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Weather Dependent Hybrid Energy Systems

Keywords: *Machine learning - Linear regression – linear algebra - weather – prediction – renewable energy - renewable energy forecasting - Energy management-*

Abstract

Optimizing and sustaining energy systems is an ongoing global pursuit. Hybrid renewable energy systems have recently emerged as a pioneering approach targeting optimizing resource utilization and reliable energy production. This research aims to reach a method to determine the viability of a given location for the implementation of wind energy and solar power stations. In the analysis, linear algebra concepts will be used to analyze large datasets. . Machine learning, including linear regression, will be performed to utilize the weather statistics for predicting the amounts of energy from the two combined sources. This capability enables the dynamic allocation of solar energy and wind power and then finally optimizes energy production.

Introduction

The project aims to develop a module that leverages linear algebra to analyze weather information. Linear algebra takes part in this study in representing weather variables as vectors and matrices, allowing for a systematic analysis of their impact on energy production. The relationships between weather parameters, such as sunlight, wind speed, and temperature, are expressed through linear equations. By incorporating weather data into the equations, we developed a multiple linear regression module that seeks to predict the amount of energy that can be generated from hybrid renewable energy stations. The multiple linear regression module is used to characterize, forecast, and test a linear relationship between the variables providing a solid result to rely upon. Furthermore, the equations form the basis for constructing a mathematical model that predicts the energy output of renewable energy stations are all linear based. The module's output shall be used to assess the sustainability of an area relying solely on hybrid renewable energy. Through math's lens, this study illuminates a path to hybrid renewable energy resilience, shaping a future where sustainability is our constant companion.

Methodology

To verify the suitability of sites for hybrid renewable energy stations, we employed two algorithms. The first is to determine the applicability of the site as a wind planet, and the other is to assess the possibility of generating solar energy. Initially, the collected weather data is used to calculate the theoretical power from a wind turbine, and a multiple linear regression model predicts power values using relevant parameters (See figure 2). The application of linear algebra principles is evident in the incorporation of the ideal gas law for air density calculation and the mathematical formulation of theoretical power based on wind speed, encapsulated in model mathematics.

Subsequently, linear regression models are utilized for wind power and Global Horizontal Irradiance (GHI) predictions, treating them as systems of linear equations with coefficients optimized to minimize prediction errors. Leveraging statistical techniques rooted in linear algebra, the code applies outlier removal based on the interquartile range.

Furthermore, the mean absolute error, mean squared error, and R-squared, were used to provide insights into the accuracy and performance of the regression models. The program concludes with a succinct determination of whether a location is suitable for a hybrid renewable energy system, solar power only, or wind power only, emphasizing the practical application of linear algebra in assessing renewable

