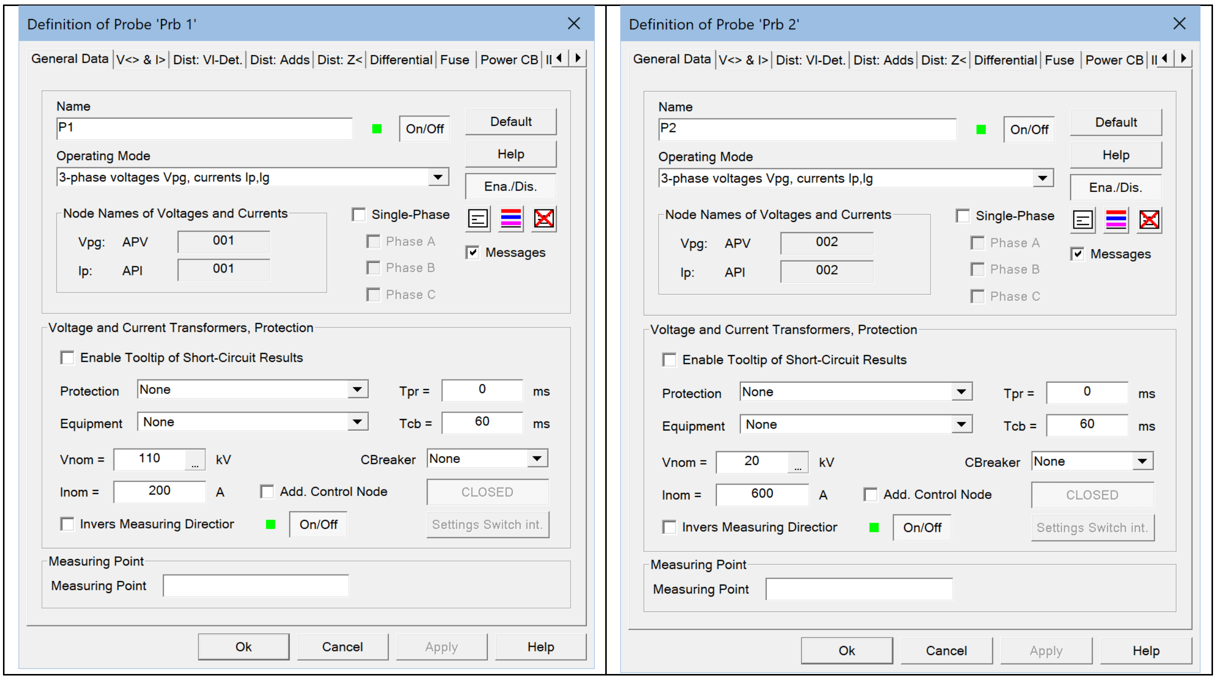


Figure 10: Setting dialogs of the network element *Probe*

11.8 Busbar connected to the 110/20kV-Transformer

In the next step, the network element **Busbar** will be connected to the network element **Probe P1**. The network element **Busbar** can be set using Drag&Drop into the drawing area and will be labelled with the identifier **Bb 1** (reference name **Bb 1**) in the network graphic.

⇨ Identifier of the reference name: **Bb** x, x = 1…9999

Setting	Description
Vnom	Nominal Voltage V_{nom} = 20V
Name	User-specific name of the busbar

Alternatively, other **Busbar** types can also be selected.

⇨ To change the **Busbar** type, the busbar must first be disconnected from all other network elements, i.e. no node of the busbar should be connected to a node of another network element. If all nodes of the network element Busbar have been disconnected, the setting Busbar Shape will be enabled and can be changed.

- Mark the network element by a **Left Mouse Button Click** on its shape.
- Move the mouse cursor over the shape of the busbar, press the left mouse button and move the busbar to a new "free" position. The nodes will be automatically disconnected. Release the left mouse button.
- Open the settings dialog with a **Left Mouse Button Double Click** on the shape[3] of the network element in the network graphic.

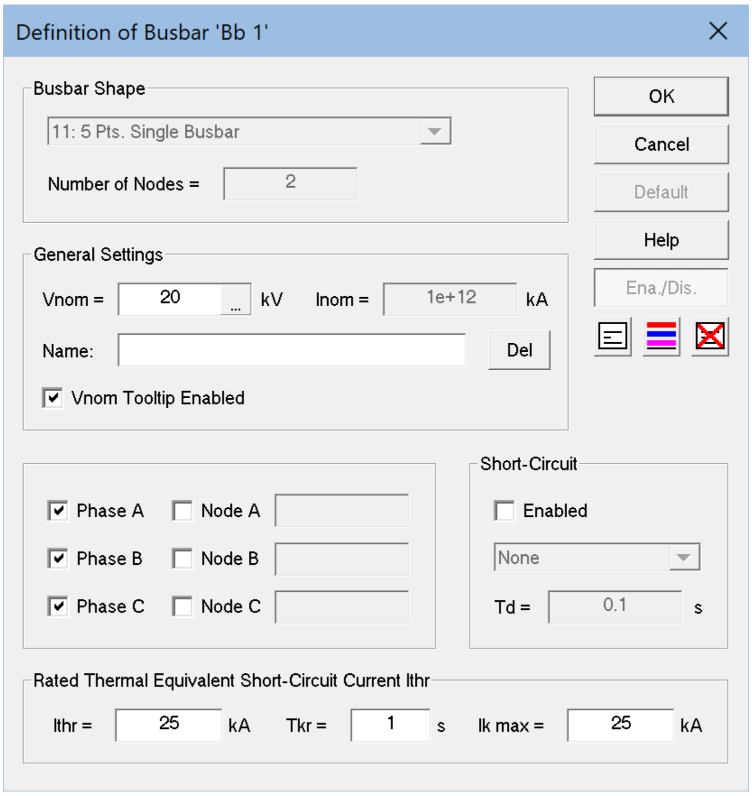


Figure 11: Settings dialog of the network element *Busbar*

11.9 Decentralised Generation System used as PQ-Node

Solar power and wind power plants are modelled by a 3-phase symmetrical power source of active power P_{nom} = const. using the network element **3-Phase Source**. The reactive power Q can be defined with a constant displacement factor cos φ or a characteristic Q(P) or Q(V). The network element can be set using Drag&Drop into the drawing area. The network element **3-Phase Source** is labelled with the user specific name **3Ph 1** (reference name **3Ph 1**) in the network graphic.

⇨ Identifier of the reference name: **3Ph** x, x = 1…9999

Setting	Description
P_{nom}	Nominal active power P_{nom} = 5MW
cosØn	Displacement factor cos φ = 0,98 under-excited (leading)
Operation Mode	Operation mode **Pnom (Ip:3p) = const.** 3-Phase symmetrical source of constant active power, feed in the positive-sequence system
Vnom init	Nominal voltage at the network connection point (NCP) V_{nom} = 20kV
Imax = 120%	Limitation of the phase currents 120% I_{nom}
Displacement Factor Cos Phi - Mode	Operation Mode **cos phi = const.** The load flow calculation uses a constant displacement factor at the network connection point (NCP).
Op. mode Ip	**Ip=f(Vpp)** The load flow calculation uses the average value of the phase-to-phase voltages measured at the network connection point (NCP) to calculate the phase currents based on the apparent power $\underline{S}$.
Load Flow: Adjusting Phase	This option must be enabled to consider the network element in the load flow calculation.
V<> - Protection	The undervoltage and overvoltage protection V< and V> is set to ±2%V_{nom} (1.02p.u. and 0.98p.u.). The operating mode **Vpp [p.u.]** will be used to monitor the phase-to-phase voltages at the network connection point (NCP).
NCP Location = 3Ph […]	The measuring location of voltages and currents used for the load flow calculation is the network connection point (NCP) of the decentralized generation system. Alternatively, a measuring location of any network element **Probe Prb x [Px]** can also be used.

Below it will be explained how the network element **3-Phase Source** will be processed in the load flow calculation.

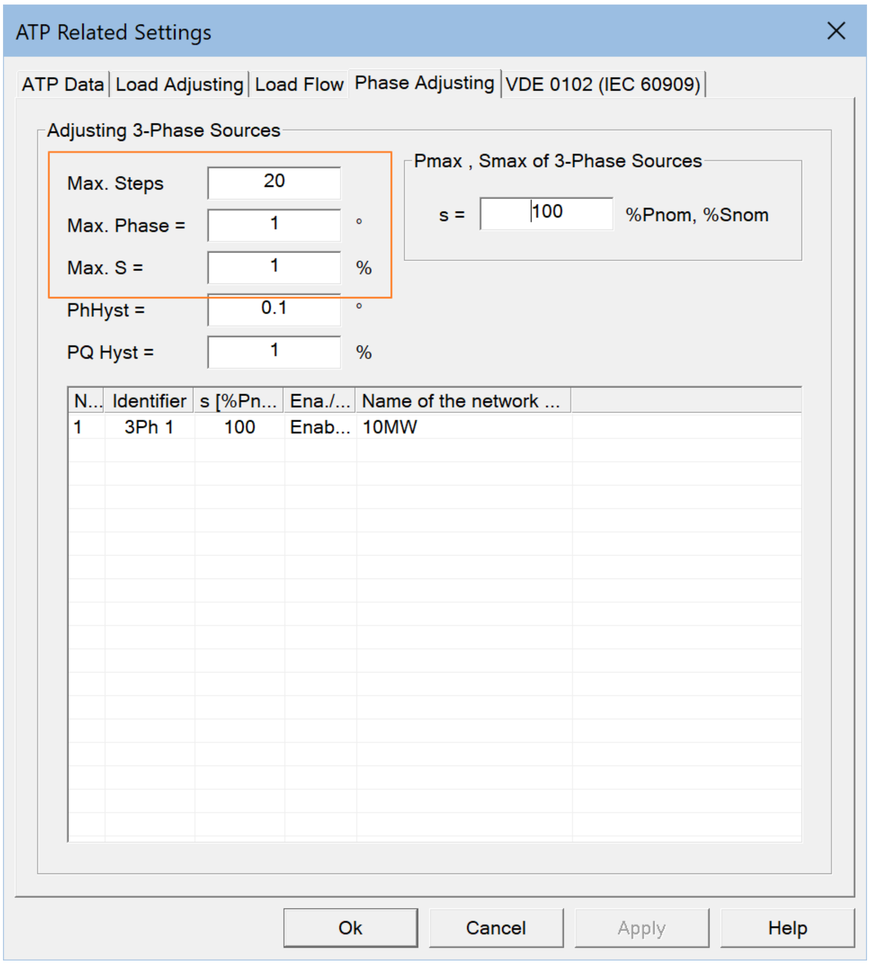
1. Starting from the initialisation value **Vnom init** at the network connection point (NCP), the amount of the phase currents $\underline{I}_{ABC}$ of every enabled current source will be calculated and used for the calculation of the steady-state condition.

2. If the operating mode **Pnom (Ip:3p) = const.** has been selected, the load flow calculation is processed in the positive-sequence system. Before every iteration step of the load flow calculation, the amount of the phase currents $\underline{I}_p$ will be calculated based on the active power **Pnom** and the amount of the positive-sequence voltage $\underline{V}_1$. The amount of the positive-sequence voltage is the result of the iteration step before the current one.

$$\underline{V}_1 = \frac{\underline{V}_{AG} + \underline{a} \cdot \underline{V}_{BG} + \underline{a}^2 \cdot \underline{V}_{CG}}{3}$$

3. ATPDesigner controls the iteration process by monitoring the accuracy of the calculated displacement factor cos φ and the calculated apparent power $\underline{S}$ of all decentralised generation systems with the enabled option **Load Flow: Adjusting Phase**. The accuracy can be set in the **ATP Data** settings dialog, tab **Phase Adjusting**.

- Main menu **Power Network**
- Menu item **ATP Data**, Tab **Phase Adjusting**



Setting	Description
Max. Steps	Maximum number of iteration steps of the load flow calculation If the maximum number of iteration steps has been reached, but the accuracies **Max. Phase** and **Max. S** have not been achieved, the load flow calculation will be stopped by divergence.
Max. Phase	Maximum permissible angular deviation of the calculated phase shift φ between the positive-sequence voltage $\underline{V}_1$ and the positive-sequence current $\underline{I}_1$
Max. S	Maximum permissible deviation of the amount of the calculated apparent power S related to its setting value

4. The setting of the **global partial load factor s** in the group **Pmax, Smax of 3-Phase Sources** is used for the calculation of the apparent power S for all network elements **3-Phase Source** with enabled option **Load Flow: Adjusting Phase** used by the load flow calculation.

$$P = P_{nom} \cdot s$$

Filling colour and abbreviation of the shape of the **3-Phase Source** can be set using the **Operating Mode** setting value in the **Load Profile** tab of the setting dialog.

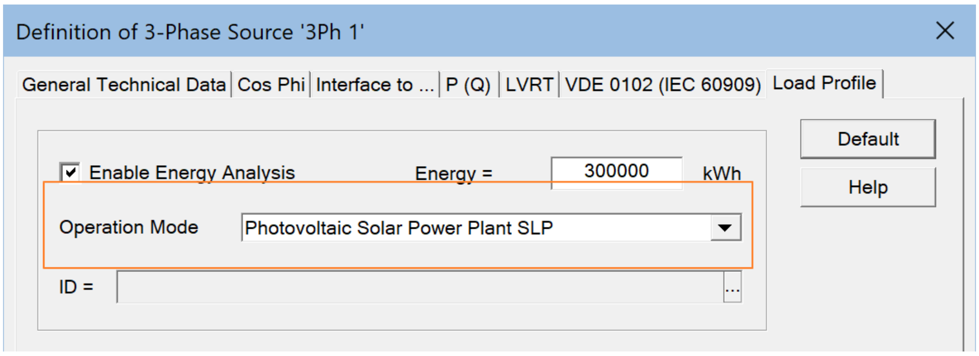


Figure 12: Setting value of filling color and abbreviation of the shape

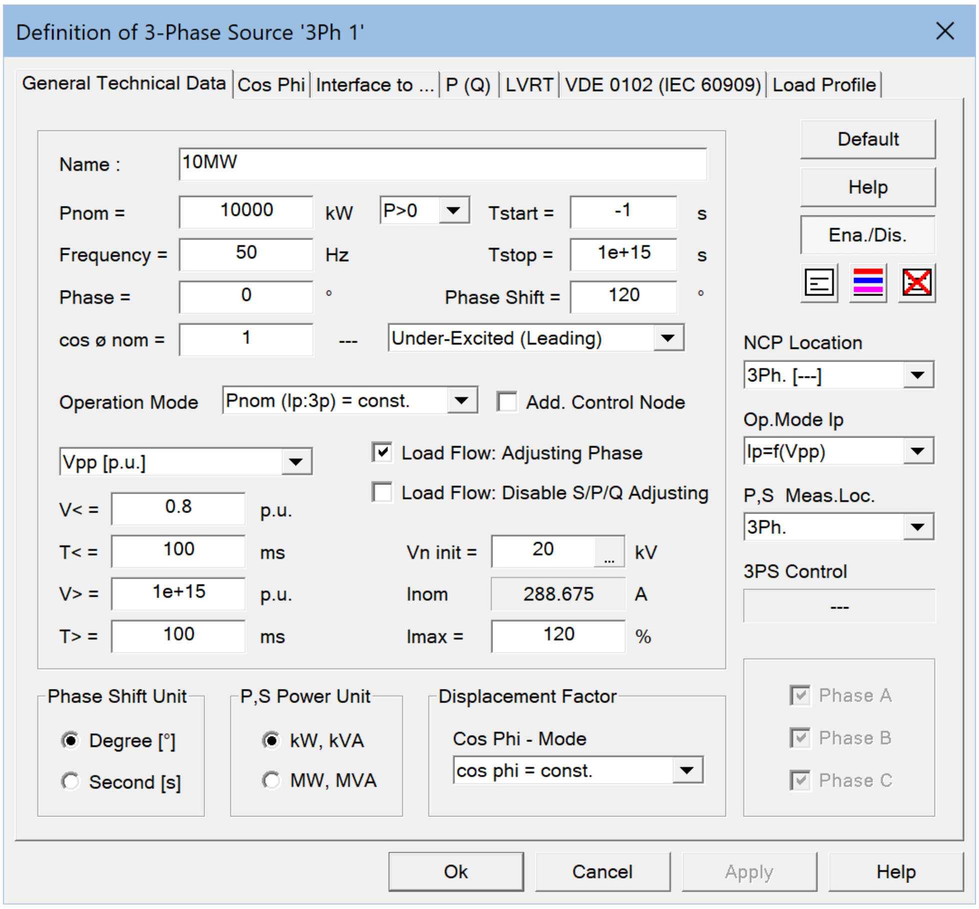


Figure 13: Settings dialog of the network element *3-Phase Source*

Setting	Description
cos Ø nom	Displacement factor cos φ = [0…1] In addition, **Under-Excited** od **Over-Excited** must be selected.
Phase	Phase shift calculated based on the displacement factor cos φ, over-/under-excited and the generation counter arrow system
Pnom	Amount of the nominal active power ▪ P > 0: active power will be feed in ▪ P < 0: active power will be consumed
Operation Mode	▪ **Pnom (Ip:3p) = const.** 3-phase symmetrical active power source, feed in into the positive-sequence system
Only used in case of the calculation of transients	Tstart, Tstop, Phase Shift, Phase Shift Unit

⇨ The network element **3-Phase Source** uses the **generation counter arrow system**.

In principle, a divergence of the load flow calculation must be considered. It is therefore always necessary to check, whether the accuracies have been achieved by the load flow calculation.

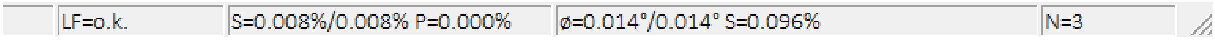


Figure 14: Accuracies of iteration with convergence

- The figure above shows the average/maximum accuracy S=0.008%/0.008% for the network elements with enabled option **Load Adjusting** e.g. **Load Impedance**.

- The figure above also shows the average/maximum phase deviation φ=0.014°/0.014° and the maximum deviation of the feed-in apparent power S=0.096% for the network elements with enabled option **Phase Adjusting**.

- In addition, the number of iteration steps N=3 is also displayed.

11.9.1 Decentralised Generation Systems - Short-Circuit Mode (LVRT Operation)

According to the grid operator's requirements [4], decentralised generation systems must feed in reactive current for voltage stabilization during short-circuit operation of the grid. The network element **3-Phase Source** can be set for the calculation of steady-state states in such a way that the requirements for LVRT (**L**ow **V**oltage **R**ide **T**hrough) operation according to the German standard VDE-AR-N 4110/4120 are always considered. In the default setting, LVRT operation is disabled for the network element **3-Phase Source** in this example.

11.10 Load Impedance used as PQ-Node

The network element **Load Impedance** can be used as a PQ node in the load flow calculation. The network element can be set using Drag&Drop into the drawing area. The network element **3-Phase Source** is labelled with the user specific name **Load 1** (reference name **Load 1**) in the network graphic.

⇨ Identifier of the reference name: **Load** x, x = 1…9999

Setting	Description
Vn	Nominal voltage V_{nom} = 20kV
P	Active power P = 5MW
cos phi	Displacement factor cos φ = 0,95 Under-Excited
Adjusting Load Impedance	Option **Adjusting Load Impedance** enabled, i.e., the network element is used as a PQ node in the load flow calculation
solid grounded	Neutral connection point is solidly grounded.
Operation Mode	**Series Impedance (Y)** ▪ 3-phase series impedance $\underline{Z}$ = R + jX

The settings shall be defined in the following order.

1. Nominal voltage V_{nom}
2. Displacement factor cos phi
3. Operation mode **Under-Excited** or **Over-Excited**
4. Active Power P

ATPDesigner automatically calculates the amount of the apparent power S and the reactive power Q as well as the load impedance $\underline{Z}$ = R + jX using the order explained above. If active power P or displacement factor cos φ has been changed, the other setting values of the **Load Impedance** are automatically recalculated.

The information to the right of the option **Adjusting Load Impedance** indicates the percentage deviation of the calculated apparent power S in relation to its setting value. A negative value of -100% is displayed before the load flow calculation is started.

The shape[3] (graphical symbol) of the network elements **Load Impedance** can be switched between the arrow symbol and the resistor symbol using the toolbar button .

[3] shape = graphical symbol

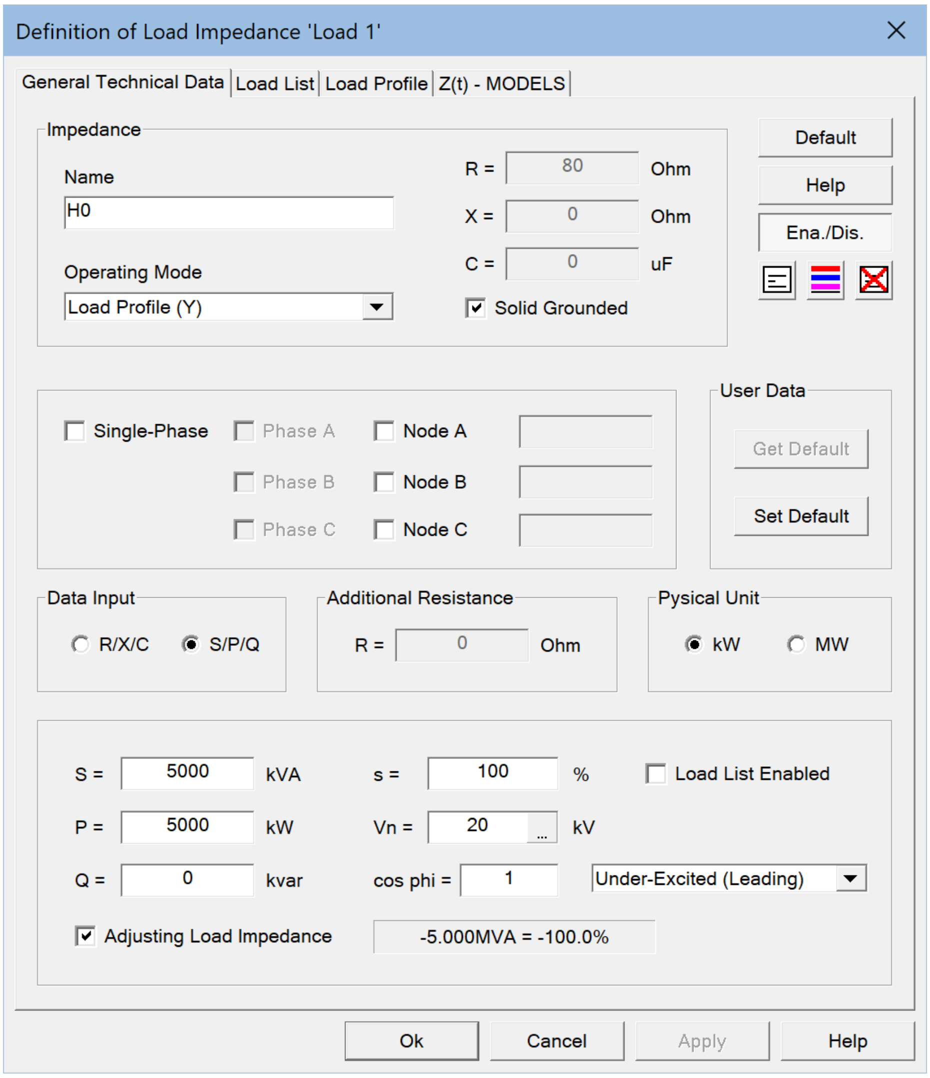


Figure 15: Settings dialog of the network element *Load Impedance*

11.11 Load Flow Calculation – Important Settings

The steady-state of an electrical power grid will be calculated using the calculation method **Load Flow Calculation**. The following procedure is typically and recommended using ATPDesigner.

1. Design of the power grid with all required equipment in the drawing area
2. Definition of the settings of all network elements (equipment) in the drawing area
3. Definition of the settings for the calculation method **Load Flow Calculation**
4. Start the calculation of steady-state of the electrical power grid
5. Open and analyse the load flow calculation report

The method **Load Flow Calculation** must be enabled in the setting dialogs **ATP Data** or **Load Flow Configuration** for the network elements (equipment).

- Main menu **Power Network**
  - Menu item **ATP Data**
  - Settings dialog **ATP related Settings**, tab **ATP Data**

- Main menu **ATP**
  -  Option **Load Adjusting** enabled
  -  Option **Phase Adjusting** enabled

- Main menu **ATP**
  - Menu item **Load Flow Configuration**, tab **Load Flow Configuration**
  - Options **Load Adjusting (PQ, PV Nodes)** and **Phase Adjusting** both enabled

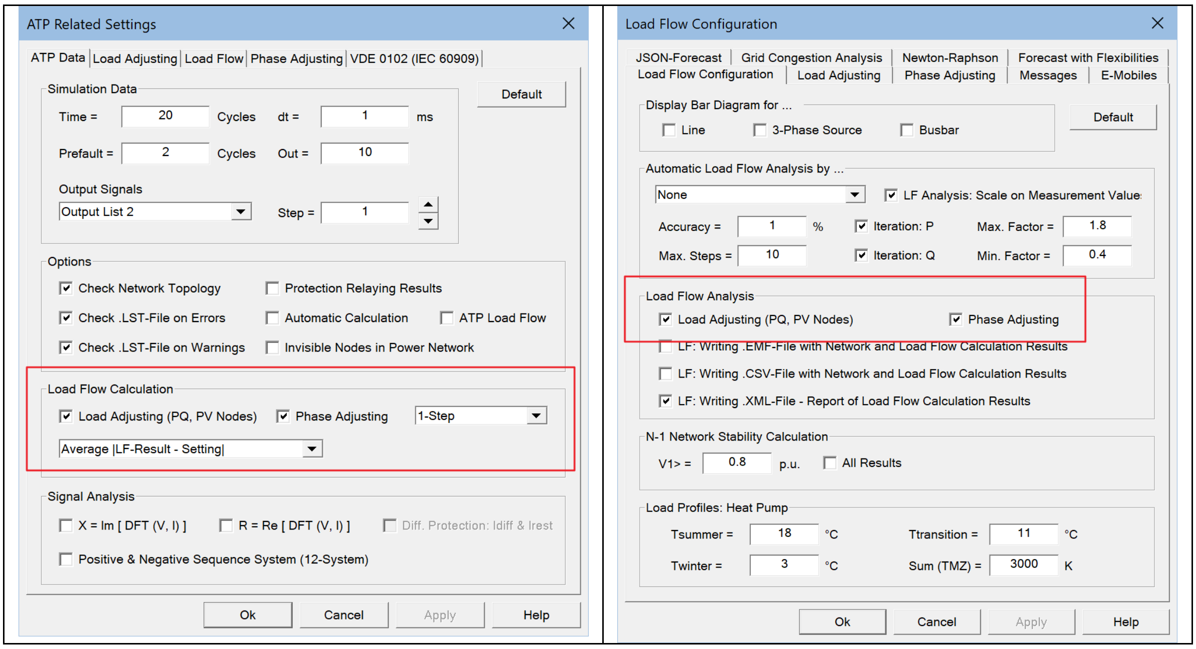
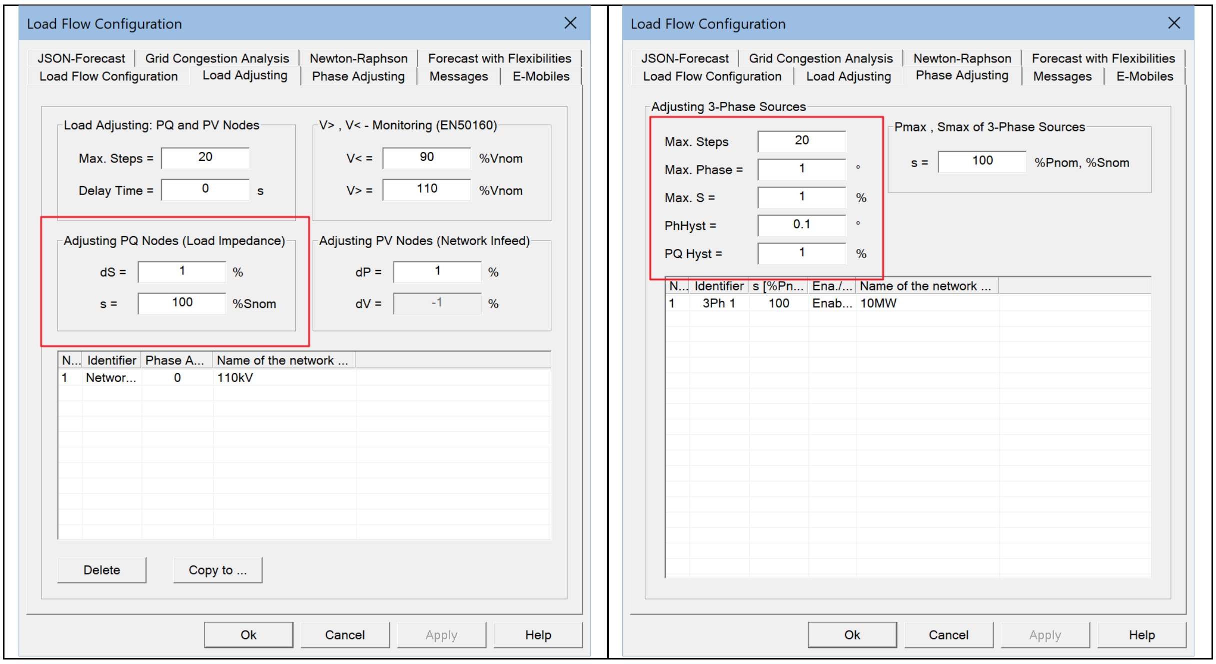


Figure 16: Settings of the method *Load Flow Calculation*

In addition, the accuracies and the maximum number of iteration steps can be changed in the tabs **Load Adjusting** and **Phase Adjusting** as shown above. It is possible to define a higher accuracy, but nevertheless, by changing the accuracy settings, the divergence of the load flow calculation (LF=failed) can be the result.


Load Flow Configuration
JSON-Forecast
Grid Congestion Analysis
Newton-Raphson
Forecast with Flexibilities
Load Flow Configuration
Load Adjusting
Phase Adjusting
Messages
E-Mobiles
Load Adjusting: PQ and PV Nodes
Max. Steps = 20
Delay Time = 0 s
V> , V< - Monitoring (EN50160)
V< = 90 %Vnom
V> = 110 %Vnom
Adjusting PQ Nodes (Load Impedance)
dS = 1 %
s = 100 %Snom
Adjusting PV Nodes (Network Infeed)
dP = 1 %
dV = -1 %
N... Identifier Phase A... Name of the network ...
1 Networ... 0 110kV
Delete
Copy to ...
Ok
Cancel
Apply
Help
Load Flow Configuration
JSON-Forecast
Grid Congestion Analysis
Newton-Raphson
Forecast with Flexibilities
Load Flow Configuration
Load Adjusting
Phase Adjusting
Messages
E-Mobiles
Adjusting 3-Phase Sources
Max. Steps 20
Max. Phase = 1 °
Max. S = 1 %
PhHyst = 0.1 °
PQ Hyst = 1 %
Pmax , Smax of 3-Phase Sources
s = 100 %Pnom, %Snom
N... Identifier s [%Pn... Ena./... Name of the network ...
1 3Ph 1 100 Enab... 10MW
Ok
Cancel
Apply
Help

11.12 Load Flow Calculation - Start

The load flow calculation can be started with a toolbar button, a menu item or a keyboard shortcut.

- Main menu **ATP**, Menu item **Short-Circuit Results**
- Toolbar-Button 
- Keyboard shortcut **CTRL + E**

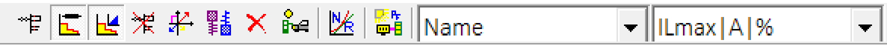
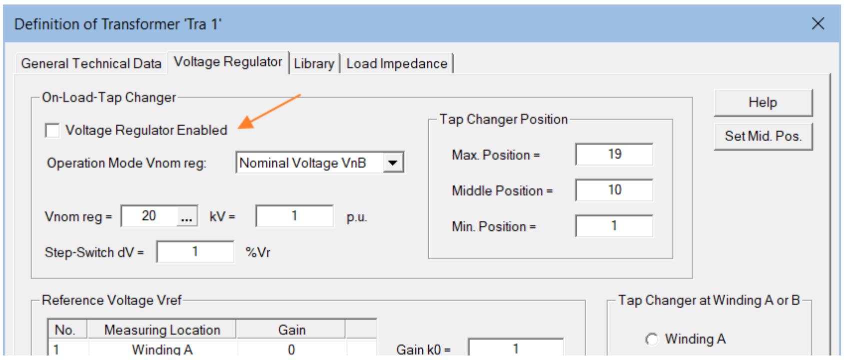
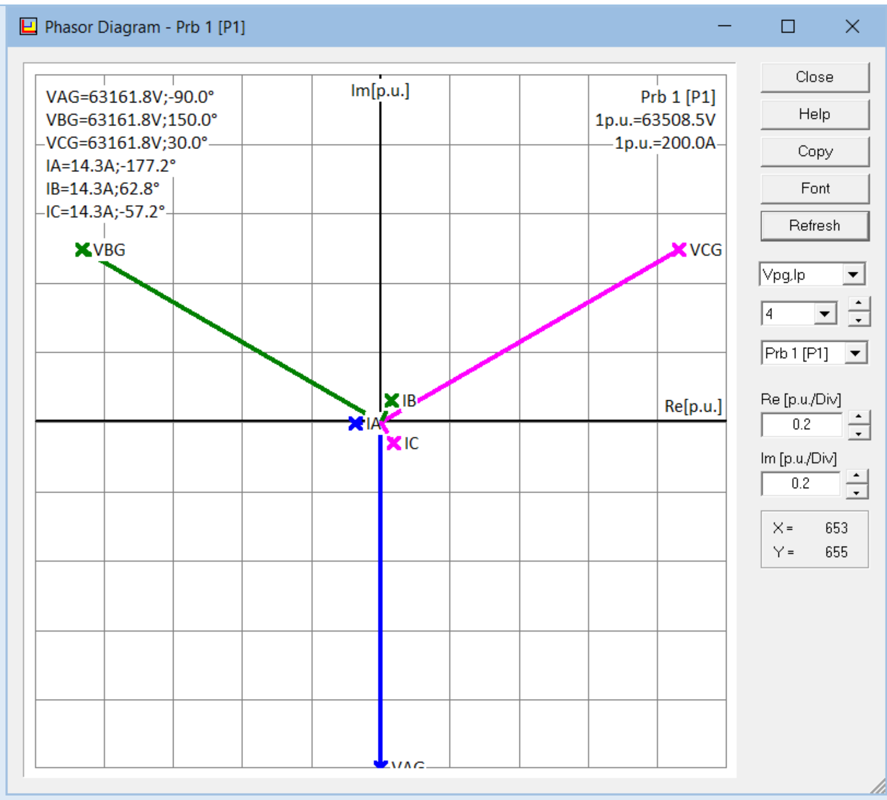
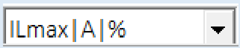


Figure 17: Load Flow -Toolbar : Toolbar to start the load flow calculation

Toolbar-Button	Description
	Start the load flow calculation
	Enable the load flow calculation for the network elements (equipment) ▪ **Load Impedance** ▪ **Network Infeed** ▪ **2-Winding Transformer** The algorithm of the load flow calculation considers tap changer and voltage regulator if enabled in the **Voltage Regulator** tab of the settings dialog of the transformer. 
	Enable the load flow calculation for the network elements (equipment) ▪ **3-Phase Source**
	Remove the results of the load flow calculation shown in the network graphic
	Open a dialog to show a phasor diagram of the results of the load flow calculation for the network element **Probe** The size of the diagram can be changed using the grip at the button-right corner in the dialog. ▪ Move the mouse cursor over the grip ▪ Press the left mouse button and keep it pressed ▪ Move the mouse ▪ Release the left mouse button

<table>
<tr><td></td><td>
</td></tr>
<tr><td>
</td><td>Settings of the network element Line displayed closed to the network element in the network graphic
⇨ This information will only be displayed, if the results of the load flow calculation are not displayed.
▪ Name: User-specific name of the network element
▪ R1|Ohm: Resistance of the positive-sequence system
▪ X1|Ohm: Reactance of the positive-sequence system
▪ L|km: Length of the line
▪ Imin: Minimum permissible phase current
▪ Imax: Maximum permissible phase current</td></tr>
<tr><td>
</td><td>Results of the load flow calculation of the network element Line displayed closed to the network element in the network graphic
⇨ This information will only be displayed, if the results of the load flow calculation are displayed in the network graphic.
▪ Ipmax|A: Maximum amount of the phase currents I_A, I_B and I_C
▪ P|MW, P|kW: Active power
▪ Q|Mvar, Q|kvar: Reactive power</td></tr>
</table>

11.13 Searching a Network Elements in the Network Graphic

The toolbar shown below can be used to search for text elements and identifiers in the network graphic in the settings of all network elements. Network elements that are found are highlighted in **red**. The search text is analysed intelligently. For example, spaces and upper/lower case are ignored.

Figure 18: Toolbar for searching a network element by analysing text elements and identifiers

Toolbar-Button	Description
	**Enter Search Text** The search text will be saved in the drop-down list and can be reused for the next search. Closing ATPDesigner, all search texts saved in the drop-down list will be saved in the registry of the operating system. During startup, ATPDesigner loads the search texts out of the registry of the operating system and store them in the drop-down list.
	**Start Searching a Network Element** If the network element has been found, it will be highlighted with a **red** background.
	Remove the **red** background
	**Continuing Searching a Network Element** The search will be continued using the same text element or identifier.
	**Delete the Content of the Drop-Down List** The selection list of search texts is deleted. The search texts in the registry database of the operating system are therefore also deleted closing ATPDesigner.

In the figure below, the 2-winding transformer has been searched using the text element “Tra 1”, found and was highlighted in **red**.

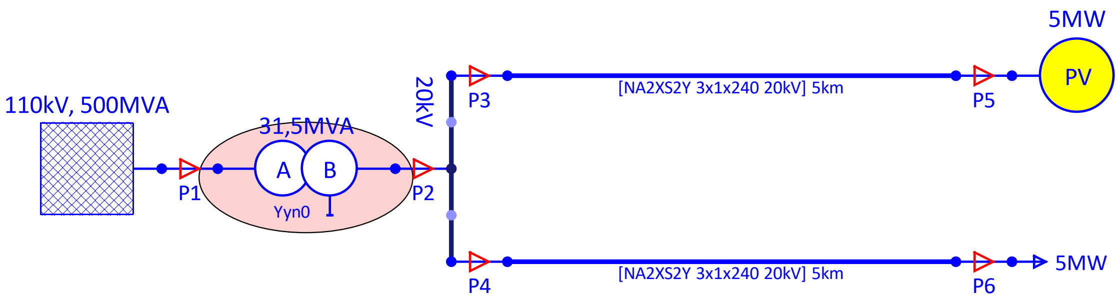
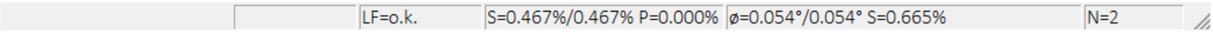


Figure 19: Searching a 2-winding transformer

11.14 Displaying the Results of the Load Flow Calculation

The most important results of a load flow calculation will be displayed directly in the network graphic. Please note, that the results are only displayed, if the load flow calculation is convergent.

⇨ If the load flow calculation is convergent, the **LF=o.k.** identifier will be displayed in the status bar.



The figure below shows the power grid with the results of the load flow calculation directly shown in the network graphic.

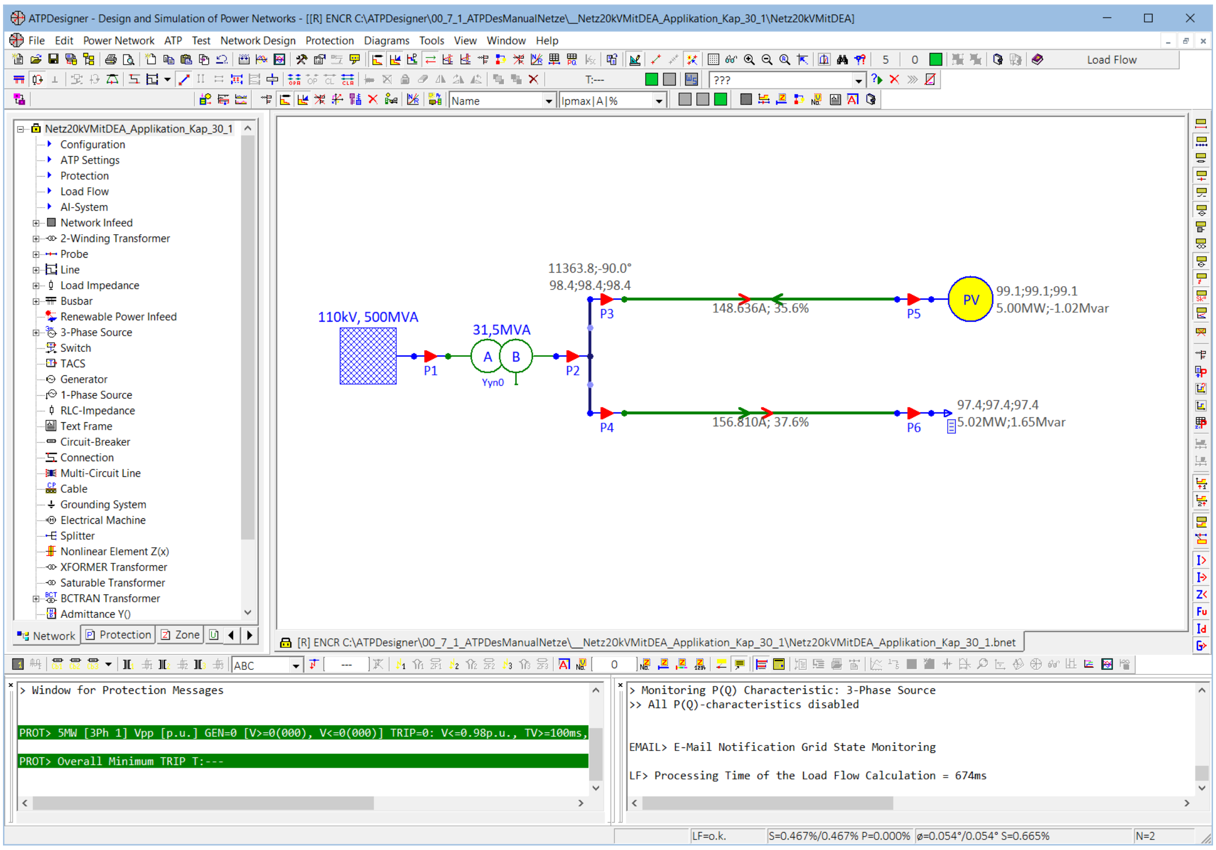


Figure 20: Results of the Load Flow Calculation displayed in the network graphic

Network Element 3-Phase Source

- Amount of the phase-to-ground voltages [$\%V_{nom}$]
- Active power P and reactive power Q

Network Element Busbar

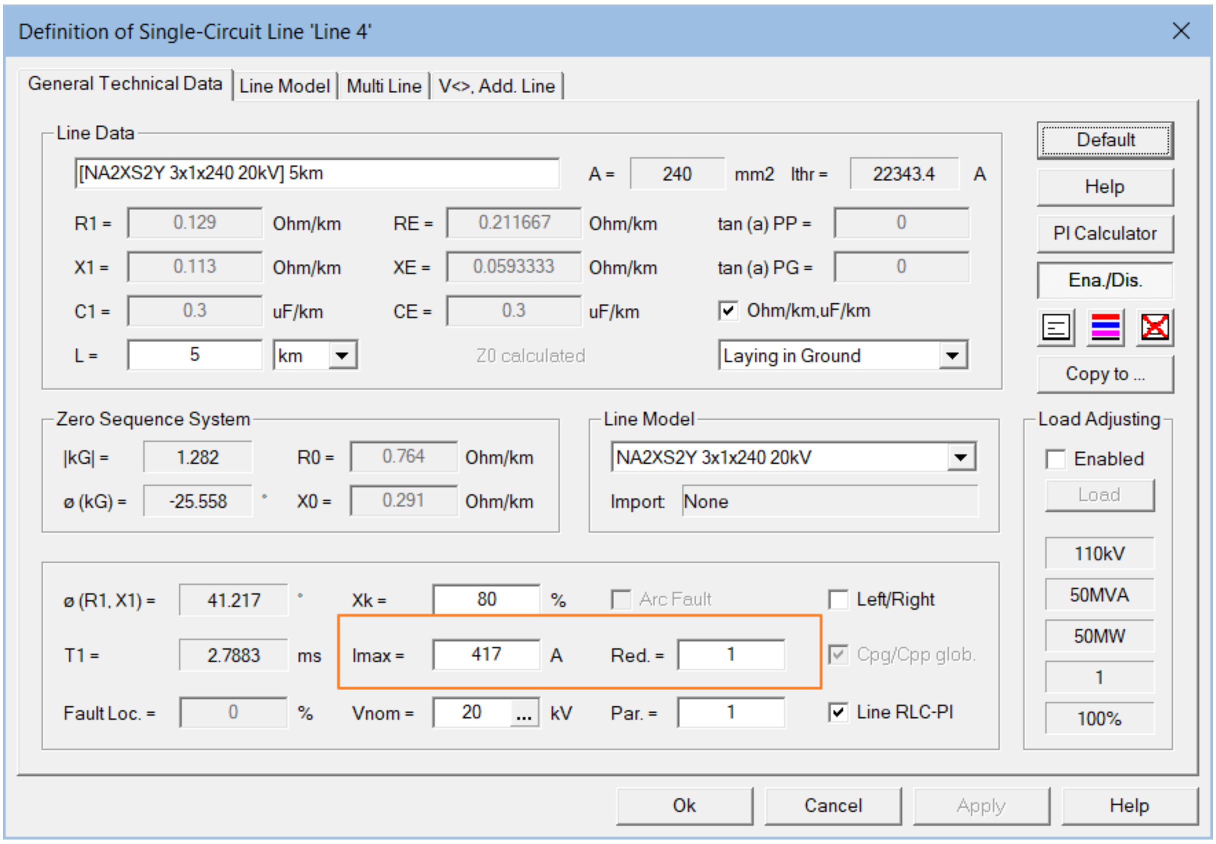
- Amount of the positive-sequence voltage in V
- Absolute phase angle of the positive-sequence voltage [°]
- Amount of the phase-to-ground voltages $\underline{V}_{AG}$, $\underline{V}_{BG}$ and $\underline{V}_{CG}$ [$\%V_{nom}/\sqrt{3}$]

Network Element Line

- Maximum amount of the phase currents $\underline{I}_{A}$, $\underline{I}_{B}$ and $\underline{I}_{C}$ [A]
- Maximum amount of the phase currents $\underline{I}_{A}$, $\underline{I}_{B}$ and $\underline{I}_{C}$ [%]

In order to calculate the maximum amount of the phase currents [%] , the both settings **Imax** and **Red.** Will be used by ATPDesigner.

$$I_{max}\left[\%\right] = \text{Imax} \cdot \text{Red.}$$



In the case of cable types defined in accordance with the standard VDE 0276 [2], the setting **Imax** corresponds to the rated current I_r of the cable type specified in the standard, depending on the type of installation, cross-section, etc.

The setting **Red.** must be calculated and set by the user.

⇨ It is recommended to determine the setting **Red.** for every line in accordance with the standard VDE 0276 [2] and applicable standards before calculating the load flow and to set it in the setting dialog of the network element **Line**.

Network Element Load Impedance

- Amount of the phase-to-ground voltages [$\%V_{nom}$]
- Active power P and reactive power Q

In addition, the results of the load flow calculation can be displayed in tooltips for network elements. To do this, the mouse cursor must be moved over the network element. Results and some important settings are displayed in a yellow-colored tooltip.

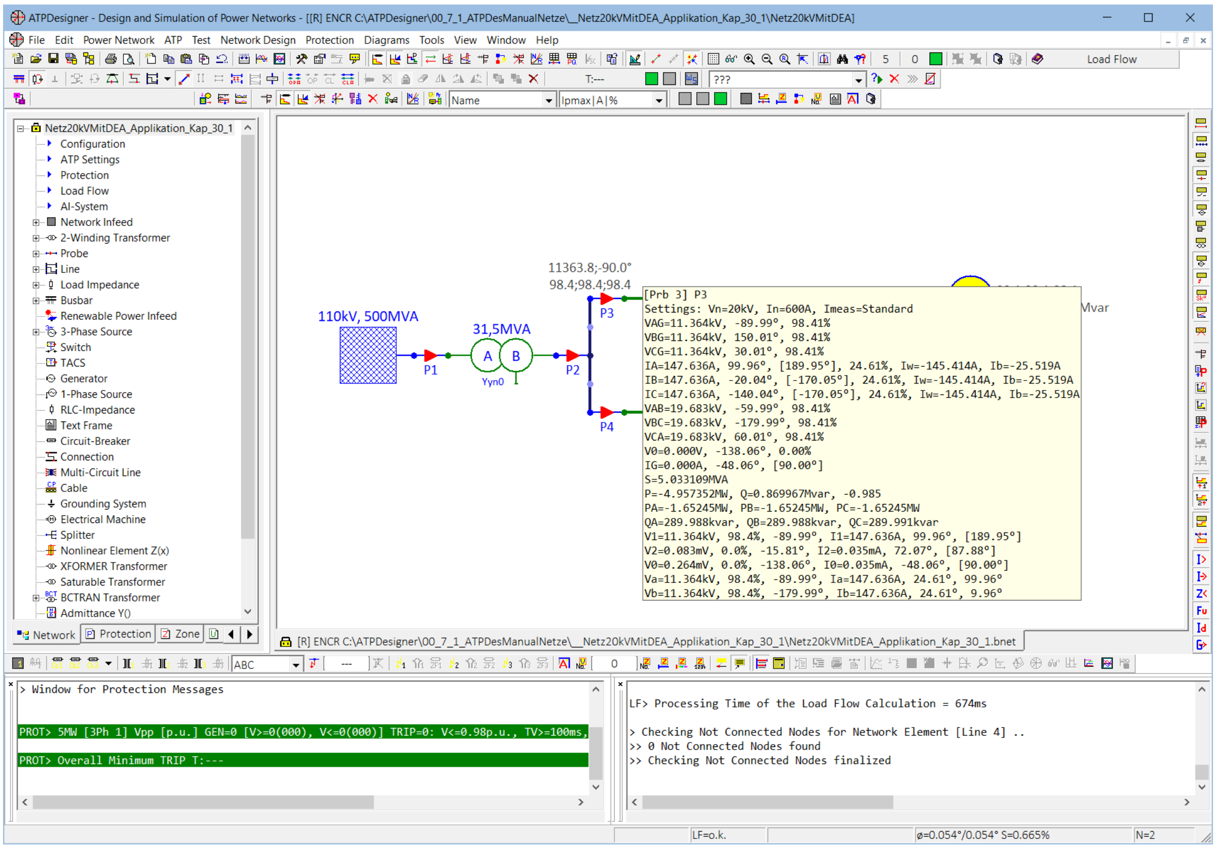


Figure 21: Results of the load flow calculation shown in a tooltip of the network element *Probe*

The results of the load flow calculation are also displayed in the **Messages Window**. The following figure shows an example. The message window can be enabled as explained below.

- Main menu **View**
- Menu item **Messages Window**, **Set Window Visible**

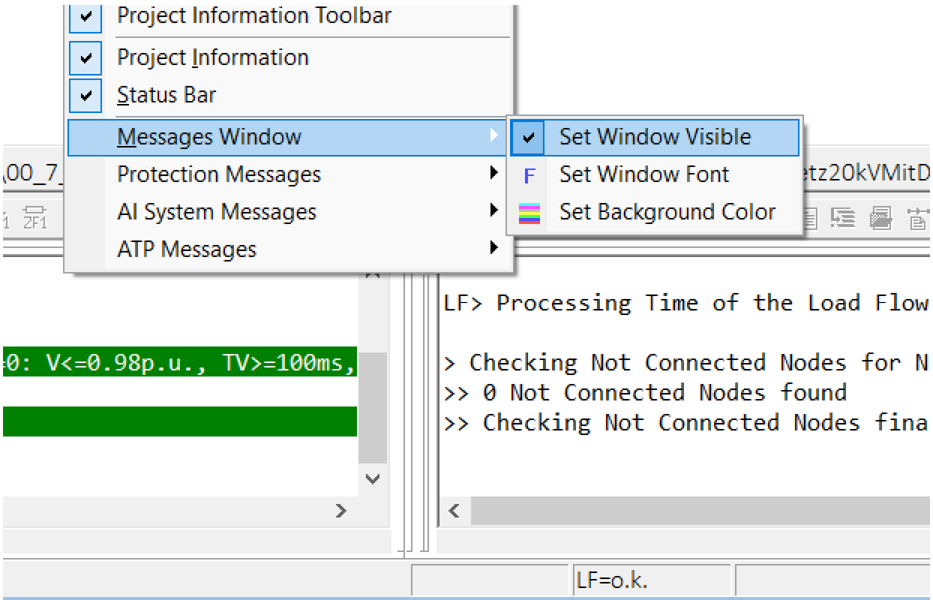


Figure 22: Enabling of the *Messages Window* for results of the load flow calculation

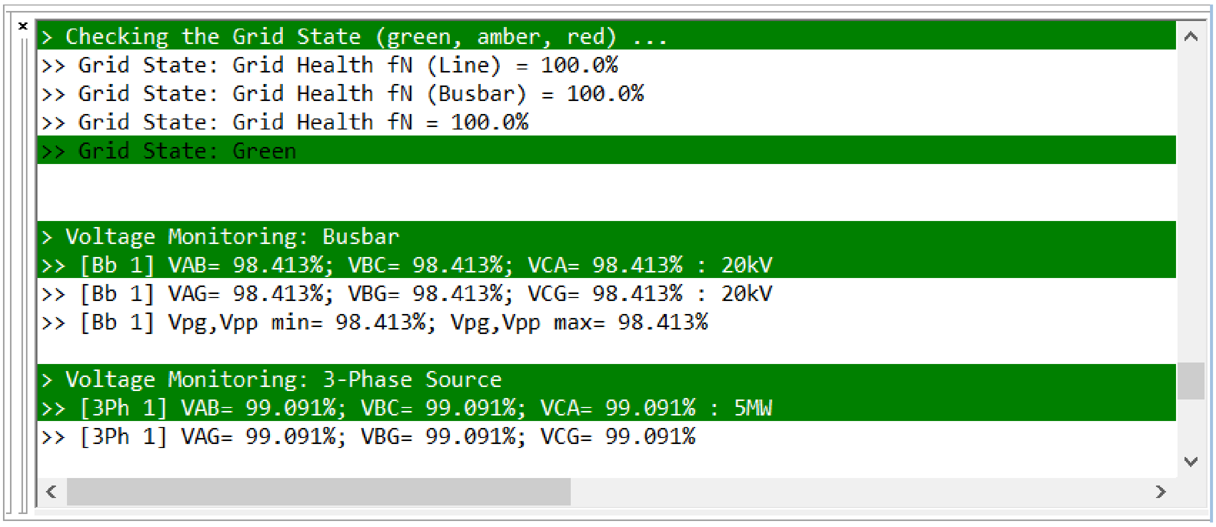
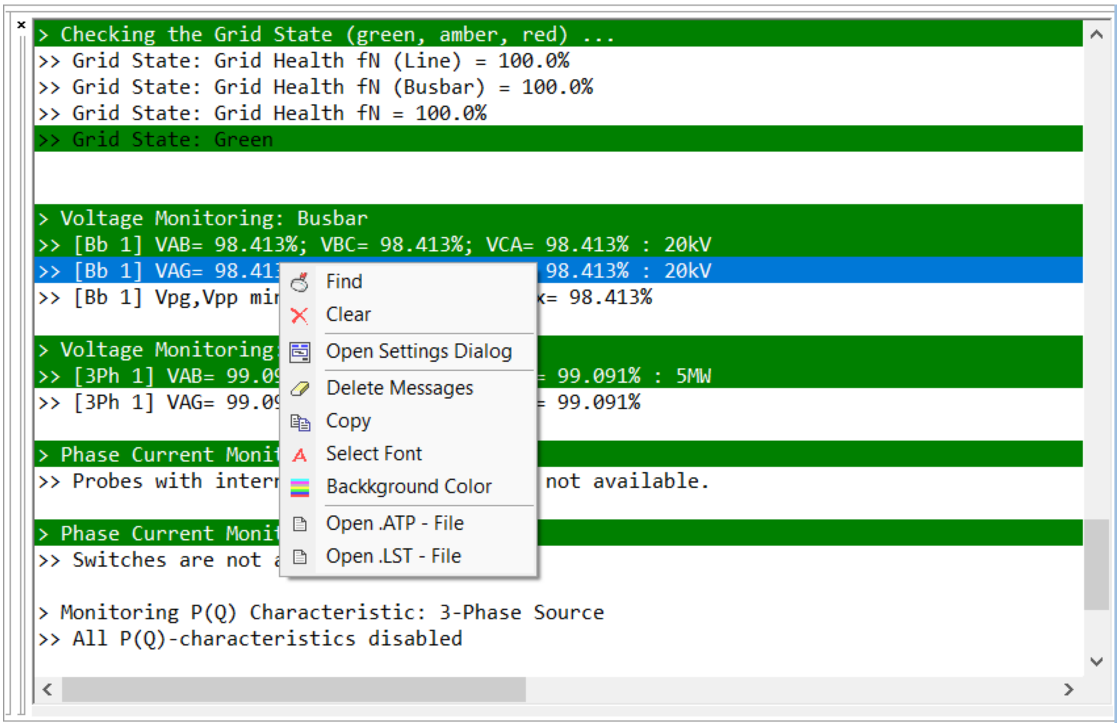


Figure 23: Results of the load flow calculation (example)

The results of the load flow calculation displayed in the **Messages Window** are self-explanatory. To find a network element in the network graphic that belongs to the results, the reference name of the network element will be used by ATPDesigner. The reference name is part of every line written in square brackets "[...]", e.g. [Bb 1].

