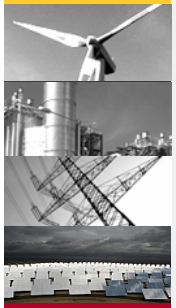
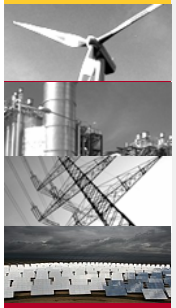


DIgSILENT **Grid Code** v1.0

Grid Code Compliance Analysis Software

July 2009



Presentation Overview

1. Introduction

2. General Concepts
   2.1. Main Menu
   2.2. Files Formats
   2.3. Parameters

3. Data Visualizer

4. Grid Code Compliance Analyzer

5. Grid Code Editor

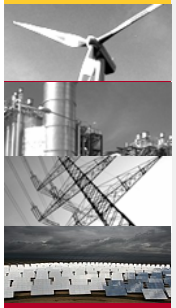
6. Model Validation Tool

7. IEC 61000-4-15 Flicker Meter

8. IEC 61000-4-7 Voltage Harmonics

9. IEC 61400-21 Toolbox
   9.1. Single File Flicker Emission
   9.2. c(ψ,va) Flicker Coefficients Calculation
   9.3. Flicker Emission during Switching Operations
   9.4. Current Harmonics Emission
10. File Edition Tools
   10.1. File Cut
   10.2. File Resampling
   10.3. File Merging

11. Generator



1. Introduction

DIgSILENT Grid Code is a standalone application. The platform gathers the necessary tools for analyzing events in power systems, especially voltage dips, according to grid codes requirements or user specifications.

The software is built on several different modules.

• **Data Visualizer**: for visualizing data, test files, plotting graphs, checking additional parameters

• **Grid Code Compliance Analyzer**: for verifying the behaviour of the control Systems of power plants during external events or perturbation like voltage dips according to grid code requirements. Grid codes can be edited with the GridCode Editor.

• **Model Validation**: compares experimental results with numerical model outputs; which is a crucial part in developing models, especially if the models take part in the decision process.

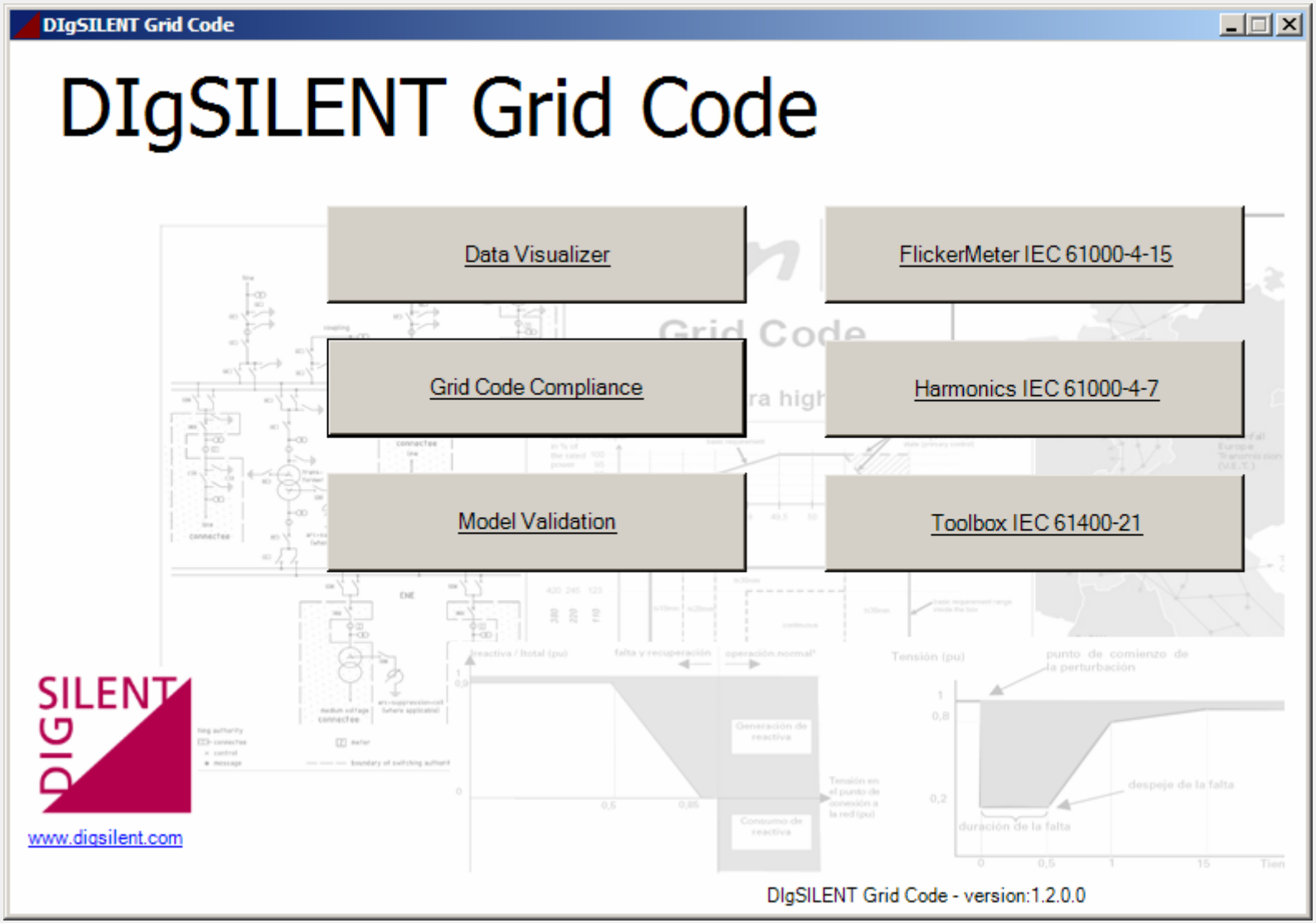
• **Flickermeter IEC 61000-4-15**: voltage flickermeter according to the standard.

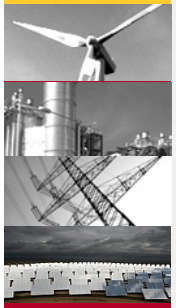
• **Harmonics IEC 61000-4-7**: analyzes voltage harmonics, inter-harmonics and higher frequency components according to the IEC 61000-4-7 standard.

• **IEC 61400-21 Toolbox**: Measurement and assessment of power quality characteristics of grid connected wind turbines: Flicker emission, Flicker during switching operation, current harmonics.

• **File Edition Tools**: Cut, Resample and Merge Files to cut the file around events, resample data series and merge files from different source (i.e wind and mechanical data records with voltage dip measurements)

Reports are automatically generated in MS Word format.


DIgSILENT Grid Code
DIgSILENT Grid Code
Data Visualizer
FlickerMeter IEC 61000-4-15
Grid Code Compliance
Harmonics IEC 61000-4-7
Model Validation
Toolbox IEC 61400-21
www.digsilent.com
DIgSILENT Grid Code - version:1.2.0.0

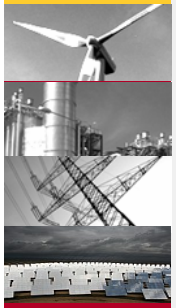


2. General Concepts – Main Menu

The Main Menu is the entry point of the program. It provides access to the different modules.

At the installation of the program, shortcuts are created on the desktop and in the Windows Start Menu.

If the program is a demo version, “DEMO” will be displayed in this window.



2. General Concepts – Files Formats

Files are generally divided into 2 types: ASCII (or text) files and binary files.

DIgSILENT Grid Code can read text files and IEEE COMTRADE files (binary and ASCII)

1. General requirements

   - The file should at least contain the data series displayed in the “File Types & Channels Editor” (see below). It can contain more columns but not less.

   - To perform analysis (Grid Code Compliance, Model validation, Harmonics, Flicker, etc.), the file should at least contain the following time series: time, 3 sinusoidal voltage series, 3 sinusoidal current series.

2. Text files requirements

   - Data series in columns – file and column headers are allowed

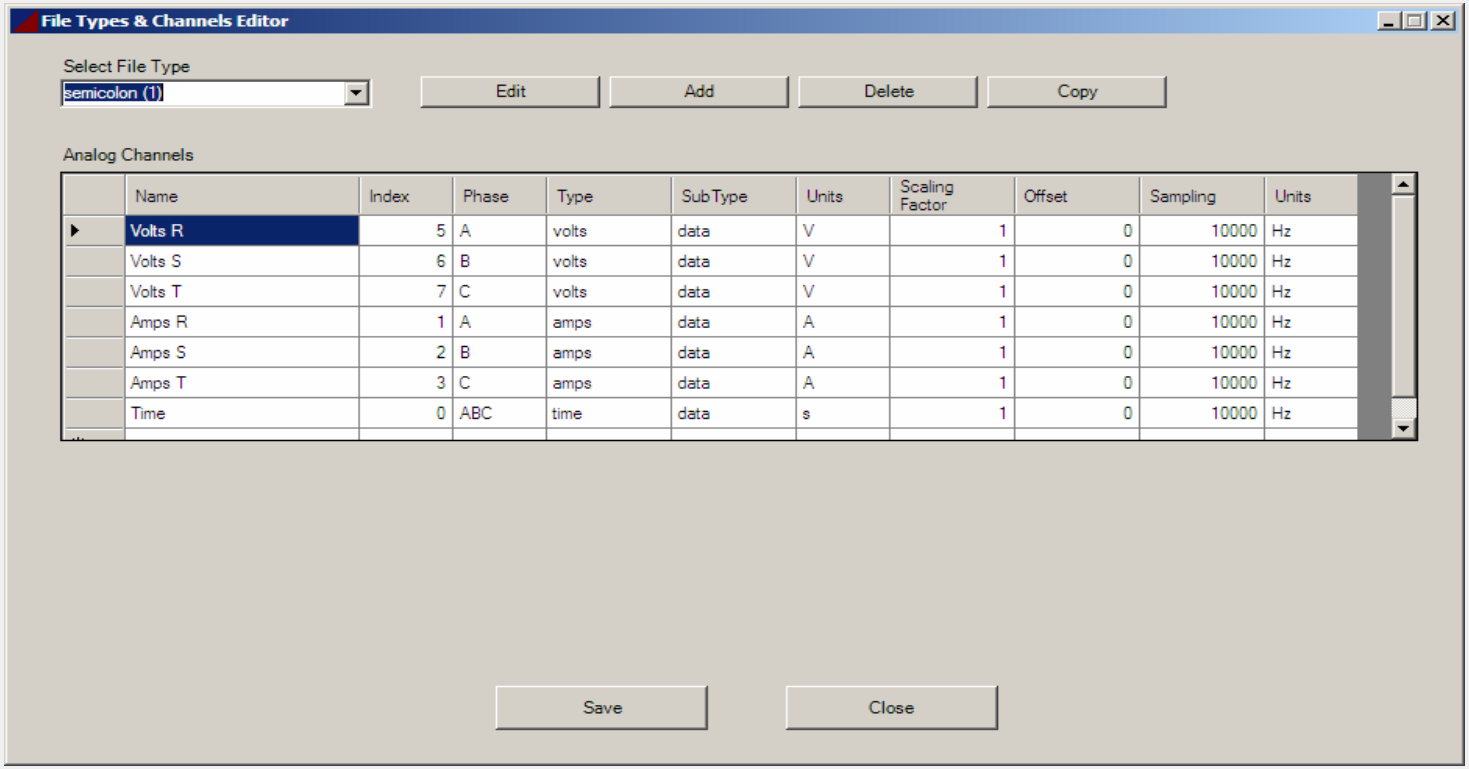
   - Separated by a unique character (i.e. “,”,”;”,tab, etc.)

3. COMTRADE files requirements

   - There are no additional requirements for COMTRADE files.

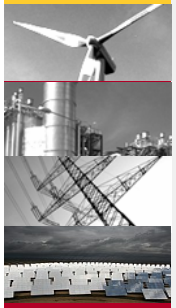
Remark: other binary files can be implemented upon user request.

File Types & Channels Editor



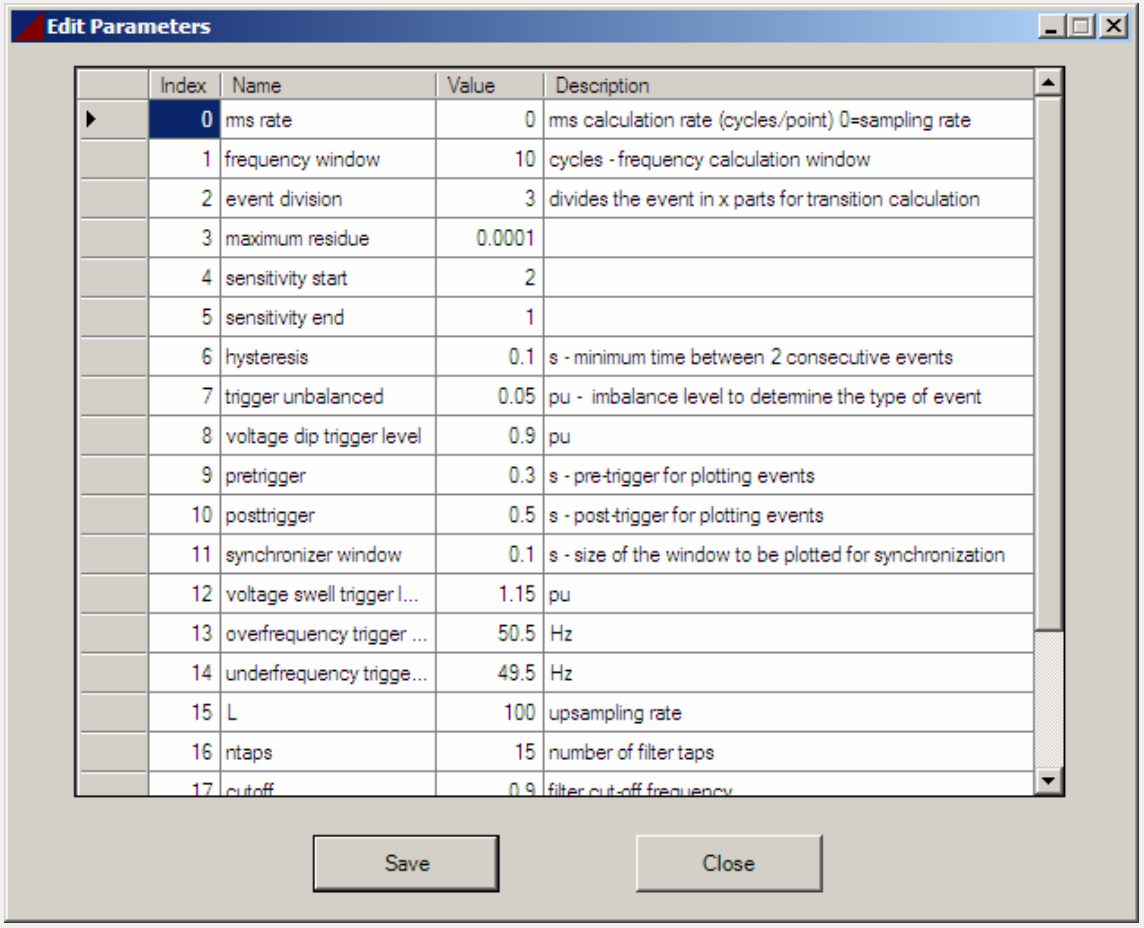
Edit each channel: index of the column in the file, phase, type, units, scaling factor and offsets, sampling rate

Types of files and channels can be added or deleted.

