Renewable energy power generation forecasting using deep learning method

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Renewable energy power generation forecasting using deep learning method

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Abstract. Smart Micro Grid in household areas aims to meet electricity needs through the integration between state power plant with renewable energy sources so that the electricity used does not depend entirely on state utility. Smart Micro Grid also enables the availability of energy management services supported by Machine Learning (ML) technology, Big Data, Artificial Intelligence (AI), Internet of Things (IoT) and smart sensors so that consumer use of electricity is more efficient. To improve energy management services and distribution of renewable energy sources, new innovations in ML technology are needed to produce accurate learning models that can be used in the energy analysis process, such as monitoring, prediction, forecasting, scheduling and decision-making. However, the complexity of the problems in the smart grid system, which includes uncertainty and non-linearity, affects the more complex the energy data structure generated. Therefore, the simple ML method will not be able to perform the Learning process because it is limited to simple raw data processing. Therefore, the Deep Learning (DL) method can be used as a Learning method on data that has a complex and large structure. In this paper, Deep Neural Network (DNN) method will be developed using Long Short-Term Memory (LSTM) as a Learning model to provide Future Accurate Prediction (FAP) on electricity use and on renewable energy plants. Prediction test using Confusion Matrix accuracy value and RMSE error value

1. Introduction

The demand for electrical energy needs is increasing along with the increasing activity of the community in using electric devices so that increasing the capacity to supply electrical energy is important. The addition of electrical energy capacity can be done by building several power plants sourced from fossil and renewable energy. Currently, the development of power plants sourced from fossil energy is very limited and is starting to be integrated with renewable energy sources through smart grid networks, especially at the micro scale for household needs. The development of a smart micro grid uses more solar energy which is then converted into electrical energy and used to support household electricity needs.

Smart Grid provides energy management services with several supporting technologies, especially machine learning. This technology is very important for handling and analyzing energy data and other data that are incorporated in big data so that it can be implemented in machine learning applications [1], [2], [3], [4]. To improve energy management services and good distribution of renewable energy sources, new innovations in machine learning are needed to produce accurate learning models that can be used in the energy analysis process. However, the complexity of the problems in a smart grid

system which includes uncertainty and non-linearity has an impact on the increasingly complex energy data structure produced [5]. Therefore, the simple ML method will not be able to carry out the Learning process because it is limited to simple raw data processing. For this reason, the deep learning method can be used as a learning method on data that has a large and complex structure.
In this research, the DL method will be developed using Neural Network (NN) and LSTM architecture as a Learning model to provide Future Accurate Prediction (FAP) on electricity use and in photovoltaic (PV) generation. This paper consists of five chapters, including chapter one discusses the background, chapter two discusses related research, chapter three discusses renewable power generation forecasting methods, chapter four discusses the analysis of experimental results, chapter five contains conclusions.

2. Related Works

Renewable energy resources (RERs) are currently an important step to respond to the depletion of energy sources from fossil fuels. In addition, RERs produce clean energy and can help reduce carbon emissions in the air. RERs can be in the form of solar, wind, biomass, and water energy which are then connected to other parts, namely conventional generation and energy storage systems and form Distributed Energy Resources (DERs) [6]. The integration of DERs with the electricity network requires a management system that has the ability to optimize, control, monitor and detect when there is a failure in the power grid. MG technology can provide solutions in management systems that have the ability to manage the integration of DERs with the power grid [7].
This research uses renewable energy that comes from solar energy. Several approaches have been developed for the prediction of solar PV generation by previous researchers. Researcher [8] developed a solar forecasting method using deep learning methods and focused experiments on the use of several neuron network structures, such as Auto encoder, Deep Belief Network, LSTM and compared to the ANN method. In this study, deep learning provides high accuracy results compared to ANN. Researcher [9] used the statistical method of Spatio-temporal to predict solar generation. The experimental results show low computational complexity. Furthermore, to handle time-series prediction problems, the use of deep learning methods with LSTM network structures is more suitable than other methods [10].

