Free Simulation Tools for Power Quality and Grid-Integration of Renewable Energies Cases

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Abstract

The analysis of Power Quality issues and/or the integration of renewable energy into the grid requires the use of different tools, among which the use of computer simulation applications stands out. The basic objective is to obtain a model of the electrical system under study that allows for knowledge, with a reasonable degree of precision, of its behavior under different operating conditions. The benefits of these tools are manifold, since they allow us to understand the response of the system, both in transient and steady-state conditions, to situations that are difficult to reproduce in practice: short circuits, failures in generation, transmission and distribution infrastructures, etc. Additionally, these tools can be used as platforms for operator training and network planning. Currently, a wide variety of commercial tools that are de facto standards can be found on the market. Some of these tools have a high cost and cannot be used by students outside the academic environment. In parallel, and thanks to the efforts of the scientific community, simulation tools have been developed that are available free of cost under several licensing models. This contribution analyzes some of the available tools, with special attention to those that are published under several open source and academic non-commercial software licenses that are available to the academic community free of cost.

Introduction

The field of simulation of electric power systems is classical enough that there exists a significant set of bibliographic references. Below are provided some references that can help the reader to understand the fundamentals of simulating electric power systems, both in the time and frequency domain.

Time domain. [1, 2, 3, 4, 5]
Frequency domain. [4, 5]

Free Software

The following is a compilation of some of the tools available as free software. This list is not intended to be exhaustive. Web links to download pages and source code were last revised as of March 13, 2023.

MATPOWER
Website: https://matpower.org/
License: BSD (3-clause)
Source Code: https://github.com/MATPOWER/matpower

PYPOWER
Website: https://pypi.org/project/PYPOWER/
License: BSD
Source Code: https://github.com/rwl/PYPOWER

PSAT
Website: http://faraday1.ucd.ie/psat.html
License: GPL
Source Code: http://faraday1.ucd.ie/psat.html

OpenDSS
Website: https://www.epri.com/pages/sa/opendss
License: BSD
Source Code: https://sourceforge.net/p/electricdss/code/HEAD/tree/

PYPSA
Website: https://pypsa.org/
License: MIT
Source Code: https://github.com/PyPSA/

GridCal
Website: https://github.com/SanPen/GridCal
License: LGPL
Source Code: https://github.com/SanPen/GridCal

GridLab-D
Website: https://www.gridlabd.org/
License: Proprietary license (BSD-style)
Source Code: https://github.com/gridlab-d/gridlab-d

PandaPower
Website: https://www.pandapower.org/
License: BSD (3-clauses)
Source Code: https://github.com/e2nIEE/pandapower

ATP/EMTP
Website: https://atp-emtp.org/
License: Proprietary license
Source Code: Not available for general users

Conclusions

The simulation of electrical power systems is a mature discipline that has a large number of free simulation tools. Many of these tools are distributed under open software licenses as GPL, LGPL, BSD and MIT, so that it is possible for researchers to access the source code to study and modify it to suit their specific needs. In this article, several tools have been reviewed, comparing their characteristics, license type and source code availability. Table 1 summarizes this comparison.

Table 1: Comparison of Free Power System simulation tools (adapted from [6]).

	MATPOWER	PYPOWER◇	PSAT	OpenDSS	PyPSA	GridCal	GridLAB-D	pandapower	ATP/EMTP
Graphical User Interface			✓△	✓		✓			✓
Time-domain			✓						✓
Frequency domain	✓	✓	✓	✓	✓	✓	✓	✓	
Loads (constant Z, constant I, constant P)			✓	✓		✓	✓	✓	✓
Lines	✓	✓	✓	✓	✓	✓	✓	✓	✓
2-Winding Transformer (π model)	✓	✓	✓	✓	✓	✓	✓	✓	✓
2-Winding Transformer (T model)			✓	✓	✓		✓	✓	✓
3-Winding Transformer			✓	✓			✓	✓	✓
DC lines	✓		✓	✓	✓		✓	✓	✓
Ideal Switches			✓					✓	✓
Votage-controlled sources	✓	✓	✓	✓	✓	✓	✓	✓	✓
Static Load / Generation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Shunt impedance	✓	✓	✓	✓	✓	✓	✓	✓	✓
Asymmetrical Impedance			✓					✓	✓
Ward equivalent (Combination of impedance and PQ loads)			✓					✓	✓
Storage Units			✓	✓	✓	✓	✓		
Source code: Matlab	✓		✓				✓		
Source code: Python		✓			✓	✓	✓	✓	
Source code: Delphi				✓					
Source code: C and C++				✓		✓			
Source code: FORTRAN									✓
BSD License	✓	✓					✓	✓	
GPL			✓						
LGPL						✓			
MIT					✓				
Proprietary license				✓		✓			✓
SCOPUS references	471	11	2,132	639	33	-	179	42	2,110
IEEEXplore references	310	8	627	457	9	-	134	25	784

(◇) Python version of MATPOWER.
(△) GUI based on MATLAB & Simulink.

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