Advanced Journal of Science and Engineering

https://adv-j-sci-eng.com
eISSN: 2717-0705

Original Research

Calculating the Power of the Charging Station of Electric Vehicles with Photovoltaic Roof

Ebadollah Amouzad Mahdiraji[1,*], Seyed Mohammad Shariatmadar[2]

[1] *Department of Engineering, Sari Branch, Islamic Azad University, Sari, Iran*
[2] *Electrical Engineering Department, Naragh Branch, Islamic Azad University, Naragh, Iran*
[*] *Correspondence*: ebad.amouzad@gmail.com (E.A.);

Advanced Journal of Science and Engineering. 2023; 4(2): 042013. https://doi.org/10.22034/advjse042013

Received: 11 September 2022 / ***Revised***: 1 February 2023 / ***Accepted***: 4 February 2023 / ***Published***: 15 May 2023

Abstract: The capacity of electric car charging stations can be increased by installing solar arrays on their roofs. In such a rechargeable station, power transmission can be two-way if needed. In this paper, a new method using random queue and forest theory to calculate the net power of the charging station concerning the random level of charge of the vehicles that enter it is presented. Due to the limited estimated time, a queuing system with limited input and limited capacity has been used to model the entry and exit of vehicles. Due to the limited estimated time, a queuing system with limited input and limited capacity is used to model the entry and exit of vehicles, and relation to calculate the service time in proportion to the charge level at which electric vehicles enter the charging station. To estimate the effect of photovoltaic ceilings on the capacity of the charging station, a method for estimating the maximum power of photovoltaic arrays using the random forest method has been used. Charging and discharging operations for Nissan and Tesla electric vehicles have been done by writing a priority list and in the process of simulating the actual efficiency of the inverter at the second charge level. The simulation results show that the proposed method is an accurate and efficient model for planning and estimating the parking capacity of electric vehicles with the photovoltaic roof.

Keywords: Limited capacity queue model; Power distribution network; Queue theory; Random forest; Service time; Solar array.

Introduction

With the increasing use of electric vehicles, including dual-fuel electric vehicles with charging ports and battery-powered electric vehicles, there is a need to build public charging stations that charge electric vehicles with higher voltages and currents than home chargers. It becomes public or private district power companies can build such charging stations in a public place such as a street or a shopping mall. This charging station can be a parking lot that earns money by providing parking services to cars and charging electric vehicles. The capacity of such a parking lot can also be used to provide services such as frequency tuning in the ancillary services market, thereby making the charging station more profitable. For more efficient use of this parking lot, one of the sources of renewable and clean electricity can be placed next to the electricity network to provide the required power to charge the batteries of electric vehicles. Installing photovoltaic arrays on the parking canopy is a good way to provide the required percentage of parking power. This parking lot can transfer the surplus to the electricity network when it has more power than it needs and reduces the cost required to provide parking capacity. There are also other issues that the car's connection to the network can help with their processor that should be addressed. Connecting the vehicle to the network can be used in issues such as creating an interaction between smart buildings [1] and the distribution network. Other issues that the car connected to the grid should be considered include energy and power planning in microgrids [2] and the creation of a virtual power plant to provide ancillary services [3]. It was investigated that the electric vehicles are connected to the grid in the vicinity of wind generators to be able to quickly compensate for wind fluctuations and the effect of power fluctuations on the bus to which the wind generators are connected [4]. In another work, a plan for connecting vehicles to the grid and examining parameters such as voltage stability, power losses, and energy losses to monitor the network and manage it after connecting electric vehicles [5, 6]. Other studies in this field include the improvement of dynamic random programming for its users to optimize the charging process of vehicles and adjust the frequency [7]. The study of the behavior of electric vehicles when connected to the grid and the new challenges posed by the use of renewable energy such as wind energy along with it has been investigated by another work [8]. The use of dynamic programming to estimate the electrical capacity in the building where electric vehicles are connected to the grid has been investigated in [9]. A real charging station with a solar canopy in a smart grid environment is investigated and a solution for data acquisition is presented [10]. Criteria for the profitability of intelligent charging and discharging methods for vehicles connected to the electricity grid are presented and the charge control of electric vehicles is performed using intelligent optimization and charge and discharge management of vehicles [11]. A method for adjusting the one-way connection of electric vehicles to the power grid has been developed [12]. Also, by considering the load constraints and power prices, optimization has been done to maximize its economic profit. A method for load control has been developed to connect a large number of electric vehicles to an intelligent network and reduce losses [13]. The role of parking lots connecting electric vehicles to the grid as resources to improve the reliability of power distribution networks based on renewable energy during blackouts has been investigated [14]. Additionally, a combined method based on linear programming and integer to coordinate the optimal charging of electric vehicles in distribution systems with distributed generation sources was presented [15]. A method for day-ahead planning and decentralized management of charging and discharging electric vehicles in the distribution network along with the provision of ancillary services has been proposed earlier [16]. In the reference works [17, 18], the infinite queue theory m/m/n is used to model the behavior of vehicles. In other reference works [19-27], a solar parking lot is used to increase the capacity of the power distribution system, and in it, a relation is presented to introduce the effect of charge and inverter efficiency. Also, the effect of charge efficiency for the amount of power required and the effect of inverter efficiency on the discharge time of the electric car battery has been considered, but in the end, it is considered to simulate the values of charge and inverter efficiency equal to 100%, which causes It has an effect on the results obtained. In previous studies, the infinite queue theory m/m/n has been used to model vehicle behavior. In these models, parking modeling is unrealistic and the methods used do not indicate how much parking capacity will be considered in a limited time. In these models, the right of way of cars according to their type, battery capacity, and charging system is not considered. In these studies, the output power of the solar array is considered constant and the effect of weather uncertainties on the generated power is not applied in a practical way.

Due to the problems mentioned in previous studies, this paper presents a new stochastic method based on finite queue theory and random forest to calculate the net power of a charging station equipped with a photovoltaic roof. To model the effect of weather uncertainties on solar array output, a random forest regression model is used to estimate the pre-power output of solar array output, which reduces the calculation error of the charge station capacity. In practice, cars enter the parking lot with a random charge level. Therefore, the new formulation is based on the level of charge of cars when entering the parking lot. To calculate the charging and discharging time of electric car batteries from proportional relations that indicate the relationship between the car charging level when entering the parking lot, the time required to charge the car, the relationship between the charging level of the electric car at the time of power transmission and the time required to Discharge of car battery is used. Because the estimated time of parking capacity is limited, the number of cars entering and leaving will be limited. Therefore, a queuing system with a finite number of inputs should be used to model the entry and exit of vehicles. In the proposed structure, the planning method based on the preparation of a list of priority rights for charging and discharging vehicles in the parking lot has been used.

