LSTM과 RNN에 기반한 공장 에너지관리시스템을 위한 하루 전 전력소비 예측모델 설계

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Design of a day-ahead power consumption prediction model for a factory energy management system based on long short-term memory and recurrent neural network

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Abstract - Predicting power consumption during the day is one of the targets that many factories are aiming for as a premise for the prediction of electricity prices per month, and maintenance plans for the factories. This paper deals with a power consumption prediction algorithm based on long short-term memory - recurrent neural network (LSTM-RNN) for a smart factory. The historical data from the company was collected and processed for the neural network training. Through training processes, the design factors of the model were determined. The accuracy of the LSTM-RNN for specified load achieved 97.2%. The results of this study can be effectively applied to accurately predict the power consumption during the day for the factory energy management system.

1. Introduction

Nowadays, artificial intelligence (AI) is widely applied in energy management systems to perform tasks of time series prediction, schedule equipment maintenance and operation, and predict power consumption during the day [1]. The power consumption predictions for factories have a prominent role to play in the energy management and control system as dynamic and seasonal changes are occurring in energy demand and supply [2]. The various data-driven AI-based methods have been used to predict power consumption such as long short-term memory (LSTM), support vector regression, multiple regression, artificial neural network, and recurrent neural network (RNN) [3]. The LSTM-based RNN is a suitable method for modeling sequential data because it provides more accurate prediction results than other methods when given the same input data and has the potential to further improve accuracy of predictions.

In this paper, the authors deal with the design of a day-ahead power consumption prediction model for a factory energy management system based on LSTM-RNN. The detailed design process of the LSTM-RNN prediction model was presented. The historical data on the operation of loads in the factory is collected and processed for training. The configuration of the LSTM-RNN with an input layer, hidden layers, and an output layer was designed. The TensorFlow library was used to design, train and test the LSTM-RNN model. Through training and testing processes, other design factors of the model including the number of neurons in the hidden layers, activation function, adapting learning function, loss function, accuracy metrics, and learning rate were identified. The target of power consumption prediction error was lower than 8%. As a result, the designed LSTM_RNN model was capable of effectively predicting the power consumption during the day for the different time series. The trained model obtained a high accuracy with a minimum error of 2.4%. The results obtained in this study can be applied to accurately estimate day-ahead power consumption for the factory energy management system (FEMS) in smart factories.

2. Design of a power consumption prediction algorithm using LSTM-RNN

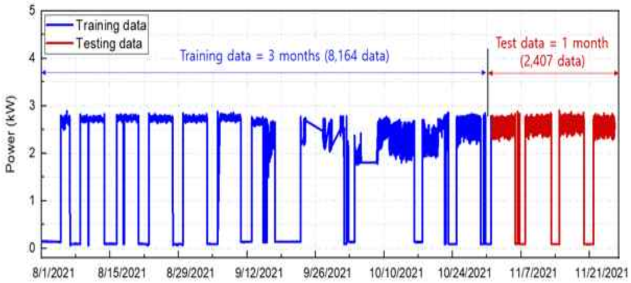
2.1 Data collection and analysis

The LSTM-RNN model was trained by the past operation dataset of the loads which was collected from the FEMS. The dataset consists of the measurement time with a time step of 15 minutes, usage, active power, line voltage, current, reactive power, power factor, and frequency. Fig. 1 shows the consumed power data of a company from August 1, 2021 to November 26, 2021. The collected number of consumed power data is 10,571. 75% of the collected data was used for the training process and remaining data to check the accuracy of the model. The accuracy of the prediction model is evaluated by symmetric mean absolute percentage error (SMAPE).