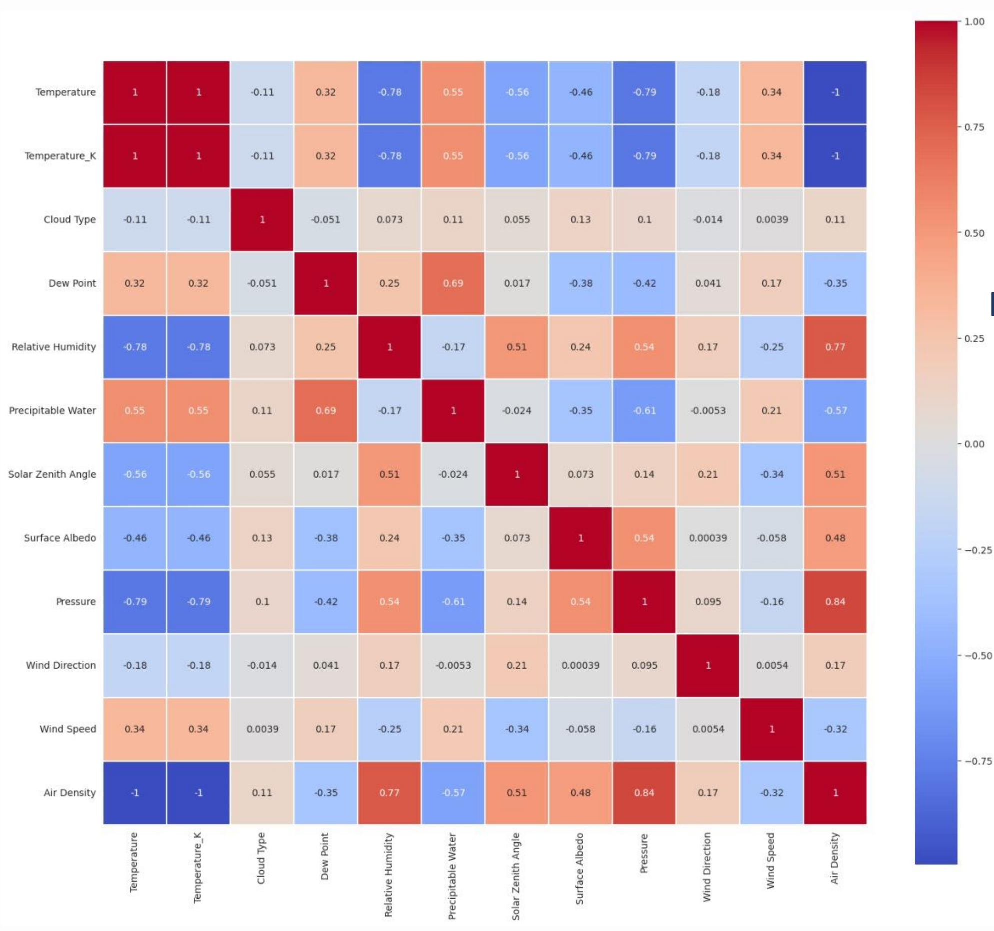

Figure 1

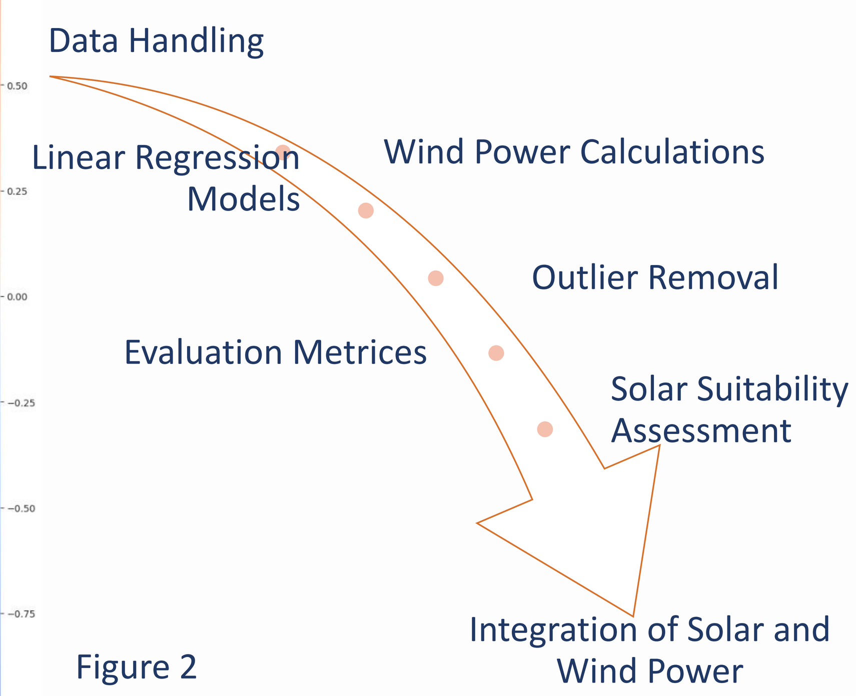

Figure 2

Results

This graph illustrates the predictive accuracy of the wind turbine power production model. It compares the real power, predicted power, and the theoretical power curve based on wind speed. The alignment between actual and predicted power, along with the theoretical curve, showcases the effectiveness of the model. (See figure 3)

