



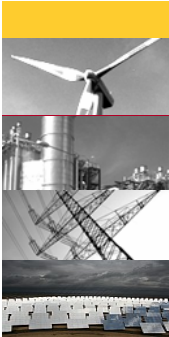
DlgSILENT Grid Code v1.0

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. $c(\psi, v_a)$ 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.

2. General Concepts – Main Menu

DIgSILENT Grid Code

DIgSILENT Grid Code

- [Data Visualizer](#)
- [Grid Code Compliance](#)
- [Model Validation](#)
- [FlickerMeter IEC 61000-4-15](#)
- [Harmonics IEC 61000-4-7](#)
- [Toolbox IEC 61400-21](#)

DIG SILENT
www.digsilent.com

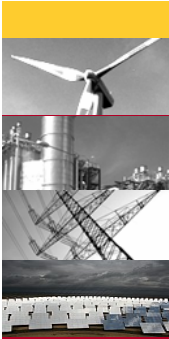
DIgSILENT Grid Code - version:1.2.0.0

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.

DIG SILENT 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

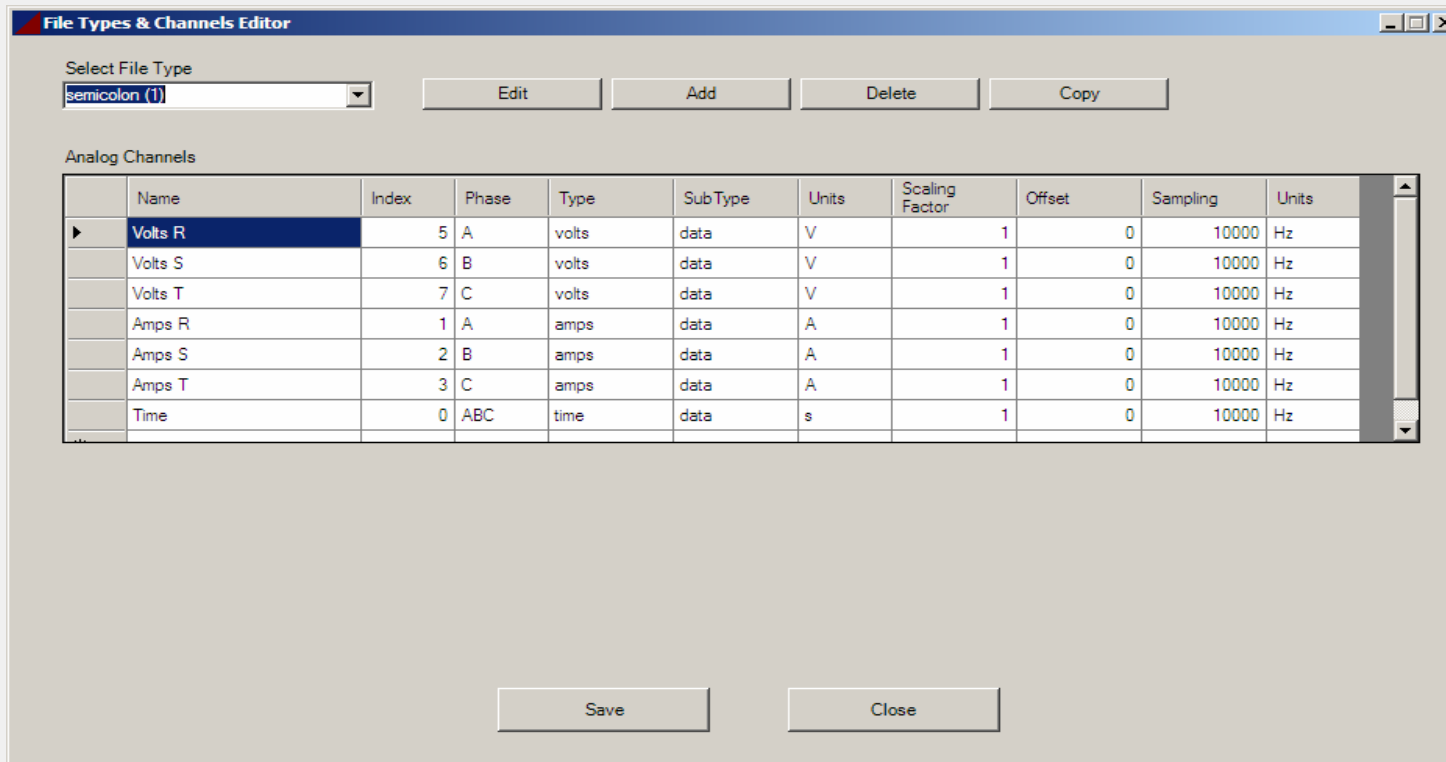
- There are no additional requirements for COMTRADE files.

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



2. General Concepts – Files Formats

File Types & Channels Editor



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

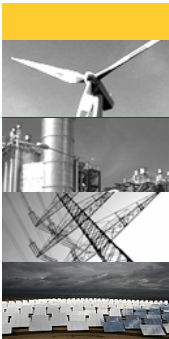
Types of files and channels can be added or deleted.



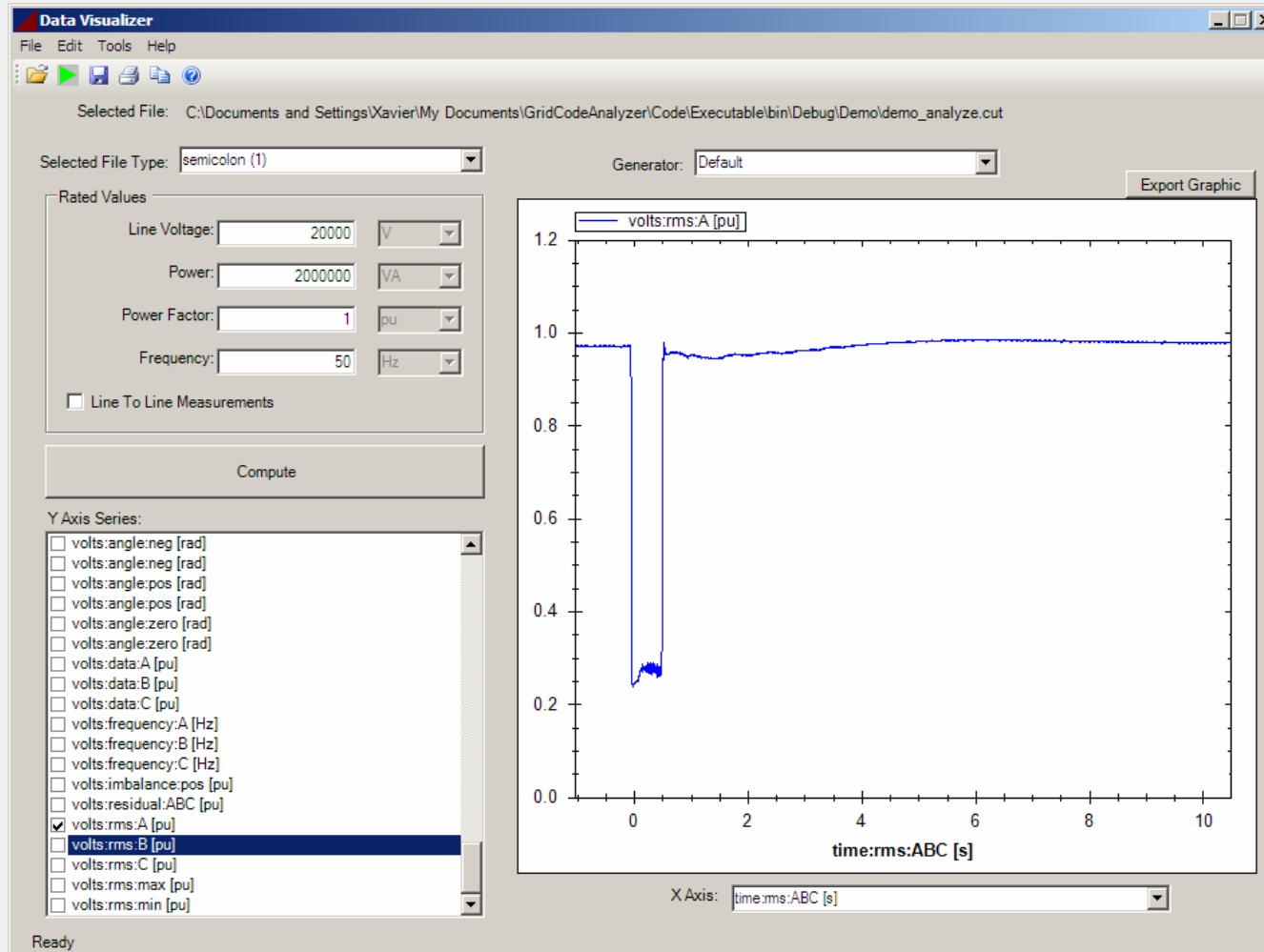
2. General Concepts – Parameters

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

Index	Name	Value	Description
0	ms rate	0	ms calculation rate (cycles/point) 0=sampling rate
1	frequency window	10	cycles - frequency calculation window
2	event division	3	divides the event in x parts for transition calculation
3	maximum residue	0.0001	
4	sensitivity start	2	
5	sensitivity end	1	
6	hysteresis	0.1	s - minimum time between 2 consecutive events
7	trigger unbalanced	0.05	pu - imbalance level to determine the type of event
8	voltage dip trigger level	0.9	pu
9	pretrigger	0.3	s - pre-trigger for plotting events
10	posttrigger	0.5	s - post-trigger for plotting events
11	synchronizer window	0.1	s - size of the window to be plotted for synchronization
12	voltage swell trigger l...	1.15	pu
13	overfrequency trigger ...	50.5	Hz
14	underfrequency trigge...	49.5	Hz
15	L	100	upsampling rate
16	ntaps	15	number of filter taps
17	cutoff	0.9	filter cut-off frequency



