Energy Forecasting: Phase 2 – Prophet and Neural Network Models

VOLT Analytics (Orange 12)
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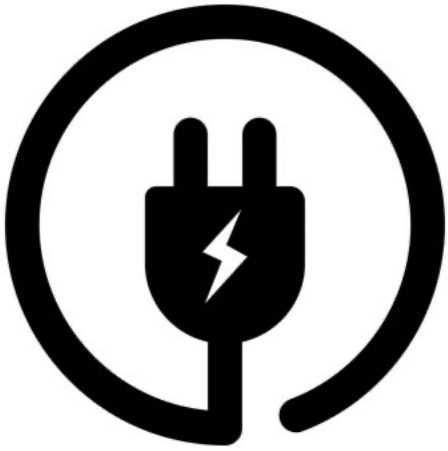

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Energy Forecasting: Phase 2 – Prophet and Neural Network Models

Overview

American Electric Power Co. (AEP) partnered with VOLT Analytics to develop a model to best forecast the Appalachian Power territory's hourly energy load in megawatts (MW). In the project's initial phase (RFP #: EF – F2.H1), we tested both exponential smoothing and seasonal ARIMA models from the provided data and concluded that the ARIMA model forecasted better due to a lower error.

In this phase, we constructed both Prophet and neural network models. According to our findings, the best model was the Prophet model, which accounts for the winter storm on December 23-24, 2022. This model boasted a mean absolute percent error (MAPE) of 4.64% and 3.47% on the two separate validation data sets. The corresponding mean absolute error (MAE) was 174.86 and 131.05 megawatts. We recommend using the Prophet model for hourly forecasting due to its consistently lower MAE and MAPE values. This model will improve forecasting accuracy and better meet the customers' needs while reducing operational expenses.

Methodology & Analysis

Data Used

The data provided contains information about the hourly megawatts (MW) load for the Appalachian Power territory of AEP from 2016 to 2023. We found that the data before January 1, 2020, did not capture the desired signal of hourly energy usage. As a result, we decided to subset the data from January 1, 2020, to October 18, 2023, comprising 33,287 hourly observations. The data contained no missing values, so imputation was not required. Figure 1 shows the subsetted data regarding its energy use.

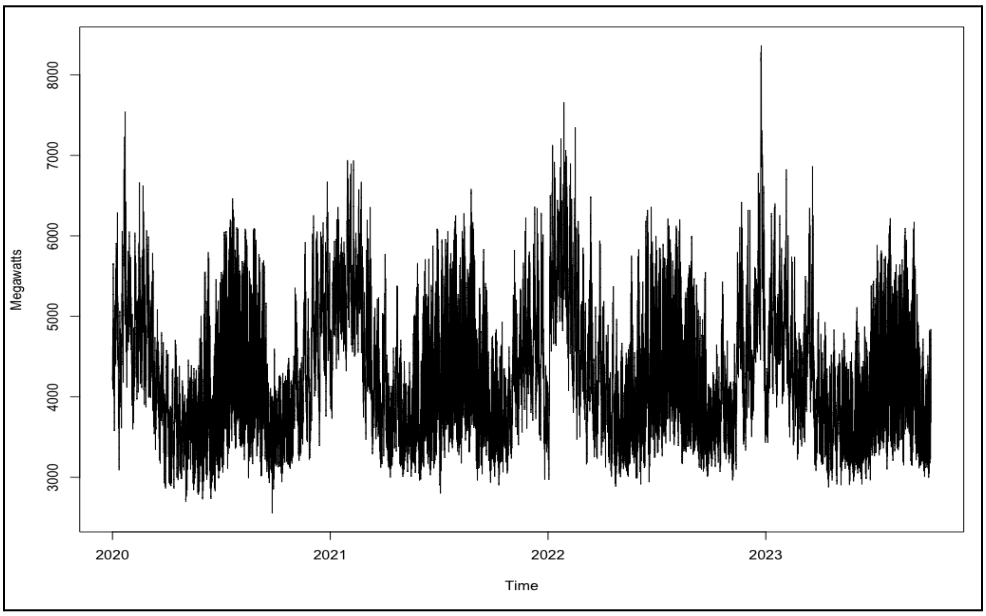

Figure 1: Hourly energy usage for data in megawatts from January 1, 2020, to October 5, 2023.

