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Preparing the Grid for Electric Vehicle Charger Installations Serving Multi-Unit Dwellings

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SUMMARY

Transportation electrification can help mitigate climate change, and environmental and public health problems. Utilities can support the adoption of electric vehicles (EVs) by planning for the deployment of EV charging infrastructure to ensure adequate capacity and through make-ready work. ComEd received a grant from the Department of Energy (DOE) to contribute to the development of a strategy to increase the availability of EVSE (Electric Vehicle Supply Equipment) to support multi-unit dwellings (MUDs) by developing a greater understanding of their impact on the grid. As part of the grant, ComEd is planning to deploy five EVSE to collect and analyze data on their distribution grid impact. At each of the intended deployment sites, a high utilization model day was created from historic AMI data on the transformer level. Projected EV loads were then applied to the model to determine whether new EVSE installation would lead to the transformer rating being violated. Based on the violation analysis, recommendations for transformer installation and opportunities for managed charging were provided. A methodology was developed to determine where EVSE might be required to serve MUDs in the future and potential charging demand at each site. The methodology could be used to train a machine learning model that estimates locational demand for EV charging and the grid capabilities, such as capacity expansions, that might be needed to accommodate demand under different EV adoption scenarios.

KEYWORDS

Multi-unit dwelling, Electric Vehicles, load model, load growth, AMI

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1. INTRODUCTION

As the transportation sector represents over a quarter of all energy consumption in the United States, beneficial electrification of transportation is one of the most effective ways to reduce carbon emissions and mitigate climate change [1-2]. Utilities play a critical role in accelerating the adoption of electric vehicles (EV) by preparing the grid for the impact of large scale EV adoption. Uncertainties related to the timescale of adoption, timing of demand and exact locations where demand will occur must be addressed through a combination of empirical approaches and analytical models. Different segments of the transportation sector will require different approaches to reflect varying trajectories of technological development, policy deployment, mobility needs and economic drivers. The focus of this work is on a subsegment of the residential market: multi-unit dwellings (MUDs).

The DOE has noted that EV adoption by MUD residents has been slower compared to single family home residents [3]. Lack of access to conveniently accessible EVSE in or near MUD properties is thought to contribute to this trend. The DOE launched a multi-stakeholder project to develop MUD EVSE deployment strategies to promote MUD resident EV adoption [4].

ComEd was selected to participate in the project to evaluate the grid considerations and impacts of MUD EVSE deployment. ComEd is a large utility serving over 4 million electric customers in Northern Illinois, including the City of Chicago. The company's transmission and distribution grid consists of 65,000 miles in primary distribution and 5,800 miles in transmission. ComEd's system includes 1,076 substations and 552,600 distribution transformers. ComEd plans to extend the duration of the study beyond the DOE's data collection period to a total of three years to gather additional data on EV adoption in vicinity of the stations and test how various electricity pricing strategies might impact charging behavior. ComEd also intends to use the data to inform charging scenarios for MUDs, model the potential grid impact of future deployment and develop grid enhancements that will support EV adoption.

The stations for the study are planned to be deployed in Bronzeville, a community on Chicago's South Side with a high proportion of MUDs. Though Bronzeville currently does not have high rates of EV ownership, the locations for EVSE deployment were determined through a collaborative process involving community stakeholders to identify locations where EV adoption in the area might increase. ComEd intends to evaluate whether EV adoption by MUD residents in the vicinity of the stations increases faster than EV adoption by MUD residents in comparable locations that lack EVSE.

Methodologies for EVSE installation have been covered broadly in the literature. [5] provides a general procedure to strategically install EVSE in many scenarios and [6] simulates charging behaviors in areas to optimize EVSE allocation planning. This paper focuses on the grid implications of EVSE installation in public locations that support MUD residents' EV usage.

The processes described in this paper aim to provide electric utilities with a simple methodology for determining what infrastructure upgrades may be necessary in advance of the deployment of public EVSE to support MUD developments as well as a roadmap for the development of advanced tools to estimate the location of and load associated with MUD EVSE. Section 2 describes a process for determining the locations where MUD-related EVSE deployment may occur in the future, and a methodology for quantifying the impact of demand to size grid

infrastructure. In Section 3, the methodology for producing a maximum utilization day load profile is outlined; this can help utilities predict the need for grid upgrades required for a specific EVSE installation. In Section 4, the analysis and recommendations for two public charger locations in ComEd’s territory are outlined. Section 5 offers a conclusion of the study to date, and next steps.

