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RESEARCH ARTICLE

Fair Management of Vehicle-to-Grid and Demand Response Programs in Local Energy Communities

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ABSTRACT Electric Vehicles (EV) are emerging in electricity grid, where the Vehicle-to-Grid (V2G) feature is a major flexibility opportunity for Demand Response (DR) programs. Optimized and fair management of EVs flexibility activation is then required. In the present paper it is proposed a methodology to deal with the complex management of the Local Energy Communities (LEC) with such resources. The method allows the fair selection of DR and V2G participants. Focusing on the EVs, it is compared two approaches: performance rate and clustering groups (considering extrinsic and intrinsic characteristics using modeling of preferences). The method was tested in five office buildings with a shared EV parking lot. Four different events were studied, and the results show that the performance rate might not be enough to have the best results from both the local manager and V2G participants. According to the numerical results, using the performance method the total reduction obtained was 60.20 kW confronting with the 105.13 kW reduced using the clustering method.

INDEX TERMS Aggregation, clustering, electric vehicles, fairness, vehicle-to-grid.

NOMENCLATURE

$C^{grid_{in}}_{(t)})$	Cost of selling on period t (m.u./kW).
$C^{grid_{out}}_{(t)}$	Cost of buying on period t (m.u./kW).
$E^{stor}_{(s,t)}$	State of charge from electric vehicle s on period t (kW).
$E^{stormax}_{(s,t)}$	Maximum state of charge from electric vehicle s on period t (kW).
$E^{stormin}_{(s,t)}$	Minimum state of charge from electric vehicle s on period t (kW).
$P^{DR}_{(c,t)}$	Flexibility provided by prosumer c on period t (kW).
$P^{DRmax}_{(c,t)}$	Maximum flexibility provided by prosumer c on period t (kW).
$P^{grid_{in}}_{(t)}$	Power sold from External Supplier on period t (m.u./kW).
$P^{grid_{out}}_{(t)}$	Power bought to External Supplier on period t (m.u./kW).
$P^{gridmax_{in}}_{(t)}$	Maximum power that can be bought from External Supplier on period t (m.u./kW).
$P^{gridmax_{out}}_{(t)}$	Maximum power that can be bought from External Supplier on period t (m.u./kW).
$P^{DR}_{(c,t)}$	Power from Demand Response active consumer c on period t (kW).
$P^{PV}_{(p,t)}$	Power from Distributed Generation p on period t (kW).
$P^{ch}_{(s,t)}$	Power from charging electric vehicle s on period t (kW).
$P^{dch}_{(s,t)}$	Power from discharging electric vehicle s on period t (kW).

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$P^{grid}_{(t)}$	Power from External Supplier on period t (kW).
$P^{load}_{(t)}$	Initial Load on period t (kW).
$W^{DR}_{(c,t)}$	Flexibility weight from prosumer c on period t.
$X^{DR}_{(c,t)}$	Availability from prosumer c on period t.
$X^{ch}_{(s,t)}$	Charging status from electric vehicle s on period t.
$X^{dch}_{(s,t)}$	Discharging status from electric vehicle s on period t.

I. INTRODUCTION

Vehicle to grid (V2G) has the potential to maximize the advantages of Electric Vehicles (EV) and play a vital role in transitioning to a sustainable and resilient energy system [1]. However, addressing technical challenges, refining business models, and establishing the required infrastructure and policies are essential for unlocking the full potential of V2G [2]. Research and development are necessary to overcome these challenges and ensure the successful implementation of V2G, contributing to a greener future [3].

This section introduces the background and motivations used to elaborate the paper, some related works found in the current literature, and this paper's main innovations and contributions.

A. BACKGROUND AND MOTIVATIONS

According to the European Commission, in 2016, the transport sector was one of Europe's significant causes of greenhouse gas emissions [4]. Furthermore, road cars account for almost 75% of all CO2 emissions among all forms of transportation [5]. During this time, different countries saw an opportunity to adopt EV to contribute to the reduction of greenhouse gas emissions and fossil fuel usage [6]. Indeed, incentives for using these type of resources, providing flexibility to deal with the volatile behavior of distributed generation, will be a crucial factor to increase the system sustainability [7]. In this way, as a result, according to International Energy Agency, these past few years, the global stock of EVs has been increasing significantly, wherein in 2020, there was a 43% increase compared to 2019 [8].

However, if the necessary measures are not taken, the high penetration of EVs can bring problems to the grid, namely the decreased performance and power failure [9]. Thus, considering this context, it is essential to apply innovative technologies such as smart grid since it makes it possible to improve the efficiency and quality of grids through bidirectional communication [10] namely through Demand Response (DR) [11]. With this solution, the consumer, who lacked direct knowledge of market transactions prior to the adoption of the smart grid concept, will now be able to participate. Will, however, lead to an increase of the resource management complexity due to the uncertain response of this new player. Still, making the consumer the main focus of the business model is obligatory due to the volatile behavior of DG, considering their flexibility as essential to achieving the system balance [12]. In addition, the smart grid allows the emergence of new technologies, such as V2G, which make it possible to transfer energy from the EV to the grid and vice versa [13].

