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2022 Grid of the Future Symposium

Managed Charging Solution to Mitigate Adverse Impact of the Maximum Demand Payment Component of a Commercial Electric Vehicle Fast-charging Facility's Electricity Bill

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SUMMARY

Among the most promising initiatives to reduce greenhouse gas emissions from the transportation sector is its electrification by the deployment of electric vehicles (*EVs*). A key requirement to realize deeper *EV* penetrations is the implementation of electric vehicle fast-charging facilities (*EVFCFs*) in every community. However, multiple researchers have questioned sustainability of *EVFCFs* due to high cost associated with the maximum demand payment component (*MDPC*) of the commercial electricity bill. Under this structure, sudden, massive peaks in power demand due to multiple *EV*s charging simultaneously, and the corresponding, high *MDPC* of the electricity bill challenge viability of an *EVFCF*. Clearly, the burden is higher on *EV* users with a lack of dedicated, private charging facilities, making the *MDPC* issue community specific. To that end, sustainability of technical solutions to the issue requires decision-making to be targeted, contextual, and reflective of key characteristics of the service community.

This work adds one possible option to the set of technical solutions to address the *MDPC* issue. It proposes a managed charging solution that builds up on the formulation and deployment of an online, smart charging algorithm to mitigate adverse impacts of the *MDPC* issue on an *EVFCF's* operations. The algorithm effectively employs facility operator specified time-flexibility to strategically control power supply to the visiting *EVs* with the objective to attenuate power demand peaks. Additionally, three different charging policies are utilized in this work to evaluate influence of the proposed managed charging solution on quality of service provided to the *EV* users. Results of the performed Monte Carlo simulations suggest that the deployment of the proposed managed charging solution can substantially reduce electricity procurement costs for the *EVFCF* operator without drastically impacting quality of service provided to the visiting *EV* users. In fact, these cost savings can then be utilized by the facility operator to offer lower charging service price to the visiting *EV* users. Indeed, the proposed solution can potentially bring significant value to *EVFCFs* operating specifically in communities where *EV* users overwhelmingly value potential cost-savings over a few, occasional instances of slightly increased charging duration.

KEYWORDS

Electric vehicle fast-charging facilities, Maximum demand payment component of electricity bill, Managed Charging, Contextual Engineering.

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1. INTRODUCTION

The adverse impacts of climate change due to greenhouse gas (*GHG*) emissions have led federal, state, and local governments in the *US* to effectively consider alternatives with a lower carbon footprint. According to the *US* Department of Energy, in 2019, the transportation sector contributed 29% to the total *US GHG* emissions, surpassing the 25% contribution of the electricity generation sector [1]. Among the most promising initiatives to reduce *GHG* emissions from the transportation sector is its electrification by the deployment of electric vehicles (*EVs*) to displace internal combustion engine vehicles [2]. A key requirement to realize deeper *EV* penetrations is the implementation of sustainable electric vehicle fast-charging facilities (*EVFCFs*) in every community [3], [4]. Such build-out is needed to overcome range anxiety of the would-be *EV* owners, whose concerns over lack of charging facilities along desired trajectories deter them from making their *EV* purchases [5].

Design and implementation of *EVFCFs* will play a key role to increase *EV* adoption [4], [6]. The 2021 Bipartisan Infrastructure Law (*BIL*) envisions 500,000 *EV* charging facilities – including slow- and fast-charging facilities – across *US*. *BIL* dedicates a transformative $7.5 billion to achieve this goal by 2030 [7]. A critical component of the dedicated investment is to implement *EVFCFs* throughout the *US* to make *EV* charging available and affordable to all.