3. Renewable Energy Power Generation Forecasting

The energy management system application in MG is carried out in several stages as shown in Figure 1, including the data monitoring stage, analytical data, forecasting, optimization and real-time control. The application developed consists of prediction and forecasting on power generation and power consumption. The data monitoring process aims to obtain data related to conditions from RERs, Conventional Generator (CG), Energy Storage System (ESS), Demand Response (DR), Weather Forecast, Grid, Electric Vehicle (EV), and others. The data obtained can be in the form of raw data and pre-processing is necessary to remove noise [11] and discrete data prior to the analysis stage. At this stage of the analysis, data that is ready to be analyzed uses machine learning techniques to deep learning. The results of the analysis process will produce a knowledge model that can be used for forecasting, prediction, classification and regression applications.

Figure 1. Energy Management Process on Micro grid.

The energy management system in MG plays an important role in increasing grid stability and availability. When MG is integrated with RERs, such as solar panels or PV as an energy generator, forecasting is necessary at the plant. The use of PV as an energy generator depends on the solar radiation received by the solar panels. Beside that it also depends on the ambient temperature and

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weather conditions as well as the geographic location of the PV panels. For this reason, modelling the forecasting process refers to weather conditions which then become weather parameters in the form of time series data.

The forecasting process can be modelled as follows: historical weather time series data in the form (x1, x2, ..., xn), where n is the number of weather parameters. To predict the solar PV power in the day-ahead category, the first step is to determine the mapping function between historical weather data and solar PV power prediction as done in research [12], namely:

$$\hat{y} = f(x_1, x_2, \dots, x_n)$$

Solar PV forecasting is represented by n = 6 weather parameters as shown in Figure 2, including:

- Irradiance (kW/m2)
- Air Temperature (°C)
- Panel Temperature (°C)
- Wind Speed (m/s)
- Wind Direction (°)
- Precipitation (mm)

Figure 2. Forecasting PV Generation Model.

The Input layer, Hidden layer and Output layer of NN architecture is shown in Figure 3. This architecture is an NN standard architecture in the form of a Multi Layer Perceptron (MLP) which consists of multiple fully connected layers of neurons.

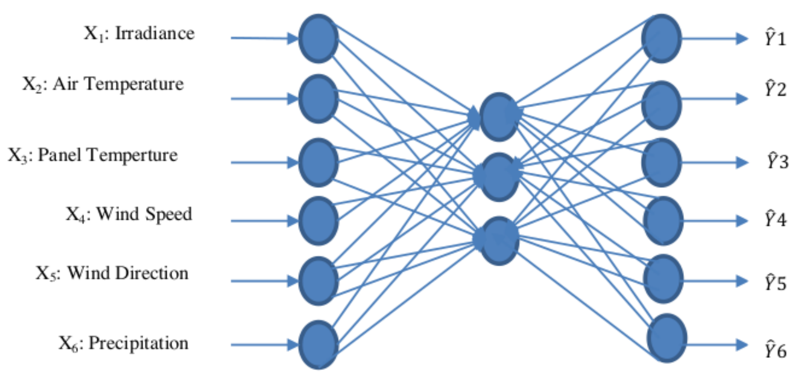

Figure 3. The Architecture of NN Layers

This architecture was then converted into a DN architecture with LSTM memory which was developed from the basic architecture of the Recurrent Neural Network (RNN) as shown in Figure 4.

Several hidden layers were added in this architecture including LSTM memory units. RNN uses temporal information as input data and can make repeated connections between neurons. LSTMs have memory cells in their neurons that have the ability to store information. The information that enters and leaves the neuron's memory cell is controlled by three gates, namely the input gate, the output gate and the forget gate. Each of these gates gets the same input from the input neuron and also has an activation function. The activation function used in this forecasting process can be tanh activaton functions and Rectified Linear Unit (ReLU) activation functions.