We assessed our models using MAPE and MAE on two separate validation sets. The first validation set (hereafter, "validation 1") encompassed 168 hourly observations from October 5, 2023, to October 11, 2023. The second validation set (hereafter, "validation 2") consisted of 168 hourly observations from October 12, 2023, to October 18, 2023. Ultimately, we compared the Prophet and neural network model to our ARIMA model, with updated validation data, from RFP #: EF – F2.H1.

Prophet Model

Our team started by building a Prophet model, where the signal is composed of trends, seasons, and holidays. The Prophet model considered the winter storm in 2022 and modeled it as part of the holiday intervention. Additionally, we removed three repeated time points that resulted from daylight savings each year to ensure equal spacing between time points. As the trend did not appear to change over time, we did not include any change points for the trend in our model.

Neural Network Model

Our team also created a neural network model. The initial model was based on the ARIMA model from RFP #: EF – F2.H1. From this previous project phase, we knew that seasonal differencing was required and that our model should have approximately two autoregressive terms and three seasonal autoregressive terms. After testing, we found that the best neural network contained one hidden layer, seasonally differenced data, zero autoregressive terms, and ten seasonal autoregressive terms.

Results

Our team found that the Prophet model outperformed both the neural network and seasonal ARIMA models when evaluating MAPE and MAE. The Prophet model had a MAPE of 4.64% on the first validation set and 3.47% on the second. On the other hand, the neural network had a much higher MAPE of 7.80% on the first validation set but a similar MAPE of 3.48% on the second. The seasonal ARIMA had a MAPE of 7.63% on the first validation set, similar to the neural network, but a slightly higher MAPE of 4.80% on the second set. Tables 1, 2, and 3 show the MAE and MAPE values for the Prophet, neural network, and seasonal ARIMA models, respectively.

Table 1: MAE and MAPE for the Prophet model.

Prophet Model	MAE	MAPE
Validation 1	174.86	4.64%
Validation 2	131.05	3.47%

Table 2: MAE and MAPE for the neural network model.

Neural Network Model	MAE	MAPE
Validation 1	290.78	7.80%
Validation 2	127.99	3.48%

Table 3: MAE and MAPE for the seasonal ARIMA model.

Seasonal ARIMA Model	MAE	MAPE
Validation 1	282.22	7.63%
Validation 2	179.15	4.80%

Figure 2 and Figure 3 illustrate the predicted and actual energy usage observed from October 12, 2023, to October 18, 2023, for the Prophet and neural network models, respectively. The predicted values are blue, while the actual values are black. The figures demonstrate that the neural network model excels in capturing intricate details within the seasonality pattern, which can be attributed to its advanced modeling capabilities. However, the Prophet model outperforms forecast capability, supported by its lower MAPE and MAE values. The forecasts from the Prophet and neural network models for October 5, 2023, to October 11, 2023, are illustrated in Figure A.1 and Figure A.2 in the appendix.

