Optimal Contract Power and Battery Energy Storage System Capacity for Smart Buildings

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***Abstract*—This paper proposed a Mixed Binary Linear Programming (MBLP) approach to find the optimal size of some components of a Smart Building (SB) attempting to reduce the overall cost. The considered SB is equipped with local resources such as Photovoltaic (PV) panels, Electrical Vehicles (EVs), and the Battery Energy Storage System (BESS). Moreover, the SB is only connected with the grid by an Energy Management System (EMS) in which the whole SB has a single Contract Power (CP) such that EMS manages the power flow among external grid, local resources, apartments, and common services, for the goal of reducing the electricity bill. Hence, the wrong choice of CP and BESS capacity will impose unnecessary charges on the electricity bill. As a results, EMS has played a crucial role in SB in determining the best CP and BESS values. The obtained results of this work show the efficiency of the model in which by finding the optimal capacity of CP and BESS, the electricity bill improves by a 34% reduction.**

***Index Terms*—Energy Management System, Mixed Binary Linear Programming, Optimal value of Contract Power, Optimal Size of BESS, Renewable Energy, Smart Building**

I. Introduction

Recently, renewables energy generation (EV, solar and wind power, etc) has been rapidly developing due to high demand for energy and environmental crisis [1], [2]. Renewables energy sources have been playing the important role in the economy and performance of Smart Buildings (SB) and smart grids, especially, for largescale units of distributed generation [3], [4]. Moreover, developing the intelligent EMS has become the global goal to supply more sustainable energy for the smart grid. The EMS in SB intelligently manages and controls the power flow between the home power generation like PV, BESS, smart appliances of SB, external grid, and EVs.

There is rich literature in energy management methods for SB [5]. Many researchers are focused on using Mixed-Integer Linear Programming (MILP) to formulate SB problems. Often, the MILP formulation has been developed for two main reasons, either it is adopted for finding the optimal schedules for EMS or finding the optimal size of the component such as BESS capacity, CP size, etc. For instance, a MILP model for SB with a BESS, PV, EV is developed in ref. [6], in which for the more effective operation of SB, the shiftable loads for washing machine and dishwasher are considered. Ref. [7] proposed a MILP model that optimizes the schedule of day-ahead appliances based on peak-power limiting strategies and hourly pricing of demand response. Some studies are developed MILP models to consider the optimal size of BESS. In Ref. [8], an optimization model is suggested aiming to optimize the schedule of the charging and discharging process of BESS. In this model, a quadratic objective function consists of reducing the cost of energy, the substation transformer losses, and the cost of the life cycle of BESS. Convex programming is extended in Ref. [9] to optimize the power management strategy and sizes of the battery pack and fuel cell system. In Ref. [10], a convex programming optimization framework is presented for energy management of single SB and optimal size of BESS that the considered SB includes BESS, EV, and PV arrays. The CP size has a crucial role in the electricity bill. Then, reducing of the total cost in the SB requires to select the best CP capacity [11], [12]. However, few studies are explored the MILP model to find the value of contract power, which the majority of them are applied for industrial clients, which can be referred to in these references [12]–[15]. Other methods explore the possibilities of reduce electricity cost by transferring loads from high-demand to low-demand times by charging/discharging batteries of EVs and a BESS [16], [17]. In order to minimize the total electricity bill of SB, this work delivers the following key ideas: i: Considering a just one CP for the entire SB. ii: Considering the discharge process for EVs' battery and using the BESS in high demand time. iii: Considering the Energy Management System (EMS) for SB to manage the flow power between the EVs, PVs, apartments, common service, and external power grid. iv: Finding the optimal CP value and BESS capacity. In this regard, an MBLP model is presented such that its solution provides a plan for EMS to control the power among the components of SB by finding the optimal CP value and optimal size of BEES capacity. Also, the optimal charging/discharging schedule for BESS and EDVs is achieved in order to reduce the SB's over all cost.

The remainder chapters are organized as follows. The problem configuration and mathematical model of System for SB are presented in Section II. In section II-4, an MBLP is formulated to solve the energy management problem. Section III reports the optimization results. Finally, the conclusions of this work are summarized in Section IV.