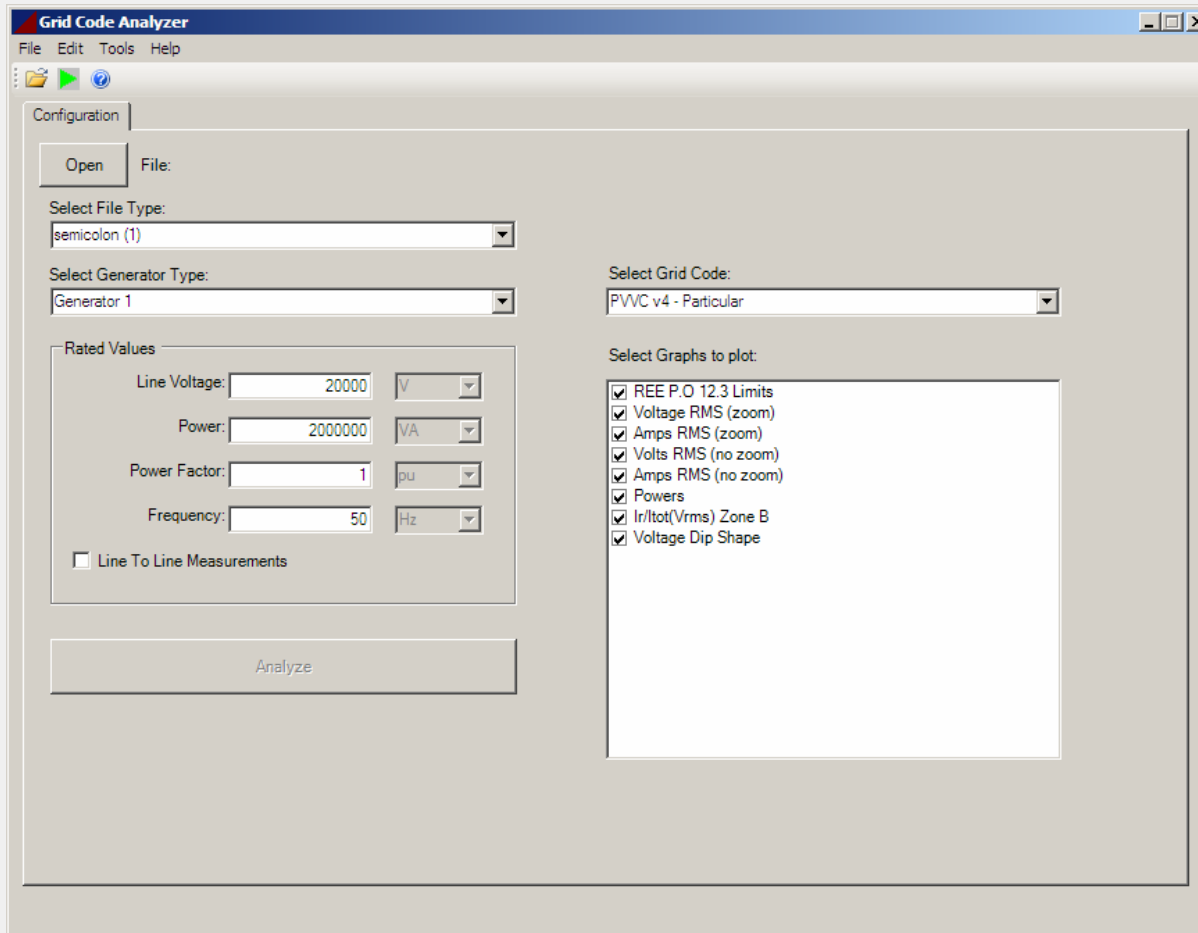
3. Data Visualizer



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 can be modified
- Export graphics data into csv-files

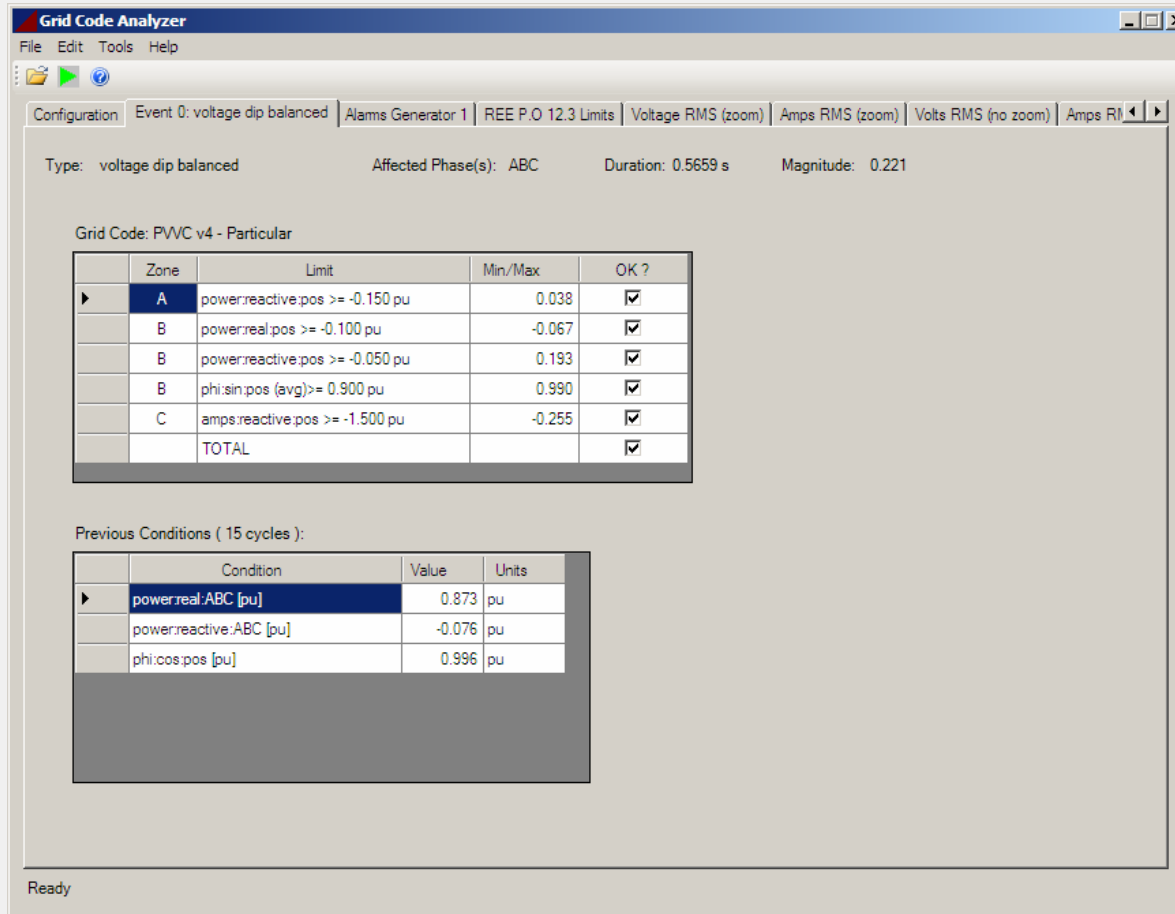
4. Grid Code Compliance Analyzer



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



The screenshot shows the 'Grid Code Analyzer' software window. The title bar reads 'Grid Code Analyzer'. The menu bar includes 'File', 'Edit', 'Tools', and 'Help'. The toolbar contains icons for file operations and analysis. The main window displays the following information:

Configuration: Event 0: voltage dip balanced | Alarms Generator 1 | REE P.O 12.3 Limits | Voltage RMS (zoom) | Amps RMS (zoom) | Volts RMS (no zoom) | Amps R...

Type: voltage dip balanced Affected Phase(s): ABC Duration: 0.5659 s Magnitude: 0.221

Grid Code: PWC v4 - Particular

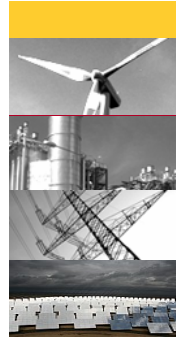
	Zone	Limit	Min/Max	OK ?
▶	A	power:reactive:pos >= -0.150 pu	0.038	<input checked="" type="checkbox"/>
	B	power:real:pos >= -0.100 pu	-0.067	<input checked="" type="checkbox"/>
	B	power:reactive:pos >= -0.050 pu	0.193	<input checked="" type="checkbox"/>
	B	phi:sin:pos (avg) >= 0.900 pu	0.990	<input checked="" type="checkbox"/>
	C	amps:reactive:pos >= -1.500 pu	-0.255	<input checked="" type="checkbox"/>
		TOTAL		<input checked="" type="checkbox"/>

Previous Conditions (15 cycles):

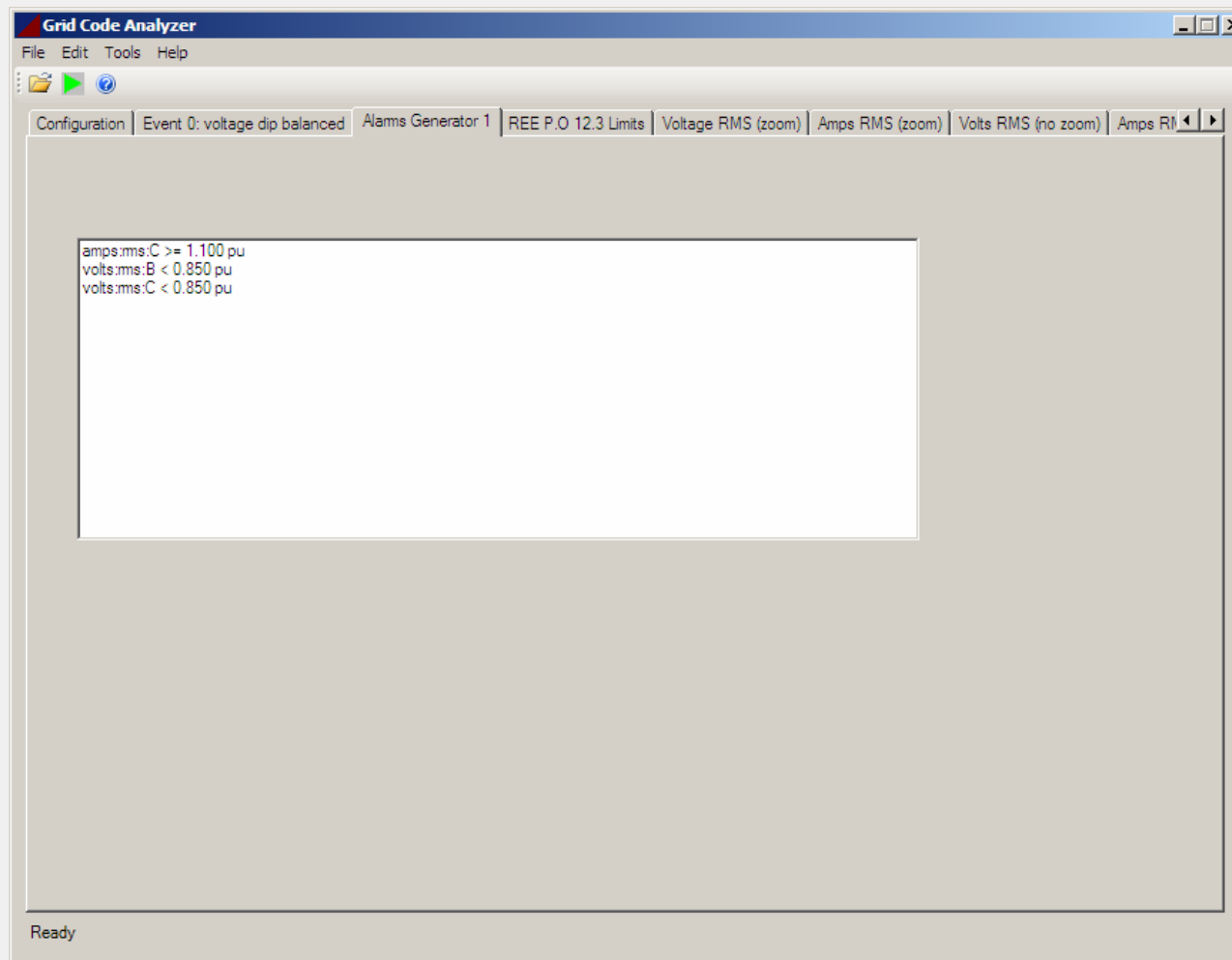
	Condition	Value	Units
▶	power:real:ABC [pu]	0.873	pu
	power:reactive:ABC [pu]	-0.076	pu
	phi:cos:pos [pu]	0.996	pu