However, multiple researchers have questioned the sustainability of existing *EVFCFs* [8], [9]. Issues related to long-term operational feasibility of these facilities raise concerns in the vehicle electrification community and among investors. Indeed, the increased stress on the incumbent utility's grid due to high charging load at *EVFCFs* necessitates multiple grid upgrades. A part of these induced upgrade costs is recovered by the imposition of the maximum demand payment component (*MDPC*) of the electricity bill. The *MDPC* of electricity bill – reflective of the highest level of power demand during a billing period – is a widely recognized barrier to economic and financial feasibility of commercial *EVFCFs* [10], [11]. Under this structure, sudden, massive peaks in power demand due to multiple *EV*s charging simultaneously, and the corresponding high *MDPC* of the electricity bill challenges the viability of an *EVFCF*. To compensate for these costs, facility operators must specify a higher charging service price for *EV* users and/or abandon business in communities where cost recovery becomes a challenge. These community specific reactions of *EVFCF* operators, induced by the *MDPC* issue, challenge notions of availability and affordability of fast-charging system in multiple regions across *US*. The burden of the issue will be higher on *EV* users residing in economically underserved communities and/or multi-unit dwellings who are forced to use *EVFCFs* to replenish the depleted charge of their *EV* batteries due to lack of dedicated, private charging facilities. If not addressed effectively, the issue can potentially deter specific communities from transitioning to electrified transportation.

Technical solutions discussed in the literature to address the *MDPC* issue include the integration of stationary [12], [13], and mobile energy storage systems (*ESSs*) [14], and the implementation of renewable energy generation systems [15]. However, a one-size-fits-all type of decision framework to community-specific *MDPC* issue impedes effective utilization of these solutions. Sustainability of the existing solutions requires decision-making to be targeted, contextual, and reflective of key characteristics of the service community. Indeed, lack of an economic justification to the integration of *ESSs* in an economically underserved community limits its usefulness. Similarly, the temporal mismatch between renewable generation and charging service demand at a facility located in a community where *EV* users prefer to charge at a particular time challenges sustainability of the solution.

Another option investigated by researchers to mitigate power demand peaks is the formulation and deployment of various power supply control strategies [16]. However, such endeavors are limited to slow-charging facilities (as opposed to *EVFCFs*) where *EV* users provide time-flexibility to replenish the depleted charge by predefining their departure time, usually in the order of several hours. In this study, specific attention is given to the operations of an *EVFCF* where *EV* users cannot predefine their departure time. To that end, this work proposes a managed charging solution to reduce the adverse impacts of the *MDPC* issue and builds up on the formulation of an online, smart charging algorithm that strategically controls power supply to each *EV* charging at an *EVFCF*. It must be acknowledged upfront that the proposed solution may not be applicable to all communities and its deployment depends upon context of the service community under consideration. In fact, the proposed solution adds one possible option to the set of technical solutions to address the *MDPC* issue. It offers an opportunity to facility operators to reduce electricity procurement costs with a minimal effect on quality of service (*QS*) provided to *EV* users. Certainly, the proposed solution can potentially bring significant value to *EVFCFs* operating specifically in communities where *EV* users overwhelmingly value potential cost-savings over a few, occasional instances of increased charging duration.

The remainder of this paper is organized as follows: In *Section* 2, an explanation to the proposed managed charging solution is provided. *Section* 3 describes numerical simulations to reflect on the effectiveness of the proposed mathematical model, and the paper is concluded in *Section* 4.

2. MODEL OUTLINE AND FORMULATION:

2.1. ELECTRICITY TARIFF

The monthly electricity bill of a commercial *EVFCF* comprises of three components: the fixed payment component (*FPC*), the energy payment component (*EPC*), and the maximum demand payment component (*MDPC*). Whereas the *FPC* is a monthly subscription fee, the *EPC* depends on the energy consumed (unit: *kWh*) over a billing period. In addition to *EPC*, the *MDPC* reflects the highest level of power (unit: *kW*) that an *EVFCF* demands over a billing period. Power demand is calculated as the mean power supply over a fixed, integer-valued interval, the so-called demand interval. The duration of a demand interval is utility specific, typically, 15, 30 or 60 *minutes*. As such, the utility meter makes instantaneous, discrete-time measurements of power supply at fixed sampling instances. The mean of measurements that lie within the duration of a demand interval is referred to as the *EVFCF's* mean power demand over that interval. The highest value of mean power demand over any demand interval in the billing period is called the maximum power demand of the *EVFCF*. The maximum power demand, multiplied by a fixed *MDPC* rate (unit: *$/kW*) makes up the *MDPC* of an *EVFCF's* electricity bill.

