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MICRO-GRID OPERATION CONSIDERING THE UNCERTAINTIES RELATED TO THE ELECTRIC VEHICLE PARKING DECK

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ABSTRACT

Micro Grid known as the building blocks of Smart Grid is the small-scale distribution network with at least one DER and one load with clearly defined electrical and geographical boundaries. Inherent merits of MG cause that DER penetration in the network increases considerably. New trends of EVs with two-way power flows, considering the variability of time, location and amount of charge, has introduced varies challenges and opportunities for power system which causes that, proper management and operation is required to the merits of EVs. On the other hand, high penetration of renewable energies in smart distribution network with uncertainties, adds to the complexity of network operation. In this regards, in this thesis, optimal operation of MG in the presence of EVs uncertainty and also uncertainties of photovoltaic as a dominant distributed generation, is aimed. The proposed scheme aims to supply the consumers demand in possible lowest costs and simultaneously preserving network constraints. In the proposed scheme, Genetic Algorithm as an efficient tool is used to find the optimum solutions. In order to clarify the effectiveness, the proposed scheme and to show the accuracy of the results, simulation studied is done on a sample MG and the results are discussed.

1. INTRODUCTION

Smart grid of electrical energy distribution is one of the last technologies in the world today. Its main purpose is to secure the subscriber's energy as well as to meet the growing needs of the customer, taking into account the environmental issues. The world's first smart grid was introduced in March 2008. Smart technology is capable of making major changes in the generation, transmission, distribution and usage of electrical energy, along with economic and environmental benefits that ultimately end in customers' needs and ensure the availability of reliable and stable electricity. On the other hand, the system also determines the collect data using in tentative situations [1]. Micro-grids [MG] are small distribution systems that connect a group of electrical customers to a numerous

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distributed generation sources and energy storage units, which in some cases are interconnected by power electronic converters [2]. Micro-grids has to be known as a minimal network of distributed energy sources that feed a group of distributed charge into network or separate from the network. Nowadays, the concept of micro-grids [MG] has become a key issue in smart networks since to require a systematic approach to its optimal structure. According to the standard of huge distribution systems has to be divided into a number of small networks so that their control becomes easier and operational infra-structures can be provided for the future networks. Therefore, a new discourse, titled with "Multi-grid", can be considered from different perspectives such as reliability, security, impact of energy sources, energy storage units, and various compensators [3]. Each micro-grid can be connected to the network so that it can be freely exchanged with high-power network. Likewise, in case of emergencies (such as the upstream error), the grid can be exploited independently of the upper-handed network (Island Shape) [4], in which case it exclusively rely on its resources to supply and counterbalance between reliability and Power quality. The future power system will be potentially need components such as energy-saving sources to achieve its goals (such as higher reliability, higher security, etc.). Energy savers will play a key role in upcoming networks for balancing production and consumption. In nutshell, it has to be said that the main task of this energy storage facility is to generate in surplus periods and deliver the energy at peak times. The benefits of using energy storage devices can also be referred to frequency adjustment capability and reducing energy congestion in the lines [5]. In addition to batteries, electric car reserves are also considered as energy storage. V2G is a new concept for energy storage, which allows bilateral power charge to electric vehicles [6]. With an appropriate and optimal utilization of electric vehicles as a reservoir and charge in the power system, the aim of reducing biofuels contaminant can also be achieved. Regarding the current policy of reducing CO_2 contamination, it seems necessary to pay attention to scenarios for achieving a clean and secure power system for the future of Japan. The purpose of the reference [7] is to quantify the technical, economic, and environmental impacts of diverse function supply options and estimate the future electric demands of Japan. In reference [8], a statistical optimization algorithm approach is proposed to coordinate the charging of electric vehicles with a view to maximum usage of renewable energy sources in supply-side of transport district demands. The uncertainty of renewable energy sources has entered into modeling. Few studies have introduced various tools for integrating renewable energy sources into the power system. Reference [9] is an optimization approach to a power system development in Brazil which will be able to achieve a high volume of variable supply of wind resources generated from wind farms that will be installed. The expected combination of wind resource development with conventional power stations, including nuclear and hydroelectric power station, will put a lot of risk on the balance of generation and consumption power. Therefore, in order to overcome the problem, the potential of electric vehicles with V2G capabilities will be used. The integration of electric vehicles and renewable energy sources into the power system provides a variety of challenges and opportunities. The security risks and reliability of the power system are caused by the inherent nature of the renewable energy and uncontrolled electric charging. Reference [10] is proposed for the management of micro-grid energy resources.