To find the corresponding network element a context-sensitive menu can be opened using a **Right Mouse Button Click**.

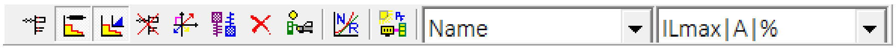
- Select a line with a **Left Mouse Button Click** on the line of the **Messages Window**
- Open the context-sensitive menu with a **Right Mouse Button Click**
- Select the menu item **Find** with a **Left Mouse Button Click** on the menu item.
  The network element will now be searched and if found, marked in **red** in the network graphic.



The results of the load flow calculation of the network elements **Probe** can also be displayed as a phasor diagram. The dialog can remain open parallel to the main window of ATPDesigner.

- Main menu **Diagrams**
- Menu item **Phasor Diagrams for Load Flow Results**

- Button in the Load Flow Toolbar



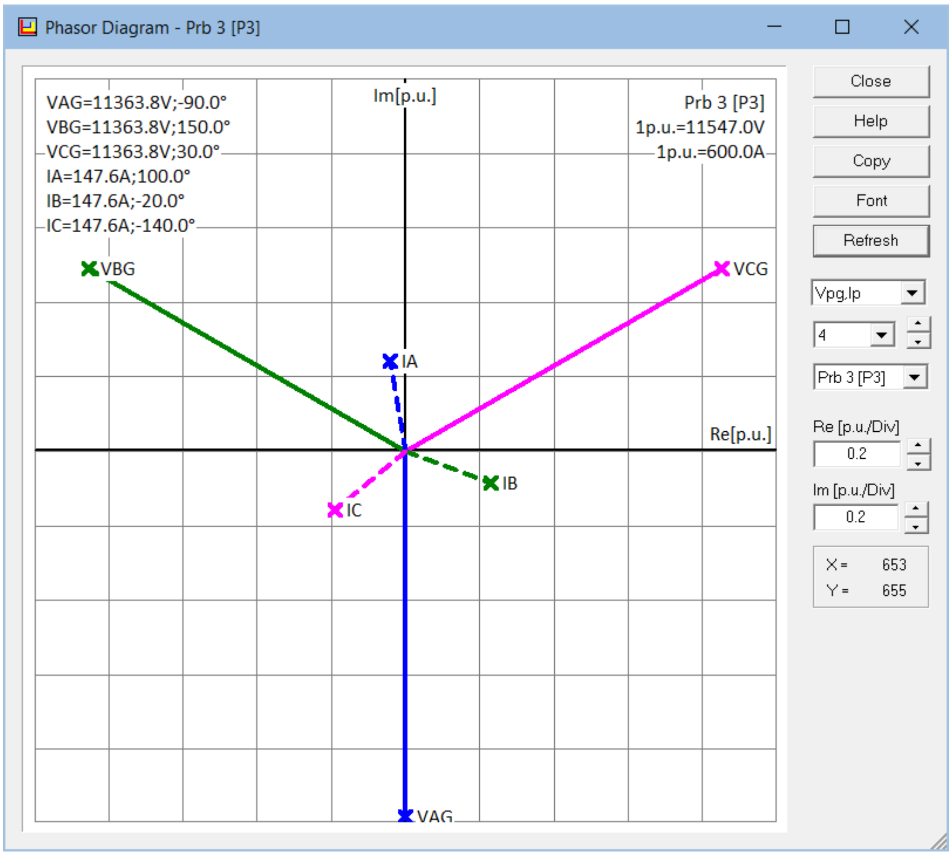


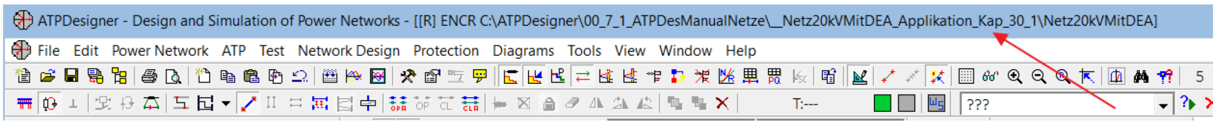
Figure 24: Results of the load flow calculation as a phasor diagram

Control	Description
Prb 1 [P1]	Drop-down list to select one of the measuring devices **Probe**
Vpg.Ip	Drop-down list of the operation mode of the diagram ▪ **Vpg**: Phase-to-ground voltages ▪ **Ip**: Phase currents ▪ **P**: Active Power ▪ **Q**: Reactive Power ▪ **012**: Voltages and currents of the 012-System, positive-sequence system, negative-sequence system and zero-sequence system ▪ **0ab**: Voltages and currents of the 0αβ-System (Clarke) ▪ **Zpg**: Impedances of the phase-to-ground measuring loop
4	Select the line thickness of the diagram
Copy	The diagram will be copied into the clipboard (.EMF-File)
Font	Select a for the diagram
Refresh	Redraw the content of the diagram
Close	Closing the dialog

11.15 Results of the Load Flow Calculation in a Report

ATPDesigner automatically writes the results of the load flow calculation in a **Report** (.XML-file) that is stored in the **Project Directory**. The **Project Directory** is the directory, where the .NET-file or .BNET-file (the file containing all data of the electrical power grid) has been saved. The name of the **Project Directory** of a .NET-file can be found in the header of ATPDesigner:

⇨ C:\ATPDesigner\00_7_1...



The **Messages** tab can be used, to enable or disable writing results of the load flow calculation into the **Report** (.XML-file).

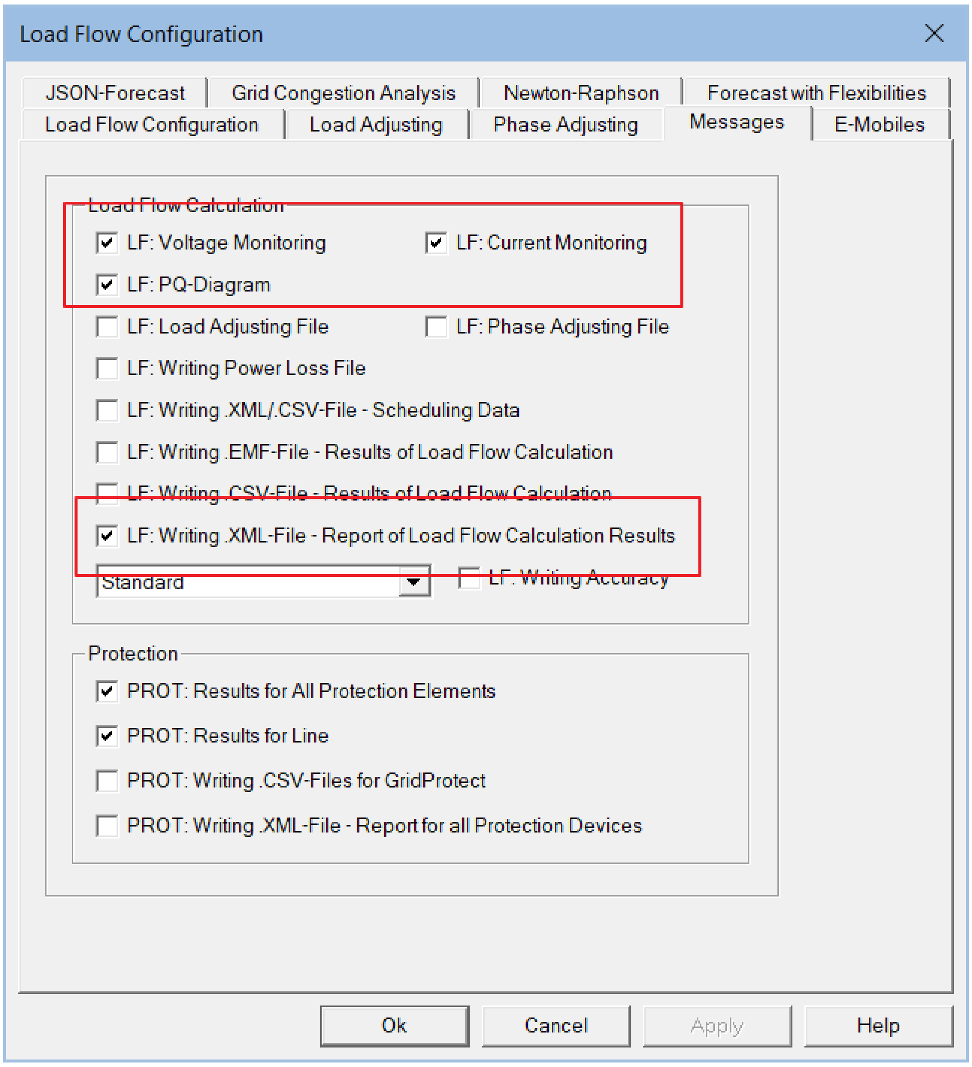


Figure 25: Enable writing the results of the load flow calculation in a *Report*

Option	
LF: Voltage Monitoring	Enable writing the results of the voltage monitoring into the report
LF: Current Monitoring	Enable writing the results of the current monitoring into the report

The user can enable or disable writing the report as shown in the figure above with the setting

⇨ **LF: Writing .XML-File – Report of Load Flow Calculation Results.**

This option must be enabled before the load flow calculation will be started. The report (.XML-file) will be stored in the **Project Directory**.

File Naming Convention:

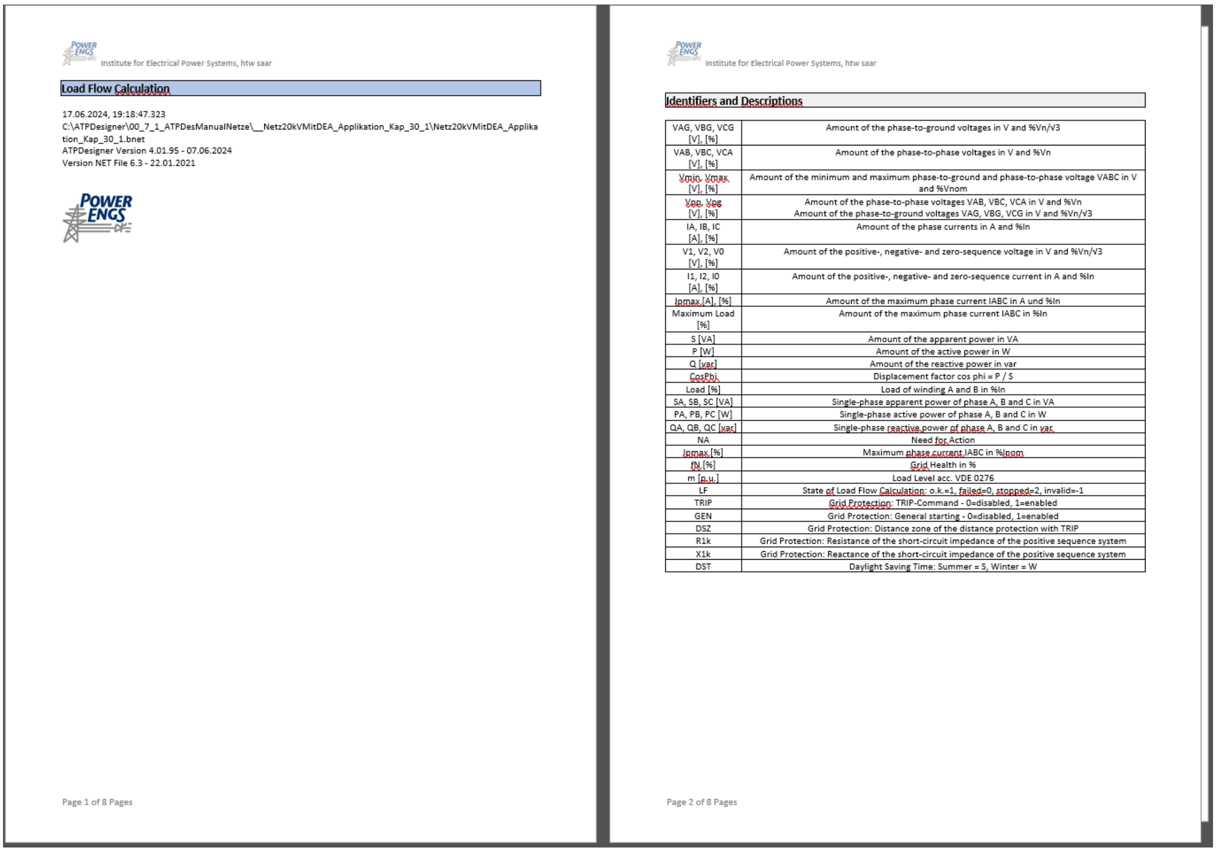
YYYYMMDDhhmmss_*Filename*_LF.xml

Storage Location:

Project Directory

Abbreviation	Description
YYYY	Year
MM	Month
DD	Day
hh	Hour
mm	Minute
ss	Second
Filename	Name of the .NET-file or the .BNET-file with file extension
_LF	Identifier **L**oad **F**low of the content of the **Report**

The following screenshots show examples of parts of the report (.XML-file). The file name of the report is defined as follows. The net file name is the file name of the associated .NET file.



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Load Flow Calculation

17.06.2024, 19:18:47.323
C:\ATPDesigner\00_7_1_ATPDesManualNetze__Netz20kVMitDEA_Applikation_Kap_30_1\Netz20kVMitDEA_Applikation_Kap_30_1.bnet
ATPDesigner Version 4.01.95 - 07.06.2024
Version NET File 6.3 - 22.01.2021

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Identifiers and Descriptions

VAG, VBG, VCG [V], [%]	Amount of the phase-to-ground voltages in V and %Vn/√3
VAB, VBC, VCA [V], [%]	Amount of the phase-to-phase voltages in V and %Vn
Vmin, Vmax [V], [%]	Amount of the minimum and maximum phase-to-ground and phase-to-phase voltage VABC in V and %Vnom
Vpp, Vpg [V], [%]	Amount of the phase-to-phase voltages VAB, VBC, VCA in V and %Vn Amount of the phase-to-ground voltages VAG, VBG, VCG in V and %Vn/√3
IA, IB, IC [A], [%]	Amount of the phase currents in A and %In
V1, V2, V0 [V], [%]	Amount of the positive-, negative- and zero-sequence voltage in V and %Vn/√3
I1, I2, I0 [A], [%]	Amount of the positive-, negative- and zero-sequence current in A and %In
Ipmax [A], [%]	Amount of the maximum phase current IABC in A und %In
Maximum Load [%]	Amount of the maximum phase current IABC in %In
S [VA]	Amount of the apparent power in VA
P [W]	Amount of the active power in W
Q [var]	Amount of the reactive power in var
CosPhi	Displacement factor cos phi = P / S
Load [%]	Load of winding A and B in %In
SA, SB, SC [VA]	Single-phase apparent power of phase A, B and C in VA
PA, PB, PC [W]	Single-phase active power of phase A, B and C in W
QA, QB, QC [var]	Single-phase reactive power of phase A, B and C in var
NA	Need for Action
Ipmax [%]	Maximum phase current IABC in %Inom
fN [%]	Grid Health in %
m [p.u.]	Load Level acc. VDE 0276
LF	State of Load Flow Calculation: o.k.=1, failed=0, stopped=2, invalid=-1
TRIP	Grid Protection: TRIP-Command - 0=disabled, 1=enabled
GEN	Grid Protection: General starting - 0=disabled, 1=enabled
DSZ	Grid Protection: Distance zone of the distance protection with TRIP
R1k	Grid Protection: Resistance of the short-circuit impedance of the positive sequence system
X1k	Grid Protection: Reactance of the short-circuit impedance of the positive sequence system
DST	Daylight Saving Time: Summer = S, Winter = W

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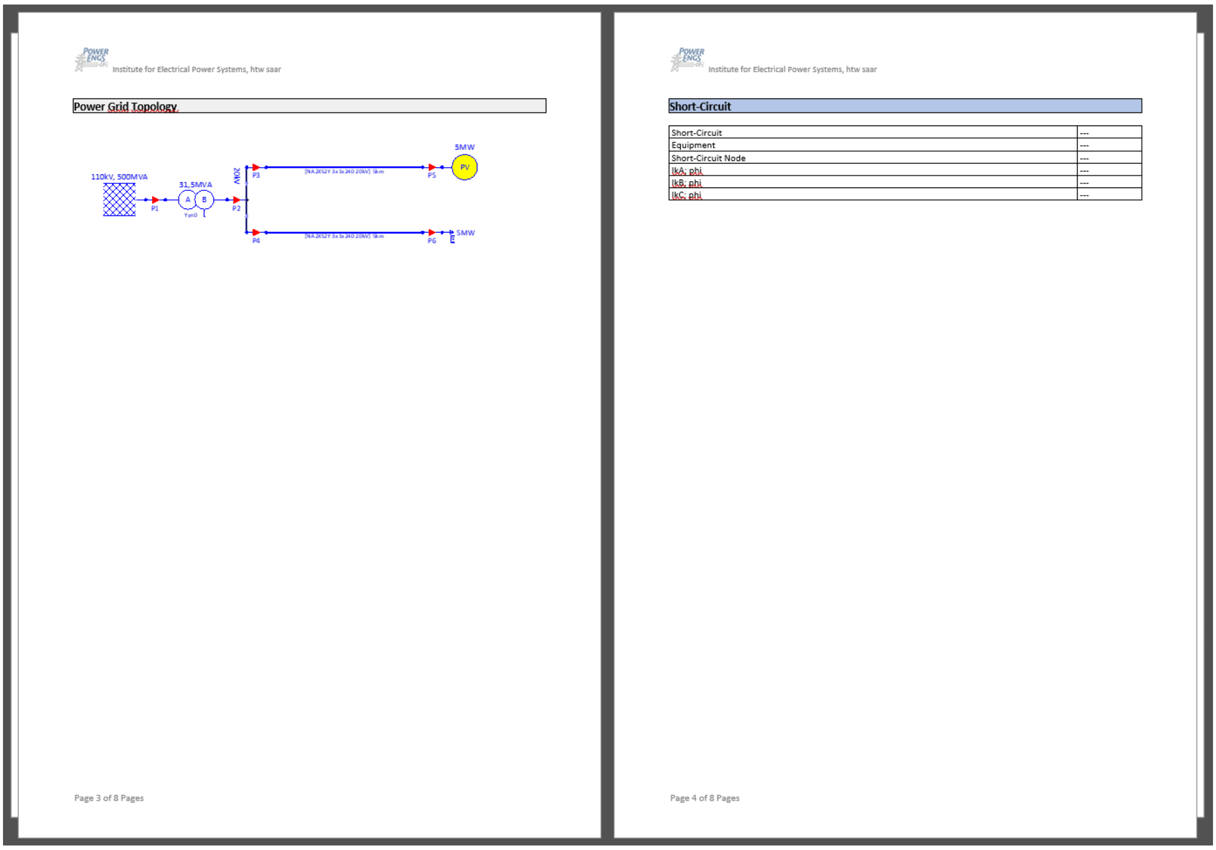
Figure 26: Report of the results of a load flow calculation



Short-Circuit

Short-Circuit	---
Equipment	---
Short-Circuit Node	---
IkA; phi	---
IkB; phi	---
IkC; phi	---

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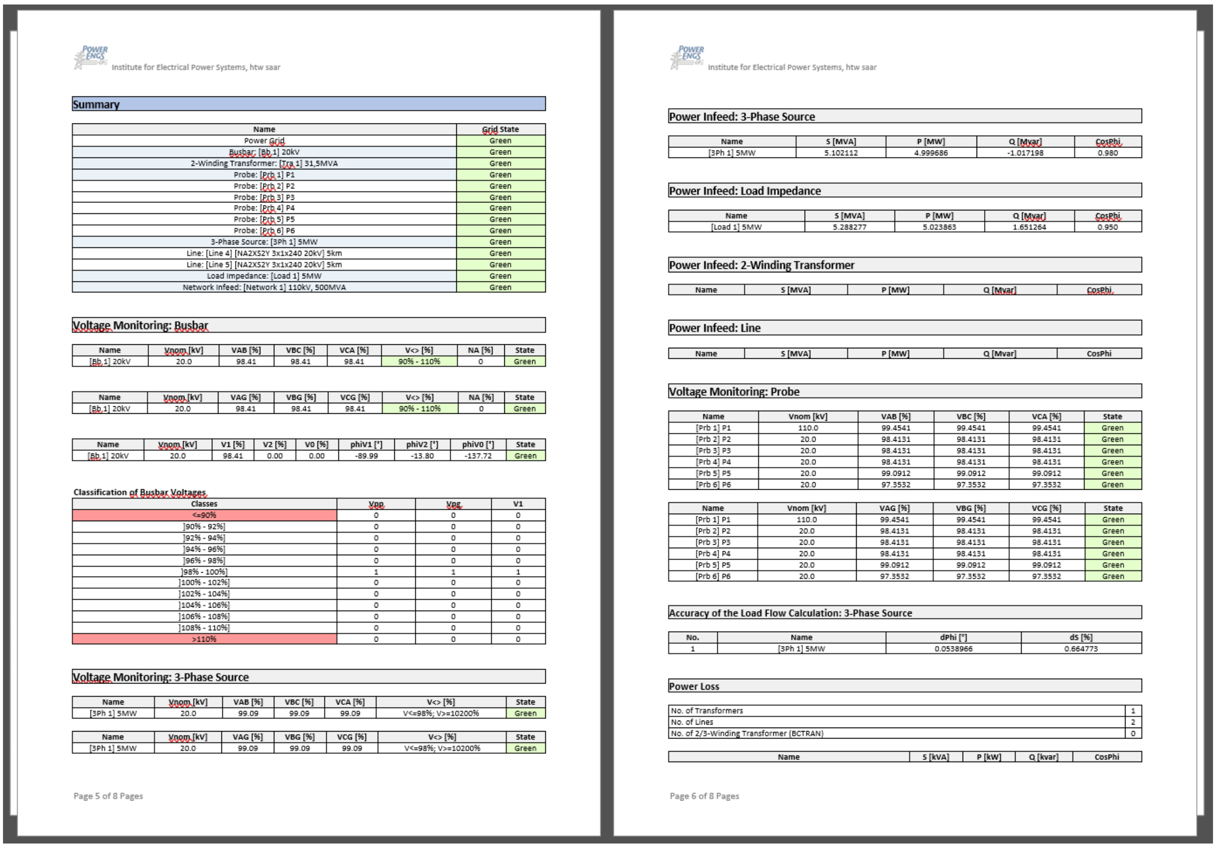
Figure 27: Report of the results of a load flow calculation



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Summary

Name	Grid State
Power Grid	Green
Busbar: [Bb 1] 20kV	Green
2-Winding Transformer: [Tra 1] 31,5MVA	Green
Probe: [Prb 1] P1	Green
Probe: [Prb 2] P2	Green
Probe: [Prb 3] P3	Green
Probe: [Prb 4] P4	Green
Probe: [Prb 5] P5	Green
Probe: [Prb 6] P6	Green
3-Phase Source: [3Ph 1] 5MW	Green
Line: [Line 4] [NA2XS2Y 3x1x240 20kV] 5km	Green
Line: [Line 5] [NA2XS2Y 3x1x240 20kV] 5km	Green
Load Impedance: [Load 1] 5MW	Green
Network Infeed: [Network 1] 110kV, 500MVA	Green

Voltage Monitoring: Busbar

Name	Vnom [kV]	VAB [%]	VBC [%]	VCA [%]	V<> [%]	NA [%]	State
[Bb 1] 20kV	20.0	98.41	98.41	98.41	90% - 110%	0	Green

Name	Vnom [kV]	VAG [%]	VBG [%]	VCG [%]	V<> [%]	NA [%]	State
[Bb 1] 20kV	20.0	98.41	98.41	98.41	90% - 110%	0	Green

Name	Vnom [kV]	V1 [%]	V2 [%]	V0 [%]	phiV1 [°]	phiV2 [°]	phiV0 [°]	State
[Bb 1] 20kV	20.0	98.41	0.00	0.00	-89.99	-13.80	-137.72	Green

Classification of Busbar Voltages

Classes	Vpp	Vpg	V1
<=90%	0	0	0
]90% - 92%]	0	0	0
]92% - 94%]	0	0	0
]94% - 96%]	0	0	0
]96% - 98%]	0	0	0
]98% - 100%]	1	1	1
]100% - 102%]	0	0	0
]102% - 104%]	0	0	0
]104% - 106%]	0	0	0
]106% - 108%]	0	0	0
]108% - 110%]	0	0	0
>110%	0	0	0

Voltage Monitoring: 3-Phase Source

Name	Vnom [kV]	VAB [%]	VBC [%]	VCA [%]	V<> [%]	State
[3Ph 1] 5MW	20.0	99.09	99.09	99.09	V<=98%; V>=10200%	Green

Name	Vnom [kV]	VAG [%]	VBG [%]	VCG [%]	V<> [%]	State
[3Ph 1] 5MW	20.0	99.09	99.09	99.09	V<=98%; V>=10200%	Green

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Power Infeed: 3-Phase Source

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi
[3Ph 1] 5MW	5.102112	4.999686	-1.017198	0.980

Power Infeed: Load Impedance

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi
[Load 1] 5MW	5.288277	5.023863	1.651264	0.950

Power Infeed: 2-Winding Transformer

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi

Power Infeed: Line

Name	S [MVA]	P [MW]	Q [Mvar]	CosPhi

Voltage Monitoring: Probe

Name	Vnom [kV]	VAB [%]	VBC [%]	VCA [%]	State
[Prb 1] P1	110.0	99.4541	99.4541	99.4541	Green
[Prb 2] P2	20.0	98.4131	98.4131	98.4131	Green
[Prb 3] P3	20.0	98.4131	98.4131	98.4131	Green
[Prb 4] P4	20.0	98.4131	98.4131	98.4131	Green
[Prb 5] P5	20.0	99.0912	99.0912	99.0912	Green
[Prb 6] P6	20.0	97.3532	97.3532	97.3532	Green

Name	Vnom [kV]	VAG [%]	VBG [%]	VCG [%]	State
[Prb 1] P1	110.0	99.4541	99.4541	99.4541	Green
[Prb 2] P2	20.0	98.4131	98.4131	98.4131	Green
[Prb 3] P3	20.0	98.4131	98.4131	98.4131	Green
[Prb 4] P4	20.0	98.4131	98.4131	98.4131	Green
[Prb 5] P5	20.0	99.0912	99.0912	99.0912	Green
[Prb 6] P6	20.0	97.3532	97.3532	97.3532	Green

Accuracy of the Load Flow Calculation: 3-Phase Source

No.	Name	dPhi [°]	dS [%]
1	[3Ph 1] 5MW	0.0538966	0.664773

Power Loss

No. of Transformers	1
No. of Lines	2
No. of 2/3-Winding Transformer (BCTRAN)	0

Name	S [kVA]	P [kW]	Q [kvar]	CosPhi

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Figure 28: Report of the results of a load flow calculation

The **Report** can be opened and read directly into a word processing software such as Word. Below two tables are explained more in details.

Grid State of Lines

Line: Validation acc.	Valid	Partly Valid	Invalid
VDE 0276	2	---	0
Green/Amber/Red acc. BDEW	2	0	0
EN 50160	2	---	0

Figure 29: Results of the Steady-State Grid Analysis of the network elements *Line*

The German standards VDE 0276 [2], EN 50160 [1] and the German discussion paper **BDEW Traffic Light Concept** are used to assess the grid condition of the lines.

- **Valid**
  The network element **Line** fulfil the criteria of the standards and recommendations.

- **Partly Valid**
  The network element **Line** fulfil the criteria of the standards, but they are in the amber phase according to the **BDEW Smart Grid Traffic Light Concept** [3].

- **Invalid**
  The network elements **Line** do not fulfil the criteria of the standards and recommendations.

Load Flow Results: Line

Name	IA [A]	IB [A]	IC [A]	Ipmax [A]	Ipmax [%]	I1 [A]	I2 [A]	I0 [A]	State
[Line 4] [NA2XS2Y 3x1x240 20kV] 5km	148.64	148.64	148.64	148.64	35.64	148.64	0.00	0.00	Green
[Line 5] [NA2XS2Y 3x1x240 20kV] 5km	156.81	156.81	156.81	156.81	37.60	156.81	0.00	0.00	Green

Name	Vnom [kV]	Vpgmin [%]	Vpgmax [%]	State
[Line 4] [NA2XS2Y 3x1x240 20kV] 5km	20.0	98.41	99.09	Green
[Line 5] [NA2XS2Y 3x1x240 20kV] 5km	20.0	97.35	98.41	Green

Figure 30: Table with results of the network steady-state conditions of the lines

The settings can be defined user-specific using the settings dialog shown below.

$$1 p.u. = V_{nom}$$

- Main menu **Power Network**
- Menu item **Network Configuration**, tab **Monitoring**

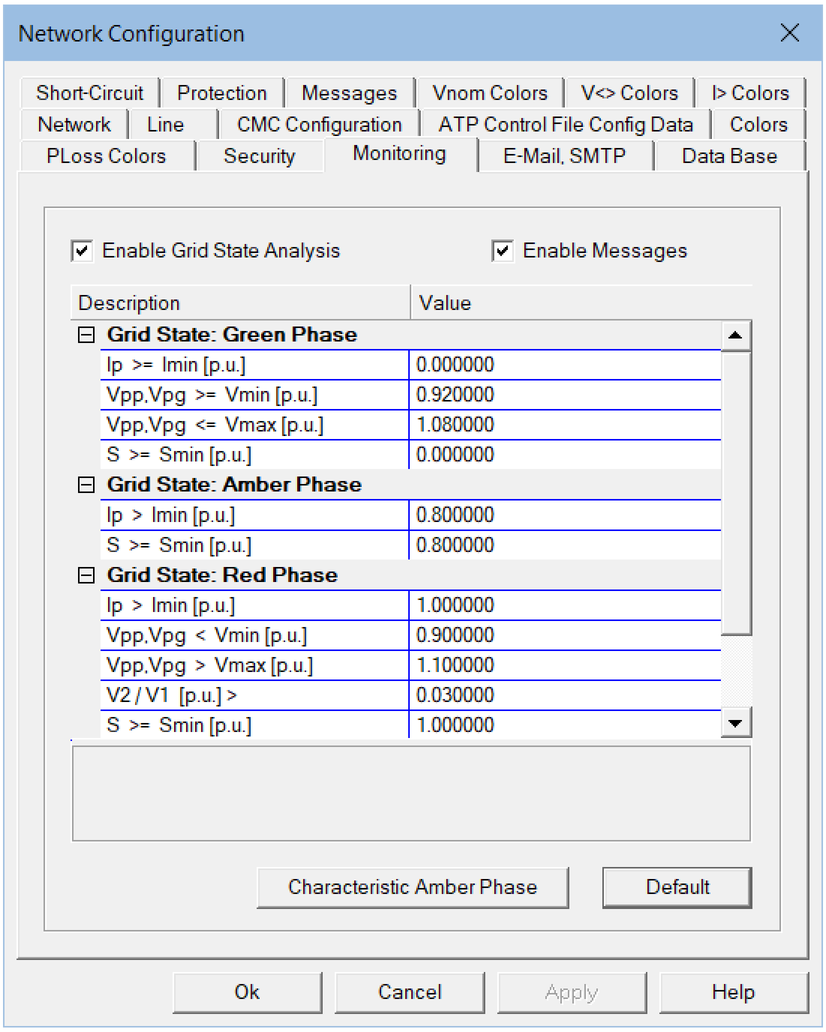


Figure 23: Settings dialog to define user-specific settings for the *BDEW Smart Grid Traffic Light Concept* [3]

12 Power Grid Utilization Analysis using Load Profiles

To perform a power grid utilization analysis (also known as power grid load analysis) over defined time periods, time series calculations (also called load flow calculations with load profiles) are generally carried out.

⇨ A **time series calculation** is generally a sequence of load flow calculations for a fixed time period using equidistant time steps of 15-minutes (**15-minute interval**).

For a time series calculation, it is assumed that the power flow remains constant within every 15-minute interval of the time series and can only change at the beginning of the next 15-minute interval. Consequently, a steady-state grid condition is assumed for every 15-minute interval, where voltages, currents, and power flows can be determined using a load flow calculation. The grid state within a 15-minute interval is considered symmetrical and fault-free, thereby defining the normal operation of the power grid. In principle, time series calculations can also be extended to consider also short-circuit conditions of the power grid.

The time labeling of the 15-minute intervals follows the definition of standard load profiles according to VDEW [8]. The timestamp used always corresponds to the end of the 15-minute interval. According to VDEW [8] or BDEW [10], for example, the last 15-minute interval of a day is labeled with the timestamp 00:00, while the first 15-minute interval of a day is labeled with the timestamp 00:15.

Power grid utilization analysis using time series calculations can be performed with the network calculation software ATPDesigner, for example, using the network calculation function **Load Flow Analysis: Load Profiles**. Standard load profiles defined by VDEW [8] or BDEW [10] or other load profiles defined according to VDEW [8] or BDEW [10] are generally used to define the consumption or infeed power of equipment for every 15-minute interval in a time series. The consumption and infeed equipment are assumed to be PQ nodes with a constant consumption or infeed power within every 15-minute interval, separately defined for active power P and reactive power Q. The available load profiles are shown in the table below.

Load Profile	General and User-Specific Load Profiles
H0	Household customers acc. VDEW
H0 dyn.	Household customers (with dynamization) acc. VDEW
G0	Shop in general acc. VDEW
G1	Business days of the week 8-18Uhr
G2	Businesses with heavy to predominant consumption in the evening hours acc. VDEW
G3	Shop all days the week acc. VDEW
G4	Shop/hairdresser acc. VDEW
G5	Bakery with bakehouse acc. VDEW
G6	Weekend business acc. VDEW
L0	Agricultural business acc. VDEW
L1	Farms with dairy farming or part-time animal husbandry acc. VDEW
L2	Farms without L1 acc. VDEW
EM0	Electromobility home scenario
EM1	Electromobility home and work scenario
EM2	Electromobility scenario comprehensive
AL0	User specific load profile
AL1	User specific load profile
AL2	User specific load profile
H25	Updated household profile (H25) acc. BDEW
G25	Updated trade profile (G25) acc. BDEW
L25	Updated agricultural profile (L25) acc. BDEW
P25	Updated combination profile PV (P25) acc. BDEW
S25	Updated combination profile PV and battery storage (S25) acc. BDEW

12.1 Standard Load Profiles acc. VDEW [8]

The network calculation software ATPDesigner uses text files based on the .CSV-format according to the German technical specification VDEW [8], which contain the active power P of the standard load profiles, defined as a constant active power for every 15-minute interval. The files of the load profile files are stored in the directory **c:\atpdesigner\exe\LoadProfiles**. The file format will be explained below using comments written in red color, which are not part of the file format.

```
(Kunde-)Name:;;
(Kanal-)Beschreibung:;;
(Kanal-)Ident3:;H0;        // name of the load profile
Summe (kWh):;1000;         // reference value of the electrical energy per year
Sommerzeit;kW              // time zone: summer; unit of values of active power
Werktag 00:15;0,08636;     // business day; 15-min interval; active power P[kW]
Werktag 00:30;0,07696;
Werktag 00:45;0,06884;
Werktag 01:00;0,06244;
Werktag 01:15;0,05804;
Werktag 01:30;0,05528;
…
```

Figure 24: Structure of a .CSV file for load profiles according to VDEW [8]

The absolute value of the active power P for the 15-minute interval can be calculated as shown below.

$$P[kW] = \frac{P_{CSV}[kW] \cdot E_{Year}[kWh]}{1000kWh}$$

- E_{Year} : Sum of the electrical energy consumption of one year
- P_{CSV} : Active power P_{CSV} read out of the .CSV-files of the standard load profiles

Below the menu items, how to start the calculation method available in ATPDesigner.

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility, Load Flow Analysis: Load Profiles**

Time Period	Description
Sommer (summer)	**15.05. – 14.09.**
Übergang (transition = spring and autumn)	**21.03. – 14.05.** and **15.09. – 31.10.**
Winter (winter)	**01.11. – 20.03.**

The structure of the file names of the .CSV files are explained below. The .CSV files are stored in the directory **c:\atpdesigner\exe\LoadProfiles**.

File name	Description
LoadProfile_**x**_**y**.CSV	**x** : Abbreviation for a standard load profile according to VDEW [8] (see table below) or for a user-specific load profile: ▪ **EM0..2** : load profiles for e-mobile ▪ **AL0..2** : user specific load profile ▪ **PV** : load profile for photo voltaic power plant ▪ **WP** : load profile for Wind power plant **Time zones available acc. VDEW [8]:** **y** : **S** = summer, **W** = winter, **U** = transition (spring and autumn)

12.2 Load Profiles acc. BDEW [10]

The network calculation software ATPDesigner also uses text files based on the .CSV-format according to the German technical specification BDEW [10], which contain the active power P of load profiles, defined as a constant active power for every 15-minute interval. The files of the load profile files are stored in the directory **c:\atpdesigner\exe\LoadProfiles**.

The absolute value of the active power P for the 15-min interval can be calculated as shown below. Please note that the reference value has been changed.

$$P[kW] = \frac{P_{CSV}[kW] \cdot E_{Year}[kWh]}{1.000.000 kWh}$$

- E_{Year} : Sum of the electrical energy consumption of one year
- P_{CSV} : Active power P_{CSV} read out of the .CSV-files of the standard load profiles

Below the menu items, how to start the calculation method available in ATPDesigner.

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility, Load Flow Analysis: Load Profiles**

In contrast to the standard load profiles acc. VDEW [8], the load profiles acc. BDEW [10] are defined for every month separately. Therefore, time zones are not used. Every load profile is stored in a .CSV-File.

File name	Description
LoadProfile_**x**.CSV	**x** : Abbreviation for a standard load profile according to BDEW [10]

12.3 Load Flow Analysis using Load Profiles stored in a .CSV File

As explained above, load profiles acc. VDEW [8] or BDEW [10] use values of the active power P for 15-minute intervals. It will be assumed that the active power P is constant for every 15minute-interval. The load profiles can be used to define the time dependent behaviour of the active power P of the network elements **Load Impedance** and **3-Phase Source**.

12.3.1 Using Load Profiles: *Load Impedance*

Before starting a power grid utilization analysis using load profiles, the network element **Load Impedance** must be set as explained below.

- Tab **General Technical Data**

Setting	Value
Operating Mode	**Load Profile (Y) or Load Profile (D)**

- Tab **Load Profiles**
  At least one load profile must be selected in the spread sheet. In addition, the sum of the energy E [kWh/a] etc. must be set.

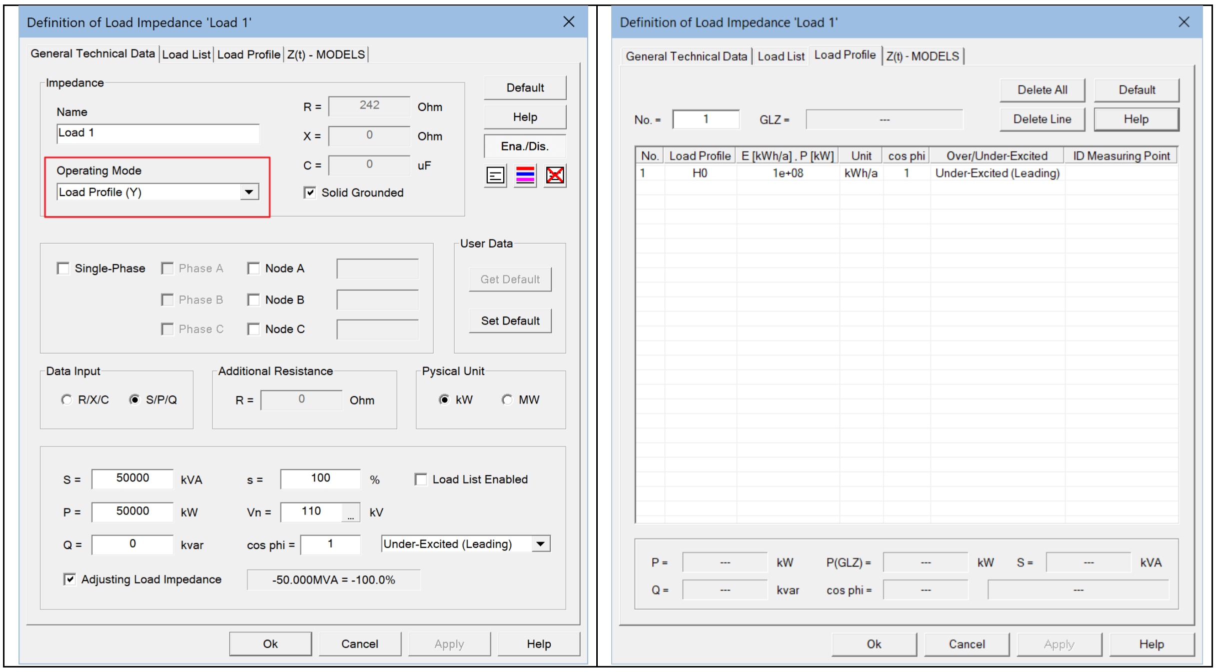


Figure 25: Settings dialog of the network element *Load Impedance*

12.3.2 Using Load Profiles: 3-*Phase Source*

Before starting a power grid utilization analysis using load profiles, the network element **3-Phase Source** must be set as explained below.

- Tab **General Technical Data**
  The **Operation Mode *Pnom(Ip:3p) = const.*** shall be preferred selected. It is also possible the use **Operation Mode *Snom(Ip:3p) = const.*.**

- Tab **Load Profile**
  Only one load profile can be selected in **Operation Mode**. In addition, the setting Energy must be set to the sum of the energy consumption of the year. The option **Enable Energy Analysis** must be enabled.

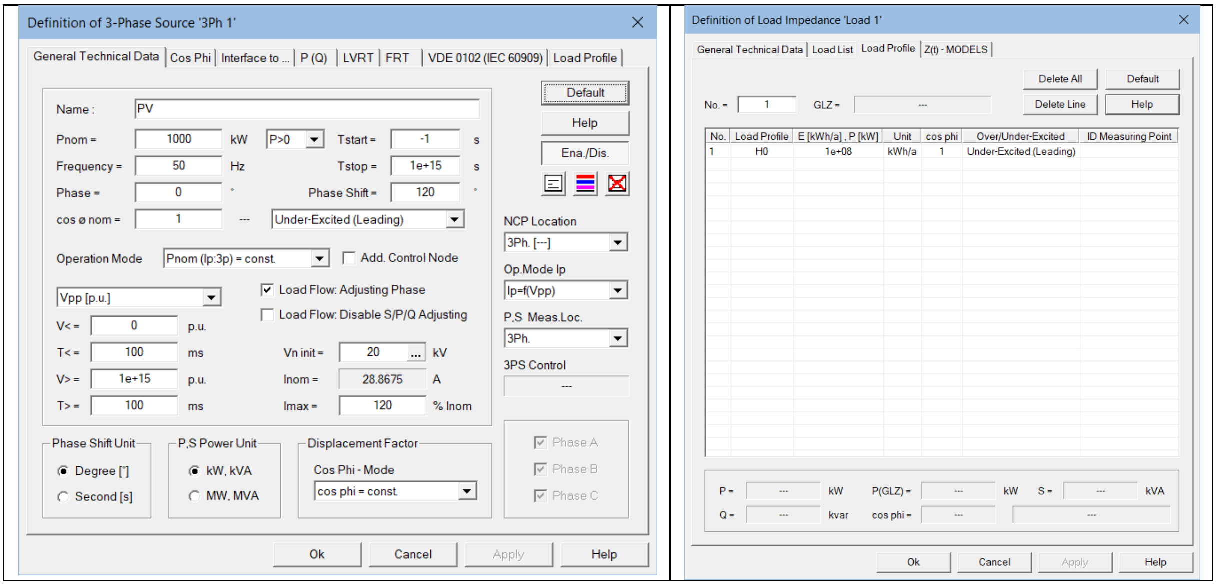


Figure 26: Settings dialog of the network element 3-*Phase Source*, tab *Load Profile*

12.3.3 Example: *Load Flow Analysis: Load Profiles*

The figure below shows a simple 20kV - power grid using a solar power plant PLP and a consumer load. Both network elements **Probe** and **3-Phase Source** are using load profiles to process a power grid utilization analysis.

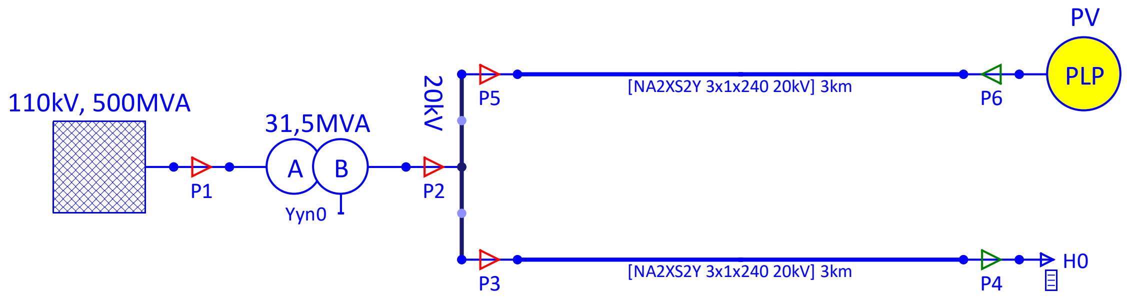


Figure 27: 20kV - Power Grid with Solar Power Plant PLP and Consumer Load both using Load Profiles

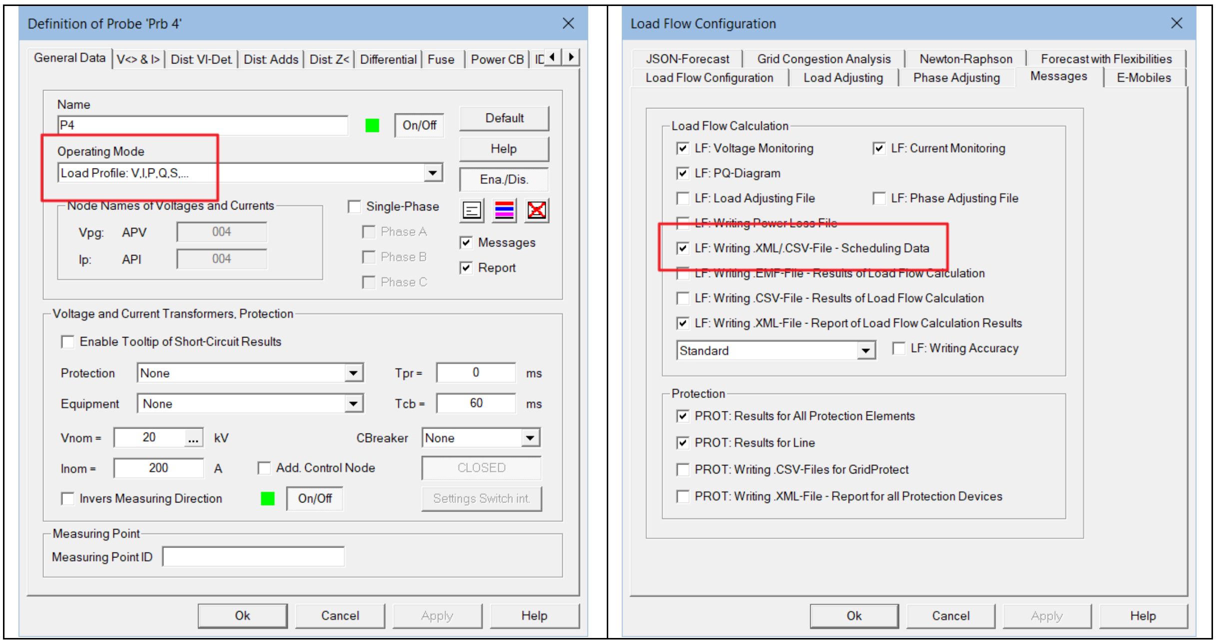


Figure 28: Operating Mode *Load Profile: V,I,P,Q,S,…* , Logging Load Flow Calculation every 15min-Intervall

The **Operating Mode** of both **Probe P4** and **P6** are configured as **Load Profile: V,I,P,Q,S,…** in the tab **General Data**. Using this operation mode the results of the load flow calculation of every 15min-intervall will be logged and stored in a .CSV-file, if the option **LF: Writing .XML/.CSV – File Scheduling Data** has been enabled.

- Main Menu: **ATP**
- Menu Item: **Load Flow Configuration**, tab **Messages**

The load flow calculation using load profiles can be started using the toolbar button  or the menu item below.

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility, Load Flow Analysis: Load Profiles**

First the dialog shown below will be displayed. The dialog shall be directly closed to check if all required .CSV-files could be loaded successfully. This can be easily done in the **Messages Window**. If an error has been detected it will not be possible to start the load flow calculation using load profiles.

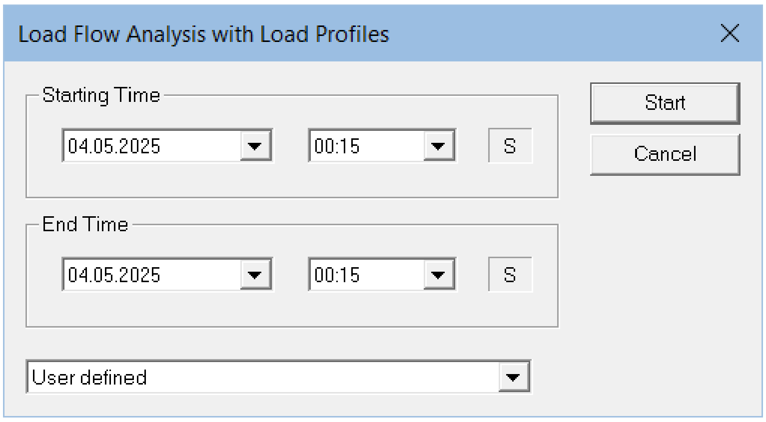


Figure 29: Load Flow Analysis using Load Profiles – Dialog to select the Time Period

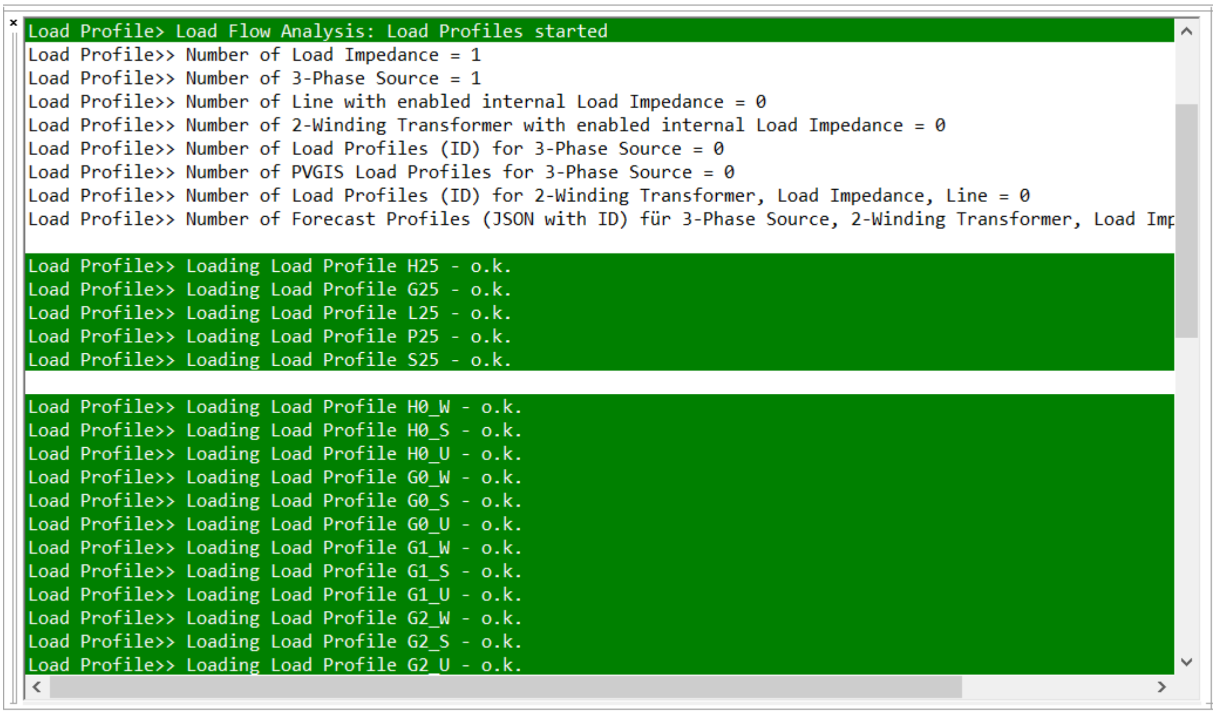


Figure 30: Messages Windows – Checking if.CSV-Files of Load Profiles could be loaded

The dialog must be now opened for the second time. In the example below the operation mode **A defined day** will be selected. ATPDesigner processes 96 times a load flow calculation. For every of the 96 15-minute interval ATPDesigner uses the active power value read out of the .CSV-files and calculates the individual active power acc. the specific energy consumption defined by the user.