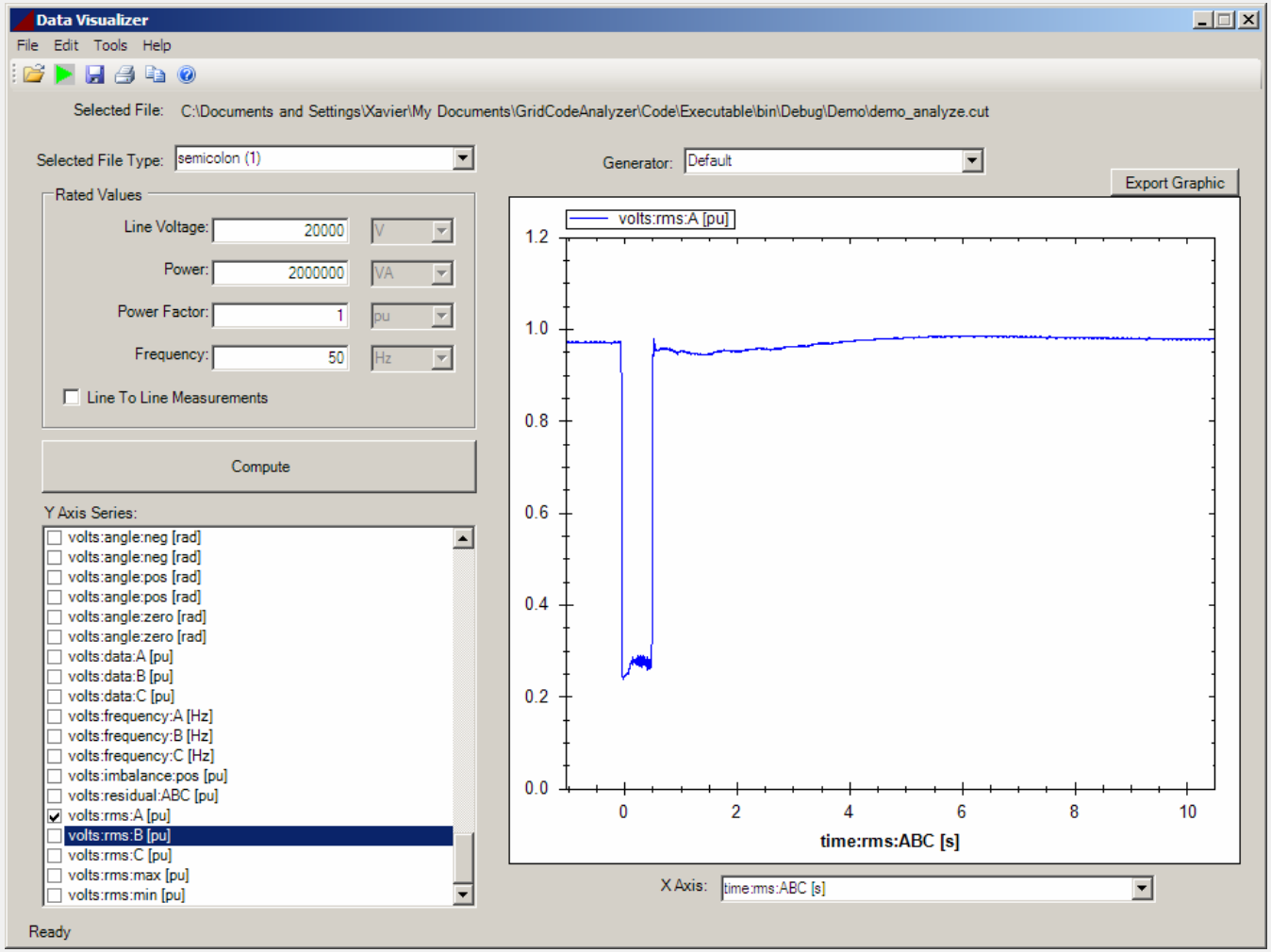


2. General Concepts – Parameters

Parameters like RMS-rate, number of cycles to compute the frequency, voltage dip trigger level, etc. can be edited in the Edit Parameters window.



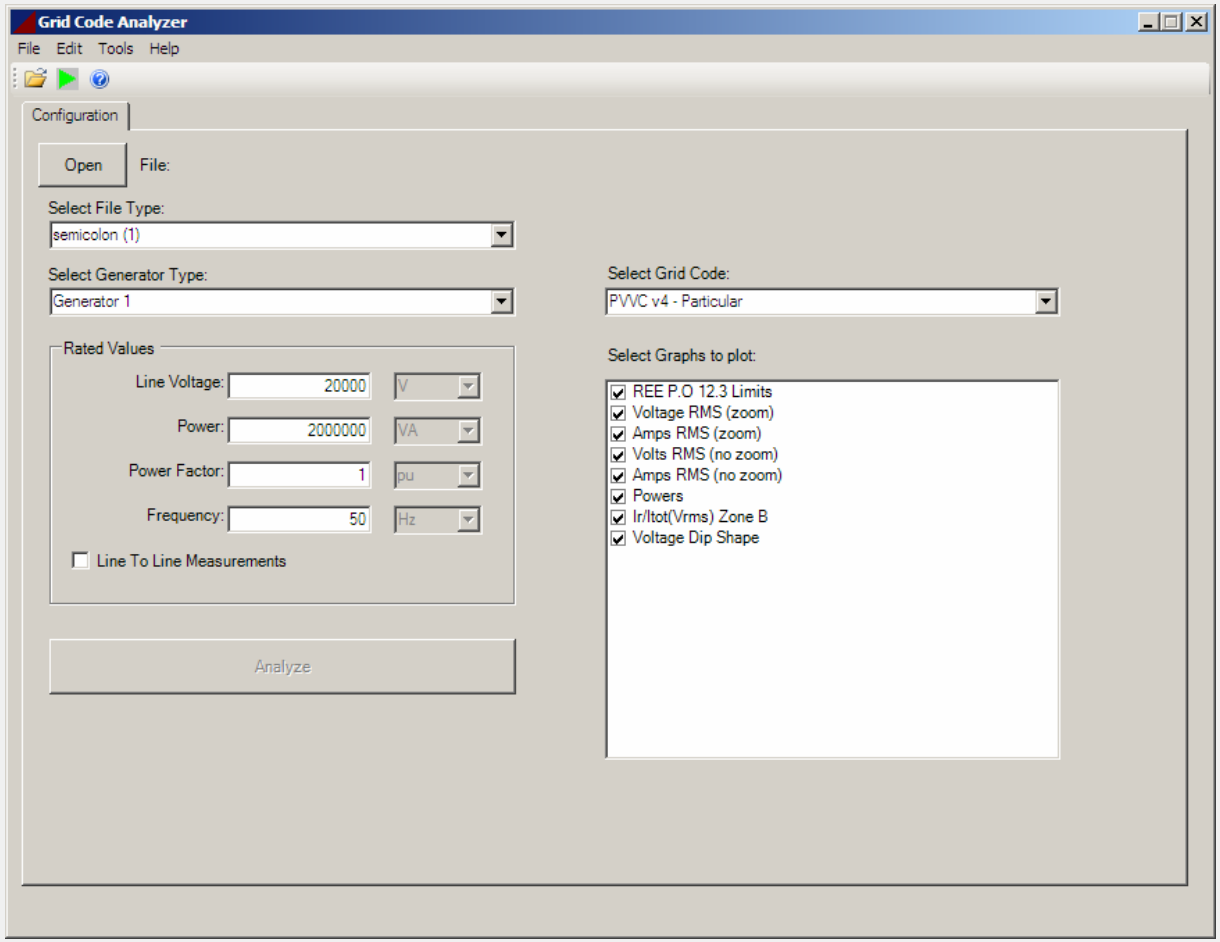
3. Data Visualizer



Characteristics:

- Immediate view of plots and graphs
- more than 100 different series can be plotted
- function copy/paste
- Visualization parameters editable
- Scales and offsets of measurement series con be modified
- Export graphics data into csv-files

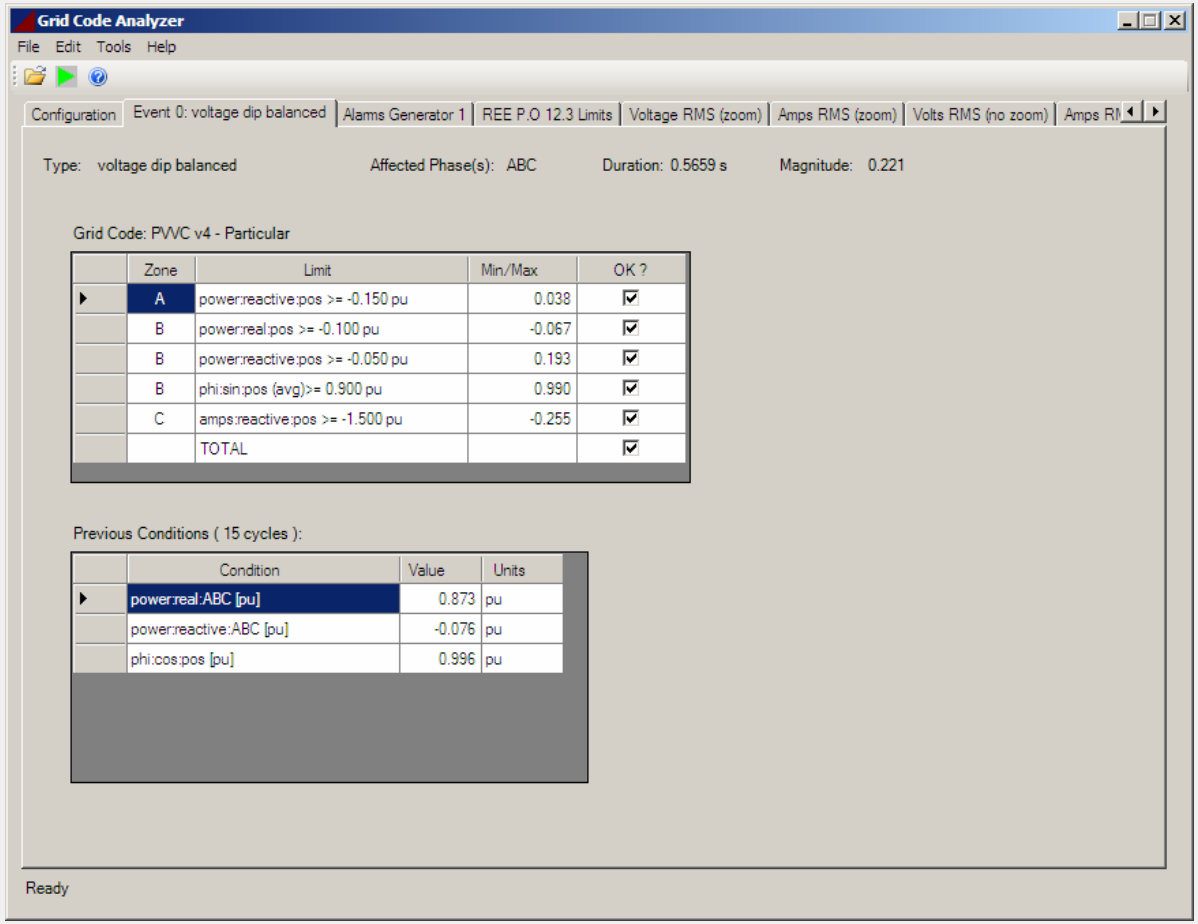
4. Grid Code Compliance Analyzer



Characteristics:

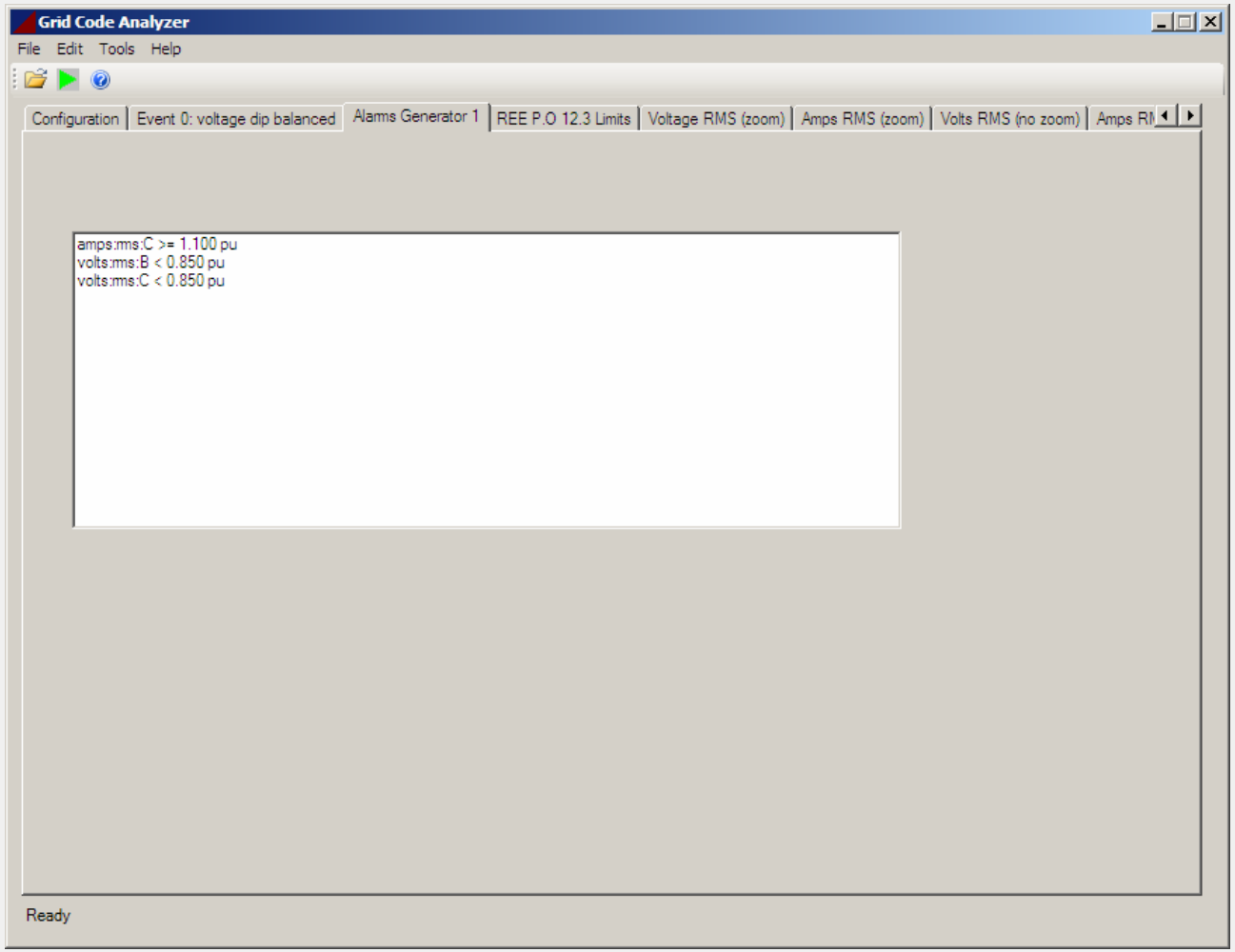
- Expandable Grid Code Library
- Immediate preview of results
- Edit plots
- Edit “grid code” parameters
- Edit plot parameters
- Edit calculations and event detection parameters
- Automatic reporting (MS Word)
- Scales and offset of measurements channels
- “Multi Files” module to analyze several files in a row
- Alarms on non-electrical parameters can be set

4. Grid Code Compliance Analyzer



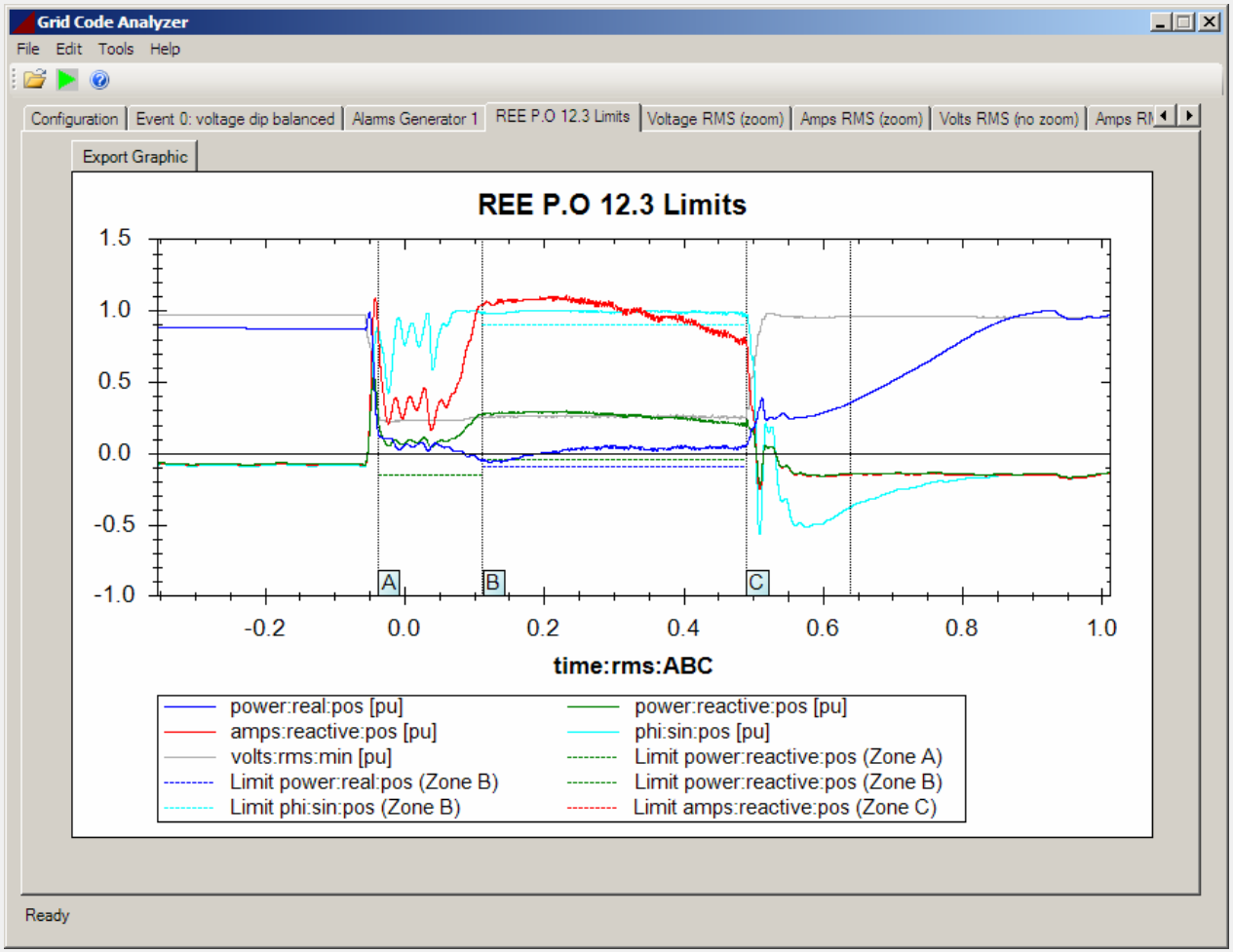
Compliance results and event previous conditions are displayed in a table

