MULTIVARIATE TIME SERIES ANALYSIS OF SOLAR IRRADIANCE FOR PHOTOVOLTAIC SYSTEMS THE HYBRIDIZATION OF NARX AND LSTM MODELS

OSAMA GAMAL MAHMOUD IBRAHIM MOTIR

UNIVERSITI TEKNOLOGI MALAYSIA

CHAPTER 5

CONCLUSION

5.1 Summary

This study has significantly contributed to advancing the understanding and methodologies in the domain of solar irradiance forecasting. The research began with an in-depth analysis of key meteorological factors, including wind direction, and their influence on predictive models. These findings highlighted the importance of selecting appropriate features to achieve high accuracy in solar irradiance predictions. The rigorous optimization of the NARX and LSTM models through hyperparameter tuning culminated in the development of a robust hybrid NARX-LSTM model. This hybrid model emerged as a superior forecasting tool, consistently outperforming standalone NARX and LSTM models across various weather conditions.

The hybrid model's robustness and adaptability were demonstrated by its ability to achieve lower normalized Root Mean Square Error (nRMSE) values under diverse scenarios. These results underscore its potential as a reliable solution for accurate solar irradiance forecasting, particularly in addressing the challenges posed by varying meteorological conditions. Furthermore, the findings reinforce the relevance of hybrid modeling approaches in enhancing prediction accuracy, paving the way for their integration into real-world energy management systems and grid stability frameworks.

5.2 Future Work

While this study has advanced the application of hybrid NARX and LSTM models for solar irradiance forecasting, it also paves the way for numerous exciting research opportunities. Future studies could delve into the exploration of other sophisticated machine learning techniques. While the current hybrid model shows promise, investigating the potential of models such as gated recurrent units (GRUs) or advanced ensemble methods could offer improvements in prediction accuracy and reliability.

Expanding the dataset is an essential step for future work. The efficacy of machine learning models is highly dependent on the diversity and quality of the data. Incorporating solar irradiance data from a wider array of geographic locations, including varied topographies and climates, would undoubtedly bolster the model's predictive power and its ability to generalize across different environments.

The concept of a multi-model ensemble system also presents an intriguing avenue for future research. Such a system could combine various models, including but not limited to, decision trees, support vector machines, and newer forms of neural networks, each specializing in different aspects of the forecasting task. The ensemble approach could mitigate individual model biases and errors, potentially leading to a consensus prediction that is more accurate and reliable than any single model output.

In terms of model interpretability, future work could apply methods like Layer-wise Relevance Propagation (LRP) or SHapley Additive exPlanations (SHAP) to decompose model predictions into contributions from each input feature. These methods can provide insights into the causal relationships within the data and help validate the model against established physical principles of solar irradiance

Lastly, with the advent of smart grid technologies, there is an opportunity to integrate predictive models directly into energy management systems. Future research could focus on real-time adaptive models that work in tandem with smart grids to optimize energy distribution based on predicted solar irradiance, thereby enhancing the efficiency and sustainability of solar energy utilization.

The roadmap for future work is as vast as it is vital, with each step bringing us closer to more sustainable and efficient solar energy management systems.