2. MUD IDENTIFICATION FOR FUTURE DEMAND LOCATION

While ComEd determined the planned study locations through a collaborative process with community stakeholders, the project team also developed a methodology to identify where MUD EVSE might be deployed by third parties in the future. The methodology was tested in the Bronzeville neighborhood, where ComEd is installing a microgrid that is connected to two feeders and over 750 kW of solar generation. Transformers within the Bronzeville Community Microgrid (BCM) were selected for MUD identification. BCM serves approximately 1,000 customers in Bronzeville and is connected to two feeders. Feeder Z1 feeds 16 transformers and feeder Z2 supplies 19 transformers. Data on all customers connected to a transformer includes the billing account, premises, address, feeder, fuse, transformer, meter, and rate.

The rate indicates whether an account is commercial, single-family residential (SFR), or multi-family residential (MUD). MUDs were identified by filtering data for customers with the multi-family residential rate, customer addresses and transformer.

While this process yielded a list of MUDs, it did not provide insight into the size of each MUD and the number of parking spots available for EVSE installation. To complicate matters, MUDs of the same size might have vastly different onsite parking spaces. Due to the variety of building configurations and parking lot sizes, MUD addresses were searched using satellite imagery to determine the number of parking spots available at each address. The number of on-street and on-site parking spots were identified for each MUD address. On-site parking spots help indicate how many customers own a vehicle at each site. For areas with low to medium population density, parking lots are typically ground level and can be seen from satellite imagery. All the addresses analyzed in the Bronzeville area had ground level parking; however, in denser areas with underground or multi-level parking structures, a manual approach may involve contacting a building manager to accurately determine available parking at an MUD site. A more advanced application might correlate construction dates with building code to determine onsite parking.

To determine where MUD EVSE installation may result in future electricity demand, the number of parking spots on site is mapped to transformers serving that area. Since a mix of commercial, single-family residential, and multi-family residential buildings can be connected to a single transformer, the load curves will vary depending on connected loads. Sites with larger numbers of total parking spaces are more likely to have a potential grid impact due to future EVSE deployment.

To determine if EVSE deployment would result in the need for distribution grid upgrades, a high utilization day model provides insight into the load profile of a site. The process for creating a model day is described in the next section.

Table 1 Sites and Proposed EVSE Installation

#	Location	# of EVSE	Total Rating (kW)	Total ports
1	99-unit MUD development	2	26	4
2	Location near multiple MUDs and 120 residential parking spots	3	39	6

3. LOAD MODELLING

Modelling is done at the transformer level because transformers typically act as a bottleneck when more load is added to a distribution circuit. Since we are interested in seeing whether transformer upgrades are needed due to installing EVSE, we try to determine the “worst case scenario” or maximum utilization day for the transformers at each site. ComEd’s Automated Metering Infrastructure (AMI) repository provides energy consumption data (kWh) every 30 minutes from AMI meters installed at customer premises. The AMI repository provides access to all data for a given transformer in a specified time range (after the installation of the smart meters). Transformer energy consumption data was downloaded from 2018 to 2020 for transformers in proximity of the selected sites. This data can be used for load modelling.

To create the load model, 30-minute energy consumption data for all meters at a site are summed for each transformer on an hourly basis, providing hourly energy consumption for each transformer. As the energy consumption is hourly (kWh/hour), the data can also be considered as power (kW). Depending on a utility’s monitoring configuration, transformer power (kW) can be directly determined from a meter on the transformer.

Next, the peak load for the entire year was identified and used to build a normalized profile for a 24-hour load model: to create the normalized profile, 24-hour energy consumption is determined for all days in a year. Data from high energy consumption days is extracted to create the maximum model. Using the 24-hour energy consumption, a list of dates when energy consumption exceeds the 95th percentile of energy consumption days is created. From this list, hour-by-hour energy consumption data is loaded for each day. For each day, hourly energy consumption is divided by the maximum power for that day to produce a normalized profile for each day. Then the normalized profiles of the days in the 95th percentile list are averaged together, creating an aggregate profile. Since averaging normalized profiles together removes the normalization, the averaged profile is then normalized by dividing each hour in the profile by the maximum value in the averaged profile, creating a normalized profile.

Finally, to create the load model, the peak load is multiplied by all the values in the normalized profile. This process was completed for the years 2018 to 2020. Normalized profiles remained relatively consistent when comparing different years. The year with the highest maximum power of the three years was used for the maximum load model.