The results of the load flow calculation, which will be calculated at the network node of **Probe P4** and **P6** will be logged in a .CSV-file, which will be stored in the subdirectory **Results** of the **Project Directory**. The .CSV-file can be opened e.g. in ATPDesigner with Drag&Drop to create a **Diagram**.

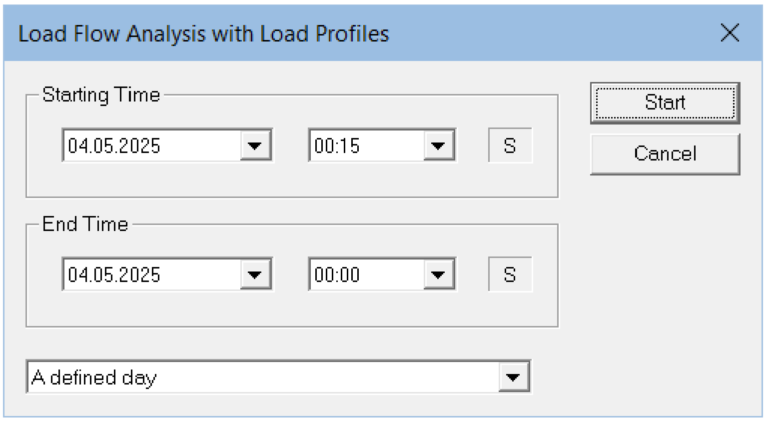


Figure 31: Load Flow Analysis using Load Profiles – Dialog to select the Time Span of One Day

File Naming Convention:

- 20250504183155074_Netz26_20kVMitPVAnlageUndLastptofilen_**FPFORC**.CSV
- 20250504183155074_Netz26_20kVMitPVAnlageUndLastptofilen_**FPFORC**.XML

YYYYMMDDhhmmss_*Filename*_FPFORC.xml

Storage Location:

Project Directory \ **Results**

Abbreviation	Description
YYYY	Year
MM	Month
DD	Day
hh	Hour
mm	Minute
ss	Second
Filename	Name of the .NET-file or the .BNET-file with file extension
_FPFORC	Identifier of the content of the **Report**

The .CSV-file can be opened in ATPDesigner using Drag&Drop. The dialog to select the output signals will be automatically opened. The .XML-file [6] can be opened in a spread sheet calculation software e.g. Excel.

- Main Menu: **File**
- Menu Item: **Open ...**

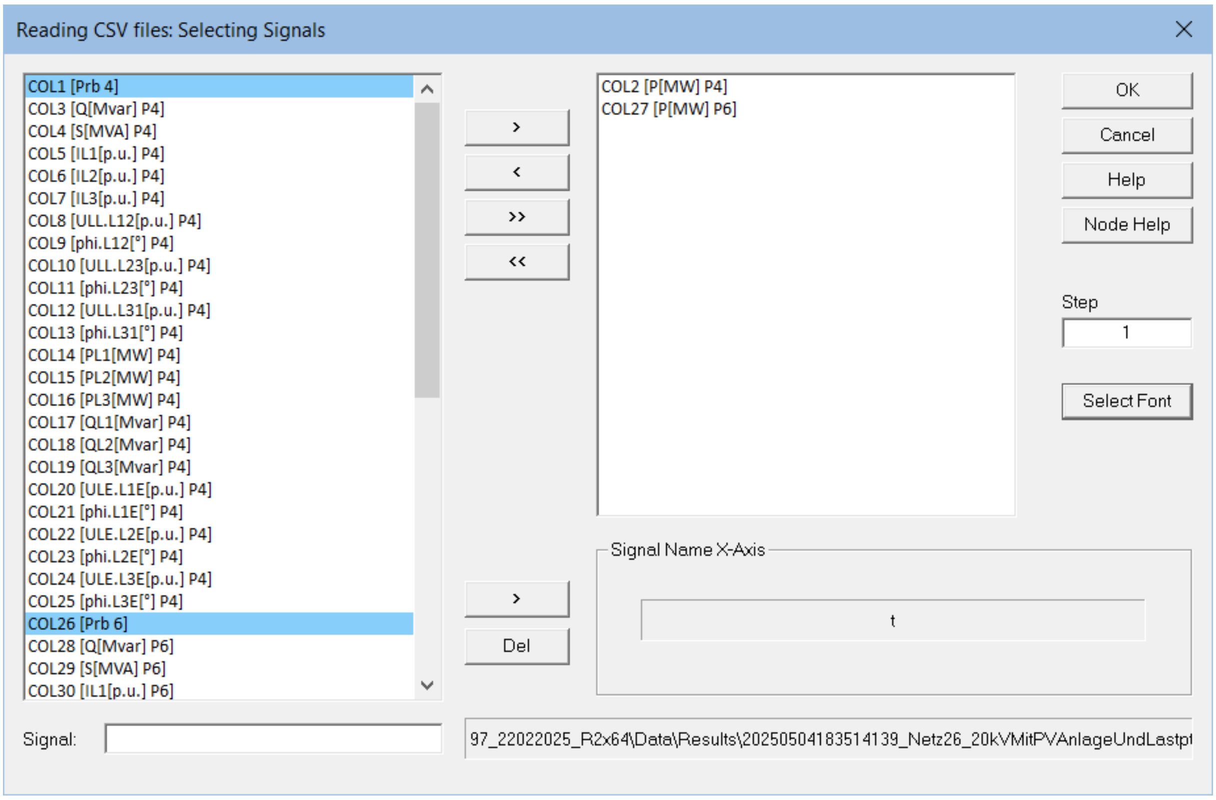


Figure 32: Selecting Signals to create the Diagram

⇨ The signals can easily be selected using a **Left Mouse Button Double Click** on the name of the signal.

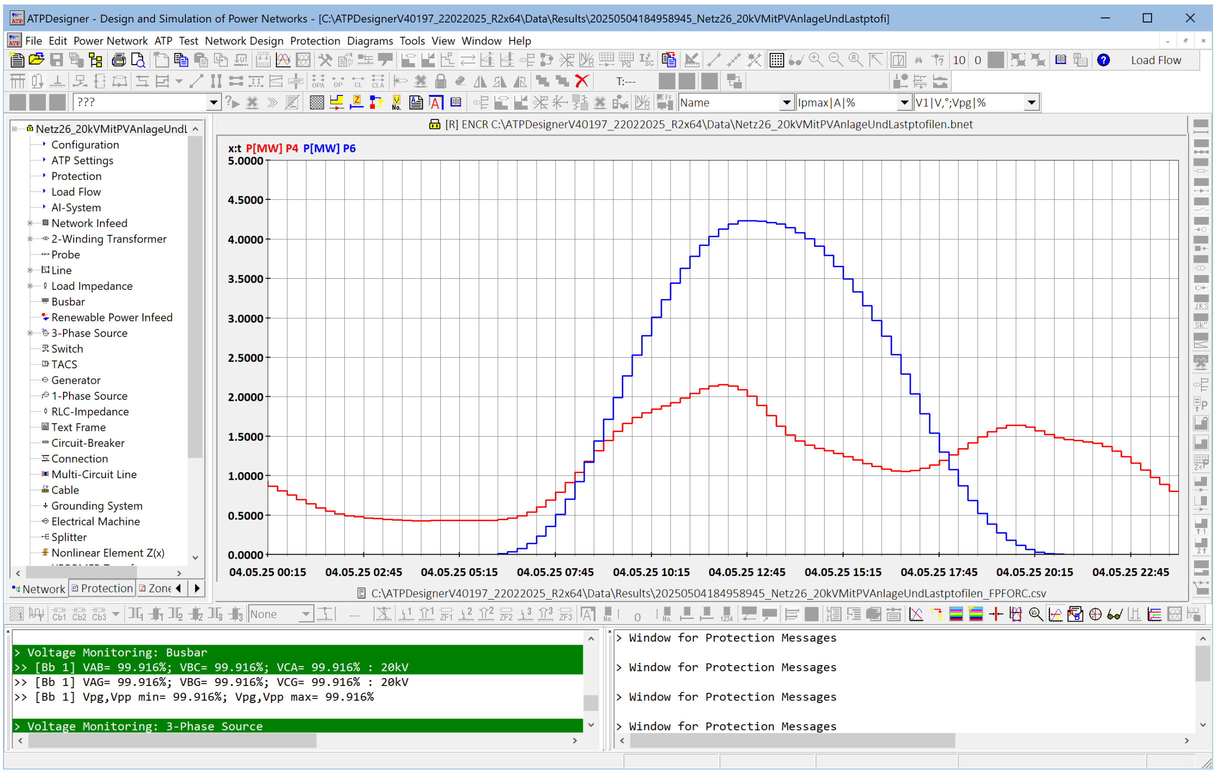


Figure 33: Diagram – Time dependent Results of the Load Flow Calculation using Load Profiles

If the operation mode **A defined time** has instead of the operation mode **A defined day** been set only one 15-minute interval can be selected as the time span. But processing the operation mode **A defined time** the results of the load flow calculation will be displayed directly in the power grid graphic as well-known from the load flow calculation using constant power settings. The tooltips at the mouse cursor position can also be used to display additional information e.g. measured at the **Probe** locations.

⇨ If the power infeed of the solar power plant modelled by the **3-Phase Source** is nearby P ≈ 0W, ATPDesigner automatically disables the network element only for the specific 15min-intervall (drawing color **magenta**) to avoid mathematical problems of the load flow calculation.

The results of the power grid utilization analysis will be written into a report [6], which will be stored in the project directory. Please note: The project directory is the directory where the.NET-file (or .BNET-file) is stored.

File Naming Convention:

20250504184959072_Netz26_20kVMitPVAnlageUndLastptofilen_**LFPROF**.XML

YYYYMMDDhhmmss_*Filename*_LFPROF.xml

Storage Location:

Project Directory

Abbreviation	Description
YYYY	Year
MM	Month
DD	Day
hh	Hour
mm	Minute
ss	Second
Filename	Name of the .NET-file or the .BNET-file with file extension
_LFPROF	Identifier **L**oad **F**low using **PROF**iles of the content of the **Report**

In the figure below, the results of the load flow calculation will be directly shown in the power network graphic using the operation mode **A defined time**.

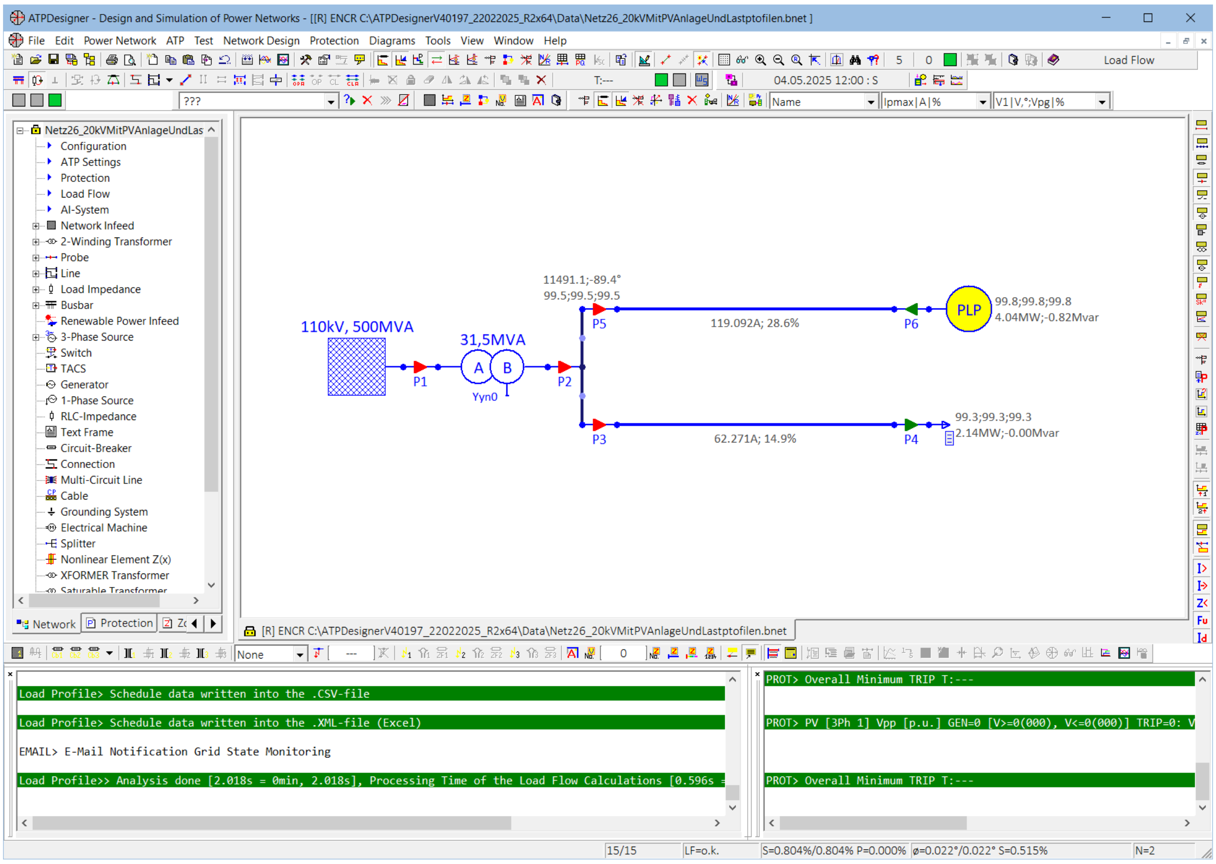


Figure 34: Load Flow Calculation using Load Profiles – Operation Mode *A defined time* with LF-Results

The settings dialog **Messages** in the figure below shows settings which are important for the generation of reports.

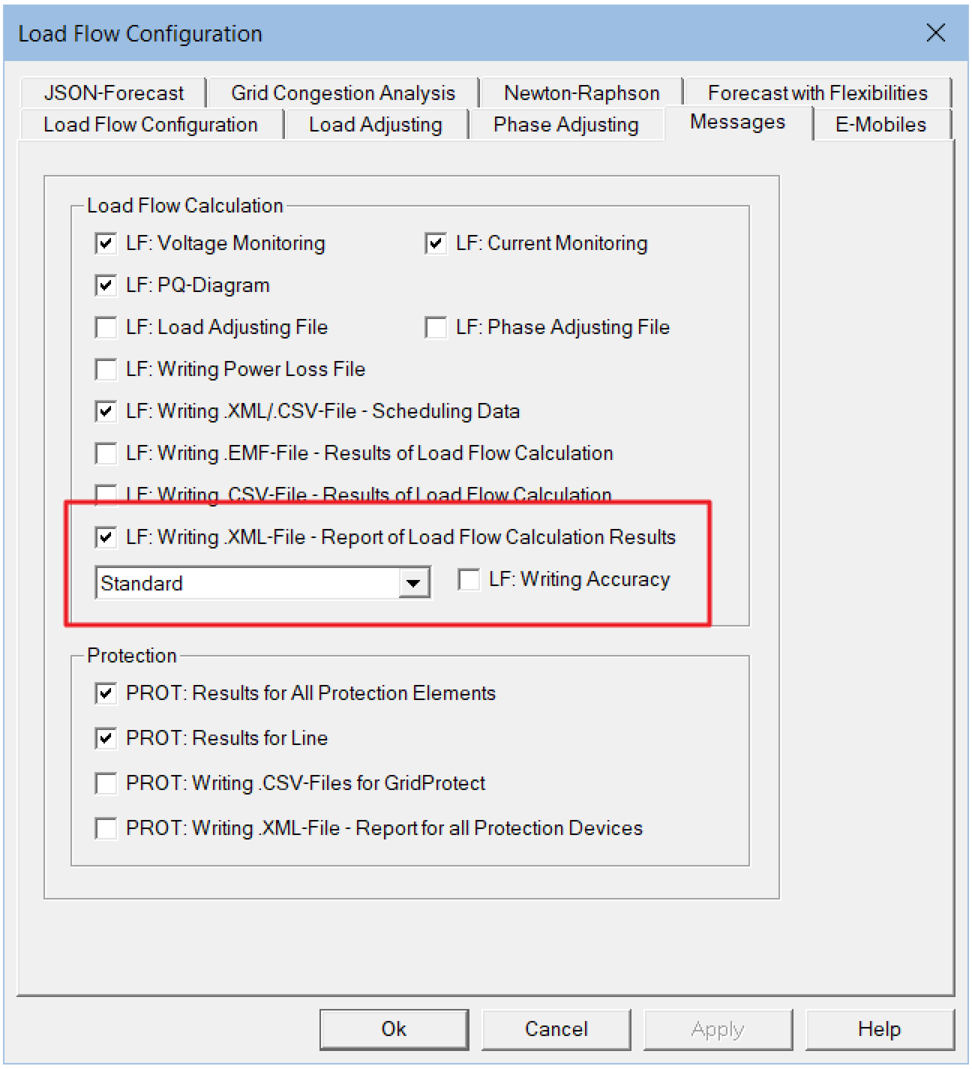
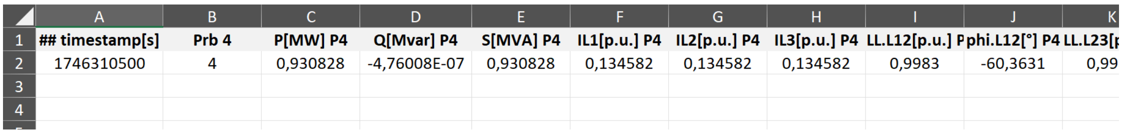


Figure 35: Writing a Load Flow Calculation Report for every 15min-Intervall

- **LF: Writing .XML/.CSV-File – Scheduling Data**
  If enabled, the results of the load flow calculation will be written into a .CSV-file and a .XML-file for every **Probe**, if the operation mode **Load Profile: V,I,P,Q,S,...** has been selected. The .CSV-file can be directly opened e.g. using Drag&Drop in ATPDesigner to create a Diagram. The .XLM-file can be opened in a standard spread sheet software e.g. Excel.



	A	B	C	D	E	F	G	H	I	J	K
1	## timestamp[s]	Prb 4	P[MW] P4	Q[Mvar] P4	S[MVA] P4	IL1[p.u.] P4	IL2[p.u.] P4	IL3[p.u.] P4	LL.L12[p.u.] P	phi.L12[°] P4	LL.L23[
2	1746310500	4	0,930828	-4,76008E-07	0,930828	0,134582	0,134582	0,134582	0,9983	-60,3631	0,99
3											
4											

- **LF: Writing .XML-File – Report of Load Flow Calculation Results**
  If enabled, a report [6] will be written for every 15-minute intervall and stored into the project directory.

12.4 Load Flow Analysis using Load Profiles stored in a JSON Forecast File

Alternatively load profiles can also be used by ATPDesigner if stored in text files using the JSON format [9].

⇨ This JSON file will now be called **JSON forecast file**.

The load profiles stored in the JSON forecast file (JSON array **timeseries**) are linked to the network elements **Load Impedance** as consumer load or **3-Phase Source** as e.g. a solar power plant by a unique **identifier ID** (JSON object **id**). The **JSON forecast file** can be used for network capacity analysis with time series calculations, for example, using the network calculation function **Load Flow Analysis: Load Profiles**.

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility, Load Flow Analysis: Load Profiles**

Below the first lines of the JSON file are displayed. The first JSON object contains header information. The load profiles are stored in the JSON-arrays **timeseries**.

```
[
	{
		"author": "Institut fuer elektrische Energiesysteme",
		"date": "12.08.2023",
		"time": "23:53:42",
		"description": "Export JSON-Prognosedatei",
		"filetype": "forecast",
		"fileversion": "1",
		"fileformat": "1",
		"simulationtime": "16.10.2023 00:15 DST=1 - 16.10.2023 00:00 DST=1",
		"operationmode": "a defined day",
		"program_version": "ATPDesigner Version Version 4.01.89 - 10.08.2023",
		"datafile": "C:\\testfile.bnet"
	},
	{
		"id": "Load 1;H0",
		"label": "Load 1;H0",
		"unit_1": "P[kW]",
		"unit_2": "Q[kvar]",
		"timeseries":
		[
			{
				"timestamp_s": 1691792100,
				"value_1": 89.840,
				"value_2": 0.000
			},
```

Figure 36: JSON file for load profiles

- The number of load profiles (JSON-Array **timeseries**) are not limited.
- Only one **JSON forecast file** can be used for the .BNET-file (or .NET-file).
- The **JSON forecast file** must be stored in the directory **Project Directory** / **Monitoring**.
- Only the most recent **JSON forecast file** will be used by ATPDesigner.

The export function **Forecast (JSON)** can be used to easily generate a template of the **JSON forecast file**.

- Main Menu: **File**
- Menu Item: **Export**, **Forecast (JSON)**

⇨ The export function provides a utility to generate a syntactically correct and contextually meaningful **JSON forecast file** as a template, which can then be manually adjusted to specific requirements.

The export function generates a separate load profile (JSON-array **timeseries**) for every network element **3-Phase Source** (e.g. solar power plant) and **Load Impedance** (consumer load) in the **JSON forecast file**. All load profiles will be written into the same **JSON forecast file**.

The time series is a sequence of 15-minute intervals, which contains

- a timestamp in seconds (JSON-object **timestamp_s**),
- active and reactive power (JSON-object **value_1, value_2** in combination with the units **unit_1** and **unit_2**) and
- a unique **identifier ID** (JSON-object **id**).

The **JSON forecast file** can be used to link one of the time series (JSON-array **timeseries**) with network elements **Load Impedance** or **3-Phase Source** using the unique **identifier ID** (JSON element **id**) for data processing. In the context of a timeseries calculation (= load flow calculation using load profiles), ATPDesigner reads the values of the active power P and optionally the reactive power Q from the linked time series (JSON-array **timeseries**) for every 15-minute interval and uses the values for the linked **Load Impedance** or **3-Phase Source**.

Using the example of the network element **3-Phase Source**, the procedure is explained for how a **JSON forecast file** with time series of 15-minute intervals (JSON-Array **timeseries**) can be created using load profile files according to VDEW [8] or BDEW [10].

To generate a timeseries as a sequence of power values P and Q for 15-minute intervals, the standard load profile for solar power plants, based on VDEW [8], is used as the data base for the network element **3-Phase Source**. The load profile consists of the three .CSV files **LoadProfile_PV_(S,U,W).CSV** located in the subdirectory **...\Exe\LoadProfiles** of the project directory.

In the first step, as shown in the following figure, the operation mode **Photovoltaic Solar Power Plant SLP** of the **3-Phase Source** according to the standard load profile (SLP) is set for the network element **3-Phase Source**. It is a must to enable the option **Enable Energy Analysis**.

⇨ It must be ensured that the setting value **ID**, as shown below, does not have a value, meaning the edit field is empty. If any value has been set, it will be used during the export to be written in the **JSON export file**. In all other cases, a replacement value will be automatically generated by ATPDesigner for the timeseries and written in the **JSON forecast file** (JSON-Array **timeseries**).

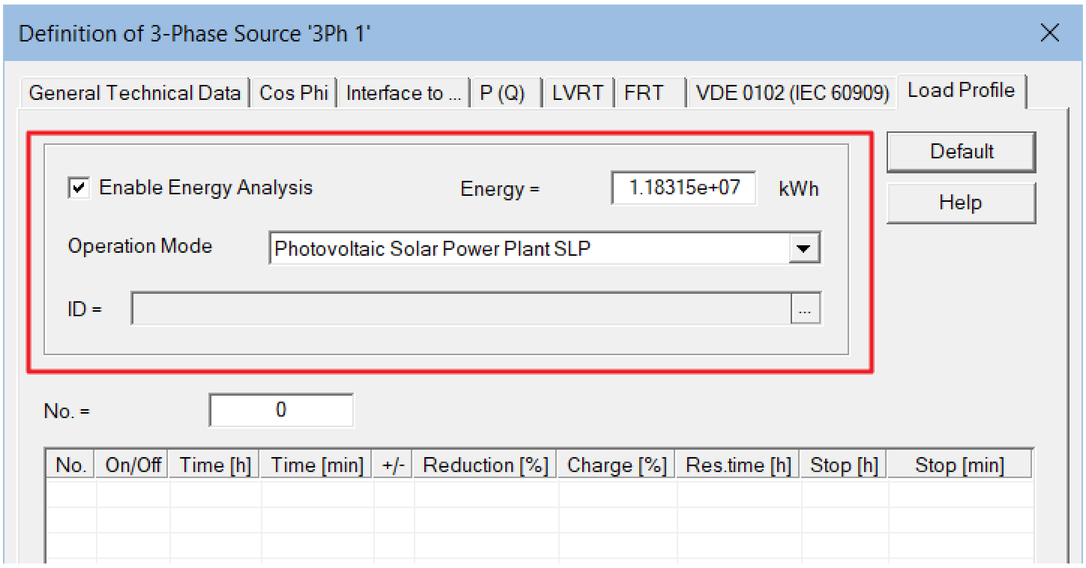


Figure 37: Settings Dialog of a generation plant (*3-Phase Source*)

By selecting the operating mode **Photovoltaic Solar Power Plant SLP**, the identifier **PLP** (**P**hoto-voltaic **L**oad **P**rofile) is displayed in the yellow-colored symbol of the network element **3-Phase Source** as shown below.

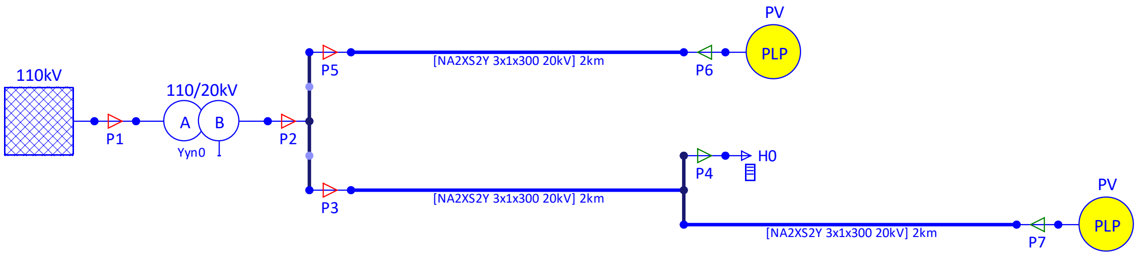


Figure 38: 20kV-Reference Network for timeseries Calculations with Load Profiles

The goal is to generate a load profile for one day, consisting of 96 15-minute intervals, which feeds in a nominal active power P_n as the rated active power of the PV power plant. This nominal active power P_n is not set directly as a parameter in the settings dialog of the **3-Phase Source** but is instead configured indirectly using the **Energy** setting. The following steps must be carried out:

1. Set the Date – Define the day for which the time series should be generated. In this example, Sunday, May 06, 2025, is selected.

2. Identify the seasonal period (summer, winter or transition (in German: Uebergang)) according to VDEW [8] – In this example, the transition period applies to the selected date. The active power values p_{SLP}, scaled to an annual energy consumption of 1000 kWh, are contained in the .CSV file **LoadProfile_PV_U.CSV**.

3. Identify the 15-minute interval with rated active power p_{SLP} in the .CSV File. The maximum active power value in kW for a Sunday is fed in during the 15-minute interval at 13:15. It should be noted that, specifically for the load profiles of a PV system, there is no difference in the profiles for weekday, Saturday and Sunday (in German: Sonntag) regarding the active power output.

```
(Kunde-)Name:;
(Kanal-)Beschreibung:;Mittelwert 2020,2021,2022
(Kanal-)Ident3:;PV        // name of the load profile
Summe (kWh):;1000         // reference value of the electrical energy per year
Uebergangszeit;kW         // time zone: transition; unit of values of active power
Werktag 00:15;0
Werktag 00:30;0
Werktag 00:45;0
Werktag 01:00;0
Werktag 01:15;0
Werktag 01:30;0
Werktag 01:45;0
Werktag 02:00;0
Werktag 02:15;0
Werktag 02:30;0
Werktag 02:45;0
Werktag 03:00;0
Werktag 03:15;0
Werktag 03:30;0
Werktag 03:45;0
Werktag 04:00;0
Werktag 04:15;0
Werktag 04:30;0
Werktag 04:45;0
Werktag 05:00;0
Werktag 05:15;0
Werktag 05:30;0
Werktag 05:45;6,11E-07
Werktag 06:00;3,83E-05
Werktag 06:15;0,000280433
Werktag 06:30;0,001277649
Werktag 06:45;0,003589949
Werktag 07:00;0,007744479
Werktag 07:15;0,014142226
Werktag 07:30;0,023325778
Werktag 07:45;0,035562161
Werktag 08:00;0,05114363
Werktag 08:15;0,070100708
Werktag 08:30;0,092405798
…
```

Figure 39: Structure of a .CSV file for load profiles according to VDEW [8]

The calculation of the setting **Energy** is performed based on the active power p_{SLP} read out the .CSV-file as shown below.

$$P[kW] = p_{SLP}[kW] \cdot \frac{Energy[kWh]}{1000kWh}$$

- The value p_{SLP} will be read out of the .CSV-file of the load profile at 13:15 with p_{SLP} = 0,422604069kW

For a nominal active power P_{3PS} = 5MW we have,

$$Energy[kWh] = \frac{P_{3PS}[kW] \cdot 1000kWh}{p_{SLP}[kW]}$$

$$Energy[kWh] = \frac{5000kW \cdot 1000kWh}{0,4226kW} = 11,831,519kWh$$

By using the calculated **Energy** setting, the active power P fed into the grid for every 15-minute interval during the timeseries calculation is determined according to the following equation.

$$P_{3PS,hh:mm\ time}\left[kW\right]=p_{SLP,hh:mm\ time}\left[kW\right]\cdot\frac{11,831,519kWh}{1000kWh}$$

At 01:15 pm (13:15), the maximum active power feed-in is as defined.

$$P_{3PS,01:15\ time}\left[kW\right]=0,4226\left[kW\right]\cdot\frac{11,831,519kWh}{1000kWh}=5MW$$

Using the network calculation function **Load Flow Analysis: Load Profiles**, the setting can be validated. In the settings dialog shown below, the date and time are configured accordingly. By selecting the operating mode **A Defined Time**, only one load flow calculation is performed for the specified 15-minute interval. The results of the load flow calculation are displayed both in the network diagram and in the tooltips of the network elements.

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility, Load Flow Analysis: Load Profiles**

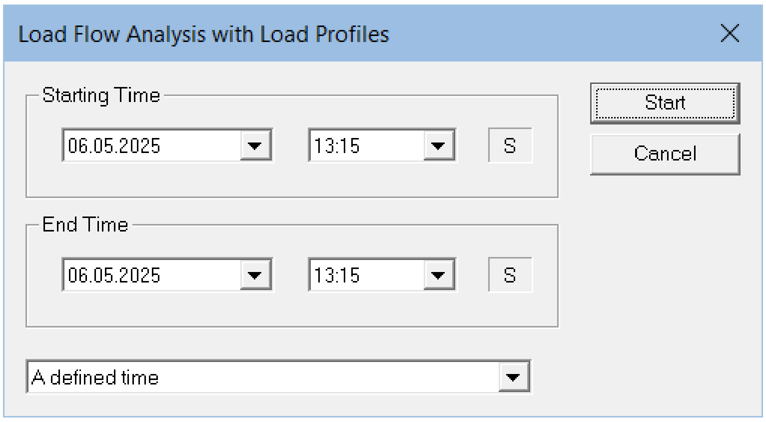


Figure 58: Configuration of the 15-Minute Interval with Rated Active Power Feed-In P_n

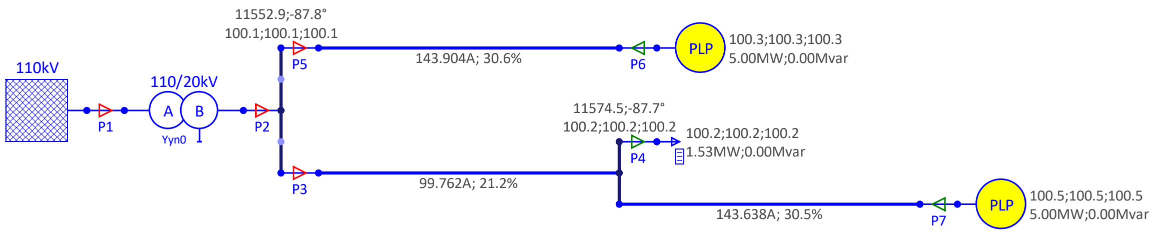


Figure 59: Active Power Feed-In at NCP (Network Connection Point): 5 MW at 01:15 pm

If the **Probe P6** at the network connection point of the **3-Phase Source** is used as a **schedule measurement device** (indicated by the **green** arrow colour of the **Probe**), the power flow for every 15-minute interval of the timeseries will be stored in a **.CSV schedule file**, can be opened in ATPDesigner and displayed as a diagram, as shown below. To enable the output of the .CSV schedule file, the option **Output Schedule Data** must be enabled in the settings dialog **Load Flow Calculation Settings**, tab **Messages**.

- Main Menu: **ATP**
- Menu Item: **Load Flow Configuration**, tab **Messages**

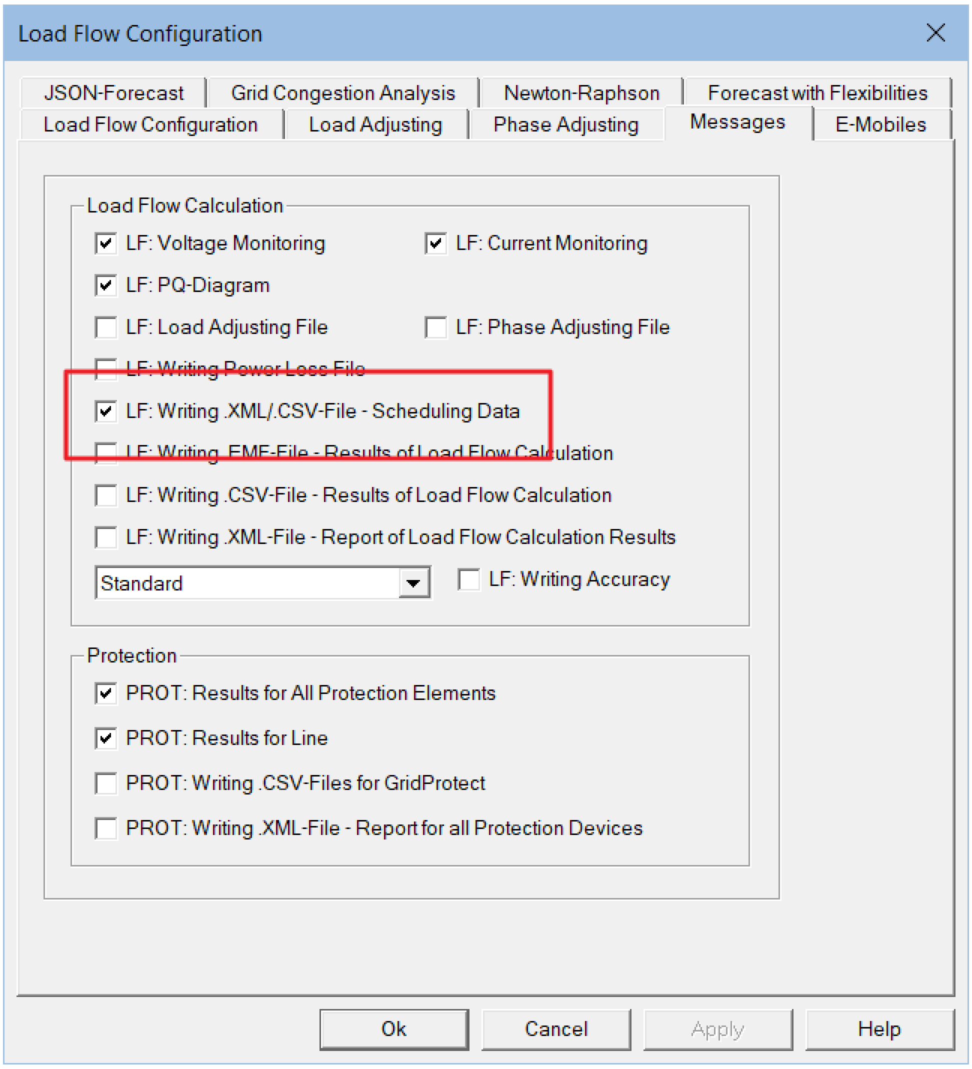


Figure 60: Enabling the Output of the .CSV Schedule File

In the next step, the time period is selected for which load profiles will be generated as a timeseries of 15-minute intervals with power values in the **JSON forecast file** (JSON-Array **timeseries**). By clicking the Start button with the **left mouse button**, the load flow calculation using load profiles **Load Flow Analysis: Load Profiles** is initiated.

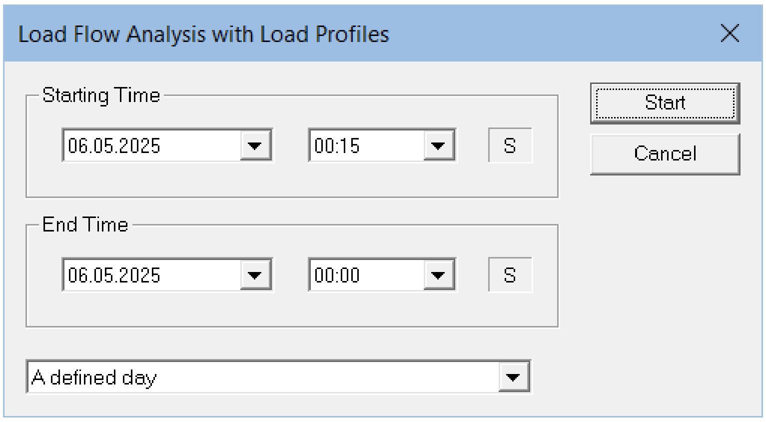


Figure 61: Configuration of the desired Time Period using *A defined day*

After successfully completing the time series calculation **Load Flow Analysis: Load Profiles**, the **.CSV schedule file** is saved in the subdirectory **Results** of the **Project Directory** and can be identified by the suffix **_FPFORC**. Additionally, it is stored as an .XML file in the Office Open XML format [6], which can be opened with spreadsheet software such as Excel. The creation date and time are prefixed to the filename of the .NET file as follows:

File Naming Convention:

YYYYMMDDhhmmss_NetFilename_FPFORC.CSV
YYYYMMDDhhmmss_NetFilename_FPFORC.XML

Storage Location:

Project Directory \ **Results**

The **.CSV schedule file** can be **dragged and dropped** into the drawing area of ATPDesigner or opened via **File > Open...** to be displayed as a diagram. The assignment of signals to a **Probe** is based on the probe name, e.g., **P6**.

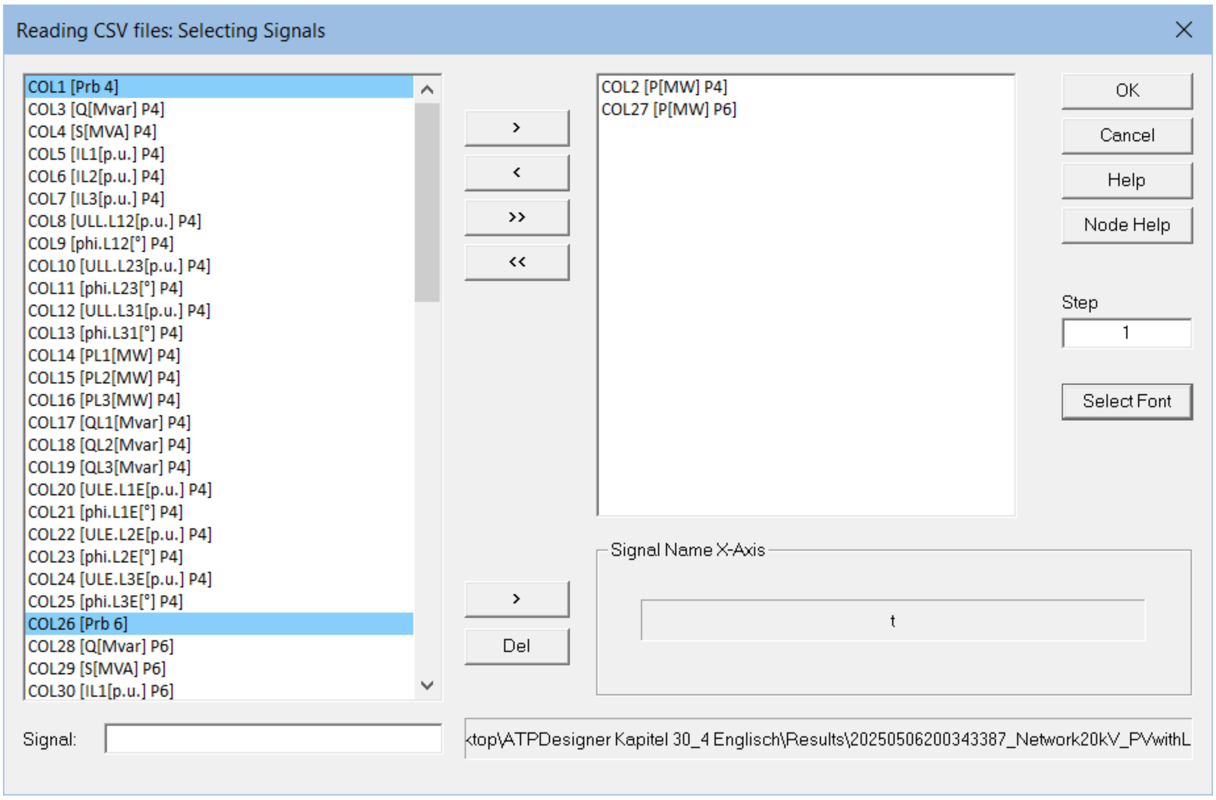


Figure 62: Selection of Signals for the Diagram

The diagram shows that the maximum power feed-in of the **3-Phase Source** at **Probe P6** amounts to approximately 5 MW around midday. The network element **Load Impedance** shows a constant active power P = 5 MW at **Probe P4**. With this configuration, the next step is to export the **JSON forecast file**.

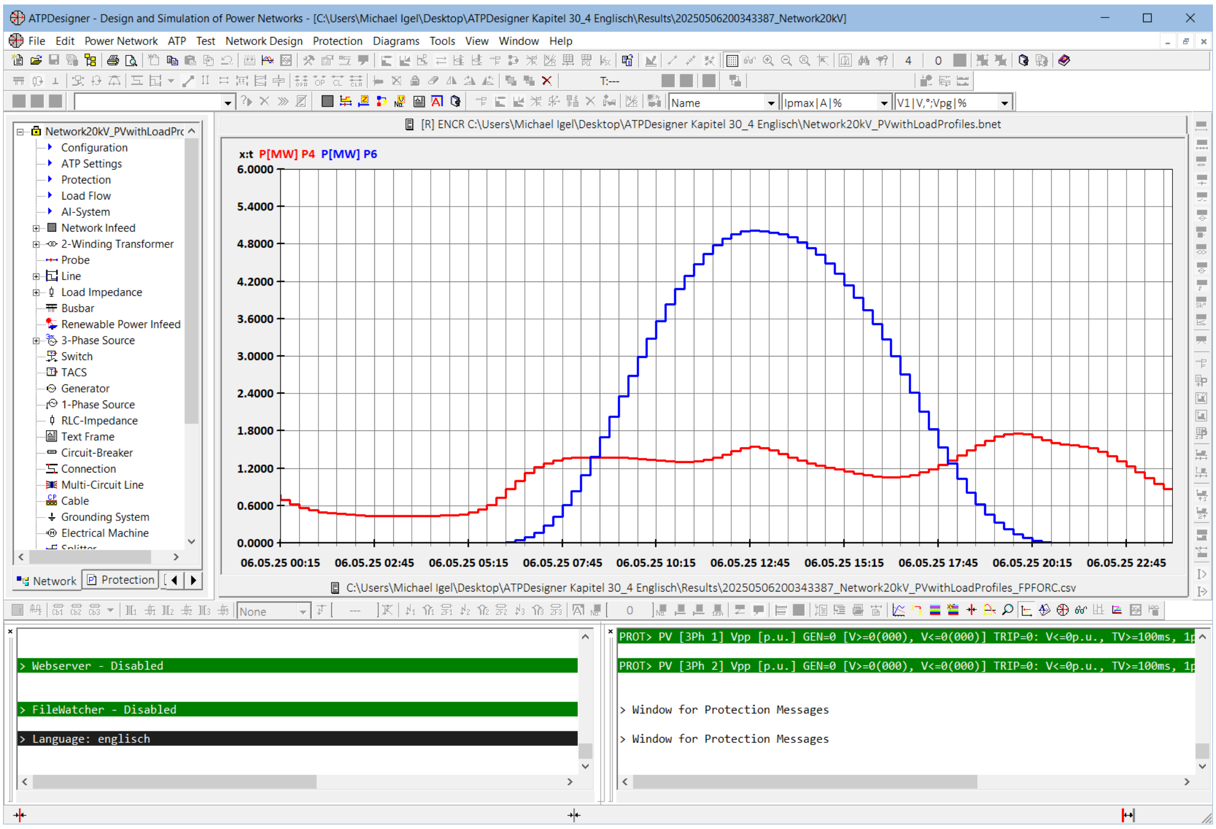
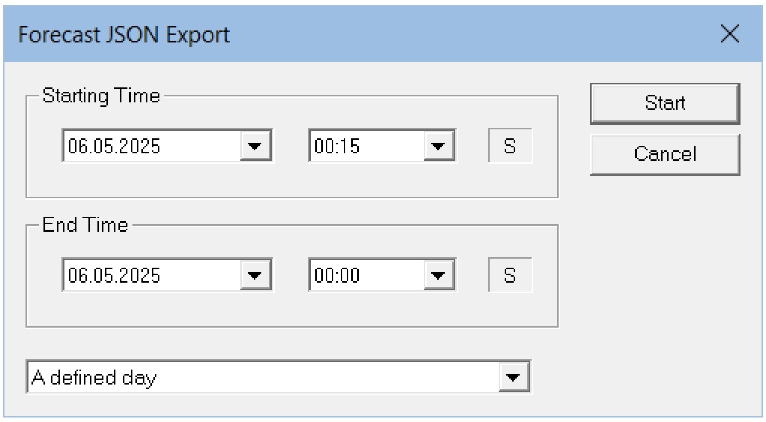


Figure 40: .CSV Schedule File – Active Power Feed-In at Network Connection Point (NCP) P6

In the next step, a **JSON forecast file** is exported using the configured settings of the **3-Phase Source**. To do this, the export function is accessed via:

- Main Menu: **File**
- Menu Item: **Export, Forecast (JSON)**

The date and the time 00:15 are set as the start time, and the operating mode **A Defined Day** is selected. By clicking the Start button with the **left mouse button**, the export of the **JSON forecast file** is initiated.



If a **JSON forecast file** is stored in the **Monitoring** subdirectory of the **Project Directory**, the following error message will be displayed. The cause of the error is that currently, only load profile files in the .CSV format according to VDEW [8] can be used and evaluated as input files for load profiles for the network elements. The **JSON forecast file** is identifiable by the suffix **_PROG**.

- Example Filename: **2025-5-6-0-15_Network20kV_PVwithLoadProfiles_PROG.JSON**

Below a part of the **JSON forecast file** has been shown, including the **Header** section and a 15-minute timeseries (JSON-array **timeseries**).

```
{
            "author": "Institut fuer elektrische Energiesysteme",
            "date": "06.05.2025",
            "time": "20:11:25",
            "description": "Export JSON-Forecast File _PROG",
            "filetype": "forecast",
            "fileversion": "1",
            "fileformat": "1",
            "status": "Export of JSON-forecast file successfully finalized",
            "process_id": "1",
            "simulationtime": "06.05.2025 00:15 DST=1 - 06.05.2025 00:00 DST=1",
            "operationmode": "A defined day",
            "program_version": "ATPDesigner Version 4.02.03 - 06.05.2025",
            "datafile": "C:\\Users\\ … \\Network20kV_PVwithLoadProfiles.bnet"
      },
      {
            "id": "3Ph 1;Photovoltaic Solar Power Plant SLP",
            "label": "3Ph 1;Photovoltaic Solar Power Plant SLP",
            "unit_1": "P[kW]",
            "unit_2": "Q[kvar]",
            "timeseries":
            [
                  {
                        "timestamp_s": 1746483300,
                        "value_1": 0.000000,
                        "value_2": 0.000000
                  },
                  {
                        "timestamp_s": 1746484200,
                        "value_1": 0.000000,
                        "value_2": 0.000000
                  },
…
```

Figure 41: JSON Forecast File exported by the function Export (JSON)

Abbreviation	Description of the JSON-Objects	m=mandator o=optional
id	Unique identifier to link the load profile (JSON-object **timeseries**) to a **Load Impedance** (consumer) or **3-Phase Source** (producer)	**m**
label	Description of the load profile	**o**
unit_1	Physical unit of **value_1** of the load profile, shall be used for the active power P, must be used in combination with the JSON-object **value_1**	**m**
unit_2	Physical unit of **value_2** of the load profile, shall be used for the reactive power Q, must be used in combination with the JSON-object **value_2**	**o**
timeseries	Load profile which consists of a series (array) of 15-minute intervals of active power P and optional reactive power Q	**m**
timestamp_s	**Epoch Unix Timestamp** of the 15-minute interval in seconds ▪ 05. May 2025, 12.00 a.m. (GMT+ 2) ➔ 1746439200	**m**
value_1	Value of the active power P using the **unit_1**	**m**
value_2	Value of the active power P using the **unit_2**	**o**

"**What is the unix time stamp ?**
The unix time stamp is a way to track time as a running total of seconds. This count starts at the Unix Epoch on January 1st, 1970 at UTC. Therefore, the unix time stamp is merely the number of seconds between a particular date and the Unix Epoch. It should also be pointed out (thanks to the comments from visitors to this site) that this point in time technically does not change no matter where you are located on the globe. This is very useful to computer systems for tracking and sorting dated information in dynamic and distributed applications both online and client side." (www.unixtimestamp.com)

The exported **JSON forecast file** can be directly read and displayed as a diagram in ATPDesigner. To do this, the .JSON-file can be either opened by Drag&Drop from the Windows File Explorer into the drawing area or opened as a file using the main menu **File**, menu item **Open**. After loading the file, the dialog shown below will open with the signals contained in the **JSON forecast file**. The signal names are derived from the JSON-objects **id** and **label** of the JSON-array **timeseries**.

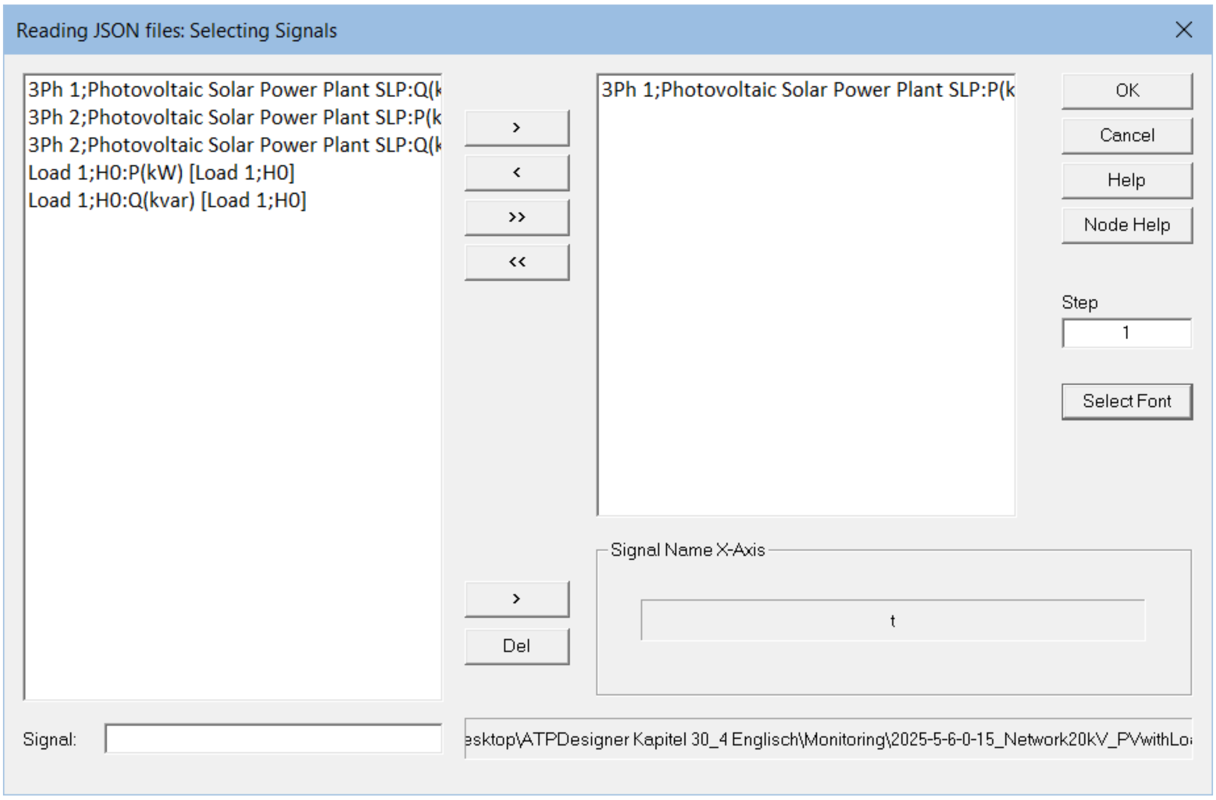


Figure 42: Dialog to select the Signals to be displayed in a Diagram

In the diagram shown below a load profile (JSON-array **timeseries**) is shown, which defines the active power feed-in at the network connection point (NCP) of the **3-Phase Source** in absolute values of the active power P in MW.