II. Problem Configuration and Mathematical Model of System

1) Problem Configuration: Authors consider a residential collective Smart Building (SB) with J apartments and a common service where each apartment is equipped with a Photovoltaic (PV) and Electrical Vehicle (EV), and the whole building includes BESS and Energy Management System (EMS) as is illustrated in Figure 1. As it is shown in Figure 1, the EMS is communicated with external grids, EVs, PVs, BESS and apartment appliances, common services, and manages the power flow among them to reduce the cost of the building. Note that EMS is in connection with the grid and can provide power from the grid and also inject power to the grid. Here, a V2B considers that the battery of each EV is designed as a bidirectional embedded charger, such that their batteries allow both charges or discharge. Also, each EV enters and exists exactly once during the day and is plugged in as soon as arrives home. In this study, the power generated by PVs is managed and shared among apartments by EMS that is used for apartment demand, charging the batteries of EVs, and inject surplus power. Because each apartment in the traditional SB has its CP, their electricity bill is raised. A wrong or unsuitable CP was chosen by apartments, which it will add an extra charge on the electricity bill. In this regard, a single CP (Just EMS is connected to the grid) is considered for the whole building and the optimal value of CP capacity is determined. Moreover, the BESS is not considered in the original SB. So, finding the desired parameters of the BESS is an important task in this work as well. The SB was analyzed for a period of one year. It is presented a charging/discharging EVs schedule and BESS that minimize the energy total cost consumption from the external power network.

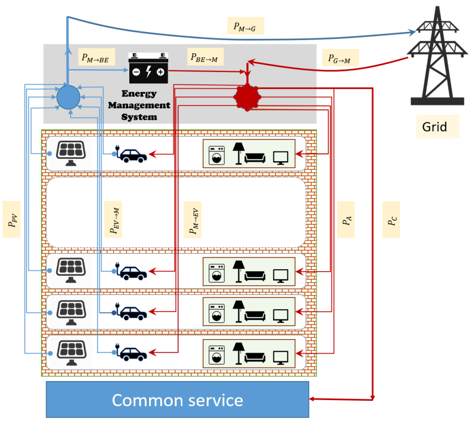

Fig. 1: Structure of the Residential SB with a BESS and EMS

2) Parameters and Variables: In this section, the required parameters, sets, and decision variables are declared. Considering that D is the number of days with duration τ, and let all time-steps in the considering time-period defined by I. And also, J is denoted as the number of apartments or EVs. Based on the problem structure in Section II-1, the required variables, parameters, and sets are defined in Table I, in which their descriptions are presented as well.

TABLE I: The List of Sets, Parameters and variable .