With V2G technology, EVs can be seen as relevant entities in energy management systems, where they can, through the charging and discharging process, bring various benefits to the grid, such as ancillary services [14]. The efficient control of the respective EV charging and discharging processes can be performed by an aggregator, where it can implement DR strategies depending on the EV owners' preferences, personal or grid objectives, and the renewable energy sources availability [15].

B. RELATED LITERATURE

DR is already a widely discussed in the literature. Nevertheless, the EVs topic, is still one of the main focus. For description of the current situation for problem statement, several studies will be explored within this sub-section. Table 1 highlights the main topics explored on the mentioned works and makes a comparison with the proposed methodology, useful for the problem statement definition.

TABLE 1. Related literature comparison.

Reference	V2G	DR	Scheduling	Fairness	DG
[10]		x	x		x
[16]		x	x		
[17]	x	x	x		x
[19]	x		x	x	
[20]	x				x
[21]	x		x		
[22]	x		x		x
[23]	x		x		x
[24]	x			x	
[25]	x	x	x		
Proposed Method	x	x	x	x	x

Habib et. al [10] used different DR programs in their study to analyze a microgrid operation with DG and EVs. Their work suggests a combined optimization strategy for the best design and management of a grid-connected home within a community rural microgrid integrating EVs. Li and Li [16] focused also on the microgrid, but this time an isolated one, where their simulation results show that including DR from EV users may direct them to actively engage in scheduling and accomplish peak load shaving, which provides a crucial solution to grid balance. In order to strike a balance between the off-grid system's energy supply and demand, Kim et. al [17] proposed a model that simultaneously optimizes the DR market and peer-to-peer energy trading. Under the optimized transaction price, EV charging facilities can direct control the demand for charging through EVs' DR while optimally determining how much energy to purchase from the market.

In the literature, there are several studies focused on the V2G models. For example, in [18] and [19], an aggregator-based model is proposed with particular attention to fairness. In [18], a two-stage optimal framework for the online dispatch is proposed to deal with the uncertainties of the renewable energy sources and load demand in a microgrid. In the first stage, this framework schedules all the energy resources of the microgrid. In the second stage, considering the max-min fairness of the EV charging power, the charging power that the charging station allocates for each EV is calculated. The simulation showed the framework's efficiency, reducing the microgrid's operating cost. In the literature, there are several studies focused on the V2G models. For example, in [18] and [19], an aggregator-based model is proposed with particular attention to fairness. In [18], a two-stage optimal framework for the online dispatch is proposed to deal with the uncertainties of the renewable energy sources and load demand in a microgrid. In the first stage, this framework schedules all the energy resources of the microgrid. In the second stage, considering the max-min fairness of the EV charging power, the charging power that the charging station allocates for each EV is calculated. The simulation showed the framework's efficiency, reducing the microgrid's operating cost. The authors from [20] considered an approach for restructured power system but only considering EVs and renewable resources, namely a hybrid wind-solar energy.

In [19], a V2G discharging strategy based on a meta-heuristic algorithm is presented to minimize the net costs of the aggregator and EVs in a confidential and fair mode. Furthermore, in this strategy, to have fairness between the EVs, a standard discharge rate is defined for all the EVs to avoid some EV owners having more benefits than the rest. The simulated results obtained with this strategy showed its efficiency compared with others. Other studies, such as [21], propose an aggregator-based model that considers the charging preferences of EV owners. With the charging preferences, this model tries to provide more control to the EV owner in the scheduling process. The results demonstrate that the EV owners' charging preferences can reduce the scheduling process's complexity. There are also studies that present V2G strategies oriented to Local Energy Communities (LEC). For example, in [22], a two-layer scheduling optimization approach is proposed to coordinate the day-ahead energy management of LEC. The results obtained through this approach illustrate that the LEC's energy resources are used efficiently, thanks to the EVs' participation. In [23], a mixed-integer linear programming model is proposed to optimally design electric services for a LEC with RES and storage systems at his disposal. The results illustrated that the V2G technology saves of 1600 €per year. Tiwari et al. [24] approach separates the charging/discharging time of EVs into time slots, treating them as strategies, with the goal of satisfying grid objectives and the economic and social interests of vehicle owners. Finally, Jin et al. [25] study is meant to use EVs with V2G capabilities for auxiliary services to the power grid. Their framework incorporates a model to forecast EV charging behaviors and minimize operation costs.

