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Research Paper

Economical Modeling for Managing the Power Transaction of EVs and Power Market in Smart Parking Lots

F. Askari*(C.A.) and A. Khoshkholgh**

Abstract: The battery of electric vehicles (EV) can be charged from the power grid or discharged back to it. Parking lots can aggregate hundreds of EVs which makes them a significant and flexible load/generation component in the grid. In a smart grid environment, the smart parking lot (SPL) can benefit from the situation of the simultaneous connection to the EVs and power grid. This paper proposes a new algorithm to maximize SPL profit from participation in the forward and spot markets. Monte-Carlo simulation is used to determine the participation of the SPL in the forward market. Then an economic model is proposed to optimize the charging or discharging time table of EVs at any hours of a day and SPL participation in the spot market in a way that maximum SPL profit and satisfaction of EV owners can be gained. The Genetic Algorithm (GA) is used to solve this optimization problem.

Keywords: Genetic Algorithm, Profit Maximization, Smart Parking Lot, EV, Power Market.

1 Introduction

DURING recent years, increasing of fossil fuels price and their usage environmental concerns, have convinced the authorities of the developed countries to consider green technologies as serious alternative energy resources [1].

According to the International Energy Agency report 2020, about 24% of direct CO2 emissions is due to fuel combustion [2]. Therefore high energy consumption of transportation systems and environmental concerns causes new developments of the green technologies in this field to be unavoidable. The most widespread use of green technologies in transportation systems are electrical vehicles, including battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCV) [3, 4].

The charging process of EVs can be done by connecting them to the power grid using the usual plug-ins [5], this charging mode is known as grid to vehicle (G2V) [6]. By modifying the power electronic circuits of these vehicles, they will be able to transfer stored electricity in their batteries back to the grid [7], the discharging mode is called vehicle to grid (V2G).

Consequently, EVs can store electricity in their batteries for transportation or feeding the power grid [8]. So, these EVs can be considered as active components in smart grids [9, 10].

The effect of a single EV on the power grid is approximately an ignorable noise due to the low storage capacity of each EV, mostly between 12.5 and 60 kWh. So, it is necessary to aggregate EVs together to have a significant and flexible load/generation role in the power grid [11]. Hence planning and operation of EV integration is both a challenge and an opportunity for smart power systems [12], that can be done by the smart parking lot (SPL) equipped with plug-in facilities or aggregators which have the ability to cumulate hundreds of EVs and, at the same time, connect them to the grid [13].

The aggregated EVs can be used for different proposes in a smart grid-like managing load fluctuation,

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* The author is with the Department of Electrical Engineering, Faculty of Jabarian, Hamedan Branch, Technical and Vocational University (TVU), Hamedan. Iran.
E-mail: faskari@tvu.ac.ir.
** The author is graduated from the Faculty of Electrical and Computer Engineering, Tarbiat Modares University (TMU), Tehran, Iran.
E-mail: a_dashtak@yahoo.com.
Corresponding Author: F. Askari.
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improving system flexibility, peak load shaving, increasing reliability, frequency regulation, and other ancillary services [14-17]. Also [18] shows the influence of electric vehicles on power quality.

During the last decade, studies about EV parking lots have been increasing quickly. In [19, 20] the impact of the EV PLs on the distribution system reliability has been studied. Economic models for maximizing the profits of aggregators, utility, and parking lots are proposed in [7], [21-24]. Reference [25] proposed a parking lot recharge scheduling (PLRE) system for recharging EVs considering the mobility/parking patterns of these vehicles with regard to two objectives: maximizing the total parking lot revenue and maximizing the total number of EVs fulfilling their requirements. In [26], parked EVs in streets are used as decentralized reactive power sources. Authors in [27] have studied the allocation of PLs in a distribution network, they have just addressed the technical aspects of the problem and the economic concerns have not been covered. In [28], a method to optimize the allocation of EV parking lots to minimize system costs including power loss, network reliability, and voltage deviations is proposed. In fact, it has both technical and economic points of view. In [29], with the aim of maximizing the distribution system profit, a simple scheduling model for the optimal charge/discharge of EVs for optimum allocation of PL using probabilistic approach is proposed. Sengor *et al*. [30] proposed an EV parking lot energy management to schedule the charging/discharging EVs to participation in peak load reduction based DR program. In this work, a stochastic approach is used to consider the state of charge and arrival and departure times of EVs.

A two-stage two-level model is proposed to investigate the mutual impacts of the behavior of PLs and renewable-based distribution systems in [31]. In this model, made decisions at the first level, should be considered in the optimization of the second level. The objective function at the first level is maximizing the profit of the PLs, while the second level aims to minimize the distribution system operator's costs.

In [12], seasonal impacts on the arrival/departure pattern of EVs on the storage capacity of PL is modeled. The storage capacity was determined by sequential Monte-Carlo simulations using real car arrival/departure data provided by the PL authority of Istanbul.

In none of these works, the forward and spot markets are not considered simultaneously.

None of these studies has modeled both forward and spot markets. This paper aims to maximize the profit of SPL while the parking participates in both of them.

In a smart grid environment the SPL can benefit from the situation of the simultaneous connection to the EVs and power grid; Once by selling the electricity to the EVs and also, by using the vehicle batteries as energy storages to participate in the spot market, so the SPL needs to be equipped with V2G and G2V facilities. Besides, as a retailer who provides the EVs power, the SPL should predict its load beforehand in order to have reasonable participation in the forward market.

