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Research paper

Proposing a suitable scheduling to use electrical vehicle in micro-grid to decrease cost by using HBB-BC algorithm

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Abstract

Provide a comprehensive plan for the electric vehicles in a micro-grid with regard to network limitations and vehicles as well as economic goals of the utmost importance. In this paper, the Hybrid Big Bang to Big Crunch algorithm has been used to provide scheduling for electric vehicle presence in the network to reduce costs. In order to verify the proposed method, studies in a 24 hour period on a distribution system and in the presence of electric vehicles have been done with real movement patterns. Effectiveness and usefulness of the proposed technique scheduling resources in a 24 hour period on a micro-grid sample tested. The results show that the proposed method of charging / discharging EV can reduce operating costs.

Introduction

In traditional networks, the supply of electric power required by the consumer is produced in a complex manner and at distances far from the consumer, which has caused problems. Among these problems, we can mention the high cost of building power plants and transmission lines at higher capacities, as well as the high losses of this type of networks. Another disadvantage of traditional networks is the low reliability of such networks. Because in the event of an error and the transmission lines are cut, it is possible that a large number of consumers will be without electricity. As a result, to overcome such a problem, more and more attention has been paid to scattered productions.

The use of scattered products for electricity production is one of the ways that is suggested today to supply the power required by the consumer. The limitations of fossil fuels and air pollution are the main incentives for the development of this technology. Generating electricity near the place of consumption, in addition to reducing losses in the system, can provide more flexibility In fact, the micro-grid is a collection of loads and producers that can work as islands or connected to the network. Microgrid manufacturers are generally distributed resource generators due to the low load and nature of the microgrid. These sources can be solar cells, wind turbines, microturbines, batteries, etc. to be One of the important issues in the field of micro-grid is the discussion of power generation costs and environmental pollution caused by micro-grid, which should be addressed with great care.

The use of electric vehicles in the transport system of developed countries has increased rapidly in recent years. So that big automobile companies have a high tendency to mass produce these types of cars. In recent years, a lot of research has been done in the field of rechargeable batteries, which are an important part of electric vehicles. Because these batteries, while providing the energy needed by the car, are considered a suitable place to store electrical energy.

In smart networks, it is tried to manage the charging and discharging schedule of cars according to the network load curve and the difference in electricity prices at different hours of the day and night. This process is such

Doi:

that car charging is mainly pushed to non-peak time and cheap electricity, and part of the energy stored in these sources is sold to the grid during the peak hour of consumption. This action can guarantee the mutual interests of the parties.

