The Impact of Plug-In Electric Vehicles Users Charging Behavior on Electric Grid

Application for 2020-2021 Graduate Research and Creative Activity (GRACA) Grant

University of Nebraska- Omaha (UNO)
M.S Student : Ahmad Almaghrebi
Faculty Mentor : Dr. Xiaoyue Zoe Cheng
Data Science / Concentration :Mathematics

Project Overview

Smart grids are electrical grids that incorporate energy efficient and renewable energy technologies, and their implementation can require substantial restructuring and re-engineering of our existing power networks [1]. These transformations are important and necessary, however, considering the multitude of environmental and economic benefits that accompany smart grid rollout. One of smart grids' biggest advantages is the flexibility that they bring to both energy suppliers and consumers [2]. As one example, demand response resources monitor energy demand and support the interaction between generators and loads to optimize satisfaction of that demand without overloading the power grid [3]. Typically, these operations incorporate renewable energy resources such as photovoltaic (PV) panels and battery energy storage systems (BESS). The emergence of electric vehicles (EVs) as yet another factor incorporated into the smart grid presents an interesting challenge [4].

While the increase in EV use is a positive step towards embracing green technology, the heightened energy demands resulting from this the rapid growth present major challenges to local energy grid load management. For context, the new EVs being deployed store approximately 100 kWh, about four times the daily electricity use of the average household in the U.S [5]. Current local distribution grids do not have the capacity to accommodate these massively increased loads. For this reason, it is important that local utilities have a full understanding of the charging demand within a given grid [6].

Building off of some of my previous work, I am leading a study in which I monitor energy consumption at both public and household charging stations. After collecting and performing statistical analysis on charging data from public charging stations located in the state of Nebraska , I applied a mathematical model that produced valuable information regarding factors that influence charging behavior at public charging stations. With this method, I determined that both the time at which the individual begins charging their car as well as the location of the charging station have a significant effect on resulting energy consumption. Using this data, I then analyzed charging demand on a session-by-session basis and applied three machine learning techniques to predict ultimate charging demand just from the information available at initial hook-up. These findings led me to my current research.

The main objective of my current research is to deepen the understanding of charging behavior at the household charging stations using real data collecting from 350 existing household charging stations in Omaha. In analyzing the charging behavior of PEV users, trends in energy consumption will be shown to inform the utility companies how the charging behavior at household charging stations could affect the stability of the electric grid.

This analysis will aid utilities in amending the regulations for using the household charging stations more efficiently by applying effective scheduling techniques EV charging scheduling methods through shifting EV load to off-peak and aligning with renewables and over-generation by solar. Also, from the perspective of an electrical grid, EVs offer an opportunity to provide ancillary services, such as DR, renewable generation integration, or providing emergency backup power. These benefits can be achieved by proper EV-grid integration. Therefore, EV has great potential to make an electrical grid more reliable. Vehicle manufacturers also benefit from data on the usage of electric vehicles, to improve performance, efficiency, and range.

Research plan

Forecasting EV load and its impact to a distribution grid has recently been brought to light by the development of smart grids and the growing number of EVs [7]. Due to limited access to real EV charging data, synthetic data from travel surveys are used for the majority of these studies. However, this research will be using real data collected from different household charging stations installed in 352 homes in Omaha. Yet the stochasticity of EV user charging behaviors, including start time, connection duration, charging duration, and energy consumption, poses a significant challenge for the management of charging scheduling. Therefore, this research will be focused on the analysis of EV charging behavior at Households by visualizing the collected data. Then, day-ahead charging demand forecasting for plug-in electric vehicles user at household charging stations using (ARIMA) Model will be presented in this research. ARIMA stands for auto-regressive integrated moving average. It is a way of modeling time series data for forecasting (i.e., for predicting future points in the series) using the past values. It is a combination of auto-regressive and moving average models [8]. This approach is validated using a dataset collected from available household Level 2 charging stations located in 352 homes in Omaha city from April 2018 to December 2020. The charging stations are single phase 40A, 240V with single port. The total dataset has 103,352 charging sessions, and for each session, the following information is considered: Session starting time, including season, day of week, time of day, and a numeric time series, describing the absolute time, connection duration - the duration between the beginning and the end of the session, charging duration- the time required to charge EVs fully or partially, kWh consumed during the charging session, Idle time, and unique driver ID. Below is a summary of the dataset collected since 2018.

Year	Number of Ports	Number of Sessions	Energy (MWh)
2018	128	10,487	119.049
2019	239	45,805	545.157
2020	352	47,060	598.705

Student and Faculty Roles

M.S Student at UNO : As the researcher for this project, I will be responsible for 1) reviewing the past work to prepare a literature for the conference paper, 2) Analyzing & visualizing the dataset using R software, 3) Applying ARIMA model and optimize the model to get the most accurate forecasting, 4) providing progress reports on the project in my weekly meeting with Dr. Xiaoyue Zoe Cheng, 5) submitting this work in SEST2021 conference. It will be also a my master project in the Data Science program at UNO. Subsequently, in the 2022 fall semester, I will prepare to present at the UNO Research and Creative Activity Fair in March 2022.