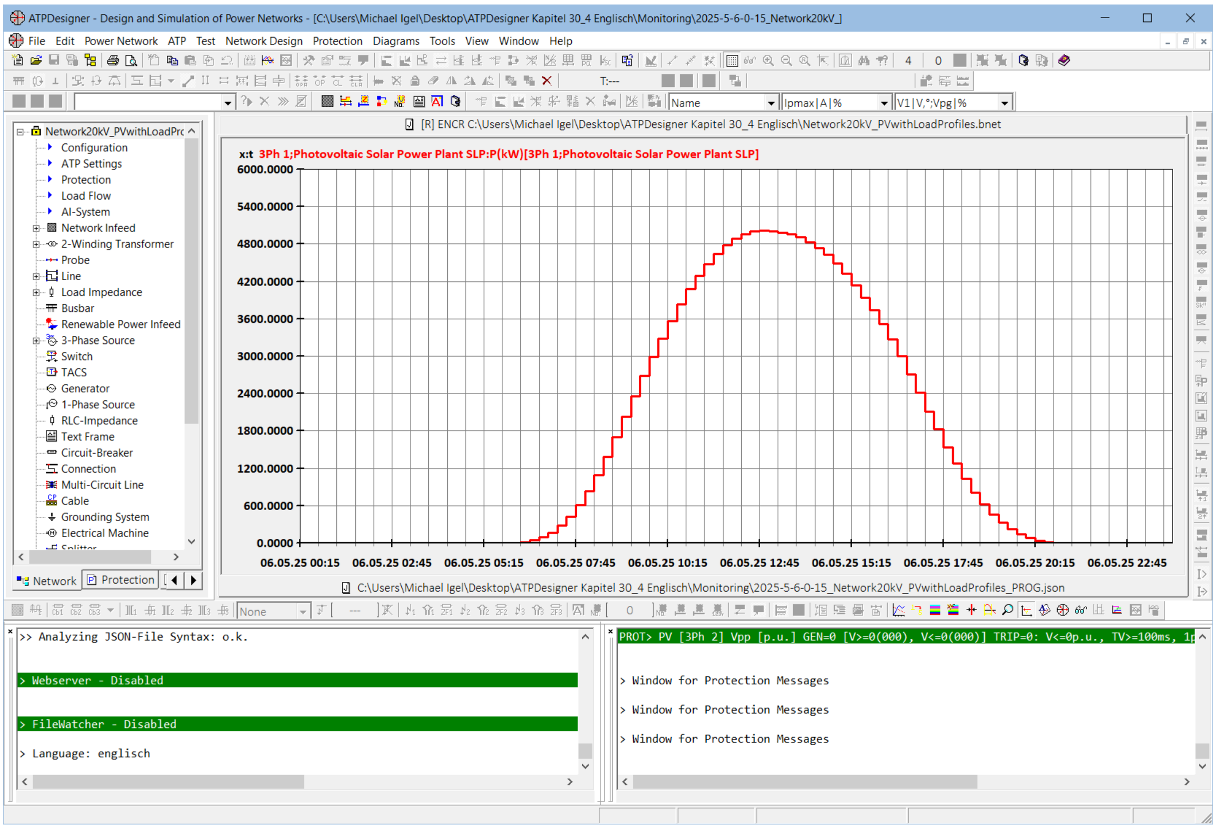


Figure 43: Active Power Feed-In at the Network Connection Point NCP (*JSON Forecast File*)

Using the **identification ID** (JSON-object **id**), the timeseries (JSON-array **timeseries**) from the **JSON forecast file** can now be associated with a **3-Phase Source** used as solar power plant.

⇨ In the settings dialog of the **3-Phase Source** tab **Load Profile**, the setting **ID = 1** has been set. This value must also be used as the **identification ID** (JSON-Element **id**) in the **JSON forecast file** to link the **3-Phase Source** with the load profile stored in the **JSON forecast file** (JSON-array **timeseries**).

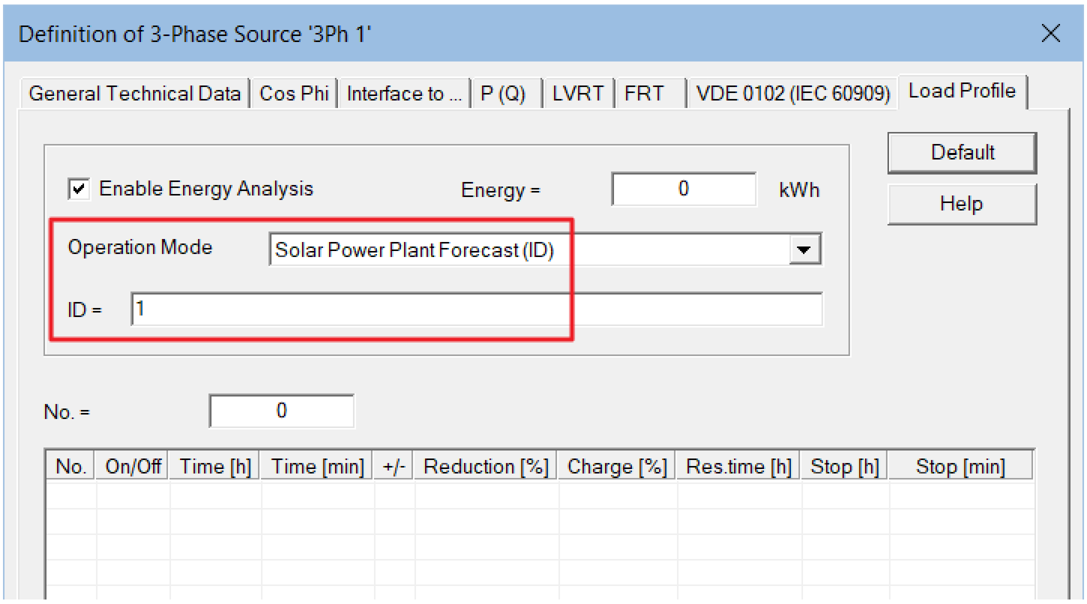


Figure 65: Using the Load Profile *ID=1* stored in the exported *JSON Forecast File*

The option **Enable Energy Analysis** must be enabled in the settings dialog. By selecting the operating mode **Solar Power Plant Forecast (ID)**, the identifier **PVF** (**P**hoto**v**oltaic **F**orecast) will be used in the symbol of the network element **3-Phase Source**, as shown below.

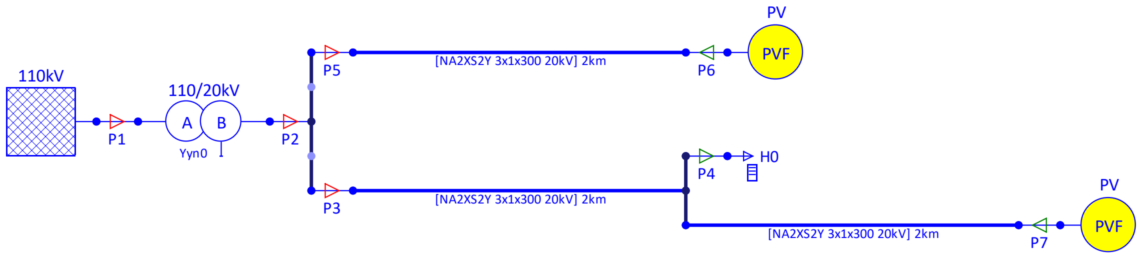


Figure 44: 20kV-Network using JSON Forecast File

The following aspects must be considered using the operation mode **Solar Power Plant Forecast (ID)**, as well as for all other operating modes using the setting **ID**:

- The setting **Energy** is not used in operating modes with **ID**, as the values for active power P and, if applicable, reactive power Q are stored as absolute values in kW and kvar in the **JSON forecast file** as shown below.

```
        "unit_1": "P[kW]",
        "unit_2": "Q[kvar]",
```

- A load profile of power values P, Q (JSON-array **timeseries**) stored in the **JSON forecast file** can be linked to any number of network elements using the **Identification ID** (JSON-object **id**).

The load profile (JSON-Array **timeseries**) stored in the **JSON forecast file** must now be set to **ID=1**. To do this, the identifier **3Ph 1** from the JSON-object "**id**": **"3Ph 1;Photovoltaic Solar Power Plant SLP"** in the file is searched for. The value of the JSON-Element **id** is then modified as shown below.

```
{
            "author": "Institut fuer elektrische Energiesysteme",
            "date": "06.05.2025",
            "time": "20:11:25",
            "description": "Export JSON-Forecast File _PROG",
            "filetype": "forecast",
            "fileversion": "1",
            "fileformat": "1",
            "status": "Export of JSON-forecast file successfully finalized",
            "process_id": "1",
            "simulationtime": "06.05.2025 00:15 DST=1 - 06.05.2025 00:00 DST=1",
            "operationmode": "A defined day",
            "program_version": "ATPDesigner Version 4.02.03 - 06.05.2025",
            "datafile": "C:\\Users\\ … \\Network20kV_PVwithLoadProfiles.bnet"
      },
      {
            "id": "1",
            "label": "3Ph 1;Photovoltaic Solar Power Plant SLP",
            "unit_1": "P[kW]",
            "unit_2": "Q[kvar]",
            "timeseries":
            [
                  {
```

```
                        "timestamp_s": 1746483300,
                        "value_1": 0.000000,
                        "value_2": 0.000000
                },
                {
                        "timestamp_s": 1746484200,
                        "value_1": 0.000000,
                        "value_2": 0.000000
                },
…
```


Figure 45: JSON Forecast File – Modification of the setting *ID*

To process a load flow calculation using load profiles with the exported **JSON forecast file**, it must be copied into the subdirectory **Monitoring** of the **Project Directory**. If the directory already does not exist, the subdirectory **Monitoring** must be created manually.

⇨ It is crucial to ensure that the **JSON forecast file** to be used for the load flow calculation using load profiles is the most recent JSON-file in the subdirectory **Monitoring**. ATPDesigner always uses only the most recent JSON-file from the subdirectory **Monitoring** for a load flow calculation using load profiles with a **JSON forecast file**.

The processing of the **JSON forecast file** for the load flow calculation using load profiles must be enabled as follows:

- Main Menu: **ATP**
- Menu Item: **Load Flow Configuration**, tab **JSON-Forecast**

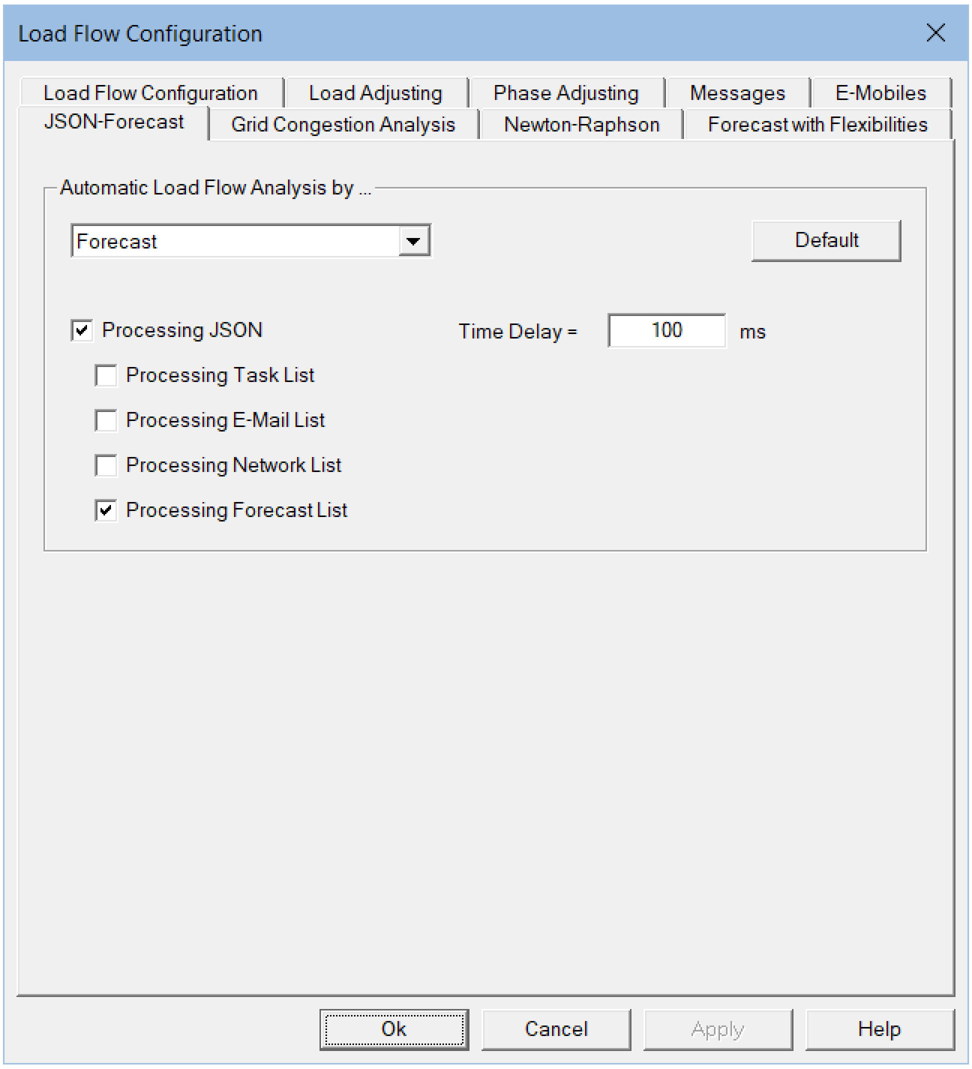


Figure 46: Enabling the JSON Forecast File Processing

The load flow calculation using load profiles processing the **JSON forecast file** can be started as follows:

- Main Menu: **Test**
- Menu Item: **Load Flow Analysis and Flexibility**, **Load Flow Analysis: Forecast**

No settings dialog for defining the time range will be opened, as ATPDesigner automatically determines and uses the time range from the first load profile (JSON-array **timeseries**) of the **JSON forecast file**.

⇨ ATPDesigner always uses the first load profile (the first JSON-array **timeseries**) which is stored in the **JSON forecast file**.

If no **JSON forecast file** is found in the subdirectory **Monitoring** of the **Project Directory**, an error message will be displayed.

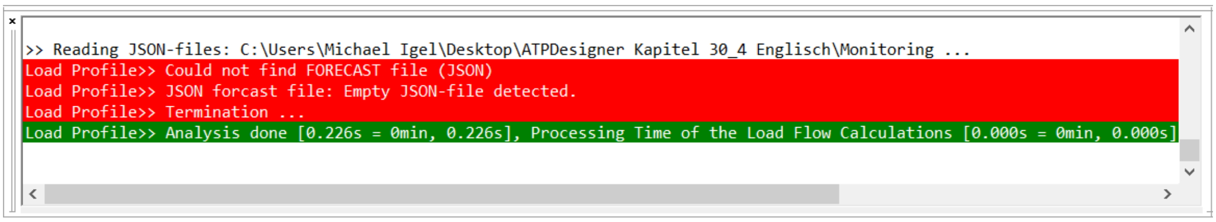


Figure 67: *JSON Forecast File* – Error Message : Not Found in the Subdirectory *Monitoring*

Another possible cause of error is shown below. After reading the **JSON forecast file**, ATPDesigner performs an integrity test on the file. As indicated by the error message, the **identification feature ID** (JSON-object **id**) **ID=1** is being used for multiple load profiles (JSON-array **timeseries**).

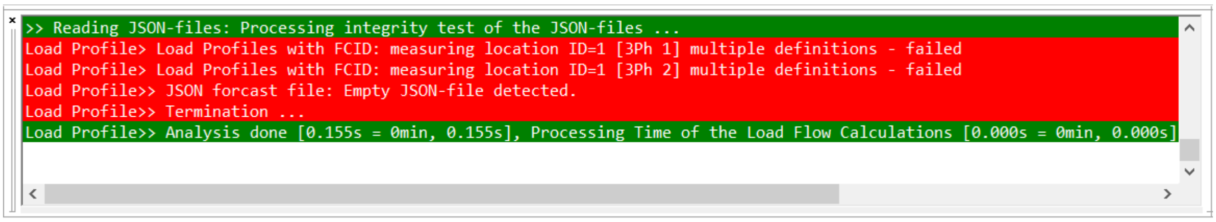


Figure 47: ***JSON Forecast File*** **– Error Message : Multiple Use of the same ID**

If the load flow calculation using load profiles has been successfully finalized, the message shown below will be displayed. It will also be indicated that the scheduled data are stored in the .CSV-file and the .XML-file, which can be found in the subdirectory **Results** of the **Project Directory**.

- Load Profile> Schedule data written into the .CSV-file
- Load Profile> Schedule data written into the .XML-file (Excel)

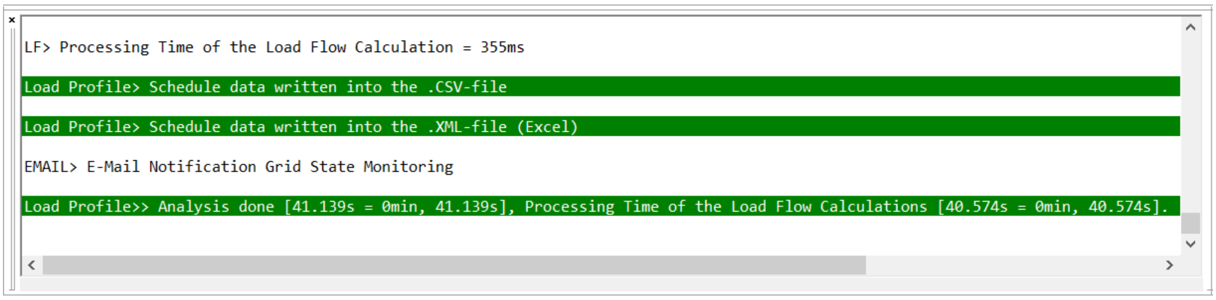


Figure 48: ***JSON Forecast File*** **– load flow calculation using load profiles successfully finalized**

The result of the load flow calculation using load profiles with the **JSON forecast file** is saved as a **report** in the file:

- **20240421165047719_Grid20_20kVwithJSONForecast_LFFORC.XML**

The schedule files are stored in the subdirectory **Results** of the **Project Directory**. Below, the active power feed-ins for the two network elements **3-Phase Source** are displayed as a diagram. Since both network elements are linked with the same **identification ID** (JSON-object **id**) **ID=1**, the schedule curves of the active power P for **Probe P6** and **P7** are identical.

- **20250508153013863_Network20kV_PVwithLoadProfiles_JSON_FPFORC.CSV**
- **20250508153013863_Network20kV_PVwithLoadProfiles_JSON_FPFORC.XML**

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Load Flow Analysis using Forecast Data

08.05.2025, 16:43:15.557
C:\Users\Michael Igel\Desktop\ATPDesigner Kapitel 30_4 Englisch\Network20kV_PVwithLoadProfiles_JSON.bnet
ATPDesigner Version 4.02.03 - 06.05.2025
Version NET File 6.3 - 22.01.2021

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Identifiers and Descriptions

VAG, VBG, VCG [V], [%]	Amount of the phase-to-ground voltages in V and %Vn/√3
VAB, VBC, VCA [V], [%]	Amount of the phase-to-phase voltages in V and %Vn
Vmin, Vmax [V], [%]	Amount of the minimum and maximum phase-to-ground and phase-to-phase voltage VABC in V and %Vnom
Vpp, Vpg [V], [%]	Amount of the phase-to-phase voltages VAB, VBC, VCA in V and %Vn Amount of the phase-to-ground voltages VAG, VBG, VCG in V and %Vn/√3
IA, IB, IC [A], [%]	Amount of the phase currents in A and %In
V1, V2, V0 [V], [%]	Amount of the positive-, negative- and zero-sequence voltage in V and %Vn/√3
I1, I2, I0 [A], [%]	Amount of the positive-, negative- and zero-sequence current in A and %In
Ipmax [A], [%]	Amount of the maximum phase current IABC in A und %In=Imax·Red.
Maximum Load [%]	Amount of the maximum phase current IABC in %In
S [VA]	Amount of the apparent power in VA
P [W]	Amount of the active power in W
Q [var]	Amount of the reactive power in var
CosPhi	Displacement factor cos phi = P / S
Load [%]	Load of winding A and B in %In
SA, SB, SC [VA]	Single-phase apparent power of phase A, B and C in VA
PA, PB, PC [W]	Single-phase active power of phase A, B and C in W
QA, QB, QC [var]	Single-phase reactive power of phase A, B and C in var
NA	Need for Action
Ipmax [%]	Maximum phase current IABC in %Inom
fN [%]	Grid Health in %
m [p.u.]	Load Level acc. VDE 0276
LF	State of Load Flow Calculation: o.k.=1, failed=0, stopped=2, invalid=-1
TRIP	Grid Protection: TRIP-Command - 0=disabled, 1=enabled
GEN	Grid Protection: General starting - 0=disabled, 1=enabled
DSZ	Grid Protection: Distance zone of the distance protection with TRIP
R1k	Grid Protection: Resistance of the short-circuit impedance of the positive sequence system
X1k	Grid Protection: Reactance of the short-circuit impedance of the positive sequence system
DST	Daylight Saving Time: Summer = S, Winter = W
State	Overall result for the equipment according to the BDEW traffic light model (green, yellow, red)

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Power Grid Topology

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Period of Time

06.05.2025 00:15 DST=S - 06.05.2025 00:00 DST=S, User defined

JSON Forecast File: 2025-5-6-0-15_Network20kV_PVwithLoadProfiles_PROG.JSON

Load Flow Results: Line

Name	Vnom [kV]	Ipmax [%]	NA [%]	15min-Period	State
[Line 4] [NA2XS2Y 3x1x300 20kV] 2km	20.0	21.576	0.000	06.05.2025 14:00	Green
[Line 5] [NA2XS2Y 3x1x300 20kV] 2km	20.0	30.623	0.000	06.05.2025 13:00	Green
[Line 6] [NA2XS2Y 3x1x300 20kV] 2km	20.0	30.567	0.000	06.05.2025 13:00	Green

Load Flow Results: Line

Name	Vnom [kV]	Vmin [%]	15min-Period	Vmax [%]	15min-Period	State
[Line 4] [NA2XS2Y 3x1x300 20kV] 2km	20.0	99.853	06.05.2025 20:30	100.242	06.05.2025 14:30	Green
[Line 5] [NA2XS2Y 3x1x300 20kV] 2km	20.0	99.937	06.05.2025 21:00	100.315	06.05.2025 14:30	Green
[Line 6] [NA2XS2Y 3x1x300 20kV] 2km	20.0	99.857	06.05.2025 20:30	100.502	06.05.2025 14:00	Green

Grid State of Lines

Line: Validation acc.	Valid	Partly Valid	Invalid
VDE 0276	3	---	0
Green/Amber/Red acc. BDEW	3	0	0
EN 50160	3	---	0

Classification Need for Action (NA) of Lines

Need for Action NA [%]	Number of Lines
=0%	3
]0% - 10%]	0
]10% - 20%]	0
]20% - 30%]	0
]30% - 40%]	0
]40% - 50%]	0
]50% - 60%]	0
]60% - 70%]	0
]70% - 80%]	0
]80% - 90%]	0
]90% - 100%]	0
>100%	0

Classification Maximum Load of Lines

Maximum Load [%]	Number of Lines
=0%	0
]0% - 10%]	0
]10% - 20%]	0
]20% - 30%]	1
]30% - 40%]	2
]40% - 50%]	0
]50% - 60%]	0
]60% - 70%]	0

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Figure 49: Load Flow Calculation using Load Profiles – Report with the Results

The .CSV-file stored in the subdirectory Results can be opened in ATPDesigner using Drag&Drop. The dialog to select signals will be opened automatically. After selecting signals a diagram will be drawn.

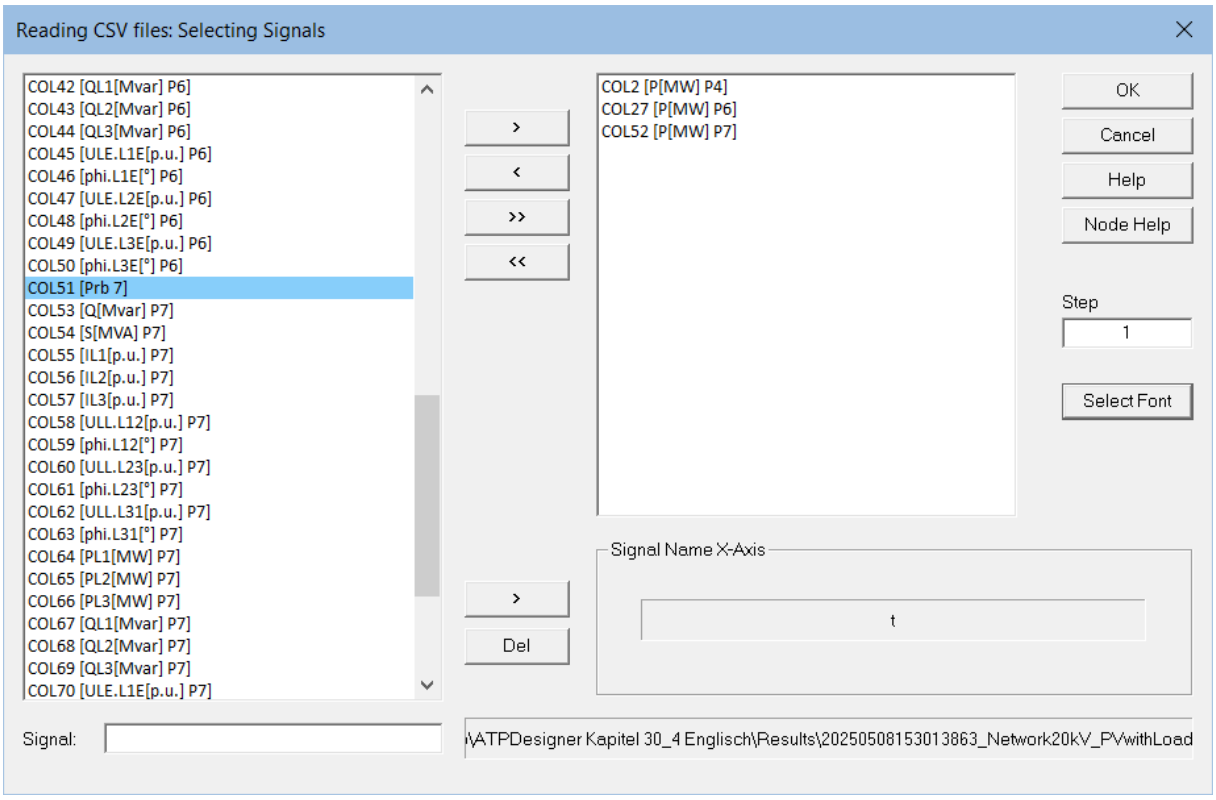


Figure 50: Dialog to select the Signals to be displayed in a Diagram

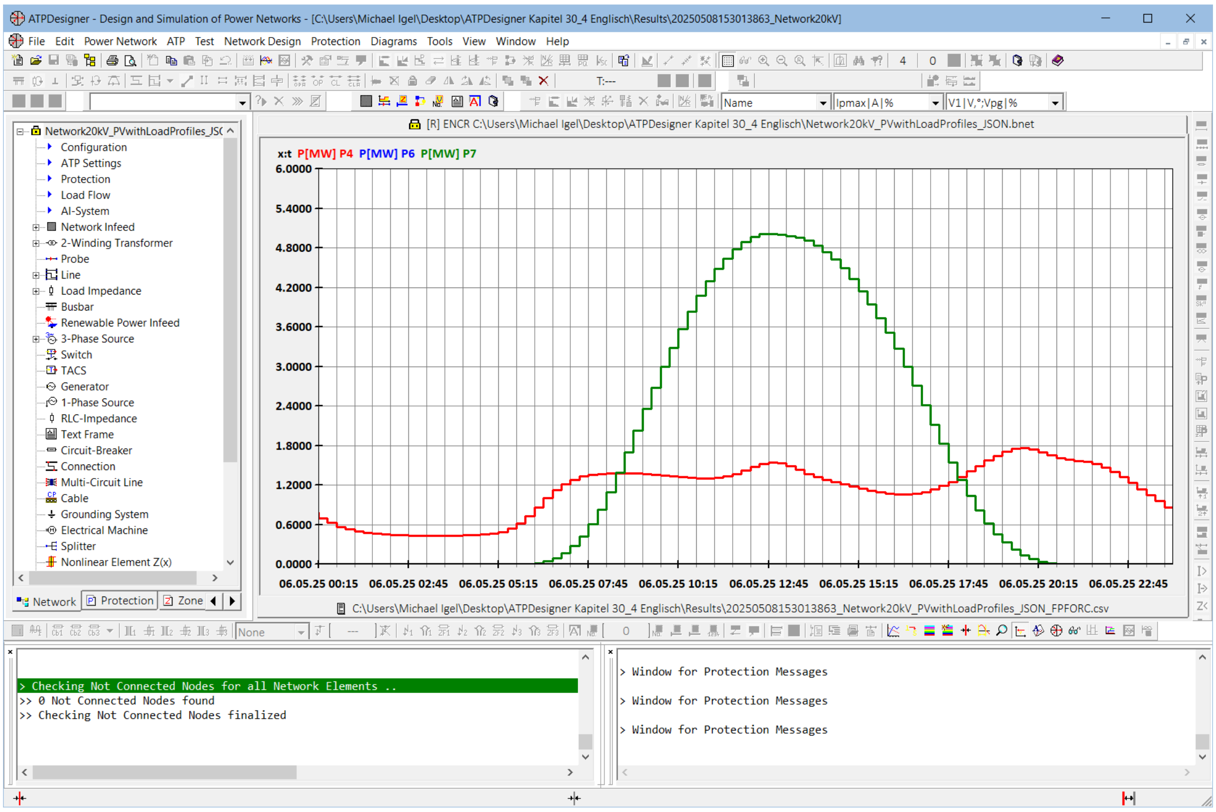


Figure 68: Schedule at *Probe* P6, P4 and P7

13 Web-based Load Flow Calculation with a Web Server based REST API

The integrated web server based REST API provides the capability to set up a web server for load flow calculations. Using an HTTP-based REST API, data can be sent from a web client to the ATPDesigner web server or retrieved from it.

⇨ In this chapter, the web server based REST API integrated in ATPDesigner will only be called **web server** or **REST API**.

The following HTTP commands are supported by the ATPDesigner **web server** based **REST API**:

- **POST**
  With the HTTP request **POST**, data are sent from a web client to the web server. The type of the HTTP request is specified by the **content-type** header.

- **GET**
  With the HTTP request **GET**, a web client requests data from the web server. The type of the HTTP request is specified by the **content-type** header.

The REST API uses the **URL parameter ID1** in the HTTP commands to define the request (task).

⇨ A **URL parameter** is a data pair (identifier-value) that is appended to a **Uniform Resource Locator** (**URL**), such as the IP address. A question mark is used as the separator between the IP address and the data pair.

Below an example of how the **URL parameter ID1** is used in HTTP commands:

- **GET** 255.255.255.255/?**ID1=1**
- **POST** 255.255.255.255/?**ID1=4**

The web server integrated in ATPDesigner uses the HTTP request to **POST** transfer data always in a **JSON forecast file**, which contains the task to be executed (JSON-Object **task**) and the associated data.

The data transmitted from the web server to the web client after a HTTP request **GET** can use various data formats:

- Reports e.g. containing the results of a load flow calculation processed by ATPDesigner are transferred in the Office Open XML format [6].

- Data can be transferred using the JSON forecast file as a wrapper, for example, the grid state red, amber or green as the result of the BDEW traffic light concept [3] in the case of a convergent load flow calculation.

As a proprietary API platform and testing environment for the web server with REST API, the software tool **Postman**[4] is recommended. It allows software developers to design, create, test, and further develop their APIs.

[4] www.postman.com

13.1 Enabling the Web Server and Web Server Settings

The following settings dialog shows the settings of the web server integrated in ATPDesigner under the tab **Webserver** of the settings dialog **Program Settings**.

- Main menu: **Tools**
- Menu item: **Webserver**, **Webserver Settings**
- Menu item: **Program Settings**, Tab **Webserver**

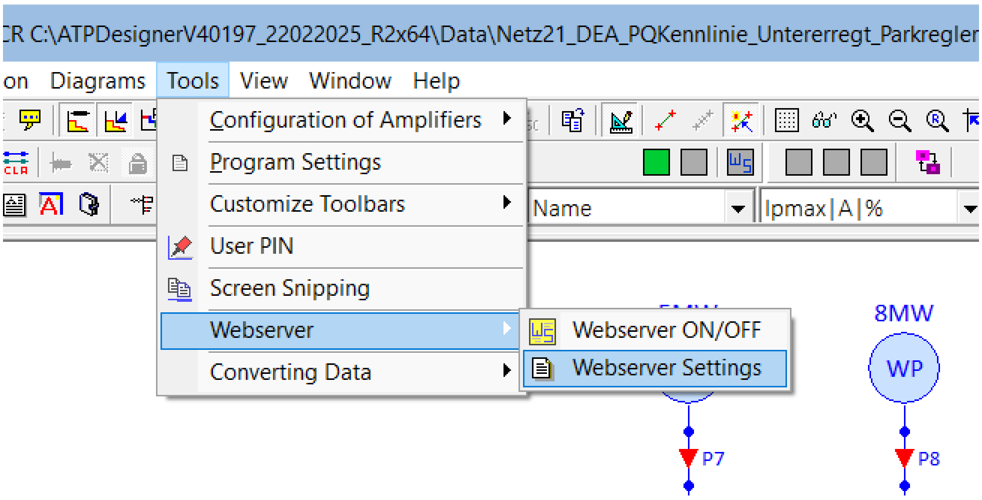


Figure 51: Web Server ON/OFF and settings dialog of the Web Server

The web server can be enabled or disabled using the menu option **Webserver ON/OFF**. Additionally, the web server can be toggled on and off using the toolbar button.

Setting	Description
Encrypted communication	The data received from the web client and the data sent to the web client are decrypted or encrypted using the Blowfish algorithm. ⇨ Encryption must be disabled if the http-based Rest API is used.
Timeout	Every time a valid http request (job) is received from the web client, a timeout is restarted as a re-triggerable time stage. The web server is automatically deactivated when the timeout expires. The timeout can be used as a further security level in addition to the whitelist.
Whitelist	List of permitted IP4 addresses of the web client The list of permitted IP4 addresses is used as a security mechanism to prevent unauthorised access by a client to ATPDesigner as a server. ⇨ If a http request is received from a web client whose IP address is not included in the list, the http request is not answered.
Default	Load default settings
IP-Adresse	The IP4 address of the web server's network adapter is determined and displayed in the **Message Window**.

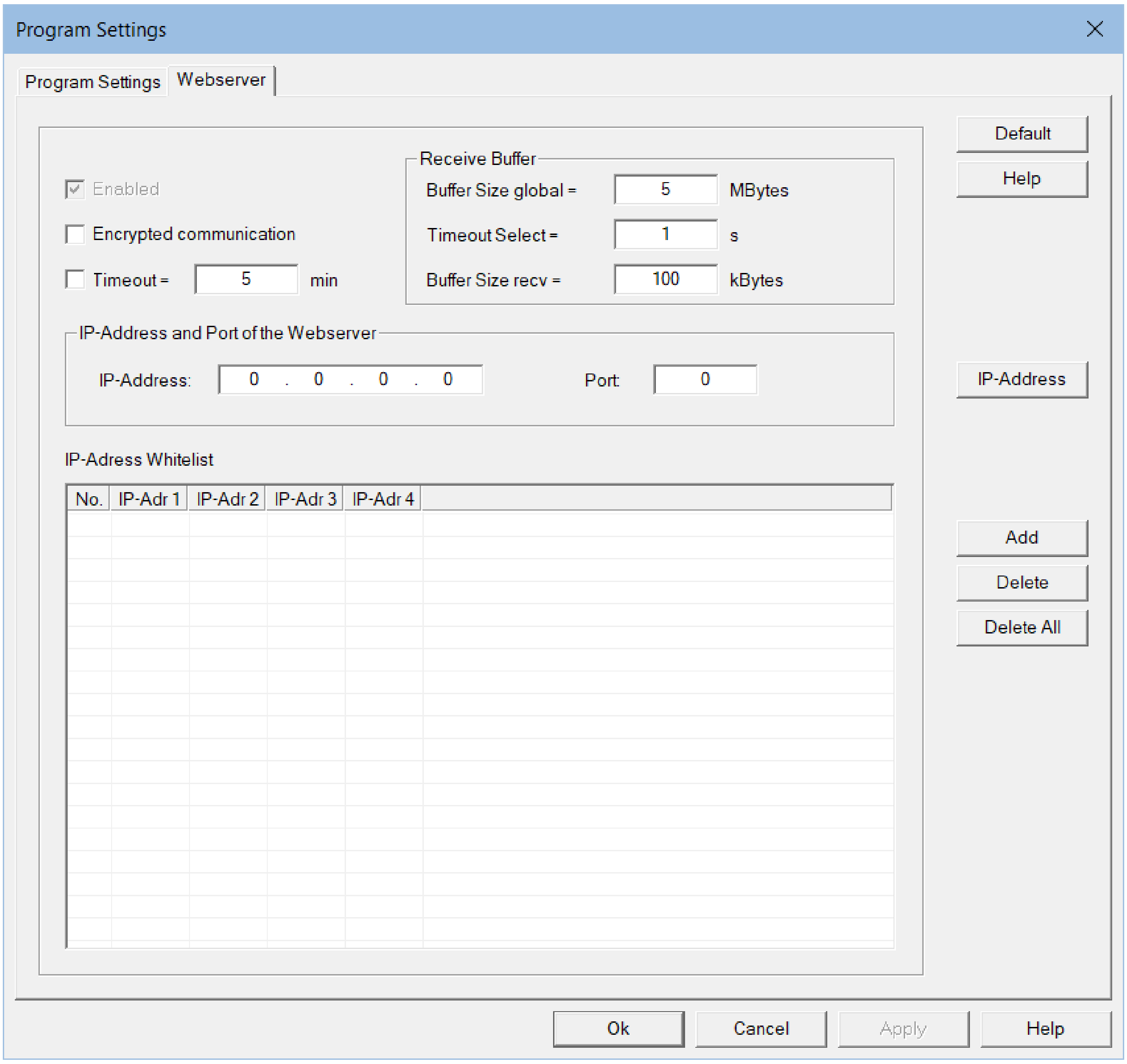


Figure 52: Settings dialog of the *Web Server*

Setting	Description
IP-Adresse	IP4-Adresse of the web server
Port	Port of the web server

Setting	Description
Add	Append a new input line to the table
Delete	Delete selected row from the table
Delete All	Delete all rows in the table

Files are usually transferred from a client to a server in several parts (data packets) via IP-based communication networks. The time span between the receipt of the individual data packets is determined by the sending client and is not known to ATPDesigner as a server. The size of the data packets can also vary greatly. In addition, there is a non-deterministic period of time between the receipt of the individual data packets by ATPDesigner. Once all data packets have been successfully received, ATPDesigner generates the file from the individual data packets and processes the received file.

In order to adapt ATPDesigner as a server to this transmission behaviour, the following setting values must be set appropriately for the specific project.

Setting	Description
Buffer Size global	Memory size of the receiving memory The memory size defines how large a file can be to be received by ATPDesigner as a server. If the JSON or CSV file to be received is too large, an error message is displayed in the **Message Window**. The receiving memory must be adapted, especially if, for example, a .NET file is contained in the JSON forecast file as a Base64-encoded character string.
Timeout Select	After receiving every individual data packet, ATPDesigner waits the timeout to receive another data packet. The timeout is restarted after a data packet has been received. If no further data packet is received before the timeout expires, ATPDesigner stops receiving the file.
Buffer Size recv	Memory size of the buffer The data transfer from a client to ATPDesigner as a server usually takes place in several data packets. The memory size defines the maximum memory size for a single data packet.

13.2 Webserver Configuration

The figure above shows the settings dialog of the web server. Below an example will be explained how to configure the web server.

⇨ If all settings of the web server settings dialog are simultaneously disabled, the current license for the ATPDesigner network calculation program does not include the web server based REST API.

The licensing of the web server can be checked in the **Message Window** directly after starting ATPDesigner. In the figure below, the option **HTTP REST-API** is enabled.

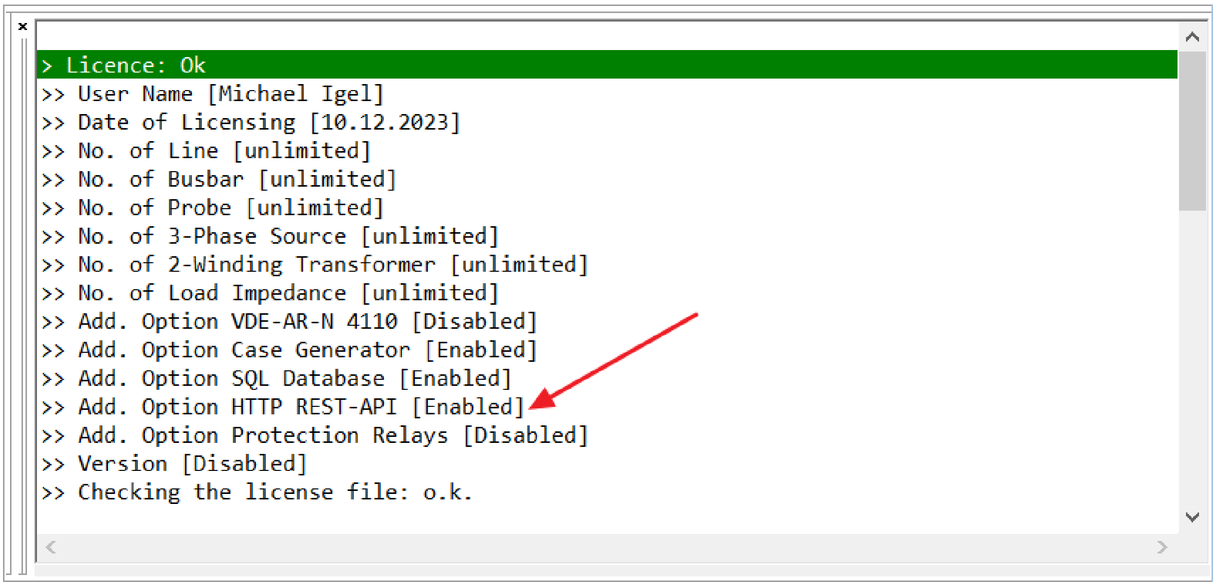


Figure 53: Checking the licensing of the web server with REST API

The following procedure is recommended for configuring the web server:

1. Disable the option **Encrypt communication** option.
2. Disable the **Timeout** option.

3. If necessary, adjust the **Buffer Size global** of the receive memory to match the maximum data volume expected from the web client.

4. Configure the **IP Address** and **Port** of the web server.
   The IP addresses and MAC addresses of the laptop/desktop can be displayed in the **Message Window** with a **Left Mouse Button Click** on the button **IP Address** button.

Next, the IP addresses of authorized web clients must be added to the **IP-Address Whitelist**. To do this, a new row in the table is opened for every authorized IP address by clicking the **Append** button with a **Left Mouse Button Click**.

⇨ If configuration settings in the tab **Webserver** have been changed, the web server must be disabled and re-enabled to apply and use the updated settings.

13.3 Start of the Webserver with REST API

The web server can be started as explained below.

- Main menu: **Tools**
- Menu item: **Webserver**, **Webserver ON/OFF**

Or using the toolbar button:

If the web server was successfully started, the following messages will be displayed in the **Message Window**. As can be seen, the web server was successfully configured, initialized and started. The last line shows that the web server is waiting for an HTTP request from a web client.

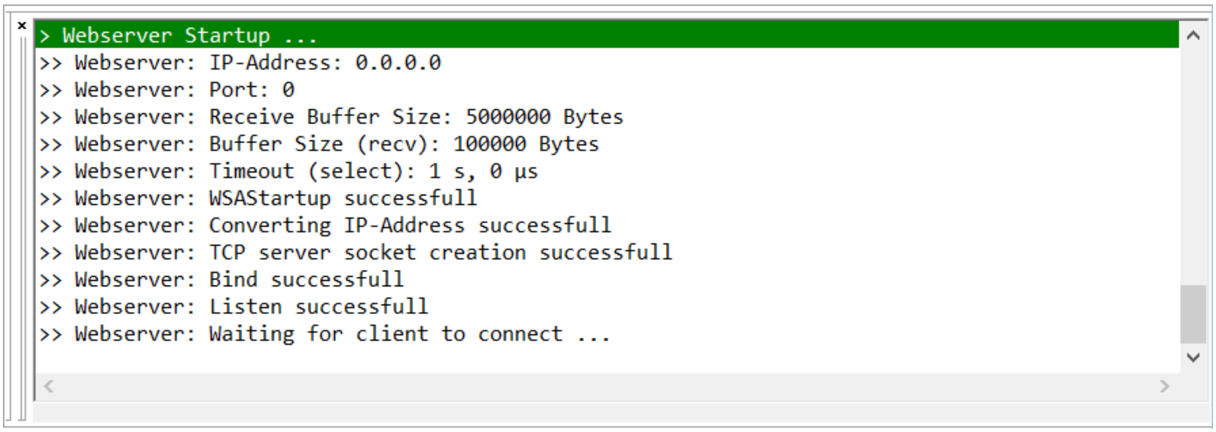


Figure 54: *Message Window* - Successful startup, waiting for a request from a web client

If the web server could not be started, for example, because the IP address of the web server is incorrectly set in the settings dialog, the following messages will be displayed in the **Message Window**.

```
> Webserver Startup ...
>> Webserver: IP-Address: 10.100.1.3
>> Webserver: Port: 80
>> Webserver: Receive Buffer Size: 5000000 Bytes
>> Webserver: Buffer Size (recv): 100000 Bytes
>> Webserver: Timeout (select): 1 s, 0 µs
>> Webserver: WSAStartup successfull
>> Webserver: Converting IP-Address successfull
>> Webserver: TCP server socket creation successfull
>> Webserver: Binding failed, error 10049
```

Figure 55: *Message Window* - The web server cannot be started

If the web server will be disabled, the following messages will be displayed in the **Message Window**.

```
>> Webserver: Port: 80
>> Webserver: Receive Buffer Size: 5000000 Bytes
>> Webserver: Buffer Size (recv): 100000 Bytes
>> Webserver: Timeout (select): 1 s, 0 µs
>> Webserver: WSAStartup successfull
>> Webserver: Converting IP-Address successfull
>> Webserver: TCP server socket creation successfull
>> Webserver: Binding failed, error 10049

> Web Server stop ...
>> Closing socket successfully
>> Webserver - Disabled
```

Figure 56: *Message Window* – Web server disabled

13.4 Example: Load Flow Calculation to determine the Grid State

With the HTTP request **POST**, a web client can send a request to ATPDesigner to initiate a load flow calculation. The HTTP request **POST** includes a **JSON forecast file** as its content to start the load flow calculation. The results of the load flow calculation can be retrieved using the HTTP request **GET**. To start a load flow calculation using an HTTP **POST** request of the **REST API**, the .NET file of the power grid must first be loaded:

- Main menu: **File**
- Menu item: **Open…** or **Ctrl + O**

Before starting the web server, it must be checked whether a convergent load flow calculation can be processed for the power grid. Therefore, a load flow calculation must be first processed by hand. Now the web server can be enabled. To send the HTTP **POST** request to the web server, a web client such as the Postman[4] API client is recommended to be used.

"*Postman is an API platform for building and using APIs. Postman simplifies every step of the API lifecycle and streamlines collaboration so you can create better APIs faster.* "[4]

Using a web client, the HTTP request **POST** can be sent to the IP address of the web server started in ATPDesigner. The HTTP request **POST** must include the following information:

- URL parameter: **/?ID1=3**
- Content-Type: **application/json**
- Content: **JSON forecast file**

To execute the HTTP request **POST** using the Postman[4] API client, the following steps must be followed the first launch of Postman API.

1. First the **Content-Type application/json** must be enabled in the tab **Headers**. To do this, the term **Content-Type** must be entered in the **Key** field and selected from the dropdown list. In the **Value** field, the desired content-type can then be selected in the same manner.

2. In the tab **Body**, the value **binary** must be selected.

3. A **JSON forecast file** must be loaded and set in the tab **Body**.

The following figure provides an example of the **Postman** API client, where the JSON file is configured as **Content** under the **Body** menu item.

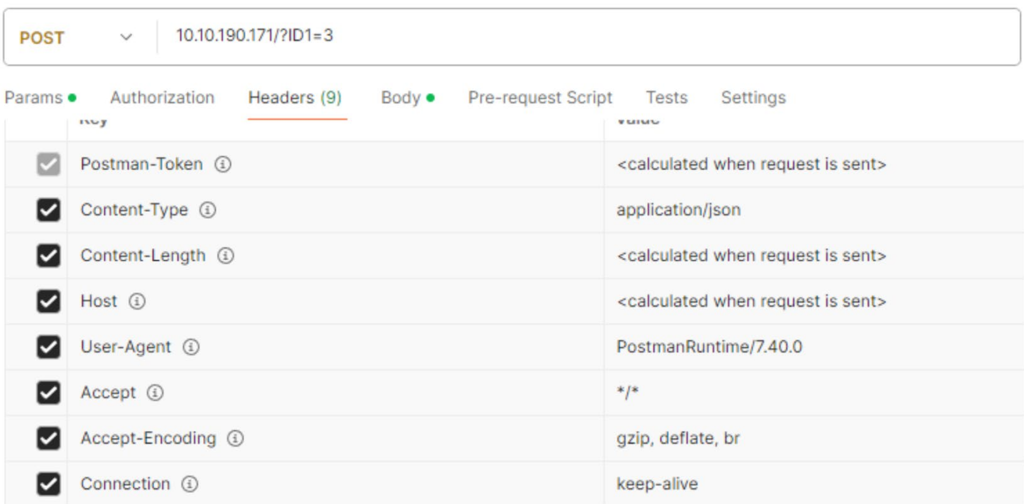


Figure 57: Configuration of the Web Client Postman API (Example)

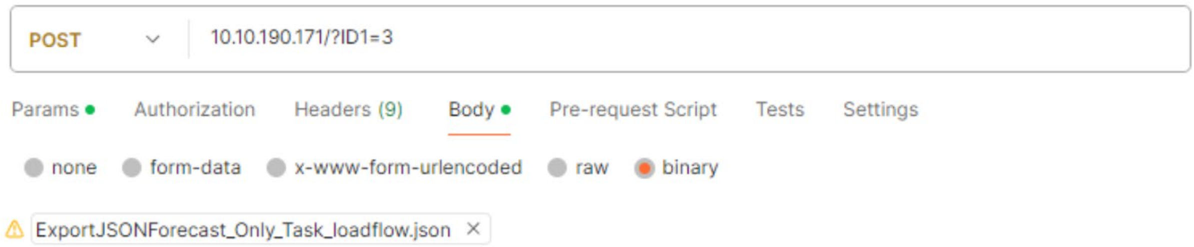


Figure 58: Configuration of the *JSON forecast file* in the tab *Body*

The figure below shows an example of a complete **JSON forecast file** to start a load flow calculation using the web server based REST API. To initiate a load flow calculation, the value **loadflow** must be assigned to the JSON-Object **task**.


```
[
	{
		"author": "Institut fuer elektrische Energiesysteme",
		"date": "23.11.2023",
		"time": "12:24:48",
		"description": "Export JSON-Forecast File",
		"filetype": "forecast",
		"fileversion": "1",
		"fileformat": "1",
		"simulationtime": "23.11.2023 00:15 DST=0 - 23.11.2023 00:30 DST=0",
		"operationmode": "User defined",
		"program_version": "ATPDesigner Version 4.01.91 - 23.11.2023",
		"datafile": "C:\\ATPDesigner\\01_28_WebServer\\network_15.bnet"
	},

	{
		"tasklist":
		[
			{
				"task": "loadflow"
			}
		]
	}
]
```


Figure 59: *JSON forecast file* to start a load flow calculation

After a convergent load flow calculation has been processed, the results of the load flow calculation can be retrieved using the HTTP request **GET** by the web client, e.g.:

- The grid state (**red**, **green**, or **yellow**) based on the BDEW traffic light concept [3].
- The load flow calculation report (Office Open XML [6]).

The HTTP request **GET** to retrieve the calculated grid state must include the following information:

- URL parameter: /?**ID1=4**
- Content-Type: **text/plain**

To execute the HTTP request **GET** using the Postman API client, the following steps must be followed after the first launch of the **Postman** API client:

1. First, the **Content-Type text/plain** must be enabled in the tab **Headers**.
2. Second, the type **none** must be selected in the tab **Body**.

In the HTTP response, the web server will send back the following **JSON forecast file** as **content** to the web client.


```
[
	{
		"author": "Institut fuer elektrische Energiesysteme",
		"date": "22.12.2023",
		"time": "12:10:35",
		"description": "Meldung an den Web Client",
		"filetype": "Lastflussberechnung",
		"fileversion": "1",
		"fileformat": "1",
		"program_version": "ATPDesigner Version Version 4.01.91 - 22.12.2023",
		"datafile": "C:_ATPDesigner_01_28_WebServer_WebServer_TestNetz.bnet"
	},
	{
		"lfresults":
		[
			{
				"gridstate": 0
			}
		]
	}
]
```


Figure 60: *JSON forecast file* to retrieve the grid state of the last load flow calculation

The grid state determined in the last load flow calculation is transmitted as the value of the JSON object **gridstate**, in accordance with the BDEW traffic light concept [3].

Grid state	Meaning
0	No current grid state available
1	Grid state: **Red**
2	Grid state: **Yellow**
3	Grid state: **Green**

The HTTP request **GET** to retrieve the report of the last load flow calculation must include the following information:

- URL parameter: /?**ID1=1**
- Content-Type: **text/plain**

In the HTTP response, the web server will send back the most recent report (i.e., the latest one) as **content** to the web client, as shown in the figure below.

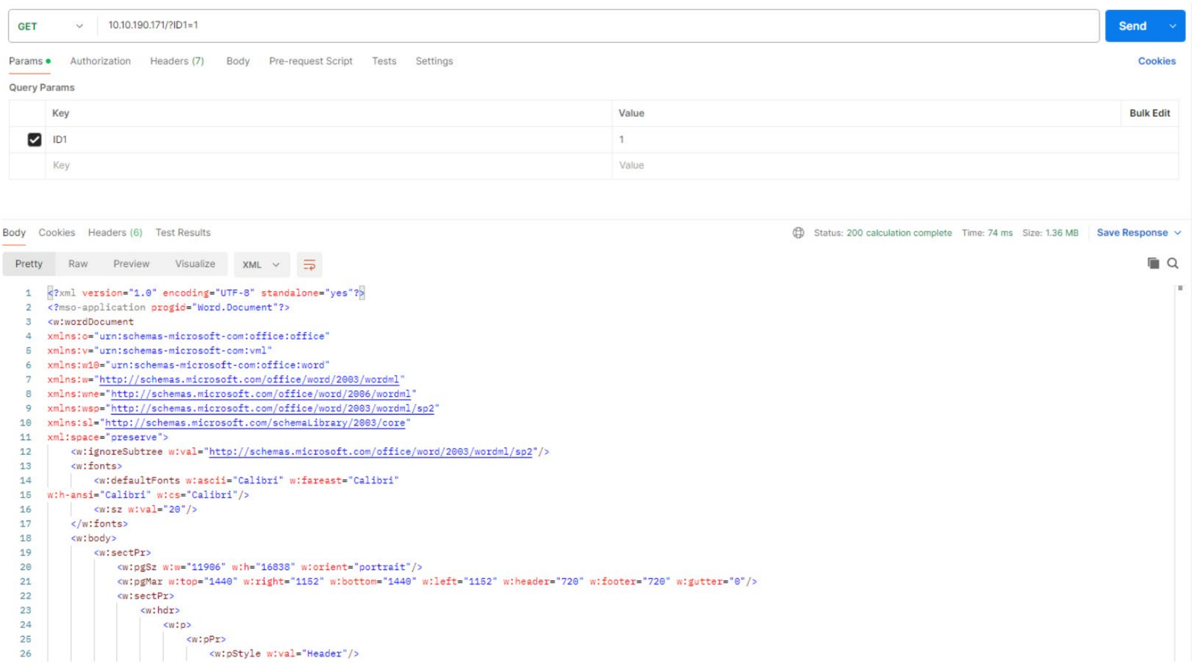


Figure 61: Load flow calculation report as HTTP response in the Postman API web client

14 Protection Relays in ATPDesigner

The grid calculation program ATPDesigner is especially designed for the simulation of electrical power grids of all voltage levels, the protection systems, protection relays and decentralised generation systems[5] used in them. The numerical models of protection functions implemented in ATPDesigner are generic, i.e. manufacturer-independent models. ATPDesigner provides generic models for the protection functions and protection relays as well as many additional protection related functions.