C. INNOVATIONS AND CONTRIBUTION

The proposed methodology provides innovative contributions in the field of LEC management, from the Aggregator perspective. This methodology allows the Aggregator to identify and schedule the more reliable resources to achieve the Distribution System Operators (DSO) reduction target. Flexibility from the consumers and V2G contribute to the system management, providing it more reliable in different contexts. The motivation, considering the inferences found out with Table 1, where is visible the lacks of models in the literature, is to develop a business model that includes all the topics highlighted, which are considered as crucial for dealing with the uncertainty of the response from Flexibility and V2G. The following features listed as innovative aspects are considered as important and crucial for solving this problem:

- Introduce a V2G perspective to aid the Aggregator on the management of communities;
- Fairness model to prioritize the charging of EVs with better performance on the V2G events and the ones with closer departure time;
- Define the EVs ready for the V2G events according to several parameters such as check-out proximity, historic of participation, State of Charge (SOC) or percentage of battery to optimally select the ones for the event context;
- Aggregation of the EVs available for the V2G event to find the proper group according to the context;
- Categorize the EV according to the actual response in previous V2G events to define a fairness model;
- Collaboration between community members regarding load balance, highlighting the importance of the role of the EVs, the consumer, the prosumer, and the local generation.

In this paper, Section I presents the background and motivations, related literature and innovations and contribution. Section II details the solution proposed for managing a LEC focusing on the EVs. Section III presents the case study followed by Section IV where the results are discussed showing the feasibility and robustness of the methodology. Finally, Section V brings the conclusions.

II. PROPOSED METHODOLOGY

For the present section, a detailed explanation regarding the proposed methodology nature and formulation is presented. The goal is to optimally manage a community with active consumers considering both DR and V2G option A load reduction is requested from the DSO to all the aggregators in charge of the local communities in the grid nearby the bus where a voltage violation was detected. With V2G, the EVs available can participate to achieve the community common goal. From the aggregator perspective, it is developed the methodology presented on Figure 1. The algorithm may be used in both real-time as well as day-ahead planning whether

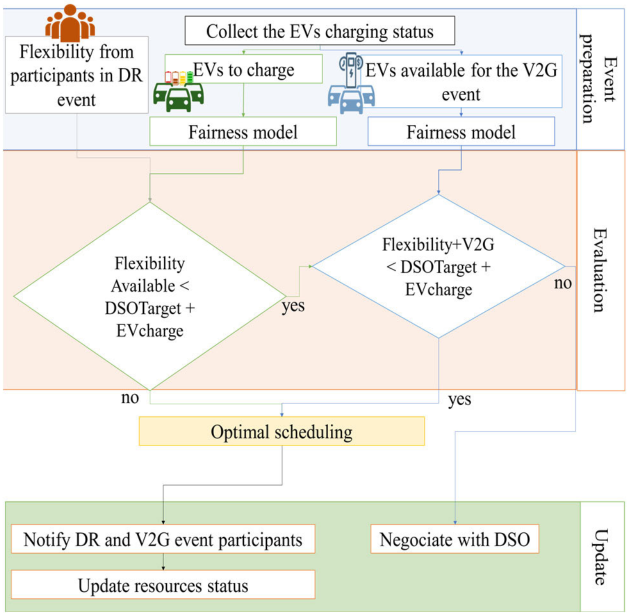

FIGURE 1. **Proposed methodology for optimally manage communities with V2G option.**

the aggregator has information regarding the DSO reduction target. Figure 1 steps will be further analyzed throughout this section. Figure 2 was created to help understand the proposed methodology steps and represents the pseudo-code for the proposed methodology algorithm. Starting the explanation, for each period it is necessary to collect all the information from each EV in community such as: check-out proximity, initial SOC, expected SOC, among others.

Within the Event preparation phase and with this information gathered is possible to understand the EVs ready for the V2G event, if triggered in the current period. After, a Fairness Model is applied for both selecting the order of charging and the participation in the V2G event. The authors already used the same method in other works to classify the participants for a DR event triggered – the contextual trustworthy rate [26]. The main goal is to categorize the consumers with higher level of trustworthiness or, in other words, better performance in DR events triggered in a specific context. Having this information, for the charging path, this model assumes that the ones with higher participation on previous events have priority if their check-out period is close, becoming important to have higher performance.

Furthermore, in the present paper it is compared a different approach, the clustering selection considering the different inputs depending on the event type:

•Intrinsic – considering EV characteristics (amount of charge and discharge)

•Extrinsic – considering the participation history, period of staying in the park and status during the stay (arrival and departure times, battery status, departure battery requirements from the owner perspective, …)

With this information, the group with the most interesting typical profile according to the event context is selected. In this way, the discharge rate will be an interesting parameter to consider so the group with higher value will be chosen. The clustering method selected was k-means, already widely used by the authors in other works [27]. Reunited all the resources, the first stage of the Evaluation step, before the optimal scheduling, is performed. Is DSO target for reduction higher than the flexibility provided by the active consumers in the community, considering the EV charging? It must be highlighted that DR event consumers are also selected with the contextual trustworthy rate and if the flexibility of the ones with higher rate is not enough, all consumers available are called to participate.