4. ANALYSIS AND RECOMMENDATIONS

A maximum utilization model for a high loading day was created for each site based on data between 2018 and 2020. The maximum power of the chargers was added to the maximum utilization model to conduct a violation analysis at each site. This entails applying the maximum charging load for a 24-hour period to determine whether the additional load violates the rating of the transformer. The violation analysis can be used to determine the number of chargers that can be installed at a location, and what infrastructure upgrades are required if the demand is likely to require additional chargers. Two chargers are planned for location 1, and three chargers are planned at location 2. Each charger has a maximum power output of 13 kW and two

charging ports. The analysis yields recommendations for upgrades or mitigation strategies at each location prior to the physical installation of EVSE.

For each location, the transformer nearest to the site was used for modelling. At location 1, the most suitable transformer has a nameplate rating of 75 kW.

Figure 1 Adding chargers to location 1

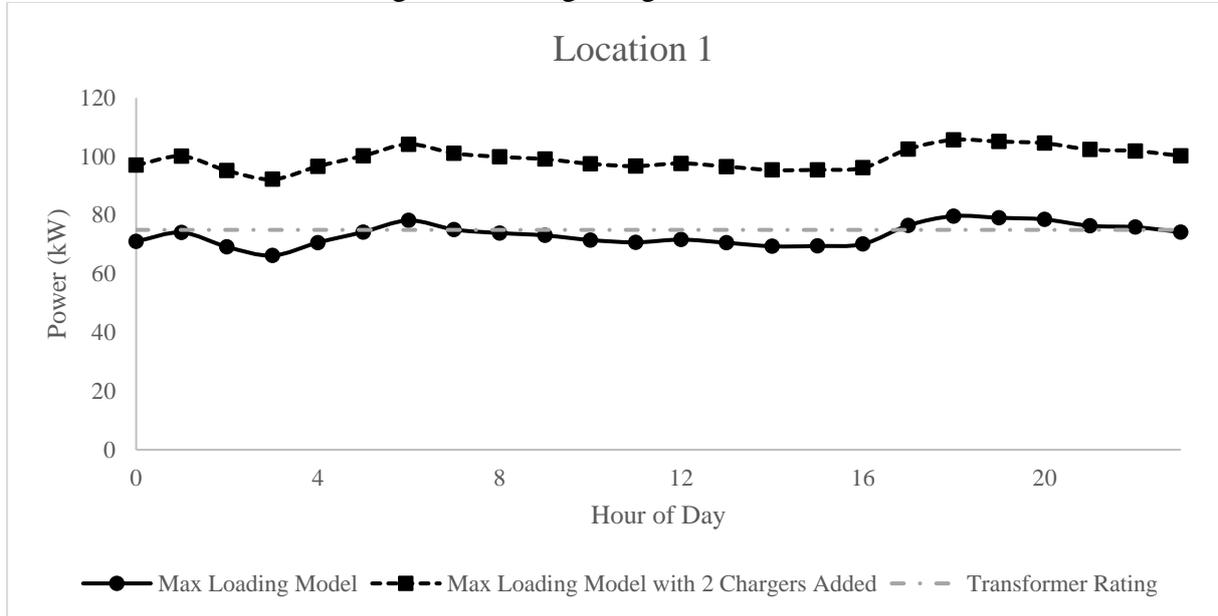


Table 2 adding chargers to location 1 hour-by-hour

Hour	Maximum Model (kW)	With 2 Chargers (kW)	Hour	Maximum Model (kW)	With 2 Chargers (kW)
12:00 AM	71.07	97.07	12:00 PM	71.69	97.69
1:00 AM	74.09	100.09	1:00 PM	70.6	96.6
2:00 AM	69.2	95.2	2:00 PM	69.41	95.41
3:00 AM	66.26	92.26	3:00 PM	69.49	95.49
4:00 AM	70.67	96.67	4:00 PM	70.17	96.17
5:00 AM	74.27	100.27	5:00 PM	76.54	102.54
6:00 AM	78.2	104.2	6:00 PM	79.71	105.71
7:00 AM	75.11	101.11	7:00 PM	79.13	105.13
8:00 AM	73.92	99.92	8:00 PM	78.57	104.57
9:00 AM	73.12	99.12	9:00 PM	76.38	102.38
10:00 AM	71.54	97.54	10:00 PM	75.93	101.93
11:00 AM	70.75	96.75	11:00 PM	74.25	100.25

Adding chargers violates the nameplate rating of the transformer. The model is also in violation of the nameplate rating, but is still within the functional limitations of the transformer. As a rule of thumb, we consider 30% above the nameplate capacity to be within the limitation of a transformer. All the maximum model hours stay within this functional rating of 97.5 kW. When chargers are added, 62.5% of the hours violate the functional rating. Installation of a new transformer is recommended for location 1. Depending on the rating of the transformer, additional chargers could be installed at this location in the future. The rating of the transformer at location 2 is 225 kW.

