ENERGY FORECAST

BLUE 6
Grant Blankenbeckler
Sam Dotson
Andrew Harris
Manisha Kasam
Tae Lee

September 11, 2023

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Energy Forecast

Overview

PJM, a regional transmission organization, provides resources within the wholesale electricity market. Within the Appalachian Power Transmission Zone (AEP), there is a need to better understand energy transmission, measured in megawatts (MW) for this area. PJM collected hourly time series data from January 2016 to June 2023 and wants to develop a model to forecast energy usage in the future.

Our team was tasked with exploring PJM's energy transmission data and building a forecast model to predict average monthly energy transmission in megawatts. To do this, we first implemented time series decomposition to identify seasonality in energy transmission. Then, we evaluated several exponential smoothing approaches before selecting Holt-Winters' Additive ESM to model and predict energy transmission. Our client's preferred accuracy measure was mean absolute percent error (MAPE), and our chosen model achieved a MAPE of 1.81%, indicating Holt-Winters' Additive ESM is a strong choice for modeling energy transmission. Given the efficacy of this model, we recommend that PJM adopt Holt-Winters' Additive ESM for their modeling needs.

Methodology

Data Used

PJM provided 66,455 hourly energy transmission data observations from January 2016 to June 2023. Each observation included 8 variables corresponding to characteristics such as date, time, region, and load of energy transmission in megawatts per hour.

The dataset was summarized by monthly energy transmission in MW and split into training, validation, and testing datasets. The training data for initial data exploration and model construction included average monthly energy transmission from January 2016 to December 2022. The validation data for selecting the appropriate model included January to April 2023. Finally, the test data included energy transmission observation from May to July 2023 and was used to evaluate the accuracy of our selected model.

Model Recalibration

As described above, we divided the monthly energy transmission data into training, validation, and testing datasets. We used the training data to construct different exponential smoothing models, and the validation dataset was used to compare different modeling approaches and select the best model. Once we selected the best model, which we identified as the Holt-Winters' Additive ESM, we incorporated the validation data into the training set. We recalibrated our model using all the January 2016 to April 2023 data. This updated model was used to calculate accuracy metrics when applied to the testing data, which included observations from May to July of 2023.

Analysis

Time Series Decomposition

In preparation for modeling, our team implemented STL time series decomposition to identify patterns in energy transmission. Specifically, this approach was used to evaluate the relative importance of the trend and seasonal components in determining average monthly energy transmission. Figure 1 shows the trend and seasonal components compared to the observed energy transmission. Notably, the seasonal component explained much of the average monthly energy usage variability. Conversely, the trend component exhibited a static trajectory and minimal variability, indicating lower importance than the seasonal component for modeling average monthly energy transmission.

