CLEVELAND STATE UNIVERSITY

Hybrid Wind-Solar Systems to Power an EV Charging Station: A Case Study

Mechanical Engineering Department

Multiscale Multiphysics Modeling and Data-Driven Analysis of Thermofluids (M^3TFluid) Lab

Faculty Advisor: Dr. Navid Goudarzi

Undergraduate Students: Nathan Baker, Youssef Mostafa

TABLE OF CONTENTS

Abstract 1

Analytical Code Development 1

Cleveland Weather Station Development 3

- Practical Analysis 3
- Hardware 3
- Software Implementation 4
- Collaboration with Campbell Scientific 4

Acknowledgments 5

References 5

ABSTRACT

This project unfolds within the dynamic context of a growing shift towards sustainable transportation solutions, exemplified by the burgeoning adoption of electric vehicles (EVs) in recent years. The imperative to develop a robust infrastructure capable of supporting the widespread utilization of EVs has emerged as a pressing necessity alongside this transformative trend. In this regard, the potential of renewable energy sources, notably wind and solar power, assumes paramount significance in fostering the emergence of clean energy EV charging stations. However, the effective harnessing of these energy reservoirs necessitates careful consideration to maximize energy output. The leading key factor among these considerations is the strategic placement of EV charging stations to optimize energy generation for EV charging purposes.

Through this study, we investigate the potential of harnessing wind and solar power within Cleveland to help advance the existing EV charging infrastructure. However, performing such analysis requires the involvement of different analytical programs to effectively, and accurately display the calculated wind energy potential. Before the analysis within Cleveland, an effective code is developed to quickly perform the calculations needed to determine locations for wind and solar energy farms.

Integral to this work is the deployment of diverse analytical frameworks to accurately assess the potential of wind energy generation. Before our investigation within Cleveland, a robust computational framework must be established to facilitate swift and precise calculations essential for pinpointing optimal locations for wind and solar energy installations.

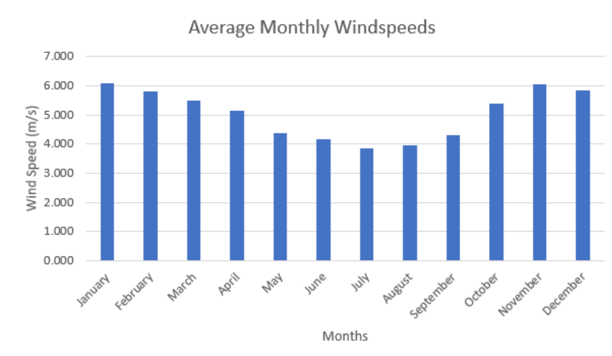
ANALYTICAL CODE DEVELOPMENT

In examining Cleveland's renewable energy potential, a decade-long dataset from 2014 to 2024 was pivotal. This data, obtainable via the Visual Crossing website, underwent careful cleaning and organization before analysis. Leveraging MATLAB, a comprehensive script was constructed to rectify missing data points in the wind speed column and standardize units from km/h to m/s, ensuring data integrity for subsequent calculations.

Segmentation of the data into monthly intervals was crucial to improve temporal variations. Each month's data was split into separate Excel sheets, a step aimed at preventing cross-contamination between different time frames. This organizational strategy facilitated focused analysis, enhancing the accuracy of results.

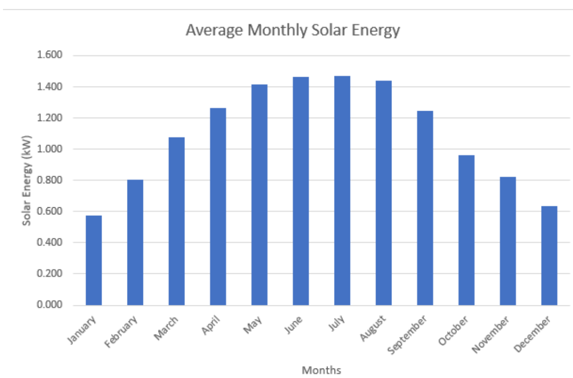
Basic data analysis involved the computation of average wind speeds and standard deviations for each month and year. Utilizing MATLAB, these calculations were executed iteratively across the segmented data sheets, culminating in the creation of a new Excel file housing the calculated averages and standard deviations.