The addition of the transport sector to the electric grids has also created numerous challenges in planning and exploiting the grid [11-12] V2G is a term used for saved energy technology stored in the battery of electric vehicles with the capability of network connection is used to supply power to the grid. Electric vehicles usage, especially V2G-capable vehicles, brings with it several benefits: reducing CO_2 pollution and picking up at low charge times by increasing intake and picking up at peak times by discharging V2G batteries[13-14]. V2G is a term used to power the grid for energy-saving technology in battery-operated electric vehicles with grid connectivity. The use of electric vehicles, especially V2G-capable vehicles, brings with it several benefits: reducing pollution and picking up at low load times with increased consumption and pickup at peak times by discharging V2G batteries [13-14].

In [15], the concept of smart parking is proposed for electric vehicles and is a model for managing energy resources in a micro-grid that has smart parking lots [16], in the next day's energy management for generation resources in the micro-grid are modeled in the form of a two-stage probable plan [17], using probable methods have been analyzing the optimization of the distributed products combination and electric vehicles with the improvement of reliability of the micro-grid. In this study, the optimal utilization of the micro-grid, in the face of the uncertainty of electric vehicles as well as the uncertainty of photovoltaic sources, has been targeted as a predominant source and small-scale energy generation source.

2. MATERIALS AND METHODS

The vehicles used in this study are all capable of bilateral power exchange with the grid as specified in the table below (Table 1).

Table 1: Types of vehicles used in this study

No.	Battery capacity(kW)	Charge rate(kW)
1	8.7	3
2	28.5	3
3	23	3
4	85.3	10
5	8.2	3
6	8.2	3
7	46.9	3
8	46.9	3

The number of vehicles based on each parking lot depends on the distribution network, which is the host of the parking lot. It is clear that each vehicle at the time of entering the parking lot has a certain level of charge, and the vehicle owner expects the vehicle extant charging level reach to a certain amount at the time of departure, which will require further travel. Therefore, the management of charging / discharging the vehicle during parking time should be such as to meet the needs of vehicle owners. In addition, for longer battery life, the battery charge level should not be lower than a certain amount. The charging / discharging process of the battery is as follows (equations 1-23):

$$SOC(\text{h}) = \eta_{ch} \times P_{ch}(h) - \frac{P_{disch}(h)}{\eta_{disch}} + SOC(h-1) \qquad (1)$$

Where the charge level at *t* time is shown in $SOC(h)$ based on (kW). Each battery is in one charge, discharged or neutral mode every hour. $P_{ch}(h)$ Charge rate of the battery (+) and the $P_{disch}(h)$ discharge rate (-) are both in (kWh). Due to the use of power electronics in charging equipment, the charge and discharge efficiency is equal and considered with η_{ch} and η_{disch}, respectively.

The constraint to be met in the charging / discharging process is as follows:

Charging / discharging of the car are limited to a maximum ($P_{ch,\max}$ and $P_{disch,\max}$):

$$0 \le P_{ch}(h) \le P_{ch,\max} \tag{2}$$

$$0 \le P_{disch}(h) \le P_{disch,\max} \tag{3}$$

The amount of charge should be in such way that the energy stored in the battery does not exceed the battery capacity ($EV_{SOC\min}$):

$$0 \le P_{ch}(h) \le \frac{EV_{BC} - SOC(h-1)}{\eta_{ch}} \tag{4}$$

As stated above, the charge in the battery should always be of a minimum value ($EV_{SOC\min}$):

$$0 \le P_{disch}(h) \le \left[SOC(h-1) - EV_{SOC\min}\right] \times \eta_{disch} \tag{5}$$

2.1 PARKING UNCERTAINTY MODELING

The first parameter that is considered for vehicle charging time is the probable driving distance. Normal logarithmic distribution (M_d) is proposed to produce a possible daily driving distance. Normal logarithmic variables are generated by the normal distribution of standard N and are calculated by the relationship of M_d.

So that N is the normal value of the standard, while U_1 and U_2 the independent values are distributed uniformly over the interval (0, 1). The μ_m and σ_m are normal logarithmic distribution parameters and compute the mean values and the M_d standard deviations proportional with the statistical information, which is specified in μ_m and σ_m.

$$\mu_m = \ln\left(\frac{\mu^2_{md}}{\sqrt{\mu_{md}^2 + \sigma_{md}^2}}\right) \tag{6}$$

$$\sigma_m = \sqrt{\ln\left(1 + \frac{\sigma_{md}^2}{\mu_{md}^2}\right)} \tag{7}$$

The in μ_m and σ_m derived from the statistics information of the vehicle's driving distance which are estimated to be approximately 30 and 40 miles. The second parameter that is effective in vehicle performance is the energy consumption per mile.