Materials and Methods

Parking Car Connection to the Network

Charging Equipment

There are three levels of charge according to the battery charge rate of electric vehicles [28]. The alternating current charge level of the first and second types and direct current charge level. AC Surface Charging Equipment The first type of charging operation provides a 120 V AC port for the electric vehicle, which allows it to travel 3.2 to 8 km per hour of charge. At this charge level, it is possible to cover 16 to 32 km per hour of charge. The first and second types of AC charging level equipment uses the standard J1772 interface. Direct current charging equipment Fast charging operation allows you to travel 80 to 112 km per 20 minutes of charging. Depending on the type of direct current charging system, CHAdeMO, Combo, and Tesla Combo ports are used in this charge level.

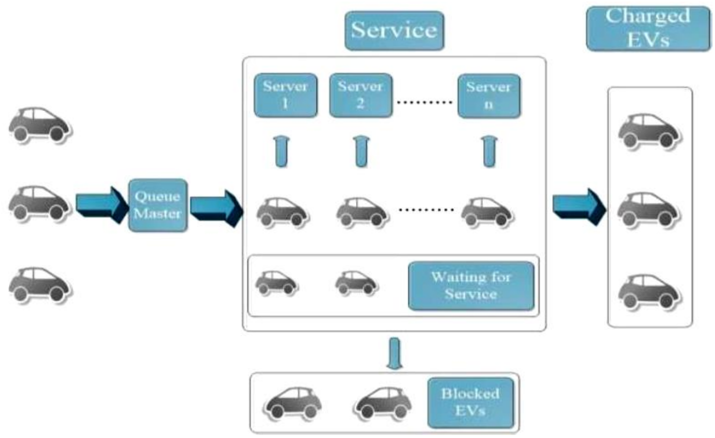

Figure 1: Model of entry and exit of vehicles in the finite queue system.

Modeling the Entry and Exit of Vehicles Using Finite Queue Theory

In previous studies modeling the entry and exit of vehicles to an electric vehicle charging station, the time has not been a determining factor, and therefore the entry of vehicles into the parking lot will be unlimited indefinitely. In day-to-day estimates, the capacity of a parking lot to connect electric vehicles to the power grid is a time-limiting factor. In the day-to-day estimate, the inspection is scheduled to take place within 24 hours, and it is clear that the capacity of vehicles to enter the parking lot will be limited. Another limiting factor is the number of servers that are supposed to charge and discharge the batteries of electric vehicles, which is the main determinant of the parking capacity of the vehicle connected to the mains. From this point of view, to model the entry and exit of vehicles, we should use a queuing system with a limited number of vehicles and a limited-service capacity. Suppose the parking lot has n visitors within 24 hours. If this parking lot has r servers to serve cars during a service period, then the capacity of this parking lot in a service period will also be equal to r. Figure 1 shows the model of entry and exit of vehicles. Modeling of such a parking lot is possible using the m/m /r/r /n queuing system. Such a parking lot is shown in Figure 2.

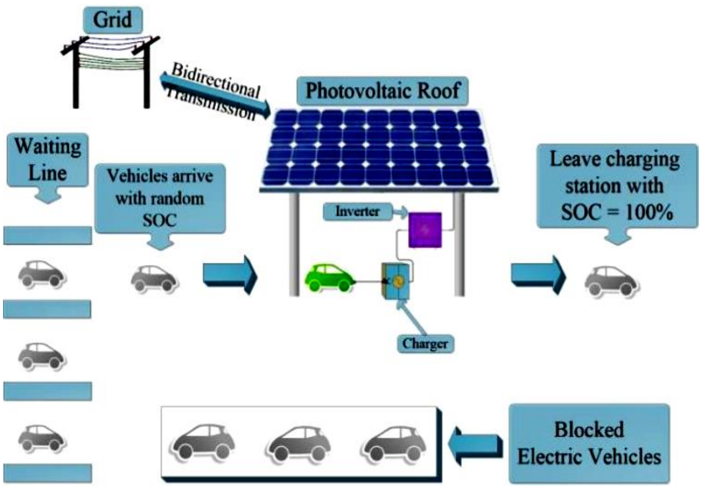

Figure 2: Charging parking for electric vehicles.

If k vehicles enter, the average rate of vehicles entering the parking lot is equal to:

$$\lambda_K = (n-k)\lambda, 0 \le k \le r \tag{1}$$

The average service rate of each server is calculated from the following equation [29]:

$$\mu_K = k.\mu, 1 \le k \le r \tag{2}$$

If the parking capacity is equal to the number of vehicles entering the parking lot, we will not lose any vehicles. But if the vehicle does not want to wait or there is no time left to provide services, we will lose the vehicle. The probability that k vehicles are connected to the server in the parking lot is equal to:

$$P_k = \binom{n}{k}\left(\frac{\rho}{1+\rho}\right)^k \left(1-\frac{\rho}{1+\rho}\right)^{n-k} \tag{3}$$

$$\rho = \frac{\lambda}{\mu} \tag{4}$$

ρ is called traffic intensity and the average number of vehicles connected to the server in the parking lot is calculated from the following equation:

$$\overline{N} = \sum_{k=0}^{r} kP_k \tag{5}$$

The number of vehicles that enter the parking lot in period i and wait to connect to the server is obtained from Eq. (6):

$$\overline{m}_i = n_i - \overline{N}_i \tag{6}$$

That is the number of vehicles connected to the server in each period of connection to the server. The number of vehicles that enter the parking lot but do not find a server to connect to it and leave the parking lot is equal to:

$$N_{Blocked} = n - \sum_{i=1}^{n_p} \overline{N}_i \tag{7}$$

Model for Estimating the Output Power of Photovoltaic Array Using Stochastic Forest Method

By constructing canopies for the charging station, electric vehicles are protected from direct sunlight, and on hot summer days, the vehicle is protected from overheating [19]. Solar panels can be installed on these canopies and the power generated by the photovoltaic array can be used to meet part of the charging station needs. The output voltage of a photovoltaic array is direct current. Therefore, by installing fast direct-current charging equipment at the charging station, the output of the photovoltaic array can directly charge the electric vehicle battery. If the AC charging equipment is installed at the charging station, it must first be charged. Using a direct current output inverter, convert the photovoltaic array to alternating current. The random forest method is a set of decision tree-dependent predictors, each of which is given a random value as input [30, 31]. This method connects the complex space of the inputs to the simpler output spaces. The nonlinearity of the problem can be managed by dividing the main problem into several sub-problems. This is done in such a way that each of the sub-problems can be solved with a simple model. As shown in Figure (3), the random forest structure consists of three types of groups [32]. Primary node or root node, separator node, and leaf node. The separator node determines which data should be sent to the right nodes and which data should be sent to the left nodes by experimenting with the sample data.

