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assetra: A Light-Weight Python Package for Resource Adequacy

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Summary

One of the imperatives of power system planners, operators, and regulators globally is to maximize power system reliability. As they modify existing practices for managing electrical grids in response to new technologies and climate change, reliability metrics benchmark and set targets for changing systems. Resource Adequacy (RA) refers to a set of reliability metrics that characterize the likelihood, frequency, and magnitude of "shortfall events", or instances when demand exceeds available supply. RA analyses typically simulate the availability of generators across a range of operating conditions, and compare time series of available capacity against expected electrical demand. Researchers and practitioners need light-weight, flexible tools to incorporate RA within their analytical frameworks. The ASSET Lab resource adequacy package (`assetra`) is an easy-to-use and extensible Python package that offers a concise and intuitive interface for constructing representations of energy systems, running probabilistic simulations, and evaluating a number of common resource adequacy metrics. Additionally, `assetra` implements the effective load-carrying capability metric, which estimates the resource adequacy contributions of new resources to an energy system. With these features, `assetra` offers researchers and practitioners a tool for maintaining system reliability while advancing decarbonization and climate adaptation.

Statement of Need

As electrification, the transition to low-carbon energy sources, and changes in weather patterns from climate change occur simultaneously, understanding the changing resource adequacy of the electricity grid is vital (Sundar et al., 2023). The `assetra` package contributes to this growing area of research by offering an easy-to-use and extensible Python package that offers a concise and intuitive interface for constructing representations of energy units and systems, running probabilistic simulations, and evaluating a number of common resource adequacy metrics. Our methodology reflects a tighter coupling between resource adequacy and meteorological modeling, and the need for tools that cater to interdisciplinary researchers (Craig et al., 2022). Existing open-source RA packages include the Probabilistic Resource Adequacy Suite (PRAS), ProGRESS, and GridPath. PRAS, written in Julia, offers a sequential Monte Carlo simulation framework that includes approximations for inter-regional transmission and energy storage (Stephen, 2021). ProGRESS, written in Python, offers advanced modeling of energy storage devices within its probabilistic simulation framework (*Probabilistic Grid Reliability Analysis with Energy Storage Systems (ProGRESS)*, 2025). GridPath, also written in Python, embeds RA within a larger modeling framework that includes RA, capacity expansion, production cost, and asset valuation (*GridPath*, 2025).

The key features which differentiate assetra from existing RA packages are the following:

- We define concise base classes to enable efficient development of custom technologies and resource adequacy metrics.
- We use Xarray data structures for all input and internal data structures.
- We provide an interface for time-varying forced outage rates, which, coupled with weather data, can be used to capture temperature-dependent forced outage rates.

In an evolving power system, quantifying resource adequacy, including tail risks and uncertainty, is vital (*Resource Adequacy Assessment Tool Guide*, 2024). This process requires a highly interpretable methodology that enables researchers to analyze detailed statistics across numerous simulations. assetra stores simulation results for a researcher-specified sample of Monte Carlo trials in Xarray. Xarray organizes these results into data structures indexed by trial number and pandas datetime objects, thereby facilitating the interpretation of patterns in resource adequacy failures. Xarray was developed for use in the meteorological community, and allows for easy integration of climate data into assetra simulations (*Xarray*, 2025). Its capabilities in lazy loading and efficient memory handling minimize memory overhead, enabling the processing of hundreds of simulations with hourly weather data. assetra also leverages Xarray's in-place operations to compute standard resource adequacy metrics for basic users, while providing researchers and developers with the flexibility to explore risks and uncertainties through more innovative approaches.

Resource adequacy modeling is often complex, computationally challenging, and lacks flexibility (*Redefining Resource Adequacy for Modern Power Systems*, 2020) (*New Resource Adequacy Criteria for the Energy Transition*, 2024). However, increasing levels of wind, solar, and storage technologies, along with evolving demand patterns, mean that our resource adequacy models must capture the reliability contributions of a diverse array of resources (*Redefining Resource Adequacy for Modern Power Systems*, 2020). The assetra package employs a bottom-up approach to understanding resource adequacy, beginning with the individual EnergyUnit objects that constitute the system. assetra EnergyUnits operate with time-varying capacity availability based on given weather profiles. Researchers can define generators in assetra with a nameplate capacity, an array of hourly maximum capacities, and a parallel array of hourly forced outage rates. Simple abstract base classes and class interfaces streamline data management complexity and enable customization to address specific research questions. The incorporated StochasticUnit and StaticUnit offer versatility to represent any generation technology, from data centers utilizing demand response programs to large wind farms. The StorageUnit and HydroUnit serve as heuristic-based units that respond to system net capacity, enabling researchers to explore how modifications to standard behaviors of these units could impact future reliability. Our object-oriented approach grants researchers the flexibility to customize specific aspects of their resource adequacy testing, such as adding new EnergyUnits or modifying probabilistic simulation methods, without needing to duplicate or alter the existing framework.

The assetra package also provides a method for quantifying the effective load-carrying capacity of potential investments on resource adequacy. assetra iteratively evaluates the amount of load a new resource can serve while maintaining the reliability level of a base system, by storing and re-using probabilistic simulation data. Efficiently calculating reliability contributions of potential investments enables researchers to broaden the scope of their analyses (Bromley-Dulfano et al., 2021). The provided framework can be customized to evaluate user-defined resource adequacy metrics or assess the reliability contributions of multiple, simultaneous investments.

By prioritizing simplicity and accessibility, the assetra package aims to redirect the focus of energy researchers to addressing policy and climate outcomes. Currently, researchers in the ASSET Lab are using assetra to model climate change impacts on reliability in the Western United States, incorporating aspects of resource adequacy into capacity expansion planning, and testing the resource adequacy benefit of building adaptation strategies in a regional context. In future versions of `assetra`, we hope to integrate multi-region transmission, parallelization, and additional outage simulators. By offering a flexible and lightweight object-oriented framework, `assetra` empowers researchers to model resource adequacy with ease and clarity, accommodating unique research needs through straight-forward customization and integration. Whether addressing the challenges of novel methods or enhancing existing analysis frameworks, `assetra` provides a powerful tool for understanding the impacts of climate change and future investments on power system reliability.

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