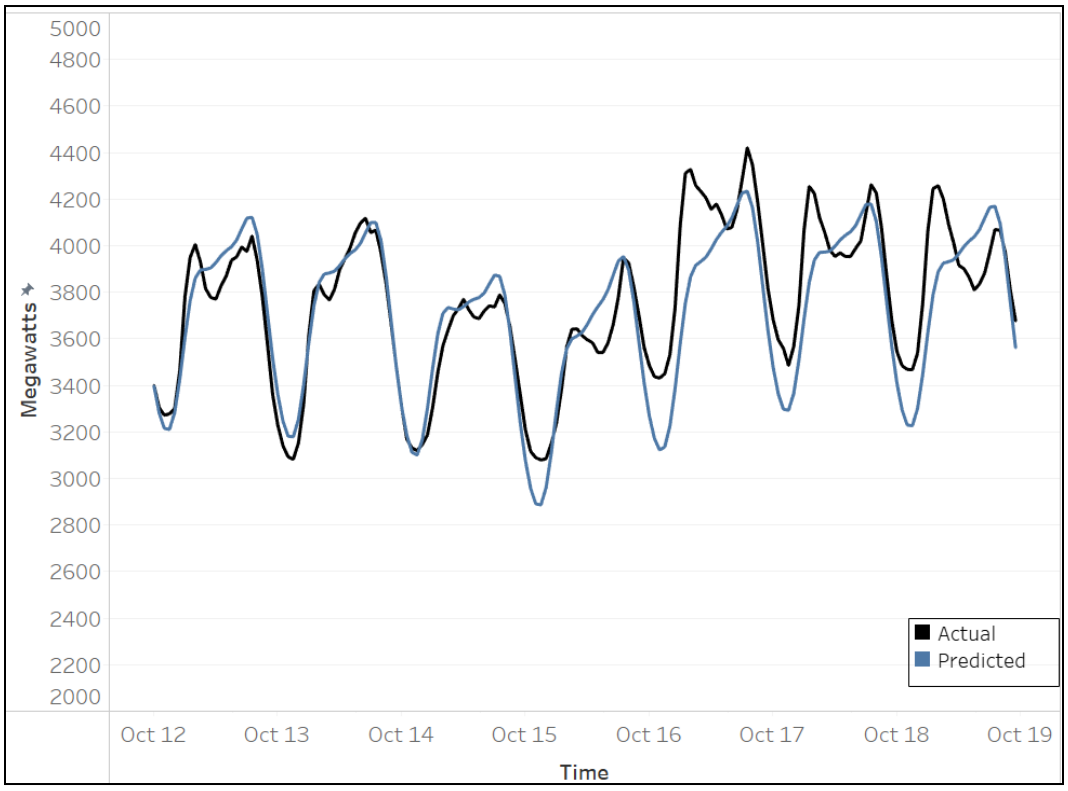

Figure 2: Time plot for the predicted energy usage of the Prophet model and the actual energy usage from October 12, 2023, to October 18, 2023.