This paper first proposes a new algorithm to estimate the load of SPL to determine its participation in the forward market. Then an economic model is developed to maximize the SPL profit, as a retailer and service provider, due to its power transactions by the EVs and spot market.

The rest of this paper is organized as follows. The proposed method is described in Section 2. In Section 3, the utilization of Monte-Carlo simulation in the prediction of the SPL daily load profile is described based on historical data. This predicted load profile and the market price curves are employed to determine the participation of the SPL in the forward market. An optimization problem, to maximize the profit of SPL, is developed in this section to find the charging/discharging time table of EVs and participation of SPL in the spot market considering the satisfaction of EVs owners. Section 4 explains the method of solving the developed optimization problem. The proposed method is employed on an SPL with a specified capacity and the results are presented in Section 5. Finally, Section 6 is dedicated to the conclusion.

2 Proposed Method

The bidirectional power transaction possibility of EVs, the SPL, and the grid enables the parking to act either as a load or generation source in the grid. So the SPL can profit from this situation by simultaneous buying and selling of energy to EVs and the power market. A part of SPL profit is due to its role as a retailer or the difference between buying and selling prices of power. Besides the SPL can store electrical energy in the battery of vehicles during off-peak and sell it at peak price. This can affect the batteries' lifetime, therefore the SPL should share the gained benefit with EV owners to compensate their detriment of batteries aging. So the SPL should satisfy the EV owners during their presence time by:

a) providing their requested charge,
b) charging the EVs at least possible cost,
c) buying their energy during peak price,
d) sharing the profits of using the capacity of batteries as storage recourses.

Fig. 1 shows the flowchart of the proposed method. First of all, the number of the parked vehicle in SPL during 24 hours are determined by historical data, which is called Vehicle present curve (VPC).

The SPL participates in both forward and spot markets. The participation of SPL in the forward market is determined based on the estimated load which is extractable from SPL historical data of vehicle presence in the parking. Then, this historical data and the price curve of the spot market are used to find the charging and discharging timetable of EVs during the day in direction of paper objectives. In this process following assumptions are considered for the power market:

a) all calculations are done on the previous day of the desirable day;
b) the price curve of the forward market is given;
c) the price curve of the spot market is predictable in different probable scenarios. Considering that the prediction of the spot market is a day-ahead prediction, such an assumption would be reasonable for this study.

3 Mathematical Model

The SPL, as a retailer, provides the demanded energy of EVs from the forward and spot power market. The SPL can profit from buying its cheaper energy from the forward market to provide its demand. The SPL estimates its required demand based on the VPC which is depended on some factors like the capacity of SPL, its location, and time of year. A typical VPC is shown in Fig. 2.

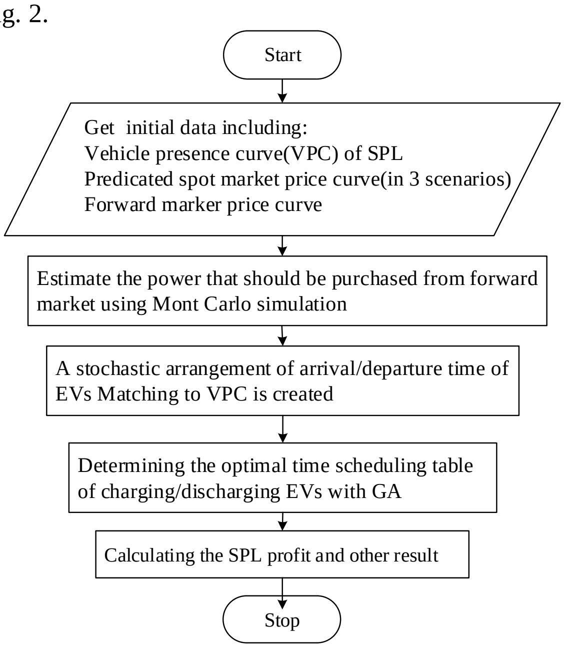

Fig. 1 The process of the proposed method.

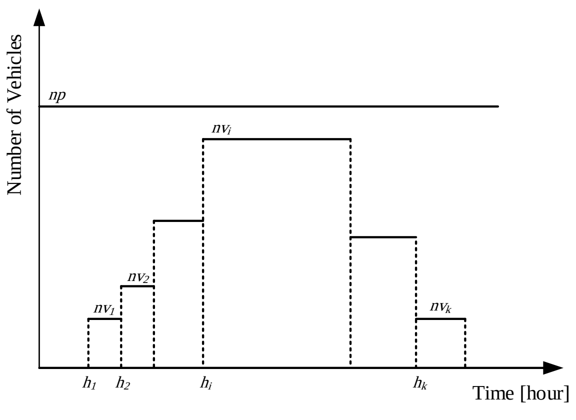

Fig. 2 The number of parked vehicles in SPL for 24 hours (VPC).

Based on this curve; different arrangements of arrival and departure time of Vehicles with different demands can form a certain VPC. Because the fact exact arrival/departure pattern of EVs is not available while participating in the forward market, a load estimation based on VPC should be run. Monte-Carlo simulation is applied to estimate the load and the level of participation in the forward market. For the Monte-Carlo simulation, the arrival and departure time of EVs are stochastically selected in a way that in each hour the number of the parked vehicles in SPL is equal to the corresponding value of VPC. The required duration of charging of each EV is also set as a stochastic value. The forward market price for 24 hours of the next day is determined, also the scenarios for spot market prices during the same time are predicted. Fig. 3 shows the process of the Monte-Carlo simulation.