In the positive case, the Scheduling phase is performed resorting to a linear approach, namely a mixed-integer linear programming optimization. The goal is to minimize the operation costs from the perspective of the Aggregator considering the fair remuneration of the participating resources. Several parameters such as the maximum capacity of the DG units, the external suppliers, the reduction capacity of the consumers belonging to DR programs, the charge and discharge rate from the EVs, as well as the tariffs associated with each resource is needed. The objective function of the problem is introduced by Eq (1). The majority of the tariffs are defined hourly. With this, the term Δt was added to adjust the consumption for a different time basis. Consumption (such as load consumption and the power to EV charge) and generation (such as distributed generation, grid power, demand response and EV discharge) must achieve balance for a proper energy management.

$$\min EB=\sum_{t-1}^{T}\left[\begin{array}{l}\left(\begin{array}{c}P_{(t)}^{grid_{in}}\cdot C_{(t)}^{grid_{in}}\\-P_{(t)}^{grid_{in}}\cdot C_{(t)}^{grid_{in}}\end{array}\right)\cdot\frac{1}{\Delta t}\\+\sum_{c=1}^{c}\llbracket P_{c,t}^{PDR}\cdot W_{c,t}^{PDR}]+\sum_{s=1}^{S}\llbracket P_{s,t}^{dch}\cdot C_{s,t}^{dch}]\end{array}\right.\rrbracket$$

$$\begin{cases}P_{(t)}^{grid_{in}}=P_{(t)}^{grid},\ if\ P_{(t)}^{grid}>0\\P_{(t)}^{grid_{out}}=P_{(t)}^{grid},\ if\ P_{(t)}^{grid}<0\\\forall t\in\{1,\ldots,T\}\end{cases}\tag{1}$$

Equation (2) provides the means to achieve this goal. The $P_{(t)}^{grid}$, power from grid variable, sign changes according to the transactions done. In other words, if the energy from the power grid is bought the value is positive, otherwise, it is negative as can be seen in Equation (3).

$$\sum_{p=1}^{P}P_{(p,t)}^{PV}+P_{(t)}^{grid}+\sum_{c=1}^{C}P_{(c,t)}^{DR}+\sum_{s=1}^{S}P_{(s,t)}^{dch}=P_{(c,t)}^{load}+\sum_{s=1}^{S}P_{(s,t)}^{ch},\forall t\in\{1,\ldots,T\}\tag{2}$$

$$-P_{(t)}^{gridmax_{out}}\leq P_{(t)}^{grid}\leq P_{(t)}^{gridmax_{in}},\quad\forall t\in\{1,\ldots,T\}\tag{3}$$

Moving to the consumers participating in DR events, two options are given through Equation (4) and Equation (5). The first one assumes that participant reduces according to their flexibility until reach the $P^{DRmax}_{(c,t)}$. The second one restricts their flexibility using connected relays, depending on the participant availability $X^{DR}_{(c,t)}$. Only when activated – using the binary variable, the loads can be shed.

$$0 \leq P^{DR}_{(c,t)} \leq P^{DRmax}_{(c,t)}, \quad \forall t \in \{1, \ldots, T\}, c \in \{1, \ldots, C\} \tag{4}$$

$$P^{DR}_{(c,t)} = P^{DRmax}_{(c,t)}.X^{DR}_{(c,t)}, \quad X^{DR}_{(c,t)} \in \{0, 1\}, \forall t \in \{1, \ldots, T\}, c \in \{1, \ldots, C\} \tag{5}$$

Regarding the EVs, several equations constraint their management. Equation (6) represents the capacity limits, where $E^{stormin}_{(s,t)}$ represents the minimum capacity needed at the check-out time and $E^{stormax}_{(s,t)}$ represents the maximum capacity. Equation (7) and Equation (8) limit charge and discharge rates for each period, respectively. Again, a binary variable is associated to guarantee the impossibility of charging and discharging in the same period. As can be seen on Equation (9), the sum of these variables must be always inferior or equal to one. Finally, Equation (10) represents the state of charge of each EV, to be updated each period.

$$E^{stormin}_{(s,t)} \leq E^{stor}_{(s,t)} \leq E^{stormax}_{(s,t)}, \quad \forall t \in \{1, \ldots, T\}, s \in \{1, \ldots, S\} \tag{6}$$

$$0 \leq P^{ch}_{(s,t)} \leq P^{chmax}_{(s,t)}.X^{ch}_{(s,t)}, \quad X^{ch}_{(s,t)} \in \{0, 1\}, \forall t \in \{1, \ldots, T\}, s \in \{1, \ldots, S\} \tag{7}$$

$$0 \leq P^{dch}_{(s,t)} \leq P^{dchmax}_{(s,t)}.X^{dch}_{(s,t)}, \quad X^{dch}_{(s,t)} \in \{0, 1\}, \forall t \in \{1, \ldots, T\}, s \in \{1, \ldots, S\} \tag{8}$$

$$X^{dch}_{(s,t)} + X^{ch}_{(s,t)} \leq 1, \quad \forall t \in \{1, \ldots, T\}, s \in \{1, \ldots, S\} \tag{9}$$

$$E^{stor}_{(s,t)} = E^{stor}_{(s,t-1)} + P^{ch}_{(s,t)} + P^{dch}_{(s,t)}, \quad \forall t \in \{1, \ldots, T\}, s \in \{1, \ldots, S\} \tag{10}$$

However, if the flexibility provided by the DR participants is not enough to achieve the DSO goal, a V2G event is triggered.