Ready

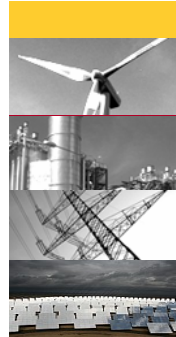
Compliance results and event previous conditions are displayed in a table



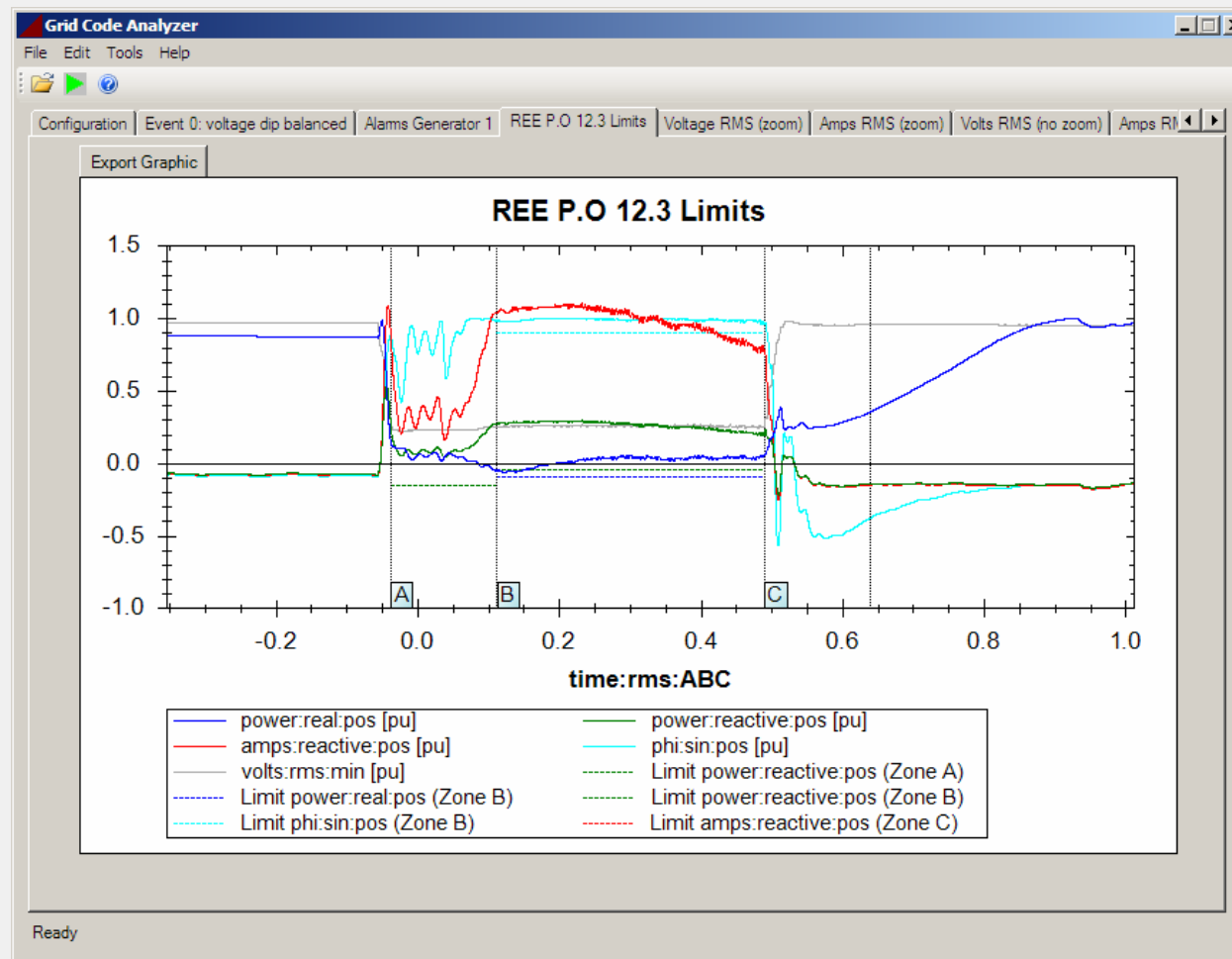
4. Grid Code Compliance Analyzer



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

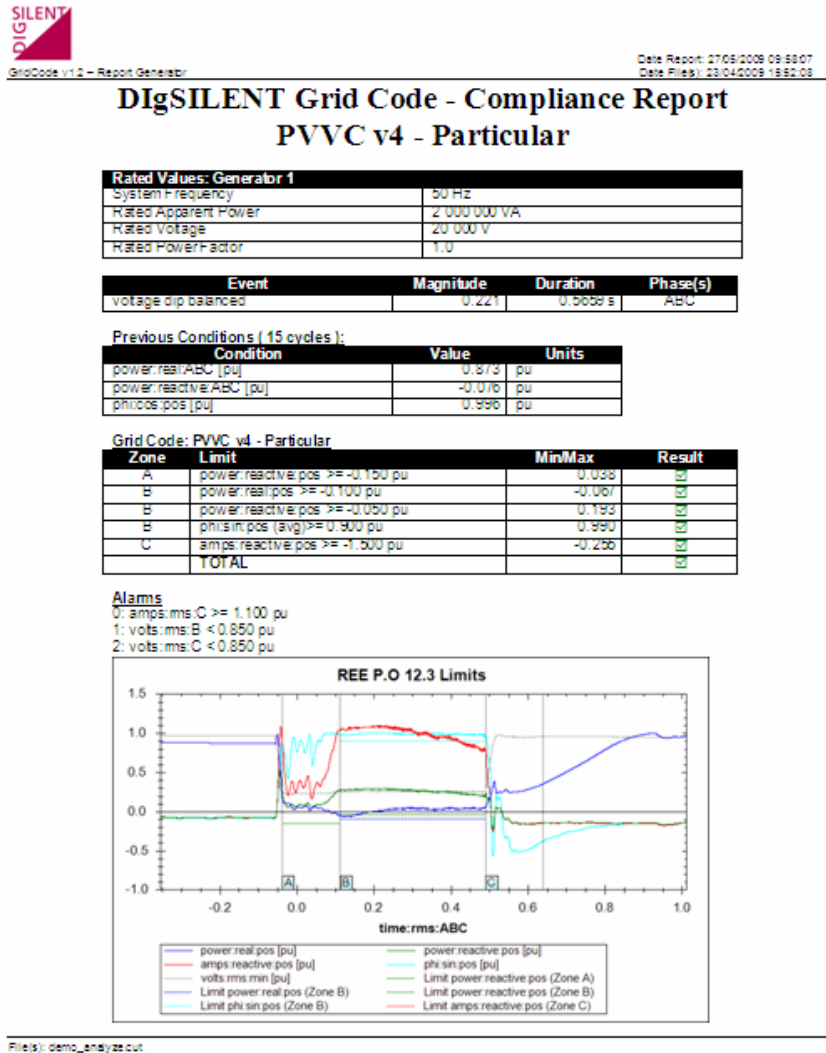


4. Grid Code Compliance Analyzer



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

4. Grid Code Compliance Analyzer



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

Edit Grid Code

Grid Code: New Delete Rename Copy

Function:

Zones:

Zone	Duration
A	0.15
B	0
C	0.15
D	0
*	0.0

Edit Delete

Shapes:

Shape
REE Voltage Dip Shape 3ph
REE Voltage Dip Shape 2ph
REE Voltage Support
*

Edit Delete

Initial Conditions:

Number of cycles: cycles

Type	SubType	Phase
power	real	ABC
power	reactive	ABC
phi	cos	pos
*		

Delete

Save Close

Plots:

Plot	Checked
REE P.O 12.3 Limits	<input checked="" type="checkbox"/>
Voltage RMS (zoom)	<input checked="" type="checkbox"/>
Amps RMS (zoom)	<input checked="" type="checkbox"/>
Volts RMS (no zoom)	<input checked="" type="checkbox"/>
Amps RMS (no zoom)	<input checked="" type="checkbox"/>
Powers	<input checked="" type="checkbox"/>
Ir/Itot(Vrms) Zone B	<input checked="" type="checkbox"/>
Voltage Dip Shape	<input checked="" type="checkbox"/>
*	<input type="checkbox"/>

Edit Delete ↑ ↓

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

Edit Zone

Name: Duration: s

Limits: Delete

	Event	Balanced	Type	SubType	Phase	Comparison	Value	Units
▶	voltageDip	balanced	power	real	pos	>=	-0.1	pu
	voltageDip	balanced	power	reactive	pos	>=	-0.05	pu
	voltageDip	unbalanced	power	real	pos	>=	-0.3	pu
	voltageDip	unbalanced	power	reactive	pos	>=	-0.4	pu
	voltageDip	unbalanced	energy	real	pos	>=	-0.045	pus
	voltageDip	unbalanced	energy	reactive	pos	>=	-0.04	pus
*								

OK Cancel

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

5. Grid Code Editor – Shape Editor

The 'Edit Shape' dialog box is shown with the following configuration:

- Name: REE Voltage Dip Shape 3ph
- Type of Shape: voltageDipShape
- Apply during (event): voltageDip
- Balanced?: balanced
- Type of limit: inferiorOrEqual
- x axis: time, ms, ABC, s
- y axis: volts, ms, min, pu

	X	Y
▶	0	1
	0	0.85
	0	0.2
	0.5	0.2
	1	0.85
	15	0.95
	16	0.95
*		

The graph shows a voltage dip shape starting at 0.2 pu at time 0, rising to 0.85 pu at time 0, then gradually increasing to 0.95 pu at time 16. The x-axis represents time in seconds (0 to 20), and the y-axis represents voltage in pu (0.0 to 1.2).