Vector X is the input vector, T is the set of decision trees, and Y is the vector of output values as follows:

$$X = \{x_1, x_2, \ldots, x_n\} \tag{8}$$

For k trees:

$$T = \{T_1(x), T_2(x), \ldots, T_K(x)\} \tag{9}$$

$$Y = \{\hat{Y}_1 = T_1(x), \ldots, \hat{Y}_m = T_m(x)\}, m = 1, \ldots, k \tag{10}$$

The final output is the average of all the outputs estimated by each decision tree in the random forest [33]:

$$\text{Predict}_{RF}(x) = 1/K \sum_{k=1}^{K} \hat{Y}_k(x) \tag{11}$$

The training set is equal to:

$$D = \{D_1, D_2, \ldots, D_n\} = \{(X_1, Y_1), \ldots, (X_n, Y_n)\} \tag{12}$$

In order to estimate the parking capacity, we must estimate the power generated by the photovoltaic array. Random forest inputs the time series of solar radiation data include received direct light radiation and scattered horizontal light radiation, wind speed, and air temperature, and the target is the output power of the solar array. The photovoltaic array consists of 220-watt panels with polycrystalline solar cells, the maximum power of the installed array is 18.5 kW. The technical specifications of these solar cells are given in Table 1. The power generated by a photovoltaic array in a day is estimated in half-hour periods and added together to determine the total power injected into the car parking lot in one day. The power that is given from the photovoltaic panels to the parking lot connected to the network in one day is equal to:

$$P_{PV} = \sum_{i=0}^{n_P} P_{max_{PV,i}} \tag{13}$$

Table 1: Technical specifications of the solar panel.

Cell type	Cell dimensions (mm)	Panel dimensions (mm)	Panel weight (kg)
Polycrystalline	156 × 156	1655 × 992 × 45	22.50

Calculation of Power and Energy

Battery charging power is calculated from Eq. (14) [19-17]:

$$P_{EV}(t) = P_{max}\left(1 - e^{-\alpha\eta_r \frac{t}{t_{max}}}\right) + P_{EV0} \quad (14)$$

In the above relation, the maximum power capacity (P_{max}) is equal to the maximum electrical energy stored in the vehicle battery. α is equal to the battery charge constant, η_r equal to the charger efficiency, (t) is the time required to charge the vehicle battery, (t_{max}) the maximum time required to charge the vehicle battery and the initial power in the electric car battery (P_{EV0}). It is assumed that an electric vehicle with an initial charge level equal to SOC_{init}, which indicates the percentage of charge remaining in the vehicle battery, has entered the parking lot with the aim of fully charging. The initial power stored in the vehicle battery can then be calculated from the following equation:

$$P_{initial} = SOC_{init}.P_{max} \quad (15)$$

$P_{initial}$ indicates the initial power stored in the car battery. The power required to charge the vehicle battery from the initial charge stored in the battery, to the maximum storage capacity of the battery ($P_{initial}$) is equal to the power that must be received from the mains to charge the electric vehicle battery:

$$P_{imp} = P_{max} - P_{initial} \quad (16)$$

$$P_{imp\_init} = P_{max}\left(1 - SOC_{init}\right) \quad (17)$$

$$P_{imp}(t) = P_{max}\left(1 - SOC_{init}\right)\left(1 - e^{-\alpha\eta \frac{t_{imp}}{t_{max}}}\right) \quad (18)$$

In the above relation, $P_{imp(t)}$ shows the power that must be received from the electricity network to charge the battery of an electric vehicle in time ($t_{imp(t)}$). Eq. (18) can be extended to the number of electric vehicles as Eq. (19) in which i indicates the type of vehicle in the parking lot and j indicates the vehicle number.

$$P_{imp}(t) = \sum_{i=1}^{N} \sum_{j=1}^{N_{ev}} P_{max_i}\left(1 - SOC_{init_{i,j}}\right)\left(1 - e^{-\alpha_i.\eta_j \frac{t_{imp_{i,j}}}{t_{max_i}}}\right) \quad (19)$$

Consider an electric vehicle with an equal charge level that intends to interrupt the charging operation and inject power equivalent to the electrical energy stored in its battery into the mains. The power of this vehicle is equal to:

$$P_{discharge^t} = P_{dep}.e^{-\eta\beta.\frac{t_{inj}}{t_{max - P_{lim}}}} \quad (20)$$

$$P_{inj} = P_{dep} - P_{discharge} \quad (21)$$

P_{lim} is the amount of power that must remain in the vehicle battery to provide the initial power to start. From locating relation (20) to relation (21) we have:

$$P_{inj}(t) = P_{dep}\left(1-e^{-\eta\beta\frac{t_{inj}}{t_{max}}}\right) - P_{lim} \tag{22}$$

$$P_{inj}(t) = \sum_{i=0}^{N}\sum_{j=0}^{N_{ev}} P_{dep_{i,j}}\left(1-e^{-\alpha_i\eta_j\frac{t_{inj_{i,j}}}{t_{max_i}}}\right) - P_{lim} \tag{23}$$

The power system at the charging station is equal to:

$$P_{n_{ev}} = P_{max}\left(1-SOC_{init}\right)\left(1-e^{-\alpha\eta\frac{t_{imp}}{t_{max}}}\right) - \left(P_{dep}\cdot\left(1-e^{-\beta\eta.\frac{t_{inj}}{t_{max}}}\right) - P_{lim}\right) \tag{24}$$

