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

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***Abstract*—We introduce PowerEdu.jl, an open-source, beginner-friendly package in the Julia programming language designed for budding power system engineers. This package addresses the current gap in accessible and comprehensive tools for transmission network computations. PowerEdu.jl covers Power Flow using innovative dense and sparse data structures, Continuation Power Flow, State Estimation, Optimal Power Flow, Small-Signal Stability, and Transient Stability Analysis. Notably, the package is scalable, allowing for analysis of systems of varying sizes. User interaction with component modules is highly customizable; for example, users can opt to print detailed intermediary steps, such as Jacobians and mismatches, in Power Flow calculations. We use DataFrames for intuitive and visually appealing data representation. In this paper, we detail the key modules of PowerEdu.jl, elaborate on the special data structures implemented, and demonstrate the breadth and flexibility of algorithm customization available to users. Our package has been rigorously validated against established benchmarks, affirming its reliability and effectiveness as a powerful training tool for the next generation of power system engineers. Mention the network and key finding in one line.**

**Why Julia?**

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

## I. Introduction

Power System Analysis of transmission systems requires competencies in a variety of aspects. Power System Analysis, which has traditionally associated with quasi-steady state studies, encompasses aspects such as Power Flow, Continuation Power Flow, Economic Dispatch, Optimal Power Flow, State Estimation and so on. Each of these aspects requires a broad knowledge of Mathematics and Physics but also a wide variety of skillsets, including strong programming skills, in order to actually test novel algorithms and bringing essential control schemes to fruition. There can be a significant gap between understanding of the theory and actual implementation for Power System studies and day-to-day operation. Aspects like Sparse Power Flow which requires usage of special data structures of the same name especially highlight how actual implementation can vary from textbook algorithms, which are often written in pseudo code. While academic curricula and textbooks provide a strong foundation in theory, there remains a pressing need for practical tools that translate these theoretical underpinnings into tangible, implementable solutions. This gap becomes particularly evident when students or new professionals are tasked with the direct application of these theories in real-world scenarios. While various open-source packages exist to aid power system researchers, many are designed with a primary focus on delivering end results. These tools may not be as accommodating for newcomers who are eager to understand the underlying processes, delve deep into the intricacies of algorithms, or get their hands dirty with the code. Our software acknowledges this gap. Recognizing the educational journey many newcomers embark upon, we've crafted our package to not only deliver accurate results but also facilitate a deeper understanding. Users can easily access internal variables during iterative processes, something many other packages shield away. Furthermore, PowerEdu.jl stands out for its high level of customizability, allowing individuals to tinker, modify, and adapt algorithms to their specific needs. For those passionate about 'coding it up' and truly comprehending the nuts and bolts of power system analyses, our package offers a unique, hands-on experience. Our free and open-source package, PowerEdu.jl aims to serve as a bridge for budding power system engineers who may find the initial stages of coding and computational analysis challenging. By offering an accessible, well-documented and easy to tinker platform, we aim to narrow the gap between newcomers to the field and seasoned experts who have dedicated years at renowned national laboratories or corporations, developing sophisticated software tools utilized by the industry.

## II. Description of Modules

### *A. Sparse Power Flow*

For Transmission Networks, most of the commonly used data structures for analyses are sparse in nature, i.e. most of their elements are zero. Data Structures such as $Y_{Bus}$, Jacobian $J$, the LU Factors of the Jacobian $LU$ are sparse in nature. The sparsity only increases as the size of the system increases. ¡Insert some values of sparsity for different transmission systems¿. This sparsity can be exploited for faster computation and smaller data storage requirements, when performing analysis w.r.t. any aspect of Power Systems. For example, using taking advantage of the sparsity of the above mentioned data structures, along with other schemes such as parallel computation and Single Instruction Multiple Data (SIMD) operations, the authors of [1] were able to perform very fast Newton Raphson Power Flow for large transmission systems.

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### *B. 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.

### *C. 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 (Systeme Internationale d'Unites 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'.

### *D. Equations*

Equations can be inserted as

$$y(x) = rx + i. \tag{1}$$

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 $s = vt$.

### *E. Tables*

An example is shown in Table I.

TABLE I
THIS IS A TABLE.

| | |
|---|---|
| One | Two |
| Three | Four |

### *F. 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*.

### *G. 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

[1]Except at the beginning of sentences.

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 $\mu_0$, 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'. [2], [3], [4], [5], [6]

## References


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