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Holistic Evaluation Methodology for Electric Vehicle Charging Station Location within Utility Service Territory

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SUMMARY

The utility industry will soon experience some of the impacts of interconnecting considerably big and intermittent loads as Electric Vehicles (EV) become more mainstream en route to a new norm. The increase in market share has been greatly motivated by technology advancements and by supportive government policies that reduce the costs of EVs. As battery technologies continue to develop and the energy industries transition into sustainable models, zero emission vehicle adoption is expected to continue to increase, transforming the transportation industry. There are still challenges to emerging EV technology that could be seen as barriers for the proliferation of its adoption, such as the limited availability of public charging stations critical for owners who cannot charge at home, or the limited driving range that precludes long distance transportation. However, stakeholders are increasingly aware of the environmental benefits that the widespread adoption of this technology would imply for the planet, and they are developing different strategies and programs to enable the increased adoption of EV technology. Vehicle manufacturers are reconceiving their core business to help meet sustainability mandates. Electric utilities are preparing their systems to enable the electrification of transportation through the interconnection of charging infrastructure to the electric system. Cities, states and municipalities, elected officials and a broad spectrum of stakeholders and consumer groups and enthusiasts see the transformation underway and are getting involved to help ensure its sustainability. This paper presents a tool developed by an electric utility for screening its service area to facilitate the identification of prime locations for the installation of EV charging stations. To maximize charging station utilization and overall EV adoption, the site selection for EV charging stations is critical. This paper demonstrates the analysis performed from the utility stand point and introduces the screening tool developed for assessing the location selection for EV charging stations within the utility service territory. The service territory was divided into sections that were evaluated according to different considerations, including potential impact on the electric grid, traffic patterns, community infrastructure and consumer demographics. Each of the sections was evaluated based on demographic factors and system conditions, each of which was scored. A composite score was calculated and mapping software was used to create heat maps to visualize resulting scores and facilitate the determination of optimal locations for EV charging station installation.

KEYWORDS

Electric Vehicle, Utility Analysis, Charging Infrastructure

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1. INTRODUCTION

Annual Electric Vehicle (EV) sales increased globally from 300,000 in 2014 to 500,000 in 2015 [1]. With Bloomberg New Energy Finance predicting that electric vehicles will be cheaper than their gas-powered counterparts in the US and Europe by 2025, the cars that once seemed like they were a fantasy may soon dominate roads across the world [2]. Beyond the economic implications of new industries emerging, this also offers dramatic possibilities for societies to limit their carbon footprint, with research suggesting that the life-time global warming emissions of EVs is roughly half that of their gas-powered counterparts [3]. To make that a reality, however, EV charging stations are crucial not only to provide convenient access to power for these future drivers, but to help demonstrate to potential-purchasers that electric vehicles are a viable way to transport themselves. This is especially salient because a key factor preventing people from purchasing electric vehicles is 'range anxiety,' or the concern that they might not have a charging station nearby when their battery runs out [4].

The electrification of the transportation industry and especially the increased amount of charging stations connected to the distribution system is expected to directly affect electric grid planning and operation, resulting in potential challenges and opportunities yet to be explored. The electric utility industry is committed to developing methods to manage the expected uptake in electricity usage from these vehicles and demonstrate the positive aspects of providing the option for customers to make electric-powered transportation decisions. There are different types of EV chargers available in the market based on the service voltage they are connected to and the current they can carry. These include Level 1 (L1), Level 2 (L2) and Direct Current Fast Charging (DCFC) stations. L1 are connected to a 120 VAC service, supplying around 3-5 miles of drive range per hour, and are mostly utilized for private outlets normally installed at the customer home [5]. L2, the most commonly used method for public charging stations, typically use 240 VAC, single phase, and supply around 10-20 miles of drive range per hour. DCFC charging stations, on the other hand, typically use 480 VDC and achieve up to 40 miles of range for 10 minutes of charging. Depending on the size of the onboard battery, EV charging time can vary drastically for each type of charging station. There are multiple ongoing efforts to determine how to leverage the different types of EV charging technology, each with its own opportunities and challenges.

This paper presents a portion of the work performed by an electric utility to evaluate the potential effect that more charging stations will have on EV adoption, and how the station location will impact grid planning and operation depending on the capacity requirements. A flexible and scalable screening tool has been developed that allows for the determination of optimal locations for charging stations within the utility's service territory while also mitigating the impact on the grid, helping demonstrate the viability of electric vehicles to a wide audience. In the following sections, the methodology for the development of the tool is described as well as the factors considered for the analysis.