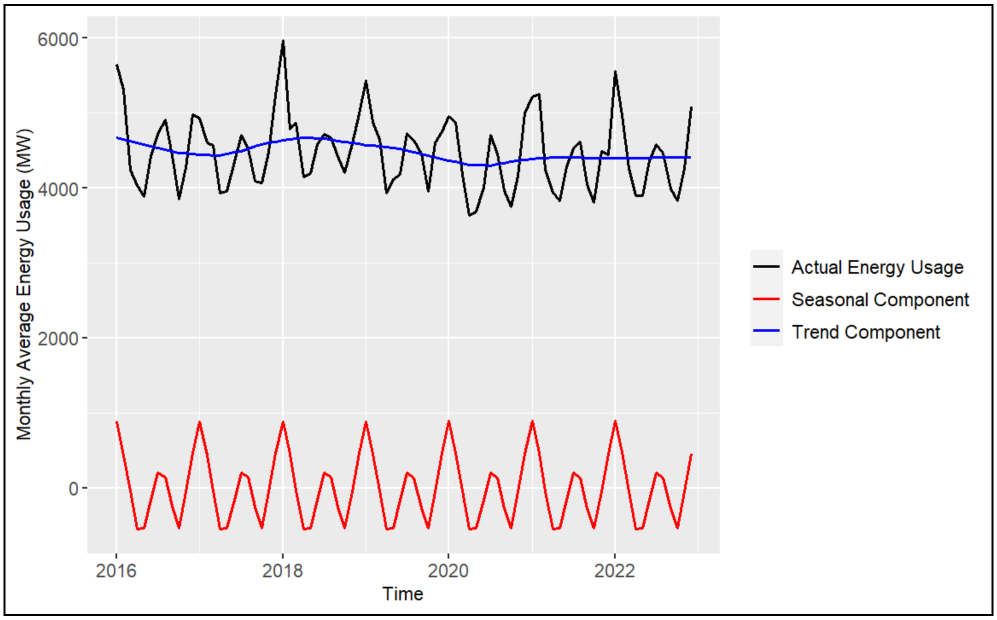

Figure 1: Average monthly energy usage (MW) overlaid with seasonal and trend components.

Our team used the insights derived from time series composition to guide efforts to model average monthly energy usage. Specifically, the decomposition in Figure 1 suggested the best modeling approach would likely account for the seasonality observed in the data. Furthermore, the STL decomposition utilizes additive seasonality, which adequately describes the data's seasonal component. Given these insights, model-building efforts included (but were not limited to) approaches that accounted for additive seasonality.

Model Development

To identify the best model for predicting average monthly energy transmission, our team compared five candidate models. Given the results of the STL decomposition described above, our team initiated model construction with Holt-Winters' Additive ESM, which accounts for additive seasonality. Using MAPE and mean absolute error (MAE), we compared the accuracy of Holt-Winters' Additive ESM and the four other candidate models. We calculated accuracy statistics using the validation dataset (January to April 2023). Alternative candidate models included ETS, Single ESM, Damped Holt Trend ESM, and Holt Trend ESM. As detailed in Table 1, Holt-Winters' Additive ESM demonstrated the highest level of accuracy, as indicated by lower MAPE and MAE, registering a MAPE of 5.73% and an MAE of 257.89. Given this result, we proceeded with Holt-Winters' Additive ESM as our best model.

Table 1: Accuracy metrics for forecasting average monthly energy transmission (validation data).

Model	MAPE	MAE
Holt-Winters' Additive ESM	5.73%	257.89
ETS	6.46%	289.86
Single ESM	18.58%	762.64
Damped Holt Trend ESM	18.58%	762.70
Holt Trend ESM	19.23%	789.63

Figure 2 compares the forecasts generated using Holt-Winters' ESM and the observed average monthly energy transmission for the validation dataset (January to April 2023). Of these four months, the predicted values for March and April were most closely aligned with the observed values.

