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Pecan: A Novel Approach to Energy Supply and Demand Forecasting in a Photovoltaic Microgrid

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Abstract— **The adoption of renewable energy is crucial to curbing carbon emissions. Localized on-site generation methods such as microgrids are implemented due to their improved reliability and the ease of inclusion of renewable energy generation. However, current forms of renewable energy generation are unreliable. Accurate forecasting of both energy supply and demand are crucial in the transition towards a renewable energy grid and reducing reliance on fossil fuel reserves. Pecan is a novel solution that combines custom deep learning models for energy supply and demand forecasting with an artificial neural network solution. Pecan uses a novel loss function to prioritize grid stability while simultaneously decreasing carbon emissions through a lower error rate. Mean absolute percentage error (MAPE) was used to measure model performance and calculate emission reductions. The supply forecasting prediction from Pecan achieved a MAPE of 1.17%, and the demand forecasting prediction achieved a MAPE of 1.05%. The improved performance of Pecan increases the feasibility and profitability of microgrids and renewable energy solutions.**

I. Introduction

Due to growing concerns regarding the effects of fossil fuel emissions, the importance of renewable energy resources has grown markedly in recent years. Currently, the industry standard for power management is a centralized power grid largely dependent on fossil fuels. However, centralized power grids present two major problems. First, the rigid, inflexible centralized grid is unable to accommodate the unpredictable nature of current distributed energy resources(DERs). Second, energy is often lost when travelling large distances between energy generation and consumption locations [1]. Distributed, or on site generation, has been proposed as a next generation smart grid solution. This method proposes advantages due to its ability to generate energy locally, greatly reducing the energy lost in transmission, and its superior reliability and resilience due to its small scale and isolation [2].

Short-term energy supply and demand forecasting are necessary to make informed and reliable decisions for distributed energy systems [3]. Currently, reserve scheduling ensures that there are adequate reserves in place when energy demand exceeds supply. These reserves are most commonly fossil fuels due to the necessity of immediate generation. Improvements in energy supply and demand forecasting have the potential to greatly reduce the necessity of fossil fuel reserves and fossil fuel energy generation as a whole. They also have the potential to increase grid stability by greatly reducing potential mismatches of supply and demand.

Multiple deep learning techniques have been proposed in the past for energy supply and demand forecasting. These include artificial neural networks (ANN), convolutional neural networks (CNN), recurrent neural networks (RNN), Long short-term memory networks (LSTM) and bidirectional long short-term memory networks (BLSTM) [4].

The purpose of Pecan is to develop a comprehensive deep learning solution for energy supply and demand in a microgrid that is more accurate and reliable than industry standards. In the present study, a novel method is developed to connect energy supply and demand forecasts to produce an intelligent demand response.

II. Methods

The primary microgrid dataset used for both energy supply and demand predictions was the UC San Diego Microgrid [5]. For this dataset, 48 hours of energy demand data in kilowatts was inputted into the energy model. The month, day, and hour were used as inputs due to strong seasonal correlations between time and energy consumption. Temperature, taken from the National Oceanic and Atmospheric Administration(NOAA) located at the San Diego Airport, was also used as an input.

The energy generation forecasting model took in the energy generation from distributed solar PV generators throughout the San Diego Microgrid. The model inputted multiple solar irradiance metrics, including Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and Diffuse Horizontal Irradiance (DHI). The same temporal variables as the energy load forecasting model were used for the energy generation forecasting model.

Both energy supply and demand forecasting models used the same novel deep learning model structure to achieve a lower forecasting error. The model contains a LSTM layer, followed by 3 bidirectional LSTM layers, followed by another LSTM layer, then finally followed by 2 artificial neural network layers. Dropout and batch normalization was used between each layer to prevent overfitting of the model.

The data was split into two parts with 90% being used for training the model and the remaining 10% being used for validation and testing the model accuracy. Temporal isolation was ensured to prevent overfitting and combat bias. To measure model performance, mean absolute percentage error (MAPE) was used. Pecan was compared to a standard ANN model, a smart persistence model, and the current industry standard. The smart persistence model used the data from the last 24 hours to generate a prediction of equal value for the next 24 hours.

III. Results

The energy generation forecasting portion of Pecan achieved a Mean Absolute Percentage Error (MAPE) of 1.13%. This was an 87% decrease compared to the Smart Persistence model, a 75% decrease in MAPE compared to the Artificial Neural Network (ANN) model and a 62% decrease in MAPE compared to the industry standard models.

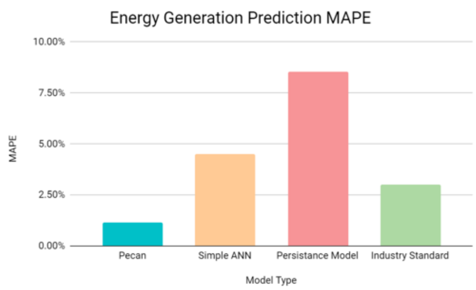

Figure 1. Energy Generation Prediction Model Comparison

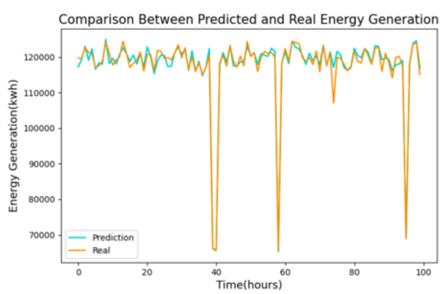

Figure 2. Energy Generation Prediction and Real Value Comparison Visualized

The load forecasting portion of Pecan achieved a MAPE of 1.05%. This was an 89% decrease compared to the Smart Persistence model, a 72% decrease in MAPE compared to the Artificial Neural Network(ANN) model and a 65% decrease in MAPE compared to the industry standard models.

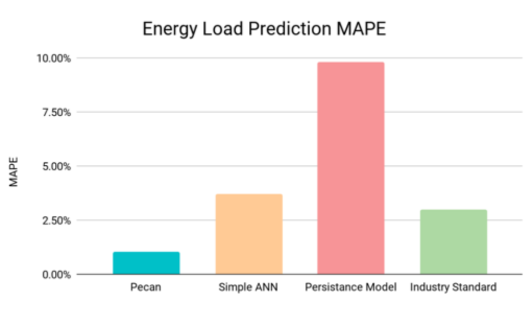

Figure 3. Energy Load Prediction Comparison

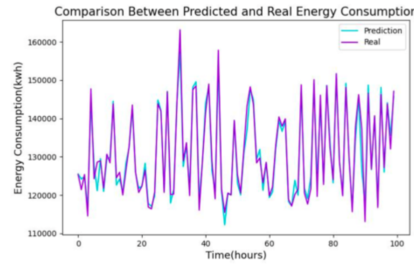

Figure 4. Energy Load Prediction and Real Value Comparison Visualized

IV. Discussion

The development of Pecan demonstrates the applicability of a novel neural network solution to energy supply and demand predictions. Pecan's more accurate supply and demand forecasts can be used to improve accuracy in the unit commitment problem, thereby increasing forecasting reliability, and greatly improving grid stability and national security. Pecan also has large-scale economic benefits, as improvements in energy forecasting accuracy allow for improved energy price forecasting, as well as lower energy purchasing from the central grid. Pecan helps to increase the feasibility and profitability of microgrids and renewable energy. Future research can build off of Pecan's novel network structure to test on a wider range of microgrid datasets to ensure generalizability, and can apply Pecan's novel structure to other forms of distributed energy resources

References

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