Is DSO target for reduction higher than the flexibility provided by both the active consumers in the community and the EVs available for the event? If so, the model moves to the following stage. Otherwise, the Aggregator must negotiate with the DSO the reduction terms according to the results found. In the present paper, the main focus is the participant selection for the V2G model considering a fairness model where the previously present approaches are compared.

III. CASE STUDY

The case study is based on a parking lot used by five private office buildings equipped with a set of photovoltaic panels each. This parking lot has operating hours between 8 am and 9 pm and has charging stations for electric vehicles, thus enabling the implementation of the V2G technology.

TABLE 2. Electric vehicles information.

Type	Model	Battery Capacity (kWh)	Charging/ Discharging Rate (kW)
1	Renault ZOE	41	5.2
2	Renault ZOE	41	10.4
3	Nissan Leaf	24	2.9
4	Renault ZOE	22	15.5
5	Renault ZOE	22	17.2
6	Nissan Leaf	30	19.4

```
For each period t
    For each consumer c
        Obtain $P^{load}_{(c,t)}$, $P^{DRmax}_{(c,t)}$
    For each distributed generation p
        Obtain $P^{pv}_{(p,t)}$
    For each electric vehicle s
        Obtain $E^{stormin}_{(s,t)}$, $E^{stormax}_{(s,t)}$, $P^{chmax}_{(s,t)}$, $P^{dchmax}_{(s,t)}$
    For each electric vehicle s
        Calculate $P^{Fairch}_{(s,t)}$, $P^{Fairdch}_{(s,t)}$, $E^{stor}_{(s,t)}$
    For each consumer c
        Calculate $P^{requestedDR}_{(c,t)}$
    If the sum of consumer $P^{requestedDR}_{(c,t)}$ <= DSO target + sum
        of electric vehicle $P^{Fairch}_{(s,t)}$
        If the sum of consumer $P^{requestedDR}_{(c,t)}$ + sum of electric
        vehicle $P^{Fairdch}_{(s,t)}$ <= DSO target + sum of electric
        vehicle $P^{Fairch}_{(s,t)}$
            Calculate Scheduling (equations (1) to (10))
            Notify DR participants
            Update resources status
            Calculate remuneration
        else
            Negotiate with DSO
    else
        Calculate Scheduling (equations (1) to (10))
        Notify DR participants
        Update resources status
        Calculate remuneration
Next
```

FIGURE 2. Pseudo code for optimally manage communities with V2G option.

For each building, it is considered six types of EVs able to participate in V2G events, and their characteristics are shown in TABLE 2, namely the brand, model, battery capacity and charging/discharging rate. Besides, each EV user must provide important information regarding the check-in, check-out, and the expected SOC at the check-out time for the proper management of the community. This information will be later used for the clustering selection method. The data related to the EVs is based on the database shared by the European Commission that is associated with the SOFIE Project [28].

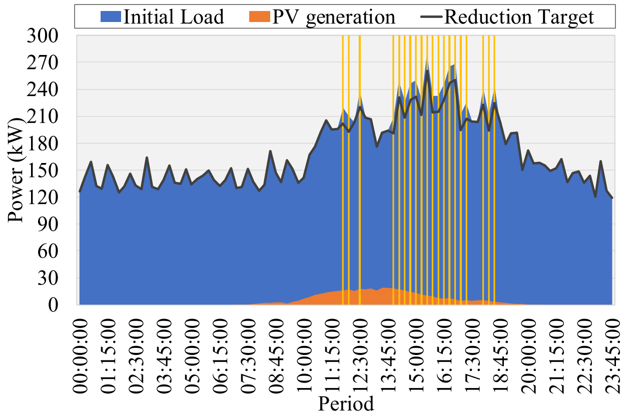

FIGURE 3. Community consumption, PV generation forecast and DSO reduction target with the respective events triggered.

Regarding DR events, Figure 3 shows the total initial load consumption for the office buildings, the respective PV generation and the reduction target with the event triggered highlighted.

In this case study, two types of DR events can be seen: fast (with 30 or less minutes) and slow (more than 30 minutes), where are identified as yellow columns. The DR event reduction target is represented with black line and, when comparing with the initial load (blue chart), the difference can be seen at the times of the events.

After gathering all the information, the flexibility provided from both office buildings, the EV discharge and the PV generation must be managed to achieve the reduction goals. Moreover, the aggregator must properly remunerate the participants in both DR and V2G events.

TABLE 3. Flexibility compensation values and access to grid values.