Buttons: Reset, OK

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

5. Grid Code Editor – Plot Editor

Title: REE P.O. 12.3 Limits Checked

Function: ZonesREE

X Axis: time ms ABC

Y Axis:

Type	SubType	Phase
power	real	pos
power	reactive	pos
amps	reactive	pos
phi	sin	pos
volts	ms	min

Delete

OK Cancel

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



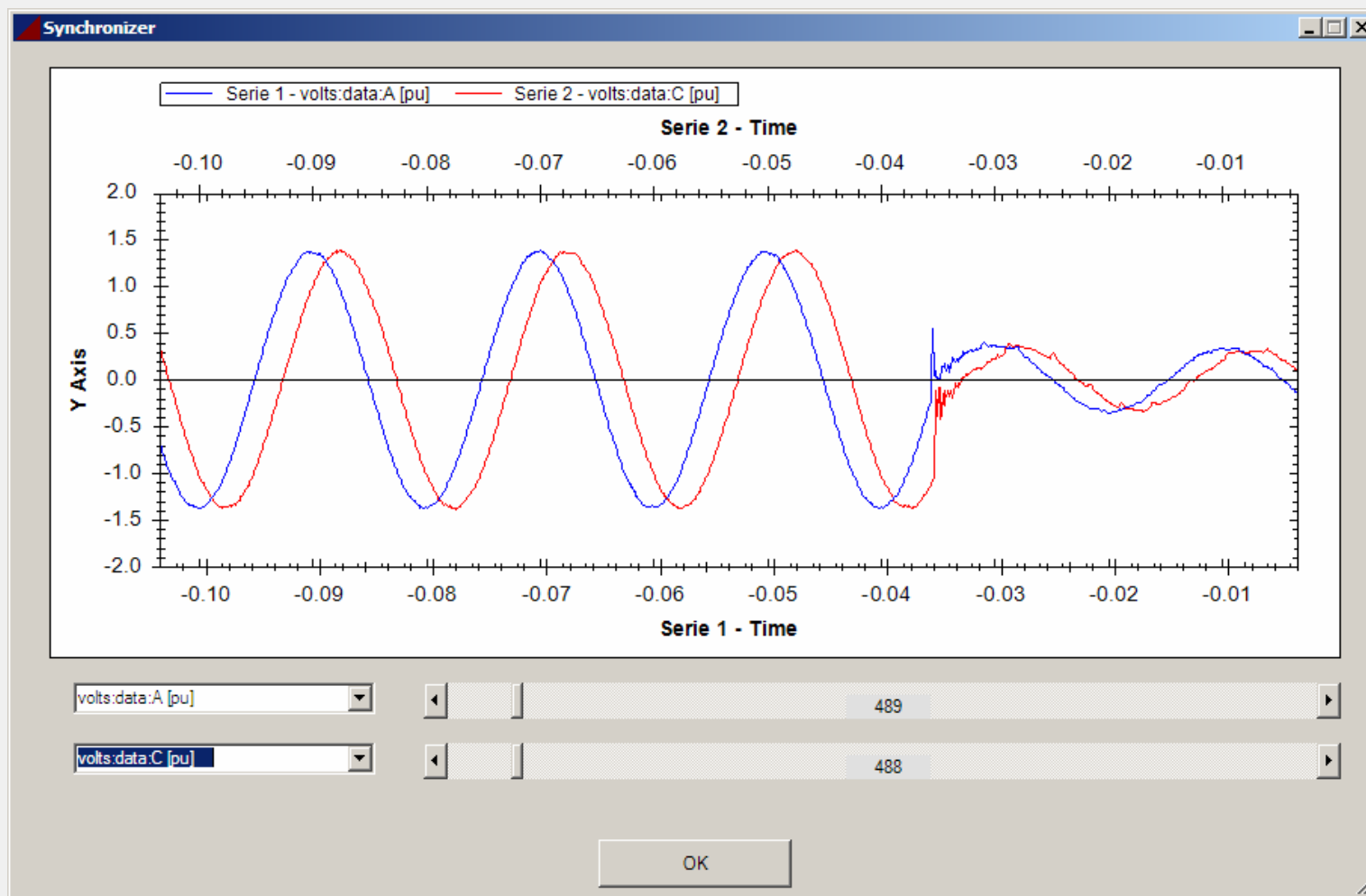
6. Model Validation Tool

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

The screenshot shows the 'Model Validation Tool' window with a menu bar (File, Edit, Tools, Help) and a toolbar. The 'Results' tab is active, displaying a table with the following data:

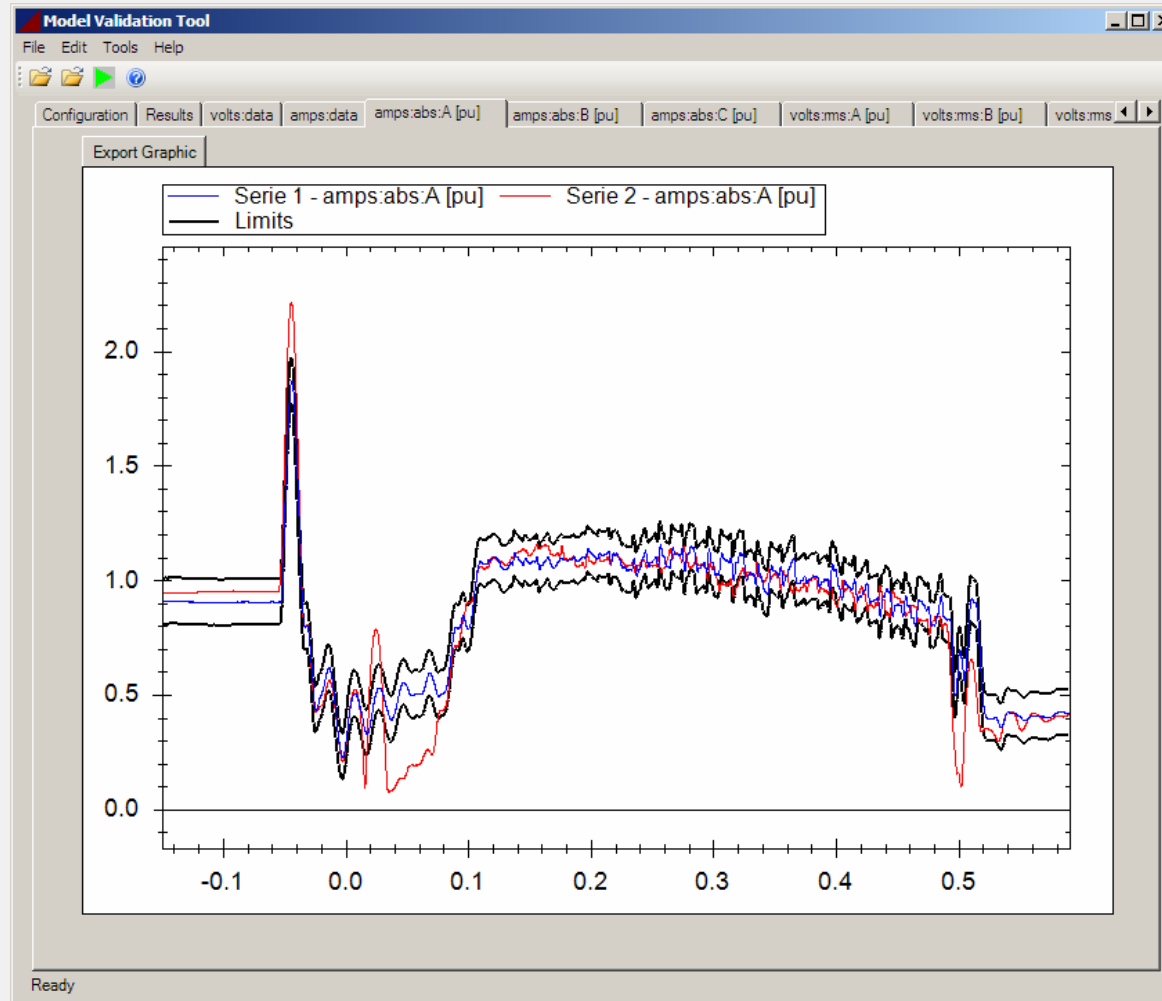
	Serie	Percentile 85	Error Max	Error Avg
▶	amps.abs:A [pu]	0.118	0.581	0.074
	amps.abs:B [pu]	0.127	0.717	0.072
	amps.abs:C [pu]	0.130	0.573	0.093
	volts.ms:A [pu]	0.020	0.243	0.013
	volts.ms:B [pu]	0.022	0.233	0.021
	volts.ms:C [pu]	0.022	0.101	0.017
	power.real.pos [pu]	0.052	0.201	0.024
	power.real:A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