Set	Index	Description
$\mathbb{I}$	i	Time-step number's set
$\mathbb{J}$	j	Electrical Vehicle number's set
$\mathbb{D}$	d	Day number's set
Parameter	**Index**	**Description**
$P_{\text{A}}(i,j)$	$i \in \mathbb{I},\ j \in \mathbb{J}$	Total demand of apartment j in time i
$P_{\text{PV}}(i,j)$	$i \in \mathbb{I},\ j \in \mathbb{J}$	PV's generated power in apartment j in time i
$T^{\text{in}}_{\text{EV}}(d,j)$	$j \in \mathbb{J}$, $d \in \{0\} \cup \mathbb{D}$	For $d=0$, $T^{\text{in}}_{\text{EV}}(d,j)=1$ and $d \in \mathbb{D}$, $T^{\text{in}}_{\text{EV}}(d,j)$ is the number of times that EV enters
$T^{\text{out}}_{\text{EV}}(d,j)$	$j \in \mathbb{J}$, $d \in \mathbb{D} \cup \{D+1\}$	For $d \in \mathbb{D}$, it is the number of times that the EV leaves and for $d=D+1$, $T^{\text{out}}_{\text{EV}}(d,j)=I+1$
$S^{\max}_{\text{EV}}(j)$	$j \in \mathbb{J}$	Maximum SoC of jth EV
$S^{\text{initial}}_{\text{EV}}(d,j)$	$j \in \mathbb{J}$, $d \in \{0\} \cup \mathbb{D}$	Initial amount of j-th EV's SoC in $T^{\text{in}}_{\text{EV}}(d,j)$
$S^{\text{min\_out}}_{\text{EV}}(d,j)$	$j \in \mathbb{J}, d \in \mathbb{D}$	Minimum SoC for j-th EV in exit time
$P^{\text{ch}}_{\text{EV}}(j)$	$j \in \mathbb{J}$	Power charged by EV
$P^{\text{diss}}_{\text{EV}}(j)$	$j \in \mathbb{J}$	Power discharging by EV
$E^{\text{ch}}_{\text{EV}}(j)$	$j \in \mathbb{J}$	EV's charge efficiency for EV
$E^{\text{diss}}_{\text{EV}}(j)$	$j \in \mathbb{J}$	EV's discharge efficiency
$S^{\max}_{\text{BE}}$		Maximum value of the BESS's SoC
$S^{\text{initial}}_{\text{BE}}$		The initial value of the BESS's SoC
$S^{\min}_{\text{BE}}$		Minimum value of the BESS's SoC
$C^{\text{buy}}_{\text{G}}(i)$	$i \in \mathbb{I}$	Electricity cost from the grid in i
$C^{\text{sell}}_{\text{G}}(i)$	$i \in \mathbb{I}$	Selling electricity cost to the grid in i
$P^{\text{ch}}_{\text{BE}}(i)$	$i \in \mathbb{I}$	Power for charging of the BESS in i
$P^{\text{diss}}_{\text{BE}}(i)$	$i \in \mathbb{I}$	Power for discharging of BESS in i
C_{BE}		BESS Capacity
Variable	**Index**	**Description**
$\alpha_{\text{EV}}(i,j)$	$i \in \mathbb{I}, j \in \mathbb{J}$	Binary variable (EV is charging)
$\beta_{\text{EV}}(i,j)$	$i \in \mathbb{I}, j \in \mathbb{J}$	Binary variable (EV is discharging)
$\alpha_{\text{BE}}(i)$	$i \in \mathbb{I}$	Binary variable (BESS is charging)
$\beta_{\text{BE}}(i)$	$i \in \mathbb{I}$	Binary variable (BESS is discharging)
$S_{\text{EV}}(i,j)$	$i \in \mathbb{I}, j \in \mathbb{J}$	The j-th EV's SoC in initial $[T^{\text{in}}_{\text{EV}}, T^{\text{out}}_{\text{EV}}]$
$S_{\text{BE}}(i)$	$i \in \mathbb{I}$	the BESS's SoC in initial of i
CP		Contract Power Capacity
$P_{\text{M}\to\text{G}}(i)$	$i \in \mathbb{I}$	Power from EMS to grid (at time i)
$P_{\text{G}\to\text{M}}(i)$	$i \in \mathbb{I}$	Power from grid to EMS (at time i)
$P_{\text{M}\to\text{EV}}(i,j)$	$i \in \mathbb{I},\ j \in \mathbb{J}$	Power from EMS to j EV (at time i)
$P_{\text{EV}\to\text{M}}(i,j)$	$i \in \mathbb{I},\ j \in \mathbb{J}$	Power from j EV to EMS (at time i)
$P_{\text{M}\to\text{BE}}(i)$	$i \in \mathbb{I}$	Power from EMS to BESS (at time i)

That $\mathbb{I} = \{1,\ldots,I\}, \mathbb{J} = \{1,\ldots,J\}$ and $\mathbb{D} = \{1,\ldots,D\}$. To have a better understanding of the variables and parameters roles, Figure 2 is plotted. Note that the index of days is denoted by $d \in \mathbb{D}$ and $d=0$ and $d=D+1$ appear as an index in some variables and parameters in Table I. Indeed, the start and end of the time-period under consideration are defined by these indexes. In this regard, the arrival time-step is denoted by $d \in \mathbb{D}$, $T^{\text{in}}_{\text{EV}}(d,j)$ in day d, and the first and last time-steps are denoted by $T^{\text{in}}_{\text{EV}}(0,j)$ and $T^{\text{in}}_{\text{EV}}(D+1,j)$. Moreover, when EV j is outside in time-step i, so the value of $S_{\text{EV}}(i,j)$ must not be considered in the formulation. For sake of simplicity, the index $i \in \mathbb{I}$ has been considered for S_{EV} in Table I, but we will care about it in the objective function and constraints.