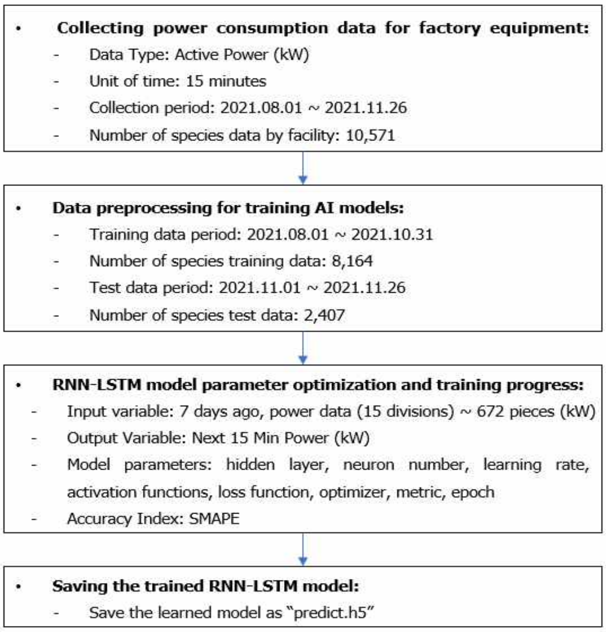
2.2 AI model design process

Fig. 2 shows the detailed design process of an LSTM-RNN for the power consumption prediction. It starts by collecting and pre-processing the data, then designing the LSTM-RNN in terms of network topology, configuration, activation function, loss function and metrics, optimizer, and learning rate.

After confirming the training performance and accuracy, the trained model is saved with the .h5 format. After tuning the parameters and testing the network, the most suitable specifications for the LSTM-RNN model were described in Table 1.



<Fig. 1> Power consumption data of the company

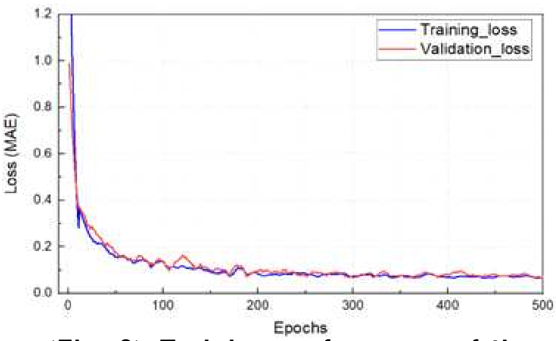


<Fig. 2> Design process of the LSTM-RNN model

<Table 1> Specifications of the LSTM-RNN model

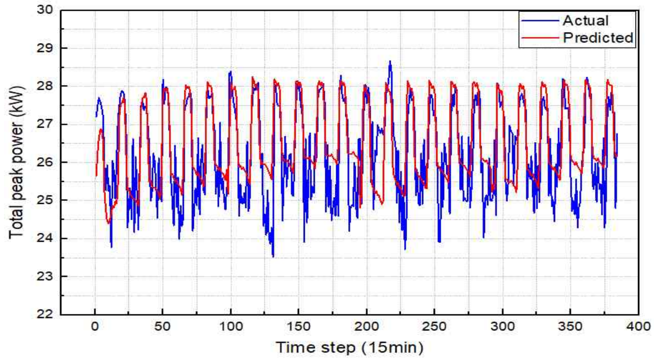
Items	LSTM-RNN
Number of inputs of the network	672
Number of hidden layers of the network	2
Number of outputs of the network	1
Number of neurons in hidden layer 1	128
Number of neurons in hidden layer 2	256
Activation function in hidden layers	Sigmoid, Tanh
Activation function in the output layer	Linear
Adapting learning function	Adam
Learning rate	0.001
Loss function	MAE
Accuracy metrics	MAE, SMAPE

3. Results and discussions



<Fig. 3> Training performance of the LSTM-RNN model

Fig. 3 shows the training and validation losses during the training process with 500 epochs. As a result, the training losses almost match the validating losses. After completing the training process, the model parameters were saved into .h5 format to load and use in the prediction testing process.



<Fig. 4> Test results of the LSTM-RNN model

The model is applied to predict the day-ahead power consumption of a specified load. Comparisons between predicted and actual results are indicated in Fig. 4. The trained LSTM-RNN model was tested randomly with a day-ahead prediction on the weekday of one week, and the accuracy of the LSTM-RNN model in the specified machine achieved a SMAPE of 97.2%.

4. Conclusion

The authors have proposed an effective power consumption prediction method based on a LSTM-RNN for the FEMS. The detailed design process of the LSTM-RNN model for the power consumption prediction was presented. The model was trained and tested based on real historical data. The model after training achieved high accuracy, and the accuracy was 97.2%. The research results will be utilized to accurately predict the day-ahead power consumption for the FEMS.

Acknowledgements

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