The EVs would be scheduled to be charged in the least price periods of both markets. So, during the EVs presence time, in each hour the expected price of the spot market and forward market are compared and the lower price is selected to form a new price curve. Hourly intervals of the simulations are considered due to the market data given in [32]. The SPL provides the required energy of each EV in off-peak of this new price curve during its presence time in parking. This results in two load curves for each EV, one of them for the forward market and the other for the spot market. Therefore, for a special arrangement of EVs, the summation of all determined forward load curves of EVs gives the power that should be bought from the forward power market in each hour.

Producing new arrangement of arrival and departure

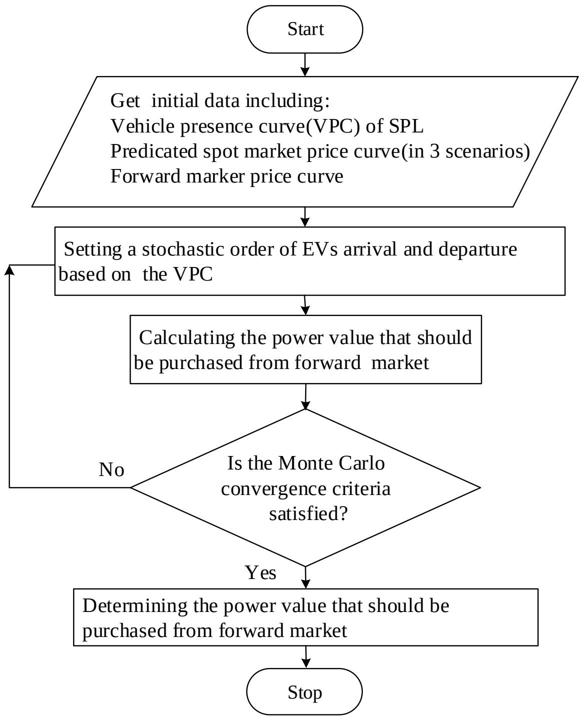

Fig. 3 Load estimation algorithm based on Monte-Carlo simulation.

time of EVs and the estimating of the power demand continues to satisfy the convergence criteria (Eq. (1)) of Monte-Carlo. The final estimated load curve is determined based on the average of calculated corresponding values for each hour in the produced arrangement.

$$\frac{\sigma(x)}{\sqrt{n}\times E(x)}<\varepsilon \tag{1}$$

where, x is the purchasing power from the forward market in each hour of a day (a 1×24 matrix), $\sigma(x)$ is the variance vector (a 1×24 matrix) of x, $E(x)$ is the expected value vector (a 1×24 matrix) of x, n is the number of iteration.

For EVs charging/discharging management, the SPL requires to know their presence time table and their initial and final state of charge (SoC), which is the amount of stored energy in the battery [33]. The presence time table of each EV includes the time schedule of its arrival and departure time and is calculable based on VPC. It is assumed that each vehicle declares its initial and final desired SoC at the arrival time. An optimization problem is developed in this section for the management of EVs charging/discharging time table to maximize the profit of SPL.

The block diagram of the power transactions between the power market, parking lot, and EVs is shown in Fig. 4. In this figure $P_{BF}(h)$ is the bought power from the forward market by SPL at hour h of the day, $P_{BSp}(h)$ is the power that the SPL buys from the spot market at hour h of the day, $P_{SSp}(h)$ is the power that the SPL sells to spot market at hour h of the day, $P_{BEV}(i,h)$ is the power that the SPL buys from the ith EV at the hour h of the day, $P_{SEV}(i,h)$ is the power that the SPL sells to the ith EV at the hour h of the day, $P_{BAT}(i)$ is the power that the battery of the ith EV can exchange through the converter.

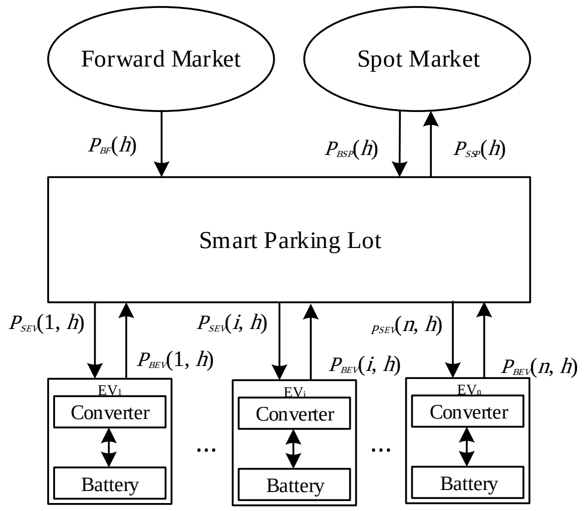

Fig. 4 Block diagram of power transaction between the power markets, SPL & EVs.