The net energy in the parking lot is equal to the integral of the net power in the parking lot. By calculating the product of the integral we have:

$$E_n = \sum_{i=1}^{N}\sum_{j=1}^{N_{ev}}\left\{t_{imp_{i,j}}\left(P_{imp\_init} - P_{dep} + P_{lim} + P_{dep}.e^{-\beta_i\eta_i\frac{t_{inj_{i,j}}}{t_{max_i}}}\right) + \frac{P_{imp\_init}.t_{max}.e^{-\alpha_i\eta_i\frac{t_{imp_{i,j}}}{t_{max_i}}}}{\alpha_i.\eta_j}\right\} \tag{25}$$

The service time for each electric vehicle in the charge or discharge operation can be calculated from a proportional relationship using the maximum power that the vehicle battery can store and the time required to store the maximum power in the battery. If the battery of an electric vehicle charges from power to power at the time then:

$$t_{imp} = \frac{P_{max}\left(1-SOC_{init}\right).t_{max}}{P_{max} - P_{limit}} \tag{26}$$

If the battery of an electric vehicle transmits power P_{max} to power t_{limit} at time t_{max}, then:

$$t_{inj} = \frac{\left(\left(SOC_{dep}.P_{max}\right) - P_{limit}\right)t_{max}}{P_{max} - P_{limit}} \tag{27}$$

The power that is injected into the parking lot through photovoltaic panels reduces its need to receive power from the mains. This reduces parking costs economically. It should also be noted that solar energy is a renewable and clean source and will reduce environmental pollution. In this case, the net power of the vehicle charging station connected to the network is equal to:

$$P_n = \sum_{i=1}^{N}\sum_{j=1}^{N_{ev}} P_{imp\_initi}\cdot\left(1-e^{-\alpha_i\eta_j\frac{t_{i,j}}{t_{max_i}}}\right) - \left(P_{dep_{i,j}}\left(1-e^{-\beta_i\eta_{inv,j}\cdot\frac{t_{i,j}}{t_{max_i}}}\right) - P_{lim_i}\right) - P_{PV} \tag{28}$$

The net energy at the charging station is calculated from Eq. (29):

$$E_n = \sum_{i=1}^{N} \sum_{j=1}^{N_{ev}} \left\{ t_{imp_{i,j}} \left(P_{imp\_initi,j} - P_{depi,j} - P_{pv} + P_{lim_{i,j}} + P_{depi,j} \cdot e^{-\beta_i \eta_i \frac{t_{inj_{i,j}}}{t_{max_i}}} \right) + \frac{P_{imp\_initi,j} \cdot t_{max\,i} \cdot e^{-\alpha_i \eta_i \frac{t_{imp_{i,j}}}{t_{max_i}}}}{\alpha_i \cdot \eta_j} \right\} \tag{29}$$

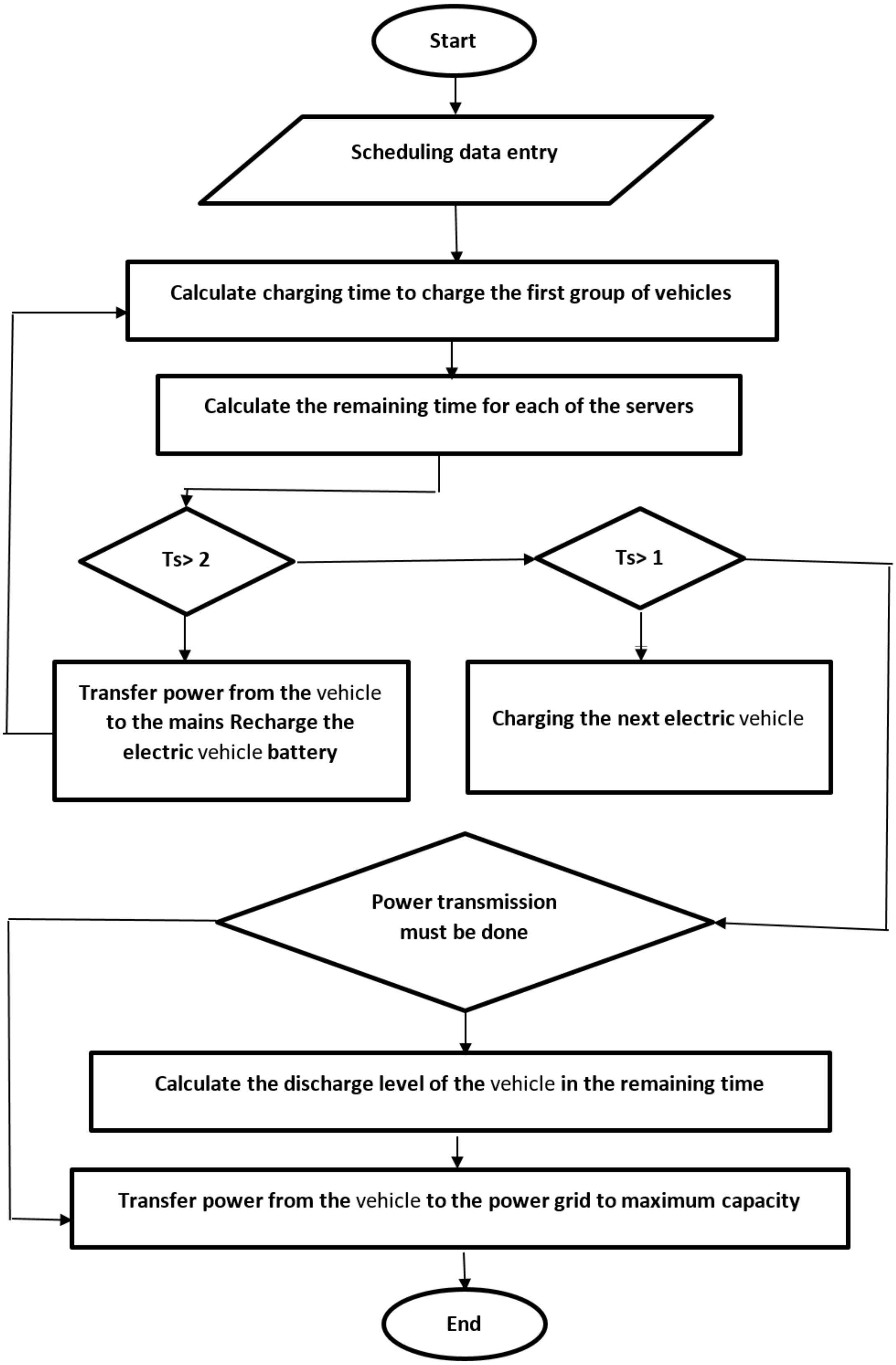

Figure 3: Flowchart of planning the charging and discharging operations of electric vehicles.

