Guest Editorial

Artificial intelligence-empowered reliable forecasting for energy sectors

Mahmoud, Karar; Guerrero, Josep M.; Abdel-Nasser, Mohamed; Yorino, Naoto

Published in:
IET Generation, Transmission and Distribution

DOI (link to publication from Publisher):
10.1049/gtd2.13130

Publication date:
2024

Document Version
Publisher's PDF, also known as Version of record

Received: 25 January 2024 | Revised: 29 January 2024 | Accepted: 29 January 2024

IET Generation, Transmission & Distribution

DOI: 10.1049/gtd2.13130

The Institution of Engineering and Technology WILEY

GUEST EDITORIAL

Guest Editorial: Artificial intelligence-empowered reliable forecasting for energy sectors

1 | INTRODUCTION

Recently, there has been a dramatic increase in the deployment of diverse types of intermittent renewable energy sources (RES), leading to significant energy supply variability. It should be emphasized that the characteristics of RES can provide several obstacles to integrating large-scale renewables in transmission systems (TS) and a significant number of dispersed renewables in distribution networks. Besides, electricity demand also has a considerably fluctuating nature, which is expected to be more challenging with the continued electrification of energy demand for heating and transport, besides the power-to-gas coupling. Accordingly, this is a global trend towards coupling energy sectors to provide more flexibility and regularity options.

In this context, reliable forecasting is an essential tool for system operators to ensure the safe and optimal operation of the energy sectors. This ambitious target can be achieved by improving the dependability and precision of forecasting methodologies required while considering data uncertainty. In this regard, Artificial Intelligence (AI) and machine learning have shown powerful prediction capabilities. This Special Issue intends to cover the most recent advances in the forecasting task in energy sectors (generation, demand, energy prices etc.) through the empowerment of AI.

1.1 | Papers in the special issue

In this Special Issue, we have received 16 papers that have been subjected to peer-review. Of the 16 originally submitted papers, 7 papers have been accepted, which were of high quality and have contributed to the success of this Special Issue. In turn, 9 papers have been rejected, withdrawn, or referred to other related journals. The accepted papers address the following key areas:

'A Hybrid Prediction Method for Short-Term Load Based on Temporal Convolutional Networks and Attentional Mechanisms': This paper proposes a new short-term power load hybrid forecasting model, called channel enhanced attention (CEA) and temporal convolutional network (TCN) based transformer comprehensive forecasting model. This method combines the short-term feature extraction ability of TCN with the long-term dependent capture ability of the Transformer for short-term load forecasting (LF). The CEA designed in this study is added to improve the prediction accuracy. On the same dataset, the designed model predicts power load mean square error of 0.056 and 0.146 for the next 24 h and the next week, respectively, which is 0.002 to 0.073 and 0.012 to 0.024 lower than the baseline model. The experimental results show that the hybrid short-term power load prediction model proposed in this paper is significantly better than the existing methods. The predicted curve is in agreement with the actual charge change, which provides good guidance for short-term power load prediction.

'Gaussian Process Regression-Based Load Forecasting Model': In this paper, Gaussian Process Regression (GPR)-based models that use the Bayesian approach to the regression analysis problem such as load forecasting (LF) are proposed. The GPR is a non-parametric kernel-based learning method that has the ability to provide correct predictions with uncertainty in measurements. The proposed model provides an hourly and monthly load forecast for an Australian city and four Indian cities in Maharashtra State. Twelve GPR models are trained with historical datasets including hourly load and environmental data. To evaluate the trained model, the actual and predicted load demand curve is plotted and mean average percentage error (MAPE) is calculated corresponding to different kernel functions of the GPR model. To the best of the author's knowledge, the prediction of load demand using GPR for Indian cities of Maharashtra state has been made for the first time. The calculated MAPE in load forecasting is 0.15% for Australia and 0.002%, 0.209%, 0.077%, and 0.140% for Indian cities viz. Nasik, Bhusawal, Kolhapur, and Aurangabad, respectively. The test results illustrate that minimum MAPE in load prediction is obtained using the proposed model which is GPR with 'Exponential' kernel functions. Furthermore, the comparative analysis with the existing approaches confirms the dominance of the proposed model.

'Machine Learning Based Hosting Capacity Determination Methodology for Low Voltage Distribution Networks': This manuscript first presents a framework to find the hosting capacity (HC) for a grid. The same framework is then applied to 503 different simulated but realistic LV distribution feeders

in Finland to find their HCs and the most effective network parameters in defining a network-specific HC. After finding the HC-defining variables, different machine learning models, that is , Decision Tree (DT), Random Forest (RF), Linear Regression (LR), K nearest neighbours (KNN), Logistic Regression, and Support Vector Machine (SVM) are implemented on the generated data. Models are compared and their KPIs are examined. For regression analysis, RF has an accuracy of 94.90% followed by 91.45% for DT and finally 90.06% for LR. For the classification case, the accuracy values for logistic regression, KNN, and SVM were 0.89, 0.84, and 0.81, respectively. The findings demonstrate that the developed machine learning-based technique will enable the distribution network operators in finding the HC of a specific network without applying any deterministic or probabilistic approaches.