The charging efficiency of converter is η_c and its discharging efficiency is η_d. The power transaction between EV and the SPL is defined by (2) and (3).

$$P_{SEV}(i,h)=\operatorname{sgn}\big(s(i,h)\big)\times\big(P_{BAT}(i)/\eta_c(i)\big) \tag{2}$$

$$P_{BEV}(i,h)=\operatorname{sgn}\big(-s(i,h)\big)\times\big(P_{BAT}(i)\times\eta_d(i)\big) \tag{3}$$

where, sgn(x) is the sign function and $s(i,h)$ shows the status of charging or discharging of each EV at hour h.

$$s(i,h)=\begin{cases}+1 & \text{If EV is charging}\\ -1 & \text{If EV is discharging}\\ 0 & \text{If EV is not connected to the SPL}\end{cases} \tag{4}$$

The state of charging or discharging of all EVs ($s(i,h)$) must be determined during the day. These values are used to form a matrix named S. This matrix would be the decision variable of the optimization problem. S is an n×24 matrix that expresses the state of n number of EVs for 24 hours a day.

Total received power from all vehicles, $P_G(h)$, and total transferred power to them, $P_L(h)$, at time h, are calculated by (5) and (6):

$$P_G(h)=\sum_{i=1}^{n}P_{BEV}(i,h) \tag{5}$$

$$P_L(h)=\sum_{i=1}^{n}P_{SEV}(i,h) \tag{6}$$

If $P_G > P_L$, the SPL acts as a generation source, otherwise it would be a load. Based on the amount of bought energy from the forward market and the difference between P_G and P_L, the exchange power between the SPL and spot market is:

$$P_{net}(h)=P_G(h)-P_L(h)+P_{BF}(h) \tag{7}$$

If $P_{net} > 0$, the SPL can sell electric power to the spot market, P_{SSp}; and if $P_{net} <0$, it buys the required power from the spot market, P_{BSp}.

$$P_{SSp}(h)=\operatorname{sgn}\big(P_{net}(h)\big)\times P_{net}(h) \tag{8}$$

$$P_{BSp}(h)=\operatorname{sgn}\big(-P_{net}(h)\big)\times\big(-P_{net}(h)\big) \tag{9}$$

3.1 Objective Function

The objective of this study is to maximize the profit of the SPL. To calculate this profit, the costs and incomes of the SPL due to energy trading should be determined. It is assumed that these price curves are available:
Pr_{BF}: the price curve of the forward market,
Pr_{Sp}: the price curve of the spot market,
Pr_{BV}: the price curve of buying electricity from vehicles,
Pr_{SV}: the price curve of selling electricity to vehicles.
Based on these price curves and the calculated power that should be provided from forward and spot market,

the total cost of buying electricity from the forward and spot markets, C_{BM}, and the total income from selling electricity to spot market, C_{SM}, obtain from (10) and (11).

$$C_{BM} = \sum_{h=1}^{24} P_{BSp}(h)\times P_{rSP}(h) + P_{BF}(h)\times P_{rBF}(h) \quad (10)$$

$$C_{SM} = \sum_{h=1}^{24} P_{SSp}(h)\times P_{rSP}(h) \quad (11)$$

Alongside participation in the power market, the SPL can profit from optimum scheduling of EVs charging/discharging table. The presence duration of EVs and their demand are important factors to find such a time scheduling table. The duration of charging/discharging of any parked EV, $t_s(i)$, depends on its initial SoC at arrival time, h_i, and its requested final SoC at departure time $t_o(i)$, h_O (12).

$$h_c(i) = \frac{\left|SoC_o(i) - SoC_i(i)\right|}{P_{BAT}(i)/E_t(i)} \quad (12)$$

where, $SoC_i(i)$ is the SoC of ith EV at arrival time, $SoC_O(i)$ is the desired SoC of i-th EV at departure time, and $E_t(i)$ is the total battery capacity of i-th EV.

As mentioned above, to satisfy EV owners the charging and discharging schedule should be in a way that the SPL sells electricity at the lowest and buy it at the highest prices. So, during the presence time, the buying and selling price curves are sorted in descending and ascending order, respectively, as (13) and (14). Then, the total cost of buying electricity from i-th EV, C_{BV}, and the total income from selling electricity to them, $C_{SV}(i)$, are calculated by (15) and (16).

$$Pr_{SV}^{as}(i,h) = \mathrm{sort}\left(Pr_{SV}(h)\right)\Big|_{h=h_i(i)}^{h=h_o(i)} \quad (13)$$

$$Pr_{BV}^{ds}(i,h) = \mathrm{sort}\left(Pr_{BV}(h)\right)\Big|_{h=h_i(i)}^{h=h_o(i)} \quad (14)$$

$$C_{SV}(i) = \mathrm{sgn}\left(SoC_o(i) - SoC_i(i)\right)\times \frac{P_{BAT}(i)}{\eta_c(i)} \times \sum_{h=1}^{h_c(i)} Pr_{SV}^{as}(i,h) \quad (15)$$

$$C_{BV}(i) = \mathrm{sgn}\left(SoC_i(i) - SoC_o(i)\right)\times P_{BAT} \times \eta_d(i) \times \sum_{h=1}^{h_c(i)} Pr_{BV}^{ds}(i,h) \quad (16)$$

and so, the net profit of the SPL is:

$$profit = \left[C_{SM} - C_{BM}\right] + \sum_{i=1}^{n}\left[C_{SV}(i) - C_{BV}(i)\right] \quad (17)$$

3.2 Constrains

At the arrival time, each of EVs declares to the SPL its duration of presence and the desired final SoC. The SPL should provide the requested demand before leave it. So, as the first constrain, at any hour of the day the SPL should check that the leaving EV is gotten its desired SoC.

$$SoC\left(i, h_o(i)\right) = SoC_o(i) \quad (18)$$

Also, the SPL should consider the capacity limits of battery vehicles. In other words, the SoC of each vehicle should not exceed its practical limits. Thus the second constrain would be:

$$SoC_{\min}(i) < SoC(i,h) < 100\% \quad (19)$$

$SoC_{min}(i)$ of each EV depends on its battery construction and technology [34].