3) Mathematical Model of system: In this section, the system of the stated problem in Section II-1 is mathematically formulated. The power balance equation in each period $i \in \mathbb{I}$

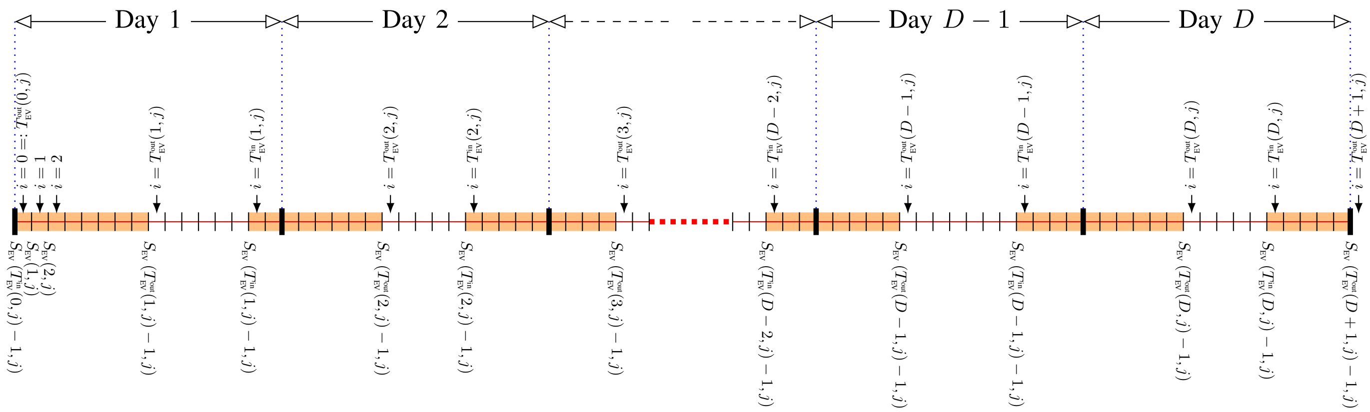

Fig. 2: Visualizing the exit and arrival times for j-th EV and the relevance parameters.

of the SB is considered by the following equation.

$$P_{\text{G}\to\text{M}}(i)+\sum_{j\in J}P_{\text{EV}\to\text{M}}(i,j)+\sum_{j\in J}P_{\text{PV}}(i,j)= \tag{1}$$

$$P_{\text{M}\to\text{G}}(i)+\sum_{j\in\mathbb{J}}P_{\text{A}}(i,j)+\sum_{j\in\mathbb{J}}P_{\text{M}\to\text{EV}}(i,j)+P_{\text{C}}(i),\quad i\in\mathbb{I}.$$

Equation (1) consists of the required power by EMS to meet each apartment's consumption, the EV's charging and the common services that are provided by the power generated by the PVs, EV's discharging, and external power grid. Moreover, the consuming power from the external grid and injected power from EMS to the grid are limited by bound constraints:

$$0\le P_{\text{G}\to\text{M}}(i)\le \text{ CP},\quad 0\le P_{\text{M}\to\text{G}}(i)\le \tfrac{1}{2}\text{CP},\quad i\in\mathbb{I}. \tag{2}$$

The capacity bound for j-th EV's battery is considered by:

$$0\le S_{\text{EV}}(i,j)\le S^{\text{max}}_{\text{EV}}(j),\quad i\in\mathbb{I},\quad j\in\mathbb{J}. \tag{3}$$

The power consumed from EMS to charge the j-th EV's battery is satisfied by following constraint .

$$0\le P_{\text{M}\to\text{EV}}(i,j)\le \alpha_{\text{EV}}(i,j)P^{\text{ch}}_{\text{EV}}(j)\tau,\quad i\in\mathbb{I},\quad j\in\mathbb{J}. \tag{4}$$

where, for $i\in\mathbb{I}$ and $j\in\mathbb{J}$, if $\alpha_{\text{EV}}(i,j)=1$, then EV charges by EMS at most $P^{\text{ch}}_{\text{EV}}(j)\tau$. Otherwise, if $\alpha_{\text{EV}}(i,j)=0$, then j-th EV does not charge by EMS and $P_{\text{M}\to\text{EV}}(i,j)=0$. Similarly, the following limits are considered for discharging EVs.

$$0\le P_{\text{EV}\to\text{M}}(i,j)\le \beta_{\text{EV}}(i,j)P^{\text{diss}}_{\text{EV}}(j)\tau,\quad i\in\mathbb{I},\quad j\in\mathbb{J}. \tag{5}$$

The EVs battery dynamics are formulated by the equations (6)-(7) that show the SoC of EVs update in each time-step based on the charging and discharging process.