The role of electric vehicles in the network

Although electric cars are a suitable option to replace conventional cars, the main concern in using these cars is that if these cars become widespread and connect them to the power grid during peak times, the possibility of disrupting the network's performance and causing Damage to the equipment is provided. Due to the fact that the return time of these cars to the place of residence, due to the end of the office work time, will interfere and coincide with the peak consumption time, this problem will appear.
In the hours when the network load is low and the energy price is low, it is usually better to charge electric cars at night, because in the low hours when the demand is low, some electric energy production units inevitably operate at less than the nominal capacity and some are stopped. .When the amount of production of power plants is less than their optimal production amount, their efficiency also decreases. On the other hand, restarting the stopped units also requires consuming some fuel without generating electrical energy. In addition, the continuous stoppage and start-up of the production units and the change in their production capacity cause wear and tear and reduce the useful life of the equipment and increase the maintenance costs. Also, since the initial investment costs for the construction of production units are very high, using them in less than the rated capacity or using them only in part of the day is not economical from an economic point of view and causes an increase in the total cost of electric energy produced. And the same is true for transmission system equipment. All these factors make the efficiency and efficiency of the system decrease with a sharp reduction in consumption during off-peak hours.
On the other hand, just as the reduction of consumption during off-peak hours creates adverse effects on the network operation, the increase of consumption during peak hours also causes many problems. The low efficiency of electric energy production during peak hours is considered one of the main problems of the electricity industry all over the world. The main reason for this is the low efficiency of power supply units during these hours. (Such as gas units) or are very polluting (such as diesel generators). Due to their lower efficiency, these production units produce and supply power at a higher cost and price, and therefore they are used only during peak hours. Therefore, in power systems, it is tried to reduce the amount of use of such units by increasing the efficiency of the whole system. In this case, if electric vehicles return the energy stored in their batteries to the grid during peak hours, they can largely replace the generation units used during peak hours. In this case, car owners can also make a significant profit by buying energy during off-peak hours when prices are low and selling it during peak hours when prices are high. Also, by using the battery capacity of electric cars, the height and height of the load curve is reduced. For this reason, electric cars can be called controllable load.
In [1] three different scenarios for the charging process of cars Electric has been mentioned, which are:
Instant charging: When the necessary infrastructure to implement the demand response discussion is not available, the consumer does not want to change the charging time of his electric car. Therefore, the consumer charges his car as soon as he gets home from work. Ironically, the time period of returning home has been adapted to pick-up time and this factor has caused the increase of pick-up time.
Time-delayed charging: A cheap and simple solution to delay the charging of car batteries is to use a timer to turn on the car when the consumer returns home, but start the charging process with a time delay set by The timer is set to change from peak hours to non-peak hours.It is mentioned in [1] that the efficiency of this method increases when consumers do not consider the same delay time for charging their car.
Charging with the management of the fleet operator: in the last scenario, the fleet operator or aggregator is responsible for determining how to charge the cars. The car owner's wishes for how to charge his vehicle's battery are taken into account through the provisions of the contract he has concluded with the fleet operator or aggregator. Whenever the car is connected to the network, the aggregator considers a charging schedule for the car that starts from the time of connection and continues until the estimated time of disconnection from the network.

Vehicle to network technology (V2G)

Currently, power grids have very little storage systems, and for this reason, matching production and consumption in them requires permanent management and control of electrical energy generating units. On the other hand, studies have shown that in general, cars are used for transportation in only 4% of the time of a day and are left unused in 96% of the hours of the day. With a little precision, it can be seen that with the increase in the number of electric cars in the coming years, the batteries of these cars can provide a powerful storage system with high availability for the power grid. In this way, an unused capital can act as an active element in the network and provide the energy stored in its battery to the network.What causes electric cars to receive special attention is the concept of car technology to the V2G network. The V2G concept is initially related to two large and independent systems, the power generation system and the transportation system. This concept is completed through two-way communication between these two systems in the smart network environment. In other words, V2G means that electric cars have the ability to pass power from the grid to the cars during charging and transfer power from the cars to the grid when these cars are used as storage.

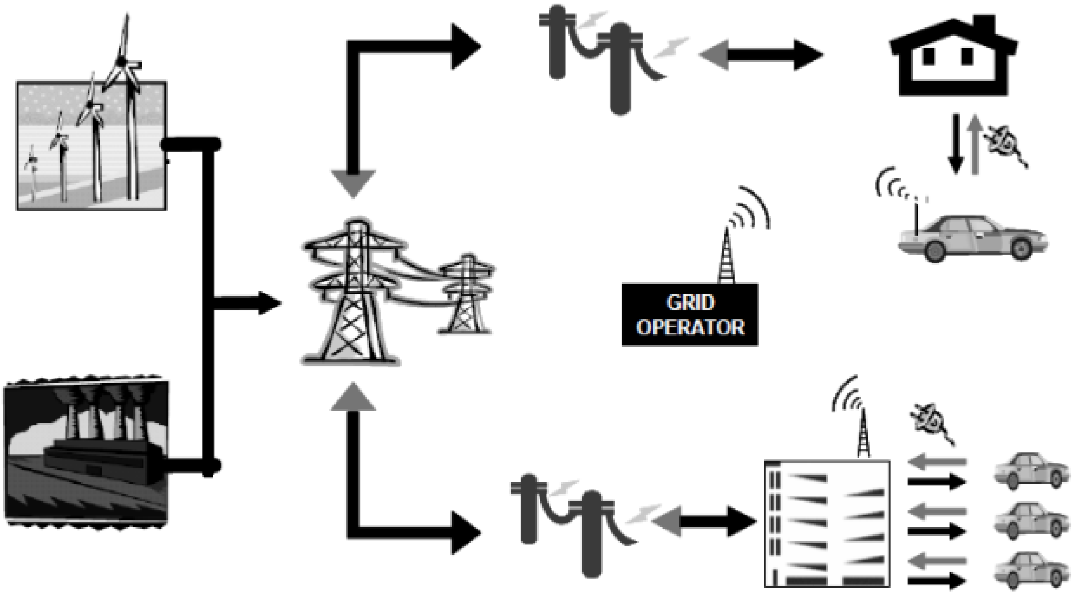

Fig. 1: Concept of car to network.