Ready

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



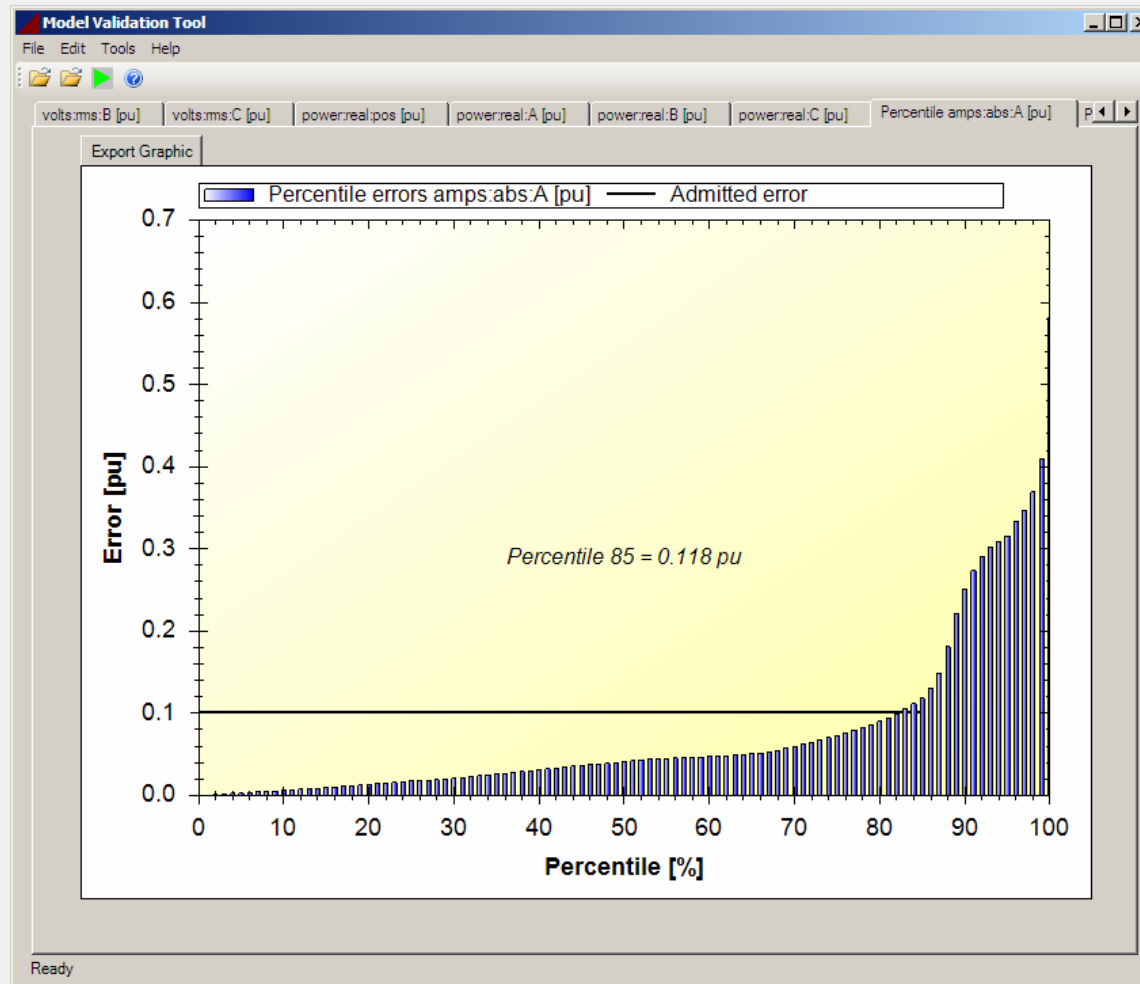
6. Model Validation Tool



Comparison graphical preview



6. Model Validation Tool



Error (percentile of the error)



6. Model Validation Tool

DIG SILENT
GridCode v1.0 - Report Generator Date Report: 27/09/2009 10:02:28
Date File(s): (1) 23/04/2009 17:45:13 (2) 23/04/2009 17:45:27

DIG SILENT 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 95	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	0.059
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

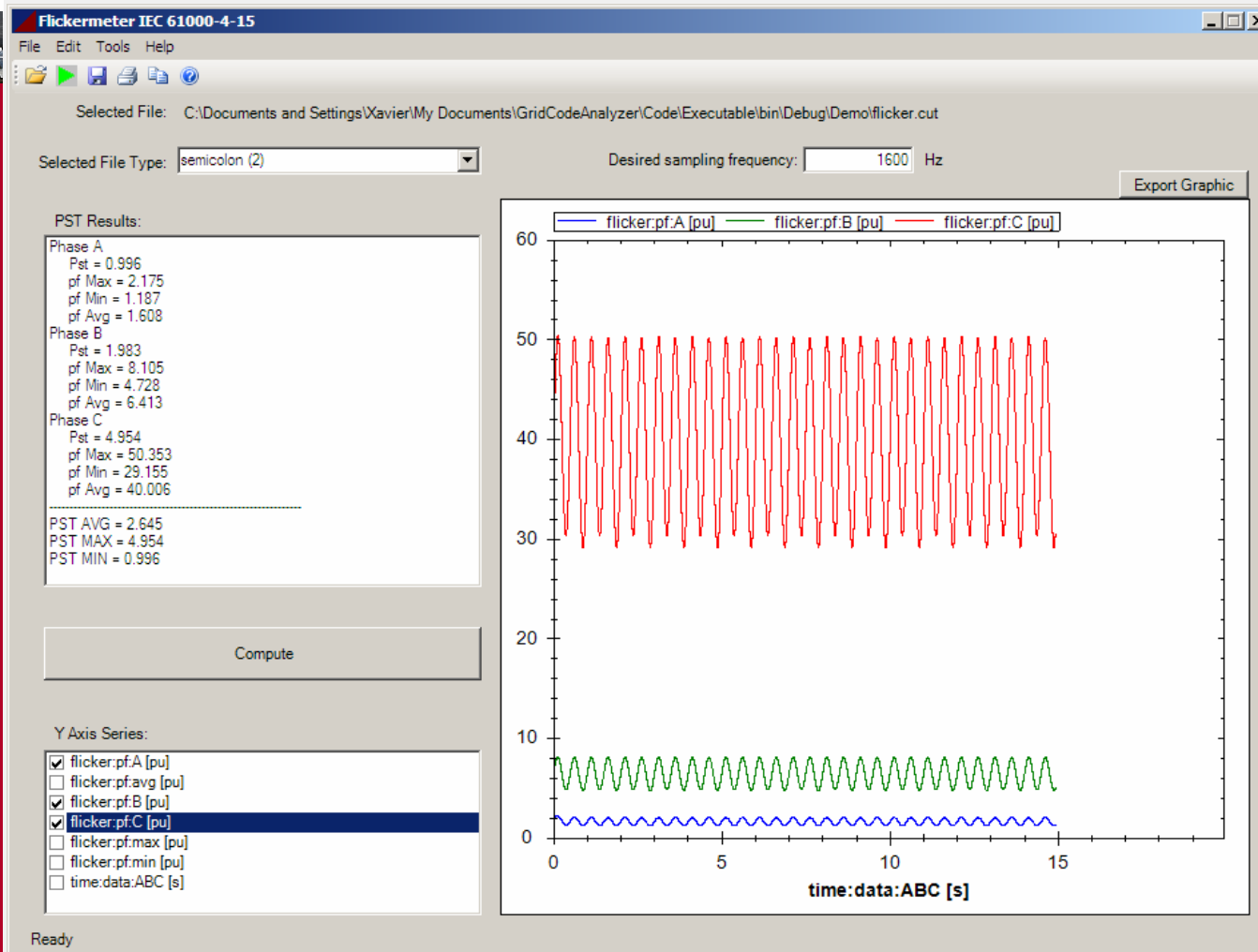
File(s): (1) validation1.cut (2) validation2.cut