Protection relays and protection schemes will be realized using one or more **Probe**. The network element **Probe** can be used as **measuring device** and/or **protection relay** also for steady-state calculations (load flow calculations) as well as for transients calculations.

⇨ **Please note**, that the behaviour of protection relays for transient calculations in ATPDesigner will be realized using the **MODELS** script language of the ATP. The amount of protection functions for transients calculations is significant smaller compared to the amount of protection functions for steady-state calculations.

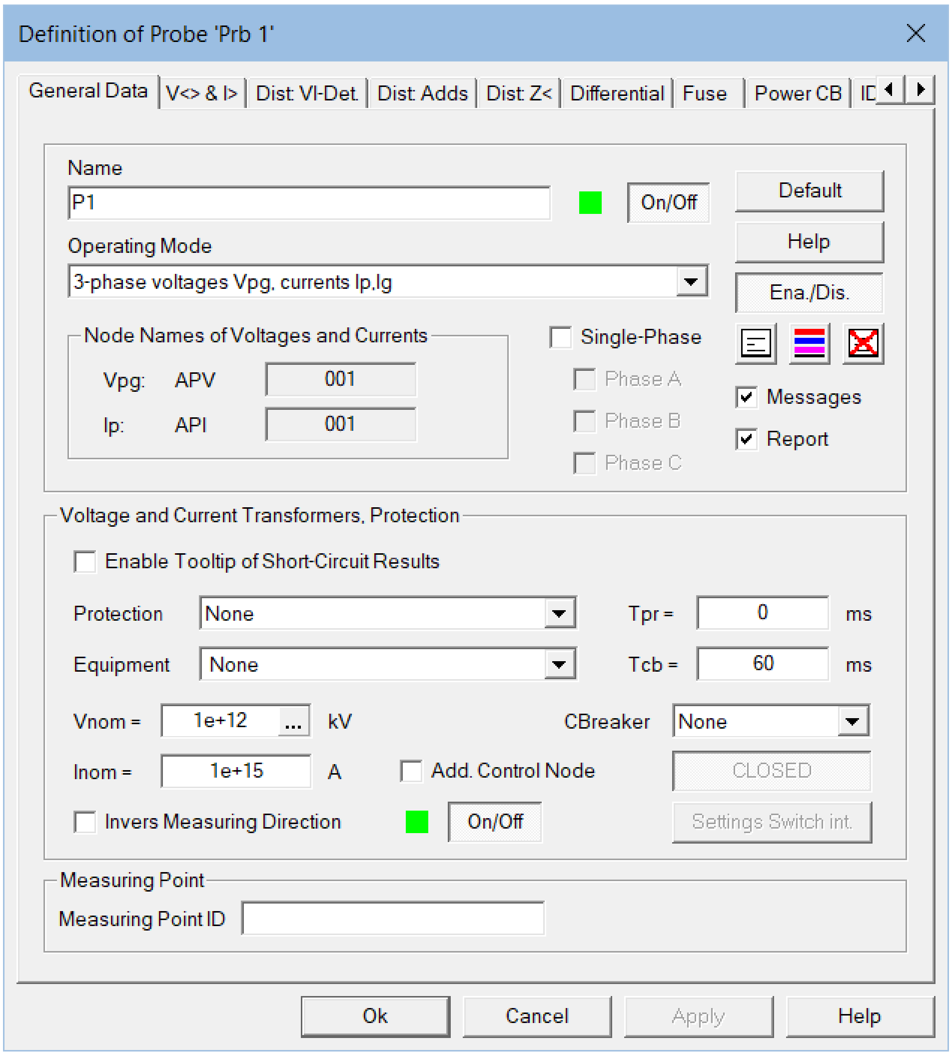


Figure 62: Settings Dialog of the Network Element *Probe* – Measuring Device and Protection Relay

In the figure below the abreviations of the tabs of the settings dialog are explained.

Tab	Protection	Logical Node acc. IEC61850
General Data	Settings which are relevant for all protection functions	**---**
V<> & I>	Undirectional Overcurrent Protection I> Directional Overcurrent Protection I> Undervoltage Protection V<> Overvoltage Protection V<>	**PTOC** **PDOC** **PTUV** **PTOV**
Dist. VI-Det.	Distance Protection: Starting System	**PDIS**
Dist: Adds	Distance Protection: Additional functions	**PDIS**
Dist: Z<	Distance Protection: Tripping characteristic	**PDIS**
Differential	Differential Protection	**PDIFF**
Fuse	Low-Voltage (NH) and High-Voltage (HH) Fuses	**PTOC**
Power CB	Undirectional Overcurrent Protection with Circuit-Breaker	**PTOC, XCBR**
IDMT	Dependent Time Overcurrent Protection	**PTOC**
Signal	Protective Signaling	**PTRC**
ARC	Automatic Reclosing	**RREC**
Z< Det.	Distance Protection: Underimpedance Detection	**PDIS**
GF Det.	Ground Fault Detection	**PSDE**
QV	Reactive Power – Undervoltage Detection	**---**
3PS Control	Steady-State (Load Flow): Regulator for **Decentralised Generation Plant** (DGP)[5] or **Unconventional Power Plant**	**---**
RPI Control	Transients: Steady-State: Regulator for **Decentralised Generation Plant** (DGP) or **Unconventional Power Plant**	**---**

Figure 63: *Probe* - Protection Functions in ATPDesigner

⇨ What is IEC 61850 ?
"IEC 61850 is an international standard that defines communication protocols to provide communication between different equipment located in a substation, such as protection, control, and measurement equipment, as well as (IEDs) intelligent electronic devices. From its first version, this standard reached considerable success in substation communication networks and systems management." (www.sgrwin.com/basic-understanding-iec-61850)

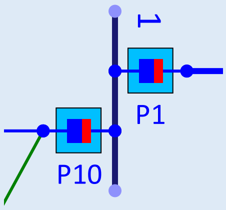
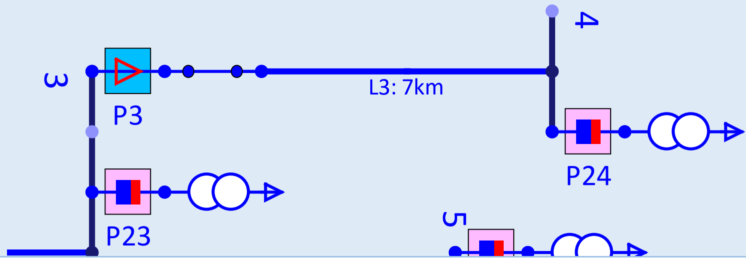
Logical Node acc. IEC61850	Description
PTOC	Time over current protection
PDOC	Directional overcurrent protection
PTUV	Undervoltage protection
PTOV	Overvoltage protection
PDIS	Distance protection
PDIFF	Differential protection
XCBR	Circuit-breaker
RREC	Automatic reclosing
PSDE	Sensitive earthfault detection protection

Figure 64: Logical nodes according IEC61850

Below the settings of the settings dialog tab **General Data** are explained.

Setting	Description
Name	User specific name of the protection relay
Vnom	Primary nominal voltage of the voltage transformers
Inom	Primary nominal current of the current transformers
Protection	Protection function e.g. Distance Protection
Equipment	Equipment to be protected e.g. **Line** or **Transformer 2-Winding**

[5] DGP = Decentralised Generation Plant e.g. solar power plant. Decentralised generation plant are also called **Unconventional Power Plant**

Invers Measur-ing Direction	The standard measuring direction is defined according to the consumer counting arrow system in the direction of the **red arrow**. If enabled the measuring direction will be inverted.
Tpr	**Steady-State**: The time which then virtual protection algorithm needs to an-alyse the short-circuit and to decide if a tripping signal **TRIP** will be send to the circuit breaker.
Tcb	Time to open the circuit-breaker if a tripping signal **TRIP** will be received.
CBreaker	An external or internal circuit-breaker can be selected and linked to the protection function. ▪ **SwtIntern**: The internal circuit-breaker will be selected. The figure below shows an example of two distance protection relays with internal cir-cuit-breaker.  ▪ **Swt x**: An external Switch can be selected and linked to the protection function. The figure below shows an example of the distance protec-tion relay **P3** using an external **Switch** as circuit-breaker.  ▪
Settings Switch int.	If the internal switch has been selected as **CBreaker**, this button will be en-abled. A settings dialog can be opened with a **Left Mouse Button Click** to change the default settings of the **Switch**.
CLOSED	The internal switch **CBreaker** can be opened or closed. The internal switch can also be opened and closed directly in the network graphic. ▪ Move the mouse cursor "over" the shape of the **Probe** ▪ The switch can be opened or closed with a **Right Mouse Button Click**.
On/Off	The protection function can be switched **ON** or **OFF**.
Operating Mode	The operating mode will be only used for transients calculations, not for steady-state calculations.
Messages	**Steady-State**: The results of the protection analysis of the protection relay will be written in the **Protection Messages Window**.
Report	**Steady-State**: The results of the protection analysis of the protection relay will be written in the Protection Report (XML-file [6]).

More explanations about the settings off the settings dialogs in the tabs will follow in the next chapters.

14.1 Reference Grid and Equipment Data

This document explains, how to design a selective grid protection concept with distance protection and HV fuses using ATPDesigner in a medium-voltage grid, so called **Reference Grid** in this document. It will also be explained, how to setup this concept using the models of protection relays and protection functions available in ATPDesigner and which software features of ATPDesigner can be used to test the large and complex **Selective Grid Protection Concepts**.

⇨ The reference grid is part of the ATPDesigner installation setup. The power grid is stored in the directory **c:\atpdesigner\data** using the filename **Netz18_20kVMitDistanzschutz.BNET**

The figure below shows the medium-voltage power grid, which is used as **Reference Grid** to design a **Selective Grid Protection Concept**.

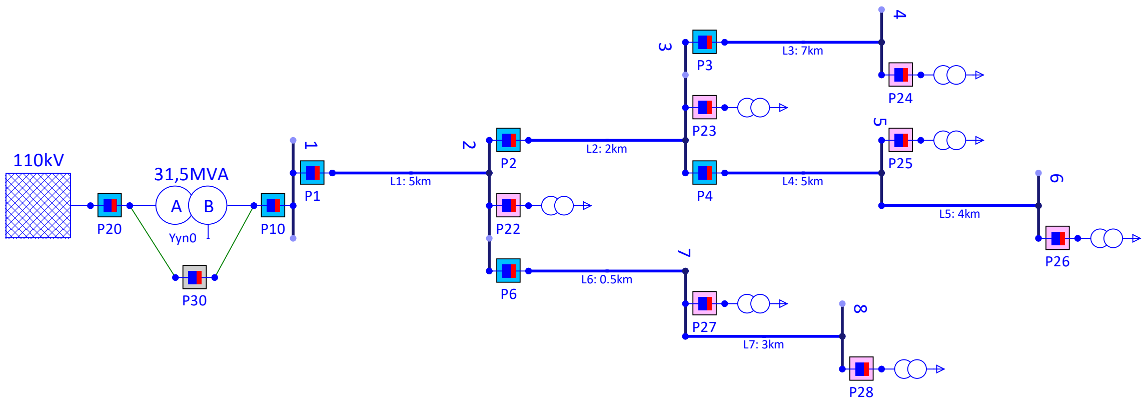


Figure 65: 20kV-Reference Grid with Distance Protection and HV-Fuses

The technical data of the equipment used in the reference grid are shown in the table below. Additional settings for the protection relays are defined in later chapters.

Network Infeed

- V_{nom} = 110 kV
- S_{SC} = 2000 MVA
- $\underline{Z}_0 = 2 \cdot \underline{Z}_1$

2-Winding Transformer 31.5MVA

- Transformer Library: 110/20kV, 31.5MVA, 12% 130kW, Yyn0
- V_{rA} = 121 kV
- V_{rB} = 21.5 kV
- Excitation Data: disabled

2-Winding Transformer 1000kVA

- From the Transformer Library
- $V_{nom\ HV}/V_{nom\ LV}$ = 20/0.4kV
- S_r = 1000kV
- u_k = 6%
- P_k = 7,6kW
- Vector Group: Dyn5

Busbar

- V_{nom} = 20 kV
- I_{thr} = 25 kA
- T_{kr} = 1 s
- $I_{k\ max}$ = 25 kA

Protection Relay (Probe) P1…P4, P6, P10

- Protection: Distance Protection
- V_{nom} = 20 kV
- I_{nom} = 600 A
- Switch: SwtIntern

Protection Relay (Probe) P20

- Protection: Distance Protection
- V_{nom} = 110 kV
- I_{nom} = 200 A
- Switch: SwtIntern

Protection Relay (Probe) P30

- Protection: Differential Protection
- V_{nom} = 20 kV
- I_{nom} = 600 A
- Switch: SwtIntern

Protection Relay (Probe) P22…P28

- Protection: Fuse (HV)
- V_{nom} = 20 kV
- I_{nom} = 600 A
- Switch: SwtIntern

Line

- Line Library: N2XSY 3x1x300 20kV
- Length: see network graphic

Table 1: Technical Data of the Equipment

14.2 Protection Report *_PROT*

The results of the behaviour of the protection relays as well the results of the protection scheme analysis will be directly shown in the network graphic view, but also written in a **Protection Report** (XML-file [6]), which will be stored in the **Project Directory**.

File Naming Convention:

20250504184959072_ **Netz18**_20kVMitDistanzschutz **_PROT**.XML

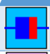
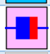
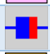
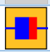
YYYYMMDDhhmmss_*Filename*_PROT.xml

Storage Location:

Project Directory

14.3 *Protection Messages Window* of ATPDesigner

More detailed results of the protection scheme analysis will be written in the **Protection Messages Window** explained below. The protection functions will be indicated using different colors for the shape of the network element **Probe**.

Symbol	
	Distance Protection
	Low-Voltage (NH) and High-Voltage (HH) Fuses
	Differential Protection
	Undirectional Overcurrent Protection

The figure below shows a 20kV power grid (reference grid) in case of a 3-phase short-circuit (3p) at **Busbar** 2. Distance protection, differential protection and HV fuses will be used to define and realise a selective protection concept.

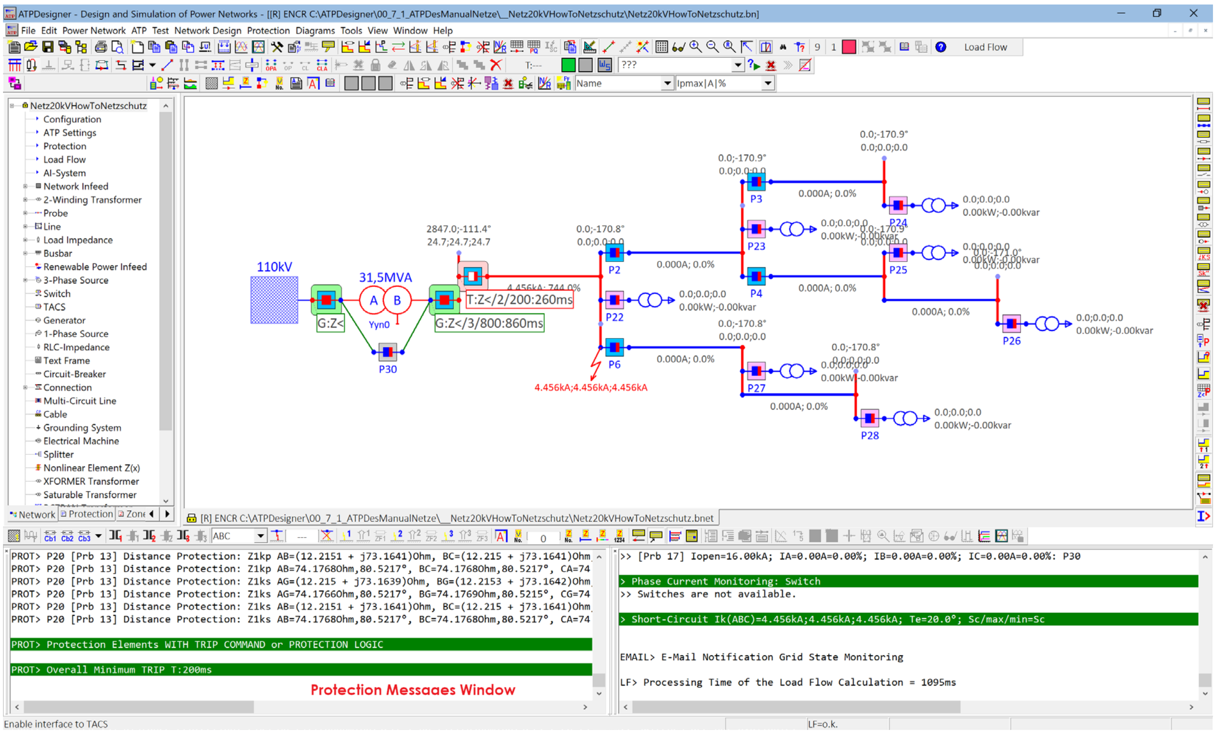


Figure 66: 20kV – Network with Protection Relays: Distance and Differential Protection, Fuses

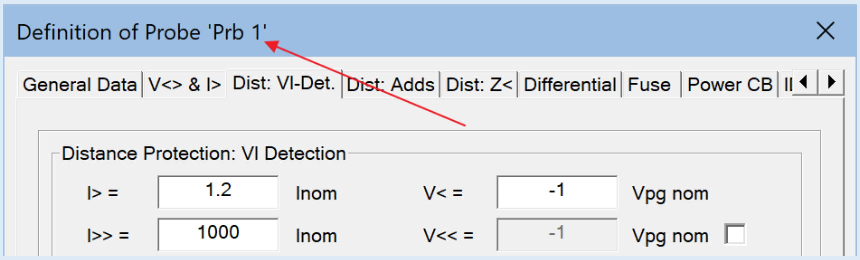
The results of the protection relays **Prb x** will be written into the **Protection Messages Window** as shown in the example in the figure below.

```
PROT> P20 [Prb 13] Distance Protection GEN=1 [V>=0(000), V<=0(000)] TRIP=0: V<, V>
PROT> P20 [Prb 13] Distance Protection GEN=1 [ARC=0 Ext. ARC: k1*DZ1/TStart=0 DZ1:k1=1]
PROT> P20 [Prb 13] Distance Protection V<>(1) GEN=1 [V>=0(000) TRIP=0] [V<=0(000) TRIP=0]
```

It is possible to copy one or more lines of the messages window into the clipboard.

- Select one line of the messages window with a **Left Mouse Button Click** on the line
- Select two or more lines of the messages window with two or more **Left Mouse Button Click** but press the **CTRL** key first and keep in pressed as long as lines shall be selected.
- Copy the selected lines into the clipboard using **CTRL + C**

<table>
<tr><th>Text Element</th><th>Explanation</th></tr>
<tr><td>Pxx [Prb yy]</td><td>User specific name [Reference Name]
The reference name of the network element will be displayed in the head-line of the settings dialog, which can be opened with a Left Mouse Button Double Click on the shape of the network element.



</td></tr>
<tr><td>GEN</td><td>General Starting information of the protection relay</td></tr>
<tr><td>TRIP</td><td>TRIP command of the protection relay to open the circuit-breaker e.g. the internal switch SwtIntern</td></tr>
</table>

15 Protection Relays based on the Network Element *Probe*

The network element **Probe** must be used to realize protection relays and protection functions in ATPDesigner. Based on this network element, large and complex protection schemes can be realized and tested. The network element can be inserted into the drawing area using **Drag&Drop**.

- Move the mouse cursor "over" the name of the network element in the tab **Network**
- Press the left mouse button and keep it pressed
- Move the mouse button to a position in the drawing area
- Release the left mouse button

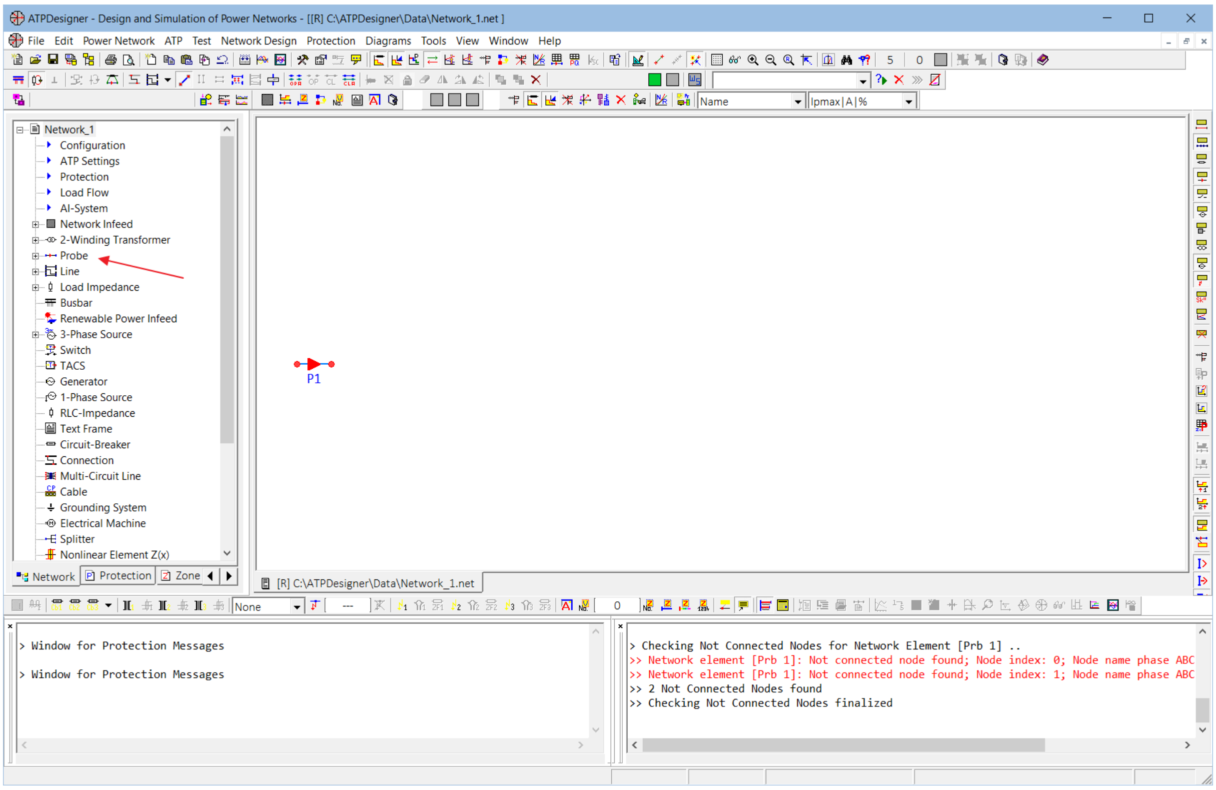


Figure 67: Insert a network element *Probe* in the drawing area using *Drag&Drop*

15.1 Open the Settings Dialog

The settings dialog can be easily opened by a **Left Mouse Button Double Click** on the shape of the network element.

- Select the network element using a **Left Mouse Button Click** on its shape ➔ then drawn in **grey** drawing colour
- Press the right mouse button down
- Move the mouse button to the line **Network Element Settings** as shown in the figure below
- Press the left mouse button to open the settings dialog

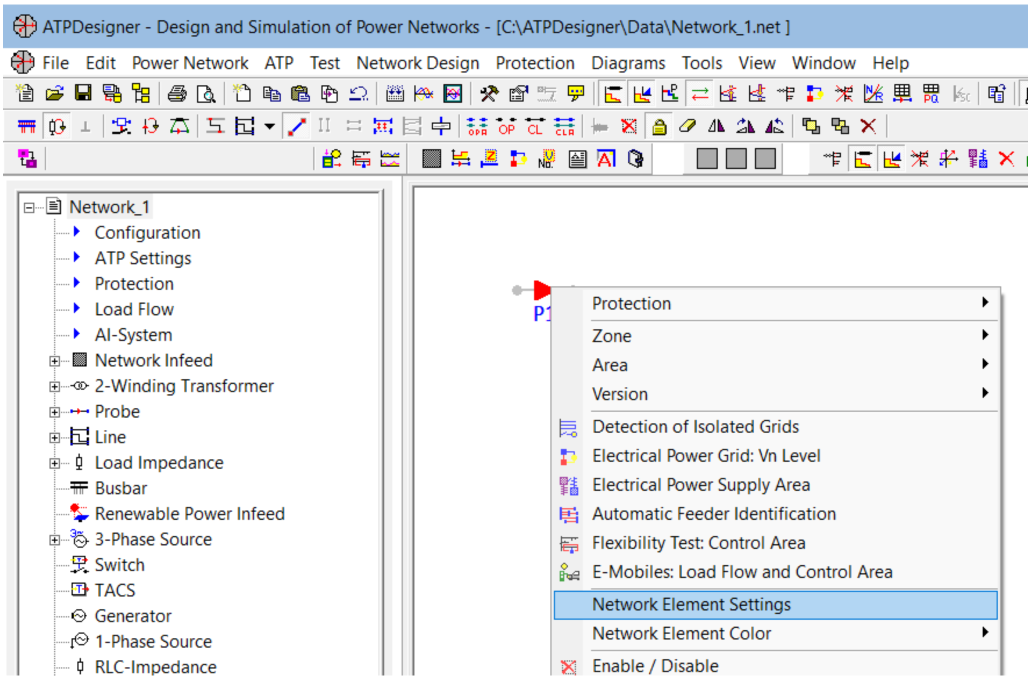


Figure 68: Open the settings dialog using a *Right Mouse Button Menu*

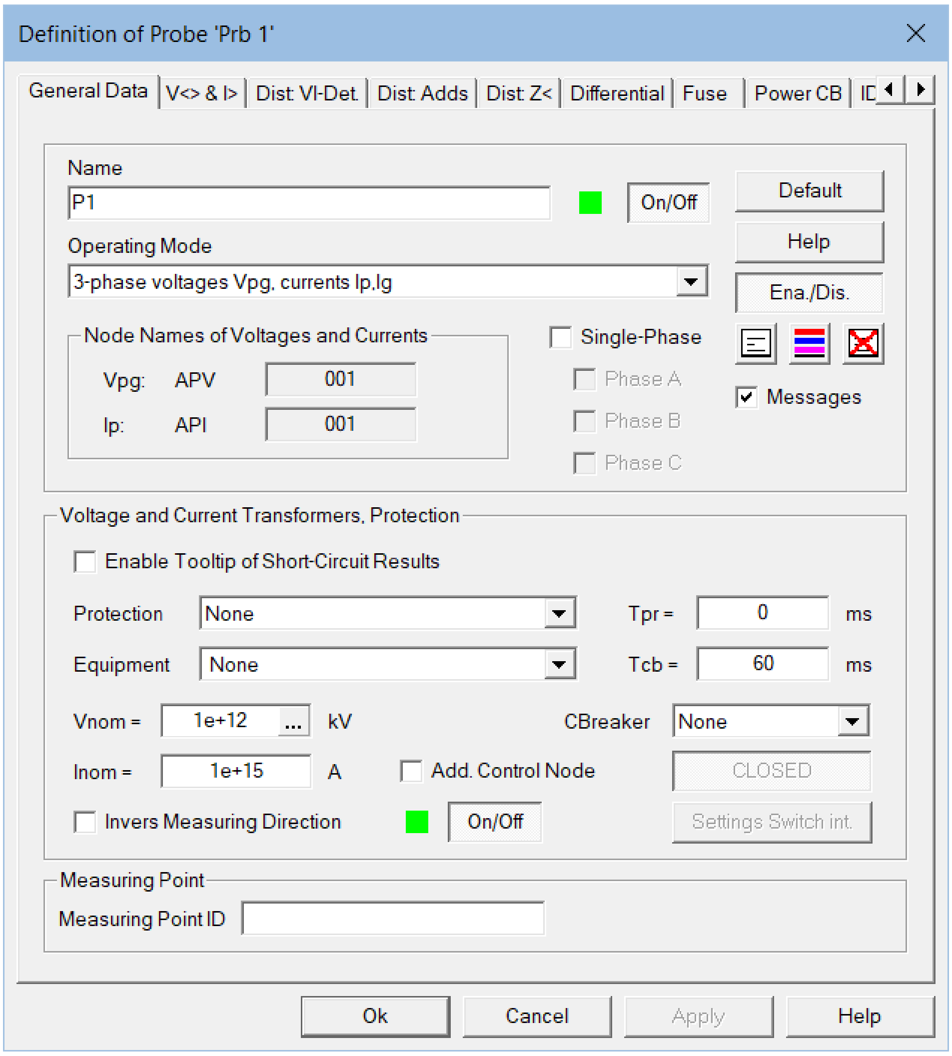


Figure 69: Settings dialog of the network element *Probe*

The settings of the network element **Probe** can be all used for the calculation of the steady-state conditions of the grid with and without a short-circuit.

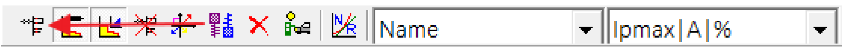
- The method to calculate the steady-state conditions of an electrical power network without short-circuit will be normally called **Load Flow Calculation**.
- In this document the calculation of the steady-state conditions of an electrical power network **with short-circuit** will also be called **Load Flow Calculation** or **Load Flow Calculation with Short-Circuit**.
- ATPDesigner uses the name **Short-Circuit Results** for the method to calculate the steady-state conditions of an electrical power network **with or without short-circuit**.
- The method **Short-Circuit Results** is identical to the method **Load Flow Calculation with and without Short-Circuit**.

The most settings of the network element **Probe** will be used for **Short-Circuit Results** means **Load Flow Calculation with and without Short-Circuit**.

⇨ In this document, only steady-state conditions of an electrical power network with and without short-circuits will be calculated.

⇨ Therefore, only the settings of the network element **Probe** for the calculation of **steady-state conditions** will be explained and used to realize protection relays and protection schemes.

- Main menu **ATP**
- Menu item **Short-Circuit Results** or **Ctrl + E** or using the toolbar button in the toolbar.

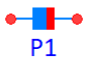
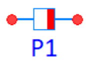
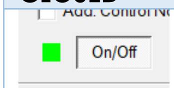


- Caused by the history of ATPDesigner the menu item is not called **Load Flow Calculation** but **Short-Circuit Results**

Toolbar	Description
	Start the **Short-Circuit Results**
	▪ If enabled, ATPDesigner uses an iteration algorithm as part of the load flow calculation to iterate the internal impedance $\underline{Z}$=R+jX acc. the settings of the active and reactive power of consumer loads (e.g. network element **Load Impedance**) ▪ If disabled, the internal impedance $\underline{Z}$=R+jX will be set to the initial values and will not be iterated by the load flow calculation algorithm ⇨ This option should be disabled if a short-circuit will be used during the **Load Flow Calculation with Short-Circuit**, means **Short-Circuit Results**.
	▪ If enabled, ATPDesigner uses an iteration algorithm as part of the load flow calculation to iterate the internal model of the network element **3-Phase Source** based on a current source, in order to achieve the setting values such as active power and reactive power but also for the **LVRT-operation mode** (**L**ow **V**oltage **R**ide **Through**) in case of a short-circuit. ⇨ This option must be enabled for the load flow calculation with and without short-circuit.

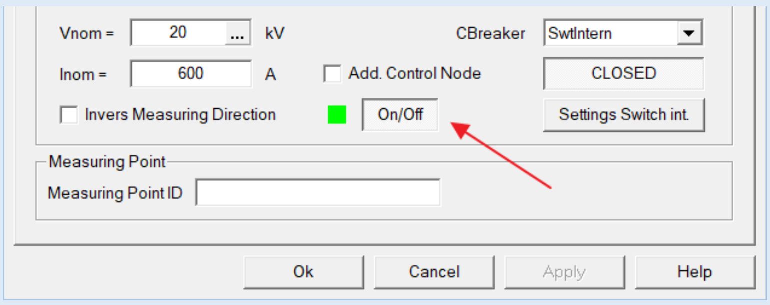
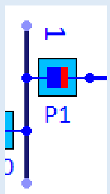
15.2 Short-Circuit Results: Settings of the Network Element *Probe*

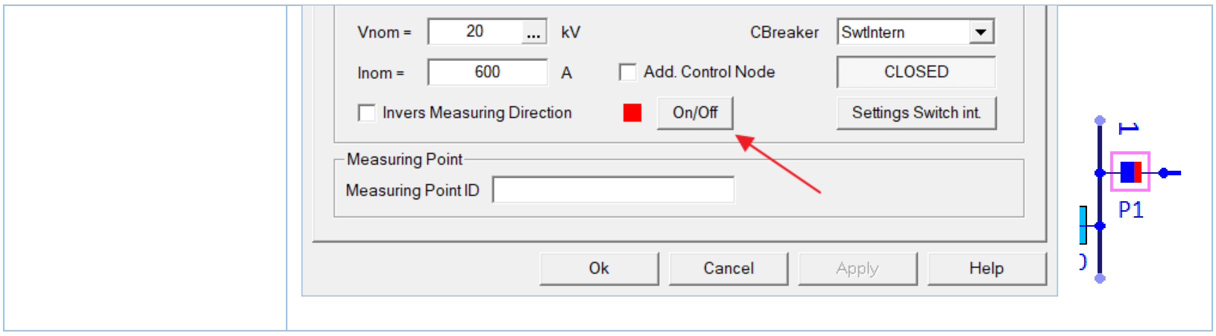
Settings of the network element **Probe**, which are important to realise protection functions and protection schemes will be explained in the figure below.

Setting	Description
Protection	Select the main protection function
Equipment	Equipment to be protected
Vnom	Primary nominal voltage
Inom	Primary nominal current
Invers Measuring Direction	▪ If enabled: consumer counting arrow system in direction of the **red arrow** ▪ If disabled: consumer counting arrow system in direction reverse to the direction of the **red arrow**
Tpr	Internal operating time of the protection relay, what means the time to execute all internal algorithms, methods, etc. of the protection relay
Tcb	Open time of the circuit-breaker after the protection relay has generated a trip command
CBreaker	▪ None: internal switch (circuit-breaker) is disabled ▪ **SwtIntern**: enabled the internal switch (circuit-breaker) **Closed**  **Open**  The internal switch (circuit-breaker) can be opened and closed. ▪ Move the mouse cursor over the shape of the **Probe** ▪ Press the **Right Mouse Button** to open or close the internal switch **SwtIntern**.
CLOSED	Open or close the internal switch (circuit-breaker) **SwtIntern**
	Enable or disable the functions of the protection relay
Messages	Enable or disable writing messages of the functions of the protection relay into the **Protection Messages Window**

15.3 Protection On/Off

The button **On/Off** can be used to enable **On** or disable **Off** the protection functions of the **Probe**. If the protection functions are disabled, a corresponding message is displayed in the message window.

Text Element	Description
Protection Relay On	The protection functions of the protection relay, which is identical to the network element **Probe** are enabled and can be used based on the user-specific settings.  
Protection Relay Off	All protection functions of the protection relay, which is identical to the network element **Probe** are disabled.



15.4 Settings of the internal Switch (Circuit-Breaker) *SwtIntern*

The setting can be used to define a typical characteristic of a switch for normal operation and short-circuit operation. The figure below shows the settings dialog.

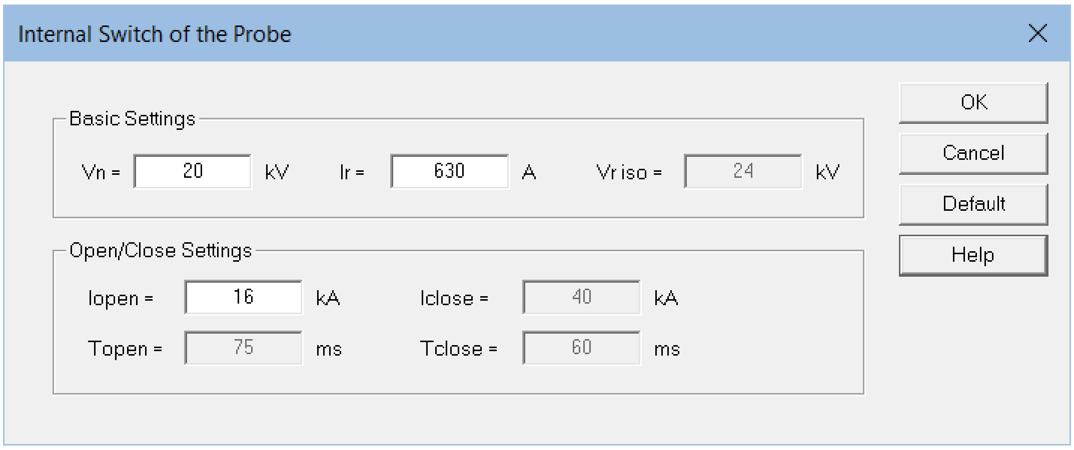


Figure 70: Settings of the internal Switch (Circuit-Breaker) *SwtIntern*

Settings	Explanation
Vn	Nominal Voltage
Ir	Rated Load Current
Vr iso	Maximum permissible insulation voltage
Iopen	Maximum permissible breaking current in case of a short-circuit
Topen	Typical switch-off time (open time)
Iclose	Maximum permissible current closing the switch
Tclose	Typical switch-on time (close time)

The settings are used in the grid state analysis to monitor the grid state and are written in the message window. The figure below shows typical results for a protection relay using an internal switch.

Use Case	Display Values
Normal Operation Mode	Amount of phase currents in A and in $\%I_r$
Short-Circuit Operation Mode	Amount of conductor currents in A and in $\%I_{open}$

```
> Phase Current Monitoring: Probe
>> [Prb 1] Iopen=16.00kA; IA=4455.81A=27.85%; IB=4455.81A=27.85%; IC=4455.81A=27.85%: P1
>> [Prb 2] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P2
>> [Prb 3] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P3
>> [Prb 4] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P4
>> [Prb 5] Iopen=16.00kA; IA=4455.81A=27.85%; IB=4455.81A=27.85%; IC=4455.81A=27.85%: P10
>> [Prb 6] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P6
>> [Prb 13] Iopen=16.00kA; IA=791.73A=4.95%; IB=791.73A=4.95%; IC=791.73A=4.95%: P20
>> [Prb 8] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P24
>> [Prb 9] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P26
>> [Prb 10] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P28
>> [Prb 7] Iopen=16.00kA; IA=0.00A=0.00%; IB=0.00A=0.00%; IC=0.00A=0.00%: P27
```

Figure 71: Short-Circuit Result - Results of the Grid State Analysis in the Messages Window

15.5 Protection Functions – Availability for Steady-State and for Transients

The following table shows which protection functions are available for the calculation of steady-state grid state so called **Short-Circuit Results** and/or for the calculation of transients.

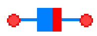
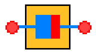
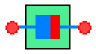
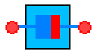
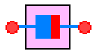
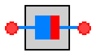
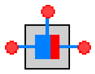
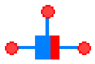
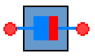
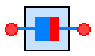
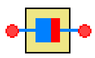
Protection Function	Tab of the Settings Dialog	Steady-State Calculations (Short-Circuit Results)	Transients Calculations
Undirectional Overcurrent	**V<> & I>**	**X**	**X**
Directional Overcurrent	**V<> & I>**	**X**	**X**
Distance Protection	**Dist: VI-Det.** **Dist: Adds.** **Dist: Z<**	**X**	**X**
Fuse	**Fuse**	**X**	**X**
Differential Protection	**Differential**	**X**	**X**
Differential Protection (3W)	**Differential**	**X**	**-**
IDMT	**IDMT**	**X**	**-**
Protective Signaling	**Signal**	**X**	**-**
Underimpedance Detecttion Z<	**Z< Det.**	**X**	**-**
Ground Fault Detection	**GF Det.**	**X**	**-**
QU	**QV**	**X**	**-**
Control System for Decentralised Generator Systems (3PS)	**3PS Control**	**X**	**-**
Control System for Decentralised Generator Systems (RPI)	**RPI Control**	**-**	**X**

15.6 Protective Functions: Colored Frame of the Network Element *Probe* On/Off

The protection function chosen for a network element **Probe** can be indicated using a colored frame in the network graphic. If the colored shall be displayed the corresponding toolbar switch must be enabled with a **Left Mouse Button Click** as shown in the figure below.

Figure 72: Colored Frame for Protection Functions On/Off

The following table shows the symbols for the network element **Probe P1** used as protection relay, if the internal switch has been enabled. The colored frame around the shape can be used to identify the protection function.

Symbol	Protection Function
 P1	Protection disabled or the colored frame of the protection function has only disabled
 P1	I> Undirectional Overcurrent
 P1	I⇾ Directional Overcurrent
 P1	Z< Distance Protection
 P1	Fu Fuse
 P1	Id Differential Protection
 P1  P1	Id Differential Protection 3-Winding The upper symbol shows the shape of the differential protection, if the colored frame has been disabled.
 P1	G> Ground Fault Detection
 P1	M Measuring Device with Monitoring System
 P1	Cb Power Circuit-Breaker (Low Voltage Protection)

16 Simulation of Transients in Electrical Power Grids

ATPDesigner also can simulate transients, e.g. the time dependent behaviour of voltages v(t) and currents i(t), so called **transients** and **simulation of transients** and **simulation** in this document. The figure below shows the reference grid used to explain how to use ATPDesigner to simulate transients. A short-circuit (**red flash**) has been set to a node of the power grid.

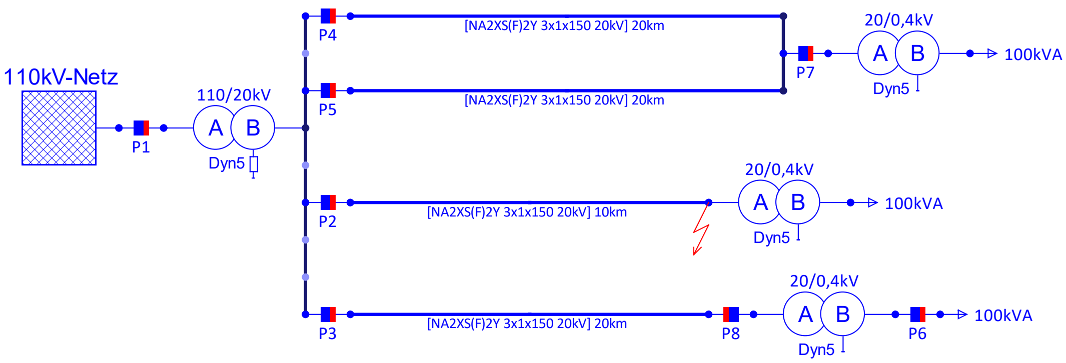


Figure 73: 20-kV-Reference Grid to simulate Transients

The most button  must be used to start the simulation of transients.

- Main Menu: **ATP**
- Menu Item: **Write ATP Control File and Start ATP**
- Short-Cut: **CTRL + R**
- Toolbar Button: 

ATPDesigner writes the **.ATP-File**, which contains the commands and **ATP** based models of the power grid, and starts the **ATP** in the background as a thread of the Windows operating system. The results can be displayed as a **Diagram** in ATPDesigner processing the **.PL4-File** generated and saved by the **ATP** itself. ATPDesigner can read and process the **.PL4-File**.

- Main Menu: **Diagrams**
- Menu Item: **Open Diagram (.PL4-File) ..**

16.1 Simulation of Transients in Power Grids 

The simulation of transients can be also started only by a **Left Mouse Button Click** on the toolbar button  or by using the short-cut **CTRL + R**. ATPDesigner writes the **.ATP-File** containing the ATP based models of the network elements into the **.ATP-File** and starts ATP in a background thread of the operating system. The ATP itself calculates voltages v(t) and currents i(t) and saves these signals into two output files: the **.LIS-File** and the **.PL4-File**.

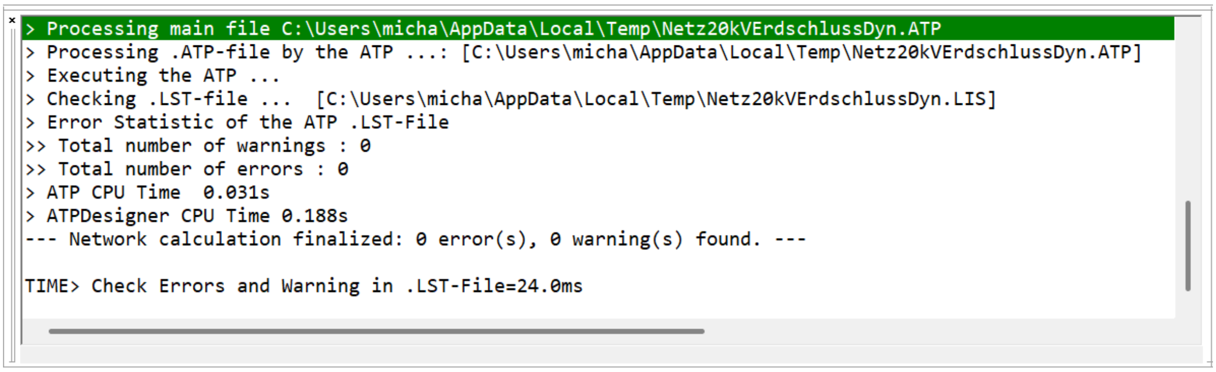
The .LIS-File contains a copy of all commands of the **.ATP-File**, additional comments and error messages written during the runtime of **ATP** and as an option the results of the so called **Steady State Analysis** of the electrical power grid. ATPDesigner analyses the .LIS-File to detect e.g. warnings and errors of the **ATP**.

The **.PL4-File** contains time-dependent signals e.g. voltages v(t), currents i(t) and active power P(t) as sampled values. ATPDesigner can create a **Diagram** processing the **.PL4-File**. The **.PL4-File** also contains output signals of **TACS** and **MODELS**. ATPDesigner uses **TACS** and **MODELS** to calculate e.g. the active power P and the reactive power Q during the simulation, using the

Discrete Fourier Transformation (**DFT**). The DFT algorithm will be implemented in **MODELS**. The **MODELS** code will be written into the **.ATP-File** by ATPDesigner if required. The figure below shows the information which will be written into the **Messages Window** by ATPDesigner.

- Total number of warnings
- Total number of errors
- ATP CPU Time
- ATPDesigner CPU Time

If no error had been detected, a **Diagram** can be created.



```
> Processing main file C:\Users\micha\AppData\Local\Temp\Netz20kVErdschlussDyn.ATP
> Processing .ATP-file by the ATP ...: [C:\Users\micha\AppData\Local\Temp\Netz20kVErdschlussDyn.ATP]
> Executing the ATP ...
> Checking .LST-file ...  [C:\Users\micha\AppData\Local\Temp\Netz20kVErdschlussDyn.LIS]
> Error Statistic of the ATP .LST-File
>> Total number of warnings : 0
>> Total number of errors : 0
> ATP CPU Time  0.031s
> ATPDesigner CPU Time 0.188s
--- Network calculation finalized: 0 error(s), 0 warning(s) found. ---

TIME> Check Errors and Warning in .LST-File=24.0ms
```

Figure 74: Simulation of Power Grids – Messages in the *Messages Window*

16.2 Basic Settings to simulate Transients

Before simulating transients, some settings must be set. The spread sheet and the figure below show the settings and the corresponding settings dialog. The settings dialog **ATP Related Settings** can be opened as follows.

- Main Menu: **Power Network**
- Menu Item: **ATP Data**
- Project Information: **ATP Settings**

The most important settings are part of the settings group **Simulation Data**.

Setting	Explanation
Time	Overall simulation time $Cycle = \frac{1}{f_{nom}}$ with f_{nom} : nominal frequency of the power grid
dt	Step-size of the sampled values used to create a **Diagram**
Prefault	The setting will be only used if one of **Line 1...3** are used in the power grid. If a short-circuit of one of **Line 1...3** has been enabled, the setting defines the prefault-time before the short-circuit occurs. ⇨ The setting can be ignored if the short-circuit (**red flash**) explained later in this chapter will be used.
Out	The setting will be only used if a test system CMCxxx from Omicron such as CMC356 will be used.
Step	The setting defines the internal step-size $\mathbf{dt_{internal}}$ used from the **ATP** for the simualtion of transients. It depends on the setting **dt**.

	$dt_{internal} = \frac{dt}{step}$ Depending on power grid and its equipment it may be necessary to use a very small internal step-size $dt_{internal}$ as used for the setp-size **dt** of the **Diagram**. Example: It may be required to use internal step-size $dt_{internal}$ = 0,01ms. For the Diagram a step-size of dt = 0,1ms is sufficient. $step = \frac{dt}{dt_{internal}} = \frac{0,1ms}{0,01ms} = 10$
Output List	Additional nodes can be added to the signal list
Default	Load the default values of the settings across all tabs

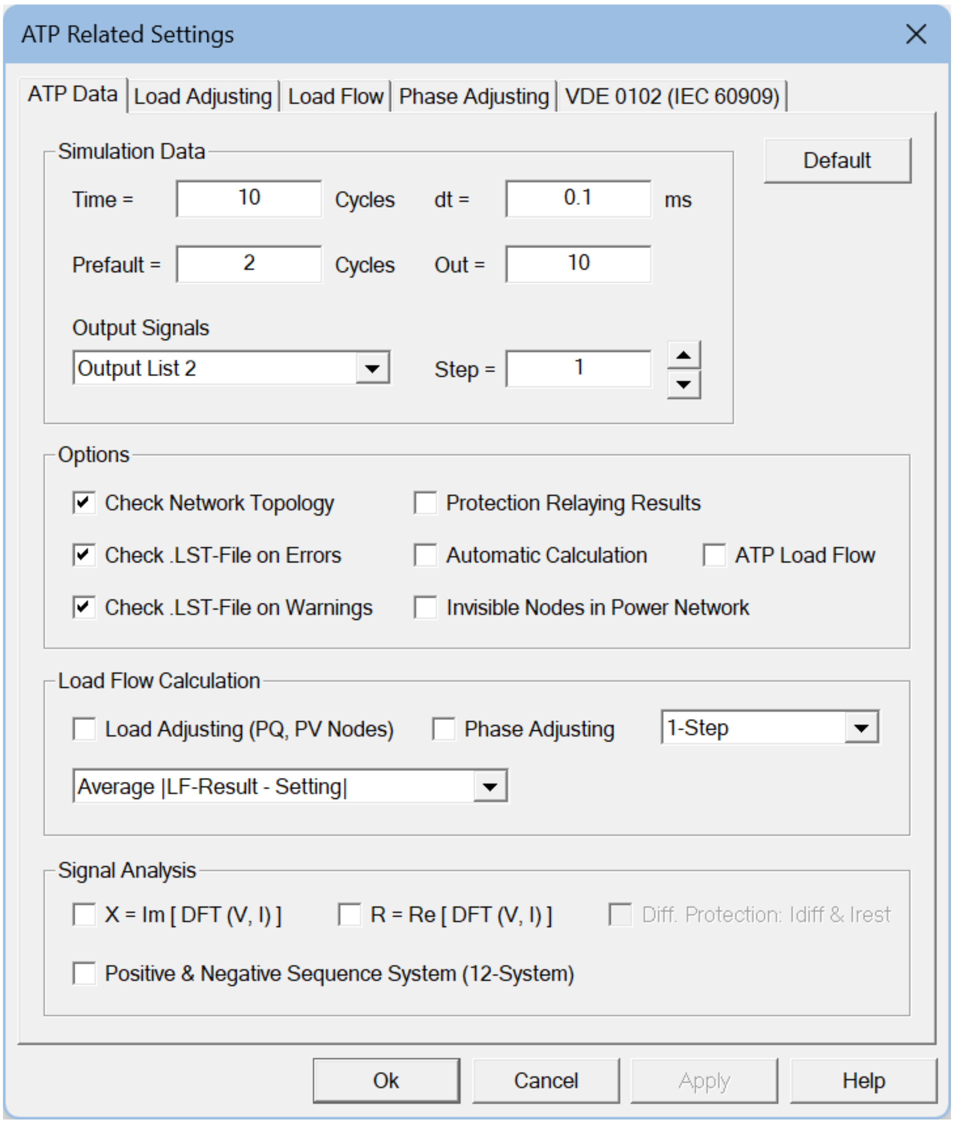


Figure 75: Basic Settings to simulate Transients

The settings in the settings dialog above are chosen to simulate ground faults in a Peterson-coil grounded 20-kV-power grid. The internal step-size and the step-size dt = 100µs are both equal.

⇨ The settings of the network element **Short-Circuit** (**red flash**) must be coordinated with the simulation settings, e.g. the **Fault Time** of the short-circuit.

16.3 Network Toolbar

The toolbar **Network Toolbar** contains several toolbar buttons, which are not part of a menu.

- if a power grid will be displayed in the graphics view

- if a **Diagram** will be displayed in the graphics view

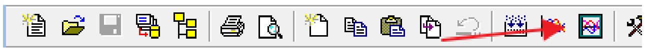
If the toolbar is not visible, it can be enabled using the menu item shown below.

- Main Menu: **View**
- Menu Item: **Network Toolbar**

16.4 Diagram to display Voltages, Currents, etc. 

If no error had been detected during the simulation of the power grid, a **Diagram** can be now created.

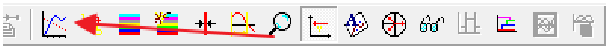
- Main Menu: **Diagrams**
- Menu Item: **Open Diagram (.PL4-File) ...**
- Short-Cut: **CTRL + 4**
- Toolbar Button: 



The **Diagram** can be created by a **Left Mouse Button Click** on the toolbar button . Now ATPDesigner opens the **.PL4-File** of the corresponding power grid simulation, reads the sampled values and processes these data to a **Diagram**.

Thereafter ATPDesigner displays the dialog shown below. The dialog **Reading .PL4-files: Selecting Signals** displays the signals contained in the .PL4-File in the left list element. The signals can easily be selected by a **Left Mouse Button Double Click** on the signal in the left list element. The signal will be moved to the right list element. It is also possible to select signals by a **Left Mouse Button Click** followed by a **Left Mouse Button Click** on the button to move the selected signals to the right list element.

⇨ If a **Diagram** is always displayed the dialog **Reading .PL4-files: Selecting Signals** can be opened using the toolbar button .