The SoC of each battery at any hour of the day is calculated by adding the initial SoC and its power transactions:

$$SoC(i,h) = SoC_i(i) + \sum_{i=1}^{t} \frac{P_{SEV}(i,h)\times\eta_c - P_{BEV}(i,h)/\eta_d}{E_t(i)} \times 100 \quad (20)$$

So, the optimization problem and its constraints would be as follow:

$$\begin{aligned} \text{Max } profit &= \left[C_{SM} - C_{BM}\right] + \sum_{i=1}^{n}\left[C_{SV}(i) - C_{BV}(i)\right] \\ \text{st. } & SoC_{min}(i) < Soc(i,h) < 100\% \\ & SoC\left(i, h_o(i)\right) = SoC_o(i) \end{aligned} \quad (21)$$

4 Optimization Method

Genetic algorithm (GA) is used in this paper as the optimization method. GA starts with a population of candidate solutions chosen randomly within the feasible range, encoded in a string of genes that forms chromosomes [25, 26]. It is a sequential random search method to find the optimized solution of a multi-variable problem. Each answer named chromosome is a string of genes. A gene represents a single variable in answer.

A chromosome made by random values makes a fitness value and a population of random chromosomes makes a set of fitness values. This is the first generation. Selecting some of the best answers (which make best fitness values) helps to make a new generation of the population.

The new population uses the crossover method to construct its chromosomes based on selected chromosomes of the previous generation. It means that a child (new) chromosome inherits some genes from its father chromosome and other genes from its mother chromosome. If any errors occur during the copying process, it will be a mutation.

After constructing the new generation using crossover and mutation methods, selecting of the best-fitted set can be accomplished. This process will be sequentially repeated until the best answer in any generation converges.

The fitness function is the benefit gained from a parking lot during a day. As the GA is usually used in minimization application, in this study the fitness function is considered as the inverse of the optimization function (21).

The charging/discharging state of each vehicle during an hour is a gene, and the states of each vehicle during all hours a day makes the corresponding chromosome of considered vehicle. Each gene can have three different values as mentioned before in (4). Fig. 5 shows a sample of the chromosome of this optimization problem. In this problem, there are *n* vehicles. The decision variables are set as the matrix of Fig. 5. The demanded power of SPL at any hour can be calculated. Consequently, the difference between this power and purchasing power from the forward market gives the amount of power wish should be the trade spot market.

5 Case Study

In this section, the proposed method is employed to maximize the profit of an SPL in real condition circumstances. Sensitivity analysis is used to evaluate the influence of different parameters variation on the method. For that, the profit of the considered parking lot is investigated in different conditions including variation of VPC, occurrence possibility of different scenarios of the spot price curve, battery capacity, and charging/discharging efficiency.

The considered SPL in this study is an on-street parking lot. It is assumed that the SPL has 50 parking spaces which it has bidirectional power transaction by EVs facilities. The required data of this SPL is determined based on real data of a parking lot located in the Livermore, California [35]. The VPCs of different days of the week are available. Figs. 6 and 7 show the VPCs of a weekday and weekend. The parameters of vehicles such as initial and final desired SoC and the battery charging/discharging efficiencies are considered to be in given restricts in Table 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	+1	+1	+1	+1	-1	+1	+1	0	0	0	-1	-1	-1	-1	0
2	0	0	0	0	0	0	0	0	+1	+1	+1	+1	-1	-1	+1	0	0	0	0	-1	0	0	0	0
3	0	0	0	0	0	0	0	-1	+1	+1	+1	+1	+1	+1	-1	0	0	0	0	0	0	0	0	0
...	0	0	0	0	0	0	0	+1	+1	+1	-1	+1	+1	-1	+1	+1	0	0	0	-1	0	0	0	0
n	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	-1	-1	-1	0	-1	-1	0	+1	+1	0	0	0

Fig. 5 Chromosome constructed for n vehicles for the optimization problem.

Table 1 Vehicle parameters, [7, 36].

Parameter	Minimum Value	Maximum Value
Battery Capacity [kWh]	15	30
SoC_o [%]	40	100
SoC_i [%]	20	100
Battery Discharge Eff, η_d [%]	80	95
Battery charge Eff, η_c [%]	80	95

As it is mentioned beforehand, the SPL participates in both forward and spot markets. The price curve of the forward market is shown in Fig. 8. The price curve of the spot market is predicted in three probabilistic scenarios, Fig. 9. The probabilities of occurrence of A, B, and C scenarios are 0.05, 0.9, and 0.05, respectively. The price curves of buying and selling energy to the EVs are illustrated in Fig. 10.