Planning the Charging and Discharging of Electric Vehicles

To charge and discharge electric vehicles in a parking lot, planning must be done so that the service time does not exceed 24 hours. To do this, the priority is to charge and discharge with cars whose batteries have a higher capacity to store energy. The type of charge that determines the charge level must be specified because the charging time depends on the type of charge and the charge level. The flowchart of the car charging schedule is shown in Figure 3. Planning parameters must first be specified. These parameters include the maximum capacity of the electric vehicle battery, the charge level of the electric vehicle when entering the charging station, the maximum time required to charge the electric vehicle battery, the minimum power that must remain in the vehicle battery, and the charge level of the electric vehicle battery when stopping. Then the time required for the first charging period of electric vehicles should be calculated according to the type of vehicle and the type of charge. In the next step, the remaining time of 24 hours to be scheduled is calculated for each server. If the number of times the full charge and discharge operation can be more than twice, the battery of the electric car can be discharged to the level of discharge, and then it can be recharged to the maximum capacity. Then we return to the step of calculating the remaining time and the above steps are repeated once again, and if the number of times that the full charge and discharge operation may be greater than or equal to once, the next car to the maximum capacity the battery is charged, if the number of times to fully charge and discharge is not possible at once and the parking lot is committed to transfer power to the mains, the next step is checked, otherwise, the program steps the shedding ends. If it is assumed that the vehicles entering the charging station should leave it at maximum capacity, after discharging, the energy stored in the battery of electric vehicles should be charged once again to the maximum capacity. The charge level at which the car battery can be discharged and recharged is calculated. The electric vehicle is discharged to that level and transmits the power stored in its battery to the network and then is charged to its maximum battery capacity. In performing charging and discharging operations, priority is given to a vehicle that has a higher charge and discharge rate and a higher energy storage capacity.

Priority is not given when there is no electric vehicle at the charging station. As long as there is free charging, charging services will be provided with the arrival of the electric vehicle from any right of way. For this purpose, an index can be determined based on which cars are classified. This index can be different in different periods. Due to the multi-stage services in the car park, the connection to the network, to determine the priority of providing services to electric vehicles, criteria must be considered. The service will be done in one, two, or three steps. The priority right index for multi-stage services is obtained from the following relationships:

$$\pi_{1\varphi} = -\delta_{1,1\varphi} t_s \tag{30}$$

$$\pi_{2\varphi} = \delta_{1,2\varphi} SOC_{init} + \delta_{2,2\varphi} \alpha - \delta_{3,2\varphi} t_s \tag{31}$$

$$\pi_{3\varphi} = \delta_1 P_{max} + \delta_2 SOC_{init} + \delta_3 \alpha + \delta_4 t_{p_{max}} \tag{32}$$

In the above relations, the priority index for recharging services is the priority right index for two-stage services including power transfer and recharging, and the priority right index for three-stage services includes recharging as much as possible, power transfer and recharging. δ is the coefficient of the importance of each factor and it should be noted that in different periods, the importance of the factors affecting the index of determining the right of precedence is different and the value assigned to each of these coefficients can be variable. Three-phase service may be delayed, so the time spent at the station in these conditions should be sufficient and the battery capacity of the selected vehicle should be worth the operation. Cancellation from the charging station is a function of the number of vehicles inside the station, if all the charges inside the station are occupied and part or all of the waiting area is occupied, cancellation from the station occurs.

$$B = \begin{cases} 0 \text{ if } n_c < S + n_W \\ 1 \text{ if } n_c = S + n_W \end{cases} \quad (33)$$

In the above relation, n_C represents the number of vehicles present in the parking lot, S represents the number of occupied charges and n_W represents the number of electric vehicles present at the waiting area.

Results and Discussion

In order to show the method presented in the paper, simulations for a charging station in Iran, in the Isfahan region, in the area of Ayatollah Taleghani Street, have been feasibility study. The necessary information about the type and number of charges from the charging station examined in an earlier work [10] is provided for this purpose. This station has six types of AC alternating current charges. Cars enter the parking lot with a random charge, and after fully charging, they can transfer some of their power to the network. Dual-fuel electric vehicles with a charging port whose batteries are charged while moving can transfer their battery power to the mains and leave the charging station using the main fuel, while electric vehicles only from They can use the power stored in the battery. Vehicles entering the parking lot are of both TMXEV and NLEV types to demonstrate the effect that differences in vehicle characteristics have on the total capacity of the parking lot.

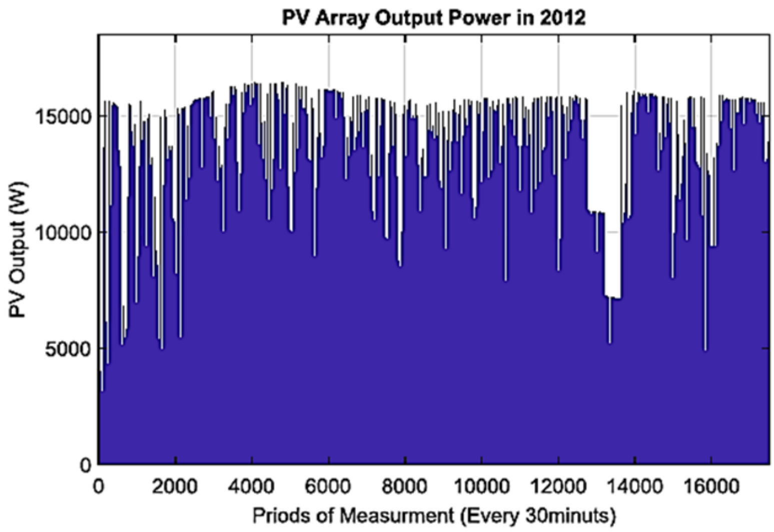

Figure 4: Solar array output power in 2012.