Schedule	Remuneration (m.u.)	From Grid (m.u.)	Sell Grid (m.u.)
22:00 – 08:00	0.1561	0.1659	0.1815
08:00 – 10:30	0.1686		
10:30 – 12:45	0.2724		
12:45 – 19:30	0.1686		
19:30 – 20:45	0.2724		
20:45 – 21:45	0.1686		

In this way, the option is to use a contextual compensation considering several schedules with different prices, as can be seen in TABLE 3. Furthermore, when the generation is not able to suppress the load consumption needs, the aggregator must resort to the grid – the prices applied are also in TABLE 3. The case study was designed to test and evaluate the proposed methodology from the V2G perspective and regarding the impact of these resources on the overall flexibility provided to achieve the community common reduction goal. With this, two different methods were applied to select the V2G participants. First, considering the performance rate, from 1 to 5, from each EV user. This is evaluated considering their participation in previous events by providing flexibility when the aggregator requests.

It must be highlighted that, considering this performance, these participants have priority of charging. So, this method can be used in both charge and discharge paths of the proposed methodology. Regarding the second method to select V2G participants, the clustering method will find the EV groups considering always that the number of the clusters (in this case k = 3) is higher than the number of samples. The second flexibility test will guarantee that the selected group is enough to achieve the goal. Otherwise, all the available EVs are called to participate. To solve this case study using the proposed algorithm, the algorithm was developed using python language. For the resource scheduling the *docplex* library, which is part of IBM Decision Optimization, was applied. For each 15-period for the studied day, the simulation time was below 30 seconds.

IV. RESULTS AND DISCUSSION

The proposed methodology will be implemented in this case study for a daily perspective, considering 15-minute periods, resulting in a total of 96, being 12 PM the first one considered. The dataset has information for a weekday, to fully understand the potential of the DR participants as well as the EV users on the V2G event triggered.

With this, the present section is divided into two different perspectives to compare two fairness models for the selection of the EVs participating in the V2G event: performance selection and clustering groups selection. The following tables show the overall results of the selected community for the buildings (TABLE 4) and PV generation resources (TABLE 5). Since EV users are the focus of the model selection, the results will be further explored.

TABLE 4. DR participants' flexibility, remuneration, and final balance.

ID	Flexibility Provided (kW)	Remuneration (m.u.)	Payment (m.u.)	Balance (m.u.)
1	9.42	58.34	-543.32	-484.99
2	9.47	58.64	-547.38	-488.74
3	9.50	58.85	-549.59	-490.74
4	9.58	59.33	-555.73	-496.40
5	9.35	57.86	-539.48	-481.62

TABLE 5. PV generation contribution, remuneration, and final balance.

ID	Contribution (kW)	Remuneration (m.u.)
1	130.39	23.67
2	43.46	7.89
3	130.39	23.67
4	43.65	7.92
5	97.57	17.71

The flexibility and PV generation contribution results are for the 24 hour study, therefore, are the sum of all participation values. According to Table 4, the five consumers provided around 10 kW of flexibility each. Also, the period in which the DR event was triggered also impacts the compensation from the participants. With this, each one was able to reduce from their bill around 58 m.u. Regarding the PV generation, all the contribution was sold to the grid and the remuneration value must be included for the final bill balance of each consumer to reduce the expense amount. These values were below 25 m.u. for the ones with higher overall contribution. Table 4 balance is the difference between the actual payment and the remuneration for participation. Since the flexibility provided is similar, the buildings final balance are also similar. Regarding Table 5 results, the ID1 and ID2 participants have the higher value of remuneration.

TABLE 6. EV users' SOC results.

ID	Initial SOC (kW)	Final SOC (kW)	Goal SOC (kW)	Number of Event Participations
1	6.83	40.63	40.59	0
2	21.17	28.97	20.50	0
3	18.32	19.77	17.28	0
4	2.03	22.00	21.56	0
5	1.57	18.77	18.70	0
6	17.50	27.20	27.00	0
7	18.22	41.00	41.00	2
8	9.19	41.00	40.59	1
9	7.96	13.03	18.72	0
10	16.32	22.00	12.76	0
11	13.57	22.00	20.46	4
12	20.62	30.00	22.80	0
13	25.73	33.53	33.62	9
14	40.49	41.00	40.59	0
15	21.96	24.00	18.00	0
16	20.45	22.00	18.48	0
17	20.33	22.00	16.06	0
18	5.89	30.00	29.70	1
19	9.67	16.17	33.62	0
20	9.37	24.97	22.96	3
21	21.66	23.11	22.56	6
22	20.52	22.00	20.68	0
23	20.70	22.00	16.06	0
24	23.20	30.00	19.20	0
25	30.99	36.19	36.90	7
26	6.28	29.68	29.52	1
27	0.37	17.04	17.04	0
28	4.48	19.98	18.26	0
29	17.93	22.00	16.28	0
30	19.61	30.00	16.80	0

A. PERFORMANCE SELECTION

For performance model, the results for EV users can be seen on TABLE 6. As previously mentioned, four different DR events were triggered. TABLE 6 shows the results regarding the State Of Charge (SOC) for different steps of the proposed methodology: the initial SOC (check-in period), the final SOC (check-out period) and the requested SOC by the EV user that should be achieved. In TABLE 6 and in TABLE 8, when the goal SOC is achieved, there table cell is green. Otherwise, the table cell is red.