'Multi-objective Optimization Method for Control Parameters of Flexible Direct Current Transmission Converters Based on Intelligent Algorithms': In the context of power dispatching and large-scale long-distance transmission applications, traditional Alternating Current (AC) Transmission Systems (TS) have many problems, such as the need for synchronization and limited capacity. In order to meet the current demand for power transmission, people have turned their attention to Direct Current (DC) transmission. When an AC Power Grid (PG) fails, it is easy to cause unsuccessful commutation in the DC system, which would increase the fault range of the system. Therefore, this paper adopted a flexible DC TS. Flexible HVDC converters have many control parameters, and these parameters have mutual influence and conflict relations. By applying an intelligent algorithm to multi-objective optimization, we can effectively solve these complex multi-objective optimization problems and find a set of optimal control parameter combinations. By applying the multi-objective optimization method based on an intelligent algorithm, the optimal control parameter combination of the flexible HVDC converter can be obtained, to improve the performance and efficiency of the system and achieve the balance between different performance indicators. This method has an important contribution and novelty in optimizing converter control parameters in flexible HVDC systems.

'Short-term Wind Power Prediction based on Combined LSTM: Combined short-term wind power prediction based on Long Short-Term Memory (LSTM) artificial neural network has been studied aiming at the non-linearity and volatility of wind energy. Due to the large amount of historical data required to predict wind power precisely, the ambient temperature and wind speed, direction, and power are selected as model input. The CEEMDAN has been introduced as data preprocessing to decompose wind power data and reduce the noise. The PSO is conducted to optimize the LSTM network parameters. The combined prediction model with high accuracy for different sampling intervals has been verified by the wind farm data of Chongli Demonstration Project in Hebei Province. The results illustrate that the algorithm can effectively overcome the abnormal data influence and wind power volatility, thereby providing a theoretical reference for precise short-term wind power prediction.

'Short-term prediction of wind power based on TCN and the informer model': In this study, a new short-term wind power prediction model based on a temporal convolutional network (TCN) and the Informer model is proposed to solve the problem of low prediction accuracy caused by large wind speed fluctuations in short-term prediction. First, an input feature selection method based on the maximum information coefficient is proposed after considering the problem of information interference caused by excessively large input features. A dynamic time planning method is used to select the optimal input step of historical power. Then, the combined forecasting model composed of TCN and the Informer is constructed per the numerical weather forecast and historical power data. Lastly, the pinball loss function is used to expand the prediction model into a quantile regression model, measure the effect of volatility, quantify the volatility range of prediction, and finally, obtain a deterministic prediction result. The actual measured data of wind farms in the Bohai Sea area are selected for analysis and calculation. The results show that the prediction model proposed in this study achieves better accuracy in deterministic prediction and interval prediction than the traditional model.

'Daily Average Load Demand Forecasting Using LSTM Model Based on Historical Load Trends': Power load is an important aspect of the electrical system, and power load forecasting has an important effect on the management, design, and analysis of the electrical system. Load forecasting has progressively become a crucial component of the energy management system with the growth of the smart microgrid. This paper represents a new framework to long-term load forecasting in the world of electricity power with the help of historical load trends. Estimating the monthly electricity demand of Chhattisgarh state in India in terms of per day average load demand using a machine learning model, LSTM (Long Short-Term Memory) is the main objective of this research work. This framework considers the average of each day load demand for months of years 2018 to 2022 and forecasts the average load for each month of the year 2023. Furthermore, the predicting accuracy is evaluated in terms of error metrics like MAE and MAPE for the training and testing phase. The MAPE values under the training and testing phase are in the range of 0.010 to 0.652 and 2.452 to 10.542, respectively. The results indicate the proposed LSTM-based model is accurate and applicable for real load data forecasting.

2 | Summary

All of the papers selected for this Special Issue have demonstrated that AI is promising for different applications in Energy Sectors, especially energy forecasting, which is steadily moving forward. The main merit of these advanced AI approaches is to provide reliable solutions that can contribute to improving the hosting capacity of modern energy sectors. The recommendation for future works is to perform more investigations, practical implementationsand case studies, and apply such AI-empowered approaches in diverse parts of the energy sectors.

ACKNOWLEDGEMENTS

The Guest Editors express their appreciation to all of the authors who contributed research articles to this Special Issue. Many thanks to the reviewers for their insightful contributions and critical input, which assisted us in reaching our conclusions. The peer-review procedure verified that the selected articles fulfilled the highest quality and importance criteria. Finally, the Guest Editors would like to convey their heartfelt appreciation and gratitude to the Editors-in-Chief, Special Issues Editor, and Editorial Office for their assistance during this mission.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

Karar Mahmoud (Senior Member, IEEE) received a Ph.D. degree from the Electric Power and Energy System Laboratory (EPESL), Graduate School of Engineering, Hiroshima University, Hiroshima, Japan, in 2016. In 2019, he has been with Aalto University, as a Research Fellow with the Group of Prof. M. Lehtonen, Department of EEA, School of Electrical Engineering, Aalto University, Finland. He has been with Aswan University since 2010, where he is currently an Associate Professor with the Department of Electrical Engineering—Faculty of Engineering.