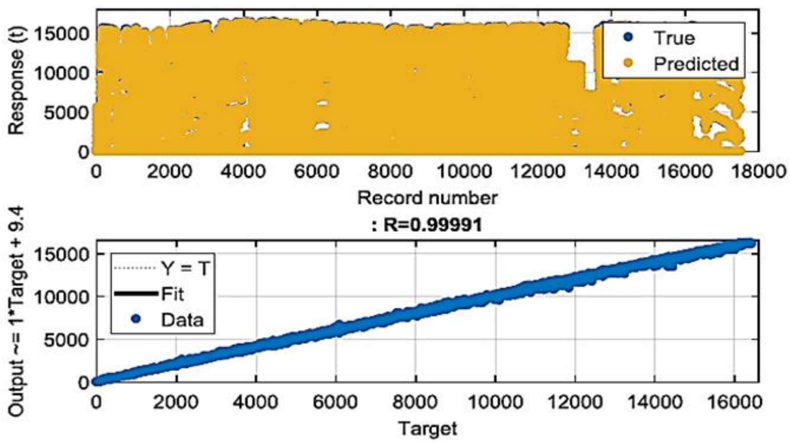

Figure 5: Model response to training and linear regression data.

Estimation of Production Capacity by a Solar Canopy

As explained, for day-to-day estimation, the power generated by the solar canopy installed on the charging station is taught based on 2012 solar radiation data [25] of a random forest model. The output power of an extractable solar array based on which a random forest is trained is shown in Figure 4. The response of the trained model to the training data and the linear regression of the random forest estimation model of the trained model was shown in Figure 5. As can be seen from the results of Figure 5, the performance of the stochastic forest forecasting system is very effective and the estimation error is appropriate. Figure 6 shows the predicted power using the prediction model proposed in this paper for the fourth days of January 2012 and May 20, 2012, in the half-hour periods as an example.

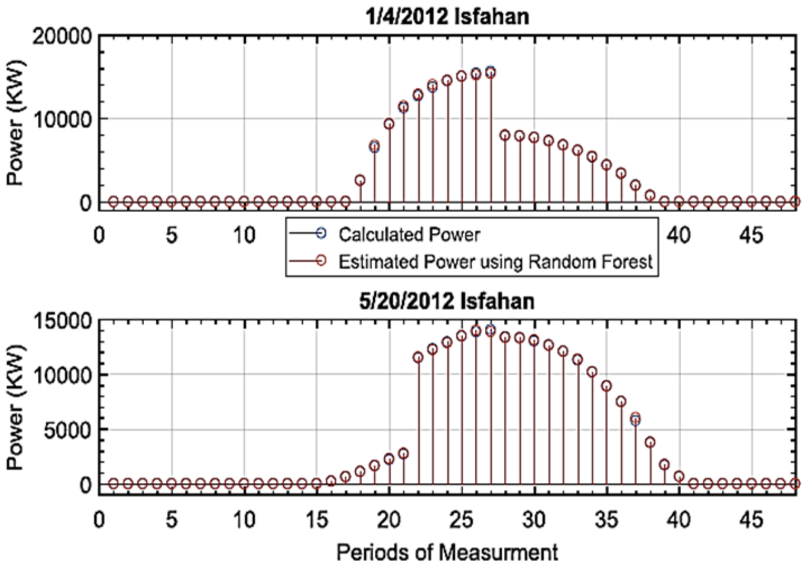

Figure 6: Maximum estimated power using stochastic forest model for January 4 and May 20 of 2012, in Isfahan.

Power and energy in the charging station

Since the full charge time for the TMXEV is less than half the full charge time of the NLEV, as well as the charge and discharge rate of the NLEV, the probability of a TMXEV being connected to the server is twice as high as the probability of a The NLEV vehicle is to the server, ie. For such a parking lot, the number of servers for TMXEV vehicles is twice that of the designated servers for NLEV vehicles, because its battery storage capacity is twice that of the NLEV vehicle. The maximum time required to fully charge the TMXEV battery is less than half the maximum time required to fully charge the NLEV battery, and the TMXEV battery charge rate is higher than the NLEV battery charge rate. For these reasons, charging priority with TMXEV is:

$$N_{server}(NLEV) = 2, N_{server}(TREV) = 4$$

If we consider the minimum level of vehicle charge when entering the parking lot is 15%, each of the servers to which the TMXEV vehicle is connected can perform charging and discharging operations at least 8 times, and each of the servers to which the NLEV car is connected. Can charge and discharge at least 4 times. So in 24 hours we have:

$$\overline{N} = 16, \overline{m} = 14, N_{Blocked} = 4$$

The simulation information is given in Table 2. As shown in Figure 7, the power taken is greater than the power transmitted to the network. By selling the surplus power exported to the grid, the cost of power supply is reduced. Therefore, the cost of providing services should be adjusted so that the charging station becomes profitable.

Table 2: Simulation information.

	P_{lim} (kW)	α	t_{max}(h)	P_{lim} (kW)	η%
TMXEV	189	10.1375	3.5	0.2	86.5
NLEV	90	4432	8	0.2	86.5

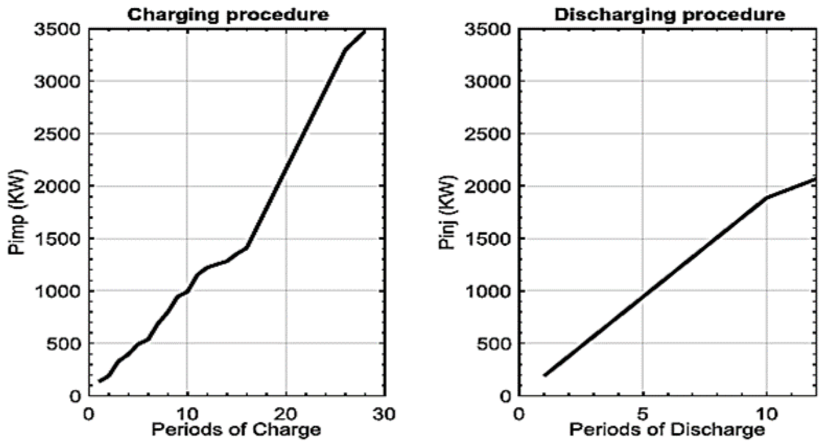

Figure 7: Receiving and transmitting power in 24 hours.