4. Grid Code Compliance Analyzer



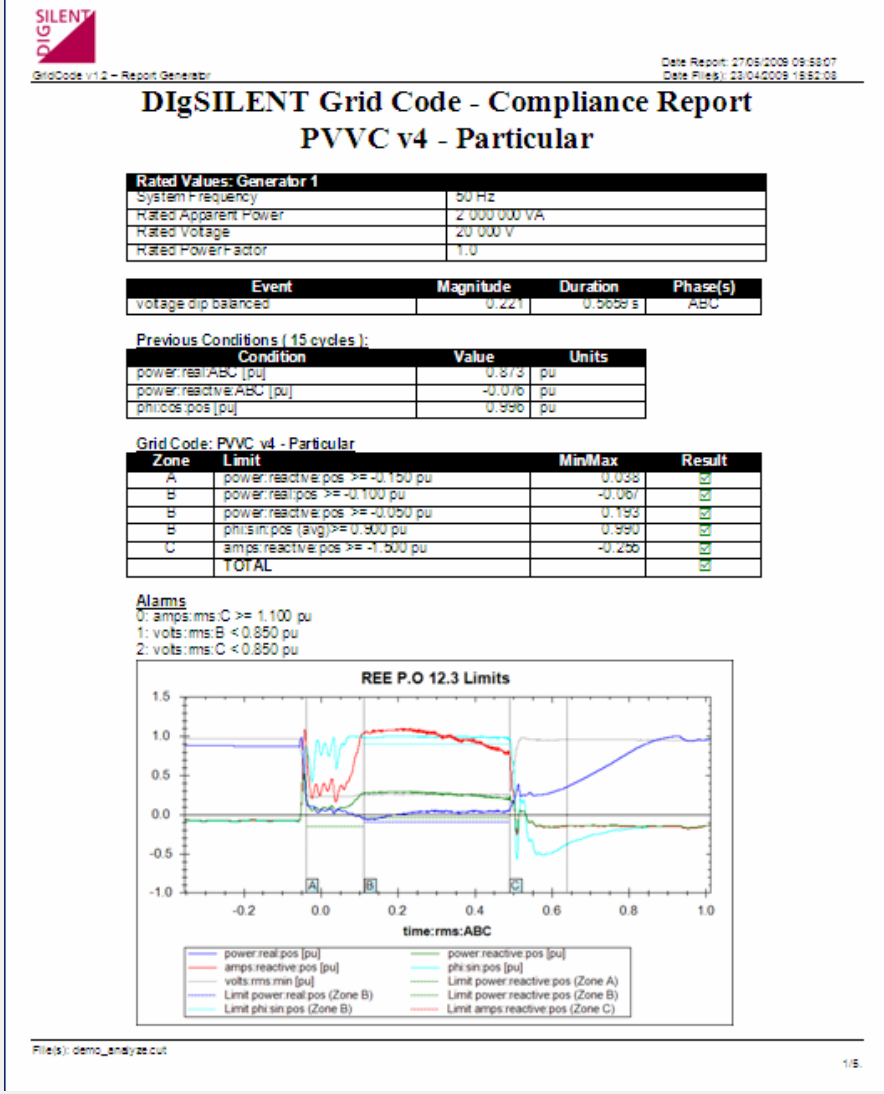
Alarms preview pane. Alarms can be set on non-electrical parameters (hydraulic pressure, etc.) if data series are present in the measurements file.

4. Grid Code Compliance Analyzer



Preview of graphical results – plotted series are editable with the Grid Code Editor

4. Grid Code Compliance Analyzer



DIgSILENT Grid Code - Compliance Report
PVVC v4 - Particular

Rated Values: Generator 1	
System Frequency	50 Hz
Rated Apparent Power	2'000'000 VA
Rated Voltage	20'000 V
Rated Power Factor	1.0

Event	Magnitude	Duration	Phase(s)
voltage dip balanced	0.221	0.5659 s	ABC

Previous Conditions (15 cycles):

Condition	Value	Units
power:real:ABC [pu]	0.873	pu
power:reactive:ABC [pu]	-0.076	pu
phi:cos:pos [pu]	0.996	pu

Grid Code: PVVC v4 - Particular

Zone	Limit	Min/Max	Result
A	power:reactive:pos >= -0.150 pu	0.038	☑
B	power:real:pos >= -0.100 pu	-0.067	☑
B	power:reactive:pos >= -0.050 pu	0.193	☑
B	phi:sin:pos (avg)>= 0.900 pu	0.990	☑
C	amps:reactive:pos >= -1.500 pu	-0.256	☑
	TOTAL		☑

Alarms
0: amps:rms:C >= 1.100 pu
1: volts:rms:B < 0.850 pu
2: volts:rms:C < 0.850 pu

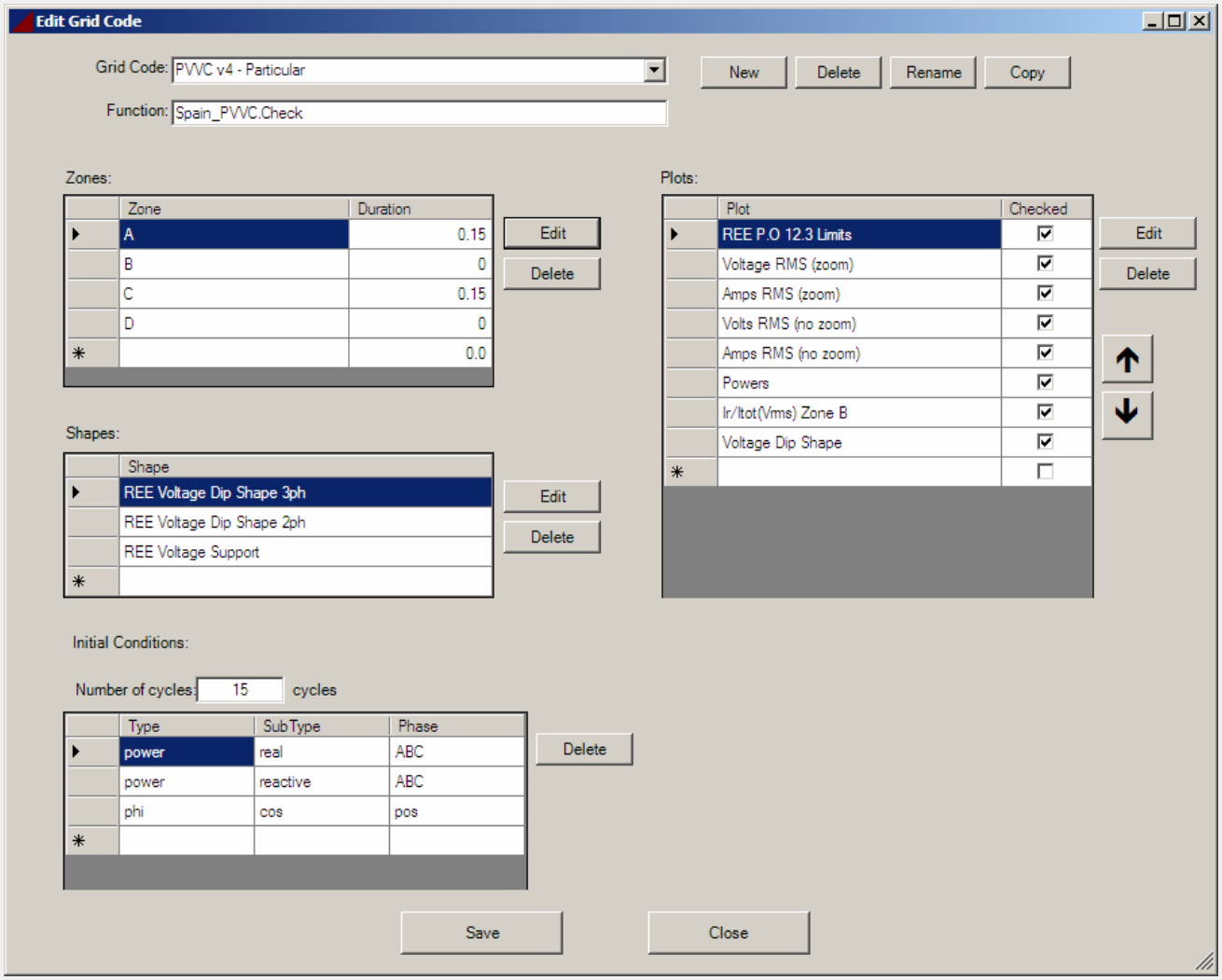
File(s): demo_analyze.cut

1/5.

Automatically generated report with results tables and graphs in MS Word format.

Template can be partially modified by the user: own company logo, etc.

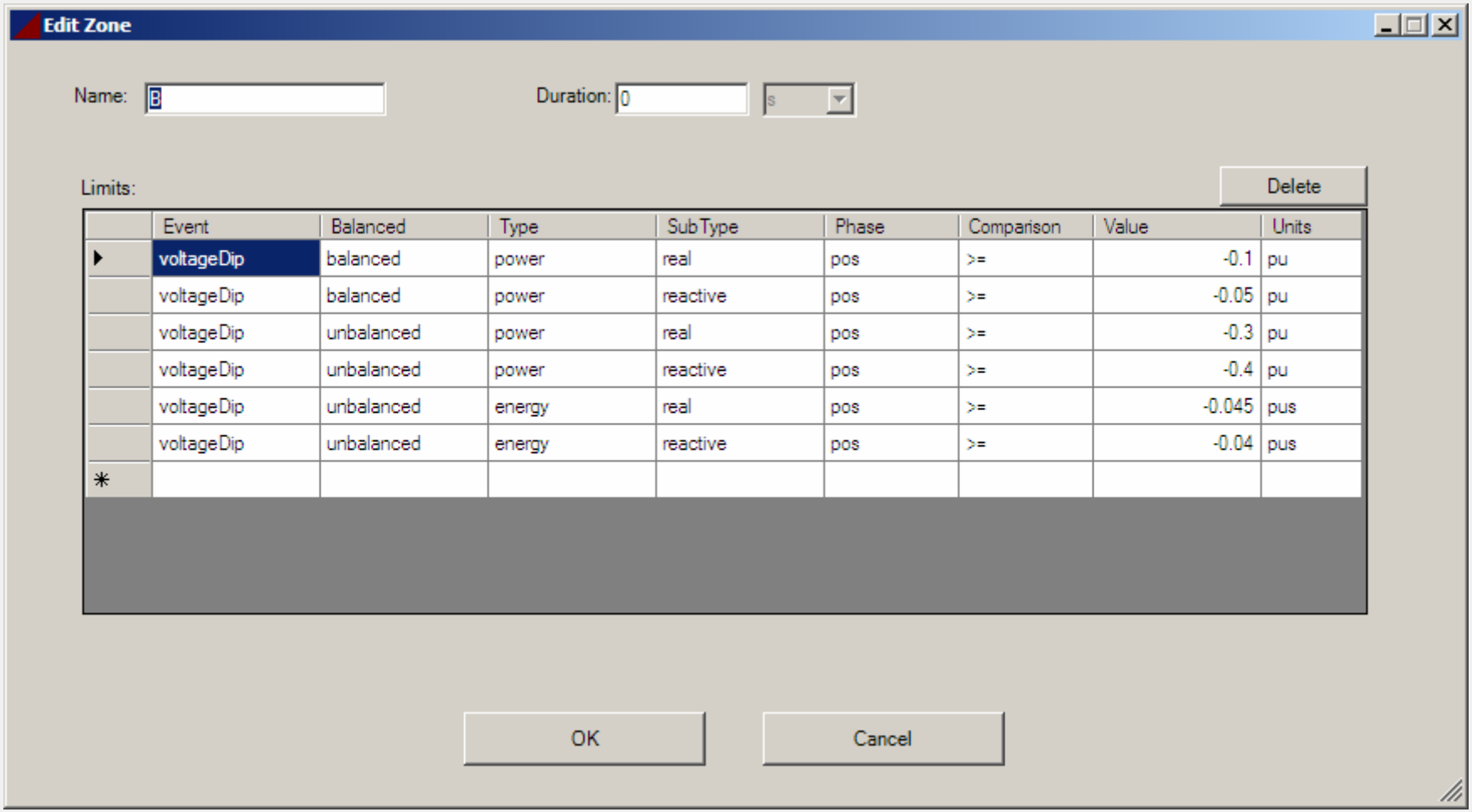
5. Grid Code Editor



Characteristics:

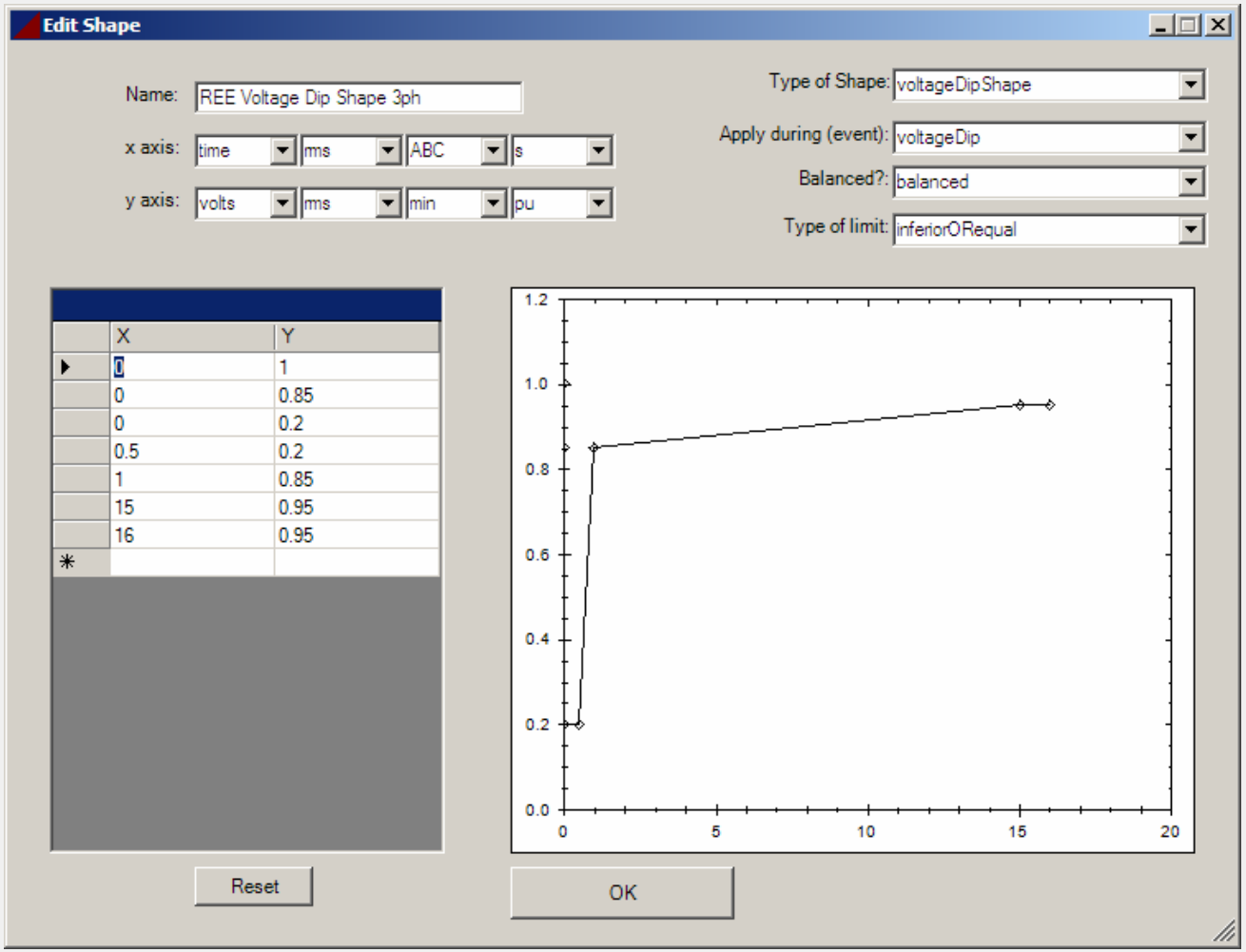
- Expandable Grid Code Library
- Customizable zones – event subdivision
- Edit plots
- Editable shapes
- Editable previous conditions
- Add, Delete and copy grid codes
- Editable compliance levels