After the introduction of electric and hybrid cars, which were only able to receive electricity from the network, by making simple changes in the power circuits of these cars, a conventional design for electric cars with the ability to connect to the V2G network was proposed. In a way that enabled them to transfer the energy stored in their battery to the network when parking [2]. Therefore, V2G can have a two-way exchange with the network, thus creating many opportunities and suitable situations that increase efficiency and reliability [3]. The electrical network must collect information to create two-way power and power-related data between network components and consumers, which requires the provision of charging and discharging infrastructure. The result of this complexity in the transfer of data and energy is the need to expand the standards of each part of the valuable V2G chain. These standards include physical infrastructure along with virtual standards that include communication, data security, convenience and information transfer among stakeholders one of the most important infrastructures required for the V2G system is fast car charging and discharging stations, which require the use of new technologies for their production. These stations must have the capability of two-way connection to the network and be designed and built in accordance with the requirements and standards of operating companies in the field of electricity supply. Another category of infrastructure is related to smart grid communication and measurement requirements. To launch V2G with all the functions and benefits that were discussed before, we need a smart network to manage and control the charging and discharging of cars. Setting up the smart grid itself requires smart measurements and telecommunication systems. Telecommunication systems in smart network considering electric cars can be formed in two ways: PLC and wireless. When cars are parked, they are considered an unused capital and it is not even possible to impose costs such as parking fees. V2G is a concept designed to exploit this unused capital [5]. Each V2G has a converter and a battery, and the structure of each V2G can be considered as follows:

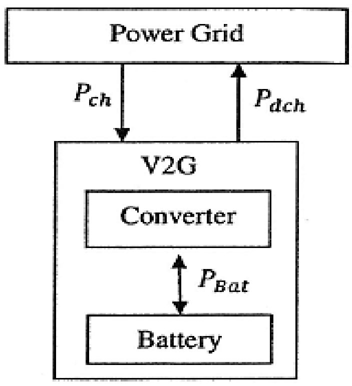

Fig. 2: Internal structure of V2G

The power transaction between V2G and network described as follows:

$$PCh=\frac{PBat}{\eta c} \quad (1)$$

$$Pdch = pBat * \eta d$$

PBat is the amount of power that V2G can deliver to or receive from the converter. It charges the battery with efficiency ɳc and delivers the battery power to the grid with efficiency ɳd. Equation (1) shows that if ɳc and ɳd are not the same, V2G must purchase more power than it stores to charge its battery, while the power it delivers to the network is less than the power stored in the battery. Therefore, the closer ɳc and ɳd are to one, the more profit the V2G owner gets from using his battery capacity [7].

Modeling the problem of power generation and storage management

In this section, the mathematical relations of the problem of renewable energy management are described. The renewable energy management problem is a mixed integer non-linear programming problem. The operating cost of the entire smart network, in which a large number of distributed productions and electric vehicles are integrated, is modeled as the following function, should be minimized. The cost objective function is described as follows.

$$F^{cost} = \sum_{t=1}^{T} [P_{grid}(t) \times \Omega(t) + \sum_{i=1}^{I} U_i\ (t) \times P_{Gi}(t) \times B_{Gi}\ (t) + SG_i\ (U_i\ (t) - U_i\ (t-1) + \sum_{v=1}^{Nv} P_{EV}(v,t) \times \Omega(t)\ ] \quad (2)$$

P_grid(t) and Ω(t) represent, respectively, the active power purchased from the main grid and the electricity price in the hours of the day during period t. I is the number of distributed generators; PGi and BGi are, respectively, the amount of power generated by distributed generators in kilowatts and the price of electricity generated by distributed generators. SGi is the startup cost of distributed generators in time period t.

