**INFORMATION ABOUT RESEARCH RESULTS**

Dissertation title: **Forecasting electrical system load**

Specialization: Electrical Engineering Code: 62520202

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1. **Summary of content**

Nowadays, the demand for electricity is always changing and tends to increase. Electricity contributes an important role in ensuring the stability of social economic development and political security of the country. The issue that needs attention is the shortage of energy, especially the demand for electrical energy. During some peak hours, the power distribution system does not enough response the demand for electricity consumption, customers must buy electricity at high prices when participating in the electricity market. Power companies must improve the upgrading of transmission and distribution lines, or they install additional transformer stations to improve load demand during peak hours. In addition, the power company needs to solve the problem of short-term load forecasting. It contributes an important role in the work of regulating the power system, planning investment, development and operation of the power system. In addition, the demand for electricity consumption reflects the development of the national economy. Therefore, electricity load forecasting is a part of economic and scientific and technical development forecasting. If the load forecast is too excessive compared to demand, the consequence is that more expensive reserve resources must be mobilized than necessary. On the contrary, if the load forecast is too low compared to demand, it results in low backup power, reducing the safety of the power supply system, and the power company cannot meet the electricity needs of consumers, causing economic damage.

In previous studies, there are many methods to solve the load forecasting problem, this is a difficult problem, depending on many input factors. Currently, the power company is solving the load forecasting problem mainly by traditional forecasting methods, which are empirical. Recent research directions, along with the development of computer science and artificial intelligence to solve the load forecasting problem. Neural networks or deep learning networks contribute effective load forecasting solutions, based on the advantages of deep learning networks such as: parallel processing structure, learning and memory ability, self-learning and generalization ability. Deep learning networks are used successfully studied and applied in areas, such as estimation in pattern recognition, forecasting... This study mainly focuses on building deep learning network models and applying them to solve the load forecasting problem (peak load and load curve forecasting). To provide the necessary parameters for operation, establish a method for dispatching the power system, and balance between generation capacity - consumption capacity. Based on the factors affecting the load, the thesis has chosen the input data for the peak load forecasting problem as the peak load in the day and temperature. For load curve forecasting, it is electricity output in the hour and temperature in the day. Seasonal factors, working days, Saturdays and Sundays, and special days of the year are also considered. PhD student uses the historical data set of the Tien Giang power grid area to apply to the proposed model.

For the peak load forecasting problem, the thesis has successively studied the application of forecasting algorithms: LSTM (Long Short-Term Memory), the combined model CNN-LSTM (Convolutional Neural Networks - Long Short-Term Memory), Wavenet (wavelet transform combined with convolutional network), and GCN-GRU (Graph Convolutional Networks - Gated Recurrent Units). In the forecasting process for all models, the results of the GCN-GRU algorithm have an error of MAPE = 0.0006, the model has a small error.

For the load curve forecasting problem, the thesis has successively studied the application of forecasting algorithms: LSTM, CNN-LSTM combination model, Wavenet, FF-DNN combined with R-DNN, Seq2Seq-LSTM, and Wavelet transform combined with HHO-GCN-LSTM model. In the forecasting process for all models, the results of Wavelet-HHO-GCN-LSTM algorithm have MAPE = 0.5473, the model has high accuracy.

1. **New contributions of the topic**

**Contribution 1:**

Proposed a network model combining graph convolution GCN and GRU Gated Recurrent Units, this model uses GCN to extract features from graph data, GRU handles time dependence, it is carried in steps. Feature extraction takes information from data in the form of graphs, represents time series features of data to input into GRU model, trainning the model, and finally test is to evaluate model performance. Based on the optimal of the GCN-GRU model in simultaneously processing the spatial and temporal dependence from data, so the load forecasting problem is used this method to improve RMSE and MAPE error to other forecasting methods. The training model is used from data of the Tien Giang power grid. The input of the forecasting model are the peaks of Pmax/day, temperature/hour and factors affecting the season, as well as special days in the year. The results of the algorithm have small errors, specifically MAPE = 0. 0006 compared to other models. Also the trainning model improves the forecasting time.

In addition to improving forecast accuracy, the GCN-GRU model also offers several important advantages over traditional methods. First, the integration of a graph convolutional network (GCN) exploits the spatial relationships between data points in the grid, which is not optimized by sequential deep learning models such as LSTM or CNN-LSTM. Second, the gate recurrent unit (GRU) allows the model to effectively memorize information in time series, mitigating the problem of vanishing gradients when working with long-term data.