5. Grid Code Editor – Zone Editor



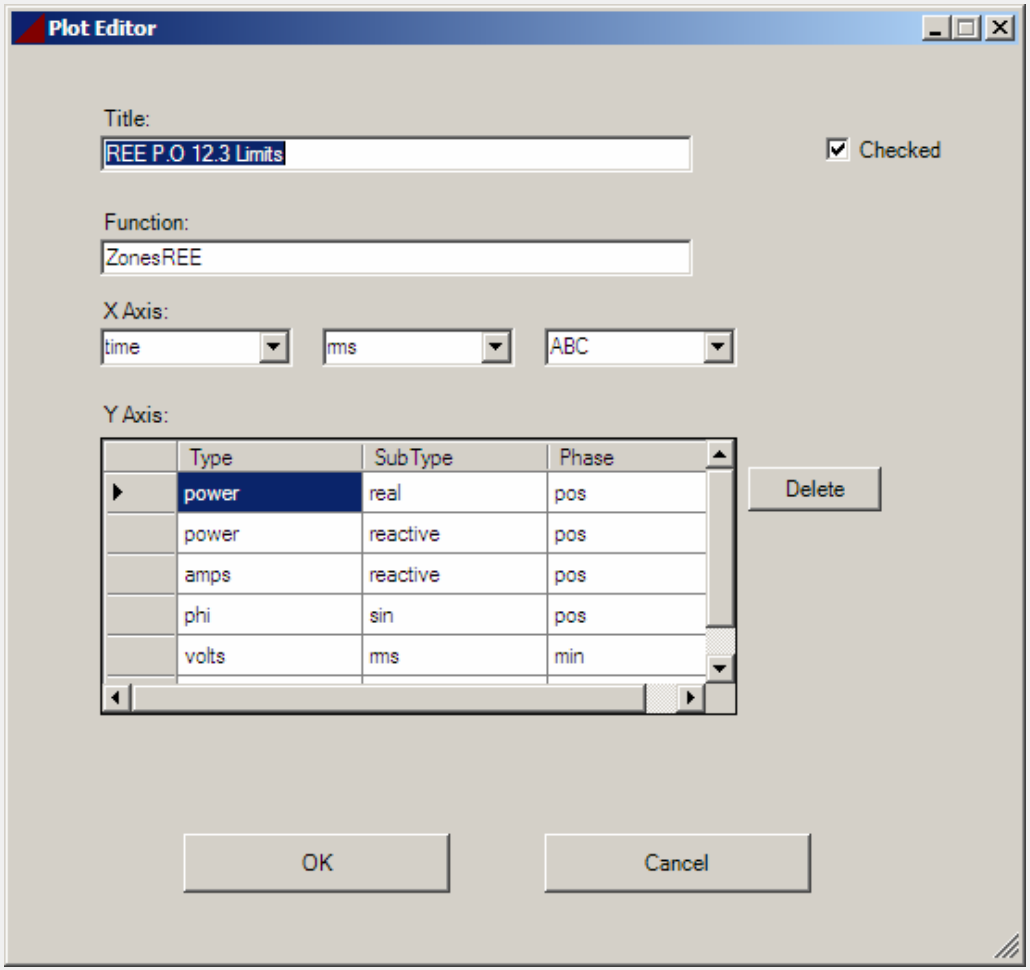
Compliance parameters and levels can be edited for each zone and type of event

5. Grid Code Editor – Shape Editor



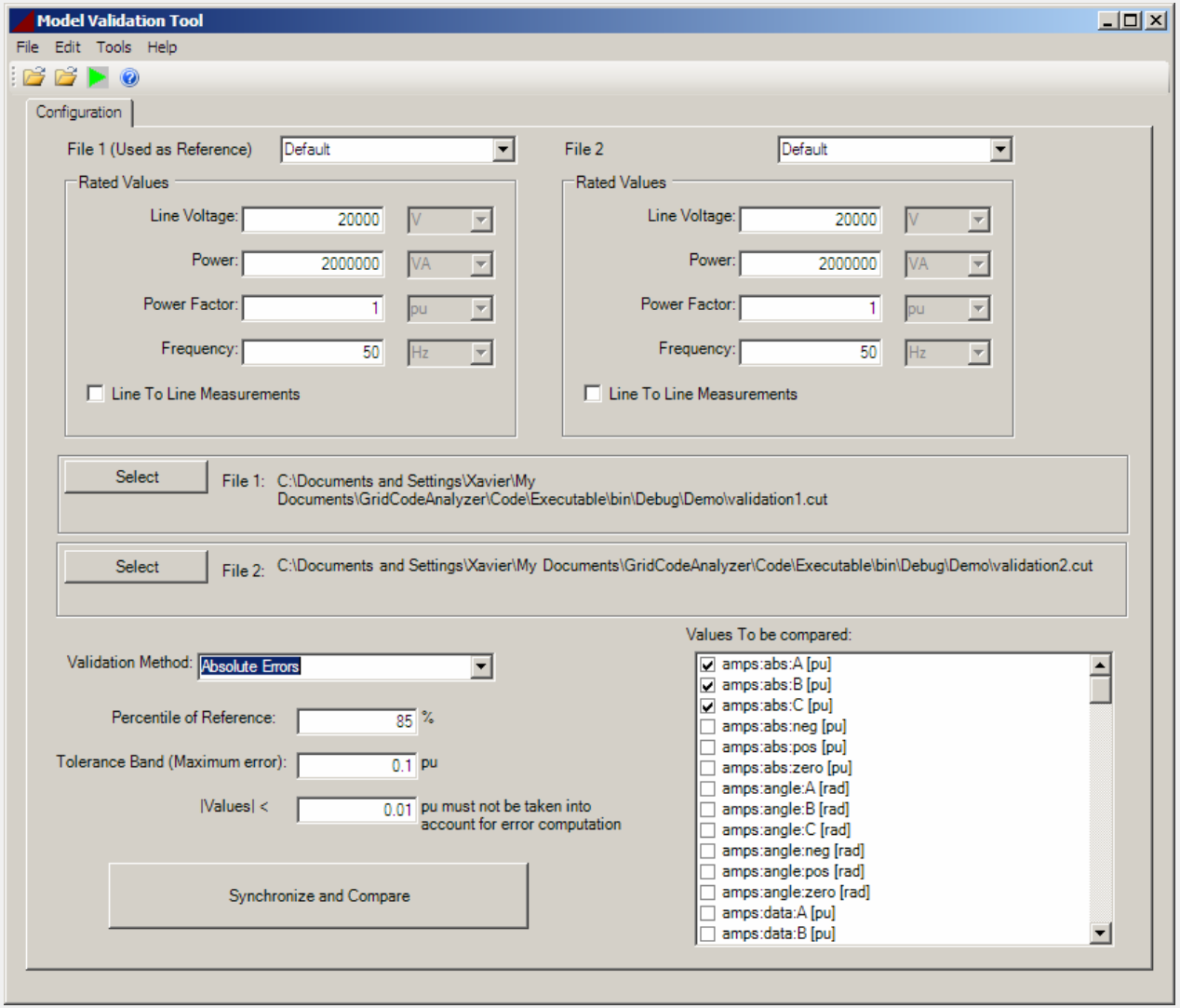
Voltage dip shapes, reactive current injection shapes, etc. can be defined by the user

5. Grid Code Editor – Plot Editor



Plotted series, graph title, etc. can be edited by the user

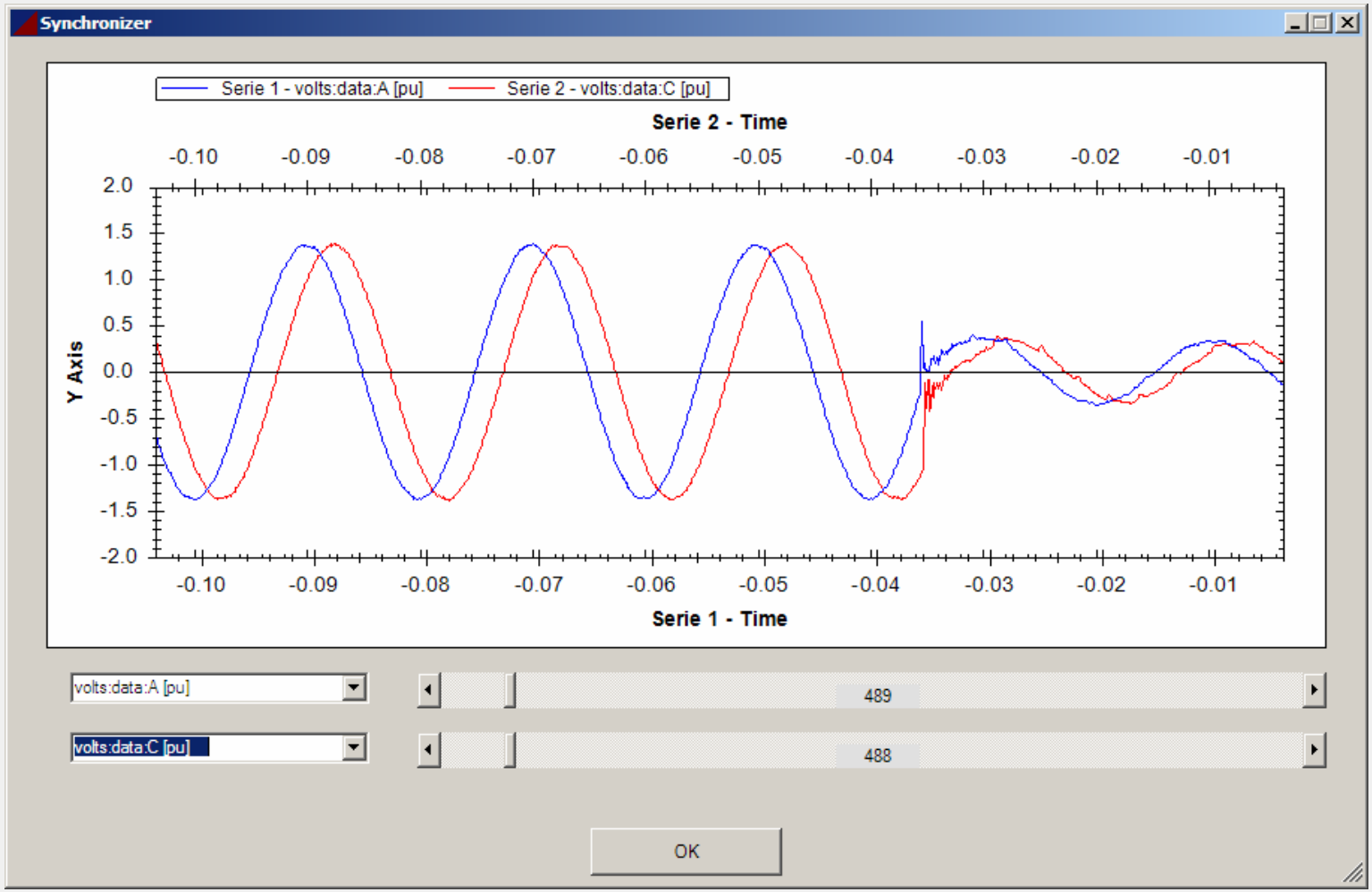
6. Model Validation Tool



Characteristics:

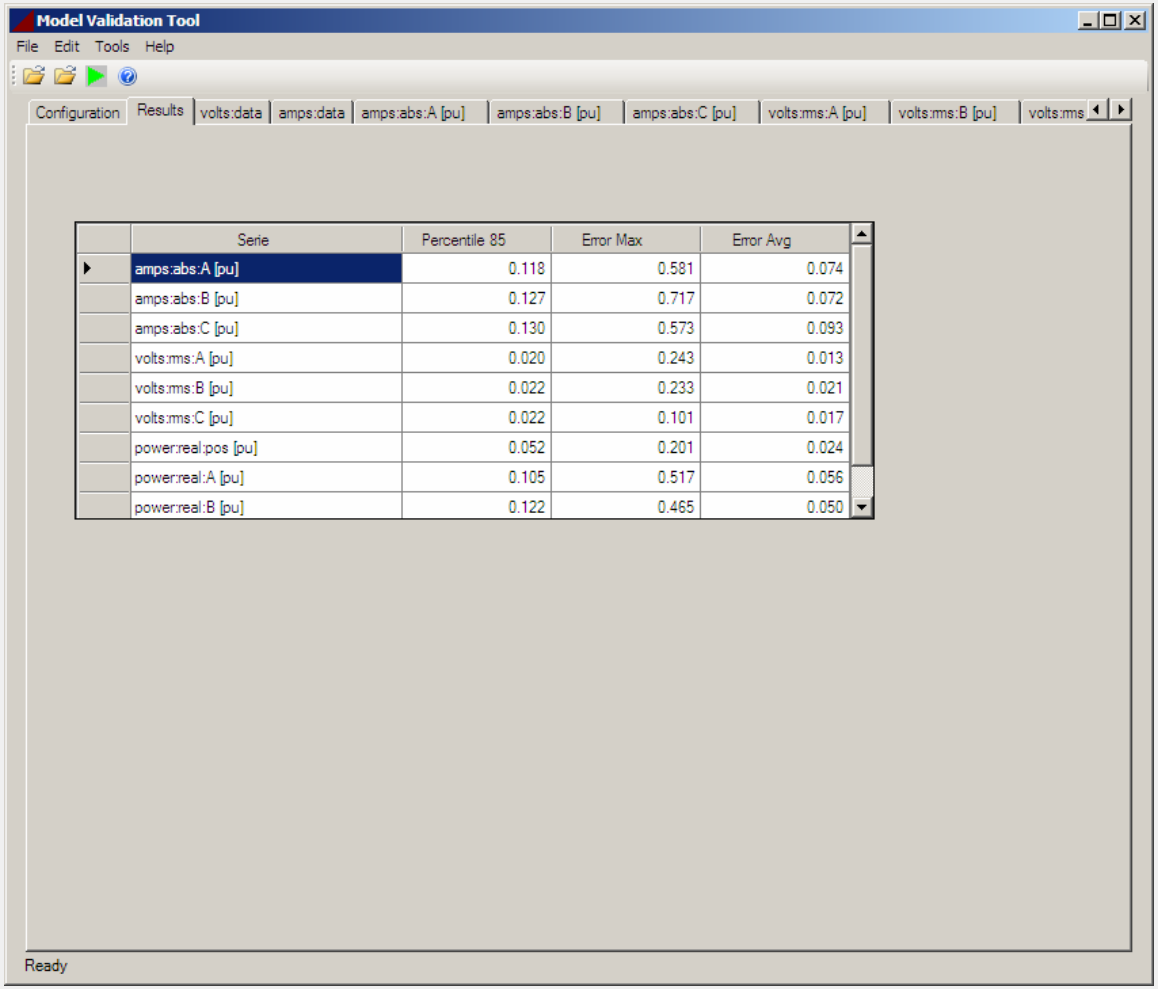
- 2 methods for validation: relative error/absolute error
- Selection of compared parameters
- Immediate preview of results
- Edit plots
- Edit plot parameters
- Edit computation parameters
- Semi-automatic synchronization window
- Automatic reporting (MS Word)
- Edit scales and offset of channels
- Comparisons settings: percentile, tolerance band, dead band

6. Model Validation Tool - Synchronization



Data series are automatically synchronized but user can manually adjust the synchronization