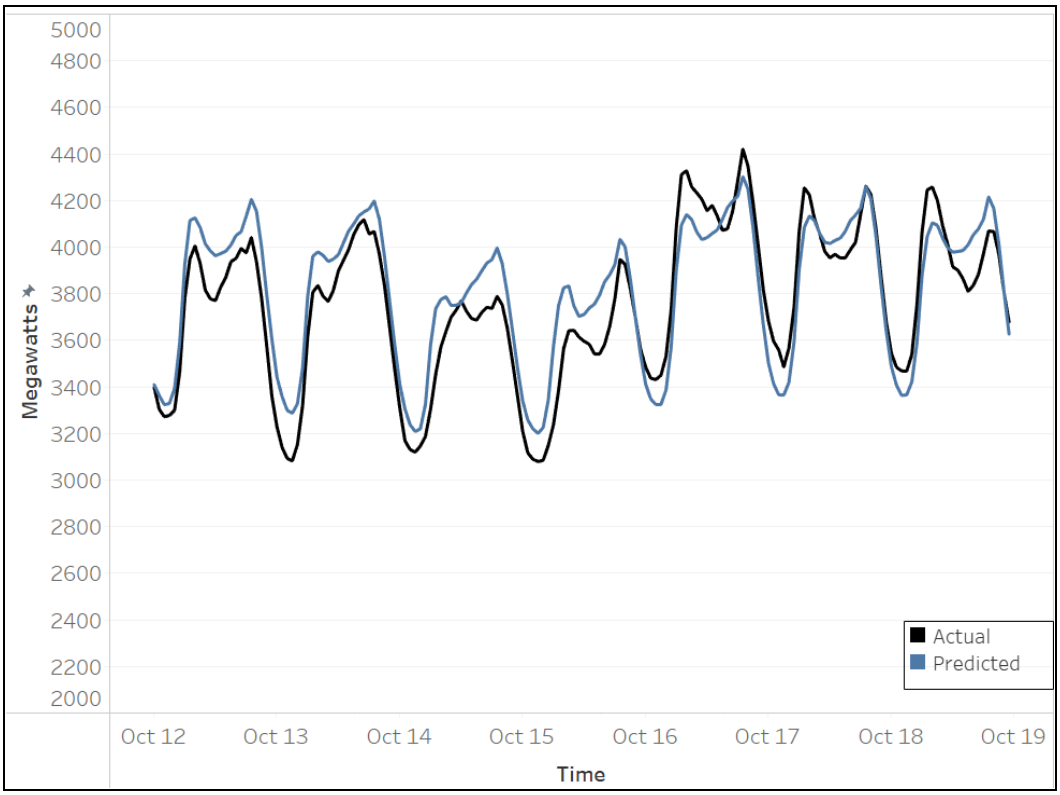

Figure 3: Time plot for the predicted energy usage of the neural network model and the actual energy usage from October 12, 2023, to October 18, 2023.

Recommendations

Based on the results of our analysis, we recommend that AEP take the following steps:

- Use the Prophet model for near-term forecasting, as it has the most predictive power.
- Incorporate weather forecasts as temperature and humidity can drive electricity usage.
- Flag any potential extreme weather events, as these can cause large surges in energy demand.
- Research any other external variables that may provide predictive value for the Prophet model.

Conclusion

Our team developed two models to predict hourly energy consumption for AEP. We found the Prophet model outperformed both the neural network and the seasonal ARIMA from the previous project phase. This model achieved MAEs of 174.86 and 131.05 and MAPEs of 4.64% and 3.47% for our two separate validation data sets. We recommend utilizing the Prophet model while incorporating extreme weather events to predict energy usage. In the future, we advise including additional weather forecasts to best predict future energy usage and exploring additional external variables to increase predictive power.