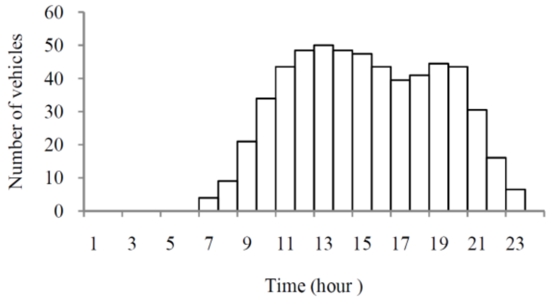

Fig. 6 The VPC of a weekday.

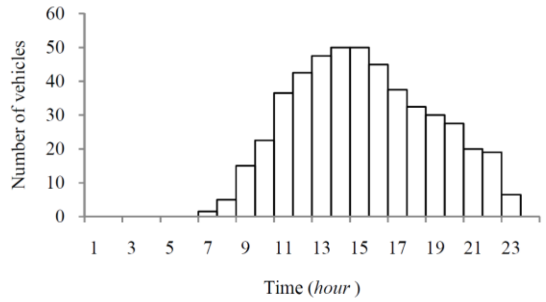

Fig. 7 The VPC of a weekend.

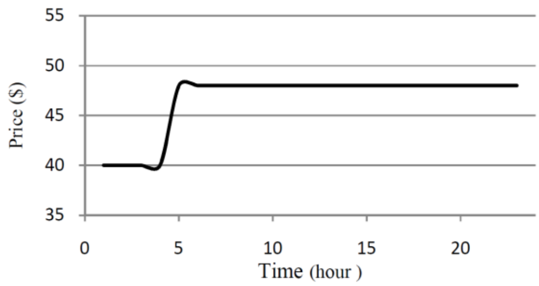

Fig. 8 The price curves of the forward power market.

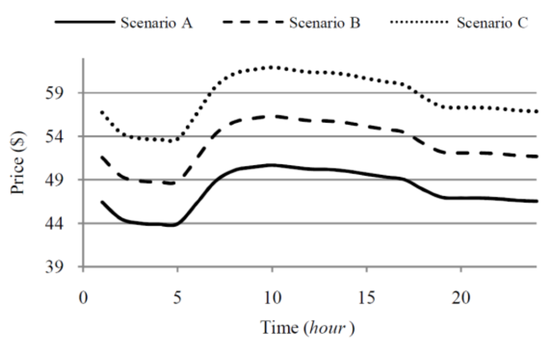

Fig. 9 The price curves of spot power market in 3 different scenarios.

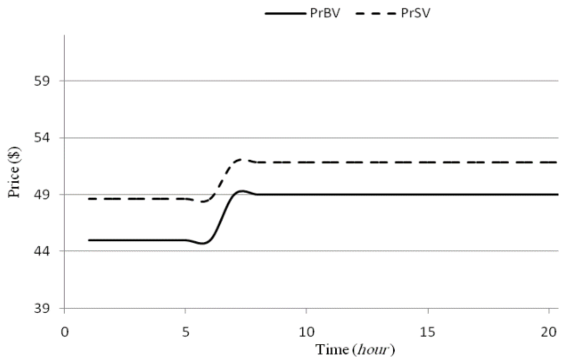

Fig. 10 The price curves of buying and selling energy to the EVs.

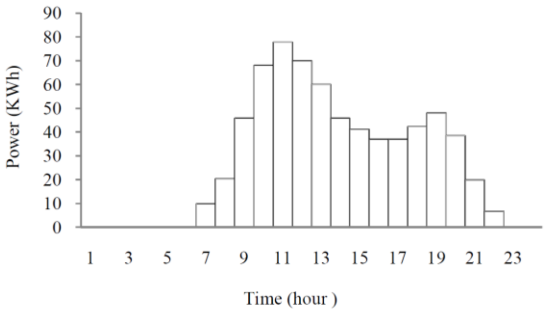

Fig. 11 The forward load curve of a weekday.

To calculate the participation of the SPL in the forward market, the parking needs to estimate its load in the considered day which is done by Monte-Carlo simulation based on the price curves of the forward and spot market, and the VPC, described in Section 3. The Monte-Carlo simulation gives the amount of energy that should be bought from the forward market. Fig. 11 shows the forward load curve (part of the load that should be provided from the forward market). Note that batteries capacity and charging/discharging efficiency are assumed to be the average of corresponding values, i.e., 22.5 kWh and 88%.

To ease the evaluation of the results in this case study the calculated SPL profits are expressed in per-unit values. The $Profit_{Base}$ is defined as the cost of charging a 22.5 kWh battery vehicle. The mean value of the forward market price during a day, Pr_{BF}^{Av} , is obtained using Fig. 8. Hence, $Profit_{Base}$ can be calculated by (22).

$$Profit_{Base} = Pr_{BF}^{Av}\,[\$/\text{kWh}] \times 22.5[\text{kWh}] = 1.024[\$] \quad (22)$$

Now, a stochastic arrangement of arrival and departure time of EVs is created based on the VPC. The total number of EVs in this arrangement is 152. Using the proposed method, the maximum profit of the SPL is 20.43 p.u.; and the calculated power transaction with the spot market in each hour of the day is illustrated in Fig. 12. In this curve, the negative values stand for those periods of time that the SPL acts as a load and positive magnitudes stand for generation mode periods.