2.2. *EVFCF* SETUP AND OPERATION

Consider the operation of an *EVFCF* equipped with n chargers, each with a power supply capability of $[0\,,\zeta]\ kWs$. In this work, a discrete-time model with time indexed by $t \in \mathcal{T} = \{1,\ \dots,\ T\}$ is formulated, where T is the total number of sampling instances in a billing period. The duration of a sampling interval is δ and the duration of a demand interval is Δ. At time t, $\mathcal{J}_t : |\mathcal{J}_t| \le n$ – the so-called active set – is the set of *EVs* $j \in \mathcal{J}_t$ connected to a charger at the *EVFCF*. The arrival time, battery capability, and the power supplied to an *EV* $j \in \mathcal{J}_t$ are represented by a_j, κ_j, and p_j, respectively. The state of an *EV* $j \in \mathcal{J}_t$ at time t is described by its remaining duration to departure $\left(d_j[t]\right)$ and its remaining energy demand $\left(e_j[t]\right)$.

The mathematical expressions for the maximum power demand at the end of a billing period $\left(\bar{P}_f^M[T]\right)$, the mean power demand of the facility at time t $\left(\bar{P}_f[t]\right)$, and the power supplied to the facility at time t $\left(P_f[t]\right)$ are given below:

$$\bar{P}_f^M[T] = \max_{t \in \mathcal{T}} \bar{P}_f[t]$$

$$\bar{P}_f[t] = \frac{1}{\Delta} \sum_{\tau\, =\, t-(\Delta-1)}^{t} P_f[\tau]$$

$$P_f[t] = \sum_{j\, \in\, \mathcal{J}_t} p_j[t]$$

The *MDPC* of the *EVFCF's* electricity bill is then calculated as the product of its maximum power demand at the end of billing period and the *MDPC* rate (π), i.e.,

$MDPC = \pi \ . \ \bar{P}_f^M[T]$

2.3. THE MANAGED CHARGING SOLUTION

The proposed managed charging solution seeks to develop and deploy an online, real-time, smart charging algorithm (*Algorithm* 1) that aims to mitigate power supply peaks, and therefore, the *MDPC* of an *EVFCF's* electricity bill.

***Algorithm* 1: Smart Charging Algorithm**

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for $t = 1, \ \dots, T$
    for $j \in \mathcal{J}_t$
line (1)   if
            $\sum_{j \in \mathcal{J}_t} \min\{\kappa_j, \zeta\} \le \bar{P}_f^M[t-1]$,
            $p_j^*[t] = \min\{\kappa_j, \zeta\}$
line (2)   else
            solve the optimization program and compute
            $\left(p_j^*[t], \ p_j^*[t+1], p_j^*[t+2], \dots, p^*{}_j[t+\Delta]\right)$
        end if
line (3)   implement $p_j^*[t]$
line (4) $d_j[t+1] = d_j[t] - 1$
line (5) $e_j[t+1] = e[t] - \delta p_j^*[t]$
    end for
line (6) $P_f[t] = \sum_{j \in \mathcal{J}_t} p_j^*[t]$
line (7) $\bar{P}_f[t] = \frac{1}{\Delta} \sum_{\tau = t-(\Delta-1)}^{t} P_f[\tau]$
line (8) $\bar{P}_f^M[t] = \max\{\bar{P}_f^M[t-1], \bar{P}_f[t]\}$
end for

Algorithm 1: Smart Charging Algorithm

In line (1) of *Algorithm* 1, a criterion is set to verify that the *EVFCF's* operations at the maximum power supply capability to each *EV* $j \in \mathcal{J}_t$ do not exceed the facility's heretofore maximum power demand. Alternatively, a linear optimization program (*OP*) in called up on in line (2) that takes the following form:

$$\underset{p_j}{\text{minimize}} \quad \frac{1}{\Delta} \sum_{\tau=t}^{t+\Delta} \sum_{j \in \mathcal{J}_t} p_j[\tau]$$

subject to,

$$\delta \sum_{\tau=t}^{\lceil d_j[t] \rceil} p_j[\tau] = e_j[t] \qquad \forall \ j \in \mathcal{J}_t$$

$$0 \le p_j[\tau] \le \min\{\kappa_j, \zeta\} \qquad \forall \ j \in \mathcal{J}_t \ , \tau = t, \ t+1, \dots, \ t+\Delta$$