1/16

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

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

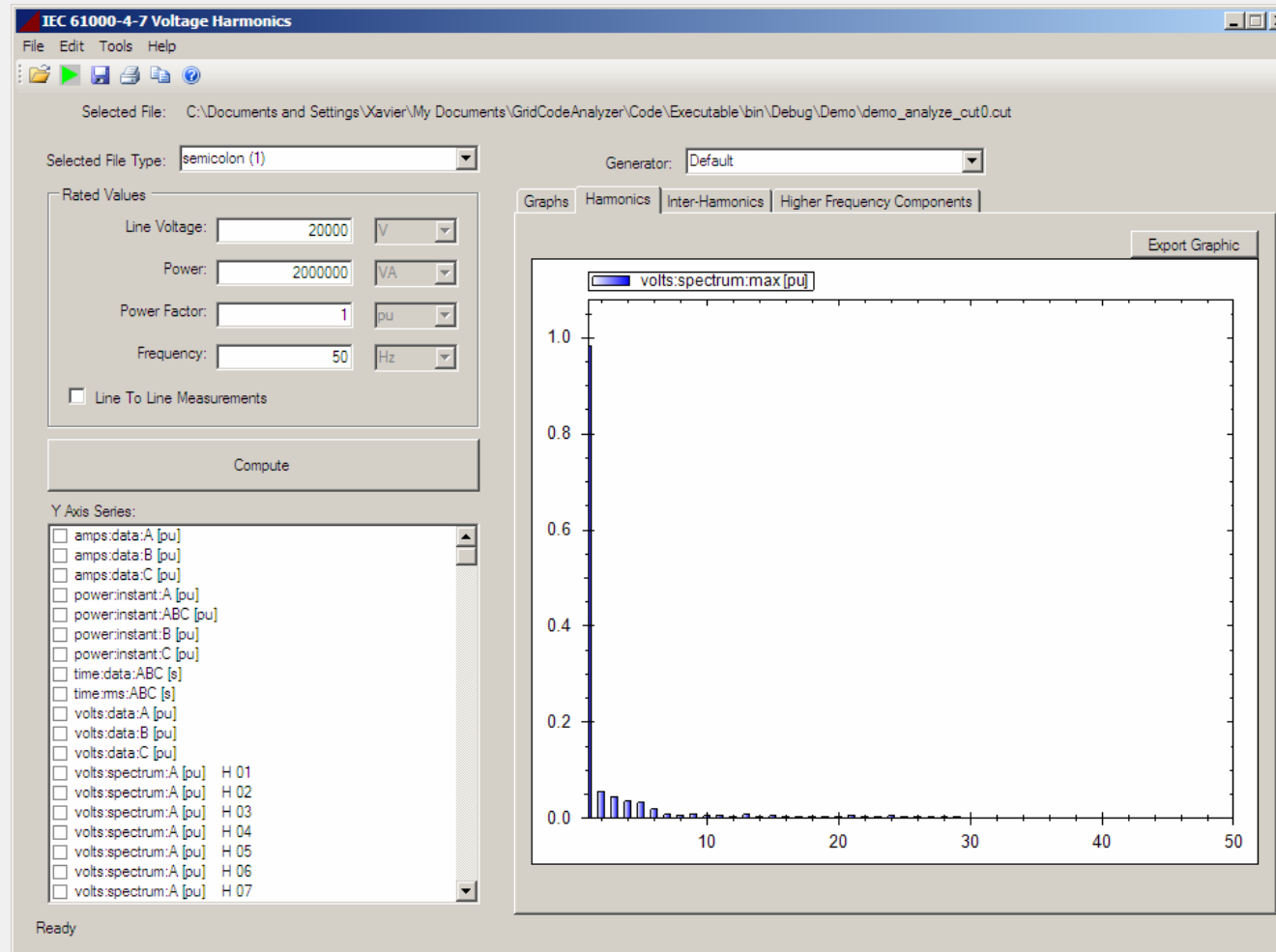
7. IEC 61000-4-15 Flicker Meter



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

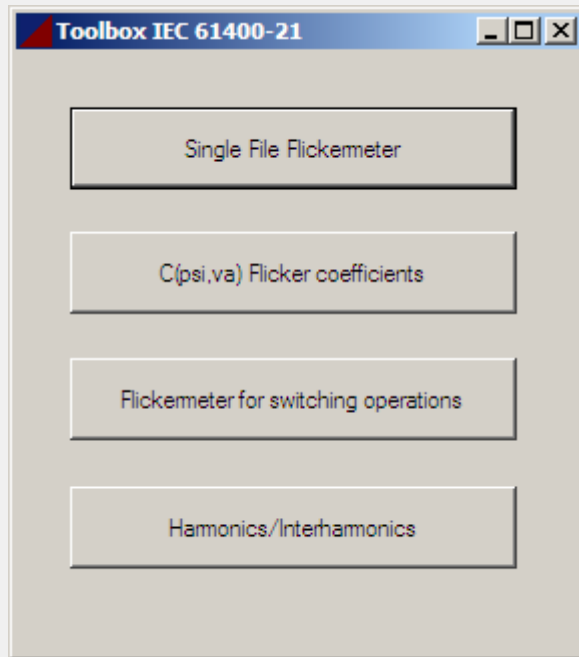
8. IEC 61000-4-7 Voltage Harmonics



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

Flickermeter IEC 61400_21

File Edit Tools Help

Selected File: C:\Documents and Settings\Xavier\My Documents\GridCodeAnalyzer\Code\Executable\bin\Debug\Demo\Flicker.cut

Selected File Type: semicolon (2) Desired sampling frequency: 400 Hz Skfco: 100000000 VA

Rated Values

Line Voltage: 20000 V
 Power: 2000000 VA
 Power Factor: 1 pu
 Frequency: 50 Hz

Line To Line Measurements

Compute

Y Axis Series:

- time:data:ABC [s]
- volts:data:A [V]
- amps:data:A [A]
- volts:data:B [V]
- amps:data:B [A]
- volts:data:C [V]
- amps:data:C [A]
- di:data:A [A]
- u0:phasor:A [V]
- ufic:phasor:A [V] - angle:30°
- flicker:pf:A [pu] - angle:30°
- ufic:phasor:A [V] - angle:50°
- flicker:pf:A [pu] - angle:50°
- ufic:phasor:A [V] - angle:70°
- flicker:pf:A [pu] - angle:70°

Export Graphic

time:data:ABC [s]

Phase	Windbin	Windspeed	Turbulence	C_30	C_50	C_70	C_85
A	2	5.0	0.0	5.403	5.374	5.331	5.226
B	2	5.0	0.0	6.208	6.193	6.189	6.273
C	2	5.0	0.0	2.803	2.479	2.302	3.354

Ready

Characteristics:

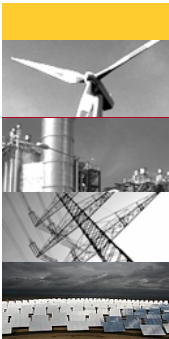
- IEC 61400-21 & IEC 61000-4-15
- C coefficients for single file
- Grid angle configurable
- Wind bins configurable
- Copy/paste graphics
- Export graphics to csv files
- Turbulence computation
- Plots of time series of u₀, u_{fic}, instant flicker (PF)



9. IEC 61400-21 Toolbox – $c(\psi,va)$ 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 – $c(\psi, v_a)$ Coefficients

Flicker Coefficients Calculation

File Edit Help

Configuration C Coefficients c(30°) c(50°) c(70°) c(85°)

Switching	Filename	Phase	Windbin	Windspeed	Turbulence	C_30	C_50	C_70	C_85
<input checked="" type="checkbox"/>	file1	A	-1	2.5	0.0	0.770	4.757	5.400	6.200
<input checked="" type="checkbox"/>	file1	B	-1	2.5	0.0				
<input checked="" type="checkbox"/>	file1	C	-1	2.5	0.0				
<input checked="" type="checkbox"/>	file2	A	-1	2.4	0.0				
<input checked="" type="checkbox"/>	file2	B	-1	2.4	0.0				
<input checked="" type="checkbox"/>	file2	C	-1	2.4	0.0				
<input type="checkbox"/>	file3	A	0	3.3	0.0				
<input type="checkbox"/>	file3	B	0	3.3	0.0				
<input type="checkbox"/>	file3	C	0	3.3	0.0				
<input type="checkbox"/>	file4	A	0	3.4	0.0				
<input type="checkbox"/>	file4	B	0	3.4	0.0				
<input type="checkbox"/>	file4	C	0	3.4	0.0				
<input type="checkbox"/>	file5	A	0	3.1	0.0				

C(psi, Va)

Windspeed	30°	50°	70°	85°
6	4.721	4.948	5.414	7.301
7.5	5.607	4.860	5.298	7.147
8.5	5.828	4.838	5.247	6.965
10	5.948	4.823	5.204	6.795
*				

Open Coefficient File Save Coefficient File Refresh graphs Compute c(psi, va)

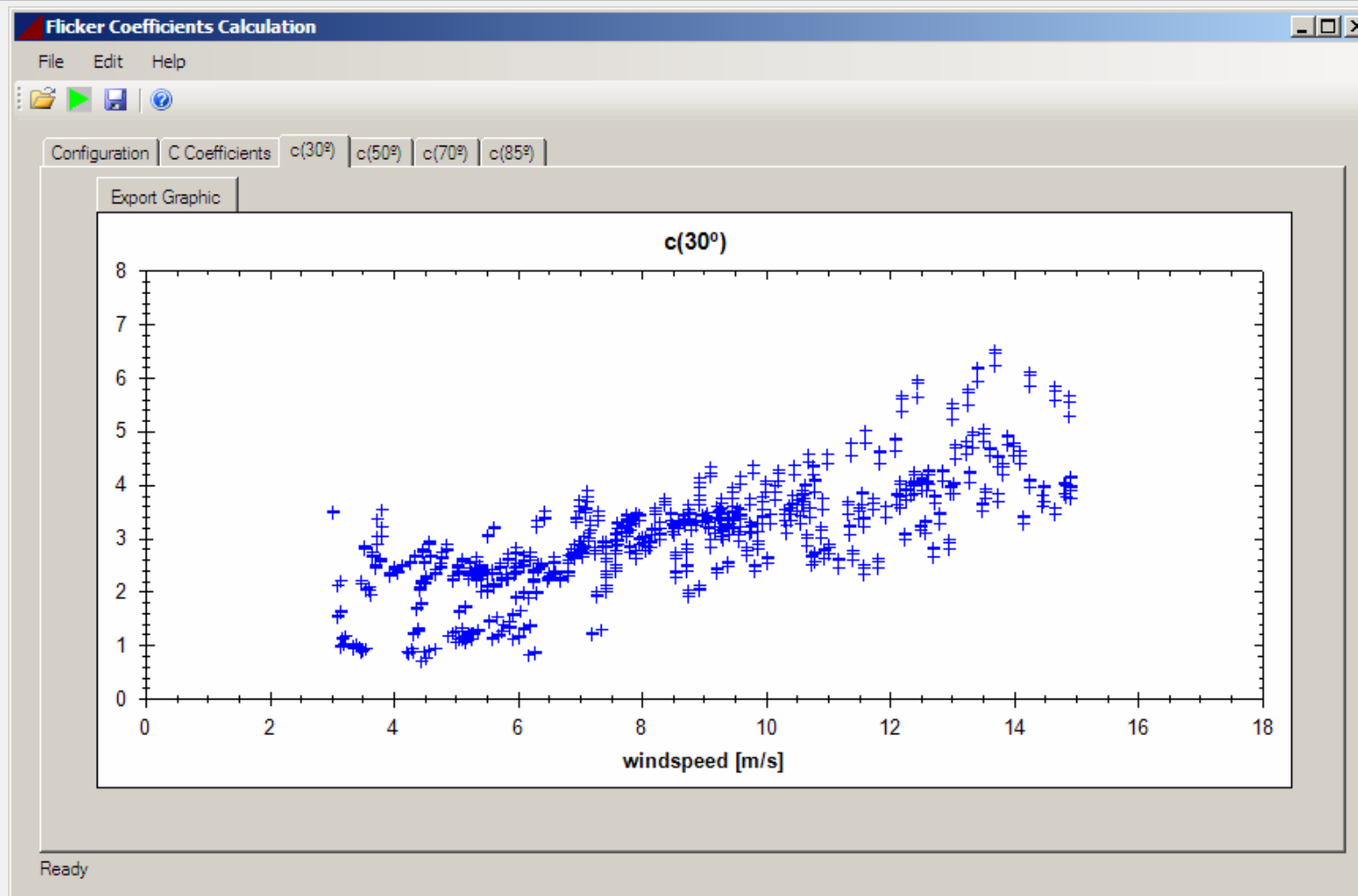
Ready

C coefficient table – from computation or loaded from existing file

Can be saved to csv-file or can be used to compute $c(\psi, v_a)$ coefficients.