In such a way that a and β are fixed values that depend on the type of vehicle and k_{EV} is the ratio of the total input energy provided by the battery. In this study, due to the focus on electric vehicle demand, the k_{EV} value is considered equal to one. The maximum driving distance for the vehicle is when the battery is fully charged and calculated as follows:

$$M_{d\ \max} = \frac{BCAP}{E_m} \quad (8).$$

$BCAP$ has the highest capacity of the battery. Now, the demand for energy required by the vehicle (E_{demand}) is calculated as

$$E_{demand} = \begin{cases} BCAP; & M_d \geq M_{d\ \max} \\ M_d . E_m; & M_d < M_{d\ \max} \end{cases} \quad (9).$$

The third parameter is the expected time of charging based on charging rate, battery capacity, and the time of arrival and departure. In order to modeling the arrival and departure time, normal distribution is used as the best common household behavior estimation. The following formula is used for this purpose:

$$t_{arrival} = \mu_{arrival} + \sigma_{arrival} . N_1 \quad (10)$$

$$t_{departure} = \mu_{departure} + \sigma_{departure} . N_2 \quad (11)$$

In such a way that the N_1 and N_2 random variables are obtained from the above relations, $\sigma_{arrival}$ and $\mu_{arrival}$ the mean and standard deviation of arrival time are based on statistical information $\sigma_{departure}$ and $\mu_{departure}$ average data and the standard deviation of departure time are based on statistical information. The parameters mentioned, $t_{arrival}$ and $t_{departure}$ should be valuable in $t_{departure} > t_{arrival}$. After the above quantities are determined, the probable duration of charge is calculated:

$$t_{duration} = t_{departure} - t_{arrival} \quad (12)$$

Now, the optimal charging status is obtained from the following equation:

$$SOC_{desired} = Min\left\{\left[SOC_{init} + \frac{E_{demand}}{BCAP}\right], \left[SOC_{init} + \frac{t_{duration} . chr}{BCAP}\right]\right\} \quad (13)$$

Based on the above parameters, the probabilistic parking model is obtained by using the probable model of each vehicle.

3. PROBLEM MODELING

Given the uncertainties caused by the parking of electric vehicles, the production of photovoltaic sources, the load and price demand, the proposed target function will be as follows:

$$Minimize \sum_{i=1}^{N_{Scen}} Prob_i \sum_{t=1}^{24} (C_{DG\_Op}(t) + C_{Parking\_Op}(t) + C_{Loss}(t) + C_{TransCo}(t)) \quad (13)$$

N_{Scen}: Number of scenarios (multiplication of scenarios of solar production in the number of load demand scenarios)

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$Prob_i$: The probability of occurrence of the scenario i (probable multiplication of the scenario of solar production in the probability of the load demand scenario)

It is clear that $N_{Scen} = N_D \times N_S$, that N_{LD} is the number of scenarios for grid load demand and N_{PV} is the number of scenarios for the production of solar solar power-station? The probability of occurrence of *i*-th scenario is as

$$Prob_i = Prob_{LD_j} \times Prob_{PV_k},$$

$Prob_{LD_j}$: The probability of scenario *j* of grid load demand

$Prob_{PV_k}$: The probability of scenario *k* the production of solar solar power station.

3.1 COST OF LOSS(C_{Loss})

Distribution network is known for having a high R / X ratio compared to the transmission network. This high ratio leads to significant voltage losses and noticeable damage throughout the distribution grid. For this reason, the reduction of losses should be considered seriously in the operation of the distribution system.

$$C_{Loss}(t) = c_{Loss}(t) \times \sum_k I_{(k)}^2 \times R_{(k)} \tag{14}$$

3.2 PURCHASE ENERGY FROM THE UPSTREAM GRID ($C_{TransCo}$)

The goal of distribution network is to provide consumers with the lowest possible cost and contract quality. Part of the power flow in the grid is consumed by subscribers, and the other part is wasted as loss of line and equipment. Part of the power purchased by the virtual power station is from the upstream grid, and remain part is supplied through the distributed generation resources which is installed on the grid. It should be noted that the presence of dispersed production sources in the consumption centers reduces the dependence of the distribution network on the upstream network. The power required for distribution network and its cost are specified in the following.