$$S_{\text{EV}}(i+1,j)=S_{\text{EV}}(i,j)+\left[P_{\text{M}\to\text{EV}}(i,j)E^{\text{ch}}_{\text{EV}}-P_{\text{EV}\to\text{M}}(i,j)/E^{\text{diss}}_{\text{EV}}\right],$$

$$d\in\{0\}\cup\mathbb{D}, i=T^{\text{in}}_{\text{EV}}(d,j)-1,\ldots,T^{\text{out}}_{\text{EV}}(d+1,j)-2, \tag{6}$$

$$S_{\text{EV}}(T^{\text{in}}_{\text{EV}}((d,j)-1),j)=S^{\text{initial}}_{\text{EV}}(d,j), j\in\mathbb{J}, d\in\{0\}\cup\mathbb{D}. \tag{7}$$

Note that the value of arrival time $T^{\text{in}}_{\text{EV}}(d,j)$ and the initial charge of j-th EV $S^{\text{initial}}_{\text{EV}}(d,j)$ are known.

The constraints (8) ensure the minimum allowable SoC of EV at the departure time:

$$S_{\text{EV}}(T^{\text{out}}_{\text{EV}}(d,j)-1,j)\ge S^{\text{min\_out}}_{\text{EV}}(j),\quad j\in\mathbb{J},\quad d\in\mathbb{D} \tag{8}$$

In day $d\in\mathbb{D}$ and in $i=T^{\text{out}}_{\text{EV}}(i,j),\ldots,T^{\text{in}}_{\text{EV}}(i,j)-1$ time-steps , EV j is out of the parking. Accordingly, the following constraints are considered:

$$S_{\text{EV}}(i,j)=0, j\in\mathbb{J}, d\in\mathbb{D}, i=T^{\text{out}}_{\text{EV}}(d,j),\ldots,T^{\text{in}}_{\text{EV}}((d+1,j)-2 \tag{9}$$

The constraints 10 ensure that EVs charging and discharging do not take place at the same time:

$$\alpha_{\text{EV}}(i,j)+\beta_{\text{EV}}(i,j)\le 1,\quad i\in\mathbb{I},\quad j\in\mathbb{J}. \tag{10}$$

Likewise, the dynamic of BESS and power within allowable bounds are depicted by:

$$S_{\text{BE}}(i+1)=S_{\text{BE}}(i)+\left[P_{\text{M}\to\text{BE}}(i)E^{\text{ch}}_{\text{BE}}-P_{\text{BE}\to\text{M}}(i)/E^{\text{diss}}_{\text{BE}}\right], \tag{11}$$

$$S_{\text{BE}}(0)=S^{\text{initial}}_{\text{BE}}, \tag{12}$$

$$S^{\text{min}}_{\text{BE}}C_{BE}\le S_{\text{BE}}(i)\le S^{\text{max}}_{\text{BE}}C_{BE},\qquad i\in\mathbb{I}, \tag{13}$$

$$0\le P_{\text{M}\to\text{BE}}(i)\le \alpha_{\text{BE}}(i)P^{\text{ch}}_{\text{BE}}\tau,\qquad i\in\mathbb{I}, \tag{14}$$

$$0\le P_{\text{BE}\to\text{M}}(i,j)\le \beta_{\text{BE}}(i,j)P^{\text{diss}}_{\text{BE}}(j)\tau,\qquad i\in\mathbb{I}, \tag{15}$$

$$\alpha_{\text{BE}}(i)+\beta_{\text{BE}}(i)\le 1,\qquad i\in\mathbb{I}. \tag{16}$$

Here, the equations (11) presents the updated SoC of BESS with the initial value (12) in each time slot. Constraints (13)-(15) are necessary to assure the BESS physical limits.

4) Optimization problem: The following section presents an MBLP to solve the energy management problem that is modeled as:

$$\textbf{Minimize}\quad \mathcal{J}(\mathbf{z}), \tag{17}$$

$$\textbf{Subject to:}\quad \mathbf{g}(\mathbf{z})=0, \tag{18}$$

$$\mathbf{h}(\mathbf{z})=0, \tag{19}$$

$$\mathbf{z}\in\mathbb{R}\cup\{0,1\}. \tag{20}$$

The decision variables $\mathbf{z}$ in consider SB II-1 are represented in Table I. Whereas, the inequality constraints $\mathbf{g}(\mathbf{z})$ in the defined SB in II-1 are grid limits (2), capacity bounds of EV and BESS (3), (8) and, (13), charging and discharging bounds of EV and BESS (4), (5), (14) and, (15) and also inequality constraints (10) and (16) are considered. While, the equality constrain $\mathbf{h}(\mathbf{z})$ is SB power balance (1), the dynamics of EVs battery and, BESS battery (6), (7), (11) and, (12).