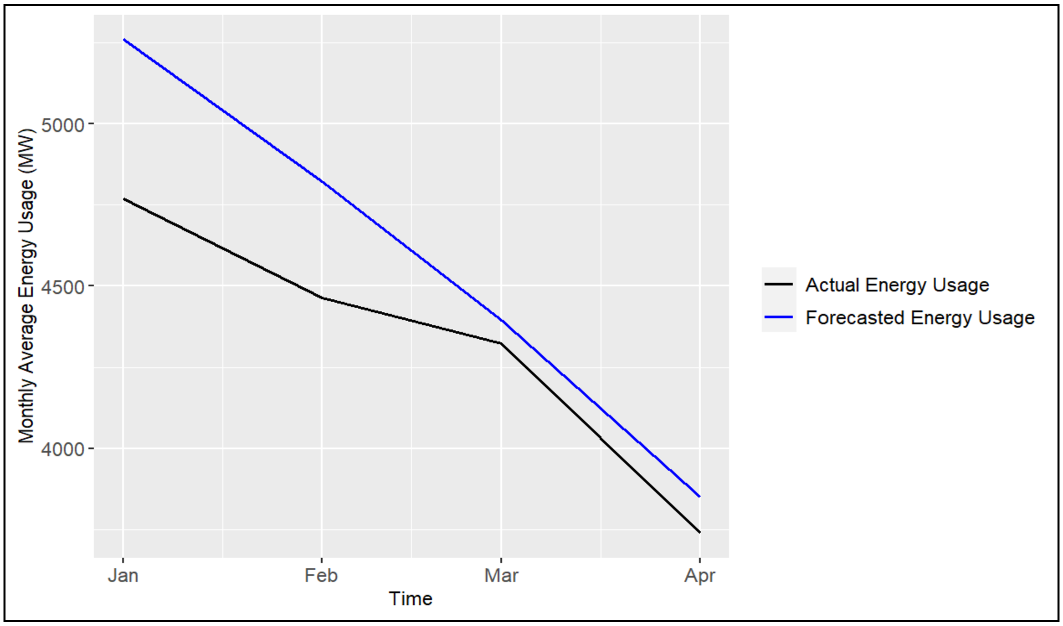

Figure 2: Observed average monthly energy usage (MW) compared to forecast (validation data).

Model Testing

As described above, once our team selected Holt-Winters' ESM as the best approach to modeling average monthly energy usage, the validation data was reincorporated into the training data, and the time series model was recalibrated before testing. Using the updated training data and Holt-Winters Additive ESM, our team generated forecasts for the test dataset, which included average monthly energy usage from May to July 2023.

Comparing the predicted and observed values for this period, our team calculated a MAPE of 1.81% and an MAE of 70.87. Therefore, model accuracy on the test set was an improvement on the accuracy for the validation set, with a 3.92-point decrease in MAPE and a 72.52% reduction in MAE. Figure 3 illustrates the proximity of the predicted values produced by Holt-Winters' Additive ESM and the observed average monthly energy transmission. These findings suggest Holt-Winters' Additive ESM is an appropriate and effective approach for modeling average monthly energy transmission.

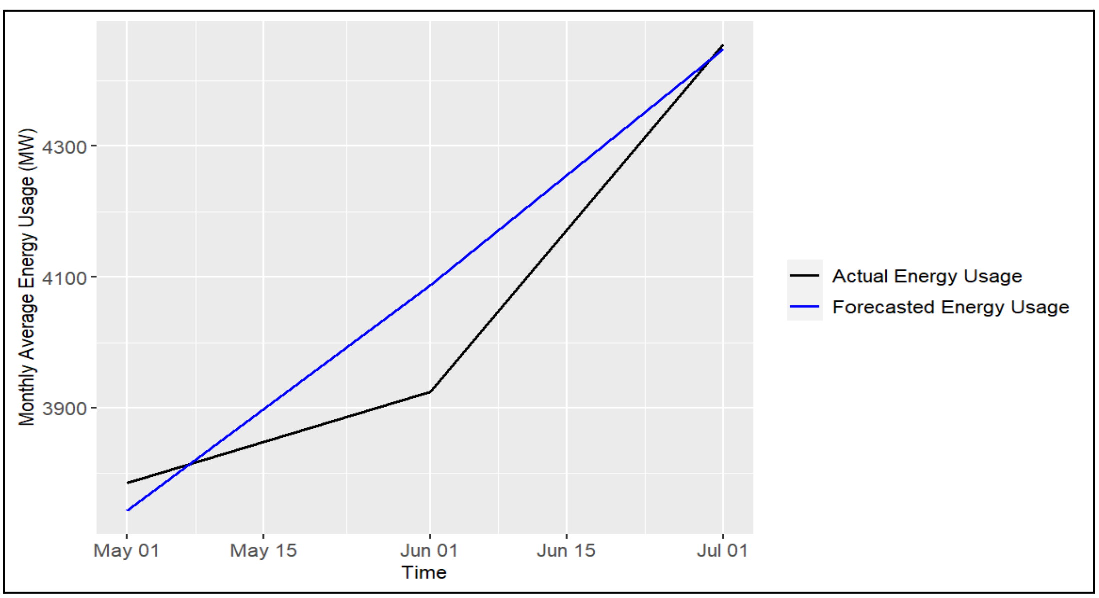

Figure 3: Observed average monthly energy usage (MW) compared to forecast (test data).