$$PM(t) = PD(t) + P_{Loss}(t) - P_{DG}(t) \tag{15}$$

$$C_{TransCo}(t) = PM(t) \times EP\ (t) \tag{16}$$

3.3 COST OF EXPLOITING DISTRIBUTED ENERGY RESOURCES

Cost of exploiting distributed energy resources [DER] (C_{DG_Op}) and ($C_{Parking\_Op}$)

$$C_{DG\_Op}(t) = \sum_n C_{Op-DG} P_{DG(n)}(t) \tag{17}$$

$$C_{Parking\_Op}(t) = C_{Op-Parking}(P_{ch\ \ Parking}(t) + P_{Disch\ \ Parking}(t)) \tag{18}$$

3.4 NETWORK STUDIED

In order to prove the efficiency and effectiveness of the proposed method and the accuracy of the results, computer simulation has been performed on a sample micro-grid [MG]. The information on the network is shown in Table 2. It should be noted that in the table below, the numerical values of the load demand for the courier are presented (Figure 1; Table 3). To underlying the uncertainty effect in this issue, load modeling in this network has been carried out for 24 hours a day; therefore, demand for each hour is presented in Table 4.

Table 2: Network Information 13 Radial Bus

Line No	Send Bus	Receive Bus	R (ohm)	X (ohm)	P (kW)	Q (kVar)
1	1	2	0.176	0.138	890	468
2	2	3	0.176	0.138	628	470
3	3	4	0.045	0.035	1112	764
4	4	5	0.089	0.069	636	378
5	5	6	0.045	0.035	474	344
6	5	7	0.116	0.091	1342	1078
7	7	8	0.073	0.073	920	292
8	8	9	0.074	0.058	766	498
9	8	10	0.093	0.093	662	480
10	7	11	0.063	0.05	690	186
11	11	12	0.068	0.053	1292	554
12	7	13	0.062	0.053	1124	480

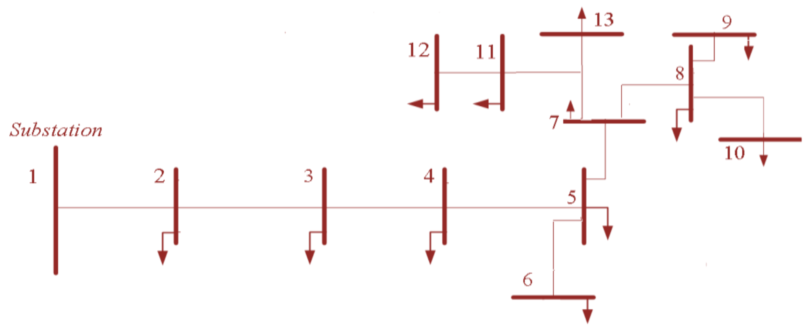


Figure 1: The structure of the micro-grid studied

Table 3: The location and capacity of distributed production resources connected to the network as well as parking of electric vehicles

Definite distributed resources of generation	Site (Bus No.)	4	7
	Size (kW)	1000	500
Photovoltaic distributed resources	Site (Bus No.)	6	11
	Size (kW)	100	200
Electric vehicle parking	Site (Bus No.)	13	
	Size (No. of EVs)	1000	

Table 4: Load demand for different scenarios (percentage of peak load)

Time	1	2	3	4	5	6	7	8	9	10	11	12
Load_1	0.61	0.53	0.49	0.45	0.49	0.53	0.62	0.72	0.86	0.88	0.85	0.75
Load_2	0.56	0.54	0.51	0.5	0.52	0.55	0.64	0.69	0.9	0.86	0.78	0.71
Time	13	14	15	16	17	18	19	20	21	22	23	24
Load_1	0.64	0.61	0.6	0.6	0.63	0.71	0.86	1	0.96	0.87	0.74	0.61
Load_2	0.68	0.65	0.64	0.64	0.67	0.73	0.91	1	0.93	0.86	0.78	0.71

It is clear that the micro-grid has a high influence on solar power resources. Therefore, the uncertainty of these resources should also be included in the modeling. For this purpose, the amount of hourly generation of solar power resources, as a percentage of the installed capacity, is presented in the following table (Table 5). Table 6, energy prices vary from day to day.