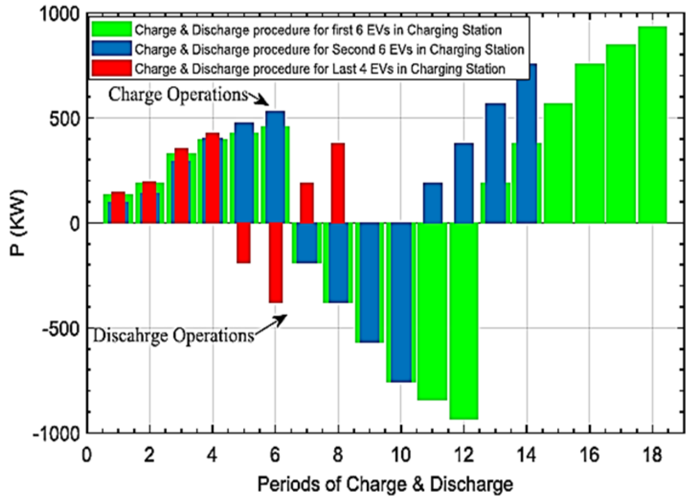

Figure 8: Charging and discharging periods of power in 24 hours.

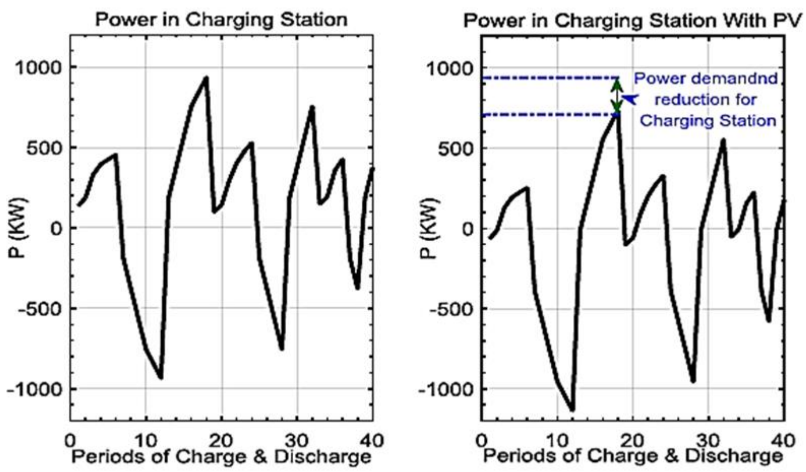

Figure 9: Charging and discharging process in the entire parking lot.

The periods of charging and discharging operations of vehicles are shown in Figure 8. The green diagram for the first period, the blue diagram for the second period, and the red diagram for the third period show the planning for charging and discharging vehicles. Time in the day-ahead forecast parking capacity is a limiting factor. As shown in Figure 8, the number of power supply cycles decreases as we approach the end of 24 hours. Bilateral contracts can be concluded with the owners of electric vehicles and the electricity network in order to maximize the profit of the charging station. Figure 9 shows the decrease in power demand from the power grid and the increase in power output to the grid despite the solar array, and the energy flow at the station is shown in Figure 10.

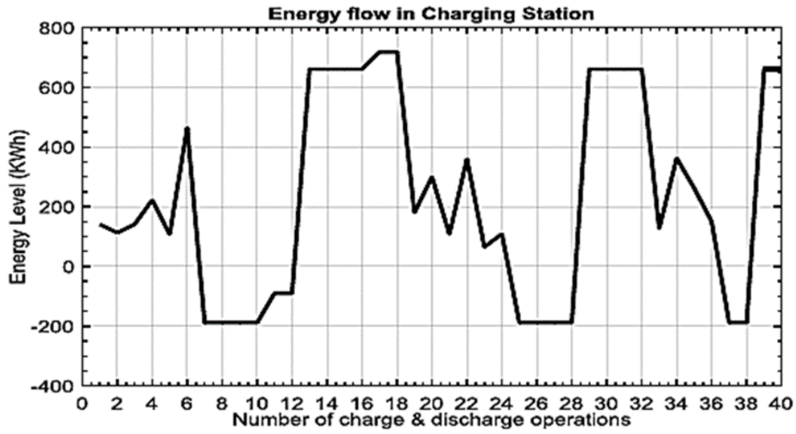

Figure 10: Energy at the charging station.

Figure 10 shows how much energy the vehicles receive from the grid when charging and what level of electrical energy in terms of kilowatt-hours is injected into the grid during charging. Negative energy level linear parts are related to vehicles that have participated in the power transmission operation, and positive linear parts show recharging of these vehicles. The level of each linear part indicates the participation of one type of vehicle in the operation of receiving and transmitting power by electric vehicles at the charging station. The simulation results show that the net power in the parking lot over some time depends on the time of presence, technical characteristics, and the type of electric vehicle. The type of participation of electric vehicles in charging and discharging operations should be planned in such a way that the charging station becomes profitable.

Conclusion

In this paper, a new stochastic method based on finite line theory and stochastic forest is presented to calculate the net power of a charging station equipped with a photovoltaic ceiling. The proposed method shows the effect of the initial charge level at which the vehicle enters the parking lot and the charge level at which the vehicle decides to transfer power to the parking capacity. Using a queuing system with finite input and capacity leads to results that are completely realistic. The results show that by using the queue model with limited input and waiting time, it is possible to predict the parking capacity of the vehicle connected to the electricity network despite the time limit, which is an effective factor in power system. Also, the use of the solar array power estimator model, in addition to showing the effect of weather uncertainties, provides an accurate estimate of the capacity of the charging station.

Disclosure Statement

The author(s) did not report any potential conflict of interest.

References

1. Amouzad Mahdiraji E. Optimal switching of micro-grid distributed management based on equilibrium models. Signal Processing and Renewable Energy. 2020; 4: 67.