According to the results, only two EVs were not able to achieve this goal: ID 9 and ID 19. The first one, had an initial SOC of 7.96 kW and the goal was to achieve 18.72 kW. However, the check-in period was at 10:30 AM and the check-out was at 12:06 PM therefore the goal was not conceivable since the charge rate is 0.73 kW.

TABLE 7. V2G results from performance approach.

ID	Flexibility Provided (kW)	Charge Payment (m.u.)	Remuneration (m.u.)	Balance (m.u.)
1	0.00	-5.61	0.00	-5.61
2	0.00	-1.29	0.00	-1.29
3	0.00	-0.24	0.00	-0.24
4	0.00	-3.31	0.00	-3.31
5	0.00	-2.85	0.00	-2.85
6	0.00	-1.61	0.00	-1.61
7	2.60	-4.21	0.71	-3.50
8	2.60	-5.71	0.71	-5.00
9	0.00	-0.84	0.00	-0.84
10	0.00	-0.94	0.00	-0.94
11	17.20	-4.25	3.35	-0.91
12	0.00	-1.56	0.00	-1.56
13	11.70	-3.24	2.11	-1.13
14	0.00	-0.08	0.00	-0.08
15	0.00	-0.34	0.00	-0.34
16	0.00	-0.26	0.00	-0.26
17	0.00	-0.28	0.00	-0.28
18	4.85	-4.81	1.32	-3.48
19	0.00	-1.08	0.00	-1.08
20	7.80	-3.88	1.85	-2.03
21	4.35	-0.96	0.96	0.00
22	0.00	-0.25	0.00	-0.25
23	0.00	-0.22	0.00	-0.22
24	0.00	-1.13	0.00	-1.13
25	9.10	-2.37	1.67	-0.70
26	2.60	-4.31	0.71	-3.61
27	0.00	-2.77	0.00	-2.77
28	0.00	-2.57	0.00	-2.57
29	0.00	-0.67	0.00	-0.67
30	0.00	-1.72	0.00	-1.72

The same situation is applied to EV ID 19: check-in period was at 10:30 AM and the check-out period was at 11:35 AM. Although the charge rate was higher (1.30 kW), achieving 33.62 kW was impossible. Still, the SOC increased from 9.67 kW to 16.17 kW.

Regarding the event participation, a total of nine different EVs participate in the V2G events triggered to aid the DR participants on achieving the DSO target. Must be highlighted that although providing flexibility, these EVs were able to leave the parking lot with the expected SOC. In this way, the V2G results, namely the remuneration and flexibility provided, as well as the charge payment can be seen on TABLE 7.

When confronting both EV result tables, it is possible to understand the weight of contribution done from each EV on the events triggered. For instance, although the EV ID 13 was the one with more participation frequency – a total of 9 period from the events triggered, was not the one with more flexibility provided. EV ID 11, with 4 participations was able to provide a total of 17.20 kW of flexibility, receiving the maximum value of remuneration – 3.35 m.u. Since this user charge payment was 4.25 m.u., the final balance decreased

TABLE 8. **EV users' SOC results.**

ID	Initial SOC (kW)	Final SOC (kW)	SOC goal (kW)	Number of Event Participations
1	6.83	40.63	40.59	0
2	21.17	28.97	20.50	0
3	18.32	19.77	17.28	0
4	2.03	22.00	21.56	0
5	1.57	18.77	18.70	0
6	17.5	27.20	27.00	0
7	18.22	41.00	41.00	2
8	9.19	41.00	40.59	2
9	7.96	13.03	18.72	0
10	16.32	22.00	12.76	0
11	13.57	22.00	20.46	9
12	20.62	30.00	22.8	0
13	25.73	34.83	33.62	10
14	40.49	41.00	40.59	0
15	21.96	24.00	18.00	0
16	20.45	22.00	18.48	0
17	20.33	22.00	16.06	0
18	5.89	30.00	29.70	3
19	9.67	16.17	33.62	0
20	9.37	24.97	22.96	4
21	21.66	23.11	22.56	7
22	20.52	22.00	20.68	0
23	20.7	22.00	16.06	0
24	23.2	30.00	19.20	0
25	30.99	37.49	36.90	8
26	6.28	29.68	29.52	2
27	0.37	17.04	17.04	0
28	4.48	19.98	18.26	0
29	17.93	22.00	16.28	0
30	19.61	30.00	16.80	0