Appendix

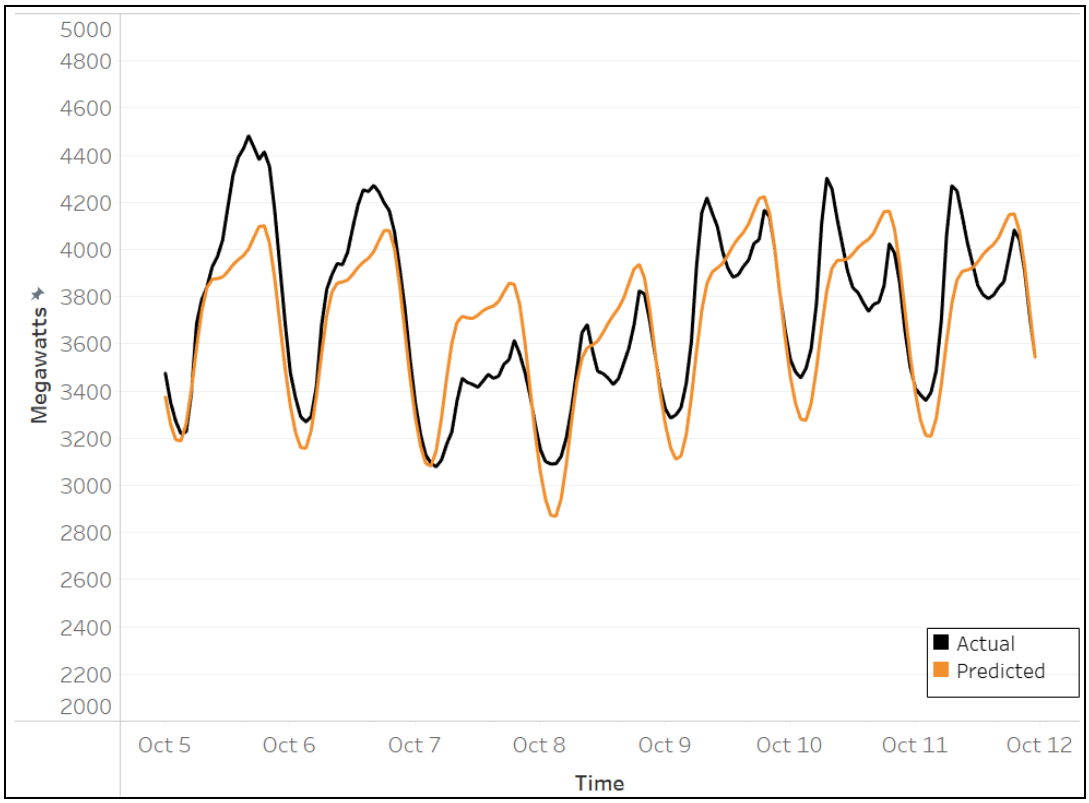

Figure A.1: Time plot for the predicted energy usage of the Prophet model and the actual energy usage from October 5, 2023, to October 11, 2023.

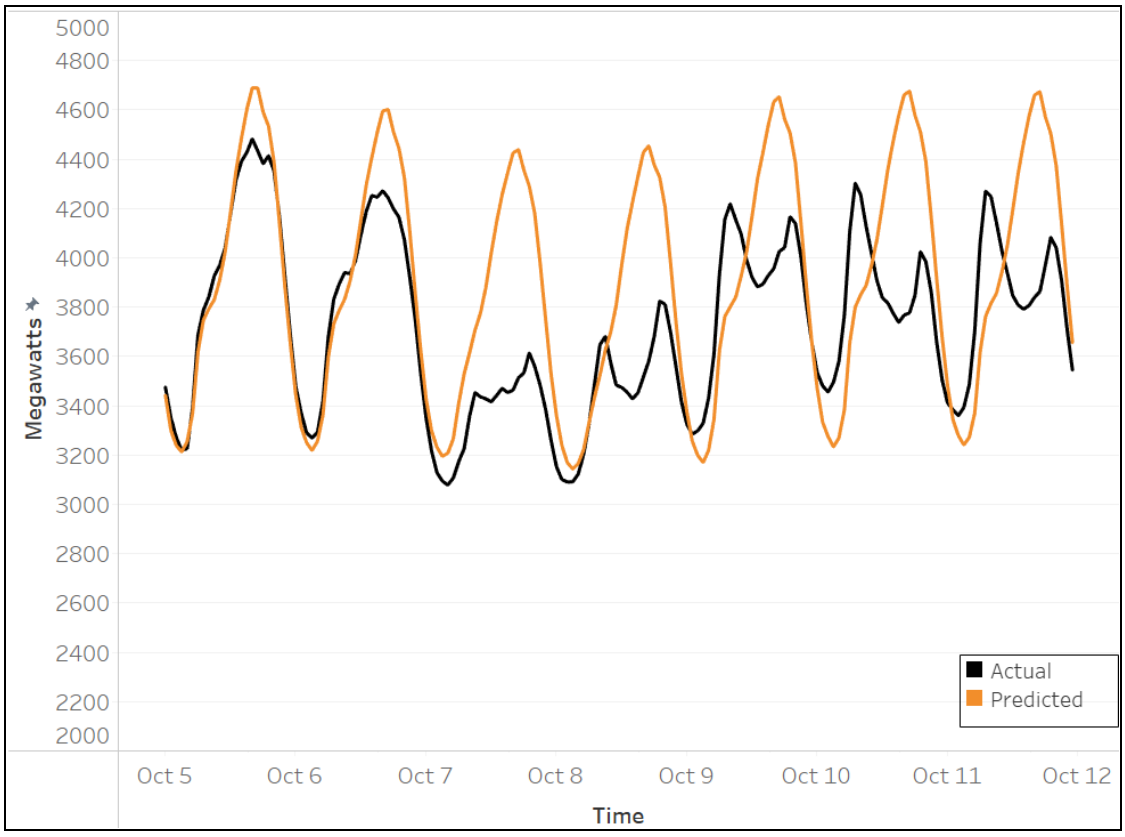

Figure A.2: Time plot for the predicted energy usage of the neural network model and the actual energy usage from October 5, 2023, to October 11, 2023.