Faculty Members : Dr. Xiaoyue Zoe Cheng, Assistant Professor, Department of Mathematics at UNO and my M.S advisors who will monitor/moderate data analysis and modeling, and provide feedback on deliverables.

Previous Internal Funding

I have not received any previous funding for this research project.

Project Timeline

Week	Project Phase	Research Activities
April 1st – April 30th 2021	Literature Review	Finalize a literature review of the impact of PEV users charging behavior on electric grid by reviewing the previous work.
May 1st – May 30th 2021	Data Analysis	Analyze the data collected using R software and investigate the trend and pattern
June 1st – June 30th 2021	Modeling	Apply time series model to forecast the charging demand a day ahead, then optimize it to get the most accurate model
July 1st – July 30th 2021	Finalizing the paper & poster	Finalize the conference paper and prepare the poster to be presented at the UNO Research and Creative Activity Fair in March 2022

Project Budget

The total amount requested for this grant is $5000. The proposed budget reflects the time allotment at a standard graduate student pay rate of ~$15per hour for the months June and July 2021.

Previous Publications :

First Author / 1 Journal paper (Energies Journal, an open access journal published by MDPI. Impact Factor is 2.8)

- Data-Driven Charging Demand Prediction at Public Charging Stations Using Supervised Machine-Learning Regression Methods. August 2020

First Author / 2 conference papers (ITEC 2019 , ITEC 2020)

- Analysis of Energy Consumption at Public Charging Stations, A Nebraska Case Study August 2020
- Analysis of PEV user charging behavior at public charging stations August 2019

Second & Third Author / 2 conference papers (IECON 2018 , IECON 2020)

- Energy Optimization Technologies in Smart Homes Jan 2021
- An overview of technologies for lower energy consumption in smart buildings Jan 2019

The only Author / 1 M.S thesis (University of Nebraska-Lincoln)

- The Impact of PEV User Charging Behavior in Building Public Charging Infrastructure April 2020

References

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[6] A. Almaghrebi, F. Al Juheshi, J. Nekl, K. James, and M. Alahmad, "Analysis of Energy Consumption at Public Charging Stations, a Nebraska Case Study," in *2020 IEEE Transportation Electrification Conference & Expo (ITEC)*, Jun. 2020, pp. 1–6, doi: 10.1109/ITEC48692.2020.9161456.

[7] L. Buzna *et al.*, "An ensemble methodology for hierarchical probabilistic electric vehicle load forecasting at regular charging stations," *Appl. Energy*, no. August, p. 116337, 2020, doi: 10.1016/j.apenergy.2020.116337.

[8] R. . Agrawal and A. K. Ratnadip, "An Introductory Study on Time Series Modeling and Forecasting Ratnadip Adhikari R. K. Agrawal," *arXiv Prepr. arXiv1302.6613*, vol. 1302.6613, pp. 1–68, 2013.

University of Nebraska Omaha

January 18, 2021
Office of Research and Creative Activity
University of Nebraska at Omaha
Omaha, NE 68182

Dear GRACA Review Board,

I am writing with regards to support the project titled *The Impact of Plug-In Electric Vehicles Users Charging Behavior on Electric Grid* by Ahmad Almaghrebi. Mr. Almaghrebi is a master student from the UNO data science program. After receiving his BS in Electrical Engineering in 2014 from Damascus University in Syria, he spent several years working as an electrical and control engineer specializing in control and automated systems.

The project described in this proposal is an ongoing data tracking project through the Nebraska Community Energy Alliance (NCEA). By analyzing the charging behavior data from PEV users, we aim to discover the trends in energy consumption and predict the charging demand in Omaha area. This research will benefit the local utility companies in maintaining the stability of the electric grid.

Mr. Almaghrebi is responsible for collecting and analyzing data about PEV charging at public and household charging stations for an initiative funded by the Nebraska Environmental Trust. Exploratory data analysis and time series analysis will be conducted and tested for pattern recognition. The proposed budget is justified as hourly pay for Mr. Almaghrebi during the summer.

As a faculty mentor, I will supervise the research and hold weekly meeting with him to review the progress and results, provide direction for the research, and suggest additional readings. As part of the meeting Mr. Almaghrebi will present the research findings in the form of oral presentations. He will also submit the final project report and results originating from this research at the end of the project for my review for potential publication in conference.

Mr. Almaghrebi is a talented researcher who has excelled throughout his academic career. I strongly support him for this GRACA grant application. Please do not hesitate to contact me if you have any additional questions.

Sincerely,

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