N_v is the number of electric vehicles. P_EV^(v,t) is the power of vehicle v at time t. In this study, the time period t is considered to be one hour. If a vehicle is charging, it is considered a load on the network and increases the cost function; if the vehicle is discharging, it is entered with a negative sign and reduces the objective function.

Constraints:

A. Load Balance

$$P_{grid}\ (t) + \sum_{i=1}^{I} P_G\ (i,t) + \sum_{v=1}^{N_v} P_{EV}^{Dch}\ (v,t) = D_t + \sum_{v=1}^{N_v} P_{EV}^{ch}\ (v,t) \quad (3)$$

$P_{EV}^{ch}(v,t)$, $P_{EV}^{Dch}(v,t)$ represent, respectively, the charging and discharging power of vehicle v in time period t, and D_t is the total active power demand at time t.

B. Capacity of active power

The output power that comes out of any distributed production is within the limit between the minimum and maximum defined production power. Also, every hour, the power of the main network does not exceed the defined minimum and maximum [8].

$$P_{Gi,min}(t) \le P_{Gi}(t) \le P_{Gi,max}\ (t) \quad (4)$$
$$P_{grid,min}\ (t) \le P_{grid}\ (t) \le P_{grid.max}\ (t)$$

$P_{Gi,min}(t)$ و $P_{grid,min}(t)$ are, respectively, the minimum active power of distributed generation and network at time t, which can be injected into the desired network. Similarly, ⍰ and ⍰ are the maximum active power i of the generation and network at hour t. They cannot inject more than this amount into the target network in one hour.

C. Constraints of electric vehicles:

Electric vehicle batteries are not charged and discharged at the same time.

$$X(\nu,t)+Y(\nu,t) \le 1 \quad \forall t \in \{1,\ldots\ldots,T\} \quad (5)$$
$$X,Y \in \{0,1\} \forall \nu \in \{1,\ldots..N_\upsilon\}$$

X(,t) and Y(t) show the binary variables related to car , the state of discharge and charge of power in a period of time. There must be energy balance in the battery of every electric vehicle. In the state of ES flux $ES(\nu, t)$ is the energy stored in the car battery until the end of period t.

$$E_S\ (\upsilon,t) = E_S\ (\upsilon, t-1) + \eta_\upsilon^C \times P_{EV}^{ch}(\upsilon,t) - E_{trip}^{\upsilon,t} - \frac{1}{\eta_\upsilon^D} \times P_{EV}^{Dch}(\upsilon,t) \quad (6)$$
$$\forall t \in \{1,\ldots\ldots,T\} \forall \upsilon \in \{1,\ldots\ldots,N_\upsilon\}$$

η_υ^C وη_υ^D are the charging and discharging efficiency for the car, respectively. During charging and discharging, we have losses to this defined amount. The range of charging and discharging for each electric vehicle according to the charging and discharging rate of the battery is as follows [8].

$$P_{EV}^{Dch}(v,t) \le P_{Dch,v}^{Max} \times X(v,t)$$
$$P_{EV}^{ch}(v,t) \le P_{ch,v}^{Max} \times Y(v,t) \forall t \in \{1,\dots\dots,T\} \forall \upsilon \in \{1,\dots\dots,N_{\upsilon}\} \quad (7)$$

$P_{Dch,v}^{Max}$ و $P_{ch,v}^{Max}$ are the maximum discharge and charge power of the electric car.

