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

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Abstract

Power systems are undergoing a paradigm shift in terms of their cyber-physical structure for attaining the goals of decarbonization, sustainability, resilience, reliability, and security. The conventional structure of the power system is being rapidly augmented with renewable energy sources like solar photovoltaics (PV), wind power, and utility-scale battery storage. Moreover, the once-passive consumers are transforming into active prosumers through having access to distributed energy resources like rooftop PV, battery units, and electric vehicles (as a result of good policy reforms by regulators) right at the location of otherwise traditional load centers. Lastly, the cyber layer for aiding communication between these new elements and the control centers is also going through a complete transformation. This added complexity has led to a need for the development of more complex tools for the design, analysis, control, and simulation of these modern power systems.

We perceive that the current transition phase of the power system should be paralleled with an equivalent transition in the training of next-generation power engineers at the university level in order to accelerate the momentum toward the ideal modern power system. Traditionally, the core power systems courses on analysis and dynamics have been taught with a good balance of conventional theory, demonstrations/training on proprietary software like MATPOWER, PSAT, PSSE, etc, and programming assignments to implement some/all parts of the theory. We submit to the teaching of conventional theory as it builds a strong foundation of the core concepts which can then be exploited to develop custom solutions to new problems. However, the reliance on proprietary software takes away the understanding of the nuances of the implementation of the theory, which impedes the development of new tools. Moreover; even though programming assignments helps one understand the nuances of implementation, the amount of effort required to develop I/O and visualization functionality is paramount lending to less time for core functionality development and testing of different algorithms within the span of a semester. Hence, there is a need for a power systems teaching tool to enhance the learning of the next-generation power system engineers which is not only good for in-class demonstrations but also provides building blocks for custom tool development, and a framework for rapid prototyping of new algorithms.

To address this gap, we propose a package, PowerEdu.jl, an open-source package written entirely in the Julia programming language. It implements the foundational building blocks of Power Systems analysis: Power Flow, Sparse Techniques in Power Flow, Continuation Power Flow, State Estimation, Optimal Power Flow, and dynamics: Small-Signal Stability Analysis, and Transient Analysis. While excellent packages for Power Systems, such as the cohort of packages from NREL-Sienna [1] initiative already exist in Julia, their primary objective is to develop a comprehensive toolkit based on advanced programming architecture for modeling and simulation of large-scale modern energy infrastructure in a scalable and computationally efficient manner; which positions them to cater to the use cases relevant to experienced researchers and industry experts in a better sense. On the other hand, our package has been developed for the purpose of training next-generation power engineers in a university setting so as to aid in the understanding of conventional algorithms through interactive scripts, and simplistic yet modular architecture promoting rapid prototyping and development of novel workflows and algorithms.

The architecture of the PowerEdu.jlis intentionally designed to be simple so as to keep the learning curve as flat as possible leading to easy comprehension of the code base and subsequent adoption. We provide parsers for IEEE CDF (Common Data Format) and CSV files for handling input data. We utilize simple Julia data structures of vectors, matrices, and data-frames throughout the entire package; and all the major functionalities are developed as highly versatile functions, which can work well for both beginners (no extra modification to function arguments, rather defaults take care of everything), as well as more experienced engineers (relevant arguments to modify the numerical and display behavior of the functions). Moreover, we dispense excellent visualization functionality for key inputs, intermediate variables, and results making debugging easy. The analysis and dynamics functionalities are developed as a reflection of standard power systems reference books: [2], [3], and [4]. Finally, to validate our package functionalities, we will compare them with the packages from NREL-Sienna for accuracy and computational efficiency. The comparison will be done across the standard IEEE test systems: 14-Bus, 30-Bus, 118-Bus, and the four machine-two area 11-Bus Kundur System.

Index Terms

Power System Analysis, Power System Dynamics, Power System Education, Julia, Open-Source Tools

References

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