The objective function $\mathcal{J}(\mathbf{z})$ in this paper minimize the electricity cost of the whole SB by considering the BESS costs to find the optimal value of CP capacity:

$$\mathcal{J}(\mathbf{z}) = c_c \text{CP} + EC(\mathbf{z}) + c_b C_{BE}. \quad (21)$$

where c_c is the CP price and c_b is the BESS price. Moreover, $EC(\mathbf{z})$ is the total electricity cost of SB that consists of the difference between the electrical energy that is purchased from the power grid and the electricity amount that is sold (injected) to the power grid.

$$EC(\mathbf{z}) = \sum_{i \in \mathbb{I}} C_{\text{G}}^{\text{buy}}(i) P_{\text{G}\to\text{M}}(i) - \sum_{i \in \mathbb{I}} C_{\text{G}}^{\text{sell}}(i) P_{\text{M}\to\text{G}}(i).$$

III. Results and Discussion

The proposed MILP is analyzed for finding the optimal CP and BESS capacity by considering the EMS. The key parameter's values are listed in Table II:

TABLE II: Parameters Value of the Considering SB.

Parameter	Value	Unit	Parameter	Value	Unit
D	365	day	$S_{\text{EV}}^{\text{max}}$	27.2	kWh
$S_{\text{BE}}^{\text{initial}}$	0	kWh	$P_{\text{EV}}^{\text{ch}}$	3.7	kWh
J	15	Apartments(EV)	$P_{\text{EV}}^{\text{diss}}$	3.3	kWh
$C_{\text{G}}^{\text{buy}}(i)$	1.24	EUR	$E_{\text{EV}}^{\text{ch}}$	0.92	
$C_{\text{G}}^{\text{sell}}(i)$	0.93	EUR	$E_{\text{EV}}^{\text{diss}}$	0.93	

In the considered building, six apartments have contract power with 6.9 kVA, another six apartments have 10.35 kVA, and the rest have 13.8 kVA. Each apartment has one EV that all EVs have the same battery capacity. Moreover, Each apartment has one 3.6 kWp PV system. The value of the model's parameters are recorded for every 15 minutes in witch some recorded data were missed that a regression approach and adjacent interpolation method were applied to fill them [18]. In this case study, the time slot, as mentioned, is one year with duration $\tau = 15$ minutes. So, each day splits into $24 \times 4 = 96$ time-steps, then, the time-period has $I = 96 * 365 = 35040$ time-steps. Moreover, we use the annual time-of-use tariff of Portugal (Bi-hourly tariff) that the details can be found in $https://www.erse.pt$. At the arrival time $S_{\text{EV}}^{\text{initial}}(j)$, the initial SoC of EVs is randomly determined.

1) Experiment 1: finding optimal characteristics of the BESS : As mentioned in the problem configuration II-1, in order to improve the total cost of the residential building, the BESS is used. In this section, some results are provided for EMS of SB to choose the optimal characteristics of the BESS. First, we consider that the EMS has a CP with 41.4 kVA value. Now, the proposed model II-4 is solved for various sizes of BESS and shows their impacts on the total cost of SB. In Figure 3, the electricity bill of SB for various sizes and charge/discharge rates of BESS is plotted for one year. Based on our results in figure 3, the SB does not need a BESS with high capacity. As we see, if the charging and discharging times of BESS are 1 and 0.9 hours, respectively, the BESS capacity of 40 kWh is optimal for considering SB. Moreover, if charging and discharging time is 4 and 3.6 hours, then a capacity of 50 kWh is optimal too.