In order to prevent damage to the battery in electric cars, it is possible to discharge to the minimum level (ψ_{υ}^{min}) and charge to the maximum level (ψ_{υ}^{max}).

$$E_S(\upsilon,t) \le \psi_{\upsilon}^{max} \quad (8)$$
$$E_S(\upsilon,t) \ge \psi_{\upsilon}^{min}$$
$$\forall t \in \{1,\dots\dots,T\} \forall \upsilon \in \{1,\dots\dots,N_{\upsilon}\}$$

ψ_{υ}^{min} و ψ_{υ}^{max} depend on the range of battery capacity for each electric vehicle and are calculated as the following relationship.

$$\psi_{\upsilon}^{max} = \emptyset_{v}^{max} \times E_{Bat,v}^{max} \quad (9)$$
$$\psi_{\upsilon}^{min} = \emptyset_{v}^{min} \times E_{Bat,v}^{max}$$
$$\forall \upsilon \in \{1,\dots\dots,N_{\upsilon}\}$$

$E_{Bat,v}^{max}$ provides the energy needed for movement [8]. $\emptyset_{v}^{max}$ و $\emptyset_{v}^{min}$represent the maximum and minimum battery capacity of electric vehicle v, expressed as a percentage. The energy stored in the electric vehicle's battery at the last connection to the grid before departure must be sufficient to meet the energy requirements for the journey [8].

Hybrid Big Bang-Big Crunch algorithm

The BB-BC algorithm was first proposed in 2006 by Erol and Eksin [9]. This algorithm is inspired by the phenomenon of how the universe begins and ends, called the big bang in the universe, which is related to the creation of the world, and the great contraction or great destruction, which is related to the collapsing of the universe and the end of its life. The BBBC algorithm consists of two stages and is similar to other evolutionary algorithms in terms of generating the initial population.

The first population generation stage is called Big Bang, in which the population is spread randomly and uniformly over the entire search space. After that, it is time for the Big Crunch phase, which is actually a converging operator [10].This operator with a large number of inputs has only one output, which is called the center of mass and is calculated by the following relationship:

$$X_i^{(k)} = \frac{\sum_{j=1}^{N} \frac{x_i^{(k,j)}}{f_j}}{\sum_{j=1}^{N} \frac{1}{f_j}}, \quad i=1, 2, 3\dots c \quad (11)$$

where $X_i^{(k)}$ ، is the i-th component of the center of gravity in the kth iteration, and is the i-th component of the j-th particle produced in the kth iteration. The objective function value of point j and n are the number of points or particles and c is the number of control variables.

But in the proposed HBB-BC algorithm, by using the capabilities of the particle consensus algorithm (PSO), the search capability of the BB-BC algorithm is improved and it prevents getting trapped in local optimal points. In the HBB-BC algorithm, like the PSO algorithm, local optimal points and global optimal points are used to generate new points [11].

$$X_i^{(k+1,j)} = \alpha_2 X_i^{(k)} + (1+\alpha_2)\left(\alpha_3 X_i^{gbest(k)} + (1-\alpha_3) X_i^{pbest(k,j)}\right) + \frac{r_j \alpha_1 (X_{imax} - X_{imin})}{K+1} \quad (12)$$

In relation (12), $A_i^{pbest(k,j)}$ is the best location of the jth particle up to the kth iteration and is the best overall location up to the kth iteration. Coefficients and are adjustable parameters that control the effect of local and global optimal points. The flowchart of HBB-BC algorithm is shown in figure (3).