Results and Recommendations

In this analysis, we explored PJM's average monthly energy transmission in the AEP Appalachian Power transmission zone from January 2016 to July 2023. To begin, we implemented STL time series decomposition and discovered seasonality played an essential role in explaining variations in average monthly energy transmission. Next, we evaluated several candidate models for forecasting energy transmission. We found that Holt-Winters' Additive ESM outperformed other models, achieving a MAPE of 5.73% and an MAE of 257.89 for the validation dataset. Proceeding with this approach as our best model, we achieved a MAPE of 1.81% and an MAE of 70.87 for the test dataset after recalibrating the model to include the validation set data. These results confirmed the efficacy of Holt-Winters' Additive ESM for predicting average monthly energy transmission.

Given the efficacy of Holt-Winters' Additive ESM discussed above, we recommend that PJM adopt this approach to modeling energy transmission for the AEP Appalachian Power transmission zone. Its accuracy for the validation and test datasets underscores its reliability and predictive power. We also advise implementing regular model updates, as up-to-date training data is essential for long-term accuracy. Furthermore, PJM should avoid making predictions in the distant future, as these are more likely to be inaccurate, especially with obsolete data. Finally, PJM should utilize visualizations to monitor data quality, illustrate forecasts, and assist in decision-making regarding ongoing model development and business strategy.

Conclusion

To conclude, Holt-Winters' Additive ESM provides an effective approach to modeling average monthly energy transmission in the AEP Appalachian Power transmission zone from January 2016 to July 2023, including the high degree of seasonality observed in the data. We recommend that PJM proceed with implementing this model to address their needs for modeling energy transmission, and we strongly encourage regular and frequent data updates to ensure the long-term accuracy of the model.

HOMEWORK REPORT CHECKLIST

Sections & Structure

Overview

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

Body Sections

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

Conclusion

AH,TL,GB,MK, SD	Does the report have a conclusion?
AH,TL,GB,MK, SD	Does the conclusion sum up the report and emphasize relevant takeaways?

Structure

AH,TL,GB,MK SD	Does each major section have a heading?
AH,TL,GB,MK ,SD	Are sections, subsections, and paragraphs organized logically for easy navigation?

Visuals

Introduction, Discussion, and Captions

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

Visual Design

AH,TL,GB,MK,SD	Do figures/tables use audience-friendly labels rather than variable names?
AH,TL,GB,MK,SD	Are the visuals easy to interpret?
AH,TL,GB,MK,SD	Are the visuals appropriately sized?
AH,TL,GB,MK,SD	Do tables appear on one page (*not split between 2 pages*)?
AH,TL,GB,MK,SD	Are legends and axis labels included for figures?
AH,TL,GB,MK,SD	Are numbers in tables right aligned?
AH,TL,GB,MK,SD	Are the visuals designed well (*ex: re-created in Word or Excel, not blurry or stretched,…*)?

Document Design

Title Page Design

AH,TL,GB,MK,SD	Does it include a descriptive title?

AH,TL,GB,MK,SD	Does it state the team name, team members' names, and the submission date?

Table of Contents Design

AH,TL,GB,MK ,SD	Does it list all the major sections of the report with corresponding page numbers?
AH,TL,GB,MK ,SD	Do the page numbers and sections in the Table of Contents match the report?

Document Design for Entire Report

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

Writing Style and Mechanics
Spelling and Capitalization

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

Grammar and Punctuation

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

Writing Style

AH,TL,GB,MK, SD	Are all sentences in the report easy for your audience to understand quickly?
AH,TL,GB,MK, SD	Are most sentences written in active voice?
AH,TL,GB,MK, SD	Are idioms and vague words eliminated from the report?
AH,TL,GB,MK, SD	Are acronyms introduced before being used?
AH,TL,GB,MK, SD	Are well-written topic sentences included at the beginning of each paragraph?
AH,TL,GB,MK, SD	Are lists parallel?

AH,TL,GB,MK,SD	Is the appropriate point of view used when addressing your audience or describing team actions?