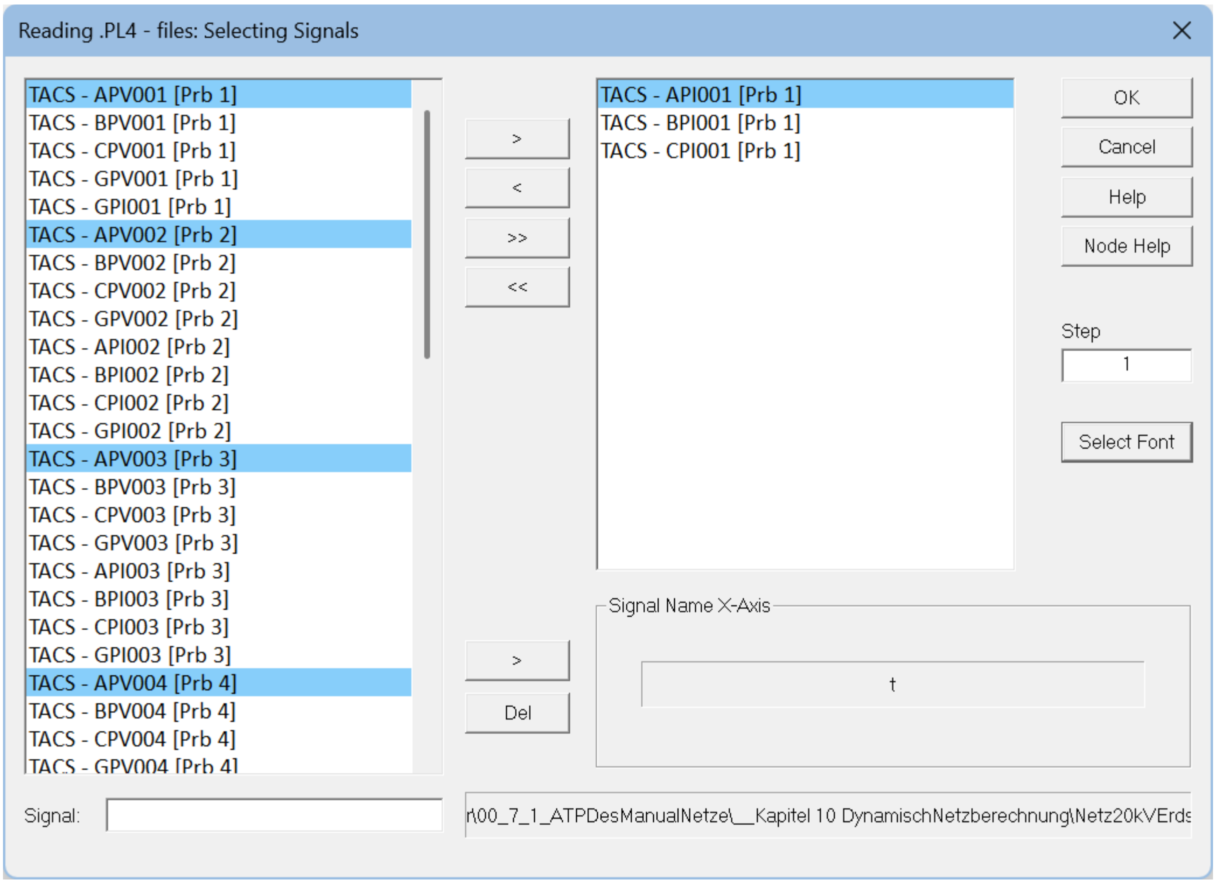


Figure 76: Dialog *Reading .PL4-files: Selecting Signals* - Signals contained in the .PL4-File

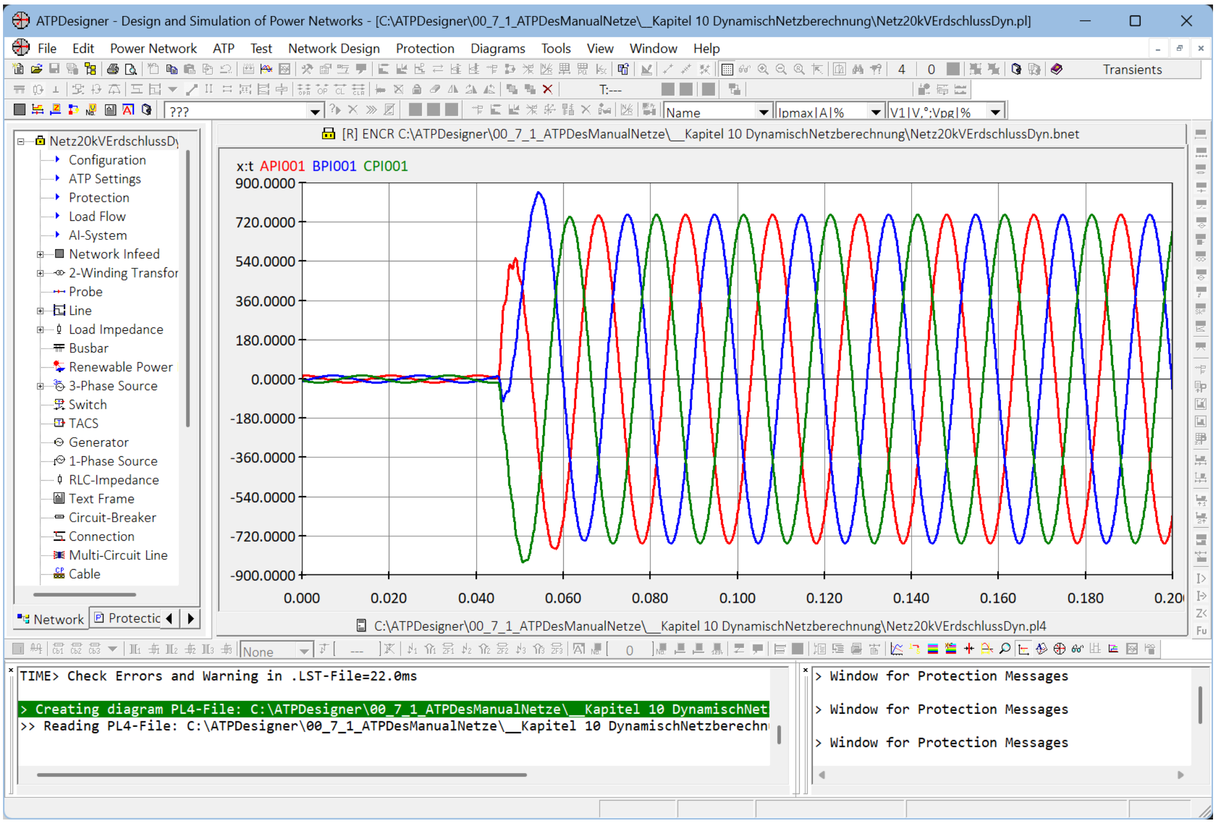


Figure 77: ATPDesigner - Diagram to display signals e.g. phase currents $i_p(t)$

Caused by the **ATP** itself, the names of signals which can be used for a **Diagram** are limited up to 6 characters. Therefore, ATPDesigner uses some rules to automatically generate signal names. The prefix **TACS** or **MODELS** indicates that the signal has been calculated by **TACS** or **MODELS** system of the **ATP**.

- **TACS – APV001 [Prb 1]**

The reference name of the network element, e.g. of the **Probe** **Prb 1** will optionally be shown in brackets.

Signal Name	Explanation
API001	Phase-current $i_A(t)$ ▪ **A** = phase identifier ▪ **P** = primary physical signal ▪ **I** = current ▪ **001** = Number of the **Probe** used as measuring location
BPI001	Phase-current $i_B(t)$ ▪ **B** = phase identifier ▪ **P** = primary physical signal ▪ **I** = current ▪ **001** = Number of the **Probe** used as measuring location
CPI001	Phase-current $i_C(t)$ ▪ **C** = phase identifier ▪ **P** = primary physical signal ▪ **I** = current ▪ **001** = Number of the **Probe** used as measuring location

The signals to be displayed in a **Diagram** can be selected in several ways. Please note, that the number of signals which can be selected and moved to the right list element is limited.

Button	Explanation
>	First select one or more signals in the left list element, move it to the right list element by one **Left Mouse Button Click**
<	First select one or more signal in the right list element, move it to the left list element by one **Left Mouse Button Click**
>>	All signals of the left list element will automatically be selected and moved to the right list element by one **Left Mouse Button Click**
<<	All signals of the right list element will automatically be selected and moved to the left list element by one **Left Mouse Button Click**
OK	The dialog will be closed and the diagram will be displayed.
Cancel	The dialog will be closed and the diagram will be no displayed.
Select Font	A dialog will be opened to select a font used the signal names in both list elements. The name and size of the font will stored in the **.INI-File** if ATPDesigner will be closed.

It is also possible to select and move one signal to the other list element only by one **Left Mouse Button Double Click** on the name of the signal displayed in the list element. The **Diagram** will be created and displayed with a **Left Mouse Button Click** on the button **OK**.

16.5 Open a stand-alone .PL4-File to create a Diagram

A **.PL4-File** can be also opened stand-alone to create a **Diagram**.

- Main Menu: **File**
- Menu Item: **File Open ..**
- Short Cut: **CTRL + O**
- Toolbar Button: , 

ATPDesigner starts the standard **File Open** dialog to read and process the **.PL4-File**.

16.6 Short-Circuit to simulate short-circuits in power grids 

Simulation of short-circuits in power grids can be easily done using the network element Short-circuit (**red flash**). The short-circuit can be set at each node of a network element and at any position along the network element **Line** excluding **Line1..3**.

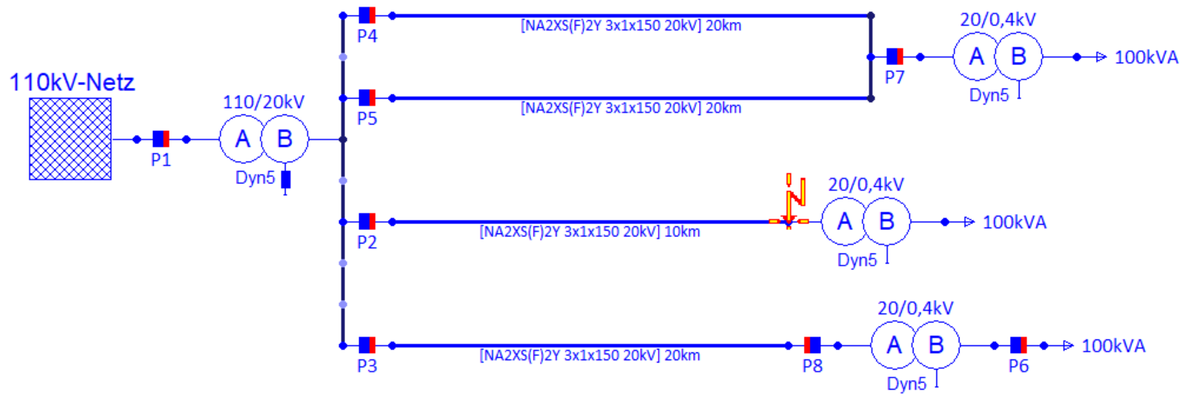
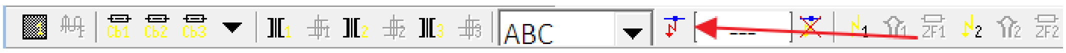


Figure 78: Set the Short-Circuit (Red Flash) at a node in the power grid

Toolbar Button	Explanation
ABC ▾	The type of the short-circuit can be selected. The fault type can be changed, if a short-circuit is used in the network graphic.
	Before a short-circuit can be set in the power grid, this button must be enabled (**ON**) by a **Left Mouse Button Click**. The shape of the cursor will be now changed to the short-circuit symbol (**red flash**) as shown in the figure above. If the tip of the short-circuit cursor identifies a node, the shape will be changed as shown in the figure above.
	Remove the short-circuit (**red flash**) from the power grid.
46.726	If the short-circuit (**red flash**) has been set at a **Line**, the position along the **Line** will shown in % of the line length. It is also possible to change the position by changing the value of the setting. After the setting has been changed the new position must be recalculated by a **Left Mouse Button Click** on the network graphic.

The figure below shows the toolbar containing the toolbar buttons explained above.



The figure below shows the settings dialog of the network element **Short-Circuit** (**red flash**).

- Main Menu: **Power Network**
- Menu Item: **Network Configuration**, tab **Short-Circuit**

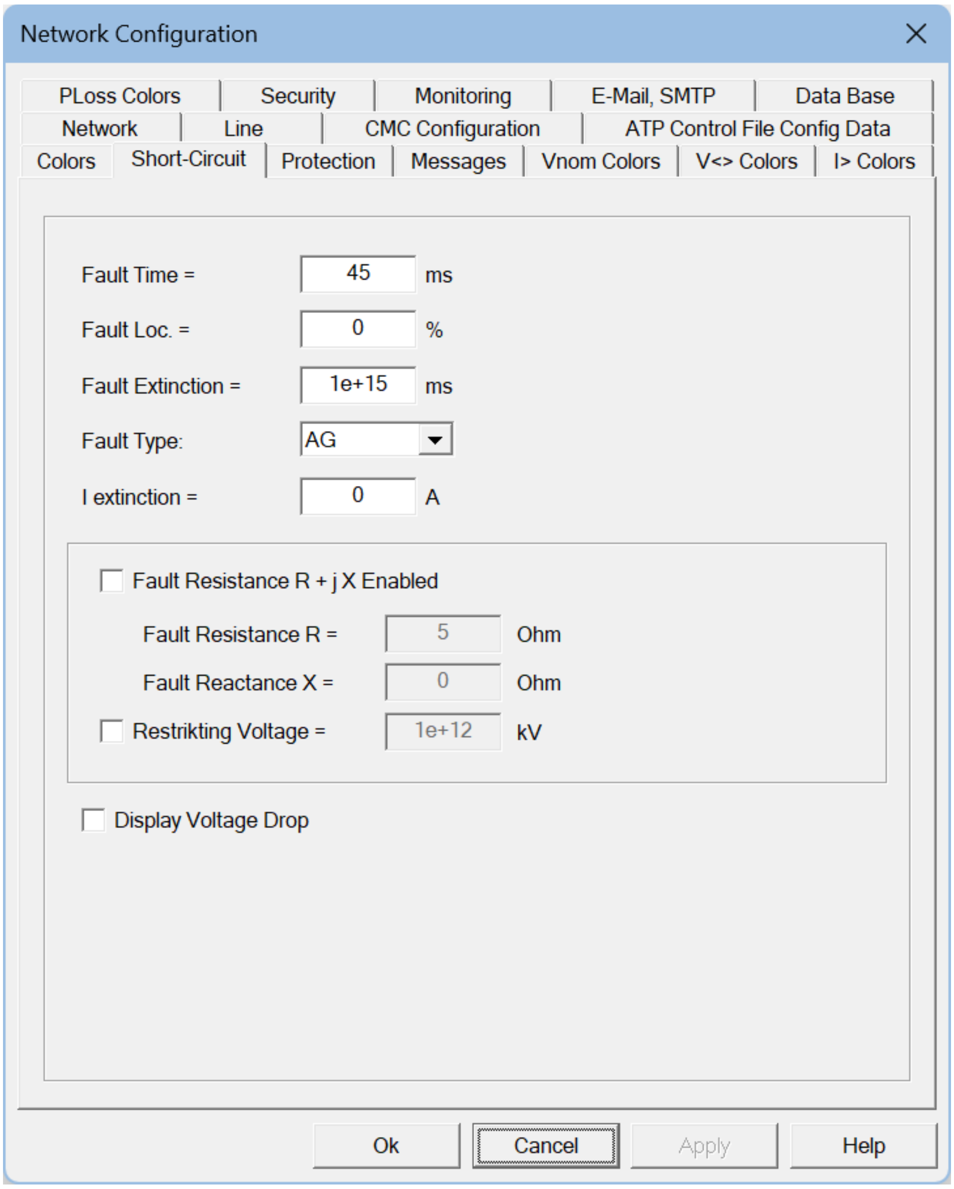


Figure 79: Settings Dialog of the Short-Circuit (Red Flash)

Setting	Explanation
Fault Time	Start time of the short-circuit
Fault Loc.	Faul location, if the short-circuit has been set along a network element **Line**
Fault Extinction	Extinction time of the short-circuit
Fault Type	Fault type of the short-circuit
I extinction	The extinction of the short-circuit occurs, if ▪ the **Fault Extinction** time has been elapsed and ▪ the sampling value of the phase currents are less $\mathbf{I_{extenction}}$. The setting can be used to simulate the extinction of the short-circuit arc.
Fault Resistance R + jX	▪ **Disabled**: The fault resistance of the short-circuit is equal 0 Ω. ▪ **Enabled**: The fault resistance of the short-circuit can be user-defined. A series impedance will be used as fault resistance model.

16.7 Graphic Cursor to analyse the Signals in a Diagram

ATPDesigner supports the analysis of signals by several methods and functions, which are based on the **Discrete Fourier Transformation** (**DFT**). The figure below shows the phase-to-ground voltages $v_{ABCG}(t)$, which are measured in the substation at the beginning of the faulty line. The ground fault AG occurs at **Fault Time** = 40ms.

⇨ The settings used for the frequency analysis using the Discrete Fourier Transformation (DFT) can be defined in the settings dialog Diagram Settings.

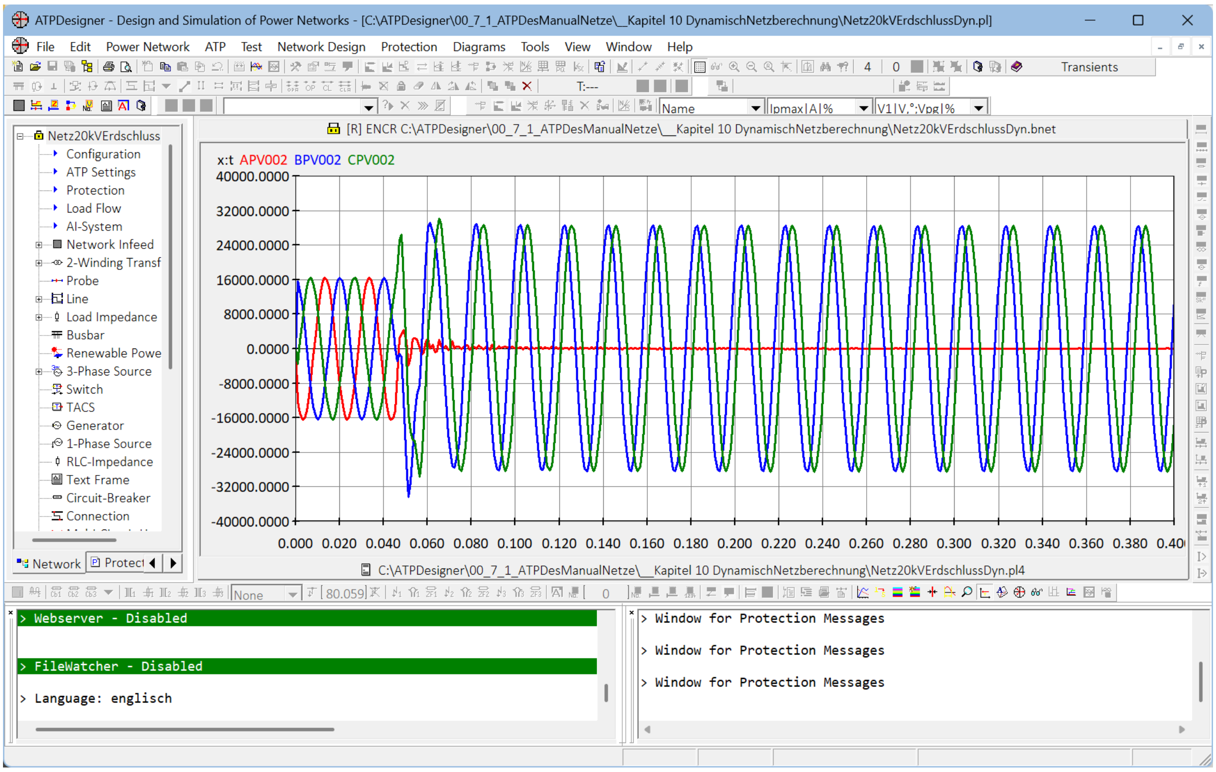


Figure 80: Phase-to-ground Fault AG: phase-to-ground voltages measured at the substation P2

Signal Name	Explanation
APV002	Phase-to-ground voltage $v_{AG}(t)$ ▪ **A** = phase identifier ▪ **P** = primary physical signal ▪ **V** = voltage ▪ **002** = Number of the **Probe** used as measuring location
BPV002	Phase-to-ground voltage $v_{BG}(t)$ ▪ **B** = phase identifier ▪ **P** = primary physical signal ▪ **V** = voltage ▪ **002** = Number of the **Probe** used as measuring location
CPV002	Phase-to-ground voltage $v_{CG}(t)$ ▪ **C** = phase identifier ▪ **P** = primary physical signal ▪ **V** = voltage ▪ **002** = Number of the **Probe** used as measuring location

The toolbar buttons of the toolbar below are now important.

Button	Explanation
	Open the dialog to select the signals for the **Diagram** ▪ Main Menu: **Diagrams** ▪ Menu Item: **Signal List** ▪ Short Cut: **Ctrl + Alt + S**
	Enable the graphic cursor
,	Open a zoom frame ▪ Enable the zoom function with a **Left Mouse Button Click** and keep the left mouse button pressed ▪ Move the mouse cursor to open the zoom frame ▪ Release the left mouse cursor
,	Reload the **.PL4-File** and refresh the **Diagram** ▪ Main Menu: **Diagrams** ▪ Menu Item: **Refresh Diagram** ▪ Short Cut: **Ctrl + Alt + R**
,	Open a dialog to calculate the frequency spectrum using the **Discrete Fourier Transformation** (**DFT**)
	Open the dialog **Signal Analysis Settings**
	Open a dialog **Colors of Diagram Curves** to select drawing colors for each signal ▪ Main Menu: **Diagrams** ▪ Menu Item: **Diagram Curve Colors** ▪ Short Cut: **Ctrl + Alt + F**
	Load the default values of the drawing colours for each signal
	Open a dialog to select scaling factors for each signal ▪ Main Menu: **Diagrams** ▪ Menu Item: **Diagram Scaling Factors**
	Open the dialog **Diagram Settings** ▪ Main Menu: **Diagrams** ▪ Menu Item: **Diagram Settings**
	The **Automatic Scaling 10^n** of the Y-axis will be enabled or disabled with a **Left Mouse Button Click**. A refresh is required.

The next figure shows the Diagram, if the horizontal graphic cursor drawn in **red** and **grey** are enabled by a **Left Mouse Button Click** on the toolbar button . The position of the graphic cursor can be moved if any other position in the Diagram will be selected with a **Left Mouse Button Click**. The cursor position also can be moved using the cursor keys **left** and **right** of the keyboard. It is important to enable the cursor keys (setting the focus) with a **Left Mouse Button Click** on the **Diagram**.

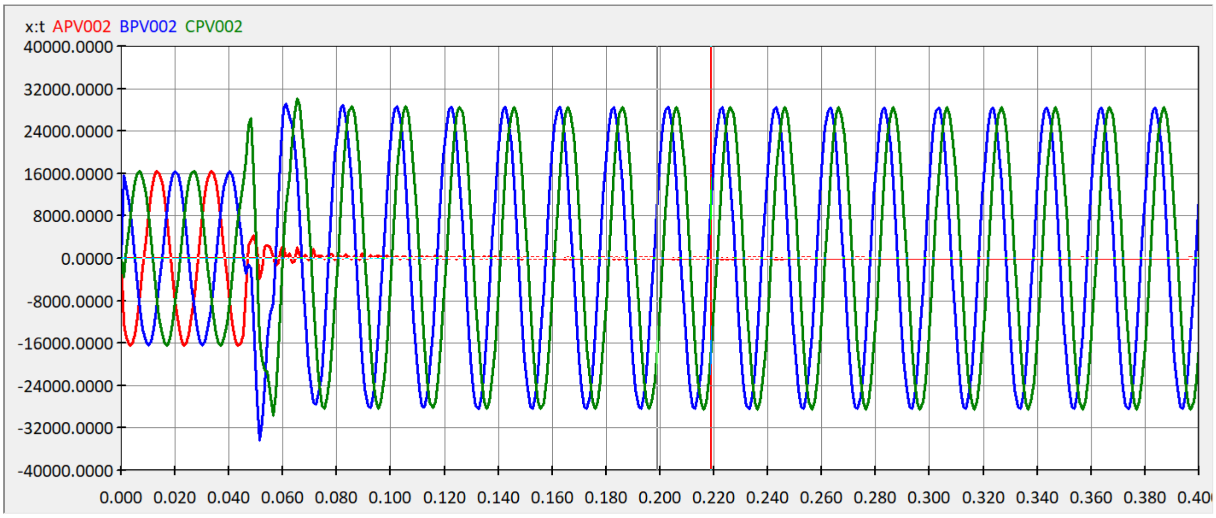


Figure 81: Diagram with graphic cursor drawn in red and grey: phase-to-ground voltages $v_{ABCG}(t)$

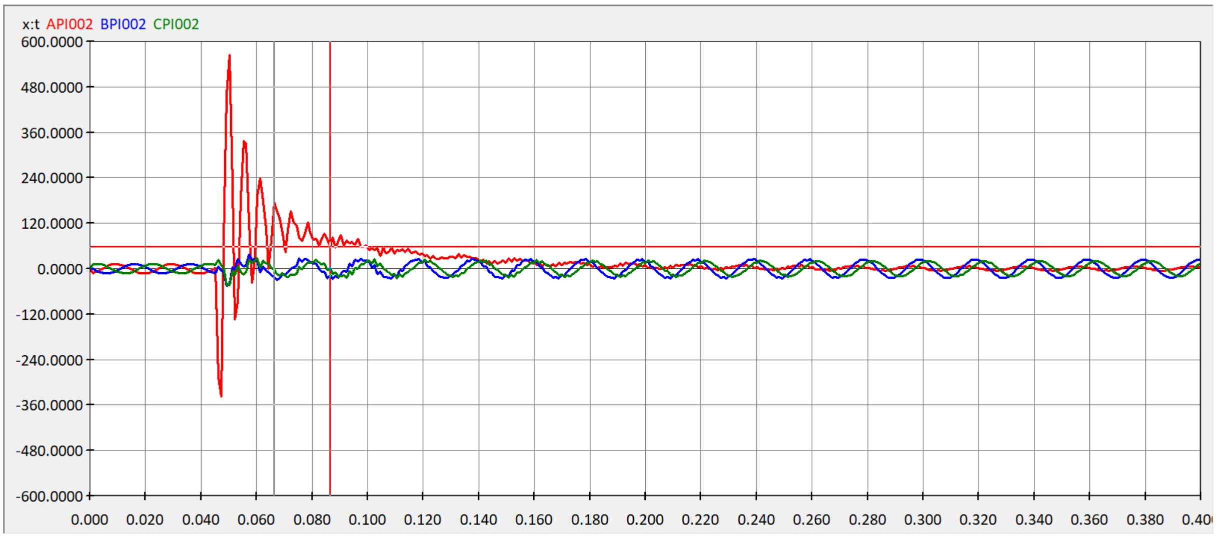


Figure 82: Diagram with graphic cursor drawn in red and grey: phase currents $i_{ABCG}(t)$

The time window of the graphic cursor drawn in **red** and **grey** is ΔT = 20ms because the default setting of the fundamental frequency of the **Discrete Fourier Transformation (DFT)** is f_{DFT} = 50Hz, the nominal frequency f_{nom} of the power grid. The **fundamental DFT frequency f_{DFT}** can be set in the settings dialog **Diagram Settings**.

⇨ The settings dialog **Diagram Settings** can only be opened, if a **Diagram** will be displayed topmost in of ATPDesigner.

The DFT algorithm calculates the frequency spectrum using the fundamental DFT frequency f_{DFT} and the sampled values of the signals within the time window of the graphic cursor. The number of sampled values within the time window of the graphic cursor can be calculated.

$$N = \frac{\Delta T}{dt} = \frac{20ms}{1ms} = 20$$

with Step-size of the sampled values **dt** (settings dialog **ATP Related Settings,** Figure 75)

The settings dialog **ATP Related Settings** can be opened as follows.

- Main Menu: **Power Network**
- Menu Item: **ATP Data**
- Project Information: **ATP Settings**

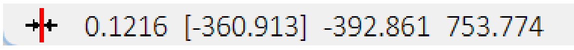
The resolution of the frequency spectrum can also be calculated.

$$\Delta f = \frac{1}{\Delta T} = \frac{1}{20ms} = 50Hz$$

The number of frequencies is equal with the number of sampled values, which are contained in the time window of the graphic cursor. The results of the frequency analysis can be displayed in additional dialogs e.g. the dialog **Signal Analysis**, which will be explained later.

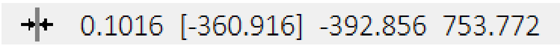
The sampled values of the signals will be automatically displayed in the status bar, if the graphic cursor is enabled. It may be necessary to re-activate the data in the status bar by a **Left Mouse Button Click** on the **Diagram** at any position in the **Diagram**. The figure below shows the status bar for a **Diagram**

At the left the time and the sampled values of the signals are displayed for the graphic cursor drawn in **red**.

- 

    - Time stamp in seconds
    - Value of the 1st signal **APV002**
      Indicated by the brackets the signal is selected for the horizontal **Y-Cursor**.
    - Value of the 2nd signal **BPV002**
    - etc.

In the centre the time and the sampled values of the signals are displayed for the graphic cursor drawn in **grey**.

- 

    - Time stamp in seconds
    - Value of the 1st signal **APV002**
      Indicated by the brackets the signal is selected for the horizontal **Y-Cursor**.
    - Value of the 2nd signal **BPV002**
    - etc.

At the right the time window of the graphic cursor will be displayed.

- 

    - Time window between both cursors in **red** and **grey** in seconds

The units of the signals will be not displayed in the stratus bar.

16.8 Frequency Spectrum ,

If the graphic cursor is enabled by a **Left Mouse Button Click** on the toolbar button , the frequency spectrum of the signals can be calculated using the **Discrete Fourier Transformation** (**DFT**) algorithm. The figure below shows the dialog **Signal Analysis**, which will be opened with a **Left Mouse Button Click** on the toolbar button . All signals displayed in the **Diagram** will be analysed using the Discrete Fourier Transformation (DFT). The results will be presented in the spread sheet of the dialog.

⇨ The dialog **Signal Analysis** is a so called non-modal dialog. A non-modal dialog can remain open alongside the main window of ATPDesigner. While the dialog is open, ATPDesigner remains fully usable in parallel.

The figure below shows the results of the frequency analysis in the tab **DFT (f)**. The phase currents $i_{ABC}(t)$ measured at the measuring location of **Probe P2** were analysed. The DFT results of tab **DFT (f)** are calculated for the fundamental DFT frequency f_{DFT}.

⇨ The results of the frequency analysis are always related to the position and time window of the graphic cursor.

Name	Explanation
No.	Number of the line
Node Name	Name of the signal ▪ **(ABC)PI002** : phase current $i_{ABC}(t)$ measured by **Probe P2** The abbreviation **TACS** indicates, that this signal is an output signal of the **ATP** specific **TACS** module (**T**ransient **A**nalysis of **C**ontrol **S**ystems). The **TACS** module provides ATPDesigner to calculate signals equal to an analogue computer. It is easy to add, subtract, multiply, etc. signals based on their sampled values.
Amount	Amount of the signal calculated for the fundamental DFT frequency f_{DFT}
Phase Angle [°]	Absolute phase angle in degree calculated for the fundamental DFT frequency f_{DFT}
Real	Real part of the phasor calculated for the fundamental DFT frequency f_{DFT}
Imag	Imaginary part of the phasor calculated for the fundamental DFT frequency f_{DFT}
DFT (n)	Number of sampled values within the time window of the graphic cursor
On Top	▪ enabled: dialog remains always on top ▪ disabled: dialog can be moved on the background
RMS	▪ enabled: r.m.s. value ▪ disabled: r.m.s. value multiplied by √2
· Sqrt (3)	▪ enabled: r.m.s. value multiplied by √3 ▪ disabled: r.m.s. value

Copy	Copy the content of the spread sheet into the clipboard using the .CSV-format
	
	`1,TACS - API002,4.844,-42.678,0.000,3.561,-3.283,20`
	`2,TACS - BPI002,17.053,-93.634,-50.956,-1.081,-17.019,20`
	`3,TACS - CPI002,14.166,-151.877,-109.199,-12.493,-6.677,20`
	`4,TACS - APV002,40.696,-67.885,-25.208,15.320,-37.702,20`
	`5,TACS - BPV002,20200.776,-174.023,-131.346,-20090.974,-2103.358,20`
	`6,TACS - CPV002,20177.325,125.884,168.562,-11826.946,16347.715,20`

0.0 Hz ▾	Frequency of the first line of the spread sheet in the tab **Harmonics**
500.0 Hz ▾	Frequency of the last line of the spread sheet in the tab **Harmonics**
Cell. Separ.	Cell separator of the using the .CSV-format, if the content of the spread sheet will be copied into the clipboard ▪ **Tab** : using tabulator as cell separator ▪ **Character** : using the character defined in the edit field

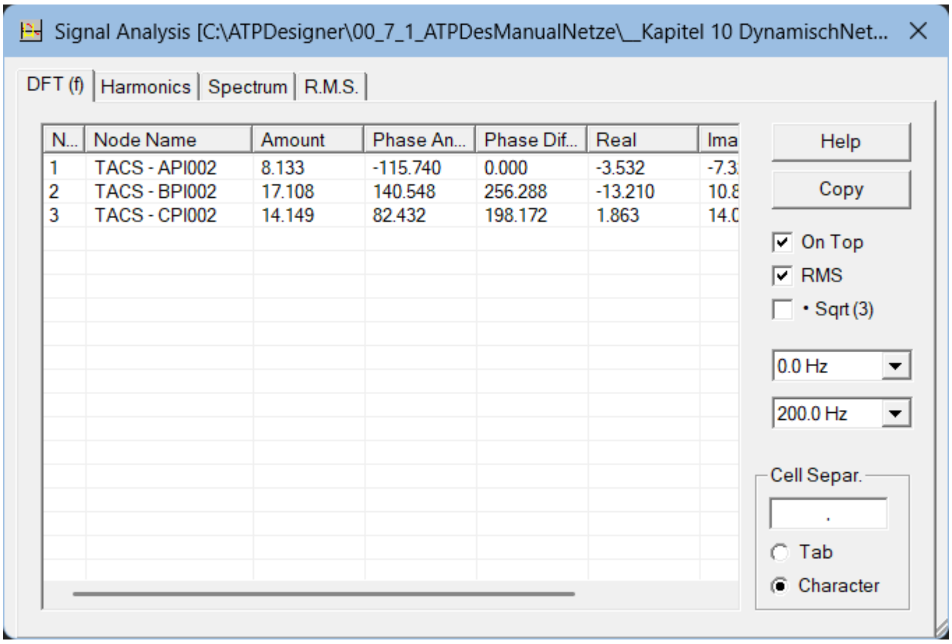


Figure 83: Results of the Discrete Fourier Transformation (DFT) of all signals

If a single signal is selected by a **Left Mouse Button Click** of its name in the spread sheet in tab **DFT (f)**, the DFT based frequency spectrum can be calculated and presented in the tab **Harmonics** in a spread sheet.

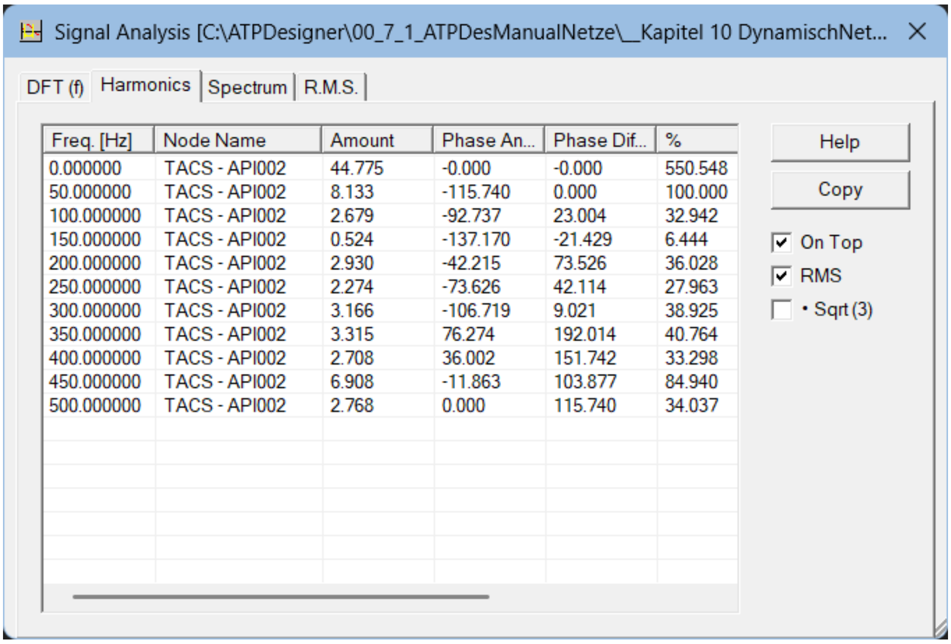


Figure 84: Results of the Discrete Fourier Transformation (DFT) of the selected signal

Then DFT based results are always calculated for the frequency **Freq. [Hz]** presented in the first column in each line of the spread sheet.

Name	Explanation
Freq. [Hz]	Frequency in Hz
Node Name	Name of the signal
Amount	Amount of the signal
Phase Angle [°]	Absolute phase angle in degree
Phase Difference [°]	Difference of the phase angle calculated for the specific frequency related to the phase angle calculated for fundamental frequency f_{DFT}

	$\Delta\varphi = \varphi(f) - \varphi(f_{DFT})$
%	Amount of the signal in % related to the nominal voltage V_{nom} or V_{nom} / √3
Real	Real part of the phasor
Imag	Imaginary part of the phasor
DFT (n)	Number of sampled values within the time window of the graphic cursor

Copy	Copy the content of the spread sheet into the clipboard using the .CSV-format
	
	`No.,Node Name,Amount,Phase Angle [°],Phase Diff. [°],%,Real,Imag,DFT (n)`
	`0.000000,TACS - API002,33.566,-0.000,-0.000,3074.455,33.566,-0.000,20`
	`50.000000,TACS - API002,1.092,-19.380,0.000,100.000,1.030,-0.362,20`
	`100.000000,TACS - API002,2.407,-68.140,-48.759,220.499,0.896,-2.234,20`
	`150.000000,TACS - API002,1.851,-65.825,-46.445,169.506,0.758,-1.688,20`
	`200.000000,TACS - API002,0.631,-58.408,-39.028,57.788,0.331,-0.537,20`
	`250.000000,TACS - API002,0.572,-13.108,6.272,52.387,0.557,-0.130,20`

On Top	▪ enabled: dialog remains always on top ▪ disabled: dialog can be moved on the background
RMS	▪ enabled: r.m.s. value ▪ disabled: r.m.s. value multiplied by √2
· Sqrt (3)	▪ enabled: r.m.s. value multiplied by √3 ▪ disabled: r.m.s. value

If always only one signal in the spread sheet in the tab **DFT (f)** has been selected, the DFT based frequency spectrum can be calculated and presented in the tab **Spectrum** as a bar diagram.

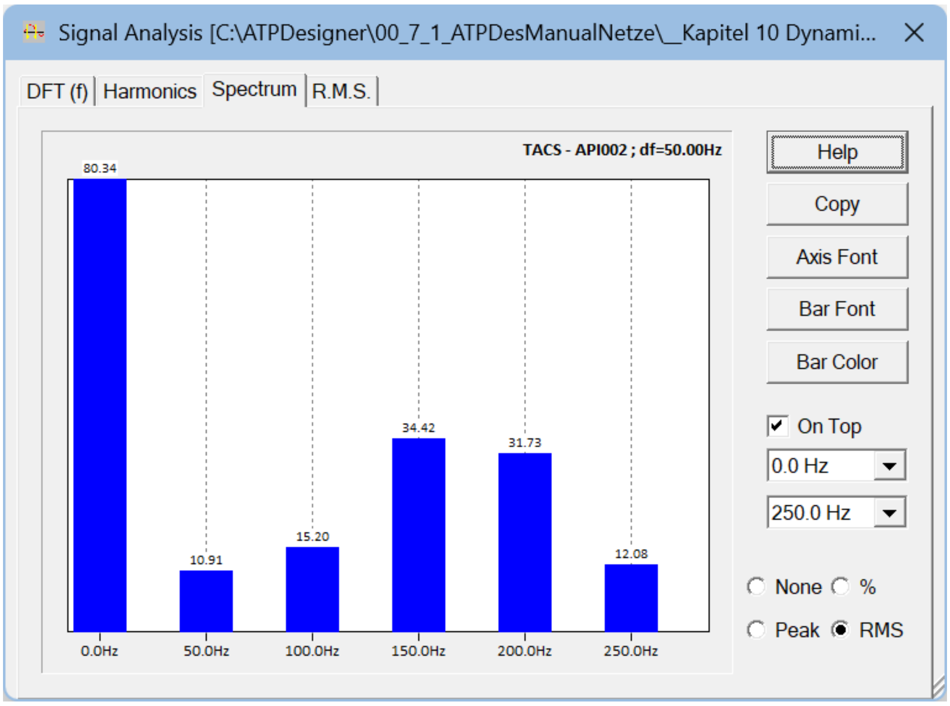


Figure 85: Results of the Discrete Fourier Transformation (DFT) of the selected signal

The settings of the dialog will be not stored into the **.NET-File** or the registry.

Name	Explanation
Copy	Copy the **Diagram** graphic into the clipboard (EMF-file format)
Axis Font	Open the dialog to select the axis font
Bar Font	Open the dialog to select the font of the bar diagram
Bar Color	Open the dialog to select the drawing colour of the bar diagram
On Top	▪ enabled: dialog remains always on top

	▪ disabled: dialog can be moved on the background
0.0 Hz	Frequency of the first bar in the bar diagram
500.0 Hz	Frequency of the last bar in the bar diagram
None	No units in the bar diagram
%	Unit in percent related to the amount of the first bar of the bar diagram
Peak	Peak value = r.m.s. value multiplied by √2
RMS	R.M.S. value = peak value divided by √2

The next tab **R.M.S.** presents the results of the TRUE R.M.S. calculation of all signals shown in the **Diagram**.

$$R.M.S = \sqrt{\frac{1}{T} \cdot \int_0^T s^2(t) \cdot dt}$$

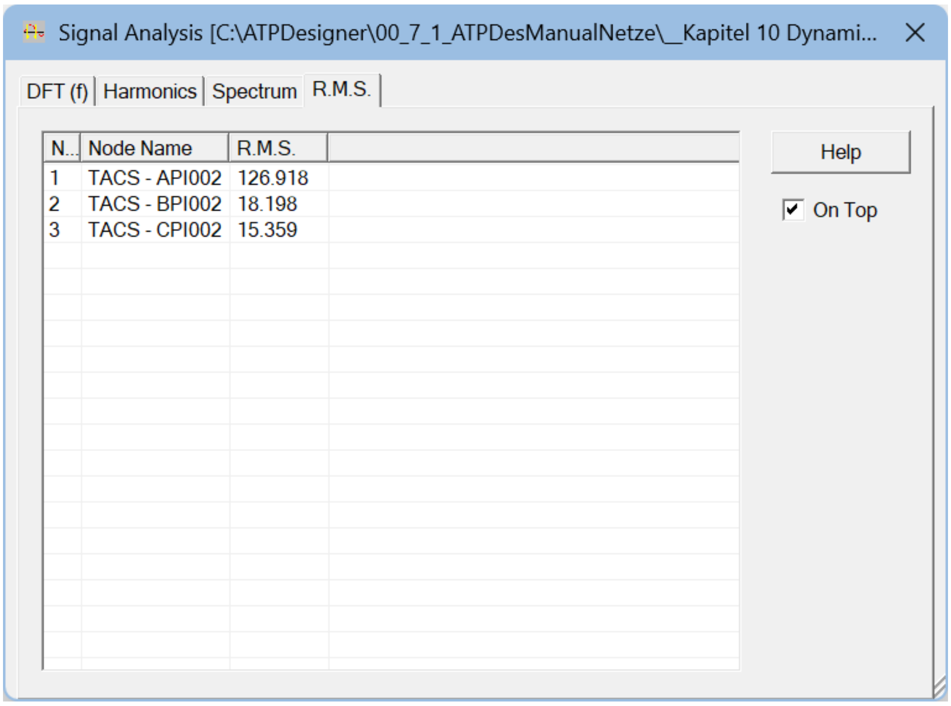


Figure 86: Results of the R.M.S. calculation of all signals

16.9 Vector Diagram

The phasors (or vectors) shown in the tab **DFT (f)** can also be visualized in a vector diagram. To do this, first set the graphic cursor and the dialog **Signal Analysis** must be opened as illustrated in the figure below. Note that least one phasor must be presented in the spread sheet.

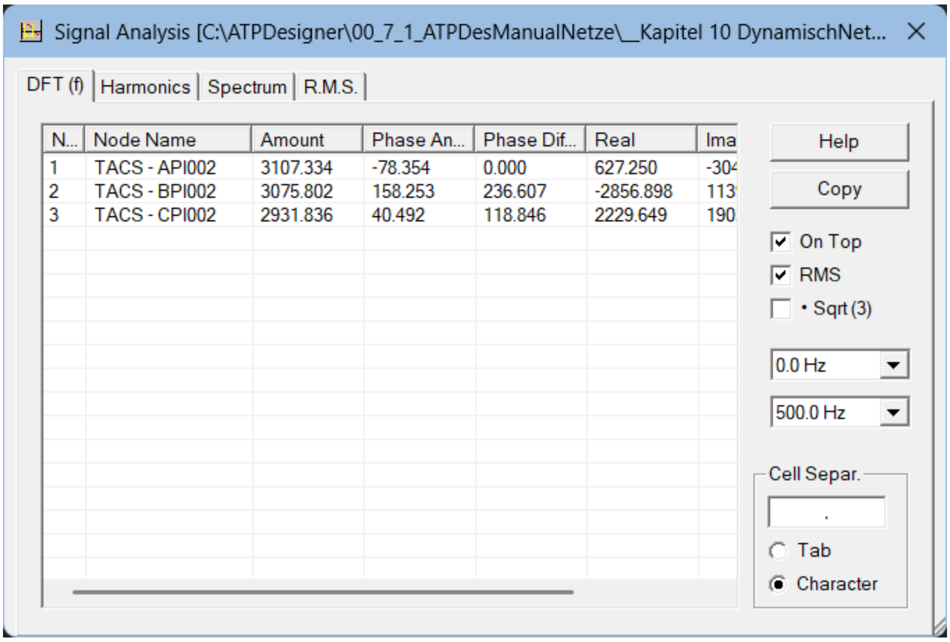


Figure 87: Results of the Discrete Fourier Transformation (DFT)

Now the dialog **Vector Diagram** can now only be accessed via the toolbar button . If the toolbar is not visible, it can be enabled as described below. Now both dialogs will be open simultaneously.

- Main Menu: **View**
- Menu Item: **Network Toolbar**

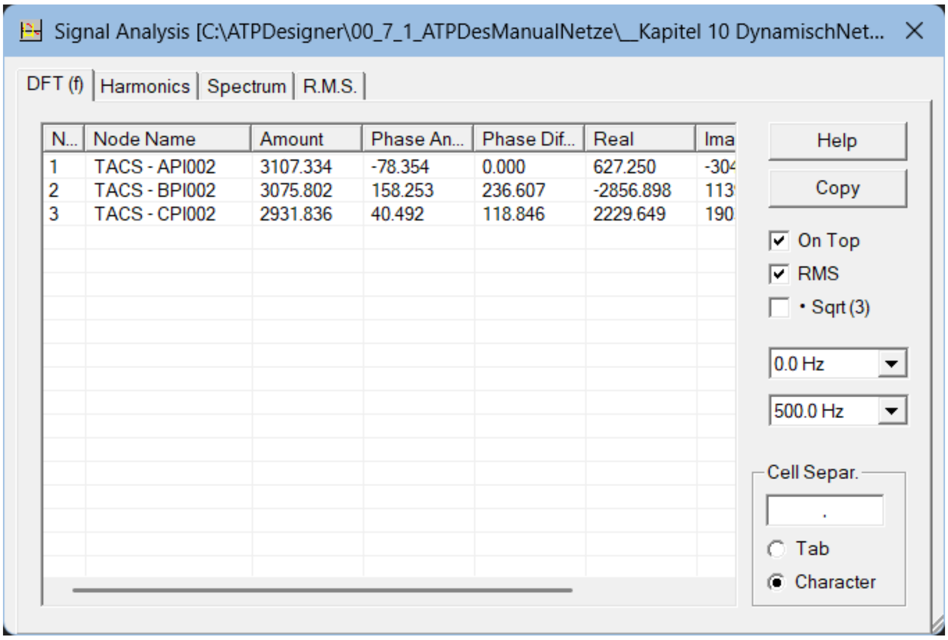
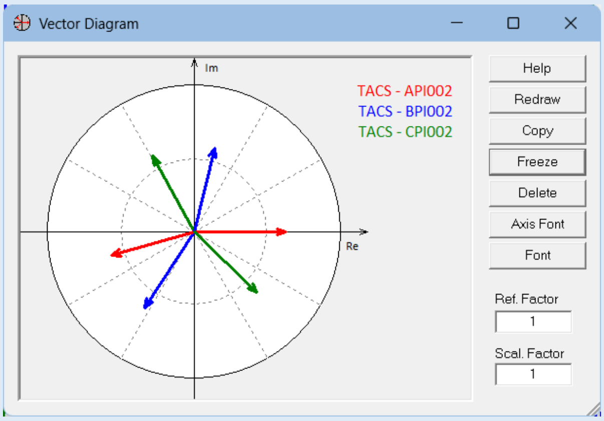


Figure 88: Vector Diagram to visualize Phasors (Discrete Fourier Transformation (DFT))

Name	Explanation
Redraw	Redraw the phasor diagram
Copy	The phasor diagram will be copied to the clipboard using the Windows Meta-file format (.EMF).
Freeze	The phasors will be internally copied and displayed as "frozen" phasors also called reference phasors. The frozen phasors can then be used as reference markers for comparison to other phasors. If the graphic cursor will be moved to an other position, new phasors will be displayed in the phasor diagram. The figure below shows an example. 
Delete	The "frozen" reference phasors will be removed.
Axis Font	Open the font settings dialog to select the desired font for axis of the diagram.
Font	Open the font settings dialog to select the desired font for the signal names. Please note, that the font colour will be applied automatically and matches the drawing colour used in the **Diagram**.
Ref. Factor	Scaling Factor for the "frozen" reference phasors
Scal. Factor	Scaling factor for the phasors defined by the graphic cursor

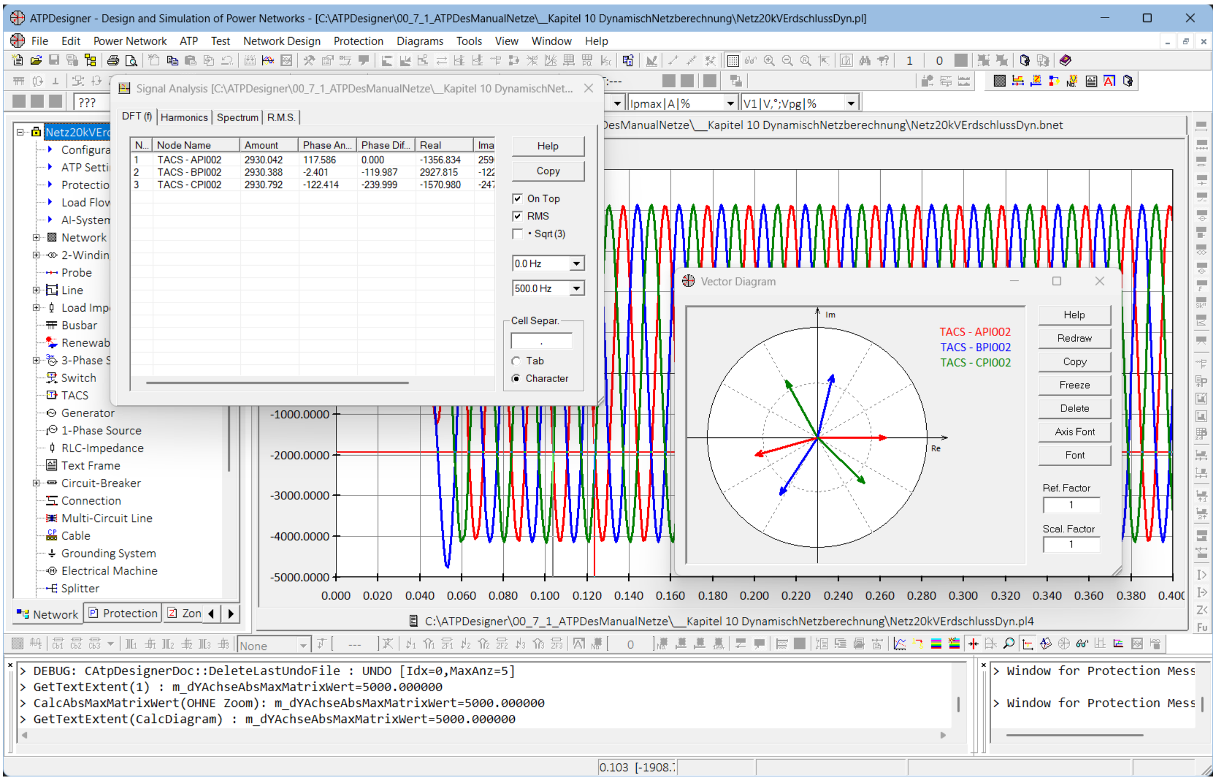


Figure 89: Signal Analysis using ATPDesigner – Vector Diagram

The figure above shows a **Diagram** presenting phase currents $i_{ABC}(t)$ in case of a short-circuit in the power grid.

⇨ Both dialogs Signal Analysis and Vector Diagram are so called non-modal dialogs. A non-modal dialog can remain open alongside the main window of ATPDesigner. While the dialog is open, ATPDesigner remains fully usable in parallel. Therefore, both dialogs can remain open. ATPDesigner automatically refresh the content of both dialogs if the graphic cursor will be moved to a different position in the **Diagram**.

16.10 Signal Analysis – Export Frequency Spectrum to *Multi Frequency Source*

The frequency spectrum can be calculated using the dialog Signal Analysis and exported into a **.CSV-File**. The **Discrete Fourier Transformation** (DFT) algorithm will be used to calculate a frequency spectrum.