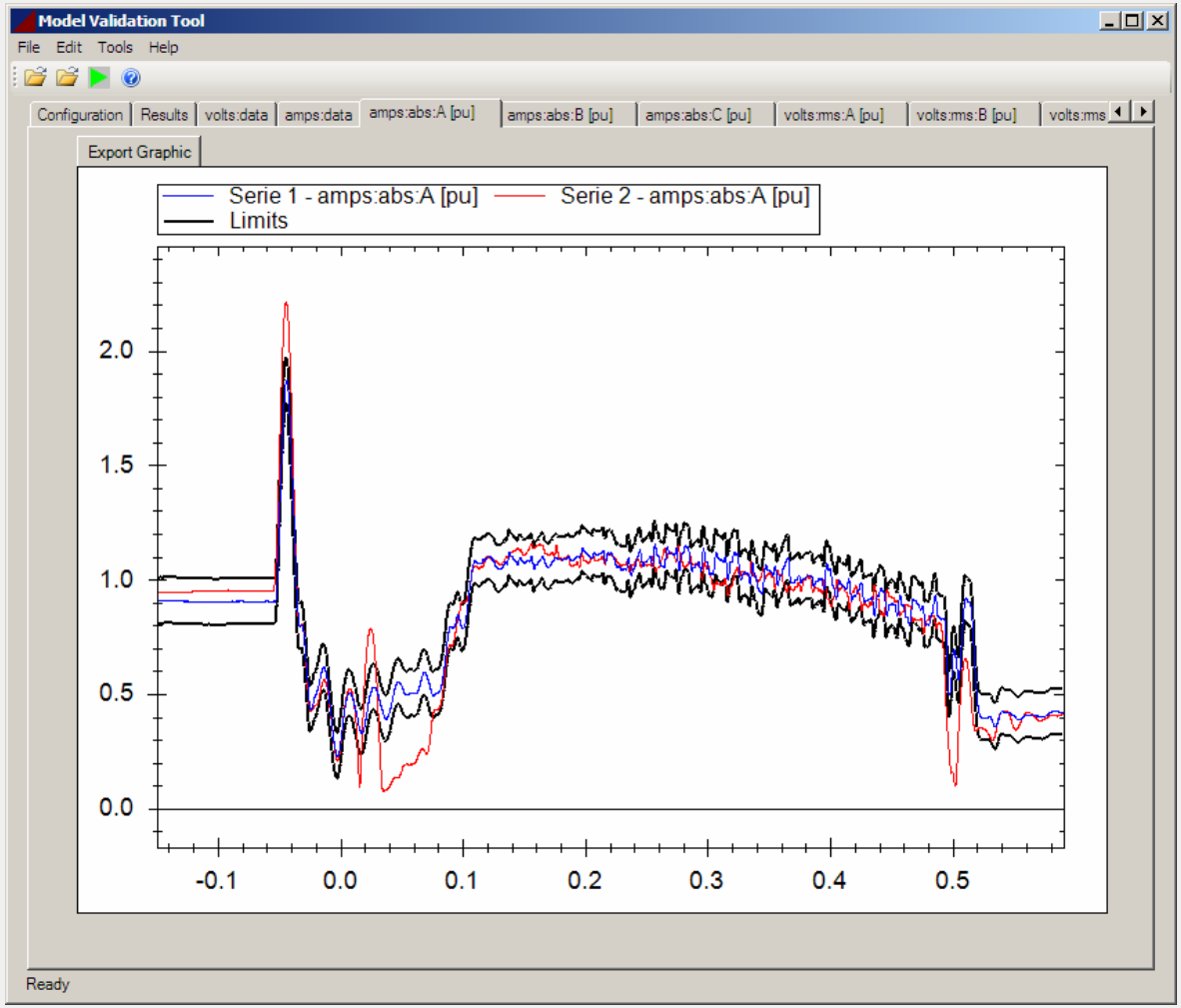
6. Model Validation Tool



Serie	Percentile 85	Error Max	Error Avg
amps:abs:A [pu]	0.118	0.581	0.074
amps:abs:B [pu]	0.127	0.717	0.072
amps:abs:C [pu]	0.130	0.573	0.093
volts:rms:A [pu]	0.020	0.243	0.013
volts:rms:B [pu]	0.022	0.233	0.021
volts:rms:C [pu]	0.022	0.101	0.017
power:real:pos [pu]	0.052	0.201	0.024
power:real:A [pu]	0.105	0.517	0.056
power:real:B [pu]	0.122	0.465	0.050

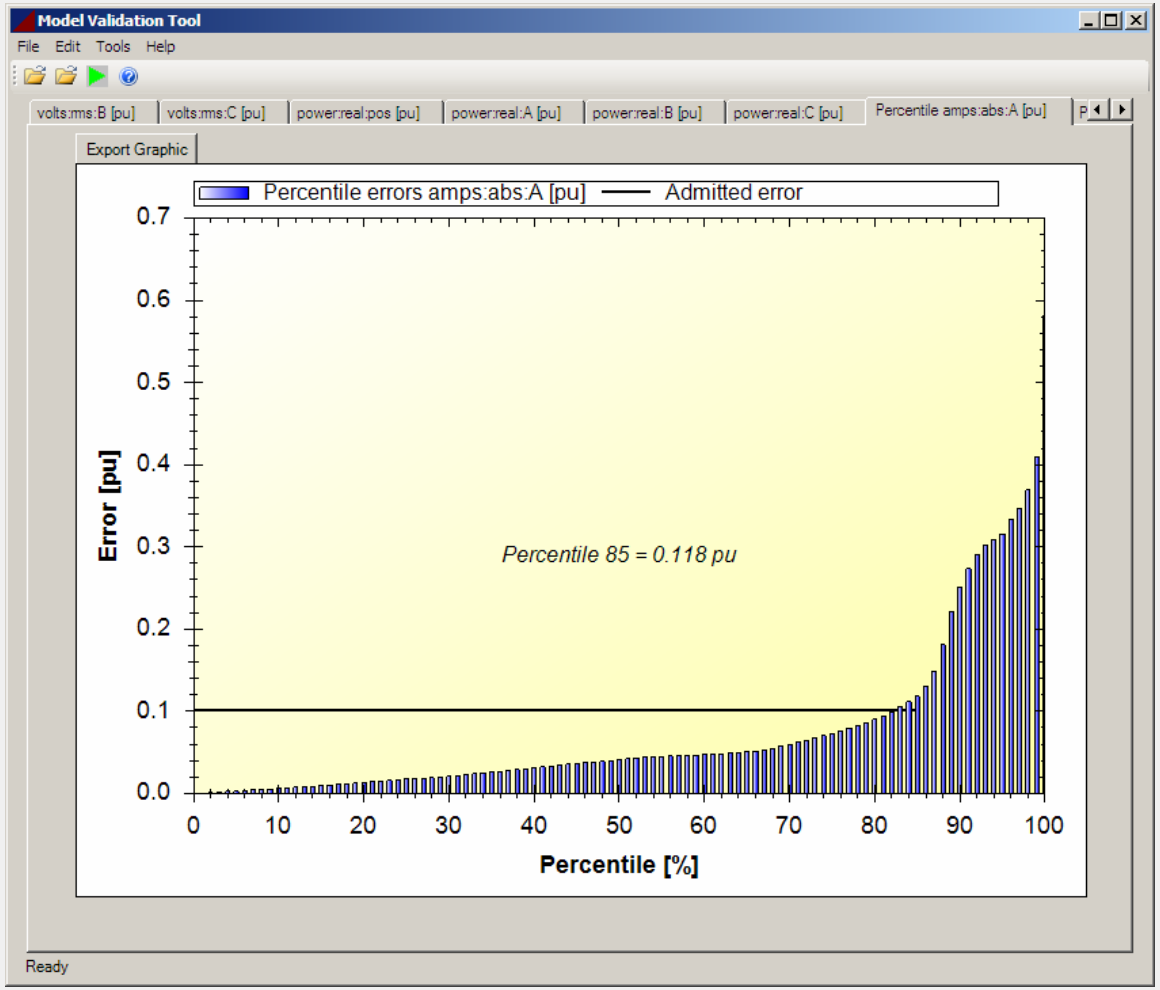
Preview of comparison errors: considered percentile, maximum and average errors

6. Model Validation Tool



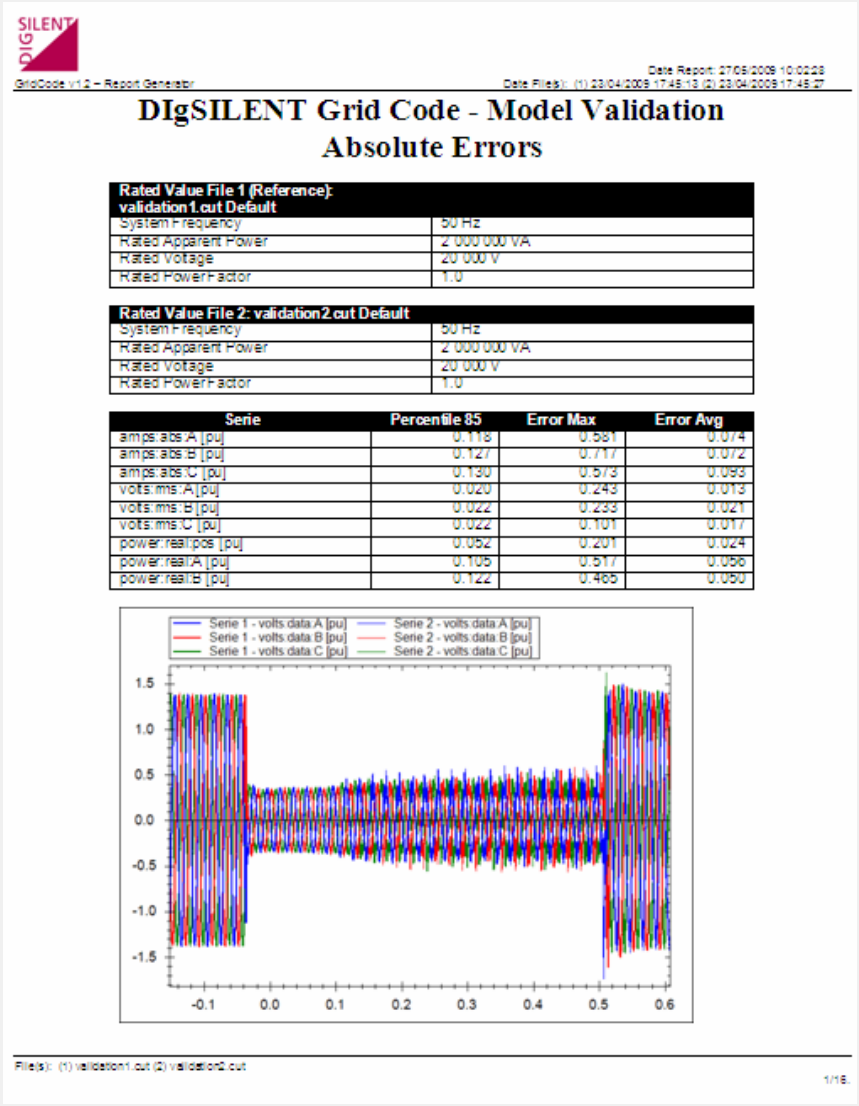
Comparison graphical preview

6. Model Validation Tool



Error (percentile of the error)

6. Model Validation Tool



GridCode v1.2 – Report Generator

Date Report: 27/05/2009 10:02:08
Date File(s): (1) 23/04/2009 17:45:13 (2) 23/04/2009 17:45:27

DIgSILENT Grid Code - Model Validation

Absolute Errors

Rated Value File 1 (Reference): validation1.cut Default	
System Frequency	50 Hz
Rated Apparent Power	2 000 000 VA
Rated Voltage	20 000 V
Rated Power Factor	1.0

Rated Value File 2: validation2.cut Default	
System Frequency	50 Hz
Rated Apparent Power	2 000 000 VA
Rated Voltage	20 000 V
Rated Power Factor	1.0

Serie	Percentile 85	Error Max	Error Avg
amps:abs:A [pu]	0.118	0.581	0.074
amps:abs:B [pu]	0.127	0.717	0.072
amps:abs:C [pu]	0.130	0.573	0.093
volts:rms:A [pu]	0.020	0.243	0.013
volts:rms:B [pu]	0.022	0.233	0.021
volts:rms:C [pu]	0.022	0.101	0.017
power:real:pos [pu]	0.052	0.201	0.024
power:real:A [pu]	0.105	0.517	0.056
power:real:B [pu]	0.122	0.465	0.050

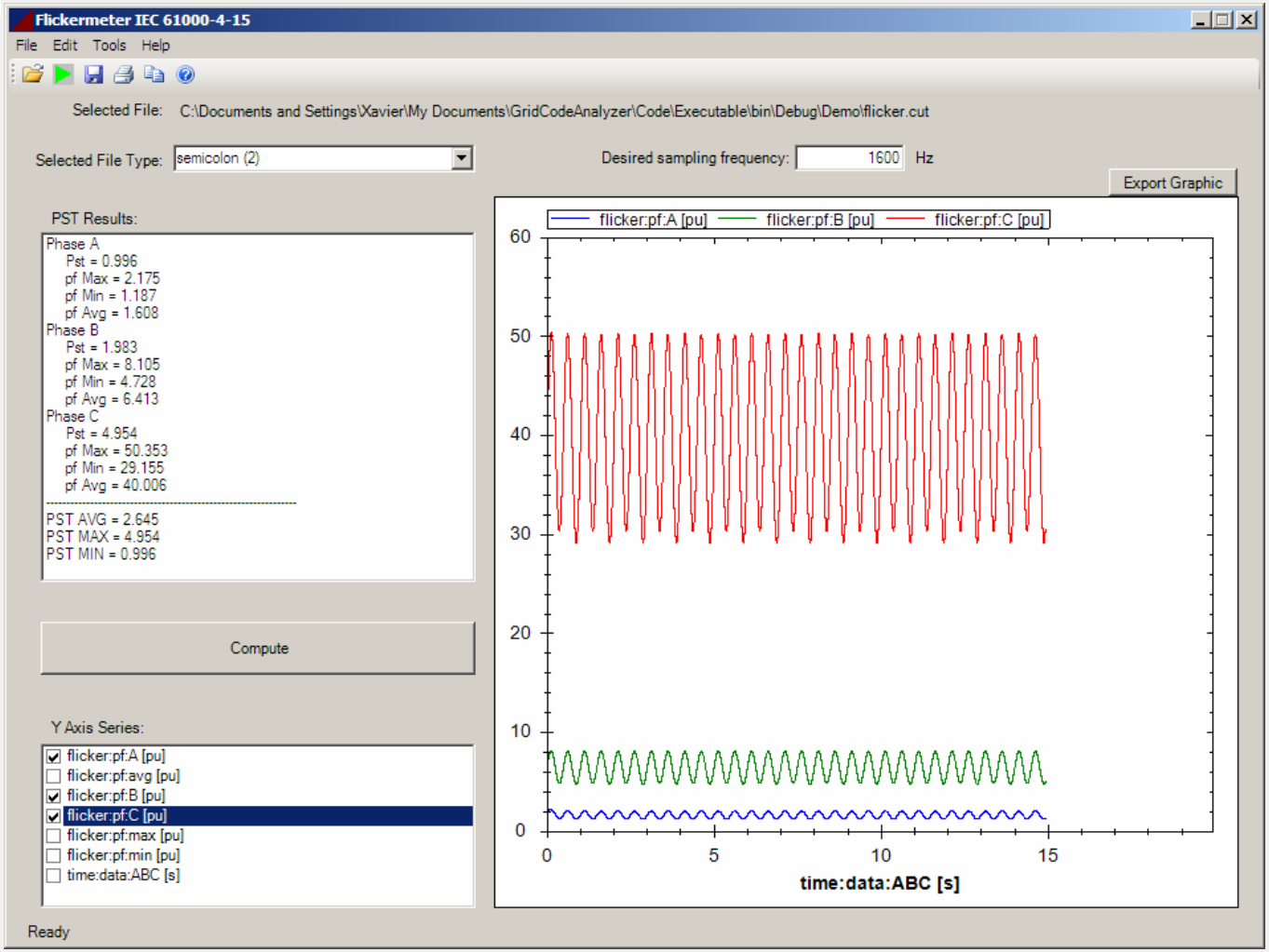
File(s): (1) validation1.cut (2) validation2.cut

1/18

Automatically generated report with results tables and graphs in MS Word format.

Template can be partially modified by the user: own company logo, etc.