At occasional instances when the line (1) criterion is not verified, the *OP* seeks to assign minimum power supply to an *EV* $j \in \mathcal{J}_t$ and guarantees that its remaining energy demand is met within its remaining time to departure. Also, the *OP* ensures that upper and lower limits on power supply to an *EV* are respected. Consequently, the *OP* returns an optimal charging profile $\left(p_j^*[t], p_j^*[t+1], p_j^*[t+2],\ldots, p^*{}_j[t+\Delta]\right)$ as a Δ-dimensional vector for each active *EV* $j \in \mathcal{J}_t$. The algorithm implements the optimal outcome $p_j^*[t]$ in line (3) and updates the state variables in lines (4) and (5). Power supplied to the facility, the mean power demand for the current demand interval, and the facility's heretofore maximum power demand is then evaluated in lines (6), (7), and (8) of the algorithm, respectively. The results of line (8) are then used to verify the criterion set in line (1) for the next time instance, i.e., $t+1$.

2.4. CHARGING POLICIES

For an *EV* user visiting an *EVFCF*, the duration of charging session (sojourn time) is a key metric and depends on the charging policy pursued by the *EVFCF* operator. This section explains three distinct charging policies utilized in this paper. The conventional approach – referred to as the conventional charging policy (*CCP*) – implies that each *EV* is always supplied power at the highest possible power supply capability. Under this structure, the smart charging algorithm does not utilize the *OP* at any time instance as the structure of *OP* is bound by the remaining energy demand constraints. The maximum time to departure for an *EV* at the time of its arrival $\left(d_j\left[a_j\right]\right)$ in the conventional case can be calculated as:

$$d_j\left[a_j\right] = \frac{e_j[a_j]}{\delta \min\{\kappa_j, \zeta\}}$$

In the uniform charging policy (*UCP*), the facility operator adds flexibility to the remaining time to departure for each *EV* by a constant flexibility factor, α_{UCP}. This implies that $d_j\left[a_j\right]$ in the uniform case can be calculated using the following expression:

$$d_j\left[a_j\right] = \frac{e_j[a_j]}{\delta \min\{\kappa_j, \zeta\}} + \alpha_{UCP}$$

In the proportional charging policy (*PCP*), the flexibility added $\left(\alpha_{PCP}\right)$ to the remaining time to departure is proportional to the energy demanded by an *EV* at the time of arrival. Indeed, the *PCP* ensures that an *EV* user who visits the facility to simply "top-up" the depleted battery charge is not penalized to contribute equal flexibility as an *EV* user with a high energy demand. The remaining time to departure for an *EV* at the time of its arrival in the proportional case can thus be computed as follows:

$$d_j\left[a_j\right] = (1 + \alpha_{PCP})\,\frac{e_j[a_j]}{\delta \min\{\kappa_j, \zeta\}}$$

Note that the flexibility factors, α_{UCP} and α_{PCP} are selected by the facility operator to enable charging management at the occasional instances to avoid power demand peaks.

2.5. QUALITY OF SERVICE

The implementation of *UCP/PCP* may impact quality of service (*QS*) due to the addition of time-flexibility to supply the energy requested by an *EV* user at arrival. An understanding of this impact is necessary to comprehensively analyze feasibility of the proposed managed charging solution. As discussed in *Section* 2.4, *QS* is significantly impacted by the sojourn time of *EV* users at the *EVFCF*. The *EV* users may abandon using the facility if the total time to charge increases significantly due to the implementation of the proposed solution. Any trade-off between *QS* provided to *EV* users and savings to the electricity procurement cost for *EVFCF* operators must be evaluated with due regards to the context of service community. In fact, in the communities where *EV* users overwhelmingly value cost-savings over a few, occasional instances of increased charging time, the proposed solution can add significant value to the operations of an *EVFCF*. These cost savings can then be utilized to offer lower charging service price to *EV* users.