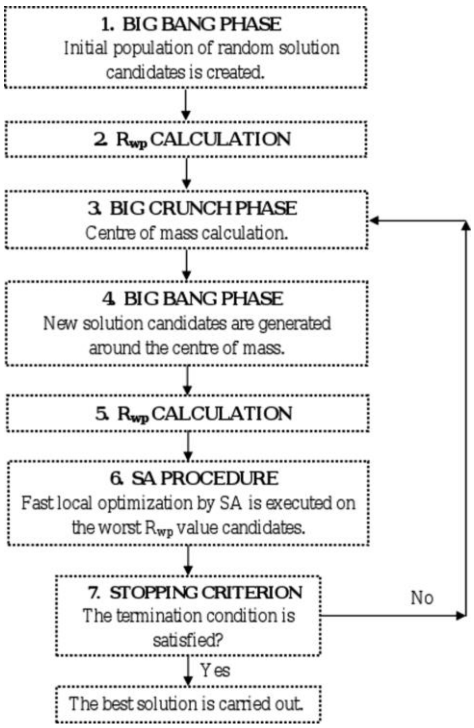

Fig. 3: General flow chart of HBB-BC optimization algorithm

Simulation results

The studied microgrid is shown in Figure (4). This microgrid includes the main grid and ten scattered productions, including two photovoltaic (PV) systems, two fuel cells (PAFC), four microturbines (MT), four wind turbines (WT) and also, at times, electric vehicles that supply the energy needed by consumers.
The load curve can be seen in Figure (5) and also the price of energy in different hours is shown in Figure (6). According to the load curve, the peak consumption is equal to 5072 kW. In this network, the price of electricity is not the same in different hours, it is cheap in off-peak hours and high in peak hours. The use of multi-rate electricity prices is due to the encouragement of consumers and producers to reduce consumption during peak hours and increase production.

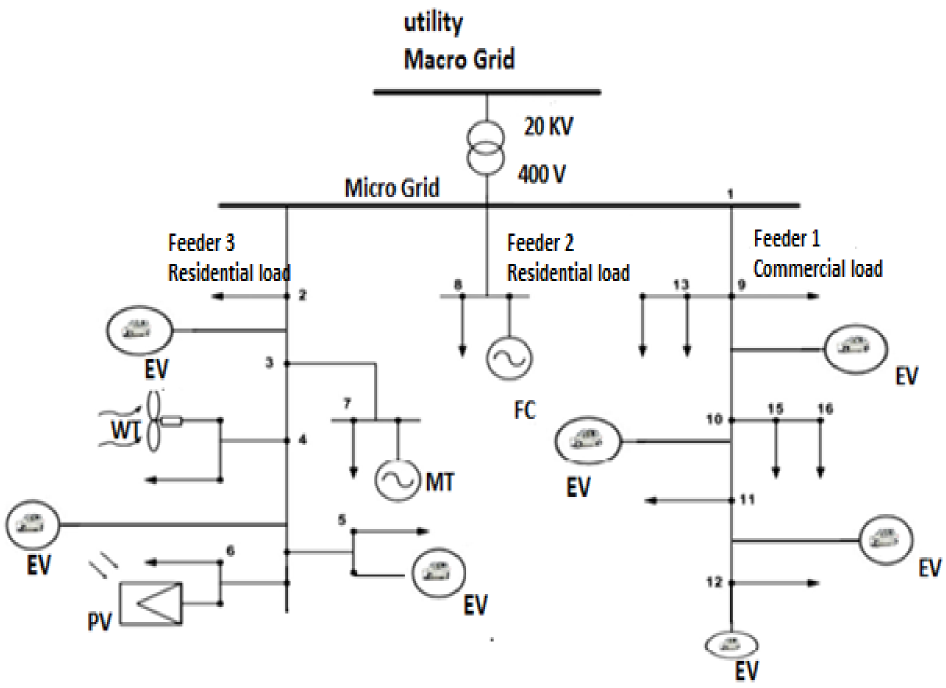

Fig. 4: Case study

Figure 5 shows the load curve, and Figure 6 shows the electricity price at different hours. According to the load curve, peak demand is 5072 kW. The electricity price in this network is time-varying; it's cheaper during off-peak hours and more expensive during peak hours. The use of time-of-use pricing is intended to incentivize both consumers and producers to reduce consumption during peak times and increase generation during off-peak times.

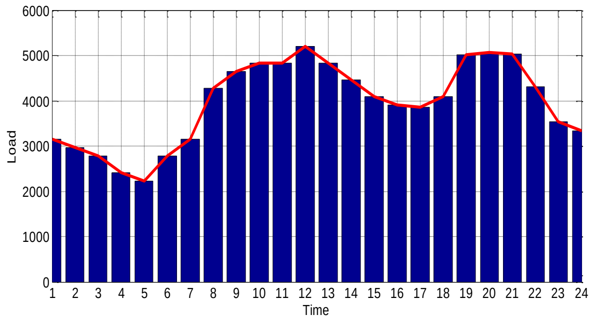

Fig. 5: of the total electric load curve in the studied network

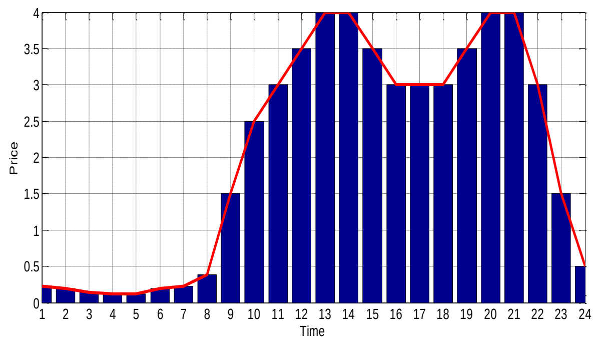

Fig. 6: energy price curve in 24 hours [8]