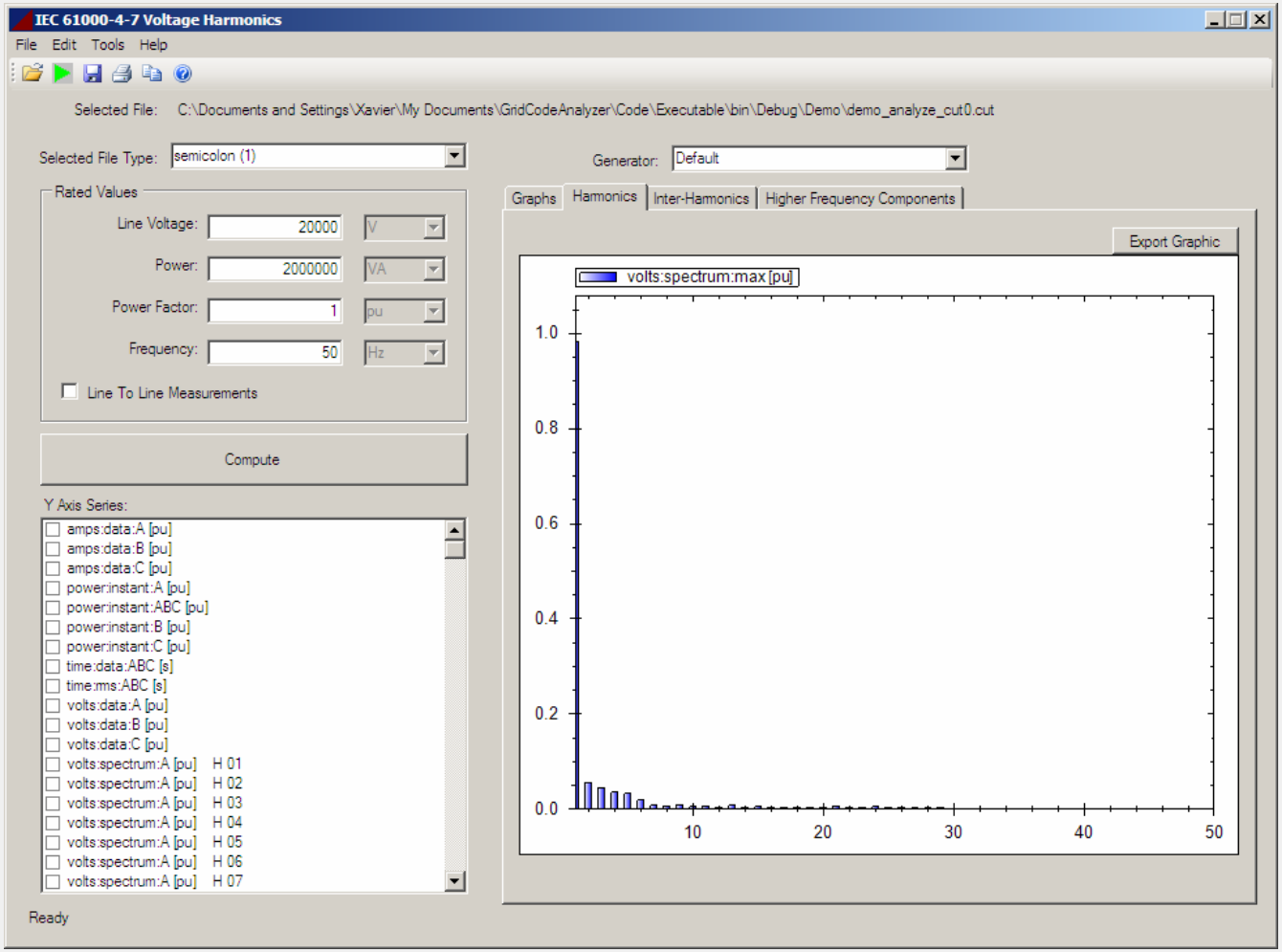
7. IEC 61000-4-15 Flicker Meter



Characteristics:

- IEC 61000-4-15
- File re-sampling
- Visualization of instant flicker (PF)
- Pst phase, min, max and avg
- Export plotted data to csv-file
- Copy/paste graphics

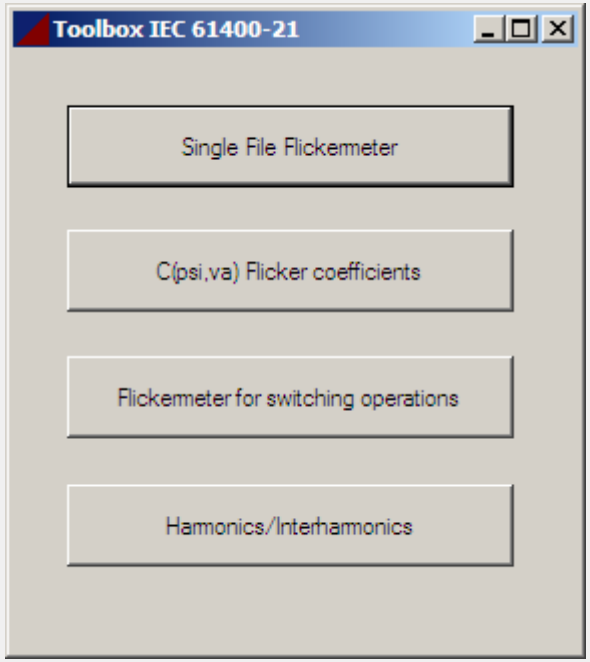
8. IEC 61000-4-7 Voltage Harmonics



Characteristics:

- IEC 61000-4-7
- Harmonics, Inter-harmonics, Higher frequency components
- Export graphics to csv file
- Copy/paste graphics
- Bar plots
- Time evolution of harmonics, inter-harmonics and higher frequency components
- Several files can be analyzed in a row

9. IEC 61400-21 Toolbox



The IEC 61400-21 Toolbox gathers the necessary tools to assess power quality characteristics of grid connected wind turbines:

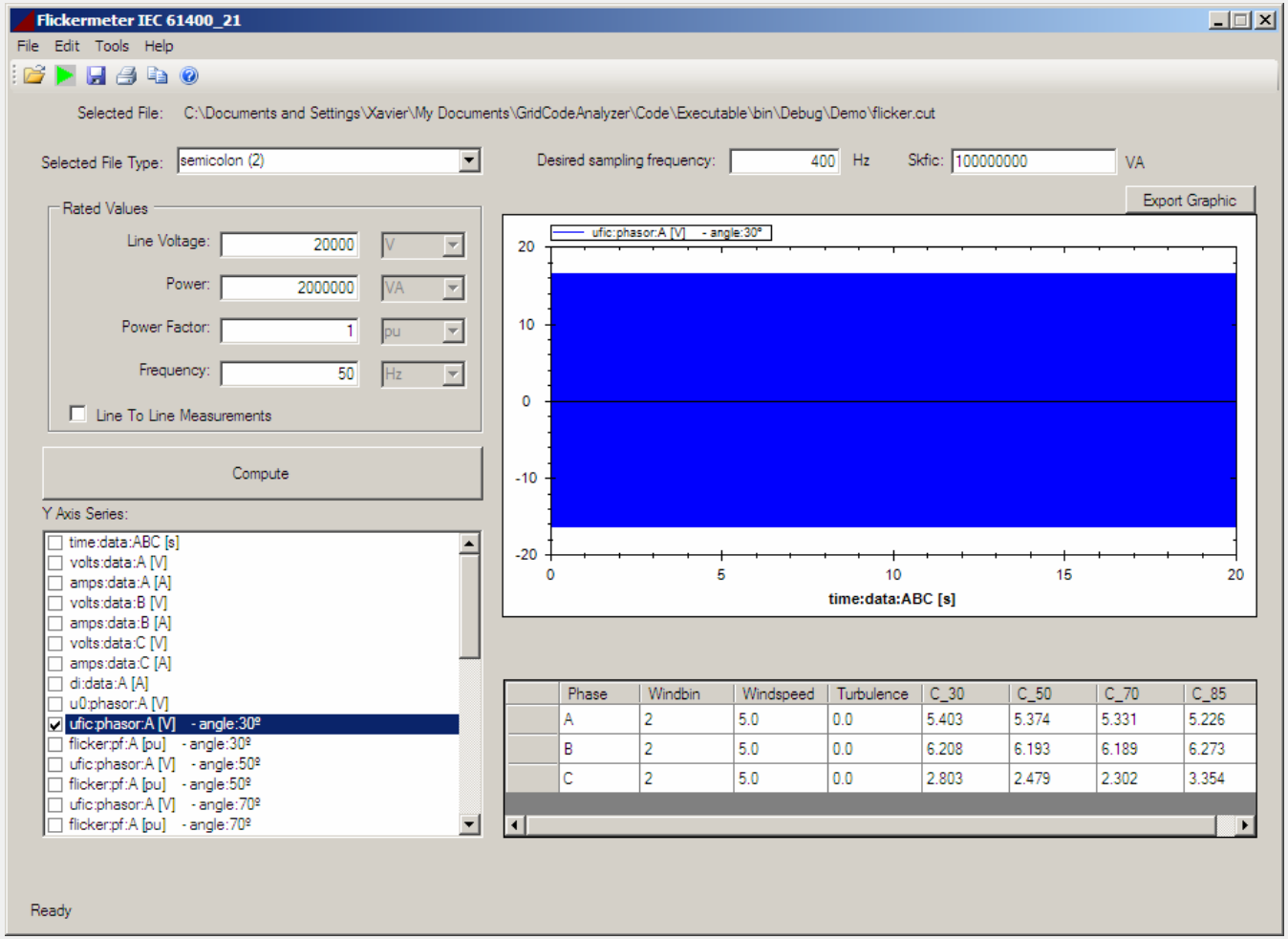
-Flicker emission

-Flicker coefficients

-Flicker emission during switching operations

-Current harmonics emissions

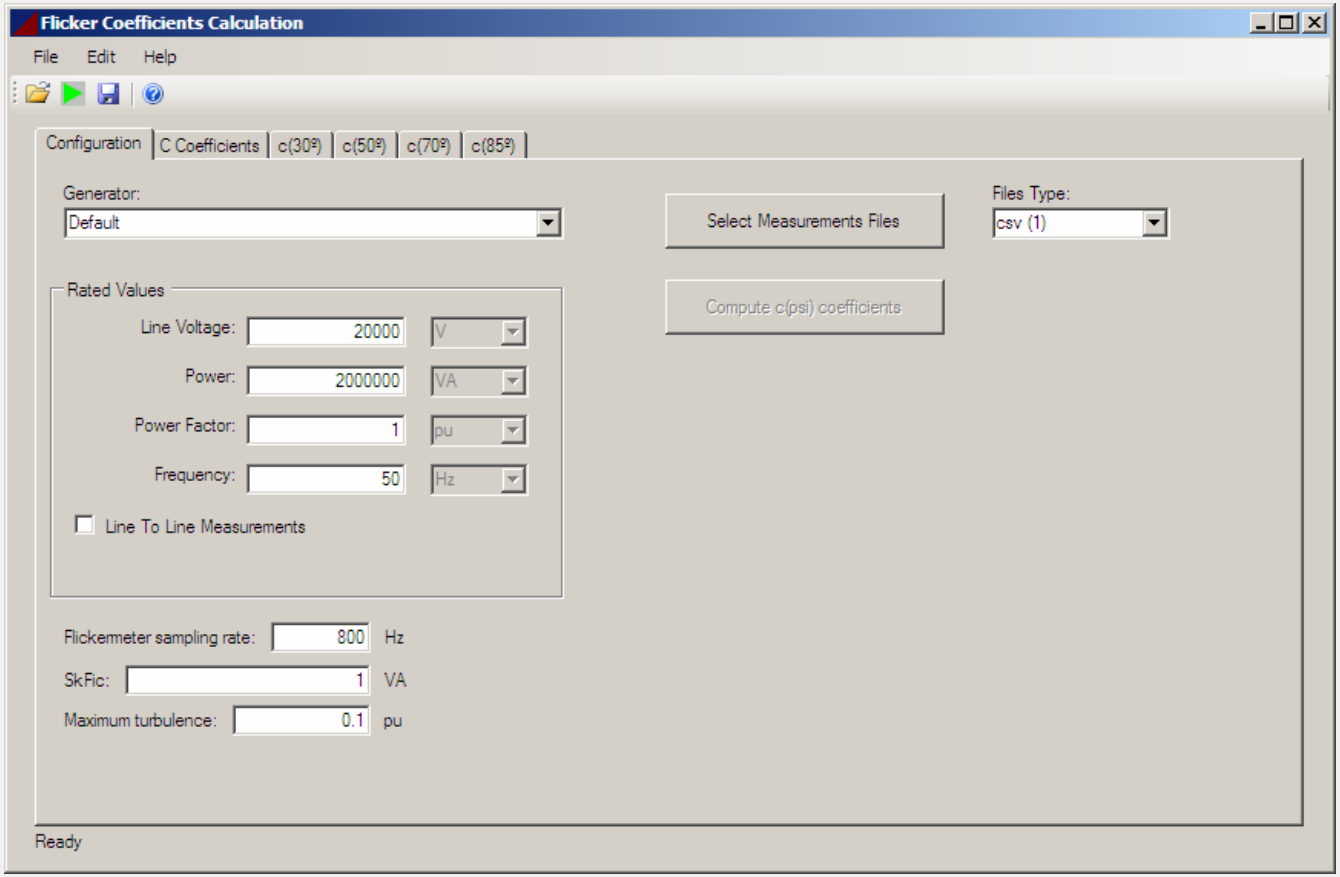
9. IEC 61400-21 Toolbox – Single File Flicker Emission



Characteristics:

- IEC 61400-21 & IEC 61000-4-15
- C coefficients for single file
- Grid angle configurable
- Wind bins configurable
- Copy/paste graphics
- Export graphics to csv files
- Turbulence computation
- Plots of time series of u_0, u_{fic}, instant flicker (PF)

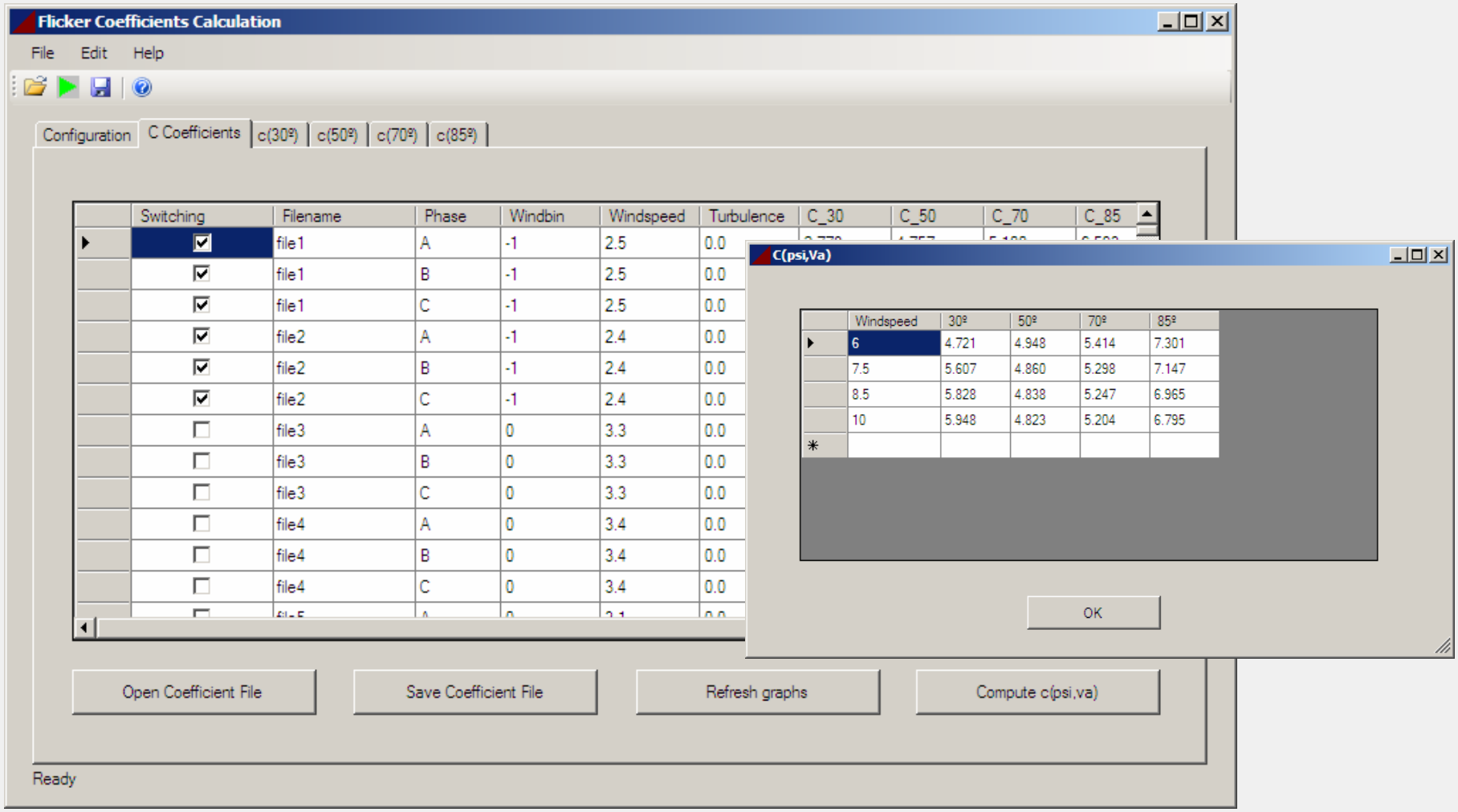
9. IEC 61400-21 Toolbox – c(ψ,va) Coefficients



Characteristics:

- IEC 61400-21 & IEC 61000-4-15
- C coefficients for multiple files
- Grid angle configurable
- Wind bins configurable
- Annual wind speed configurable
- Computation from previous c coefficients file
- Export c coefficients to csv file
- Copy/paste graphics
- Export graphics to csv files
- Turbulence computation
- Files can be marked as switching operation to be removed from computation
- Graphics of c coefficients in function of the grid angle