In this work, the *QS* provided to an *EV* (ξ_v) is defined as the ratio of its sojourn time under the *UCP/PCP* to the sojourn time under the *CCP*. The facility's overall *QS* $\left(\xi_f\right)$ is then defined as the average value of *QS* provided to each *EV* that visits the *EVFCF* over the duration of a billing period. *Table* 1 provides mathematical expressions for the *QS* provided to each *EV* visiting the *EVFCF* as well as the facility's overall *QS* during a billing period. In *Table* 1, $\mathcal{V} = \{v: v = 1, \dots, |\mathcal{V}|\}$ is the set of all *EVs* that visit the *EVFCF* during a billing period and $\mathfrak{d}_v$ represents the realized sojourn time of an *EV* $v \in \mathcal{V}$. Since the *UCP/PCP* provides the *EVFCF* operator with additional time-flexibility due to the incorporation of flexibility factor, this suggests that $\xi_v \geq 1$ and $\xi_f \geq 1$. Certainly, the definitions of *QS* used in this work imply that the values of ξ_v and ξ_f nearer to 1 result in a higher *QS*. $\xi_v = 1$ indicate that the sojourn time of an *EV* is not altered due to the application of *UCP/PCP* and therefore, the implementation of the proposed solution does not adversely impact the *QS* provided to an *EV*. Similarly, $\xi_f = 1$ reflects that the overall *QS* provided at the *EVFCF* remains unaffected by the implementation of the managed charging solution.

Table 1: Mathematical Expressions for Quality of Service

charging policy	quality of service (*EV*)	quality of service (*EVFCF*)
UCP	$\xi_v\big\|^{UCP} = \frac{\mathfrak{d}_v\|^{UCP}}{\mathfrak{d}_v\|^{CCP}}$	$\xi_f\big\|^{UCP} = \frac{\sum_{v\in\mathcal{V}} \xi_v\|^{UCP}}{\|\mathcal{V}\|}$
PCP	$\xi_v\big\|^{PCP} = \frac{\mathfrak{d}_v\|^{PCP}}{\mathfrak{d}_v\|^{CCP}}$	$\xi_f\big\|^{PCP} = \frac{\sum_{v\in\mathcal{V}} \xi_v\|^{PCP}}{\|\mathcal{V}\|}$

3. CASE STUDY

3.1. MODEL SETUP

Consider the operation of an *EVFCF* equipped with $n = 10$ chargers over a 30-day billing period. The upper limit on power supply capability of each charger is 350 *kW* and the duration of sampling interval is 1 *minute* (i.e., $\frac{1}{60}$ *hours*). The facility operates between 06:00 a.m. and 12:00 a.m., daily, and an equal probability of vehicle arrival at any time instance during the hours of operation is assumed. If an *EV* user finds no empty charging spot at arrival, it leaves the facility and does not wait for a spot to become available. In the operational territory of this *EVFCF*, the duration of demand interval specified by the incumbent utility is 30 *minutes*. It is assumed that $|\mathcal{V}| = 800$ vehicles of four different types (with battery capabilities described in *Table* 2) visit the facility during the billing period. When an *EV* arrives, it requests 20, 30, 40, or 50 *kWh* energy that must be fulfilled within adequate time defined in *Section* 2.4 – according to the charging policy pursued by the facility operator. The specific values of the flexibility factors implemented by the facility operator are also reported in *Table* 2.

Table 2: Simulation Data

EV battery capability in *kW*	150	175	200	225
energy demand at arrival in *kWh*	20	30	40	50
MDPC rate in *$/kW*	19.9			
flexibility factor (*UCP*)	5			
flexibility factor (*PCP*)	1.2			

Under these assumptions and data, the managed charging solution is implemented with the smart charging algorithm initialized with maximum demand of 100 *kW*. 10 experiments, i.e., 10 Monte-Carlo simulations, are carried out by randomly generating data for arrival time, battery capability and energy demand of *EVs* vising the facility during the billing period. For each experiment facility's maximum power demand and *QS* under the three different charging policies are calculated.

