

PowerEdu.jl - A Julia Package for Teaching Power System Courses

Ninad Gaikwad, Aryan Jha, Sajjad Uddin Mahmud, Anamika Dubey, Noel Schulz, and Mani Venkatasubramanian
School of Electrical Engineering & Computer Science, Washington State University, Pullman, WA, USA
{ninad.gaikwad, aryan.jha, sajjaduddin.mahmud, anamika.dubey, noel.schulz, mani}@wsu.edu

Abstract—helloKitty! We introduce PowerEdu.jl, a beginner-friendly, open-source Power Systems package in the Julia programming language for enabling a broad yet quick overview of essential programming aspects required for analyses in multiple domains of Power Systems to budding power system engineers. This package covers Power Flow using Dense and Sparse Data Structures, Continuation Power Flow, State Estimation, Optimal Power Flow, Small-Signal Stability and Transient Stability Analysis. The package is scalable and user interactions with its component modules are highly customizable. In this paper, the main modules as part of the package have been described, including any special data structure implementations required for the same, and the available scope of customizing algorithms as per the user's needs.

Index Terms—Power System Analysis, Power System Dynamics, Power System Education, Julia, Open-Source Tools

I. INTRODUCTION

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed

diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

II. CONFERENCE PAPER PREPARATION

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim.

Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or section headings unless they are unavoidable.

B. Units

- Metric units are preferred for use in light of their global readership and the inherent convenience of these units in many fields. In particular, the use of the International System of Units (Système International d'Unités or SI Units) is advocated. This system includes a subsystem of units based on the meter, kilogram, second, and ampere (MKSA). U.S. Customary units, or British units, may be used as secondary units (in parentheses). An exception is when U.S. Customary units are used as identifiers in trade, such as 3.5-inch disk drive. The LaTeX package `siunitx` provides an excellent interface to deal with unit of measurements.
- Avoid combining SI and U.S. Customary units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
- Do not mix complete spellings and abbreviations of units: Wb/m² or *webers per square meter*, not *webers/m²*. Spell out units when they appear in text, e.g. *a few henries* and not *a few H*.
- Use a zero before decimal points: '0.25', not '.25'. Use 'cm3', not 'cc'.

C. Equations

Equations can be inserted as

$$y(x) = rx + i. \quad (1)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Refer to your equation as (1) and not as Eq. (1) or equation (1)¹. Both the `align` and `eqref` commands are part of the `amsmath` package, so make sure you have it installed in order to compile this code successfully.

In-line math is usually typed as $s = vt$.

D. Tables

An example is shown in Table I.

¹Except at the beginning of sentences.

TABLE I
THIS IS A TABLE.

One	Two
Three	Four

E. Figures

See the source code. Refer to figures as, for example, Fig. 1, even at the beginning of a sentence. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity *Magnetization*, or *Magnetization*, M , not just M . If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write *Magnetization (A/m)*, not just A/m . Do not label axes with a ratio of quantities and units. For example, write *Temperature (K)*, not *Temperature/K*.

F. References

References are important to the reader; therefore, each citation must be complete and correct. There is no editorial check on references; therefore, an incomplete or wrong reference will be published unless caught by a reviewer and will detract from the authority and value of the paper. References should be readily available publications. List only one reference per reference number. If a reference is available from two sources, each should be listed as a separate reference.

Unless there are six authors or more give all authors names; do not use 'et al.'. Papers that have not been published, even if they have been submitted for publication, should be cited as 'unpublished'. Capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation. Papers that have been accepted for publication, but not yet published, should be cited as 'in press'.

III. COMMON MISTAKES TO AVOID

- The word 'data' is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter o .
- In American English, commas, semi-colons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)

- A graph within a graph is an 'inset', not an 'insert'. The word alternatively is preferred to the word 'alternately' (unless you really mean something that alternates).
- Do not use the word 'essentially' to mean 'approximately' or 'effectively'.
- In your paper title, if the words 'that uses' can accurately replace the word 'using', capitalize the 'u'; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones 'affect' and 'effect', 'complement' and 'compliment', 'discreet' and 'discrete', 'principal' and 'principle'.
- Do not confuse 'imply' and 'infer'.
- The prefix 'non' is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the 'et' in the Latin abbreviation 'et al.'.
- The abbreviation 'i.e.' means 'that is', and the abbreviation 'e.g.' means 'for example'. [1], [2], [3], [4], [5]

REFERENCES

- [1] M. L. Crow, *Computational Methods for Electric Power Systems (Electric Power Engineering Series)*. Boca Raton, FL, USA: CRC Press, Jun. 2021. [Online]. Available: <https://www.amazon.com/Computational-Methods-Electric-Systems-Engineering/dp/1032098228>
- [2] "Nrel-sienna github.com," accessed: 2023-05-29. [Online]. Available: <https://github.com/NREL-Sienna>
- [3] J. J. Grainger and W. D. Stevenson Jr, *Power system analysis*. McGraw-Hill series in electrical and computer engineering, 1994.
- [4] "Nrel sienna," accessed: 2023-04-21. [Online]. Available: <https://www.eia.gov/consumption/>
- [5] P. S. Kundur, *Power System Stability and Control*. New York, NY, USA: McGraw Hill, Jan. 1994. [Online]. Available: <https://www.amazon.com/System-Stability-Control-Prabha-Kundur/dp/007035958X>