1. Open the dialog Signal Analysis
2. Move the mouse cursor over the spread sheet in the tab **DFT (f)**
3. Open the context sensitive menu by a **Right Mouse Button Click**
4. Export the frequency spectrum of the signals in separate .CSV-files by a **Left Mouse Button Click** on the menu item

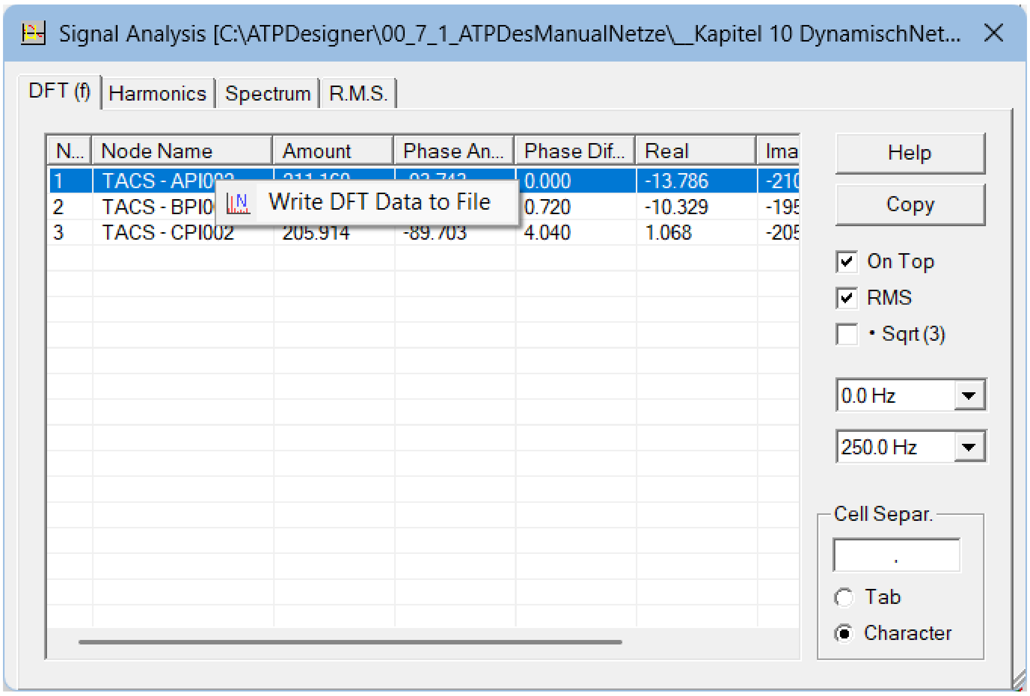


Figure 90: Export Frequency Spectrum to *Multi Frequency Source*

ATPDesigner generates a separate **.CSV-File** for each signal listed in the spread sheet in the tab **DFT (f)**. The format of the .CSV-File is shown below. The .CSV-Files will be stored in a directory, which can be selected by the user.

```
##f[Hz];value r.m.s[V,A];phi[°]
0;78.4614;-0;
50;60.8971;-156.522;
100;73.9339;-160.718;
150;153.754;-175.41;
200;116.885;82.1489;
250;34.0383;72.2343;
300;7.24869;89.5666;
350;23.6941;112.357;
```

```
400;15.4795;112.212;
450;13.7453;140.943;
500;6.48422;-180;
```

- One header line
- One line for each frequency of the frequency spectrum

Examples for the filenames are shown below. The filename contains the name of the .BNET-file and the signal name presented in the dialog **Reading .PL4-files: Selecting Signals**.

- Netz20kVErdschlussDyn_TACS - API002.CSV
- Netz20kVErdschlussDyn_TACS - BPI002.CSV
- Netz20kVErdschlussDyn_TACS - CPI002.CSV

The .CSV-File can directly read by the network element **Multi Frequency Source**.

16.11 Network Element *Multi Frequency Source*

The network element **Multi Frequency Source** is exclusively intended for transient simulations. It cannot be used in steady-state or frequency-domain analysis. The figure below shows the settings dialog.

The user can define a frequency spectrum by applying current sources or voltage sources across the range of frequencies in the spread sheet. It is not possible to mix current sources and voltage sources for the same network element **Multi Frequency Source**.

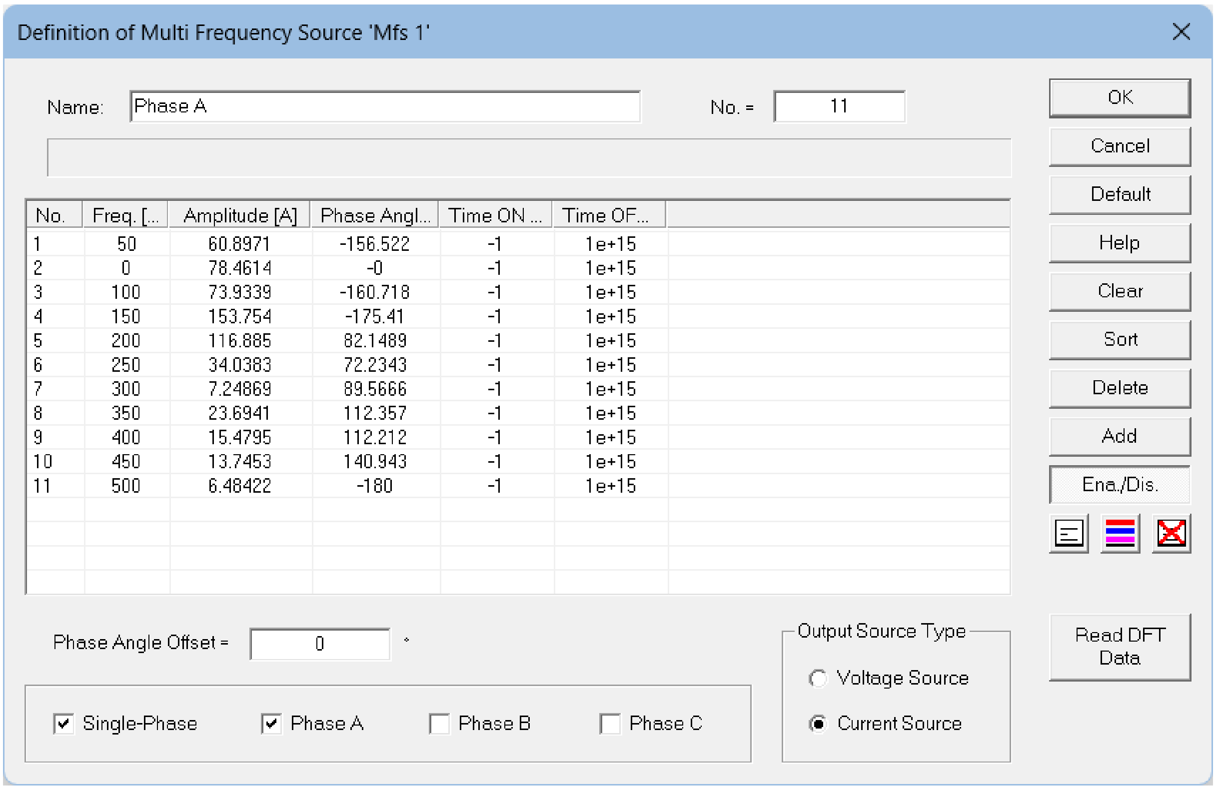


Figure 91: Frequency spectrum realized by the *Multi Frequency Source*

The network element **Multi Frequency Source** can be used to model the behaviour of electronic devices such as converters in decentralized power generation systems. The network element can be easily used in combination with the Signal Analysis available in ATPDesigner.

Setting	Explanation
OK	Confirm all changes made since opening the dialog and store the settings internally without saving to disk
Cancel	Discard all changes made since opening the dialog without saving
Default	Load the default settings
Name	User specific name
No.	Number of lines in the spread sheet
Clear	Delete all lines of the spread sheet
Sort	Reorganize the frequency list in the spread sheet
Delete	Delete the selected line and reorganize the spread sheet
Add	Add a new line to the spread sheet
Ena./Dis.	Enable or disable the network element ▪ **Enable** The network element will be considered for the simulation of transients. ▪ **Disable** The network element will be not considered for the simulation of transients.

Read DFT Data	Read a .CSV-File to generate a frequency spectrum
	
	`##f[Hz];value r.m.s[V,A];phi[°]`
	`0;78.4614;-0;`
	`50;60.8971;-156.522;`
	`100;73.9339;-160.718;`
	`150;153.754;-175.41;`
	`200;116.885;82.1489;`
	`250;34.0383;72.2343;`
	`300;7.24869;89.5666;`
	`350;23.6941;112.357;`
	`400;15.4795;112.212;`
	`450;13.7453;140.943;`
	`500;6.48422;-180;`

Single-Phase	The network element can be used either in single-phase or three-phase mode. The phases can be enabled or disabled independently.
Voltage Source **Current Source**	The network element uses either current sources or voltage sources for each frequency listed in the spreadsheet.
Phase angle offset	Offset of a phase angle for all frequencies

Name	Explanation
Freq. [Hz]	Frequency in Hz
Amplitude [A], [V]	Amplitude of the current or voltage source
Phase Angle [°]	Absolute phase angle of the current or voltage source
Time ON	Start time to be considered for the simulation of transients The negative start time ensures that the current source or voltage source is active from the beginning of the simulation.
Time OFF	End time to be considered for the simulation of transients

16.11.1 Example: Frequency Spectrum calculated by *Signal Analysis*

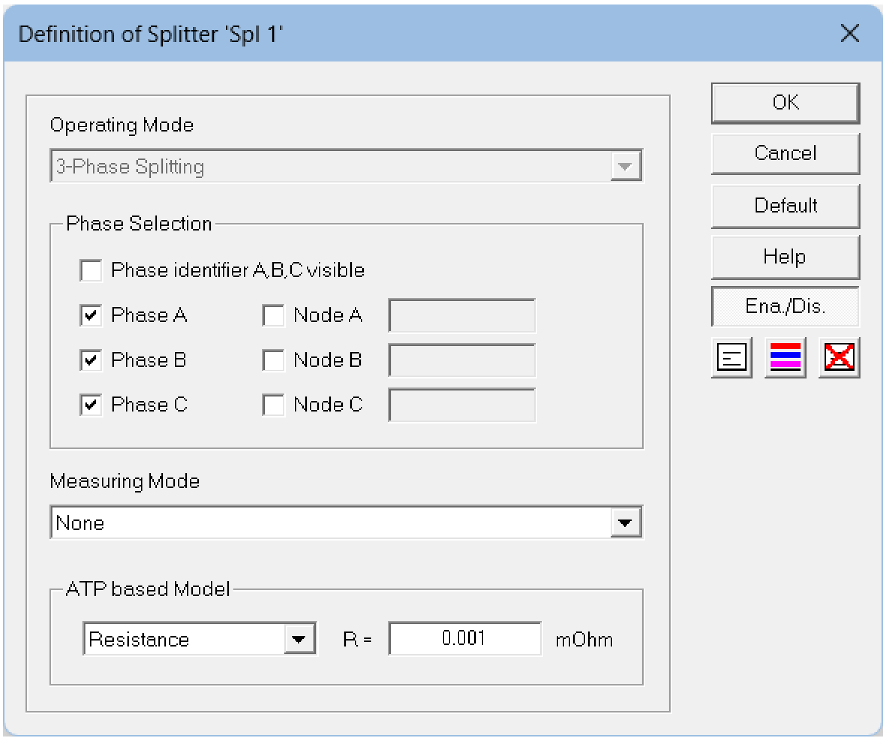
Frequency spectra of three phase currents were be calculated using the dialog Signal Analysis as explained in chapter 16.10. The three .CSV-Files were stored on disk. The three frequency spectra shall be now used to realize a three-phase current source to simulate the transient behaviour of an electronic device such as a power converter. To realize such a converter, appropriate network elements must be configured and connected accordingly.

- One network element **Splitter**
- Three network elements **Connection**
- One network element **Multi Frequency Source**
- One network element **Probe**

The power grid will be extended as explained below.

- Insert three network elements **Multi Frequency Source** in the power grid, each for one of the phases A, B and C
  The settings dialog is shown above. Only **Phase A** of the **Multi Frequency Source** is enabled, **Phase B** and **Phase C** must be disabled.

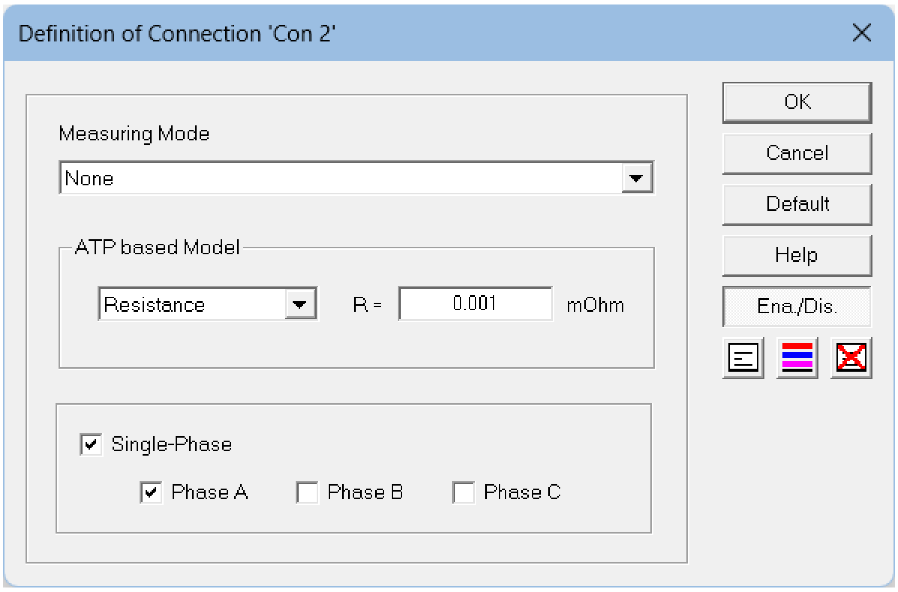
- Insert a network element **Splitter** in the power grid
  The settings dialog is shown below. All three phases A, B and C of the **Splitter** must be enabled.



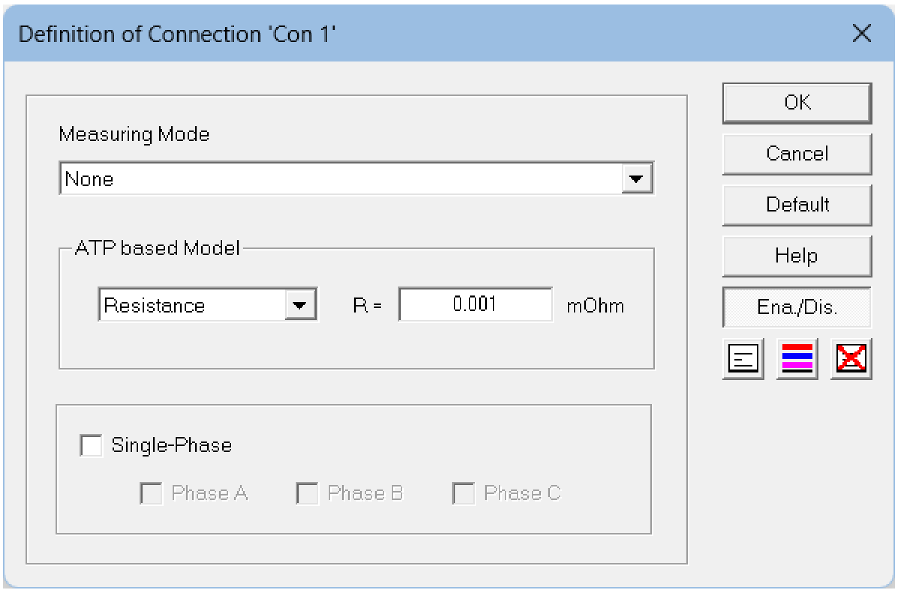
- Connect each single-phase output node of the **Splitter** with the node of one **Multi Frequency Source** using a **Connection**. It is required to assign all network elements **Connection** to **Phase A**. The **Splitter** must be explicitly assigned to **Phase A**, **Phase B** and **Phase C** must be disabled to ensure correct single-phase behaviour. These both network elements **Splitter** are now configured as single-phase network elements.

  ⇨ ATPDesigner internally maps all single-phase network elements to **Phase A**, if a network element is used as **single-phase network element**. Therefore, it is mandatory to assign **Phase A** to all network elements in a single-phase network.

  It is not absolutely necessary to use the single-phase network elements **Connection** to connect the **Splitter** to the three network elements **Multi Frequency Source**. It is also possible to directly connect the **Splitter** to the three network elements **Multi Frequency Source**.



- Connect the network element **Probe** to the tree-phase output node of the **Splitter**.
- Connect the network element **Probe** to another three-phase network element such as a **Busbar** using a **Connection**.



The extended power grid is shown in the figure below.

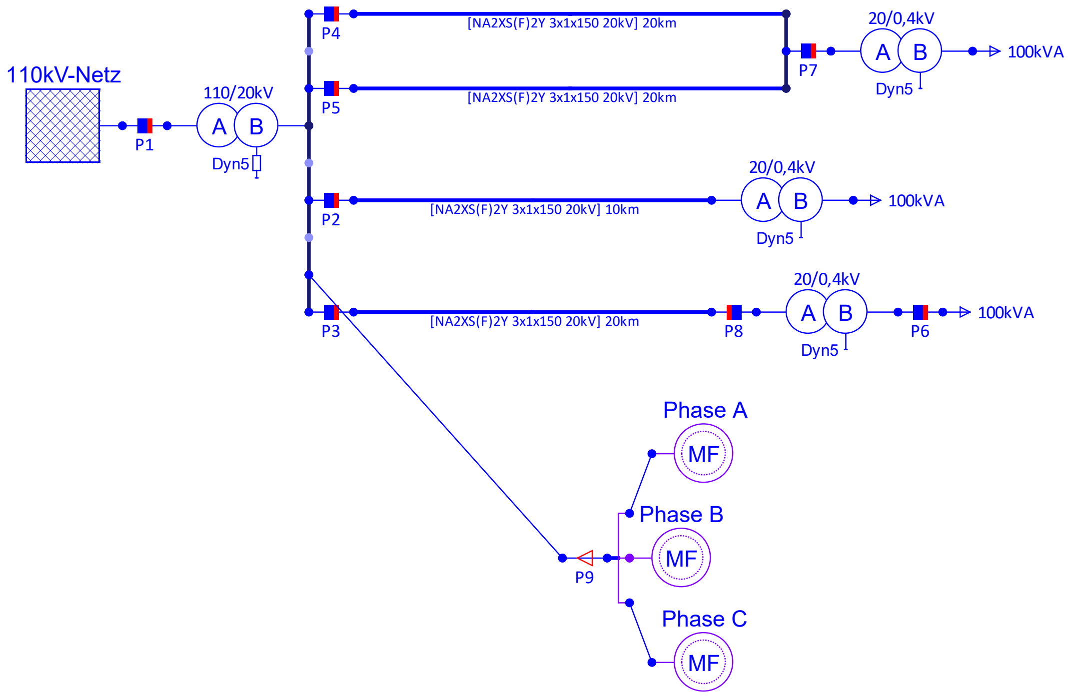


Figure 92: Power Grid with *Multi Phase Source* to simulate a Converter

The figure below shows the result of the simulation of transients.

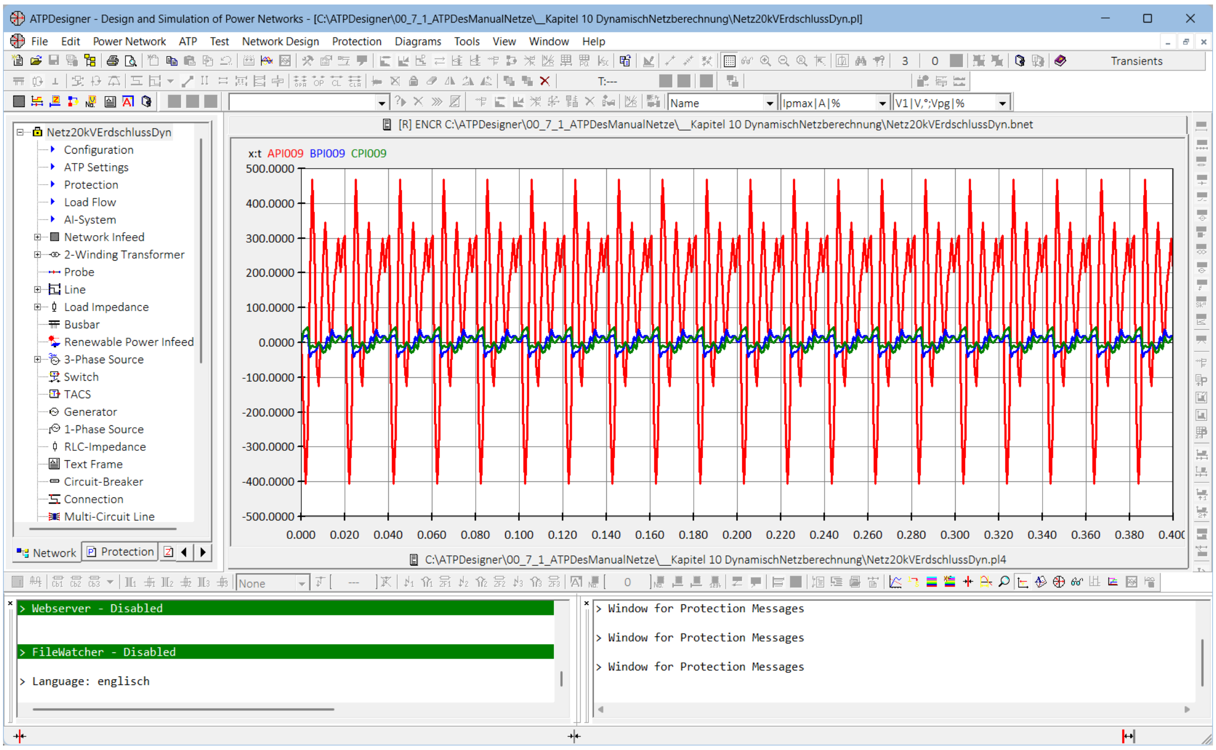


Figure 93: Phase currents measured by *Probe* P9

16.12 Network Element *Probe* - Simulation of Transients

ATPDesigner uses the **ATP** specific **TACS** and **MODELS** to calculate several signals based on the phase-to-ground voltages and phase currents as the result of the **ATP** calculation itself. The calculations methods are part of the network element **Probe** and can be selected with the setting **Operating Mode** shown in the figure below.

⇨ The setting **Operating Mode** will also be used by the **Load Flow Calculation**.

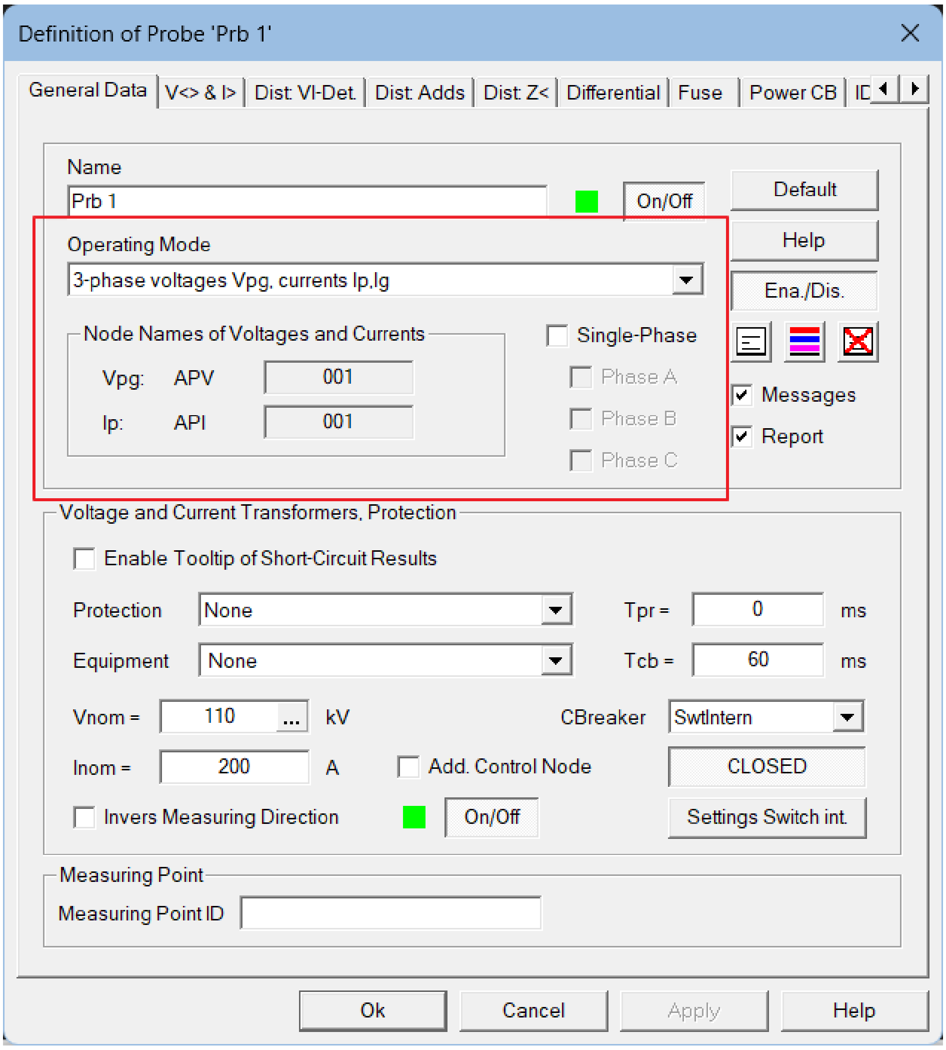


Figure 94:Network Element *Probe* used for the Simulation of Transients

The group **Node Names of Voltages and Currents** displays the **ATP** related signal names used in the **.ATP-File** and therefore in the **.PL4-File**, which contains the calculated signals. In the spread sheets below the network element **Probe P2** (reference name **Prb 2**) will be used to illustrate how these signal names are specified across various dialogs and within the **Diagram**.

⇨ The network element **Probe** uses the consumer counter arrow system in the measuring direction, i.e. in the direction of the **red arrow**.

Signal Name	Explanation
APVxxx **APIxxx**	Phase-to-ground voltage $v_{AG}(t)$ ▪ **A**, **B**, **C** = phase identifier ▪ **P** = primary physical signal, **S** = secondary physical signal ▪ **V** = voltage, **I** = current ▪ **xxx** = Number of the **Probe Pxxx** used as measuring location

The spread sheet below displays the configured **Operating Mode** along with the results of the simulation of transients. The figure below presents the dialog **Selecting Signals**, which lists the signal names corresponding with the selected **Operating Mode**. These signals are generated using the **TACS** (Transient Analysis of Control Systems) module within **ATP**.

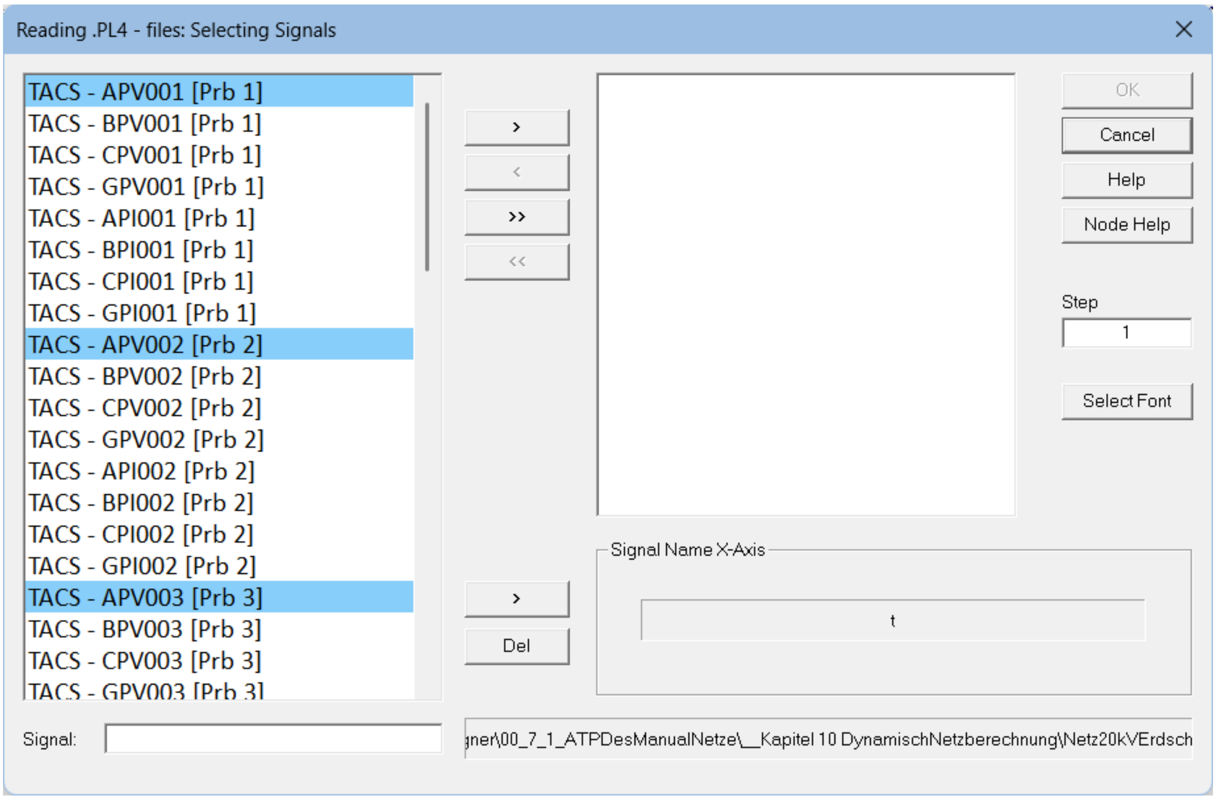


Figure 95: Selecting Signals – Reading .PL4-File and select Signals to create a Diagram

The setting **Operating Mode** is applied individually to each network element **Probe Px**. This allows for precise control over the number of output signals included in the **.PL4-File**. ATPDesigner uses the **Discrete Fourier Transformation (DFT)** algorithm to calculate the amount and phase angle of time-dependent signal. The physical unit for each signal is specified in **[…]**.

Setting *Operating Mode*	Explanation (applied to network element *Probe* P2)	TR	LF
None	No signals are stored in the **.PL4-File**.	X	-
3-phase voltages Vpg, currents Ip, Ig	▪ Phase-to-ground voltages $v_{ABCG}(t)$ [V] : **(ABC)PV002** ▪ Zero-sequence voltage [V] : **GPV002** ▪ Phase currents $i_{ABC}(t)$ [A] : **(ABC)PI002** ▪ Ground fault current $i_g(t)$ [A] : **GPI002** $v_0(t) = \frac{v_{AG}(t) + v_{BG}(t) + v_{CG}(t)}{3}$ $i_g(t) = i_A(t) + i_B(t) + i_C(t)$	X	-
3-ph. voltages Vpg	▪ Phase-to-ground voltages $v_{ABCG}(t)$ [V] : **(ABC)PV002**	X	-
3-ph. currents Ip,Ig	▪ Phase currents $i_{ABC}(t)$ [A] : **(ABC)PI002** ▪ Ground fault current $i_g(t)$ [A] : **GPI002**	X	-
3-phase voltages Vpg, Vpp, currents Ip, Ig	▪ Phase-to-ground voltages $v_{ABCG}(t)$ [V] : **(ABC)PV002** ▪ Phase-to-phase voltages $v_{AB}(t)$, $v_{BC}(t)$, $v_{CA}(t)$ [V] : **ABV002, BCV002, CAV002** ▪ Zero-sequence voltage [V] : **GPV002**		

	▪ Phase currents $i_{ABC}(t)$ [A] : **(ABC)PI002** ▪ Ground fault current $i_g(t)$ [A] : **GPI002**		
Load Profile: V,I,P,Q,S,...	Not used for the simulation of transients	**-**	**X**
AI-System: V,I,P,Q,S,...	Not used for the simulation of transients	**-**	**X**

When calculating derived signals, such as the apparent power S, ATPDesigner utilizes the **MODELS** module within the **ATP** to implement the **Discrete Fourier Transformation (DFT)** algorithm. The figure below shows the dialog **Selecting Signals** with **MODELS** based signals.

⇨ The dialog presents first all **TACS** based signals, after that the **MODELS** based signals.

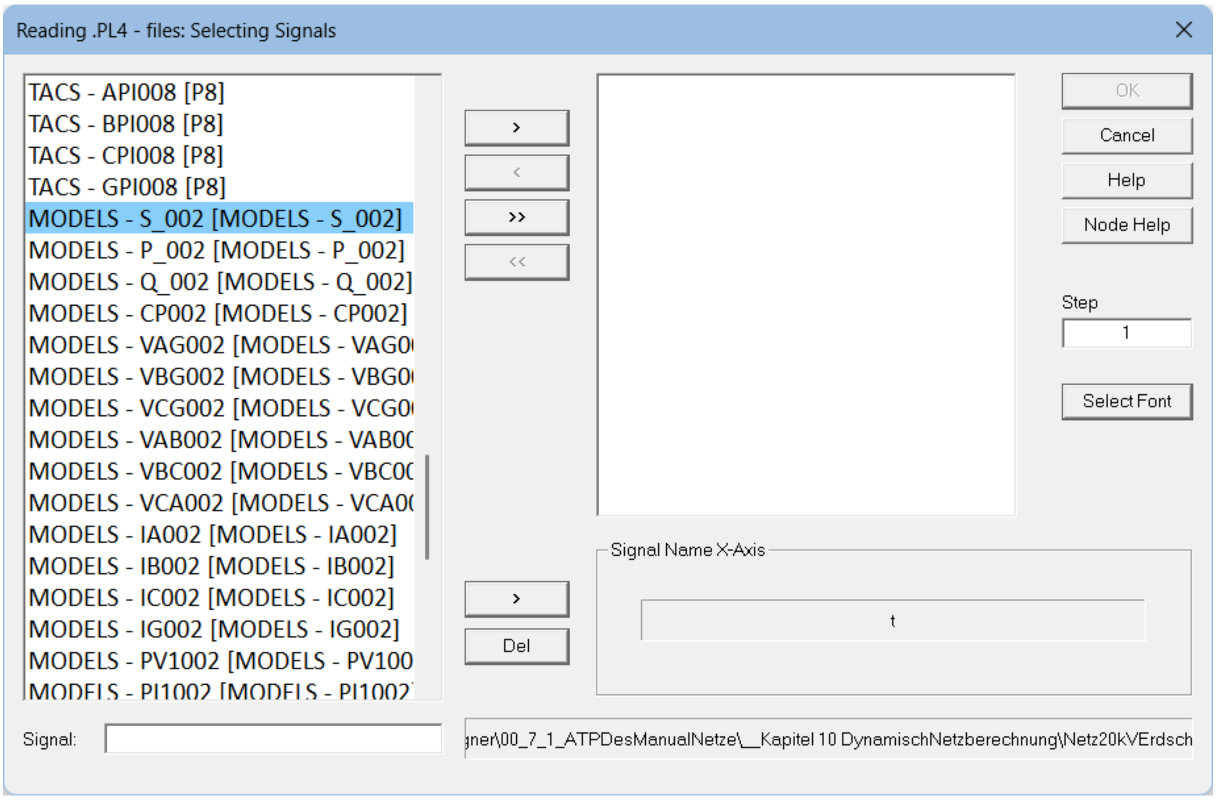


Figure 96: Selecting Signals – Reading .PL4-File and select Signals to create a Diagram

The results of the **Discrete Fourier Transformation (DFT)** algorithm will be represented as a complex phasor. The results of the **Discrete Fourier Transformation (DFT)** algorithm are also expressed as primary physical signals within the 012-sequence system, representing the zero-, positive-, and negative-sequence components of the original three-phase quantities.

⇨ The per-unit (**p.u.**) value represents different physical quantities depending on the signal.

No.	Setting *Operating Mode*	Explanation	TR	LF
1	**S, P, Q, cos Ø, Vpg, Ip (3-ph.)**	Time-dependent signals (**TACS**) ▪ Phase-to-ground voltages $v_{ABCG}(t)$ [V] : **(ABC)PV002** ▪ Zero-sequence voltage [V] : **GPV002** ▪ Phase currents $i_{ABC}(t)$ [A] : **(ABC)PI002** ▪ Ground fault current $i_g(t)$ [A] : **GPI002**	**X**	**-**

Results of **Discrete Fourier Transformation (DFT)** algorithm as primary physical signals (**MODELS**) for the nominal frequency f_{nom}

- Apparent power $|\underline{S}|$ [MVA] : **S_002**
- Active power P [MW] : **P_002**
- Reactive power Q [Mvar] : **Q_002**
- Displacement factor cos φ : **CP002**
- Phase-to-ground voltages $|\underline{V}_{pg}|$ [p.u. = $V_{nom}/\sqrt{3}$] : **V(ABC)G002**
- Phase-to-phase voltages $|\underline{V}_{pp}|$ [p.u. = V_{nom}] : **VAB002**, **VBC002**, **VCG002**
- Phase currents $|\underline{I}_{ABC}|$ [A] : **I(ABC)002**
- Ground fault current $|\underline{I}_{G}|$ [A] : **IG002**

Results of **Discrete Fourier Transformation (DFT)** algorithm as primary physical signals calculated within the **012-System** (**MODELS**) for the nominal frequency f_{nom}

Positive-Sequence System

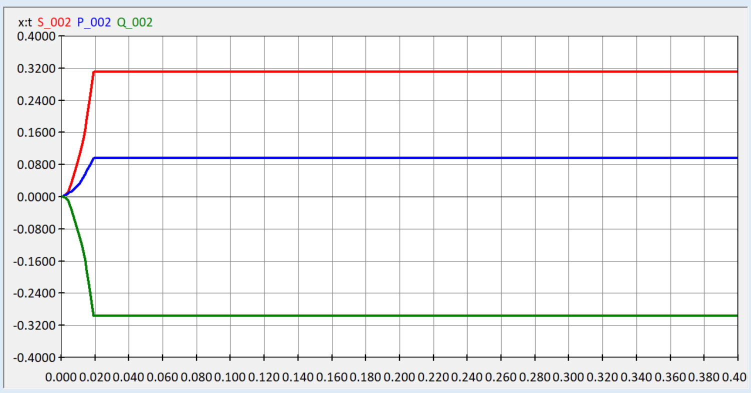
- Phase-to-phase voltage $|\underline{V}_{1pp}|$ [V] : **PV1002**
- Phase current $|\underline{I}_{1}|$ [A] : **PI1002**
- Phase current (active) Re($\underline{I}_{1}$) [A] : **PIW002**
- Phase current (reactive) Im($\underline{I}_{1}$) [A] : **PIR002**
- Active power P_1 [W] : **PP1002**
- Reactive power Q_1 [var] : **PQ1002**
- Displacement factor cos φ_1 : **PC1002**

Negative-Sequence System

- Phase-to-phase voltage $|\underline{V}_{2pp}|$ [V] : **NV1002**
- Phase current $|\underline{I}_{2}|$ [A] : **NI1002**
- Phase current (active) Re($\underline{I}_{2}$) [A] : **NIW002**
- Phase current (reactive) Im($\underline{I}_{2}$) [A] : **NIR002**
- Active power P_2 [W] : **NP1002**
- Reactive power Q_2 [var] : **NQ1002**
- Displacement factor cos φ_2 : **NC1002**

Zero-Sequence System

- Phase-to-phase voltage $|\underline{V}_{0pp}|$ [V] : **ZV1002**
- Phase current $|\underline{I}_{0}|$ [A] : **ZI1002**
- Phase current (active) Re($\underline{I}_{0}$) [A] : **ZIW002**
- Phase current (reactive) Im($\underline{I}_{0}$) [A] : **ZIR002**
- Active power P_0 [W] : **ZP1002**
- Reactive power Q_0 [var] : **ZQ1002**
- Displacement factor cos φ_0 : **ZC1002**



2	**S, P, Q, cos Ø, Vpg, Vpp, Ip (3-ph.)**	▪ Signals of **No. 1** Time-dependent signals (**TACS**) ▪ Phase-to-phase voltages $v_{AB}(t)$, $v_{BC}(t)$, $v_{CA}(t)$ [V] : **ABV002**, **BCV002**, **CAV002**	**X**	**-**
3	**S, P, Q, cos Ø, Vpg, Vpp, Ip (3-ph.), hab**	▪ Signals of **No. 1** Time-dependent signals (**MODELS**) **hαβ-System (Clarke Transformation)** ▪ Voltage of the h-System [V] : **VTH002** ▪ Voltage of the α-System [V] : **VTA002** ▪ Voltage of the β-System [V] : **VTB002** ▪ Current of the h-System [A] : **ITH002** ▪ Current of the α-System [A] : **ITA002** ▪ Current of the β-System [A] : **ITB002**	**X**	**-**
4	**S, P, Q, cos Ø, Vpg, Vpp, Ip (3-ph.), 0dq**	▪ Signals of **No. 1** Time-dependent signals (**MODELS**) The signals of the **0dq-System** are calculated in the time domain using a phase-locked loop (PLL). **0dq-System (Park Transformation)** ▪ Active power P [MW]: **P_X002** ▪ Reactive power Q [Mvar] : **Q_X002** ▪ Frequency f [Hz]: **F_X002** ▪ Angular frequency ω [Hz] : **OMX002** ▪ Phase angle of the PLL [rad] : **PLX002** ▪ Voltage $v_d(t)$ [V] : **UDX002** ▪ Voltage $v_q(t)$ [V] : **UQX002** ▪ Current $i_d(t)$ [A] : **IDX002** ▪ Current $i_q(t)$ [A] : **IQX002**	**X**	**-**

16.12.1 TACS: Signal Names *Probe*

The signals are time-dependent primary signals.

Signal	Explanation
(ABC)PVxxx	Primary phase-to-ground voltages $v_{AG}(t)$, $v_{BG}(t)$ und $v_{CG}(t)$ ▪ Phase **A**, **B** or **C** ▪ **P** = primary ▪ **V** = Voltage ▪ **xxx** = Number of the network element **Probe**
GPVxxx	Primary zero-sequence system voltage $v_0(t)$ ▪ **G** = Ground ▪ **P** = primary ▪ **V** = Voltage ▪ **xxx** = Number of the network element **Probe**
(ABC)PIxxx	Primary phase currents $i_A(t)$, $i_B(t)$ und $i_C(t)$ ▪ Phase **A**, **B** or **C** ▪ **P** = primary ▪ **I** = current ▪ **xxx** = Number of the network element **Probe**
GPIxxx	Primary ground fault current $i_G(t)$ ▪ **G** = Ground ▪ **P** = primary

	▪ **I** = current ▪ **xxx** = Number of the network element **Probe**
ABVxxx	Primary phase-to-phase voltage $v_{AB}(t)$ ▪ Phase-to-phase **AB** ▪ **V** = Voltage ▪ **xxx** = Number of the network element **Probe**
BCVxxx	Primary phase-to-phase voltage $v_{BC}(t)$ ▪ Phase-to-phase **BC** ▪ **V** = Voltage ▪ **xxx** = Number of the network element **Probe**
CAVxxx	Primary phase-to-phase voltage $v_{CA}(t)$ ▪ Phase-to-phase **CA** ▪ **V** = Voltage ▪ **xxx** = Number of the network element **Probe**

16.12.2 MODELS: Signal Names *Probe*

The values of the time-dependant signals are calculated using the **Discrete Fourier Transformation (DFT)** algorithm for the fundamental frequency. The network element **Probe** uses the consumer counter arrow system in the measuring direction, i.e. in the direction of the **red arrow**.

- **xxx** = Number of the network element **Probe**

Signal	Explanation
S_xxx	Apparent power [MVA]
P_xxx	Active power [MW]
Q_xxx	Reactive power [Mvar]
CPxxx	Displacement factor cos φ
VAGxxx	Amount of the phase-to-ground voltage V_{AG} [p.u.]
VBGxxx	Amount of the phase-to-ground voltage V_{BG} [p.u.]
VCGxxx	Amount of the phase-to-ground voltage V_{CG} [p.u.]
VABxxx	Amount of the phase-to-phase voltage V_{AB} [p.u.]
VBCxxx	Amount of the phase-to-phase voltage V_{BC} [p.u.]
VCAxxx	Amount of the phase-to-phase voltage V_{CA} [p.u.]
IAxxx	Amount of the phase current I_A [A]
IBxxx	Amount of the phase current I_B [A]
ICxxx	Amount of the phase current I_C [A]

Signal	Explanation
PV1xxx	Positive-sequence system: Amount of the phase-to-phase voltage [V]
PI1xxx	Positive-sequence system: Amount of the phase current [A]
PIWxxx	Positive-sequence system: Amount of the active current [A] > 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
PIRxxx	Positive-sequence system: Amount of the reactive current [A] > 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
PP1xxx	Positive-sequence system: Active power [W]
PQ1xxx	Positive-sequence system: Reactive power [W] [var]
PC1xxx	Positive-sequence system: Displacement factor cos φ_1

Signal	Explanation
NV1xxx	Negative-sequence system: Amount of the phase-to-phase voltage [V]
NI1xxx	Negative-sequence system: Amount of the phase current [A]
NIWxxx	Negative-sequence system: Amount of the active current [A]

	> 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
NIRxxx	Negative-sequence system: Amount of the reactive current [A] > 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
NP1xxx	Negative-sequence system: Active power [W]
NQ1xxx	Negative-sequence system: Reactive power [W] [var]
NC1xxx	Negative-sequence system: Displacement factor cos φ_2
ZV1xxx	Zero-sequence system: Amount of the phase-to-phase voltage [V]
ZI1xxx	Zero-sequence system: Amount of the phase current [A]
ZIWxxx	Zero-sequence system: Amount of the active current [A] > 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
ZIRxxx	Zero-sequence system: Amount of the reactive current [A] > 0 : Active power flow in measurement direction < 0 : Active power flow in opposite to in measurement direction
ZP1xxx	Zero-sequence system: Active power [W]
ZQ1xxx	Zero-sequence system: Reactive power [W] [var]
ZC1xxx	Zero-sequence system: Displacement factor cos φ_2

16.12.3 MODELS: Signal Names *Probe*

The signals are time-dependant primary signals calculated using the **MODELS** module of the **ATP**.

- **xxx** = Number of the network element **Probe**

Signal	Explanation
VTHxxx	Voltage $v_0(t)$ (0-System) [V]
VTAxxx	Voltage $v_\alpha(t)$ (α-System) [V]
VTBxxx	Voltage $u_\beta(t)$ (β-System) [V]
ITHxxx	Current $i_0(t)$ (0-System) [A]
ITAxxx	Current $i_\alpha(t)$ (α-System) [A]
ITBxxx	Current $i_\beta(t)$ (β-System) [A]

Signal	Explanation
P_Xxxx	Active power P(t) [MW]
Q_Xxxx	Reactive Power Q(t) [Mvar]
F_Xxxx	Frequency [Hz]
OMXxxx	Angular Frequency ω [Hz]
UDXxxx	Voltage $v_d(t)$ of the d-System [V]
UQXxxx	Voltage $u_q(t)$ in q-System in V
IDXxxx	Current $i_d(t)$ in d-System [A]
IQXxxx	Current $i_q(t)$ in q-System [A]
PLXxxx	Absolute phase angle at the output of the PLL (Phase Locked Loop) for calcu-lating the dq components

16.12.4 MODELS: Signal Names *Probe – Overcurrent Protection (PTOC)*

The signals are binary messages from a protection function.

- **xxx** = Number of the network element **Probe**

Signal	Explanation
IA0xxx	General starting: 0=inactive, 1=active

	IA0xxx = IA1xxx OR IA2xxx OR IA3xxx
ITPxxx	State of the circuit-breaker for interrupting the short-circuit current 0= Switch closed 1= Switch open, short-circuit current interrupted
IVGxxx	Starting signal V> protection 0=inactive, 1=active
IVKxxx	Starting signal V< protection 0=inactive, 1=active

16.13 Diagram Settings

The figure below shows the dialog **Diagram Settings**.

- Main Menu: **Diagrams**
- Menu Item: **Diagram Settings**
- Toolbar Button:

The settings dialog contains several settings groups.

Setting	Explanation
Drawing Area	Pen size, colors, etc. related to the drawing area
Signal Analysis	Settings for the signal analysis e.g. the frequency analysis using the Discrete Fourier Transformation (DFT)
Scalig & Min/Max	Settings related to the X/Y-diagram presenting the signals

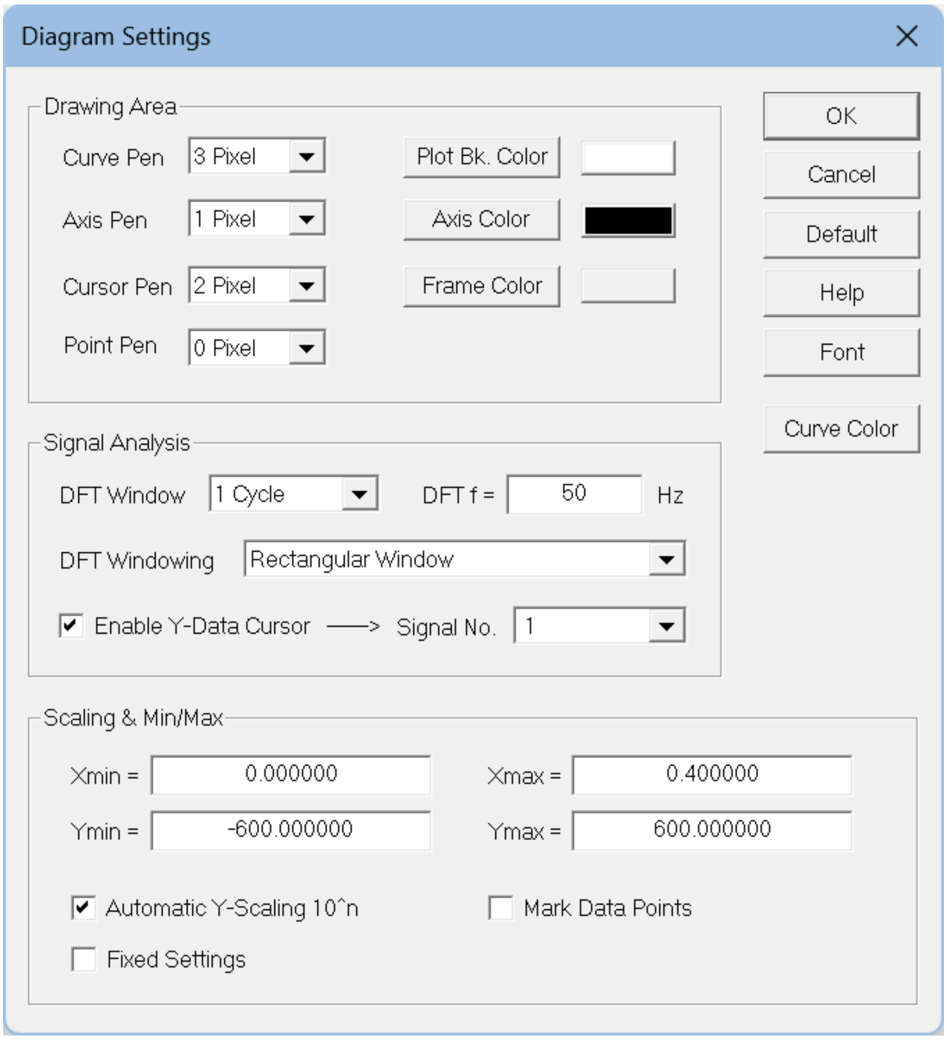


Figure 97: Dialog *Diagram Settings*

Setting	Explanation
Curve Pen	Pen size of the curves of the signals
Axis Pen	Pen size of the axis of the signals
Cursor Pen	Pen size of the graphic cursor
Point Pen	Pen size of the points of load profile curves

Plot Bk. Color	Drawing color of the background
Axis Color	Drawing color of the axis
Frame Color	Drawing color of the frame
DFT Window	Measuring window used by the **Discrete Fourier Transformation** (**DFT**) algorithm, between the graphic cursor drawn in **red** and **grey**
DFT f	Frequency used by the **Discrete Fourier Transformation** (**DFT**)
DFT Windowing	Select the windowing function used by the **Discrete Fourier Transformation** (**DFT**)
Enable Y-Data Cursor → Signal No.	An additionally horizontal **Y-Cursor** will be enabeld and used in the **Diagram**. The **Y-Cursor** can be used to read the sampled value of a signal at the Y-axis. This signal can be selected using the setting **Signal No.**, which corresponds with the sequence of signal names in the top area of the diagram.
Xmin	Minimum value of the X-axis
Xmax	Maximum value of the X-axis
Ymin	Minimum value of the Y-axis
Ymax	Maximum value of the Y-axis
Automatic Y-Scaling 10^n	Automatic scaling of the positive and negative maximum of the Y-axis
Mark Data Points	The sampled values will be marked by a cross.
Fixed Settings	The settings **Xmin**, **Xmax**, **Ymin** and **Ymax** definied in the settings dialog will be fixed and not automatically calculated by ATPDesigner.
Curve Color	Open the dialog **Colors of Diagram Curves**  to define the drawing colors of the signals
Font	Open a dialog to select the font used by the **Diagram**

17 Settings of a Power Grid Project

The settings and configuration of a power grid project can be exported as a **Report** in the **Office Open XML** [6] file format, which can be opened and edited using word processing software such as Microsoft Word. The figure below shows the dialog **Find Network Element**.

- Main menu **Edit**
- Menu Item **Find**
- **STRG + F**

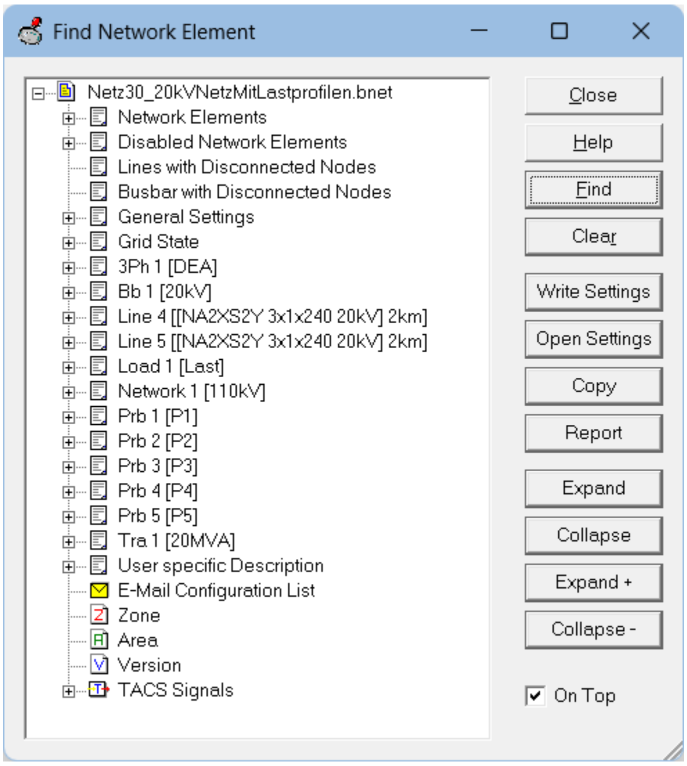


Figure 98: Dialog *Find* to export Settings and Configuration of a Power Grid Project

The settings and configuration of a power grid project can be exported by a **Left Mouse Button Click** on the button **Report**. Alternatively, the dialog **Find** can also be opened, and the **Report** can also be exported via the menu options listed below.

- Main menu **File**
- Menu item **Export**, item **Report: Settings**

The dialog can remain open alongside the main window of ATPDesigner. ATPDesigner opens the dialog **File Save**, allowing the user to select a directory and specify a filename. The **Report** is saved using the file extension **XML**.

The file name format (**DESC** = settings and configuration of a power grid project):

- **YYYYMMDDhhmmss_NetFilename_DESC**.XML

The following figures illustrate examples from the **Report**.