2. Amouzad Mahdiraji E, Ramezani N. Optimal in smart grids considering interruptible loads and photo-voltaic sources using genetic optimization. Signal Processing and Renewable Energy. 2020; 4: 37.
3. Amouzad Mahdiraji E. Model reference adaptive control of linear system despite sensor bias. Computational Research Progress in Applied Science & Engineering, CRPASE: Transactions of Electrical, Electronic and Computer Engineering. 2020; 6: 245.
4. Amouzad Mahdiraji E, Yousefi Talouki A. oltage stability of wind turbines equipped with DFIG based on PID-based control method. Journal of Chemical Reviews. 2021; 3: 40.
5. Amouzad Mahdiraji E. Investigation of overvoltages caused by lightning strikes on transmission lines and GIS substation equipment. Computational Research Progress in Applied Science & Engineering, CRPASE: Transactions of Electrical, Electronic and Computer Engineering. 2020; 6: 238.
6. Chukwu UC, Mahajan SM. Real-time management of power systems with V2G facility for smart-grid applications. IEEE Transactions on Sustainable Energy. 2013; 5: 558.
7. Mahdiraji EA. Introducing a new method to increase critical clearing time (CCT) and improve transient stability of synchronous generator using brake resistance. Gazi Muhendislik Bilimleri Dergisi. 2020; 6: 138.
8. Donadee J, Ilic MD. Stochastic optimization of grid to vehicle frequency regulation capacity bids. IEEE Transactions on Smart Grid. 2014; 5: 1061.
9. Amouzad Mahdiraji E. Fault locating in distributed generation network based on the use of phasor unit measurement in oil and gas industry. Journal of Chemical Reviews. 2021; 3: 147.
10. Kumar KN, Sivaneasan B, Cheah PH, So PL, Wang DZ. V2G capacity estimation using dynamic EV scheduling. IEEE Transactions on Smart Grid. 2013; 5: 1051.
11. Amouzad Mahdiraji E, Sedghi Amiri M. Improving the accuracy of the state estimation algorithm in the power system based on the location of PMUs and voltage angle relationships. Journal of Engineering Technology and Applied Sciences. 2020; 5: 133.
12. Amouzad Mahdiraji E. Time-based development plans for distribution networks in the presence of distributed generators and capacitor banks. Journal of Scientific Perspectives. 2020; 4: 245.
13. Amouzad Mahdiraji E, Sedghi Amiri M. Locating, sizing, and optimal planning of the distribution substations using vanadium flow battery storage to improve the efficiency of the power distribution network. International Journal of Smart Electrical Engineering. 2020; 9: 13.
14. Tian W, Jiang Y, Shahidehpour M, Krishnamurthy M. Vehicle charging stations with solar canopy: a realistic case study within a smart grid environment. IEEE Transportation Electrification Conference and Expo (ITEC). 2014: 1.
15. Mahdiraji EA, Shariatmadar SM. Improving flexibility and control the voltage and frequency of the island micro-grid using storage devices. Advanced Journal of Science and Engineering. 2020; 1: 27.
16. Schuller A, Dietz B, Flath CM, Weinhardt C. Charging strategies for battery electric vehicles: economic benchmark and V2G potential. IEEE Transactions on Power Systems. 2014; 29: 2014.
17. Amouzad Mahdiraji E, Shariatmadar SM. Locating and offering optimal price distributed generation resources to increase profit using ant lion optimization algorithm. International Journal of Smart Electrical Engineering. 2019; 8: 143.
18. Amouzad Mahdiraji E, Shariatmadar SM. A new method for simplification and reduction of state estimation’s computational complexity in stability analysis of power systems. International Journal of Smart Electrical Engineering. 2019; 8: 51.
19. Amouzad Mahdiraji E, Ramezani N. Transient modeling of transmission lines components with respect to corona phenomenon and grounding system to reduce the transient voltages caused by lightning Impulse. International Conference on Knowledge-Based Engineering and Innovation (KBEI). 2015; 2: 405.
20. Antunez CS, Franco JF, Rider MJ, Romero R. A new methodology for the optimal charging coordination of electric vehicles considering vehicle-to-grid technology. IEEE Transactions on Sustainable Energy. 2016; 7: 596.
21. Amouzad Mahdiraji E. Optimal purchase and sale of energy in electricity markets due to various uncertainties in microgrid. Quantum Journal of Engineering, Science and Technology. 2022; 3: 29.
22. Amouzad Mahdiraji E, Shariatmadar SM. Improving the transient stability of power systems using STATCOM and controlling it by honey bee mating optimization algorithm. International Journal of Smart Electrical Engineering. 2019; 8: 99.
23. Amouzad Mahdiraji E, Ramezani N. Evaluation of the corona phenomenon and grounding system impact on the lightning waves propagation by using EMTP-RV. International Journal of Mechatronics, Electrical and Computer Technology. 2015; 5: 2585.
24. Chukwu UC, Mahajan SM. V2G electric power capacity estimation and ancillary service market evaluation. IEEE Power and Energy Society General Meeting. 2011: 1.

25. Amouzad Mahdiraji E, Mohammadi Shah Kilah S, Hosseini AS. Locating single phase to ground fault in three-phase underground power cables using modal theory and fourier transform. Journal of Organizational Behavior Research. 2018; 3: 2528.
26. Chukwu UC, Mahajan SM. V2G parking lot with PV rooftop for capacity enhancement of a distribution system. IEEE Transactions on Sustainable Energy. 2013; 5: 119.
27. Amouzad Mahdiraji E. Multi-objective optimization of distributed generation despite energy storage systems for optimal management. International Journal of Engineering and Innovative Research. 2022; 4: 44.
28. Amouzad Mahdiraji E, Sedghi Amiri M. Market clearing due to the reliability of electricity generation units. Advanced Journal of Science and Engineering. 2021; 2: 42.
29. Amouzad Mahdiraji E, Sedghi Amiri M, Shariatmadar SM. (2021). Analysis of lightning strikes on the transmission Line by considering the frequency-dependent model. Quantum Journal of Engineering, Science and Technology. 2021; 2: 12.
30. Amouzad Mahdiraji E, Sedghi Amiri M, Shariatmadar SM. Voltage load shedding considering voltage sensitivity and reactive power. Quantum Journal of Engineering, Science and Technology. 2021; 2: 55.
31. Geurts P, Ernst D, We Henkel L. Extremely randomized trees. Machine Learning. 2006; 63: 3.
32. Phan H, Maaß M, Mazur R, Mertins A. Random regression forests for acoustic event detection and classification. IEEE/ACM Transactions on Audio, Speech, and Language Processing. 2014; 23: 20.
33. Amouzad Mahdiraji E, Sedghi Amiri M. Simultaneous compensation of active and reactive power in the power system using grid-connected electric vehicles. Advanced Journal of Science and Engineering. 2022; 3: 35.

- **How to cite this article:** Amouzad Mahdiraji E, Shariatmadar SM. Calculating the power of the charging station of electric vehicles with photovoltaic roof. Advanced Journal of Science and Engineering. 2023; 4: 042013.
- **DOI:** 10.22034/advjse042013
- **Link:** https://sciengpub.com/adv-j-sci-eng/article/view/advjse042013