TABLE 9. **V2G results from clustering approach.**

ID	Flexibility provided (kW)	Charge payment (m.u.)	Remuneration (m.u.)	Balance (m.u.)
1	0.00	-5.61	0.00	-5.61
2	0.00	-1.29	0.00	-1.29
3	0.00	-0.24	0.00	-0.24
4	0.00	-3.31	0.00	-3.31
5	0.00	-2.85	0.00	-2.85
6	0.00	-1.61	0.00	-1.61
7	2.60	-4.21	0.71	-3.50
8	5.20	-6.14	1.42	-4.72
9	0.00	-0.84	0.00	-0.84
10	0.00	-0.94	0.00	-0.94
11	38.70	-7.82	7.86	0.05
12	0.00	-1.56	0.00	-1.56
13	13.00	-3.67	2.60	-1.07
14	0.00	-0.08	0.00	-0.08
15	0.00	-0.34	0.00	-0.34
16	0.00	-0.26	0.00	-0.26
17	0.00	-0.28	0.00	-0.28
18	14.55	-6.41	3.96	-2.45
19	0.00	-1.08	0.00	-1.08
20	10.40	-4.31	2.56	-1.75
21	5.08	-1.08	1.08	0.00
22	0.00	-0.25	0.00	-0.25
23	0.00	-0.22	0.00	-0.22
24	0.00	-1.13	0.00	-1.13
25	10.40	-2.80	2.16	-0.65
26	5.20	-4.74	1.42	-3.33
27	0.00	-2.77	0.00	-2.77
28	0.00	-2.57	0.00	-2.57
29	0.00	-0.67	0.00	-0.67
30	0.00	-1.72	0.00	-1.72

for 0.91 m.u. Another interesting example is the one from EV ID 21.

This user participated six event periods, providing a total of 4.35 kW of flexibility. The initial SOC was 21.66 kW, and the intended goal was 22.56 kW. So, the proposed methodology was able to manage to include this resource for a V2G event and still charge to achieve the target SOC. Furthermore, from the users' perspective, the remuneration value from participating in the V2G event was enough to suppress the charge payment.

So, both sides benefice with this approach: the DSO goal was achieved, and the user did not pay for charging the EV.

B. CLUSTERING SELECTION

The clustering groups selection results can be seen on TABLE 8 and TABLE 9. Again, when the goal SOC is achieved, there table cell is green. Otherwise, the table cell is red. When comparing the results from the previous approach, namely from TABLE 6, there were also a total of nine participants for the events triggered throughout the day. However, for this case, there were more participations for the DR events triggered. Must be highlight that simulations were made for the same context. Since there were no limitations like the previous where there was the condition of having a performance rate superior to the denominated minimum.

Here, all EVs were included for the selection considering their characteristics (extrinsic or intrinsic mentioned earlier), also including this performance rate as input. Although, EV might be less uncertain than an appliance, the authors find important to add an indication of contextual trustworthiness to define the EV user.

For most of the cases, the EVs were able to participate at least one more time than with the performance method and still being able to achieve their SOC goal. For instance, the EV ID 11 participated four times with performance approach and with the clustering method was able to attend to five more events and still excess the SOC goal of 20.46 kW having a final SOC of 22.00 kW.

The impact of this effect can be seen on the V2G results seen on TABLE 9. Starting with EV ID 8, previously the final balance was a negative 5.00 m.u. and, with the clustering approach, since this EV participated one more time in the V2G event, was able to reduce its balance to a negative 4.72 m.u. The next one, EV ID 11, was the one with higher difference from the previous results. Achieving a flexibility of 38.70 kW in this approach confronting with the 17.20 kW on the previous one. With this was able to not only excess the SOC goal, pay for its charge but also receive a compensation resulting in a balance of positive 0.05 m.u. Other example of a significative impact of this approach in the final balance is the EV ID 18. The previous flexibility provided was 4.35 kW and now achieved the 14.55 kW resulting in a reduction of 1.03 m.u. in the bill. Almost all the remaining participants were able to reduce their final balance with this approach –

EV ID 7 was the only one that did not because participated the same number of times. With this, the resource performance can be a good indicative for fair selection but should not be the only one.

V. CONCLUSION

The EV introduction in the power and energy sector will revolutionize the management of local communities. The uncertainty from the DR participants adds already complexity to balance between generation and demand. Having resources that can move geographically throughout the grid implies different strategies to avoid congestions and creation of new peaks on the load curve. With this, this paper introduces a methodology to deal with consumers participating in DR events by providing their flexibility to achieve a reduction target goal. As innovation from previous works, a V2G event can be triggered to also aid on the success of this mission by the local community manager.

The focus of the present study is the comparison between two different fairness models used to select the proper participants for a V2G event: using a trustworthiness rate that describes the EVs according to previous performances or a clustering method that forms several EVs groups resorting to extrinsic or intrinsic characteristics. From the results, it was possible to conclude that a clustering method would be beneficial for both parties: more event participation, achieving the SOC goal and be able to reduce the final consumer bill. Although the performance is a good indicator of the resource expected availability, alone might not be the best approach for selecting the EVs for a V2G event since it can reduce the possibility of available resources to participate in the events. As future works, the authors believe that working on the selection of the proper clustering groups, for instance, considering other parameter than the discharge rate for the choice.

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