2. METHODOLOGY PROPOSED

The methodology used for the development of the tool was adapted from a previously performed evaluation of the utility service territory for a public purpose microgrid installation [6], and is based on a holistic, data-driven approach that made it possible to rank different areas in the utility service territory to identify prime locations for EV charging stations. The service territory was divided into more than 50,000 0.25 square mile (0.5mile x 0.5 mile) quarter sections, which were evaluated based on different factors such as proximity to points of interest and main roads, existing charging infrastructure, population density and loading status of the system. This resulted in several layers of information contributing to the final ranking.

Each of the sections was evaluated in terms of demographic factors as well as system conditions receiving a score ranging from 0 to 4 for each identified factor. Each factor contributed towards a composite score calculated as a weighted summation of the individual scores. A mapping tool was used to create heat maps to visualize the resulting scores and facilitate the determination of suitable locations for EV charging station installation.

The charging stations that were considered for deployment in the study described in this paper are L2 and DCFC stations. Some of the factors considered for the evaluation of each of the sections are related to the specific characteristics and requirements of the charging station to be deployed, such as the likely dwell time for a customer at a station, which varies drastically depending on the type of station used. Consequently, targeted locations for both types will likely differ (i.e. L2 charging stations would be deployed closer to residential and commercial areas where customers spend longer periods of time, while DCFC stations would be deployed in strategic points closer to highways enabling longer distance travelling for EV owners). Therefore, the proposed methodology provides a holistic framework for separate screening of locations for L2 and DCFC charging stations.

2.1 Feeder Loading Metric

The feeder loading metric evaluates the loading condition of the distribution circuits crossing a specific quarter section. This metric reflects the potential impact that the interconnection of an EV charging station would have on the area grid. It is a standard utility procedure to perform studies in the system when a new customer requires service, to determine whether the circuit that will serve the load needs to be upgraded in order to avoid overloading. The feeder loading scores were determined according to the additional capacity available in the quarter section and based on an evaluation of the circuits' readiness to accommodate the load added by a new charging station. The feeder loading scores were determined by appropriate thresholds for each type of charging station (i.e. DCFC stations require more capacity; consequently the feeder loading thresholds for the scores were set much lower than for L2). The quarter sections with lower average feeder loading score higher, representing recommended locations for installation of charging stations.

2.2 Landmark Metric

The landmark metric identifies prime locations where people frequently spend their time. Different types of landmarks were first categorized into various groups such as business facilities, transportation centers, city parking, government buildings, education centers, retail and dining businesses, hotels, etc., prioritized based on expected dwell time. The landmark score was determined for each quarter section based on the quantity of landmarks located within it, as well as the amount of time visitors typically spend in these landmarks (i.e. places such as business facilities with longer expected dwell time were given a higher score; rental agencies and bus stations were considered to have little potential and were given a lower score). Again, L2 and DCFC Landmark metric scores utilized the common framework, but were built independently, with different types of landmarks being targeted for each of them based on the average time that a customer normally spends in them (i.e. business facilities, parking lots and hotels scored higher for L2; gas stations, rest areas and fast retail scored higher for DCFC). The quarter sections with the highest score represent the more advantageous locations to install charging stations.

2.3 Population Density Metric

The population density metric identifies areas of the service territory where EV owners reside, and potentially where EV owners commute to, providing potential locations with a greater need for L2 charging stations. Data available from the utility customer count per quarter section was leveraged for this purpose. The population density score was determined based on the number of customer accounts registered in each quarter section, with higher scores representing higher customer counts, and the most suitable candidate locations to install EV charging stations. The population density metric was not taken into consideration for the DCFC evaluation since targeted locations are assumed to be among travel corridors and do not necessarily correlate with populated areas.

2.4 Existing Stations Metric

The existing stations metric identifies areas with existing charging stations, where the installation of new charging stations might be redundant. One of the motivations to promote deployment of EV charging stations is to increase the coverage area to reduce range anxiety of EV drivers, so it is important to place stations strategically to avoid redundancies. Similarly to the previously mentioned metrics, L2 and DCFC existing stations scores were built using the holistic evaluation framework, considering only stations of the same type for each score (i.e. L2 existing stations score was calculated based on the count of public L2 stations; DCFC existing stations score was calculated based on the count of DCFC stations). In this case, higher scores represent fewer existing charging stations, d therefore optimal candidate locations for the installation of new stations.

2.5 Distance to Highway Metric

The distance to highway metric captures proximity to the main transportation corridors in the service territory. These routes are taken by people driving longer distances, who may need to recharge their EV in a short period of time allowing them to continue their trip. Therefore this metric is one of the key components contributing to the evaluation of DCFC optimal locations, but is not indicative of optimality for L2 charging station location, and was therefore not taken into consideration for the L2 evaluation. The distance to highway score was determined based on the distance of the center of the quarter section to the closest major road (such as an interstate). For this metric, the higher scores representing lower distance, and ideal candidate locations to install DCFC charging stations.