Following data processing, the refined dataset was integrated into an Excel template engineered to automate the generation of graphs and wind energy density tables. This template not only expedited the analysis of Cleveland's hourly data but also served as a standardized framework for future assessments. Through this meticulous approach, a robust foundation was established to evaluate Cleveland's wind and solar energy potential comprehensively.



Monthly Weibull Parameters				
Month	*k*	*c* (m/s)	Wind Power Density (W)	Wind Energy Density (kWh/m^2/hour)
January	2.254	6.857	0.005	234.799
February	2.107	6.576	0.006	219.775
March	1.915	6.175	0.007	201.090
April	1.902	5.801	0.009	168.077
May	1.894	4.928	0.015	103.491
June	2.031	4.702	0.016	83.309
July	2.068	4.333	0.020	64.033
August	2.068	4.484	0.018	70.950
September	2.125	4.850	0.014	87.489
October	2.173	6.089	0.007	169.578
November	2.202	6.841	0.005	237.757
December	2.176	6.591	0.005	214.920

Figure 1: Cleveland Wind Energy Density Results



Monthly Averages		
Month	Average Solar Energy (kW)	Average Standard Deviation (kW)
January	0.573	0.457
February	0.803	0.652
March	1.075	0.829
April	1.266	0.959
May	1.415	1.045
June	1.462	1.051
July	1.468	1.061
August	1.437	0.985
September	1.248	0.901
October	0.963	0.755
November	0.822	0.627
December	0.634	0.507

Figure 2: Cleveland Solar Energy Density Results

Based on the comprehensive analysis conducted in Cleveland, we can calculate the peak power generation over the course of the year. Referring to Figure 1 for wind energy data and Figure 2 for solar energy metrics specific to Cleveland, November emerges as the month with the highest combined power output. During this period, wind energy density reached 237.757 kWh, complemented by a solar energy production of 0.822 kWh. Consequently, the synergistic effect of wind and solar energy culminates in a maximum power production of 238.579 kWh, highlighting November as the most prolific month for renewable energy generation in Cleveland.

Practical Analysis

The practical segment of the project embarks on a thorough analysis aimed at assessing the potential of wind energy resources within Cleveland. Central to this examination is the strategic placement of a Campbell Sonic sensor atop Cleveland State University's tower. This positioning is crucial for gathering indispensable wind data necessary for evaluating wind energy potential in the Cleveland region. The preference for the Sonic sensor over traditional mechanical ones is justified by its compact and robust design, lacking mechanical components that could compromise durability and lead to wear and tear, thereby ensuring consistent and dependable data collection over extended durations.

Hardware

The hardware ensemble deployed encompasses various components geared toward effective wind data acquisition (*purchased from other funding sources*). This includes the Campbell Scientific METSENS500 Wind Sonic Sensor, specifically engineered for precise measurement of wind speed and direction. Additionally, a robust mounting bracket or mast is utilized to securely affix the sensor to the rooftop or tower. The Campbell CR350 Data Logger is instrumental in interfacing with the Campbell Sonic sensor to capture and store wind data seamlessly. This choice ensures compatibility and facilitates uninterrupted data acquisition. Depending on the specifications of the data logger and sensor, a suitable power supply or battery backup may be incorporated to maintain continuous operation. Furthermore, the establishment of high-quality cables and connectors ensures robust connections between the sensor, data logger, and power supply, safeguarding data integrity.

Figure 3: CR350 Data Logger and METSENS500 Wind Sonic Sensor

Software Implementation

After completing the hardware setup, the focus shifts to software installation, enabling efficient interaction with the acquired data. The software interface empowers users to specify the CR350 Data Logger, granting access to comprehensive wind parameter information. Offering real-time data visualization, wireless connectivity, and customizable data logging intervals, the software enhances flexibility and accessibility in data collection strategies. Furthermore, users can effortlessly download data in various formats, facilitating seamless integration into analysis workflows. Integrated data management tools streamline organization and archiving, bolstering efficiency in data handling and retrieval for subsequent analysis.