Wind turbines (WT) and photovoltaic systems (PV) cannot produce constant power during all hours of the day and night. Figure (7) shows the power generation curve by wind turbine and Figure (8) shows the power generation curve by photovoltaic system. Figure 7. The power produced by the wind turbine [8].

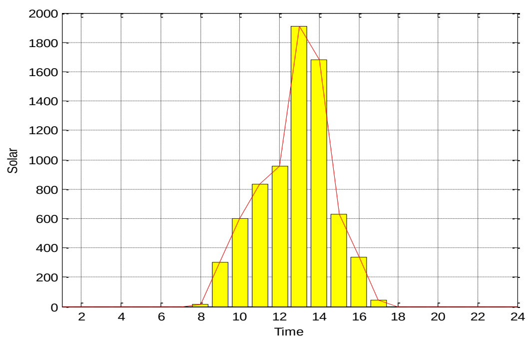

Fig. 8: Power produced by the photovoltaic system [8]

In this network, 1000 electric cars are used, which are divided into seven groups based on the same conditions of the car owners] 13. [In the performed simulation, the car connection in the network is represented by the number one, the absence of cars in the network with the purpose of movement is represented by the number Zero and number two are considered for standby mode. The stand-by mode is the mode in which the vehicles are not connected to the monitored network and are also not moving (does not participate in charging and discharging). Table (1) shows the presence and absence of electric vehicles in the network.

Table 1: presence and absence of electric vehicles in the network

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

Table 1. The presence and absence of electric doors in the network Paying attention to the information about the number of electric cars and the time of connection to the grid, in this article it is assumed that the owners of electric cars move at a constant speed and each car consumes an average of three kilowatts of power per hour. A point that should be taken into account when examining smart

networks despite electric cars is the energy stored in the car battery in order to cover the travel distance, which should be sufficient. In this article, we have studied the Nissan car with a capacity of 24 kW and used the characteristics of these cars.
For scattered productions and different groups of electric vehicles, the maximum and minimum ranges of power changes per hour are given in table (2).

Table 2: maximum and minimum ranges of power changes per hour

Min	Max	DG
200	1000	MT
200	1000	PAFC
0	2000	PV
0	2000	WT
-800	800	**EV1**
-800	800	**EV2**
-400	400	**EV3**
-800	800	**EV4**
-600	600	**EV5**
-400	400	**EV6**
-200	200	**EV7**
-10000	10000	**Network**

The charging and discharging limits for each group of electric vehicles have been defined. Positive values in Table 2 indicate the power that vehicles can receive while charging, and negative values indicate the power that vehicles can deliver while discharging. The positive and negative limits for the main grid are set to allow for the purchase of power from the studied network.
To increase battery lifespan, electric vehicles should maintain a minimum charge of 15% and a maximum charge of 90% during discharge. Hourly checks are required to ensure that if vehicles are acting as power providers (discharging), their power output does not fall below the minimum limit defined in Table 3 for each group. Conversely, if vehicles are consuming power (charging), their power intake should not exceed the maximum limit defined in Table 4 for each group. These limits were chosen based on the number of vehicles in each group, battery type, and charging/discharging efficiency.