2.6 Composite Metric

The composite metric was calculated as a weighted sum of the scores from each of the metrics described in the previous quarter sections. As explained before, some of the metrics contribute only towards the composite metric of one of the two types of charging stations, having a weight of zero toward the composite metric of the other type of station. The different preliminary weighting factors, which are presented in Table 1, were assigned for each metric for L2 versus DCFC stations based on engineering experience and recommendations from subject matter experts. Nonetheless, these factors are easily modifiable, allowing for different sensitivities to be considered in the future.

	Weighting Factor	
Metric	**L2**	**DCFC**
Feeder Loading	20%	30%
Landmark	40%	20%
Population Density	20%	0%
Existing Stations	20%	20%
Distance to Highways	0%	30%

Table 1: Weighting Factors for Different Metrics and Types of Charging Stations

Quarter section	**Feeder Loading**		**Landmarks**		**Existing Stations**		**Distance to Highway**		**Composite Metric**
	Score	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	
A	3	0.9	0	0	4	0.8	0	0	1.7
B	4	1.2	1	0.2	4	0.8	4	1.2	3.4
C	2	0.6	0	0	4	0.8	4	1.2	2.6

Table 2: Example of Scoring Methodology for DCFC

The composite metric was then calculated as the sum of the weighted scores for each metric. A representative example of the sum of the weighted scores that yield into the composite metric is presented in Table 2 for DCFC chargers. The column on the right shows the weighted sums of the score for each data layer, representing the composite metric.

Therefore, the quarter sections resulting with the highest composite metric show the most beneficial placement locations. Figures 1 and 2 show samples of the heat maps used to visualize the results of the analysis for L2 and DCFC stations location, due to the sensitive nature of the information contained in the maps.

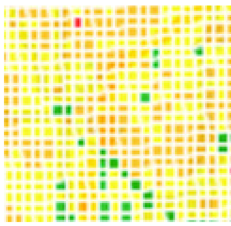

Figure 1: Sample of L2 Composite Metric Heatmap

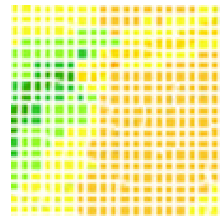

Figure 2: Sample of DCFC Composite Metric Heatmap

3. RESULTS OF THE ANALYSIS

As shown above, the mapping tool was leveraged to create heat maps that visualize the composite metric results and facilitate the evaluation of the service territory in terms of recommended locations for charging station installation. Heat maps representing the scores for each of the individual factors evaluated were also generated as a helpful resource to determine the driving factors for each quarter section's composite score. The results showed that L2 charging stations' recommended locations are aggregated near metropolitan areas, as well as around populated suburban areas and town centers. DCFC optimal locations are mainly aggregated along the highways, to fulfill the final goal of creating a long-range charging network that would allow EV drivers to travel around the country without range anxiety.

Leveraging the results obtained from the study, a simplified strategy to select deployment locations for L2 charging stations was developed. Quarter sections of the service territory scoring 3.8 to 4 in the composite metric were selected as high priority. The selected quarter sections are distributed along 69 townships out of 376 in the service territory. These 69 townships were ranked based on the count of high priority quarter sections within them.

A tiered deployment strategy was proposed, targeting higher ranking townships for tier 1 locations, while avoiding adjacencies and promoting diversity of selection, taking into account new and proposed locations for charging station deployment. Once the targeted township were selected, the heat maps representing the composite metric by quarter section where leveraged to determine the best locations for the charging stations to be installed within the township.

4. CONCLUSION

As the number of EVs and EV charging stations continues to increase across the United States, there is need for analysis methodologies that allow developers to determine the recommended locations where the installation of the charging stations would be beneficial. This paper presents a strategic screening tool to determine beneficial locations for the placement of L2 and DCFC stations, considering the status of the electric system.

The tool developed is flexible and can be easily modified to produce new results given specific conditions and targets. The study results presented consider system conditions as well as customer behavior and necessities. These results provide the utility a comprehensive assessment of the recommended locations to install charging stations in their service territory.

Given the results obtained from this study, the next steps would include determining additional factors that could be included in the evaluation, as well as performing a sensitivity analysis to capture the impact on the composite metric in case modifications are made to the factors or the weights assigned to each of them and their contribution to the composite metric. As an additional next step to facilitate the location selection based on the results from this analysis, a further functionality would be added to the tool that automatically updates the data with any new proposed location for a charging station to be installed, to avoid redundancies in following selections.

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