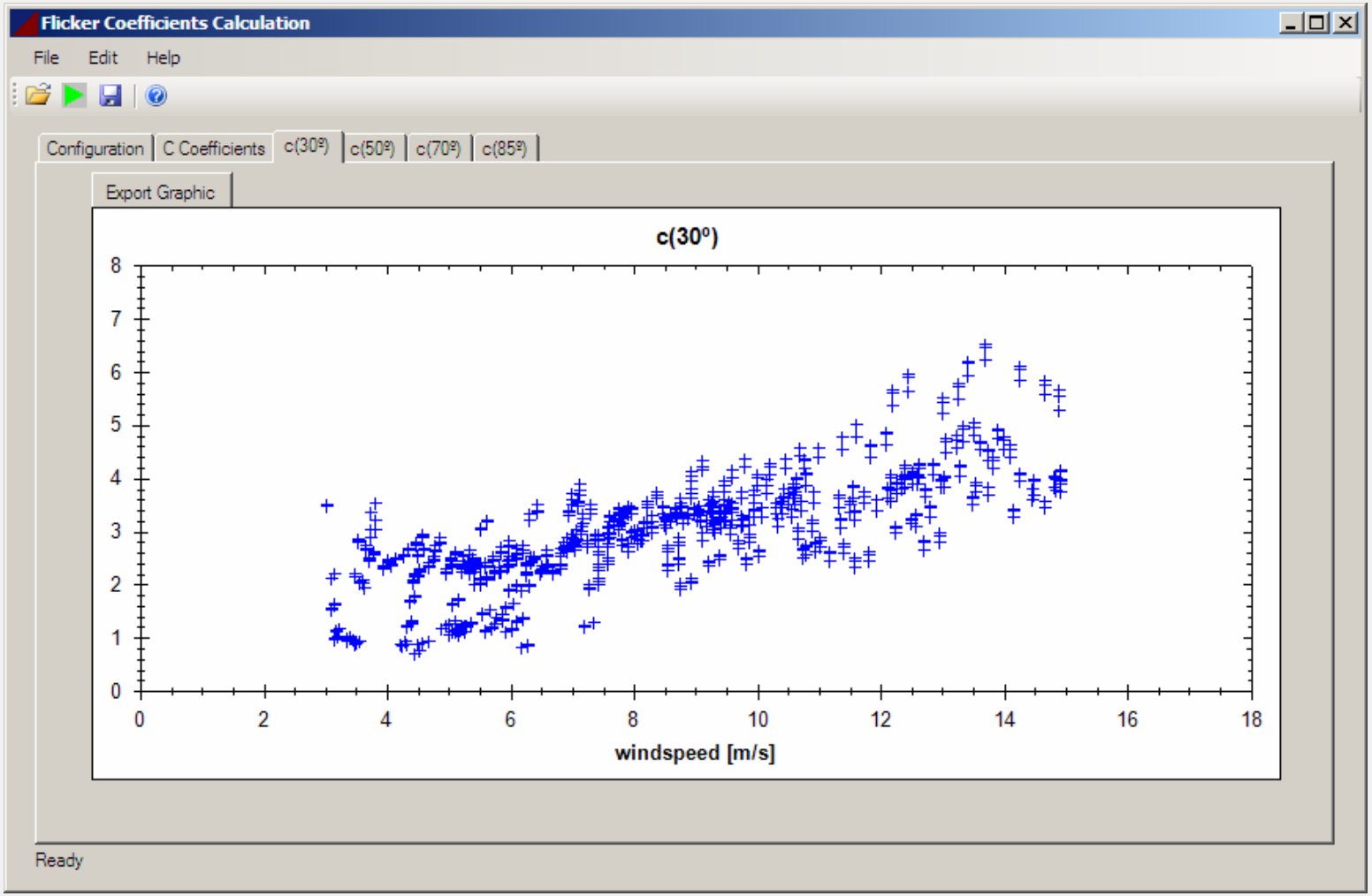
9. IEC 61400-21 Toolbox – c(ψ,va) Coefficients



C coefficient table – from computation or loaded from existing file

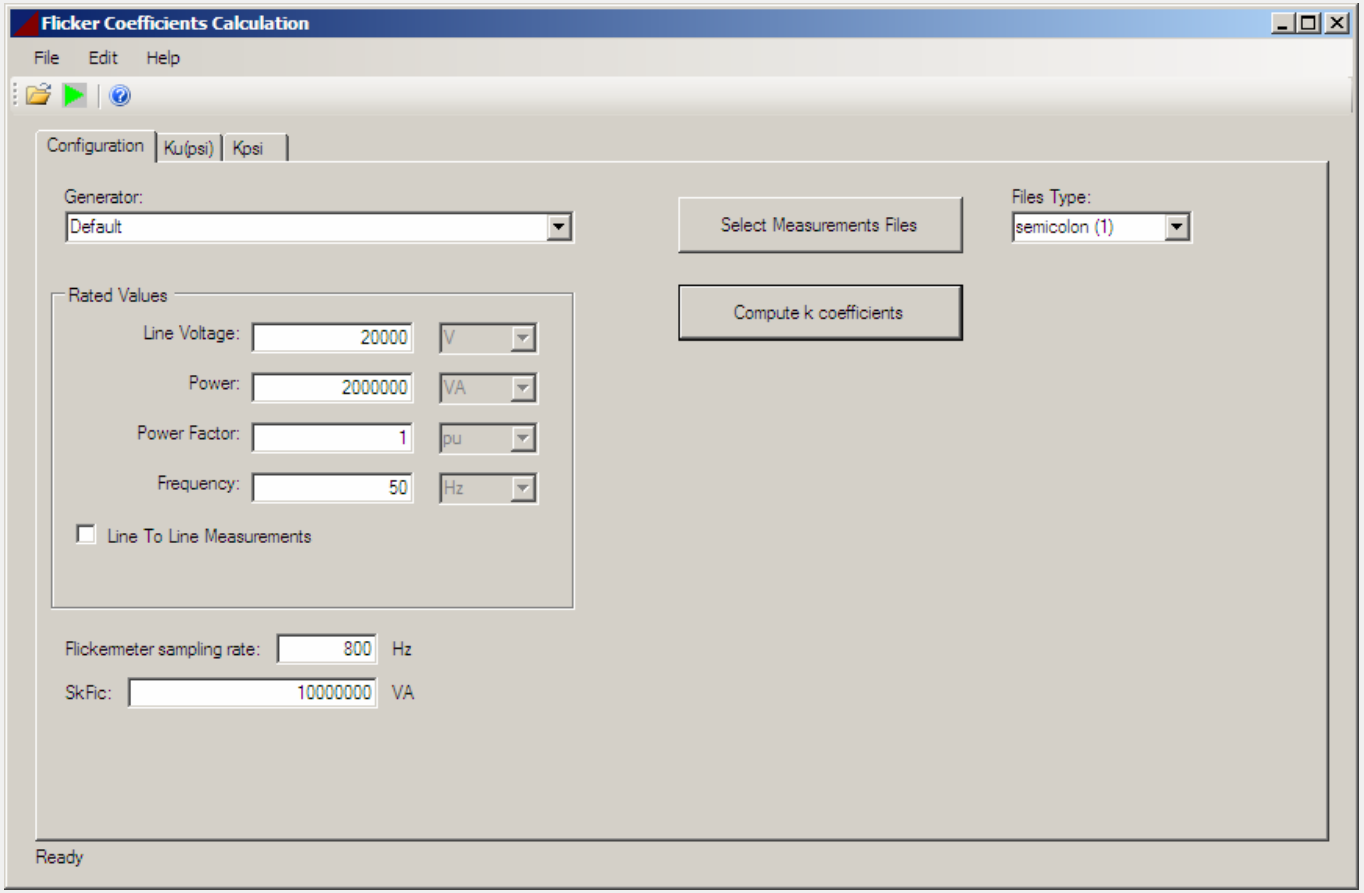
Can be saved to csv-file or can be used to compute c(ψ,va) coefficients.

9. IEC 61400-21 Toolbox – c(ψ,va) Coefficients



Plot of c coefficients according to the grid angle – this visualization helps to identify switching operations in the list of files.

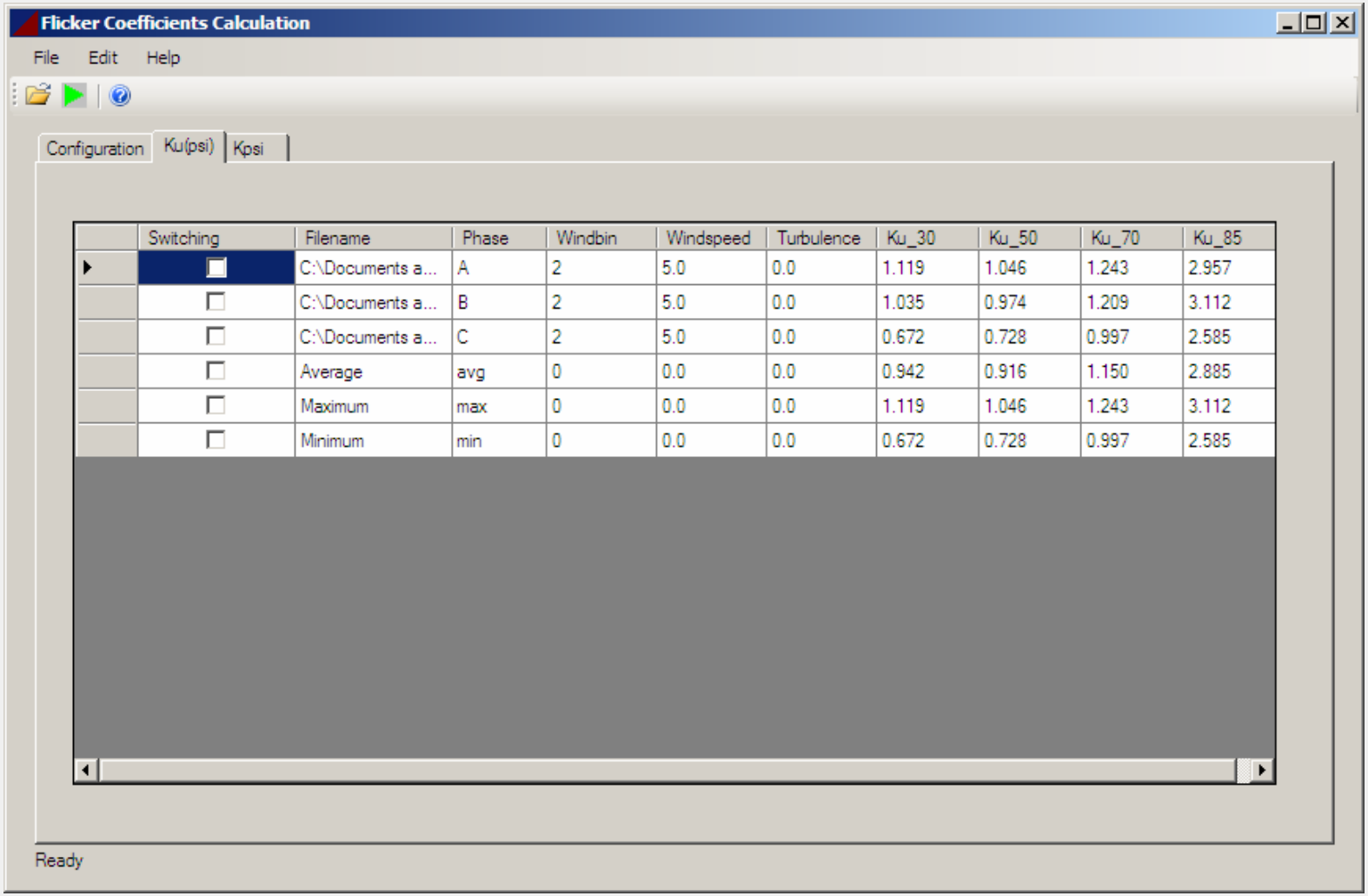
9. IEC 61400-21 Toolbox – Switching Operation



Characteristics:

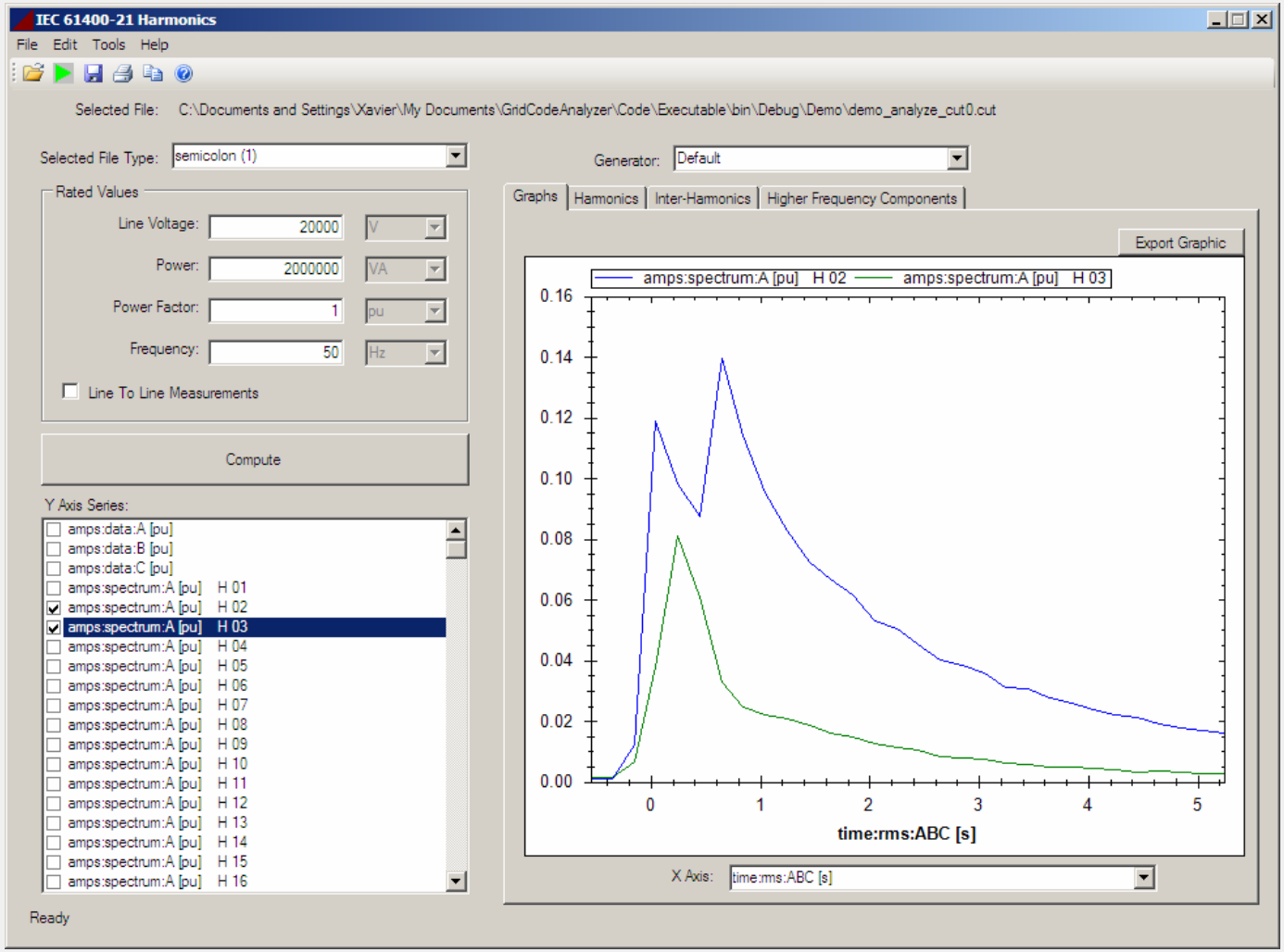
- IEC 61400-21 & IEC 61000-4-15
- Ku and kψ coefficients for single or multiple files
- Grid angle configurable
- Wind bins configurable
- Copy/paste graphics
- Export graphics to csv files
- Turbulence computation
- Computation of min, max and avg of ku and kψ