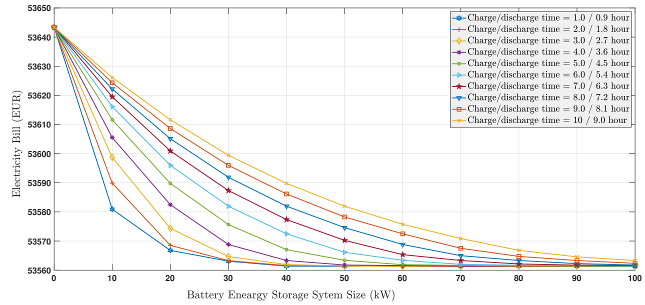

Fig. 3: The Electricity Bill of SB for various values of BESS

2) Experiment 2: Finding Optimal Contract Power value: Now, by considering the optimal capacity of BESS 40 kWh, the optimal CP capacity is obtained for SB by applying the proposed MBLP II-4. For this purpose, model II-4 is solved for various values of CP size. We solve model II-4 for six existing standard choices of CP capacity. Figure 4 and Table III show the obtained results of the electricity bill and the max load consumption. The achieved result in Figure 4 and

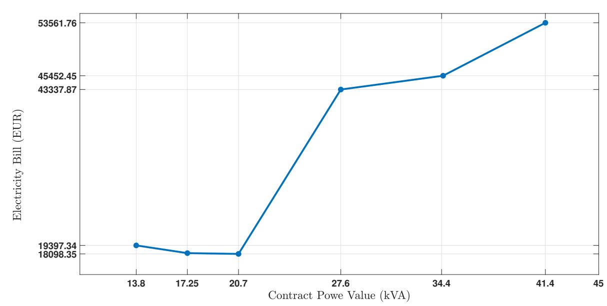

Fig. 4: The Electricity Bill of SB for various values of CP

Table III show that the optimal CP capacity for considering SB with optimal capacity od BESS $C_{BE} = 40$ kWh is obtained $CP = 20.7$ kVA. The obtain results such as power among grid, apartments, common service, PVs, EVs, and BESS in SB corresponding of $CP = 20.7$ kVA is plotted in Figure 5.

TABLE III: The Annual Total Cost and Energy For SB.

CP Value (kVA)	Total Cost (EUR)	Max Peak Load (KWh)
13.8	19397.34	13.80
17.25	18176.35	17.25
20.70	**18098.35**	**20.70**
27.60	43337.87	24.31
34.50	45452.45	24.92
41.40	53561.76	25.24

The influence of BESS in the objective function (electricity bill) is depicted in Figure 5. This Figure shows that the storage system saves the extra power during the times of low demand and use it at the high demand time. Note that, thanks to more efficiency of the proposed model MBLP the CP value is reduced from $CP = 41.4$ kVA in to $CP = 20.7$ kVA. Moreover, the total cost of the building had a significant reduction from 53561.76 EUR to 18098.35 EUR. In other words, the obtained

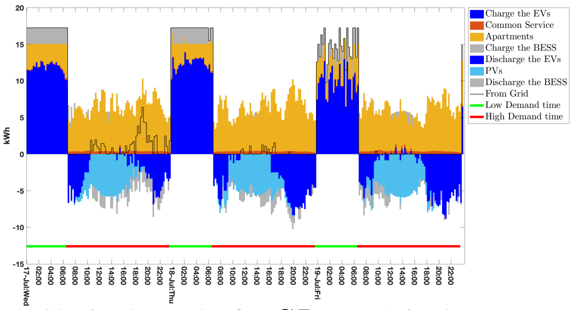

Fig. 5: Obtained Results for $CP = 20.7$ in three sunny days

results indicate that considering the optimal value for CP and BESS leads to a 34% reduction in the electricity bill of SB.

IV. Conclusion

The main aim of paper was analyzing of component size effects on the total cost of SB. In this regard, an MBLP was proposed to minimize the total electricity cost of a residential collective SB. The electricity energy consuming of the SB includes CP capacity cost and energy consumption cost from the external grid and, BESS cost. Some ideas are considered to improve the cost of considering building. First, a flexible CP was assumed for each apartment and the whole building equipped with a single CP. Furthermore, the electrical vehicle's charging and discharging processes, as well as BESS, were considered to reduce the electrical energy cost. The EMS was considered to control the flow of electricity between EVs, PVs, apartments, common service, and the grid to minimize electricity costs. The results show that the proposed MBLP successfully optimizes EMS for scheduling of charging/discharging of EVs and BESS. Furthermore, the total electricity cost of the SB had a 34% reduction due to determining the optimal CP and BESS

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