3.2. RESULTS

Figure 1 presents the results of Monte-Carlo simulations to report on the facility's maximum power demand under the different charging policies. The results show a considerable reduction in maximum power demand of the *EVFCF* upon the implementation of the proposed managed charging solution with *UCP* and *PCP* as compared to conventional charging under the *CCP*. The simulation results suggest that an *EVCFC* operator can significantly reduce demand peaks, and therefore, *MDPC* of the electricity bill by the deployment of the proposed managed charging solution.

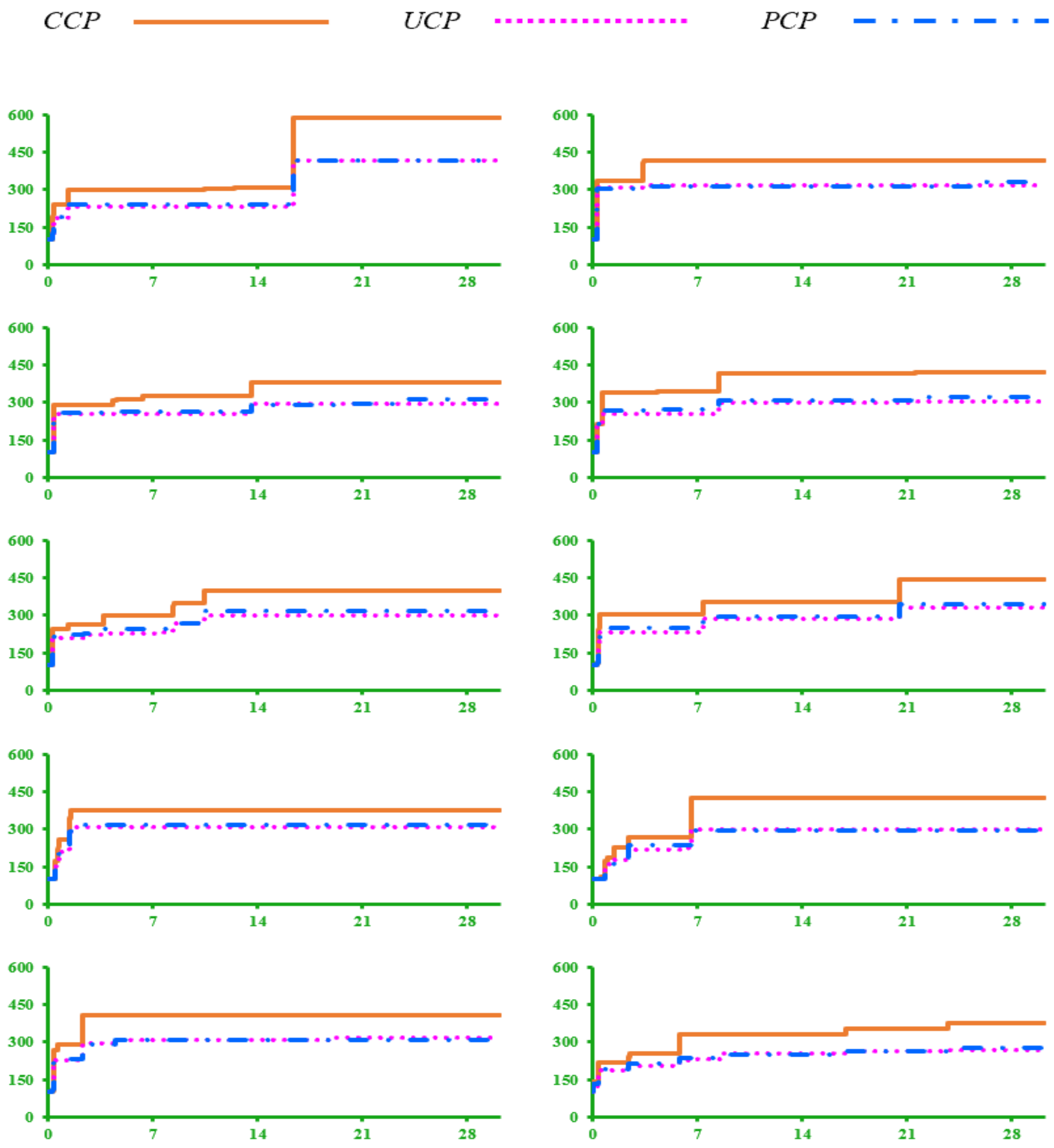

Figure 1: Maximum power demand over a 30-day billing period, *y*-axis: maximum power demand in *kWs*; *x*-axis: time in days.