His research interests include power systems, energy storage, forecasting, electrical vehicles, renewable energy, smart grids, and applied machine learning. He has published many advanced scientific papers, including more than 100 scientific papers, in several high-level publishing houses, including scientific journals, international conferences, and scientific book chapters. He holds the position of topic editor in four classified scientific journals, in addition to being a guest editor for three special scientific publications on advanced scientific engineering topics. He is also an accredited reviewer of scientific research, as he has reviewed more than 260 scientific papers in 41 different scientific journals. He has awarded the Prestigious Egyptian State Encouragement Award in the field of engineering sciences in 2021 and was honored by Egypt's Academy of Scientific Research and Technology (ASRT).

Josep M. Guerrero (Fellow, IEEE) received the B.S. degree in telecommunications engineering, the M.S. degree in electronics engineering, and the Ph.D. degree in power electronics from the Technical University of Catalonia, Barcelona, in 1997, 2000, and 2003, respectively. Since 2011, he has been a Full Professor with the Department of Energy Technology, Aalborg University, Denmark, where he is responsible for the Microgrid Research Program (www.microgrids.et.aau.dk).

His research interests are oriented to different microgrid aspects, including power electronics, distributed energy-storage systems, hierarchical and cooperative control, energy management systems, smart metering, and the internet of things for AC/DC microgrid clusters and islanded minigrids; recently specially focused on maritime microgrids for electrical ships, vessels, ferries, and seaports. Prof. Guerrero is an Associate Editor for a number of IEEE TRANSACTIONS. He has published more than 500 journal papers in the fields of microgrids and renewable energy systems, which are cited more than 30,000 times. He received the best paper award of the IEEE Transactions on Energy Conversion for the period 2014 to 2015, and the best paper prize of IEEE-PES in 2015. As well, he received the best paper award of the Journal of Power Electronics in 2016. During five consecutive years, from 2014 to 2018, he was awarded by Clarivate Analytics (former Thomson Reuters) as a Highly Cited Researcher. In 2015 he was elevated as IEEE Fellow for his contributions on 'distributed power systems and microgrids'.

Mohamed Abdel-Nasser received his Ph.D. degree in July 2016 (Cum Laude) from Universitat Rovira i Virgili, Spain. He has received the 2017 Marc Esteva Vivanco prize for the best Ph.D. dissertation on A.I. In 2020, He has been a Director of Research at the Department of Computer Engineering & Mathematics, Universitat Rovira i Virgili. Currently, he is an Associate Professor of Electronics and Communications at Aswan University, Egypt. In 2022, he received the State Encouragement Award from the Egyptian Academy of Science and Technology for his excellent research track. He is the Principle Investigator of the Ensenyo project (AI-Powered online education platform funded by E.U.). He participates in many R&D projects funded by the European Commission and local funding agencies. He serves as a Guest Editor for many Special Issues in Indexed journals. He has published more than 80 scientific papers in International Journals and Conferences. His research is focused on applied artificial intelligence.

Naoto Yorino (Senior Member, IEEE) received the B.S., M.S., and Ph.D. degrees in electrical engineering from Waseda University, Japan, in 1981, 1983, and 1987, respectively. He joined Research and Development Section, Fuji Electric Company, Japan, from 1983 to 1984. Since 1987, he has been with Hiroshima University, where he has been a Professor, since 2005, and the Vice Dean, from 2009 to 2017. He was a Visiting Professor at McGill University, Canada, from 1991 to 1992, and Hohai University, China, from 2014 to 2017. He has authored/coauthored over 130 transaction papers in power and energy area. His activity includes the Vice President of Power and Energy Society, IEE of Japan, from 2009 to 2011; a Neutral Member of the Rulemaking Committee, ESCJ, from 2007 to 2015; a Steering

Committee Member of Japan Power Academy, from 2012 to 2014 and from 2018 to 2019; the Board of Director at iREP, in 2007, and IEIE of Japan, from 2013 to 2019; and a member of CIGRE.

Karar Mahmoud[1]
Josep M. Guerrero[2]
Mohamed Abdel-Nasser[1]
Naoto Yorino[3]

[1] *Electrical Engineering Department, Aswan University, Sahary, Egypt*
[2] *Aalborg University, Aalborg, Denmark*
[3] *Graduate School of Advanced Science and Engineering, Hiroshima University, Hiroshima, Japan*

Correspondence
Karar Mahmoud, Electrical Engineering Department, Aswan University, Sahary, Egypt.
Email: karar.mostafa@aalto.fi

ORCID
Karar Mahmoud https://orcid.org/0000-0002-6729-6809