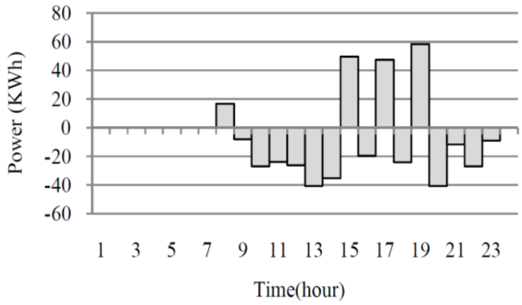

Fig. 12 Power transaction between the SPL and spot market in a weekday.

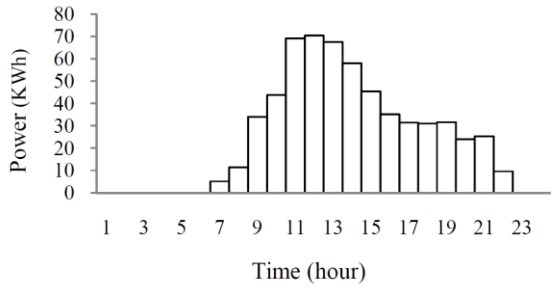

Fig. 13 The forward load curve of a weekend.

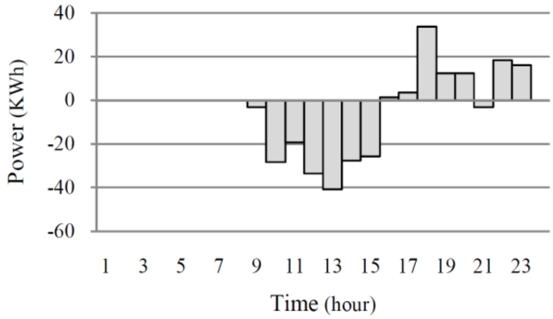

Fig. 14 Power transaction between the SPL and spot market in a weekend.

The SPL profit can be divided into two parts. If the SPL does not use the storage possibility of EVs, its profit gains only from purchasing electricity at a low price from the market and selling it to EVs at a higher price or vice versa, this part can be called exchange profit. But if use the aforementioned possibility, it can gain more profit due to buying electricity in off-peak and selling it at peak hours. And this additional profit can be called storage profit, in this case, the total profit is 20.43 p.u., exchange profit 17.12 p.u. and storage profit 3.13 p.u. It is notable that the SPL should share a part of storage profit with EV owner to compensate the aging of batteries.

The VPC of a weekend is shown in Fig. 7. The price curves of the forward and spot markets are assumed to be the same as Figs. 8 and 9. The forward load curve of this day is presented in Fig. 13.

There are 106 EVs in the selected arrangement for this VPC. Based on the simulation results the SPL profit is 15.3 p.u. in which 2.9 p.u. is due to using the storage capacity of EVs. Its power transaction to the spot market is illustrated in Fig.14.

The influences of the variations of effective parameters on parking profit are discussed as follows.

5.1 Charging/Discharging Efficiency

Improvement of batteries discharging efficiency reduces the discharging loss which can increase EVs power transaction to the SPL in a specific period. When the SPL uses the batteries as energy storages, it should pay the loss costs. So, as discharging efficiency improves the SPL has more tendencies to buy the stored energy in batteries and sell it in the spot market. Fig. 15 illustrates the SPL profit vs. the variation of vehicles discharging efficiency in permanent charging efficiency.

The effect of charging efficiency increment on the SPL profit is shown in Fig. 16 with fixed discharging efficiency. According to this curve in low charging efficiencies, EVs must buy more energy to cover the high losses of charging equipment. So, the SPL can benefit more by selling more energy. On the other hand, the high efficiency of charging equipment convinces the SPL to use battery vehicles as storage sources and increases its profit by participating in the spot market.

5.2 Uncertainty in Spot Market Prices

As mentioned before, in this paper, the prediction of the spot market price is assumed to be in three probabilistic scenarios (Fig. 9). Scenario B shows the expected prices, and scenarios A and C are pessimistic and optimistic predictions. Decreasing the probability of scenario B means increasing spot market uncertainty.

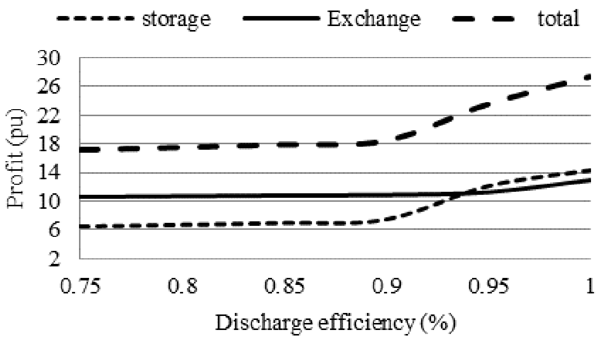

Fig. 15 Variation of different parts of SPL profit versus increment of batteries discharging efficiency.

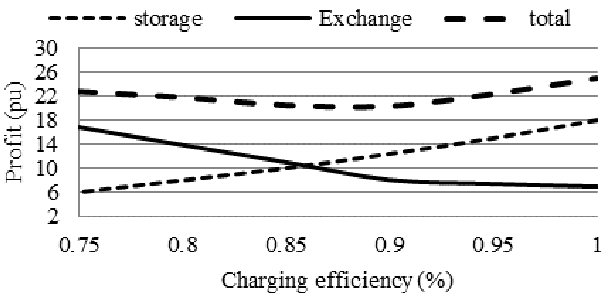

Fig. 16 Variation of different parts of SPL profit versus increment of batteries charging efficiency.

