SLR for: Advancements in Renewable Energy

Paper 1

Title: Towards Scalable FMI-based Co-simulation of Wind Energy Systems Using PowerFactory **Authors:** Arjen A van der Meer, Rishabh Bhandia, Edmund Widl, Kai Heussen, Cornelius Steinbrink, Przemyslaw Chodura, Thomas I. Strasser, Peter Palensky **Published:** 2023-09-27T15:33:04Z **Link:** http://arxiv.org/abs/2309.15727v1 **Abstract:** Due to the increased deployment of renewable energy sources and intelligent components the electric power system will exhibit a large degree of heterogeneity, which requires inclusive and multi-disciplinary system assessment. The concept of co-simulation is a very attractive option to achieve this; each domain-specific subsystem can be addressed via its own specialized simulation tool. The applicability, however, depends on aspects like standardised interfaces, automated case creation, initialisation, and the scalability of the co-simulation itself. This work deals with the inclusion of the Functional Mock-up Interface for co-simulation into the DIgSILENT PowerFactory simulator, and tests its accuracy, implementation, and scalability for the grid connection study of a wind power plant. The coupling between the RMS mode of PowerFactory and MATLAB/Simulink in a standardised manner is shown. This approach allows a straightforward inclusion of black-boxed modelling, is easily scalable in size, quantity, and component type. **Overview:** The paper discusses the challenges and solutions for conducting scalable co-simulations of wind energy systems using DIgSILENT PowerFactory and the Functional Mock-up Interface (FMI). Due to the complexities brought about by increased renewable energy sources and smart components, modern power systems require multi-disciplinary assessment methods. Co-simulation offers a way to integrate specialized simulation tools for different subsystems, but this approach requires standardized interfaces and scalability.

The authors focus on incorporating FMI into PowerFactory to enhance the co-simulation process. They test this integration's efficacy, accuracy, and scalability for studying the grid connection of wind power plants. A standardized coupling between PowerFactory's RMS mode and MATLAB/Simulink is demonstrated, facilitating the inclusion of black-box models and allowing significant scalability in terms of system size, component quantity, and type.

The paper highlights the transition from traditional fossil-fueled power systems to modern grids dominated by inverter-controlled dynamics, which necessitates new simulation approaches. These approaches include advanced hardware-in-the-loop (HIL) testing and lab-based assessments, supported by initiatives like the European ERIGrid project that aim to comprehensively test and validate components and subsystems as the energy sector evolves.

Paper 2

Title: Wind energy potential of Germany - Limits and consequences of large-scale wind energy use **Authors:** Axel Kleidon **Published:** 2023-04-27T12:59:15Z **Link:** http://arxiv.org/abs/2304.14159v1 **Abstract:** The transition of our energy system to renewable energies is necessary in order not to heat up the climate any further and to achieve climate neutrality. The use of wind energy plays an important role in this transition in Germany. But how much wind energy can be used and what are the possible consequences for the atmosphere if more and more wind energy is used? **Overview:** The paper "Wind energy potential of Germany: Limits and consequences of large-scale wind energy use" by Axel Kleidon explores the potential and implications of expanding wind energy in Germany as part of the country's transition to a climate-neutral energy system by 2050. The German government plans to allocate 2% of the land for wind energy expansion, aiming for an installed capacity of 150-200 gigawatts, contributing an estimated 330-770 TWh annually. By comparison, at the end of 2021, Germany had 56 GW of wind capacity across 28,230 turbines, generating 90.3 TWh annually and accounting for nearly 16% of the nation's electricity output.

The study goes beyond technical possibilities, analyzing the atmospheric physics relevant to wind energy extraction. In Germany, wind turbines harness energy from large-scale atmospheric circulation linked to global pressure systems caused by unequal solar heating. This process is part of a thermodynamic heat engine driven by temperature and air pressure differences. The kinetic energy available from this atmosphere-driven process can be estimated using thermodynamics principles. Ultimately, the paper assesses how increased wind energy extraction might affect atmospheric conditions and the implications for sustainable energy conversion and climate goals.

Paper 3

Title: Machine Learning of Public Sentiments toward Wind Energy in Norway **Authors:** Oskar VÃ¥gerÃ¶, Anders BrÃ¥te, Alexandra Wittemann, Jessica Yarin Robinson, Natalia Sirotko-Sibirskaya, Marianne Zeyringer **Published:** 2023-04-05T12:03:57Z **Link:** http://arxiv.org/abs/2304.02388v1 **Abstract:** Across Europe negative public opinion has and may continue to limit the deployment of renewable energy infrastructure required for the transition to net-zero energy systems. Understanding public sentiment and its spatio-temporal variations is as such important for decision-making and socially accepted energy systems. In this study, we apply a sentiment classification model based on a machine learning framework for natural language processing,

NorBERT, on data collected from Twitter between 2006 and 2022 to analyse the case of wind power opposition in Norway. From the 68828 tweets with geospatial information, we show how discussions about wind power intensified in 2018/2019 together with a trend of more negative tweets up until 2020, both on a regional level and for Norway as a whole. Furthermore, we find weak geographical clustering in our data, indicating that discussions are country wide and not dominated by specific regional events or developments. Twitter data allows for detailed insight into the temporal nature of public sentiments and extending this research to additional case studies of technologies, countries and sources of data (e.g. newspapers, other social media) may prove important to complement traditional survey research and the understanding of public sentiment. **Overview:** The study "Machine Learning of Public Sentiments Toward Wind Energy in Norway" explores the public sentiment surrounding wind power in Norway, using machine learning techniques. The researchers employed a sentiment classification model utilizing NorBERT, a natural language processing framework, to analyze tweets from 2006 to 2022. They sought to understand the temporal and spatial variations in public opinion, especially given that negative sentiment can hinder the deployment of renewable energy infrastructure necessary for a net-zero energy transition. From analyzing 68,828 geolocated tweets, the study found increased discussions and negative sentiment about wind power peaking in 2018/2019, with trends continuing until 2020. The sentiment was found to have weak geographical clustering, suggesting broad nationwide engagement rather than being confined to specific regions. The research highlights Twitter as a valuable real-time source for understanding public sentiments and suggests that additional data from other social media or newspapers could further enhance the insights, complementing traditional survey methods. The study underscores the significance of understanding public acceptance of wind energy, which varies due to multiple factors such as proximity to wind farms and ecological impacts, reflecting a need for more cross-country studies to better grasp these dynamics.