9. IEC 61400-21 Toolbox – $c(\psi, v_a)$ 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

Configuration | Ku(ψ) | Kψ

Generator: Default

Select Measurements Files

Files Type: semicolon (1)

Compute k coefficients

Rated Values

Line Voltage: 20000 V

Power: 2000000 VA

Power Factor: 1 pu

Frequency: 50 Hz

Line To Line Measurements

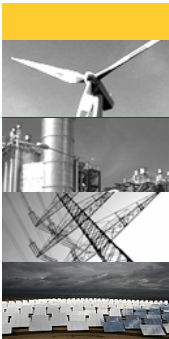
Flickemeter sampling rate: 800 Hz

SkFic: 10000000 VA

Ready

Characteristics:

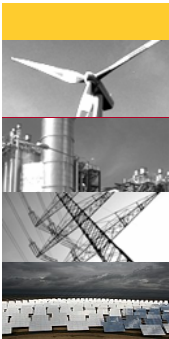
- IEC 61400-21 & IEC 61000-4-15
- K_u and k_ψ coefficients for single or multiple files
- Grid angle configurable
- Wind bins configurable
- Copy/paste graphics
- Export graphics to csv files
- Turbulence computation
- Computation of min, max and avg of k_u and k_ψ



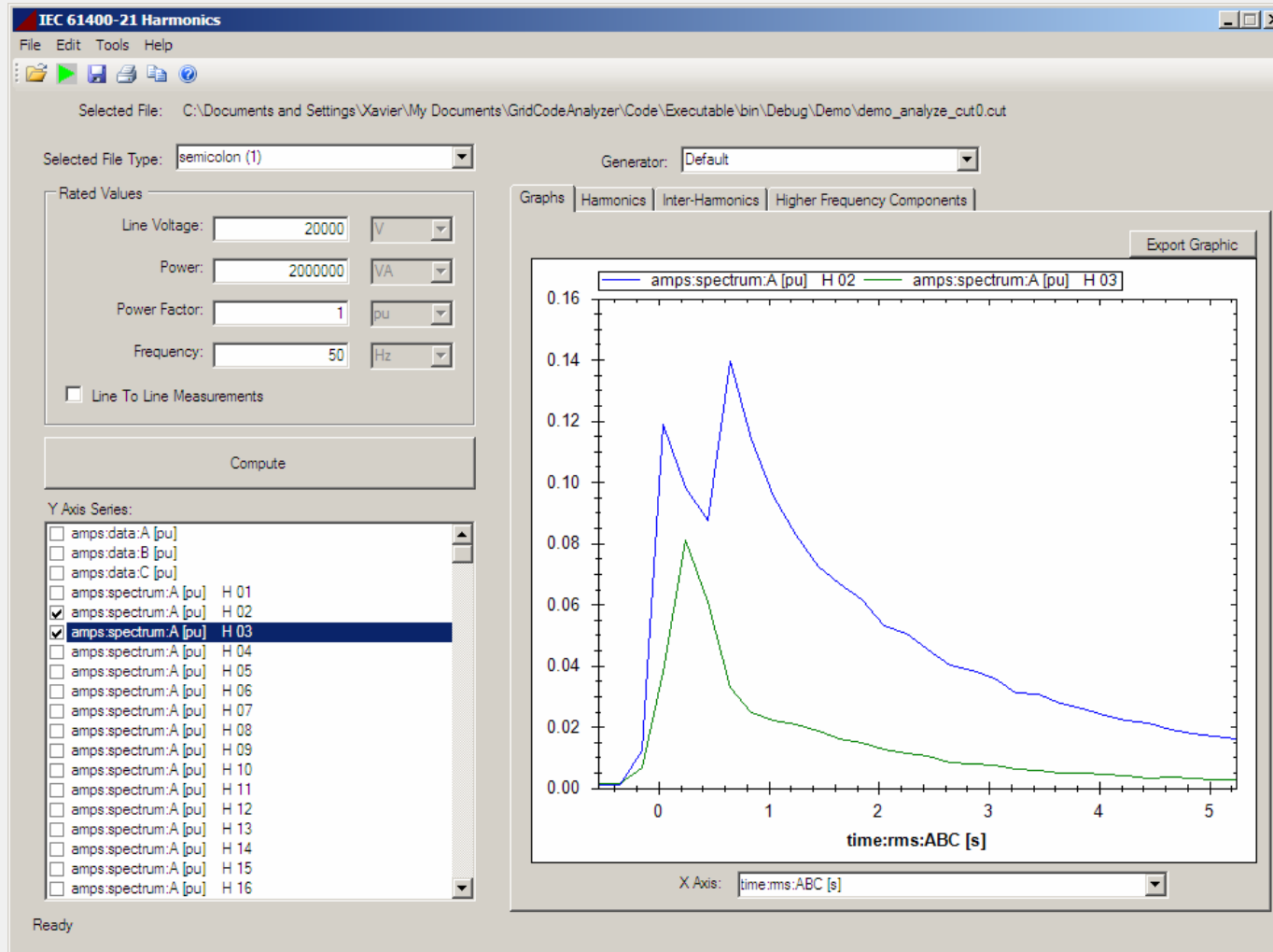
9. IEC 61400-21 Toolbox – Switching Operation

	Switching	Filename	Phase	Windbin	Windspeed	Turbulence	Ku_30	Ku_50	Ku_70	Ku_85
▶	<input type="checkbox"/>	C:\Documents a...	A	2	5.0	0.0	1.119	1.046	1.243	2.957
	<input type="checkbox"/>	C:\Documents a...	B	2	5.0	0.0	1.035	0.974	1.209	3.112
	<input type="checkbox"/>	C:\Documents a...	C	2	5.0	0.0	0.672	0.728	0.997	2.585
	<input type="checkbox"/>	Average	avg	0	0.0	0.0	0.942	0.916	1.150	2.885
	<input type="checkbox"/>	Maximum	max	0	0.0	0.0	1.119	1.046	1.243	3.112
	<input type="checkbox"/>	Minimum	min	0	0.0	0.0	0.672	0.728	0.997	2.585

Ku and k_{ψ} coefficients table

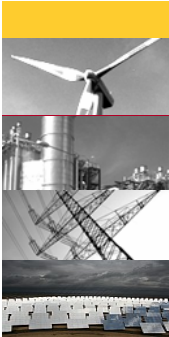


9. IEC 61400-21 Toolbox – Current Harmonics Emission

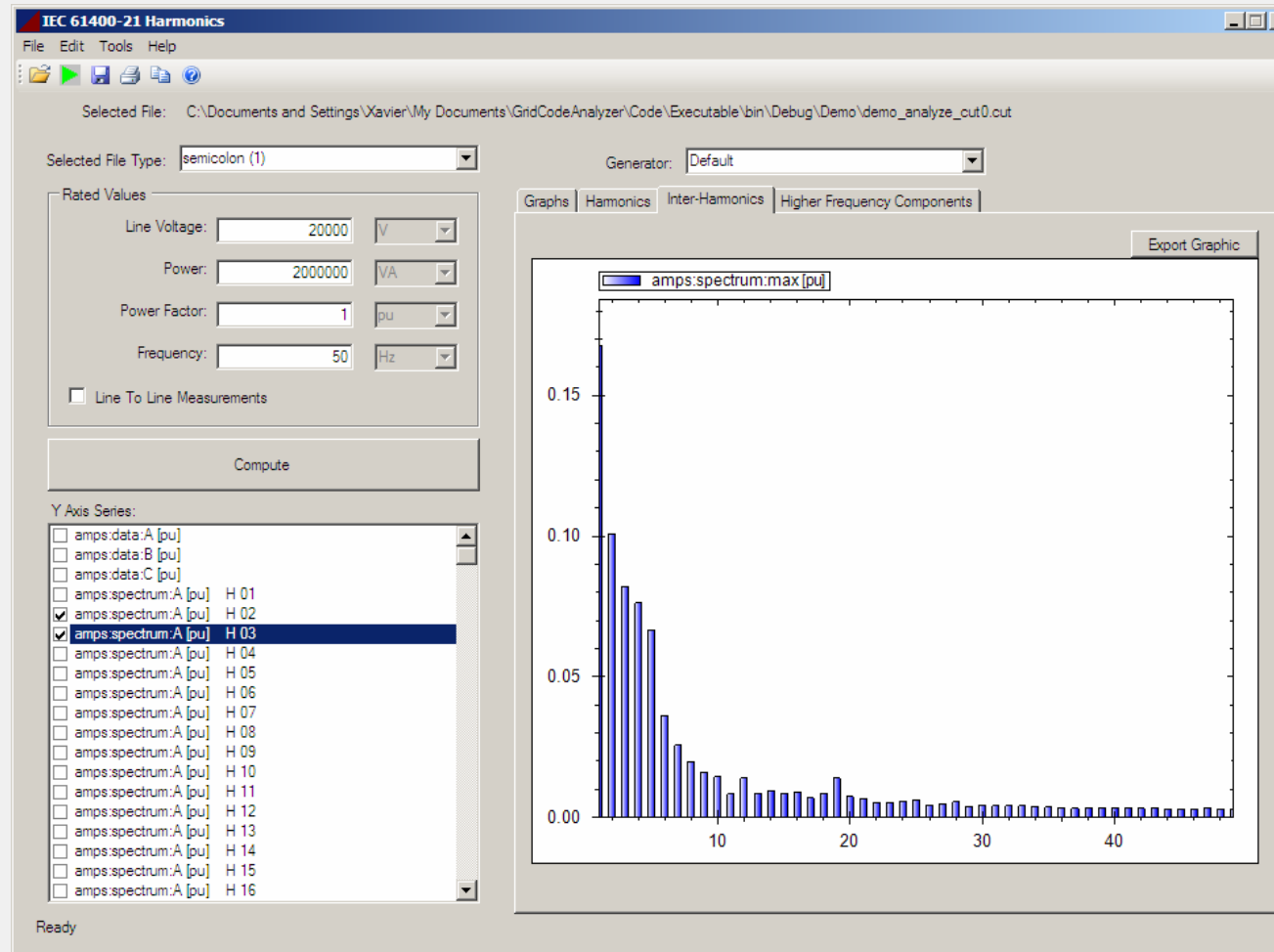


Characteristics:

- 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

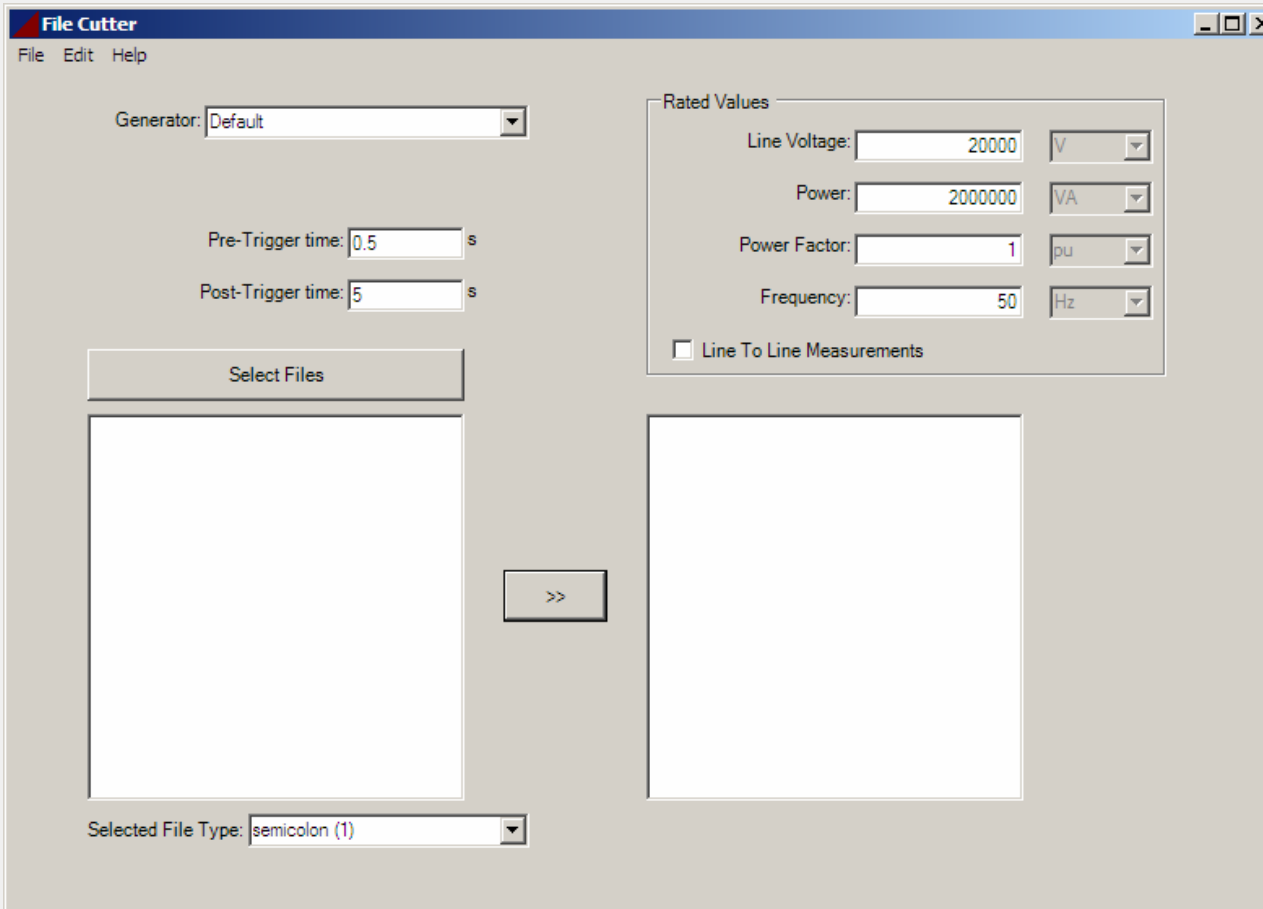


9. IEC 61400-21 Toolbox – Current Harmonics Emission



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

10. File Edition Tools – File Cutting

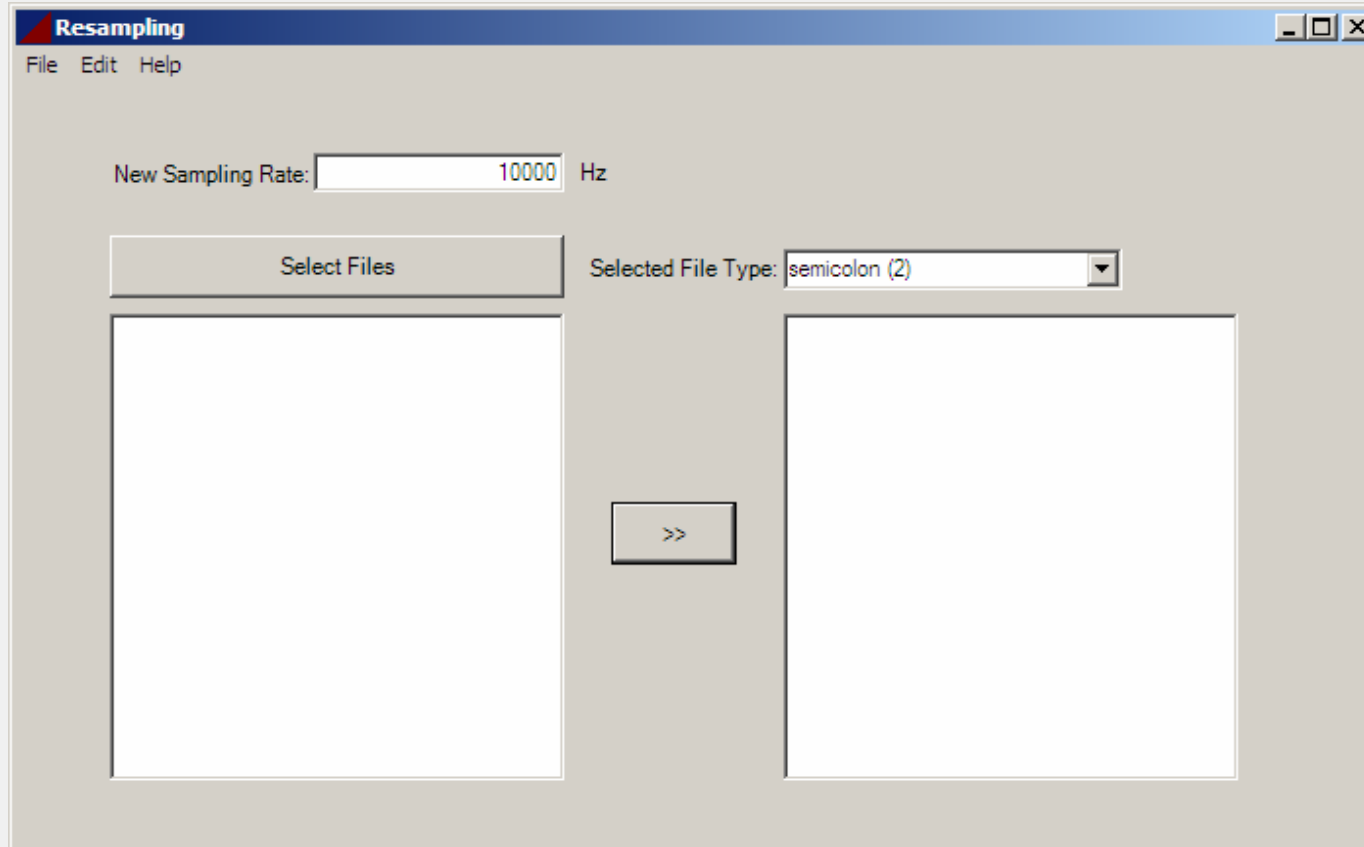


The screenshot shows the 'File Cutter' application window. It features a menu bar with 'File', 'Edit', and 'Help'. The main interface includes a 'Generator' dropdown menu set to 'Default'. Below this are input fields for 'Pre-Trigger time' (0.5 s) and 'Post-Trigger time' (5 s). A 'Select Files' button is positioned above a large empty list box. To the right, a 'Rated Values' section contains four rows of input fields: 'Line Voltage' (20000 V), 'Power' (2000000 VA), 'Power Factor' (1 pu), and 'Frequency' (50 Hz). A checkbox for 'Line To Line Measurements' is currently unchecked. A '>>' button is located between two large empty list boxes. At the bottom, a 'Selected File Type' dropdown menu is set to 'semicolon (1)'.

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

Merge Files

File Edit Help

Rated Values

Line Voltage: 20000 V

Power: 2000000 VA

Power Factor: 1 pu

Frequency: 50 Hz

Line To Line Measurements

Generator: Default

File 1: [] ... csv (1)

File 2: [] ... csv (1)

Merge

File 1: voltages and currents from an oscilloscope
File 2: pitch angle, wind speed, etc.

Ready

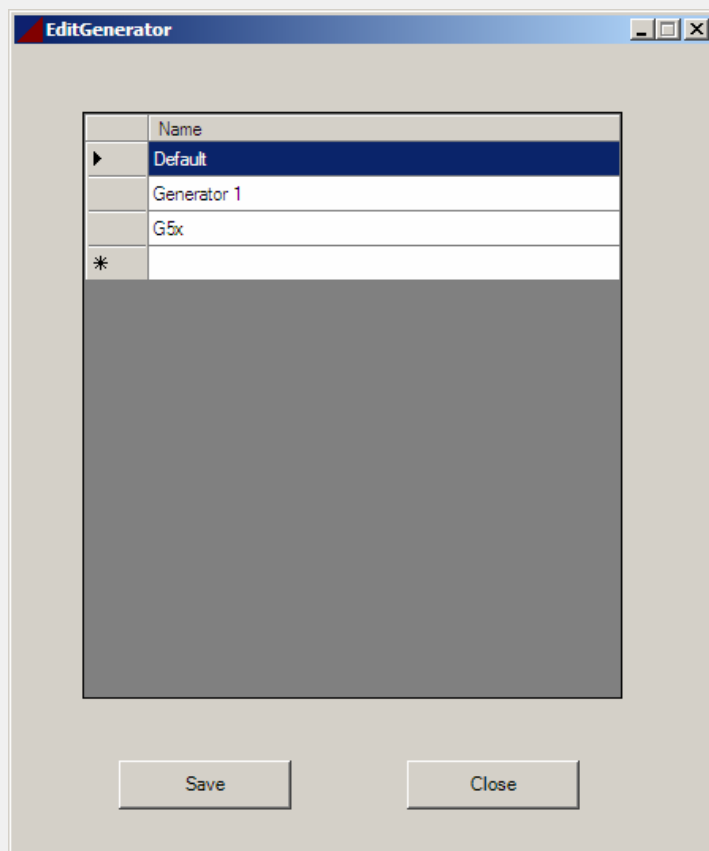
Characteristics:

- 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