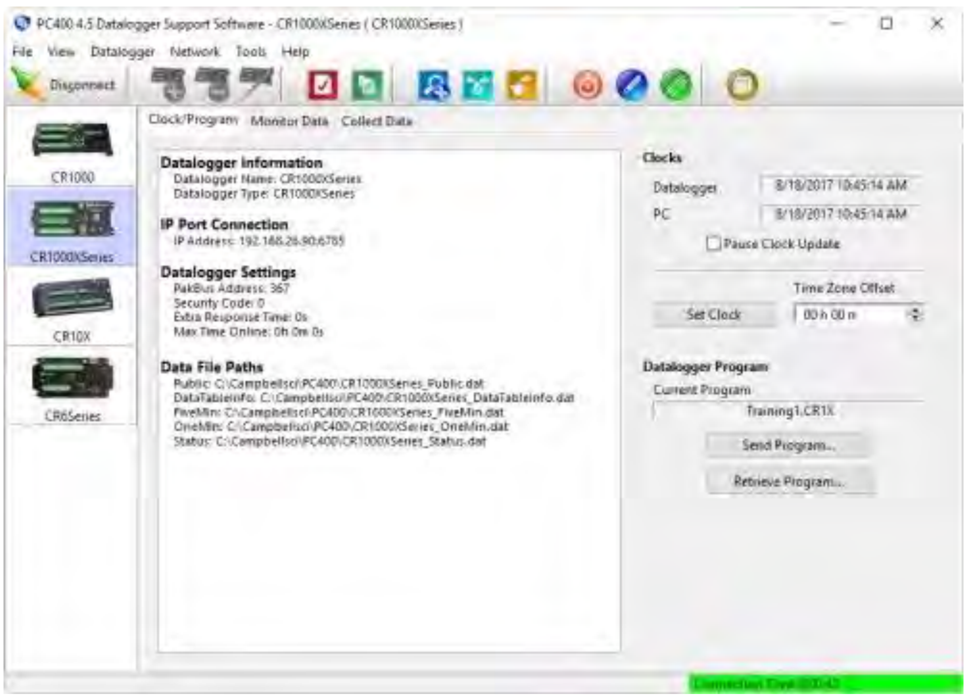


Figure 4: Campbell Scientific PC400

Collaboration with Campbell Scientific

During the implementation phase of this research, navigating technical intricacies necessitated collaboration with Campbell Scientific, the manufacturer of the sensors and data loggers utilized in the study. Multiple Zoom meetings were conducted with Campbell Scientific's technical support team to address challenges related to the wiring and coding of the data loggers and sensors, ensuring seamless integration and functionality. These collaborative efforts were instrumental in troubleshooting issues and optimizing the setup process, underscoring the importance of industry partnerships and expert guidance in overcoming technical hurdles. By leveraging the expertise of the manufacturer's support team, the research team was able to streamline the setup process and enhance the reliability of data collection, reinforcing the importance of collaborative problem-solving in scientific endeavors.

ACKNOWLEDGMENTS

We acknowledge EPRI for supporting the performed research. We also acknowledge Visual Crossing for providing us with access to historical data in Cleveland.

REFERENCES

[1] Gorla, RSR., et al. "Use of Rayleigh Distribution Method for Assessment of Wind Energy Output in Cleveland–Ohio ." *Renewable Energy Research and Applications (RERA)*, vol. 1, no. 1, 19 Oct. 2019, pp. 11–18. *11-18*.

[2] Goudarzi, N., et al. *An Assessment on the Wind Energy Potential and Possible Solutions for Power Generation in Baltimore County in Maryland, USA*, 3 Aug. 2014.

[3] Grewal, Parbir S., and Parwinder S. Grewal. "Can cities become self-reliant in energy? A technological scenario analysis for Cleveland, Ohio." *Cities*, vol. 31, Apr. 2013, pp. 404–411, https://doi.org/10.1016/j.cities.2012.05.015.

[4] Li, Jiale, and Xiong (Bill) Yu. "Onshore and offshore wind energy potential assessment near Lake Erie Shoreline: A spatial and temporal analysis." *Energy*, vol. 147, Mar. 2018, pp. 1092–1107, https://doi.org/10.1016/j.energy.2018.01.118.

[5] Mekonnen, Addisu D., and Pece V. Gorsevski. "A web-based participatory GIS (PGIS) for offshore wind farm suitability within Lake Erie, Ohio." *Renewable and Sustainable Energy Reviews*, vol. 41, Jan. 2015, pp. 162–177, https://doi.org/10.1016/j.rser.2014.08.030.

[6] Smith, Colton, et a;. "The Solar and Wind Economy in Ohio: Industry Analysis and Policy Implications." *Consilience*, no. 20, 2018, pp. 43–61. *JSTOR*, https://www.jstor.org/stable/26760102. Accessed 7 May 2024.