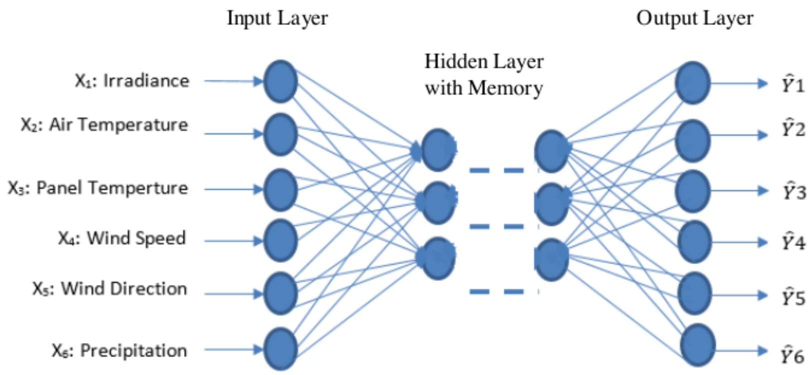

Figure 4. The Architecture of DNN with LSTM

4. Result and Discussion

The time series data used in this study were collected from two public dataset [13]. This dataset consists of voltage current curve (V-I) data and environmental meteorological data for the PV module. In addition, this dataset is measured at three locations with different climates during one year. The measurement location is in Cocoa, Florida (subtropical climate); Eugene, Oregon (marine west coast climate); and Golden, Colorado (semi-arid climate). In this study, the dataset used is Cocoa and Golden, each of which is located in a different climate.

To evaluate and verify the effectiveness of the proposed ML algorithm, we conducted several experimental simulations to predict future solar power plants. The ML algorithm is implemented using the Keras API for Python with the framework used, namely TensorFlow. This study uses two evaluation measurements to compare the predictive accuracy of the algorithms used, namely Mean Absolute Error (MAE) and Mean Square Error (MSE). Prediction accuracy measurement is done by comparing several learning algorithms used including Regression, ARIMA, Moving Average and Neural Network on each dataset. Figures 5 and 6 show the design results of the predictive accuracy measurements made.

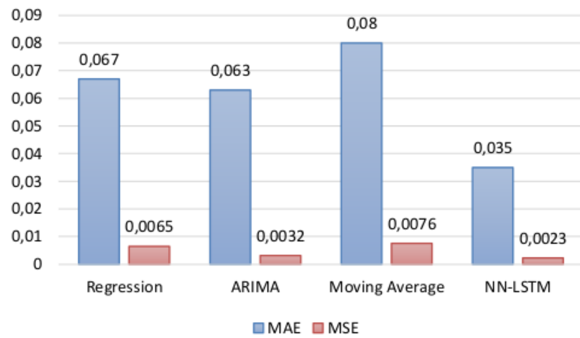

Figure 5. Prediction performance on the Cocoa dataset

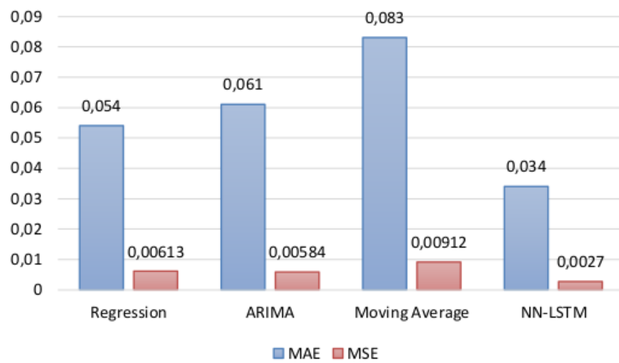

Figure 6. Prediction performance on the Golden dataset

5. Conclusion

Integration between state power plants with renewable energy sources, namely solar energy through the use of PV provides a solution to support household electricity needs. In order for the electricity supply from renewable energy to be used properly, it is necessary to forecast the energy produced by PV. This study uses a neural network model as an ML method for the forecasting process. From the results of the experiments conducted, the ML model used gave better results than the other methods tested on the two datasets.

Acknowledgments

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