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 in co-simulating wind energy systems within the context of modern and future electric power grids, which are increasingly heterogeneous and complex due to the integration of renewable energy sources and intelligent components. Co-simulation offers a promising approach for the multi-disciplinary assessment of such systems, allowing different domain-specific subsystems to be simulated using specialized tools. To make co-simulation effective, factors like standardized interfaces, automated case creation, initialization, and scalability must be addressed.

The authors investigate the integration of the Functional Mock-up Interface (FMI) for co-simulation into the DIgSILENT PowerFactory simulator and test its accuracy, implementation, and scalability with a focus on grid connection studies of wind power plants. They demonstrate a standardized coupling between PowerFactory's RMS mode and MATLAB/Simulink, enabling the incorporation of black-box models in a scalable manner across size, quantity, and component types.

The paper highlights the significant shift in power systems from predominantly physical systems to those dominated by controlled inverter dynamics, necessitating new types of behavior simulations. The transition demands comprehensive simulation studies and advanced testing (like hardware-in-the-loop) to properly assess the grid integration of renewables and support the deployment of smart grid technologies. The European ERIGrid project is mentioned as an effort to develop holistic methods for testing and validating power system components and subsystems. Traditional simulation approaches that simplify subsystems for transient stability analysis are becoming insufficient for future power systems, which require more detailed modeling reflecting device and control interactions.

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 transition to renewable energy in Germany, especially through wind energy, is critical for achieving climate neutrality by 2050. The German government aims to allocate 2% of the countryâ€™s land for wind energy, potentially resulting in 150-200 gigawatts of installed capacity, contributing 330-770 terawatt-hours annually to electricity generation. Currently, only 56 gigawatts of capacity exist across 28,230 turbines, producing 90.3 terawatt-hours annually and fulfilling just under 16% of the national electricity needs as of 2021.

A significant increase in wind energy installation is required to meet the climate goals. This paper, authored by Axel Kleidon, explores the potential and limitations of wind energy usage in Germany, focusing on atmospheric physics and the impact of energy extraction from wind. Germany's wind turbines primarily harness large-scale winds generated by atmospheric pressure systems linked to planetary solar radiation differences.

The atmospheric circulation, driven by these differences, leads to movement and distribution of air masses, which dissipates potential energy, transports heat, and balances solar heating disparities. Wind energy comes from this kinetic energy, which is produced in a natural conversion chain starting with solar energy. Understanding this thermodynamic process allows for estimating the power of large-scale atmospheric circulation and its potential for wind energy production. The discussion emphasizes the importance of considering atmospheric dynamics when planning large-scale wind energy use in Germany.

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:** This study investigates public sentiment toward wind energy in Norway using machine learning and natural language processing, specifically applying the NorBERT model to analyze Twitter data from 2006 to 2022. The study is motivated by the role of public opinion in the deployment of renewable energy infrastructure necessary for achieving net-zero energy systems in Europe. The research observes that discussions about wind power intensified around 2018/2019, with a trend towards more negative sentiments peaking around 2020. Interestingly, the analysis reveals weak geographical clustering of sentiments, suggesting widespread discussions across Norway not limited to specific regional events. By leveraging Twitter data, this research offers detailed insights into the temporal aspects of public sentiments and indicates the potential benefits of similar studies across different technologies, countries, and data sources, such as newspapers or other social media, to enhance traditional survey approaches in understanding public opinion. This work underscores the need for a more nuanced comprehension of the spatial and temporal dynamics influencing public acceptance of wind energy.