Table 3. Min and Max of battery

EV7	EV6	EV5	EV4	Ev3	Ev2	Ev1	
1080	2160	3240	4320	2160	4320	4320	Max
120	240	360	480	240	480	480	Min

Table 4. Cost of generation and operation

	MT	PAFC	PV	WT
Cost of generation	0/457	0/295	2/584	1/073
Cost of operation	0/96	1/65	0	0

After presenting the appropriate pattern of charging and discharging cars by HBB BC algorithm, the results have been recorded. Figure (9) is related to the total cost of the desired network in the state without considering the car and with the car in mind. The corresponding red line curve is the energy level of the network without considering the car and the blue line curve is related to the energy cost in the state with the car. In the diagram below, the negative value represents the profit for the owners of electric cars. In hours 1 to 5, the curve of the blue line is higher than the curve of the red line, which means that despite the electric cars, the cost has increased. Because in these hours, in addition to providing the power needed by the consumer, we also have to charge the cars, and this will require paying more. It can be seen in the graph below that the red dashed curve is higher than the blue curve in the peak hours of consumption, i.e. 11:00 to 16:00.This means that with the addition of electric cars to the desired network, electric cars provide a part of the energy needed by the consumer, and electric cars act as a producer. Between 16:00 and 22:00, the energy cost has increased despite electric cars compared to the energy cost without electric cars. This means that electric cars do not have enough power to discharge. They usually act as consumers. At 23:00 and 24:00, due to the low price of electricity, electric cars are charged and act as consumers.

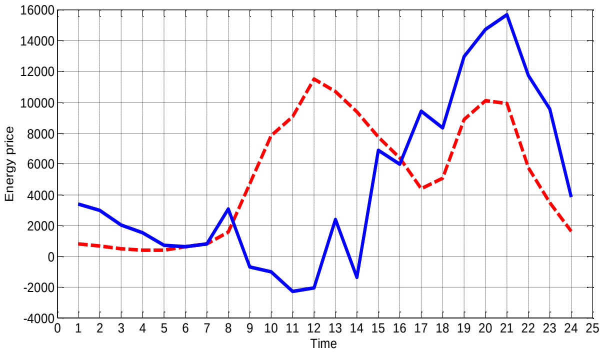

Fig.9: Comparison of network energy cost despite electric car and without electric car

The total cost of electric energy in 24 hours for each group of cars is shown in Table 5.From the positive values, it can be concluded that the cost of cars is more than the income, charging and discharging are not done optimally at different hours, and this group of cars is not economical. Negative values mean that the income from the sale of electricity is more than the cost of the car. It can be said that charging and discharging have been done correctly and the most optimal results have been achieved.

Table 5. Total cost for each EVs

Type of EV	Cost
EV1	-2672/05
EV2	-2032/04
EV3	-372/64
EV4	-3082/51
EV5	-1312/27
EV6	-2420/70
EV7	247/80

The total electricity cost for the studied network, with the inclusion of electric vehicles, is calculated to be 42,116.44 monetary units (the specific currency is not mentioned). This indicates a reduction in overall cost compared to a scenario without electric vehicles. Therefore, the vehicle owners benefit from this arrangement. Figure 10 shows the power exchanged with the grid.

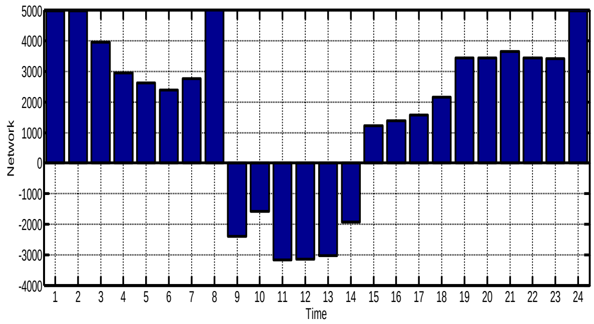

Fig. 10: power exchanged with the grid

Based on the definition provided, the main grid has the capacity to both inject and draw power from the studied network. Between hours 1 and 8, due to the low electricity price, the main grid acts as a power injector. Between hours 9 and 14, the negative values in the graph indicate that the main grid not only fails to inject power but actually draws power from the studied network. From hours 15 to 24, the main grid again acts as a power injector. Figure 11 shows the power output of each generator for each hour.

Author Contributions

Each author role in the research participation must be mentioned clearly.

Example:

J. Safaei designed the experiments, collected the data, carried out the data analysis and interpreted the results and wrote the manuscript.

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Conflict of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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