*This contribution was published in the scientific research article:*

1. **Duong Ngoc Hung**, Nguyen Minh Tam, Nguyen Thanh Hoan. and Tran Thanh Phong. “Application of Seasonal Trend Decomposition using Loess and Long Short- Term Memory in Peak Load Forecasting Model in Tien Giang”. Engineering, Technology & Applied Science Research. 13, 5 (Oct. 2023), 11628–11634. DOI:https://doi.org/10.48084/etasr.6181.

**Contribution 2:**

The thesis proposes a combined network model, this model applies Wavelet filter to preprocess data for HHO-GCN-LSTM, in the study, the reliability of the collected historical data source is considered. In addition, the thesis uses the Probability Density Function (PDF) to evaluate the data distribution according to probability, the PCA (Principal Component Analysis) function to analyze and classify data into correlated components, and the Dendrogram to classified and divided into data. Finally, applying Wavelet filter to different data groups (separated to ensure relatively similar normal distribution - based on PDF graph) to preprocess data, combined with the proposed method HHO-GCN-LSTM for the problem of daily graph forecasting. The HHO algorithm aims to optimize the objective function, update weights during the training model creation process. The LSTM short/long-term memory processes time series data.

The training model used data from Tien Giang power grid. The input of the forecasting model is power output/hour, temperature/hour and seasonal influence factors. The algorithm results have high accuracy MAPE = 0.5473. The study compared to the results of the forecasting model with LSTM, CNN-LSTM, Wavenet, deep learning network combined with FF-DNN and R-DNN, Seq2Seq-LSTM combined network, the proposed model has superior error.

In addition to achieving lower errors than traditional models, the Wavelet-HHO-GCN-LSTM model brings many outstanding advantages in the load curve forecasting problem. First of all, the Wavelet filter helps to separate the data into different frequency components, remove noise and extract useful features before feeding into the deep learning model, which significantly improves the input quality. Next, the HHO optimization algorithm is used to fine-tune the model parameters, helping to optimize the training process, minimize errors and enhance convergence.

In addition, the combination of GCN and LSTM in the model helps to fully exploit the spatial and temporal relationships of load data. GCN is capable of learning the structure of data in the form of graphs, suitable for the complex connection characteristics between transformer stations and power consumption areas. Meanwhile, LSTM helps to memorize time series information, which is especially useful in load forecasting with data that varies seasonally and hourly.

*This contribution was published in the scientific research article:*

1. **Hung Duong Ngoc**, Hoan Nguyen Thanh, and Tam Nguyen Minh, “Short term load forcast using deep learning,” 2019 Innov. Power Adv. Comput. Technol. i-PACT 2019, Mar. 2019, doi: 10.1109/I-PACT44901.2019.8960036.
2. **Dương Ngọc Hùng**, Nguyễn Tùng Linh, Nguyễn Thanh Hoan, Nguyễn Minh Tâm. “Mô hình kết hợp HHO-GCN-LSTM ứng dụng trong dự báo đồ thị phụ tải cho lưới điện nhỏ,” Tạp chí Khoa học và Công nghệ Đại học Công Nghiệp Hà Nội, vol. 58, no. 4, pp. 8-15, 2022, [Online]. Available: https://jst-haui.vn/media/30/uffile-upload-no-title30857.pdf.
3. **Dương Ngọc Hùng**, Nguyễn Tùng Linh, and Nguyễn Minh Tâm, “So sánh thuật toán tối ưu của mạng wavenet trong bài toán dự báo phụ tải điện - Compare the optimal algorithms for wavenet applications in load forecasting”, Tạp chí Khoa học và công nghệ đại học Thái Nguyên, Tập 228, Số 07 (2023), doi: https://doi.org/10.34238/tnu- jst.6956.
4. **Ngoc Hung Duong**, Minh Tam Nguyen, Tung Linh Nguyen, Thanh Hoan Nguyen, and Thanh Duy Nguyen. “Applying seq2seq-lstm in a short-term load forecasting model for the power grid in Tien Giang”. TNU Journal of Science and Technology, 228(14), 290–301. https://doi.org/10.34238/tnu-jst.9060
5. **Ngoc Hung Duong**, Minh Tam Nguyen, Tung Linh Nguyen, Thanh Hoan Nguyen, and Thanh Duy Nguyen. “Application of combining data preprocessing with wavelet filtering for GCN-LSTM network with HHO optimization algorithm in load forecasting mode”. TNU Journal of Science and Technology, vol. 229, no. 06, pp. 160–169, 2024, https://doi.org/10.34238/tnu-jst.9875

HCMC, March 10, 2025

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