Power Grid: Equipment, Characteristics and Settings

12.10.2025, 10:34:00.313
C:\Software\ATPDesignerSetup\00_7_ATPDesignerDemoNetze\Netz30_20kVNetzMitLastprofilen.bnet
ATPDesigner Version 4.02.07 - 11.10.2025
Version NET File 6.3 - 22.01.2021

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Identifiers and Descriptions

nom	Nominal value, e.g. nominal voltage Vnom
r	Rated value, e.g. rated current Ir
VAG, VBG, VCG [V], [%]	Amount of the phase-to-ground voltages in V and %Vn/√3
VAB, VBC, VCA [V], [%]	Amount of the phase-to-phase voltages in V and %Vn
Vmin, Vmax [V], [%]	Amount of the minimum and maximum phase-to-ground and phase-to-phase voltage VABC in V and %Vnom
Vpp, Vpg [V], [%]	Amount of the phase-to-phase voltages VAB, VBC, VCA in V and %Vn Amount of the phase-to-ground voltages VAG, VBG, VCG in V and %Vn/√3
IA, IB, IC [A], [%]	Amount of the phase currents in A and %In
V1, V2, V0 [V], [%]	Amount of the positive-, negative- and zero-sequence voltage in V and %Vn/√3
I1, I2, I0 [A], [%]	Amount of the positive-, negative- and zero-sequence current in A and %In
Ipmax [A], [%]	Amount of the maximum phase current IABC in A und %In=Imax-Red.
Load [%Inom]	Amount of the maximum phase current IABC in %In
Load Smax, Smin [%Sr]	Amount of the maximum or minimum apparent power S in %Sr
S [VA]	Amount of the apparent power in VA
P [W]	Amount of the active power in W
Q [var]	Amount of the reactive power in var
Vpgnom	Vpgnom = Vnom/√3
max	maximum
min	minimum
CosPhi	Displacement factor cos phi = P / S
Load [%]	Load of winding A and B in %In
SA, SB, SC [VA]	Single-phase apparent power of phase A, B and C in VA
PA, PB, PC [W]	Single-phase active power of phase A, B and C in W
QA, QB, QC [var]	Single-phase reactive power of phase A, B and C in var
NA	Need for Action
Ipmax [%]	Maximum phase current IABC in %Inom
fN [%]	Grid Health in %
m [p.u.]	Load Level acc. VDE 0276
LF	State of Load Flow Calculation: o.k.=1, failed=0, stopped=2, invalid=-1
TRIP	Grid Protection: TRIP-Command - 0=disabled, 1=enabled
GEN	Grid Protection: General starting - 0=disabled, 1=enabled
DSZ	Grid Protection: Distance zone of the distance protection with TRIP
R1k	Grid Protection: Resistance of the short-circuit impedance of the positive sequence system
X1k	Grid Protection: Reactance of the short-circuit impedance of the positive sequence system
DST	Daylight Saving Time: Summer = S, Winter = W
State	Overall result for the equipment according to the BDEW traffic light model (green, yellow, red)
Enabled (Ena) Disabled (Dis)	Network element: enabled (Ena) or disabled (Dis)

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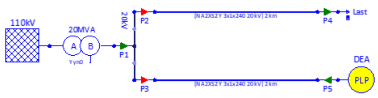
Power Grid Topology



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Number of Network Elements

Name of the network element	Number
Network Infeed	1
Line	2
Busbar	1
Load Impedance	1
2-Winding Transformer	1
Probe	5
3-Phase Source	1

Compilation of Disabled Network Elements

Name of the network element	Ena./Dis.

Disabled Network Elements not detected

2-Winding Transformer

Name of the network element	Srt	VnomA, VnomB	uk
Tra 1 [20MVA]	20 MVA	110 kV, 20 kV	8 %

Load Impedance

Name of the network element	Vnom	P	Q
Load 1 [Last]	20 kV	2 MW	0.406117 Mvar

Characteristics of the Power Grid

Line	Value
Number	2

Vnom	Length	Number
20 kV	4 km	2

Transformer	Value
Number	1
Sum of Apparent Power S	20 MVA

Load Impedance (Load Impedance, 2-Winding Transformer)	Value
Number of Load Impedance : N1 =	1
Number of Load Impedance of 2-Winding Transformer : N2 =	0
Sum = N1 + N2	1
Sum of Active Power P	2 MW = 2 MW + 0 MW
Load Profile: Sum of Energy E	1000 MWh = 1000 MWh + 0 MWh
Load Profile: Sum of Energy E of Heat Pumps (HP(ID))	0 kWh = 0 kWh + 0 kWh
Load Profile: Sum of Active Power P of E-Mobils (EMOB(ID))	0 kW = 0 kW + 0 kW
Load Profile: Number of Load Profiles with Forecast (ID) e.g. FC(ID)	0 = 0 + 0

3-Phase Source	Value
Number Photovoltaic Solar Power Plant	1 / 1
# Sum of Active Power P	2 MW
# Sum of Energy Consumption E	1000 MWh
Number Electromobile	0 / 1
# Sum of Active Power P	0 kW
# Sum of Energy Consumption E	0 kWh
Number Wind Power Plant	0 / 1

Setting	Explanation
Close	Close the dialog
Find	If a network element such as **Bb 1 [20kV]** has been selected by a **Left Mouse Button Click** on its name, the graophic shape of the network element will be marked by **red frame**.
Clear	Remove the red frame in the power grid that highlights a selected network element.
Copy	The contents of the tree structure displayed in the dialog can be copied to the clipboard. Please note that the export uses plain text format only.
Write Settings	The contents of the tree structure displayed in the dialog can be saved in a text file. Please note that the text file uses plain text format only.
Open Settings	**Write Settings** will be executed and the text file will be opened in a text editor.
On Top	▪ enabled: dialog remains always on top ▪ disabled: dialog can be moved on the background

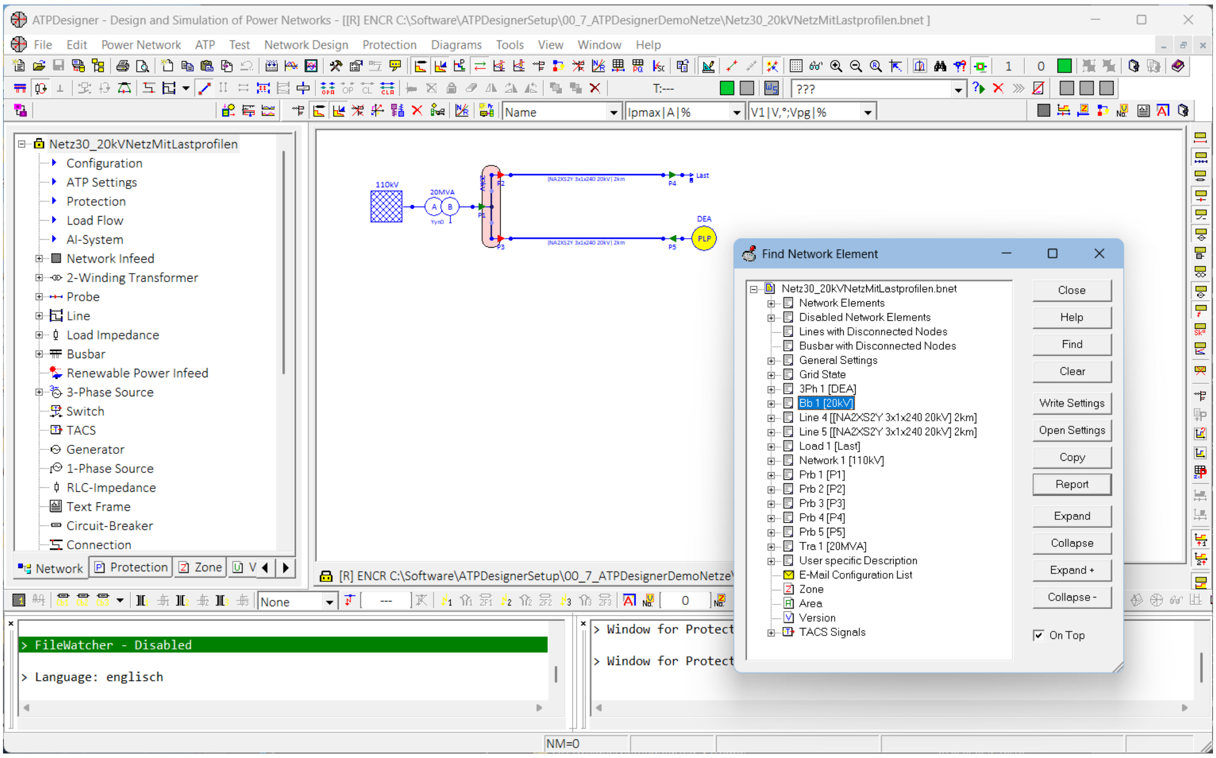


Figure 99: Find a network element in the Power Grid

18 Settings Dialogs

18.1 The *ATP Settings* Dialog

The settings dialog **ATP Settings** contains settings related to the calculation methods available in ATPDesigner, for the simulation of transients and also for the **Load Flow Calculation**.

- Main menu **Power Network**
- Menu item **ATP Data**
- **Project Information**, tab **Network**, item **ATP Settings**

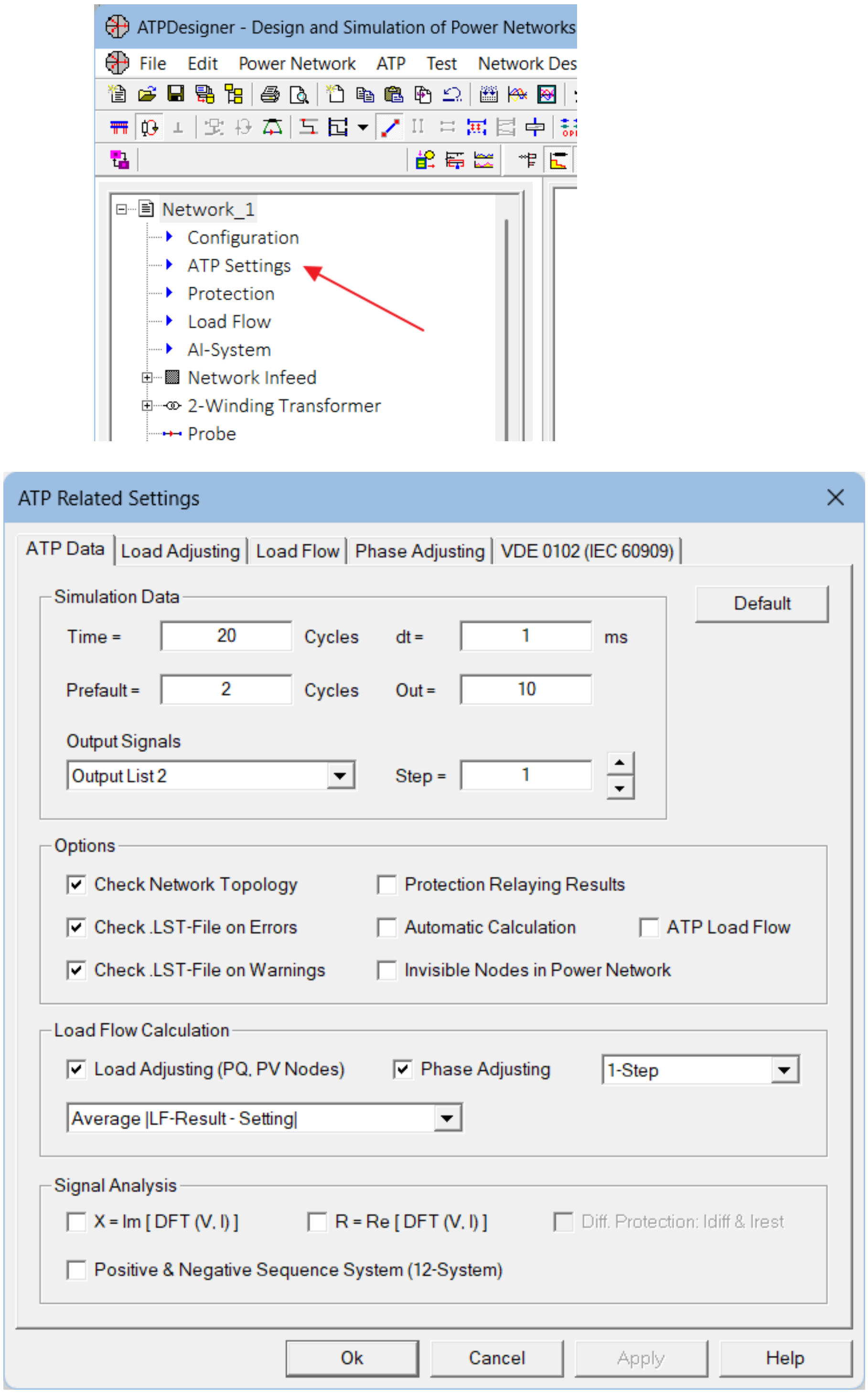


Figure 100: Settings Dialog *ATP Settings*

18.1.1 ATP Settings: Tab *ATP Data*

The settings dialog includes configuration options for **ATP** itself, parameters for simulating transients, and controls for the **Load Flow Calculation** executed by ATPDesigner.

Setting	Explanation
Time	**Simulation of Transients**: Overall simulation time $Cycle = \frac{1}{f_{nom}}$ with f_{nom} : nominal frequency of the power grid
dt	**Simulation of Transients**: Step-size of the sampled values used to create a **Diagram**
Prefault	**Simulation of Transients**: The setting will be only used if one of **Line 1...3** are used in the power grid. If a short-circuit of one of **Line 1...3** has been enabled, the setting defines the prefault-time before the short-circuit occurs.
Out	**Simulation of Transients**: The setting will be only used if a test system CMCxxx from Omicron such as CMC356 will be used.
Step	**Simulation of Transients**: The setting defines the internal step-size $dt_{internal}$ used from the **ATP** for the simulation of transients. It depends on the setting **dt**. $dt_{internal} = \frac{dt}{step}$ Depending on power grid and its equipment it may be necessary to use a very small internal step-size $dt_{internal}$ as used for the setp-size **dt** of the **Diagram**. Example: It may be required to use internal step-size $dt_{internal}$ = 0,01ms. For the Diagram a step-size of dt = 0,1ms is sufficient. $step = \frac{dt}{dt_{internal}} = \frac{0,1ms}{0,01ms} = 10$
Output List	**Simulation of Transients**: Additional nodes can be added to the signal list
Default	Load the default values of the settings across all tabs,

The settings below are related to the **Load Flow Calculation** of ATPDesigner. The **Load Flow Calculation** algorithm consists of two basic algorithms, which shall be configured separately.

- Load Adjusting
- Phase Adjusting

It is possible - and sometimes necessary - to enable or disable both basic algorithms independent from each other.

Setting	Explanation
Load Adjusting (PQ, PV-Nodes)	If enabled, the **Phase Adjusting** executes the **Load Flow Calculation** for the specified network elements. The **Load Adjusting** algorithm controls the amount of the apparent power S across all network elements **Load Impedance** as well as across all internal **Load Impedance** of the network elements **Line** and **Transformer 2-Winding**. The algorithm aims to achieve an accuracy better

	than the specified threshold **dS**. The algorithm also considers the displacement factor cos φ, which is specified individually for each network element. The **Load Adjusting** algorithm also controls the tap changer and voltage regulator of the network elements **Transformer 2-Winding**.
Phase Adjusting	If enabled, the **Load Adjusting** executes the **Load Flow Calculation** for the specified network elements. The **Phase Adjusting** algorithm controls the amount of the apparent power S and the phase angle between positive-sequence voltage $\underline{V}_1$ and the positive sequence current $\underline{I}_1$ at the network connection point (NCP) across all network elements **3-Phase Source**.

The settings below are related to the **Load Flow** of the **ATP** itself.

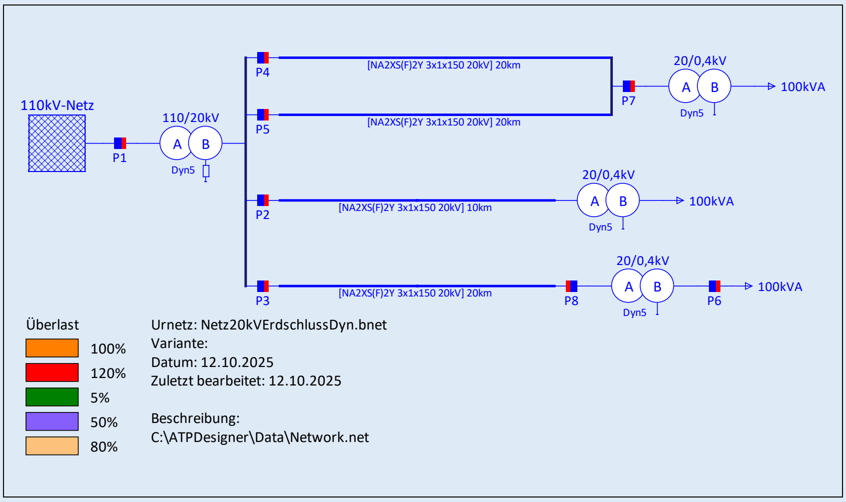
Setting	Explanation
ATP Load Flow	If enabled, the **Load Flow** of the **ATP** itself can be used.

The settings below are related to the network configuration.

<table>
<tr><th>ATP Load Flow</th><th>If enabled, the Load Flow of the ATP itself can be used.</th></tr>
<tr><td>Invisible Nodes in Power Network</td><td>

- enabled: The nodes will be not drawn.
- disabled: The nodes will be drawn

The figure below illustrates an example without drawing the nodes.



</td></tr>
</table>

18.1.2 ATP Settings: Tab *Load Adjusting*

The settings dialog includes configuration options for the **Load Flow Calculation** executed by ATPDesigner. The **Load Adjusting** settings provide access to the load flow algorithm applied to the network elements specified below.

Network Element	PQ-Node	PV-Node
Load Impedance	X	---
Transformer 2-Winding: Voltage regulator and tap changer	---	---
Transformer 2-Winding: Internal **Load Impedance**	---	X
Line: Internal **Load Impedance**	---	X
Network Infeed	---	X
Generator	---	X

- Main menu **ATP**
- Menu item **Load Adjusting**
- Toolbar button 

To enable **Load Adjusting**, the option must be selected by a **Left Mouse Button Click**.

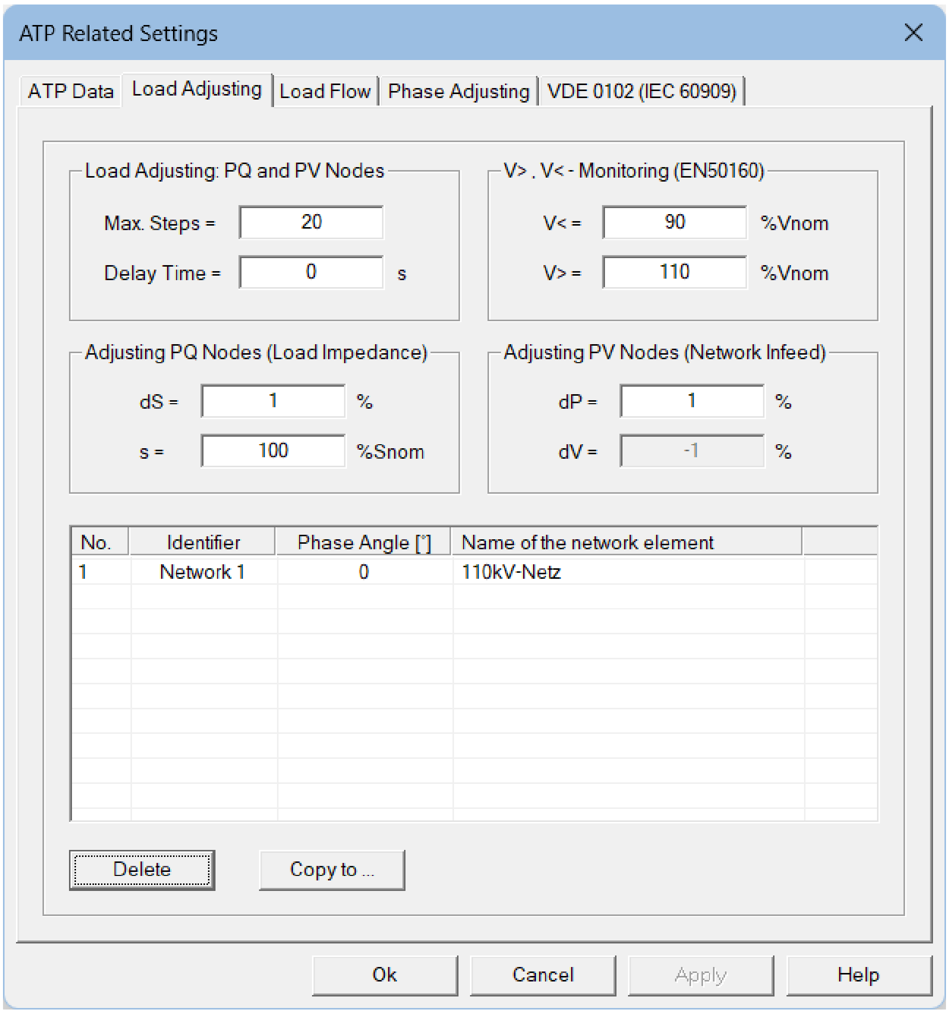


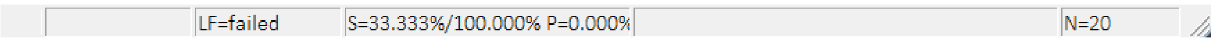
Figure 101: Settings Dialog *ATP Settings*, Tab *Load Adjusting*

The settings below are used to control the **Load Adjusting** part of the **Load Flow Calculation**.

Setting	Explanation
Max. Steps	**Load Adjusting:** Maximum number of iteration steps If the maximum number of iteration steps are exceeded, the **Load Flow Calculation** will be stopped and ATPDesigner writes **LF=failed** in the status bar.
Delay Time	Delay time between two iteration steps of the **Load Flow Calculation**
dS	**Load Adjusting:** Maximum accuracy of the apparent power S across all **Load Impedance** The convergence criterion is used to monitor the relative deviation of the apparent power. The algorithm evaluates the magnitude of the difference between the calculated and specified apparent power.
s	Partial load factor across all **Load Impedance** $S_{LoadFlow} = s \cdot S_{Setting}$
dP	**Load Adjusting:** Maximum accuracy of the active power P across all **Network Infeed** and **Generator**
dV	**Load Adjusting:** Maximum accuracy of the voltage of the positive-sequence system V_1 across all **Network Infeed** and **Generator**

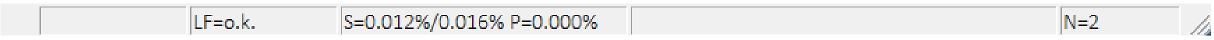
At the end of the **Load Flow Calculation**, ATPDesigner displays messages in the status bar.

Load Flow Calculation fails



- LF=failed : **Load Flow Calculation** fails (**Divergence**)
- N=20 : Number of iteration steps

Load Flow Calculation o.k.



- LF=o.k. : **Load Flow Calculation** has succeeded (**Konvergence**)
- N=2 : Number of iteration steps

The settings below allow monitoring the voltages at all nodes of the power grid.

Setting	Explanation
V<	Threshold of the overvoltage detection
V>	Threshold of the undervoltage detection

18.1.3 ATP Settings: Tab *Load Flow*

The settings dialog includes configuration options for the **Load Flow** performed directly by **ATP**. If this **ATP**-based load flow is to be used, it is strongly recommended to consult the official **ATP** rule book to ensure correct application. Alternatively, it is advisable to use the **Load Flow Calculation** provided by ATPDesigner, which includes the so-called **Load Adjusting** and **Phase Adjusting** methods. Explanations of the settings shown below are provided in the **ATP Rule Book**.

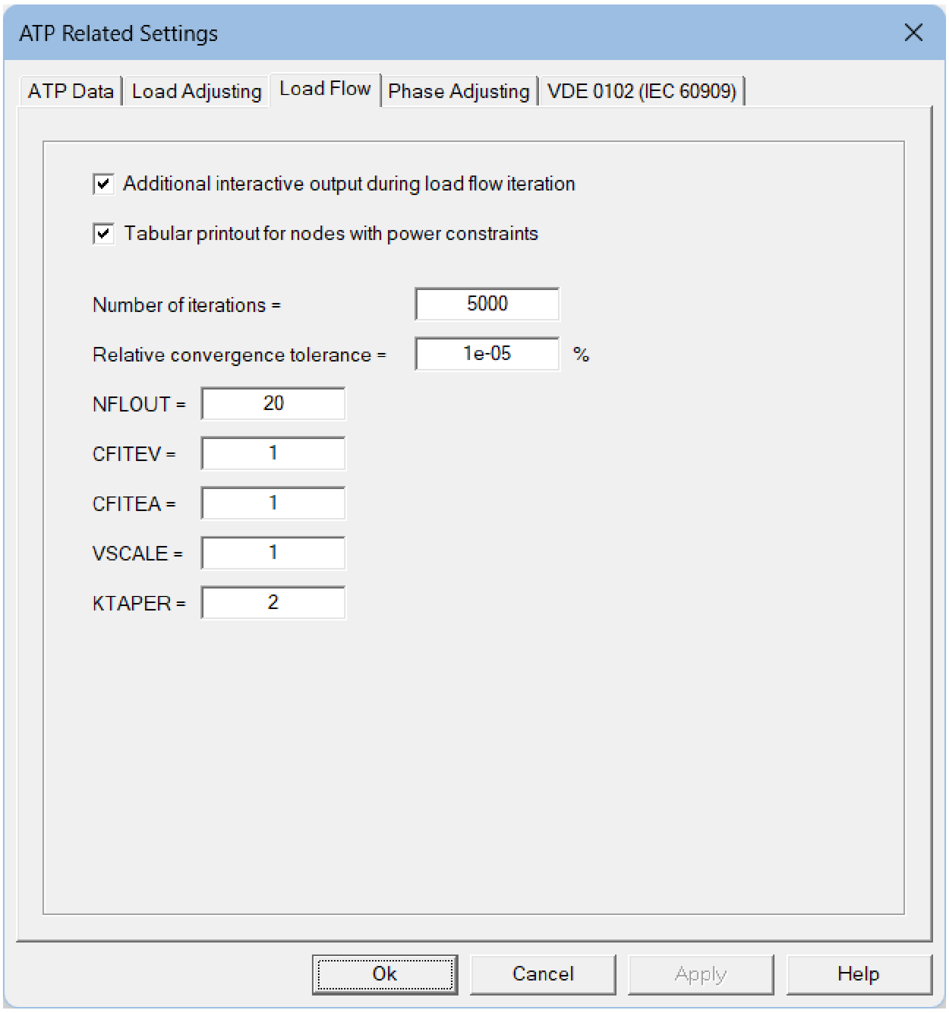


Figure 102: Settings Dialog *ATP Settings*, Tab *Load Flow*

18.1.4 ATP Settings: Tab *Phase Adjusting*

The settings dialog includes configuration options for the **Load Flow Calculation** executed by ATPDesigner. The **Phase Adjusting** settings provide access to the load flow algorithm applied to the network elements specified below.

Network Element	PQ-Node	PV-Node
3-Phase Source	X	---

- Main menu **ATP**
- Menu item **Phase Adjusting**
- Toolbar button 

To enable **Phase Adjusting**, the option must be selected by a **Left Mouse Button Click**.

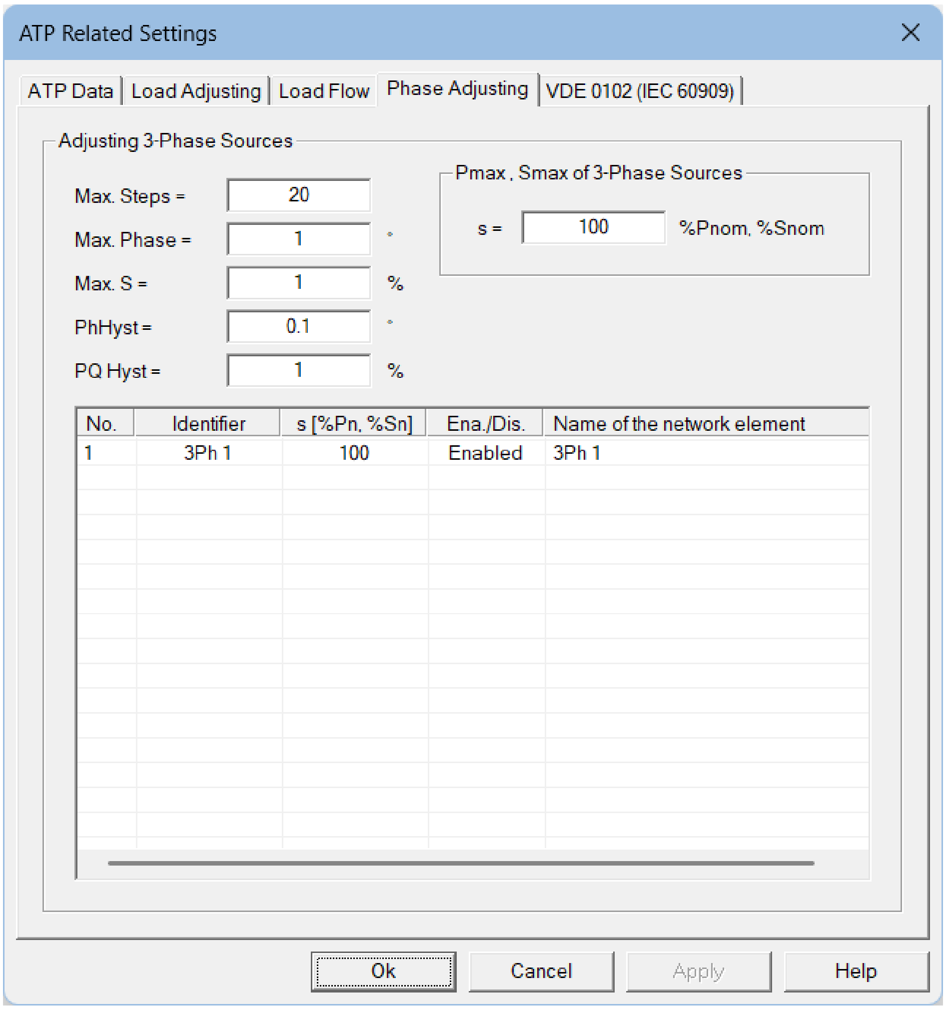
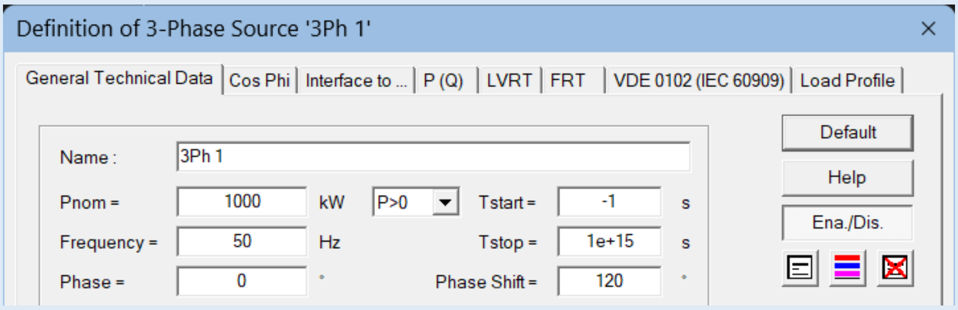


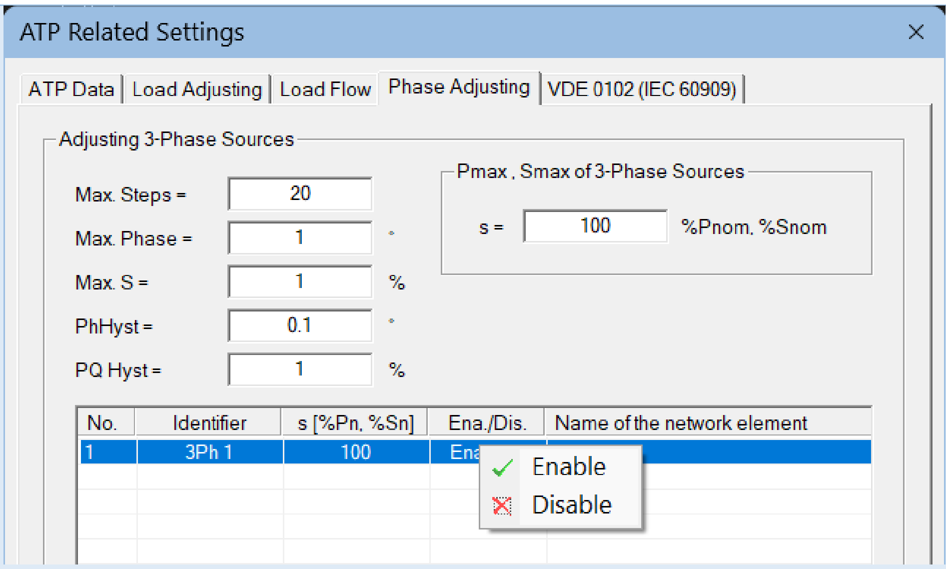
Figure 103: Settings Dialog *ATP Settings*, Tab *Phase Adjusting*

Setting	Explanation
Max. Steps	**Phase Adjusting:** Maximum number of iteration steps
Max. Phase	**Phase Adjusting:** Maximum accuracy of the phase angle φ across all **3-Phase Source**
Max. S	**Phase Adjusting:** Maximum accuracy of the apparent power S across all **3-Phase Source**

	The convergence criterion is used to monitor the relative deviation of the apparent power. The algorithm evaluates the magnitude of the difference between the calculated and specified apparent power. 1. Mean value of the relative deviation across all **3-Phase Source** 2. Maximum value of the relative deviation across all **3-Phase Source**
PhHyst	**Phase Adjusting: Hysteresis for the angular rotation of phasors** Due to the mathematical algorithms of the **ATP**, absolute phase angles may be calculated outside the standard range: greater than 360° or less than 0°. Since angles like 362° and 2° are electrically identical, the **Phase Adjusting** algorithm normalizes phase angles to the interval [0°, 360°] to improve convergence behaviour.
PQ Hyst	**Phase Adjusting:** Hysteresis of the PQ characteristic across all **3-Phase Source**
s	Partial load factor across all **3-Phase Source** $$S_{LoadFlow} = s \cdot S_{Setting}$$

The spread sheet shows all network elements **3-Phase Source** used in the power grid.

Setting	Explanation
Identifier	Reference name of the network element The reference name uniquely identifies the network element and will be displayed in the headline of the settings dialog. 
S [%Pn, %Sn]	
Ena./Dis.	▪ **Enabled**: The network element is enabled and will be considered in both the **Load Flow Calculation** and the simulation of transients. ▪ **Disabled**: The network element is disabled and will be not considered neither the **Load Flow Calculation** nor the simulation of transients. The network element can also be enabled or disabled by a **Left Mouse Button Click** on the corresponding cell. A context sensitive menu will appear.

	
Name of the network element	User specific name of the network element

18.1.5 ATP Settings: *VDE 0102 (IEC 60909)*

The settings dialog includes configuration options for the short-circuit calculation according to the standard **IEC 60909-0:2016 (VDE 0102:2016-12) Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents**.

"*IEC 60909-0:2016 is applicable to the calculation of short-circuit currents in low-voltage three-phase AC systems, and in high-voltage three-phase AC systems, operating at a nominal frequency of 50 Hz or 60 Hz. It establishes a general, practicable and concise procedure leading to results which are generally of acceptable accuracy and deals with the calculation of short-circuit currents in the case of balanced or unbalanced short circuits. This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.*" (https://www.vde-verlag.de/iec-normen/222518/iec-60909-0-2016.html)

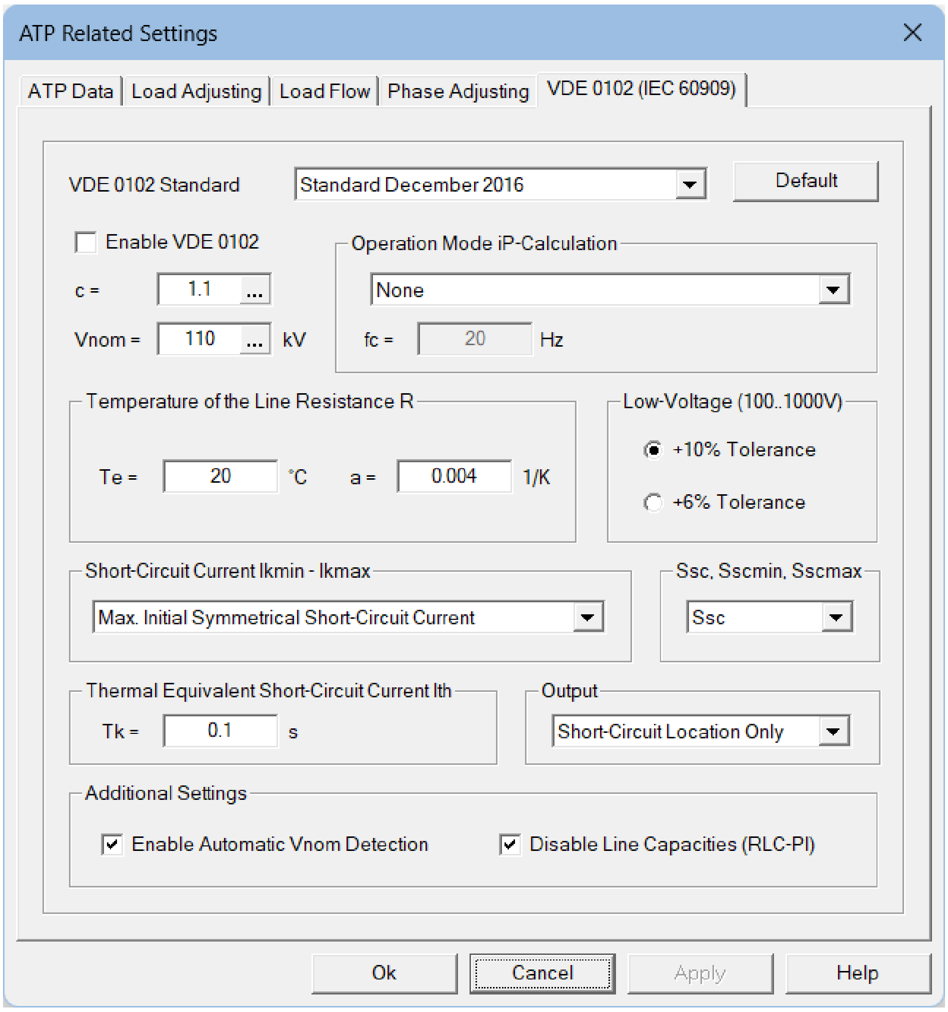


Figure 104: Settings Dialog *ATP Settings*, Tab *VDE 0102 (IEC 60909)*

Setting	Explanation
Default	Load the default settings of the tab
Enable VDE 0102	▪ **enabled**: Short-circuit calculation according to **IEC 60909 (VDE 0102)** will be executed ▪ **disabled**: Short-circuit calculation using steady-state analysis will be executed.
VDE 0102 Stand-ard	▪ **Standard December 2016** ▪ **Standard December 2016 (mod)** This option may be used with caution, as it represents a modification of the **Standard December 2016**. ▪ **Standard July 2002**

	This option should no longer be used, as the corresponding standard is no longer valid.
c	Voltage factor of the voltage source at the fault location
Vnom	Nominal voltage of the voltage source at the fault location
Operation Mode iP-Calculation	Method to calculate the initial symmetrical short-circuit current i_P ▪ None ▪ R/X-Ratio at SC Location ▪ Equivalent Frequency fc
fc	Equivalent frequency to calculate the R/X-ratio
Te	Temperature to calculate the resistance of the network element **Line**
a	Temperature coefficient to calculate the resistance of the network element **Line**
Short-Circuit Current Ikmin-Ikmax	▪ Max. Initial Symmetrical Short-Circuit Current ▪ Min. Initial Symmetrical Short-Circuit Current
Ssc, Sscmin, Sscmax	Short-circuit apparent power of all network elements **Network Infeed** used for the short-circuit calculation acc. IEC 60909 (VDE 0102) ▪ Ssc ▪ Ssc min ▪ Ssc max
Tk	The durations of the short-current T_k (time from the beginning up to the extinction of the short-current) is used to calculate the thermal equivalent short-circuit current I_{th}.
Output	Output of the short-circuit results at: ▪ Short-Circuit Location Only ▪ All Nodes
Enable Automatic Vnom Detection	The nominal voltage **Vnom** will be determined at the short-circuit location. It will be recommended to validate the result to ensure the correct short-circuit calculation results.
Disable Line Capacities (RLC-PI)	The phase-to-phase and phase-to-ground capacitances of all network elements **Line** will be disabled.

The results will also be displayed in the **Messages Window**.

```
Results of the Short-Circuit Calculation acc.  [Calculation iP disabled]
> VDE 0102 (IEC 60909) Standard December 2016
> Calculation of Max. Initial Symmetrical Short-Circuit Current Ikmax
> Short-Circuit ABC; Te=20°; Vnom=20kV; c=1.1; Ssc
>> Ik"PF(3-Phase Source)=0A
>> Ik"=2.032kA;2.032kA;2.032kA
>> Zk=6.250Ohm;6.250Ohm;6.250Ohm
>> 46.9887°;46.9887°;46.9887°
>> Re(Zk)=4.264Ohm;4.264Ohm;4.264Ohm
>> Im(Zk)=4.570Ohm;4.570Ohm;4.570Ohm
>> R/X=0.93288;0.93288;0.93288
>> X/R=1.07194;1.07194;1.07194
>> T=3.412ms;3.412ms;3.412ms

> Thermal Equivalent Short-Circuit Current
>> [Bb 1] Ithr=25.000kA; Tkr=1.000s; Tk=0.100s; Ithz=79.057kA :
>> [Bb 2] Ithr=25.000kA; Tkr=1.000s; Tk=0.100s; Ithz=79.057kA :


> Results of the Short-Circuit Calculation acc. VDE 0102 (IEC60909) : 3-Phase Source
>> 1 : [3Ph 1] 3Ph 1, Isc"maxPF=0A, Setting: Isc"=0A, ABC

LF> Processing Time of the Load Flow Calculation = 494ms
```

Figure 105: Messages Window - Results of the Short-Circuit Calculation acc. IEC 60909 (VDE 0102)

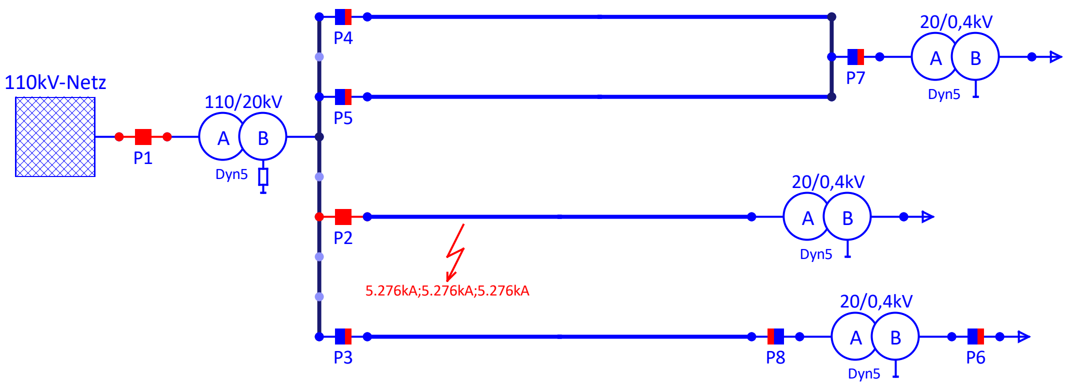
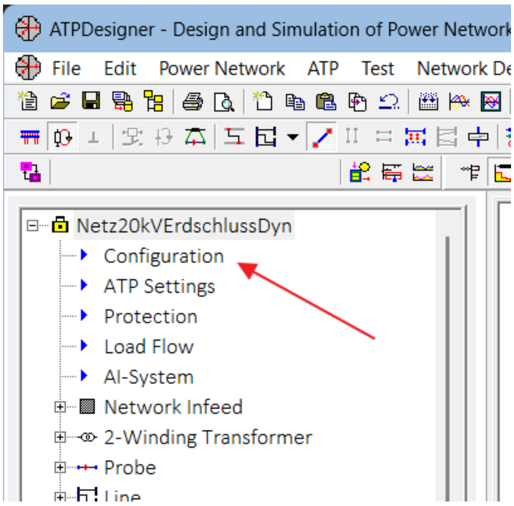


Figure 106: Short-Circuit Current displayed at the Short-Circuit Location

18.2 The *Network Configuration* Dialog

The settings dialog **Network Configuration** contains several settings related to the configuration of the power grid and the methods to analyse the power grid available in ATPDesigner.

- Main menu Power Network
- Menu item **Network Configuration**
- **Project Information**, tab **Network**, item **Configuration**



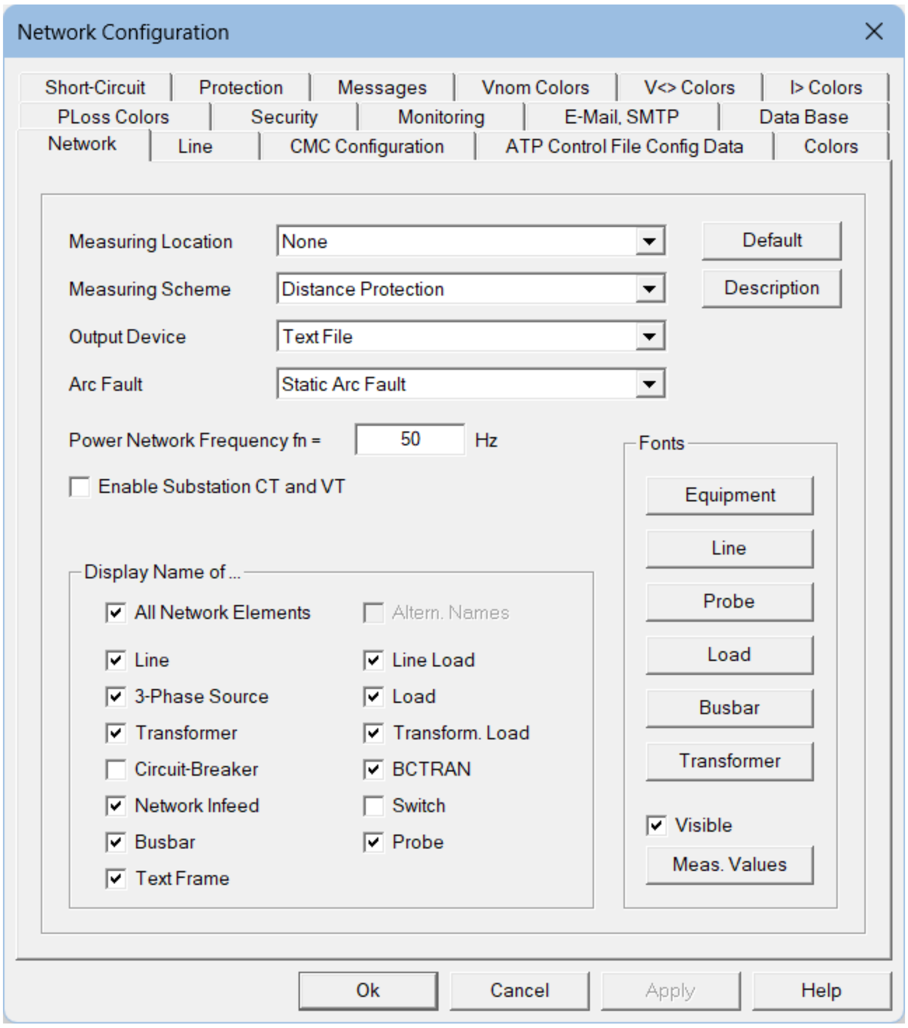


Figure 107: Settings Dialog *Network Configuration*

18.2.1 Network Configuration: Tab *Network*

Setting	Explanation
Default	The default settings will be loaded across all tabs of the settings dialog and all existing settings will be overwritten.
Display Name of ..	The display of user-specific names in the power grid graphic can be controlled through several available options.
Altern. Names	**Alias Names**: Alternative names will automatically be generated and displayed.
Fonts	User-specific fonts can be chosen by several available options.
Meas. Values	The font displaying measurement values such as results of the load flow calculation can be chosen. ▪ **Visible** enabled: measurement values are displayed ▪ **Visible** disabled: measurement values are not displayed
Description	A description can be added to the power grid project.
Power Network Frequency fn	Nominal power network frequency used for the load flow calculation and for the simulation of transients.
Enable Substation CT and VT	**Simulation of Transients**: The model of the current-transformer and voltage-transformer can be enabled.
Measuring Locations	**Simulation of Transients**: The measuring locations can be chosen if one of the network elements **Circuit-Breaker Cb1…5** will be used. The setting Measuring Locations is important, if a protection device will be tested using a **Omicron CMC Test System**.
Measuring Scheme	**Simulation of Transients**: It can be chosen between the measuring scheme **Distance Protection** and **Diff. Protection**.
Output Device	**Simulation of Transients**: The output device can be chosen if protection device shall be tested using the simulation of transients. ▪ **CMC Test System** ▪ **COMTRADE File** ▪ **Text File** ▪ **Text File (Excel)** ▪ **Load Flow (Prbx)** ▪ **Protection (Prbx)**
Arc Fault	**Simulation of Transients**: The model to simulate arc faults can be chosen ▪ **Static Arc Fault** The arc fault will be simulated using a polygonal characteristic. ▪ **Dynamic Arc Fault** The arc fault will be simulated using a differential equation 1st order implemented in **MODELS**.

18.2.2 Network Configuration: Tab *Short-Circuit*

The settings dialog includes configuration options for a short-circuit (commonly referred to as the **red flash** due its graphical symbol in the network graphic).

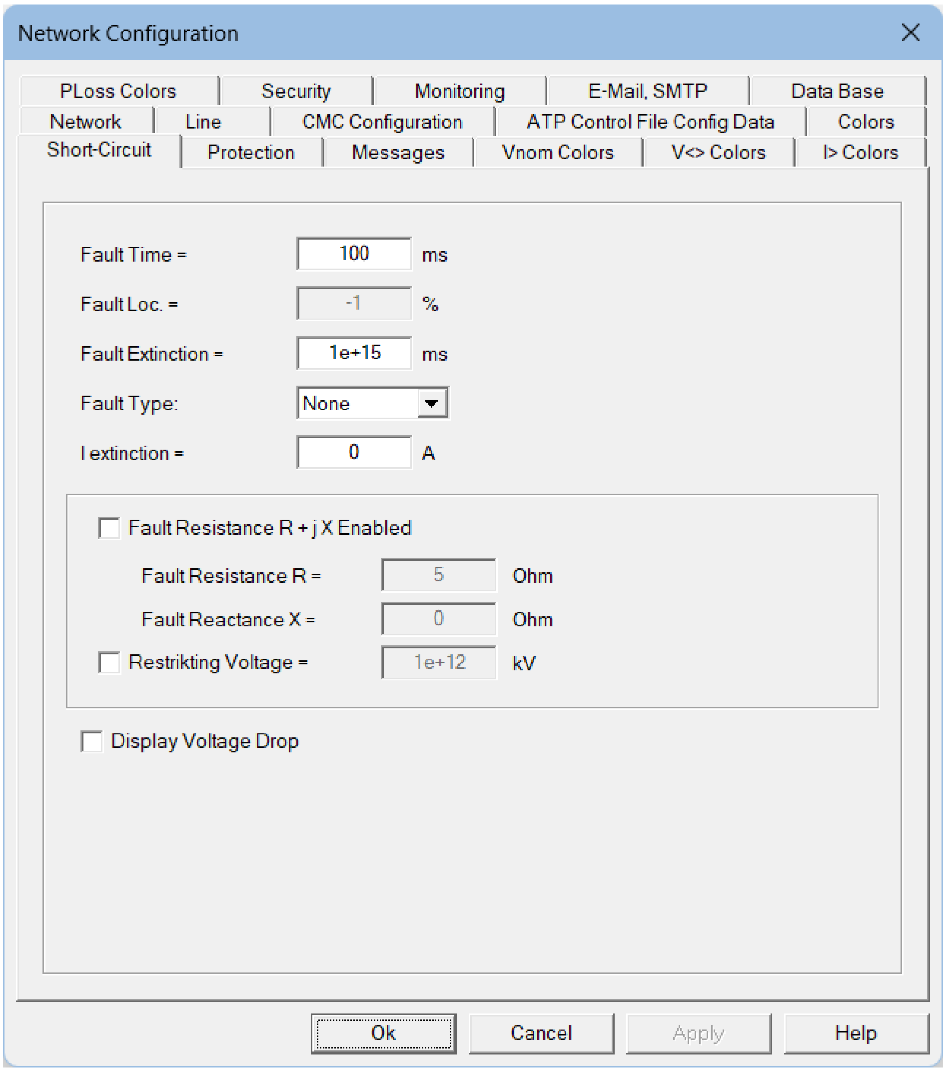


Figure 108: Settings Dialog *Network Configuration*, Tab *Short-Circuit*

Setting	Explanation
Fault Time	Start time of the short-circuit
Fault Loc.	Faul location, if the short-circuit has been set along a network element **Line**
Fault Extinction	Extinction time of the short-circuit
Fault Type	Fault type of the short-circuit
I extinction	The extinction of the short-circuit occurs, if ▪ the **Fault Extinction** time has been elapsed and ▪ the sampling value of the phase currents are less $I_{extenction}$. The setting can be used to simulate the extinction of the short-circuit arc.
Fault Resistance R + jX	▪ **Disabled**: The fault resistance of the short-circuit is equal 0 Ω. ▪ **Enabled**: The fault resistance of the short-circuit can be user-defined. A series impedance will be used as fault resistance model.

19 Documents

[1] EN 50160
Voltage characteristics of electricity supplied by public electricity networks
German Standard

[2] VDE 0276-620
Power Cables; German Standard

[3] Smart Grid Traffic Light Concept
Discussion paper; BDEW, German Association of Energy and Water Industries; Berlin, 10 March 2015

[4] VDE-AR-N 4110
Technical Connection Rules for Medium-Voltage (TCR Medium Voltage)

[5] VDE-AR-N 4120
Technical Connection Rules for High-Voltage (TCR High Voltage)

[6] Office Open XML
ECMA-376 *Office Open XML File Formats*, ISO/IEC 29500)

[7] ATP
Alternative Transients Program, www.eeug.org

[8] Anwendung der Repräsentativen VDEW-Lastprofile
VDEW Materialien, VDEW-Frankfurt 2000

[9] JSON (JavaScript Object Notation)
ECMA-404 The JSON Data Interchange Standard (www.json.org)

[10] Hinweise zu den aktualisierten Standardlastprofilen Strom
Aktualisierte Lastprofile H25 (Haushalt), G25 (Gewerbe), L25 (Landwirtschaft), P25 (Kombinationsprofil PV), S25 (Kombinationsprofil PV-Speicher)
BDEW, Berlin, 17. März 2025

[11] IEC 61850
Communication networks and systems for power utility automation
www.webstore.iec.ch/en/publication/6028