Table 3 presents a comparative analysis of the *MDPC* of the *EVFCF's* electricity bill, the implied cost savings and the overall *QS* provided to *EV* users at the facility upon the implementation of the managed charging solution under different charging policy structures. Note that the application of the proposed solution does not heavily impact the facility *QS* under the two pursued charging policies, i.e., *UCP* and *PCP*. As such, the simulation outcomes depict on average an approximately 25% (23%) reduction in the *MDPC* of facility's electricity bill with an average, overall *QS* value of 1.2 (1.1) for the *EVFCF* upon the implementation of *UCP* (*PCP*). These results suggest that the *EVFCF* operator can substantially reduce electricity procurement costs and pass on the dollar savings by offering charging service at a lower price to the *EV* users, provided they are willing to slightly compromise on the charging duration. According to the simulation results, the average charging time for *EV* users visiting the specific *EVFCF* marginally increases, for instance, from 10 *minutes* to 12 *minutes* (11 *minutes*) under *UCP* (*PCP*).

Table 3: Simulation Results

exp. #	*CCP*	*UCP*			*PCP*		
	MDPC in *$*	*MDPC* in *$*	% saving	$\xi_f\big\|^{UCP}$	*MDPC* in *$*	% saving	$\xi_f\big\|^{PCP}$
1	11,691	8,314	28.89	1.16	8,342	28.70	1.08
2	8,342	6,314	24.31	1.21	6,582	21.09	1.11
3	7,595	5,896	22.37	1.21	6,198	18.39	1.10
4	8,358	6,059	27.50	1.20	6,403	23.38	1.10
5	7,944	5,926	25.40	1.20	6,302	20.67	1.09
6	8,805	6,586	25.91	1.18	6,893	21.72	1.09
7	7,528	6,182	17.87	1.22	6,356	15.57	1.11
8	8,441	5,964	29.35	1.24	5,890	30.22	1.11
9	8,125	6,292	22.56	1.18	6,125	24.61	1.09
10	7,462	5,361	28.16	1.22	5,482	26.53	1.11

4. CONCLUSION

The *MDPC* of a commercial *EVFCF's* electricity bill is a widely recognized barrier to the deeper penetration of these facilities in multiple communities in the *US*. In this work, a managed charging solution is proposed to effectively mitigate adverse impacts of the *MDPC* issue. As such, an online, smart charging algorithm is formulated, with a key focus on the evolution of the facility's maximum power demand during a billing period. The algorithm also utilizes a linear *OP* to strategically control power supply to each *EV* connected to a charger at the *EVFCF*. Additionally, Monte Carlo simulations are performed to comprehensively analyze cost savings upon the implementation of the proposed managed charging solution at a specified *EVFCF*. The simulation results show a significant (approximately 25%) reduction in the *MDPC* of the facility's electricity bill without drastically impacting quality of service provided to *EV* users visiting the facility.

The model, and simulation outcomes of this work provide multiple opportunities to researchers to further extend their understanding and analysis of the *MDPC* issue faced by facility operators. In the future work, the authors will study the deployment of the proposed solution to report on its feasibility in communities of diverse character and condition. For this purpose, one key approach that will be extensively utilized is the Contextual Engineering (*CE*) framework [17]. The *CE* framework employs an investigatory process drawn from social sciences to inform researchers about place-based characteristics that often determine whether a technical solution to a community particular problem will function as intended, and endure.

Another area of research that will be pursued by the researchers is to apply the formulations presented in this study to design and deploy flexibility differentiated pricing mechanisms. These mechanisms can then be utilized to propose novel, community-specific business models where an *EVFCF* operator can introduce various grades of fuel (electricity) based on level of power supply to *EVs* – similar to the various grades of fuel (gas) offered at gas stations.