Table 2 shows the probability of each scenario in four case studies from "a" to "d" with increasing level of uncertainty. The simulation results of these case studies are shown in Figs.17 and 18.

The difference between participating in the forward market in case "a" and case "d" is about 50 KWh which approximately is the energy needed to charge two EVs. On the other hand, the difference between profits of SPL in these two cases is about 1 p.u. which is the cost of charging one EV. It shows the proposed method reduces the side effects of uncertainty in market prices.

5.3 Different Utilization of SPL

The type of utilization of SPL affects the VPC. The VPC is the key factor to determine the purchasing power from the forward market. Hence these two curves have similar trends. But the profit is a function of many more factors like prediction of spot market price curve.

In this case study the different utilization of the SPL has been investigated. Fig.19 shows the purchasing power from the forward market for each type of utilization listed in the first column of Table 3, based on Livermore, California data [35]. Also for comparison, shifted and scaled spot price curve is added to this figure. The last column in Table 3 shows the SPL profit for each case.

Table 2 Possibility of spot market prices with different uncertainty levels.

State	Scenarios A 1.1 pu	Scenarios B 1 pu	Scenarios C 0.9 pu
a	0.05	0.9	0.05
b	0.1	0.8	0.1
c	0.15	0.7	0.15
d	0.2	0.6	0.2

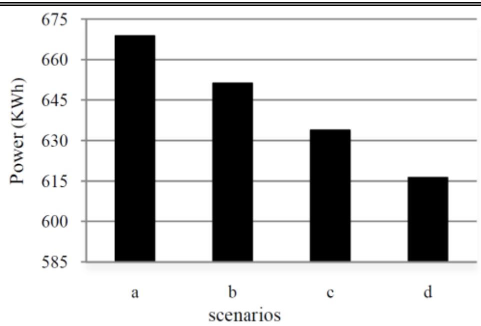

Fig. 17 The participation of the SPL in the forward market in different scenarios of the spot market.

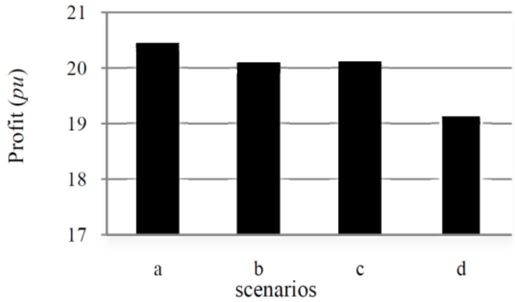

Fig. 18 The SPL profit in different scenarios of the spot market.

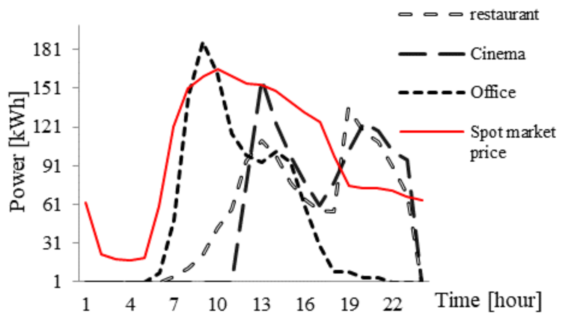

Fig. 19 The purchasing power from the forward market of the possible utilization of parking lots in the Livermore.

Table 3 Profit of SLP for different utilizations.

State	Total purchasing power from the forward market [kWh]	Profit [$]
Restaurant	1213.69	32.67
Cinema	1212.62	34.46
Office	1166.67	36.54

Fig.19 and Table 3 show that more similarity between the spot market price curve and purchasing power from the forward market curve leads to better profit. It can be explained as follow. When the spot market price is high, the SPL can profit from selling electricity in the battery of EVs. So when the peak of spot market price, means that there are more batteries available at that time to be discharged back to the grid. This lead to an increase in profit.

6 Conclusion

In this paper, an economical model was proposed to manage the power transaction in SPLs using Monte-Carlo simulation and GA. The model has been used to calculate the profit of an SPL in different cases. Results showed that based on the exceptions capacity of batteries, the capacity of SPL and discharge efficiency have a direct effect on SPLs profit. Also, it can be said that the similarity between VPC and spot market price curve, can make more profit. Finally, simulation results proved that the proposed method can reduce the side effect of uncertainty in the spot market prices.

To improve the proposed method, the depreciation cost of batteries can be modeled. Also as well as spot market price curve, VPC can be considered as a stochastic curve. The proposed model can be used to make decision about participating in demand side management programs like interruptible loads and so on. Finally, the purposed method can be used to analyze competition between SPLs and proposing new incentives to EVs in a competitive market.

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F. Askari received B.Sc. degree from Kashan University on Aug 2008, and her M.Sc. degree from Tarbiat Modares University in November 2011. She is currently a faculty member of the Department of Electrical Engineering of Technical and Vocational University (TVU), Hamedan, Iran. Her research interests include smart grid, renewable energy, electric vehicle, and power distribution systems.

A. Khoshkholgh received B.Sc. degree from Shahid Beheshti University (SBU) in Aug 2003, and his M.Sc. degree from Tarbiat Modares University in Jan 2006. His research interests are power distribution systems, smart grid, and reliability.