Bachelor's Thesis Proposal

Wind Power Generation Forecasting Using Transformer-based Time Series Models

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1 General and Specific Objectives

1.1 General Objective

The objective of this research is to develop and evaluate a Transformer-based model for forecasting wind power generation using historical time series data. The model will be applied to a case study using wind power generation data from Spain, and its performance will be compared against other state-of-the-art forecasting techniques to assess its accuracy and effectiveness

1.2 Specific Objectives

- To conduct a literature review on time series forecasting models, with a focus on Transformer-based architectures and their applications in wind power generation.
- To collect and preprocess historical wind power generation data from Spain, ensuring data quality and preparing it for model training and evaluation.
- To implement Transformer-based models for wind energy generation prediction and evaluate its performance using established metrics for time series forecasting.
- To compare the forecasting performance of the Transformer-based model with other state-of-the-art techniques, identifying the strengths and limitations of the proposed approach.

2 Motivation

Wind energy is one of the most promising and fastest-growing renewable energy sources worldwide. According to the International Renewable Energy Agency (IRENA), the installed capacity of wind energy has significantly increased in recent decades and is expected to remain an important component in the transition towards a more sustainable energy system, reducing reliance on fossil fuels [IRENA, 2023]. However, wind energy generation is inherently variable, heavily influenced by meteorological factors that are challenging to predict with high accuracy. This variability creates difficulties in integrating wind energy into the power grid, as inaccurate forecasts can lead to grid stability issues and increased operational costs. Consequently, enhancing the accuracy of wind power predictions is required for more efficient power system planning and operation.

In this context, various forecasting strategies have been proposed, ranging from traditional statistical models, such as AutoRegressive Integrated Moving Average (ARIMA), to more advanced deep learning approaches, including recurrent neural networks (RNNs) and long short-term memory (LSTM) networks. While these methods have shown some success in capturing the temporal dependencies in wind power generation, they often face limitations. Traditional models like ARIMA struggle with non-linear patterns and long-term dependencies, while RNNs and LSTMs, though more adept at handling sequential data, can suffer from vanishing gradient problems and high computational costs as the sequence length increases. To address these challenges, Transformer-based models have emerged as a powerful alternative. Transformers leverage self-attention mechanisms, allowing them to capture long-range dependencies more effectively and parallelize computations, which leads to faster training times and improved accuracy [Brownlee, 2020].

In recent years, various studies worldwide have utilized Transformer-based models to refine the prediction of meteorological variables and energy-related outputs. For instance, Wu et al. (2022) proposed a multistep wind speed prediction model using a transformer architecture, which significantly outperformed traditional models across various time horizons [Huijuan Wu, 2022]. Additionally, Ziyabari et al. (2022) introduced a self-attentive transformer for short-term solar irradiance forecasting, demonstrating the model's ability to retain historical information over long sequences without the risk of vanishing gradients, thereby enhancing both solar and wind energy forecasting applications [Saeedeh Ziyabari, 2022]. Furthermore, L'Heureux et al. (2022) applied transformer-based models to electrical load forecasting, showing improved performance in capturing temporal dependencies, which further supports the use of these models in renewable energy forecasting [Alexandra L'Heureux, 2022]. In line with this growing body of research, the present thesis aims to develop and evaluate a Transformer-based model for wind power generation forecasting using historical data from Spain. By building upon the strengths of Transformer architectures, this work seeks to enhance the accuracy of wind energy predictions, addressing the limitations of traditional methods and contributing to more reliable integration of wind energy into the power grid.

3 Proposed Methodology

The methodology of this Bachelor's Thesis is structured into several stages to achieve the proposed objectives. First, a comprehensive review of the state of the art in Transformer models will be conducted, with a particular focus on their application to wind power time series forecasting. Following this, historical wind power generation data from Spain will be gathered by evaluating various official sources and online repositories to ensure a reliable dataset for the prediction task. Next, a thorough data preprocessing stage will be carried out to clean, and prepare the data for modeling. Once the data is preprocessed, Transformer models will be implemented to forecast wind power generation. Finally, the model's performance will be evaluated using standard time series forecasting metrics, and the results will be compared with other state-of-the-art techniques, such as RNN-based models, to assess the advantages and limitations of the proposed approach.

4 Proposed Table of Contents

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