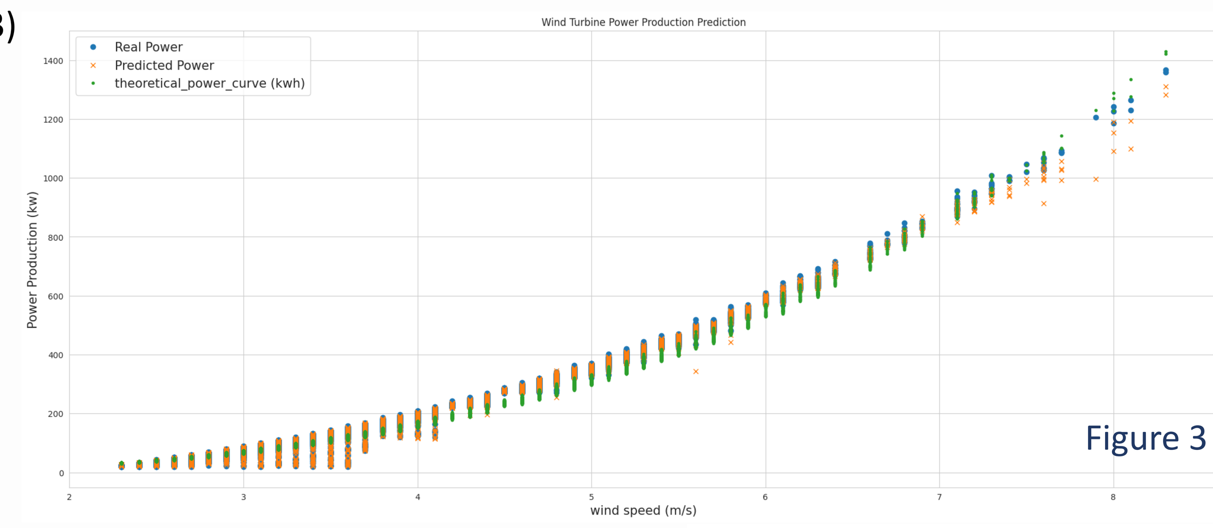

Figure 3

This graph assesses the suitability of a location for solar power generation. It incorporates factors like Global Horizontal Irradiance (GHI) and temperature. The visual representation highlights conditions conducive to solar energy production, aiding in site selection for solar projects. (See figure 4)

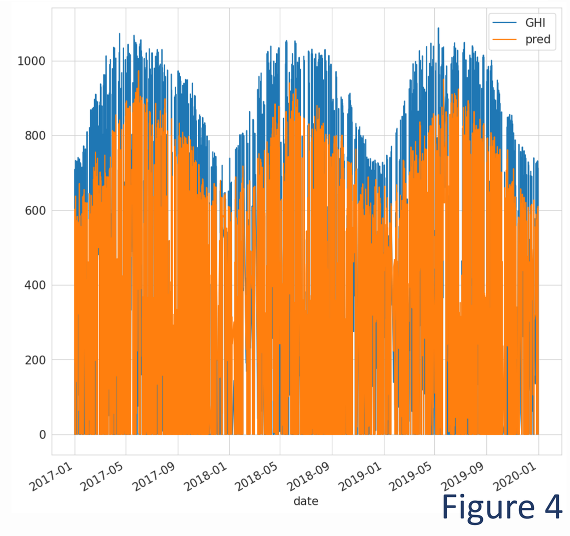

Figure 4

This is the final output function. It combines factors from both energy sources, aiding in the determination of whether a location is suitable for a hybrid renewable energy system.

```
[ ]  if(is_suitable_for_solar_power(data) and is_suitable_for_wind_power(data)):
       print("This location is suitable for Hybrid renewable energy system!")
     elif(is_suitable_for_solar_power(data)):
       print("The location is suitable for solar power only")
     else:
       print("The location is suitable for wind power only")

     This location is suitable for Hybrid renewable energy system!
```

Figure 5

Discussion and Conclusion

This section is going to highlight the main parts of the project. The project seamlessly used linear algebra fundamentals along with machine learning and prediction algorithms for renewable energy site selection. The program calculated parameters using scientific notations and operated to predict a final two-bit binary output through more than one linear regression model. It efficiently generated a final output with a notably high accuracy.

All in all, the project handheld weather data in Egypt and draws meaningful conclusions from it by using various linear algebra applications to finally indicate the applicability of implanting hybrid renewable energy stations.

Achievements and Skills Gained

Learned how to apply linear algebra
Learned how to connect machine learning with linear algebra
Got an insight on how to best utilize machine learning for future reference

Recommendations

The project stands to benefit from the incorporation of a weather prediction module, enhancing its autonomy and adaptability. Further, the inclusion of additional renewable energy sources like hydro energy would broaden its utility and make it more versatile. Exploring sophisticated methodologies such as deep learning or neural networks could lead to improved accuracy in predictions, elevating the project to the forefront of innovation. These strategic enhancements align with the evolving landscape of renewable energy and artificial intelligence, ensuring the project remains dynamic and capable of addressing emerging challenges.

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