5. BIBLIOGRAPHY

[1] United States Environmental Protection Agency, "Inventory of U.S. greenhouse gas emissions and sinks 2019," 2020. [Online]. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks. [Accessed July 27, 2022].

[2] Z. A. Needell, J. McNernery, M. T. Chang and J. E. Tranick, "Potential for widespread electrification of personal vehicle travel in the United States," *Nature Energy*, vol. 1, pp. 1-7, 15 August 2016.

[3] M. E. Biresselioglu, M. D. Kaplan and B. K. Yilmaz, "Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making process," *Transportation Research Part A : Policy and Practice*, vol. 109, pp. 1-13, 8 January 2018.

[4] S. Hardman and G. Tal, "Understanding discontinuance among California's electric vehicle owners," *Nature Energy*, vol. 6, pp. 538-545, 26 April 2021.

[5] W. Kempton, "Electric vehicles driving range," *Nature Energy*, vol. 1, pp. 1-2, 15 August 2016.

[6] E. Kontou, C. Liu, F. Xie, X. Wu, and X. Lin, "Understanding the linkage between electric vehicle charging network coverage and charging opportunity using GPS travel data," *Transportation Research Part C*, vol. 98, pp. 1-13, 18 November 2018.

[7] US Department of Transportation, "President Biden, U.S. Department of Transportation releases toolkit to help rural communities build out electric vehicle charging infrastructure," 2 Feb 2022. [Online]. Available: https://www.transportation.gov/briefing-room/president-biden-us-department-transportation-releases-toolkit-help-rural-communities#:~:text=President%20Biden's%20Bipartisan%20Infrastructure%20Law,make%20these%20projects%20a%20reality. [Accessed May 27, 2022].

[8] W. Wei, S. Ramakrishnan, Z. A. Needell, and J. E. Trancik, "Personal vehicle electrification and charging solutions for high-energy days," *Nature Energy*, vol. 6, pp. 105-114, 21 January 2021.

[9] Z. J. Lee, J. Z. Pang, and S. H. Low, "Pricing EV charging service with demand charge," *Electric Power Systems Research*, vol. 189, pp. 1-9, 1 August 2020.

[10] D. McFarlane, M. Prorok, B. Jordan, and T. Kemabonta, "Analytical white paper: Overcoming barriers to expanding fast charging infrastructure in the midcontinent region," Great Plains Institute, July 2019.

[11] D. Tucker, "Demand charges & electric vehicle fast-charging – An intermountain west assessment," National Association of State Energy Officials, 27 October 2021.

[12] A. Hussain, V.-H. Bui, J.-W. Baek, and H.-M. Kim, "Stationary Energy Storage System for Fast EV Charging Stations: Simultaneous Sizing of Battery and Converter," *Energies*, vol. 12, pp. 1-17, 27 November 2019.

[13] A. Hussain, V.-H. Bui, J.-W. Baek, and H.-M. Kim, "Stationary Energy Storage System for Fast EV Charging Stations: Optimality Analysis and Results Validation," *Energies*, vol. 13, pp. 1-18, 2 January 2020.

[14] J. Qin, K. Poolla, and P. Varaiya, "Mobile storage for demand charge reduction," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, pp. 7952-7962, 16 June 2021.

[15] M. Ghofrani and M. Majidi, "A comprehensive optimization framework for EV-renewable DG coordination," *Electric Power Systems Research*, vol. 194, pp. 1-11, 31 January 2021.

[16] Z. J. Lee, G. Lee, T. Lee, C. Jin, R. Lee, Z. Low, D. Chang, C. Ortega, and S. H. Low, "Adaptive Charging Networks: A Framework for Smart Electric Vehicle Charging," *IEEE Transactions on Smart Grid*, vol. 12, pp. 4339-4350, 20 April 2021.

[17] A. Chattopadhyay, A. P. Witmer and P. Sauer, "The Need for Teaching Place-Based Contextualization for Sustainable Power System Infrastructure Design", *IEEE Transactions on Power Systems*, vol. 36, pp. 5846-5853, 9 April 2021