Homework Report Checklist

As instructed by Dr. Egan Warren, the team member(s) responsible for checking each item should enter their initials in the field next to each question. All items should be addressed before submitting the assignment with the initialed checklist attached.

Sections & Structure

Overview

OB	Is the overview concise?
OB	Does it provide context about the business problem? <Content>
OB	Does it briefly address your team's work, quantifiable results, and recommendations? <Action>
OB	Does it offer audience-centered reasons for recommendations? <Context>

Body Sections

OB	Does the report body include information on methods, analysis, quantifiable results, and recommendations?
OB	Is content grouped into appropriate sections (*methodology*, *analysis*, *results*, *recommendations*)?

Conclusion

OB	Does the report have a conclusion?
OB	Does the conclusion sum up the report and emphasize relevant takeaways?

Structure

OB	Does each major section have a heading?
OB	Are sections, subsections, and paragraphs organized logically for easy navigation?

Visuals

Introduction, Discussion, and Captions

OB	Is each visual introduced in the text before it appears?
OB	Is each visual close to where it is introduced?
OB	Does each visual include a title with the following information: type (*table* or *figure*), number, and a descriptive caption?
OB	Is each visual discussed and interpreted in the text?
OB	Are figures and tables numbered separately?
OB	Are table captions above the table? Are figure captions below the figure?

Visual Design

TY	Do figures/tables use audience-friendly labels rather than variable names?
TY	Are the visuals easy to interpret?
TY	Are the visuals appropriately sized?
TY	Do tables appear on one page (*not split between 2 pages*)?
TY	Are legends and axis labels included for figures?
TY	Are numbers in tables right aligned?

TY	Are the visuals designed well (*ex*: *re-created in Word or Excel*, *not blurry or stretched*,...)?

Document Design

Title Page Design

TY	Does it include a descriptive title?
TY	Does it state the team name, team members' names, and the submission date?

Table of Contents Design

TY	Does it list all the major sections of the report with corresponding page numbers?
TY	Do the page numbers and sections in the Table of Contents match the report?

Document Design for Entire Report

TY	Is a standard typeface (*Calibri*, *Arial*, *etc.*) used?
TY	Is the size of the body text between 10-12 pt.?
TY	Are headings and subheadings used to organize information?
TY	Are distinctive text styles (*bold*, *italic*, *etc.*) used to distinguish between heading levels?
TY	Are text styles for headings used consistently (*ex*: *all level-one headings are bold*)?
TY	Are all paragraphs an appropriate length (*fewer than 12 lines*)?
TY	Is white space used to indicate paragraph breaks?
TY	Are bullet lists used for a series of items and numbered lists to show a hierarchy?

Writing Style and Mechanics

Spelling and Capitalization

TF	Are spelling errors located and corrected?
TF	Is spelling consistent throughout (*no switching between acceptable spellings*)?
TF	Is capitalization used appropriately (*proper nouns*, *etc.*)?
TF	Is capitalization of words consistent throughout the report?

Grammar and Punctuation

TF	Are verb tenses used appropriately?
TF	Are marks of punctuation used appropriately?
TF	Is subject-verb agreement used in every sentence?
TF	Is the grammar checker updated and are underlined grammar issues addressed?

Writing Style

TF	Are all sentences in the report easy for your audience to understand quickly?
TF	Are most sentences written in active voice?
TF	Are idioms and vague words eliminated from the report?
TF	Are acronyms introduced before being used?
TF	Are well-written topic sentences included at the beginning of each paragraph?
TF	Are lists parallel?
TF	Is the appropriate point of view used when addressing your audience or describing team actions?