9. IEC 61400-21 Toolbox – Switching Operation



Ku and k_ψ coefficients table

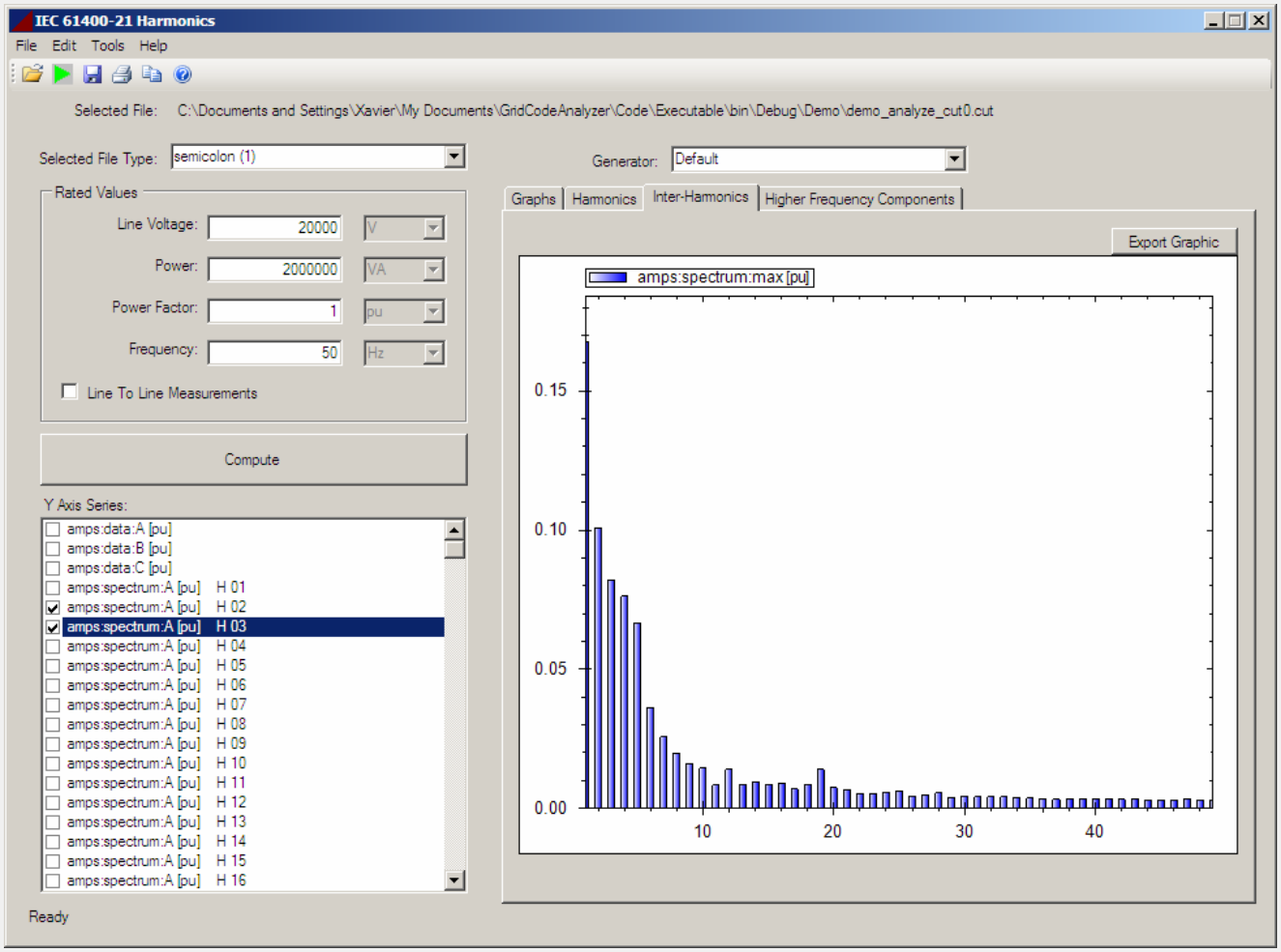
9. IEC 61400-21 Toolbox – Current Harmonics Emission



Characteristics:

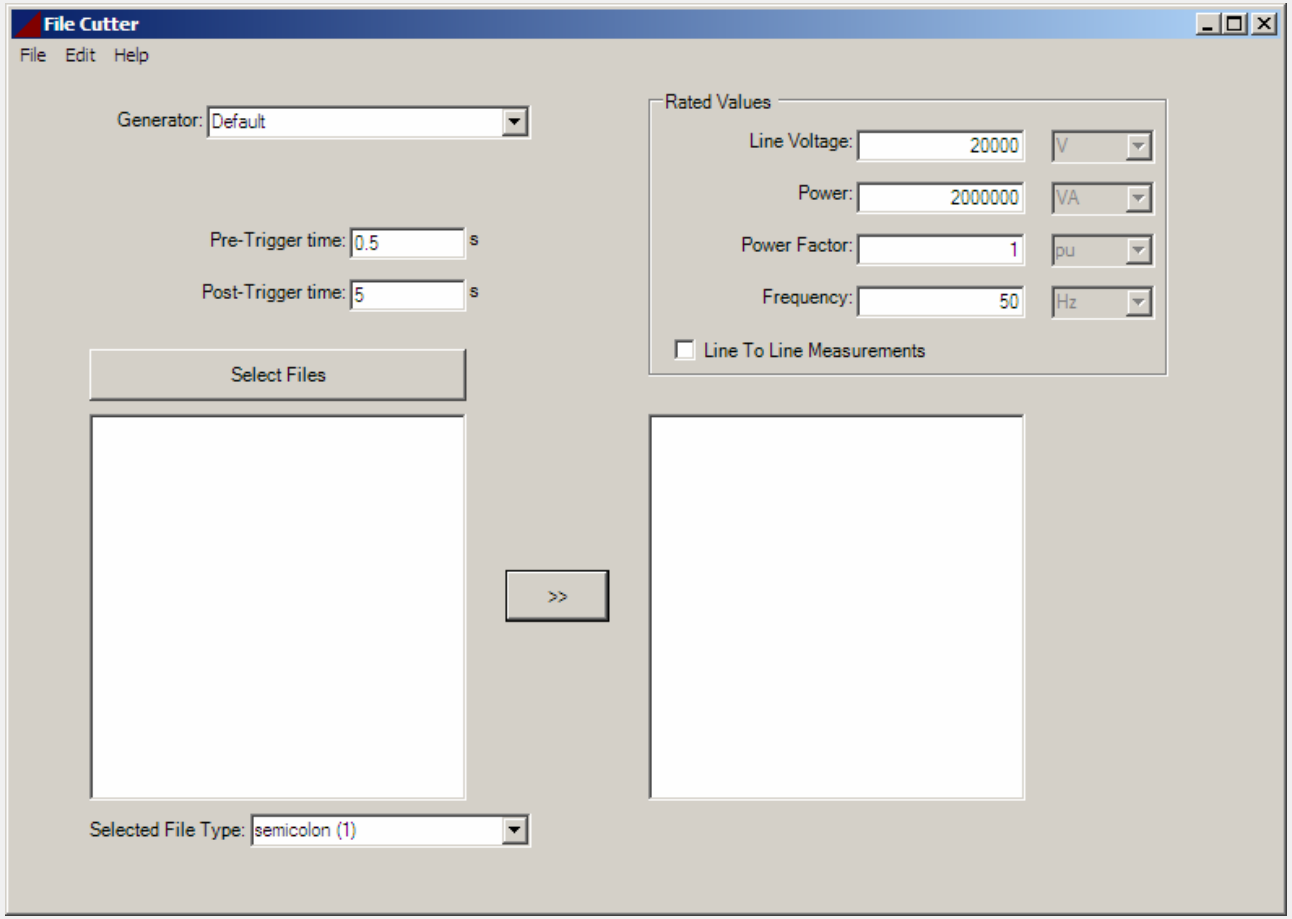
- IEC 61400-21 & IEC 61000-4-7
- Current harmonics – inter-harmonics and higher frequency components
- Time evolution of harmonics, inter-harmonics and higher frequency components
- Bar diagrams of harmonics, inter-harmonics and higher frequency components
- Copy/paste graphics
- Export graphics to csv files
- Single or multiple files analysis

9. IEC 61400-21 Toolbox – Current Harmonics Emission



Bar diagrams of harmonics, inter-harmonics, and higher frequency components can be exported as csv-files.

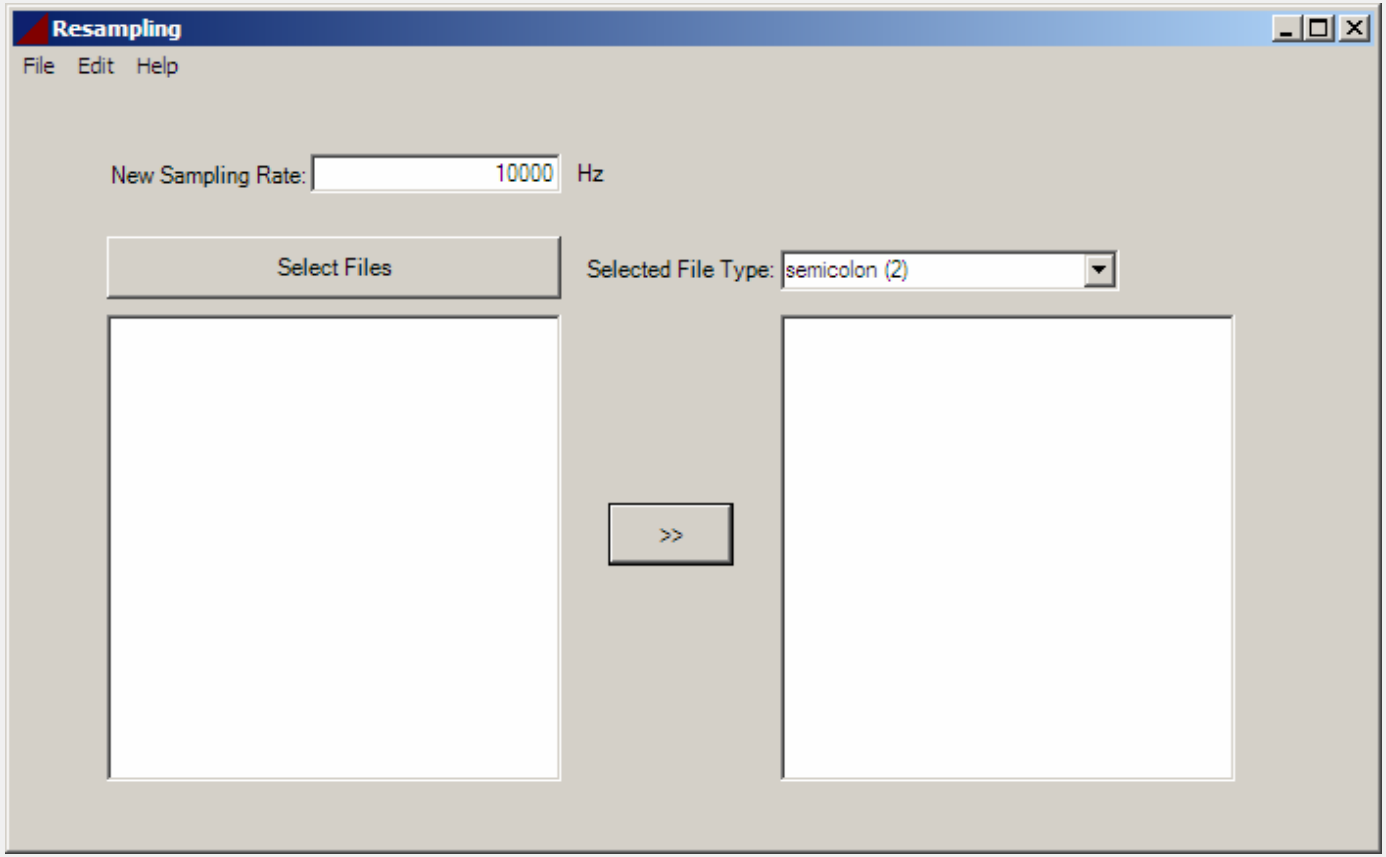
10. File Edition Tools – File Cutting



Characteristics:

- Cut file around events
- Pre-trigger and post-trigger
- Single or multiple files
- If no event detected, pre-trigger uses the beginning of the file and post-trigger is the duration of the generated output file

10. File Edition Tools – File Re-sampling



Characteristics:

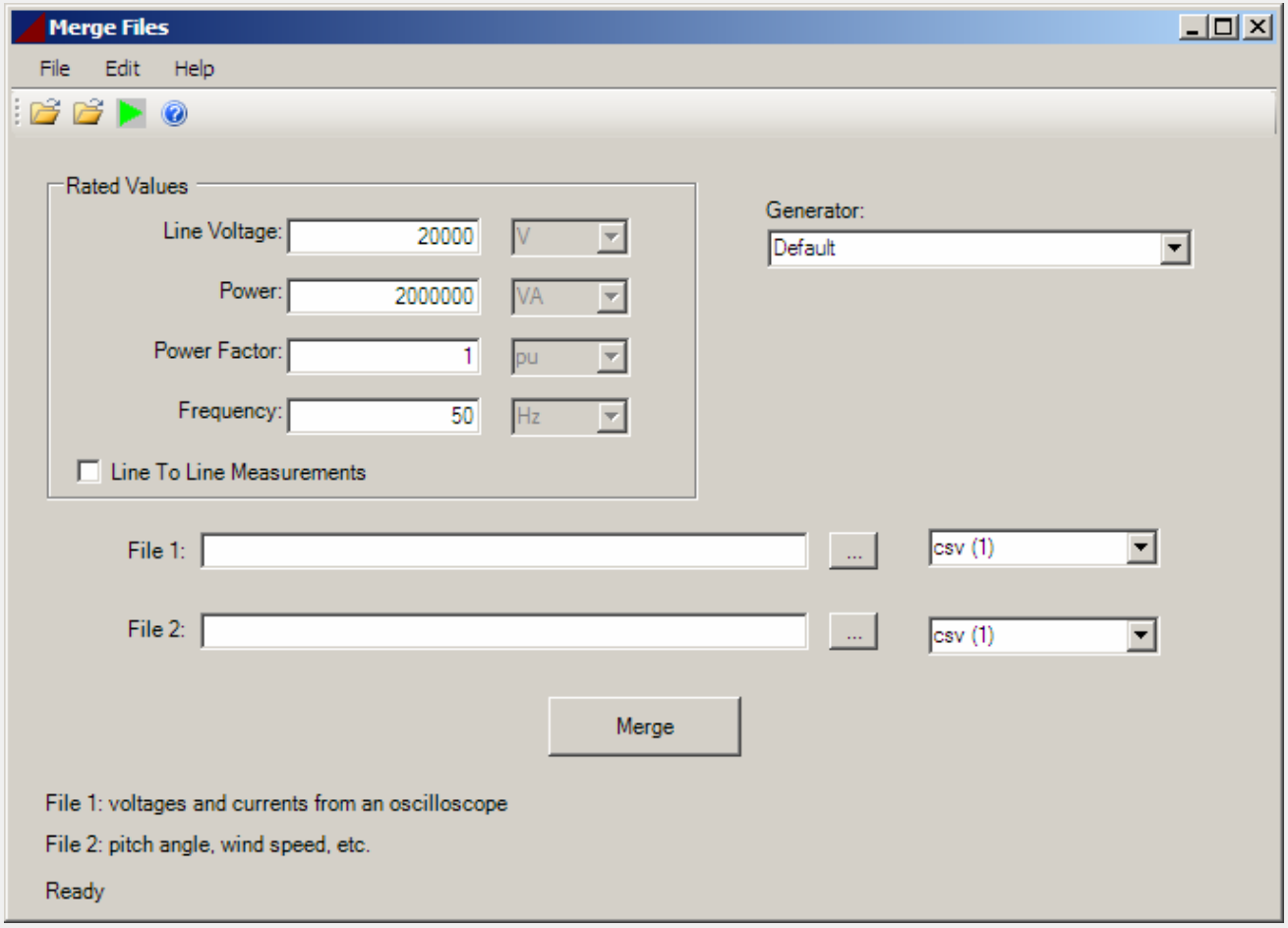
- Resample file
- Single or multiple files
- Output file format = input file format
- Filter parameters settings

Re-sampling methods: up-sampling + interpolation

10. File Edition Tools – File Merging

Merge 2 files: File 1 with electrical data and File 2 with other data (i.e. mechanical data, hydraulic pressure, etc.)

Requirements: both files should have a voltage series in common

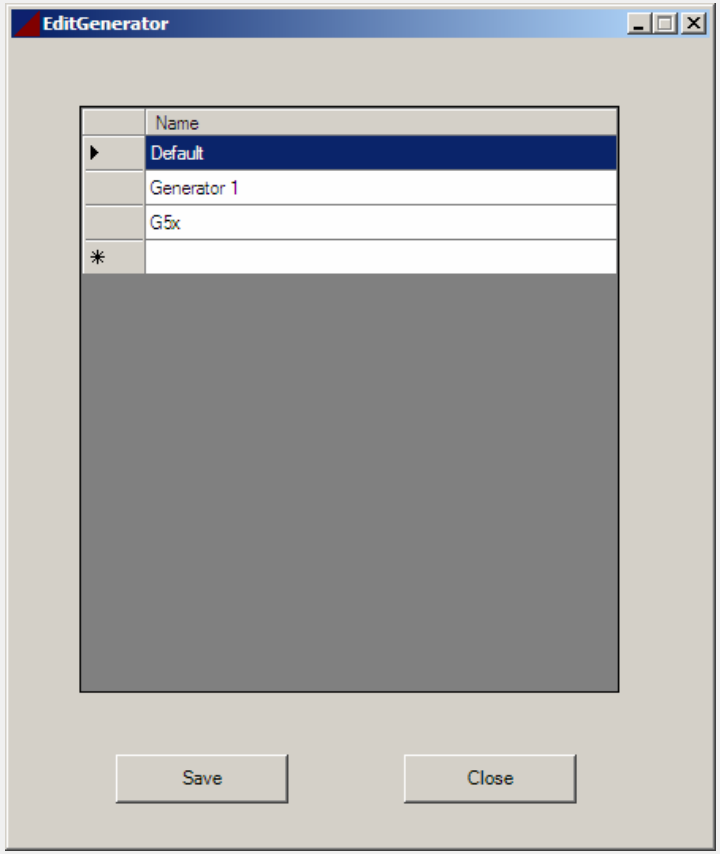


Characteristics:

- Automatic re-sampling of lowest rate file
- Output file format = csv
- Filter parameters settings

11. Generator

Generator objects allow to set up pre-recorded rated values parameters and alarms levels



Individual generator are accessed through the generators list