Figure 2 adding chargers to location 2

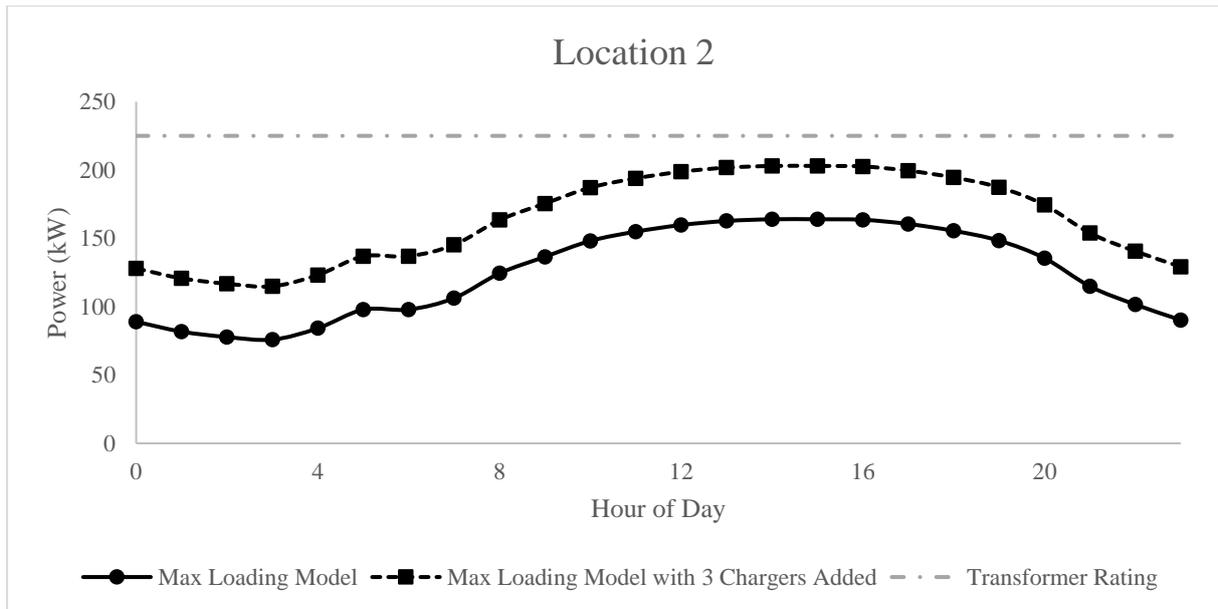


Table 3 adding chargers to location 2 hour-by-hour

Hour	Maximum Model (kW)	With 3 Chargers (kW)	Hour	Maximum Model (kW)	With 3 Chargers (kW)
12:00 AM	88.98	127.98	12:00 PM	159.74	198.74
1:00 AM	81.74	120.74	1:00 PM	162.72	201.72
2:00 AM	77.80	116.80	2:00 PM	163.96	202.96
3:00 AM	75.91	114.91	3:00 PM	163.96	202.96
4:00 AM	84.19	123.19	4:00 PM	163.59	202.59
5:00 AM	97.83	136.83	5:00 PM	160.52	199.52
6:00 AM	97.93	136.93	6:00 PM	155.51	194.51
7:00 AM	106.27	145.27	7:00 PM	148.33	187.33
8:00 AM	124.40	163.40	8:00 PM	135.51	174.51
9:00 AM	136.51	175.51	9:00 PM	114.88	153.88
10:00 AM	148.13	187.13	10:00 PM	101.54	140.54
11:00 AM	154.90	193.90	11:00 PM	90.24	129.24

After adding three chargers, no violation of the transformer rating occurs at location 2. Since the transformer also services a commercial building, the loading on the transformer is much higher throughout the day than it is at night. With the low nightly loading, this location would be suitable for additional managed charging enabled EVSEs. If additional chargers were to be installed on this transformer, the charging should be managed.

5. CONCLUSION

Anticipating the timescale and precise locations where demand from MUD EVSE is likely to occur in the future is challenging, yet critical to utility planning. The manual process outlined in this paper could be refined to train a model that identifies MUD sites and estimates potential charging demand based on a potential EV adoption and charging scenarios. In combination with the development of models for other segments of the transportation sector, it may help utilities support transportation electrification, providing benefits from improved air quality to lower fuel costs and mitigating climate change.

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