Table 5: Hourly generation of photovoltaic resources for different scenarios (percentage of installed capacity)

Time	1	2	3	4	5	6	7	8	9	10	11	12
PV_1	0	0	0	0	0	0	0	0.46	0.83	0.9	1	0.96
PV _2	0	0	0	0	0	0	0	0.54	0.73	1	1	0.88
Time	13	14	15	16	17	18	19	20	21	22	23	24
PV _1	0.97	0.85	0.32	0.4	0	0	0	0	0	0	0	0
PV _2	0.9	0.75	0.42	0.32	0	0	0	0	0	0	0	0

Table 6: Hourly energy cost

Time	1	2	3	4	5	6	7	8	9	10	11	12
Price	61	53	49	45	49	53	62	72	86	88	85	75
Time	13	14	15	16	17	18	19	20	21	22	23	24
Price	64	61	60	60	63	71	86	100	96	87	74	61

The cost of exploiting each of the distributed resources of generation and parking is specified in the table 7.

Table 7: The cost of exploiting distributed generation resources

Source type	Optimization Cost$/KWh
Solar Cells	0.01
Certain sources of production	0.046

3.5 Power Distribution Relationships

$$P_{D,i} + P_{PV} + P_{Ch} + P_{Disch} - V_i \sum_{k=1}^{n} V_k \quad Y_{ik} \cos(\delta_i - \delta_k - \theta_{ik}) = 0$$

$$Q_{D,i} - V_i \sum_{k=1}^{n} V_k \quad Y_{ik} \sin(\delta_i - \delta_k - \theta_{ik}) = 0 \qquad (19)$$

The amplitude and phase of the bus reference voltage

$|V_1| = 1\, p.u.$

$\delta_1 = 0$

3.5.1 VOLTAGE LIMITATION

When the voltage range of a bus is allowed in the operating range, this means that there is no deviation. But this is not always the case, but the important thing is that in the optimization process, the decision maker can ignore the part of the deviations to improve the other target functions. Establishing a voltage limitation can be represented by mathematical formulation. In this method, the allowed operating range is defined as $[0.95, 1.05]$. As long as the voltage range exceeds this range, the amount of satisfaction decreases, until it reaches to its minimum critical value $(0.9, 1.1)$ outside the critical voltage range.

$$\mu_i^V = \begin{cases} \frac{V_i - 0.9}{0.95 - 0.9} & 0.9 \le V_i \le 0.95 \\ 1 & 0.95 \le V_i \le 1.05 \\ \frac{V_i - 1.1}{1.05 - 1.1} & 1.05 \le V_i \le 1.1 \\ 0 & else \end{cases} \quad (20)$$

The value obtained from the above equation indicates the conditions for setting the voltage limitation of the i-th bus. Based on the above equation, the average value for all network buss provides the information on the total network voltage conditions.

$$\text{PenaltyV}_t = \frac{\sum_{i=1}^{No.of\ nodes} \mu_i^V}{No.of\ nodes} \quad (21)$$

3.5.2 Thermal Limitation of Feeders

Calculation of the indicator shows the value of the feeder flows) in a similar manner to μ^I (the voltage.

$$\mu_i^V = \begin{cases} \frac{1.2 * I_{i,\ Thermal\ Limit} - I_i}{1.2 * I_{i,\ Thermal\ Limit} - I_{i,\ Thermal\ Limit}} & I_{i,Thermal\ Limit} \le I_i \le 1.2 * I_{i,Thermal\ Limit} \\ 1 & I_i \le I_{i,Thermal\ Limit} \\ 0 & else \end{cases} \quad (22)$$

$$PenaltyI_t = \frac{\sum_{i=1}^{No.of\ nodes-1} \mu_i^I}{No.of\ nodes - 1} \quad (23)$$

In order to apply different technical constraints in the proposed issue, the cost of technical dissatisfaction is obtained from the following:

$$Penalty = dc \times \max\{(1 - \sum_t \frac{PenaltyI}{24}), (1 - \sum_t \frac{PenaltyV}{24})\}$$

Optimization in this study is trying to access the following:

- Charging and discharging hours of electric vehicle parking
- The amount of generation of resources, controllable generation resources

Like other optimization algorithms, the algorithm begins with the generation of a primitive population chance. The primary population consists of all the unknowns of the problem and may be the final answer to the problem. For each population, the amount of the cost function must be calculated, for this, the population must be distributed, the types of costs involved in the final target function must be calculated and even the population must be evaluated from the compliance point of view. Finally, by comparing the value of the objective function of the formed populations, each population with the lowest value of the target function is chosen as the optimal answer.

4. RESULTS AND DISCUSSION

In order to solve this problem, a genetic algorithm has been used. The convergence process of the genetic algorithm in the problem-solving process is as follows: the downward trend of the convergence path implies the accuracy of the modeling and the ability of the proposed method in the garlic to be the minimum solution (Figure 2).

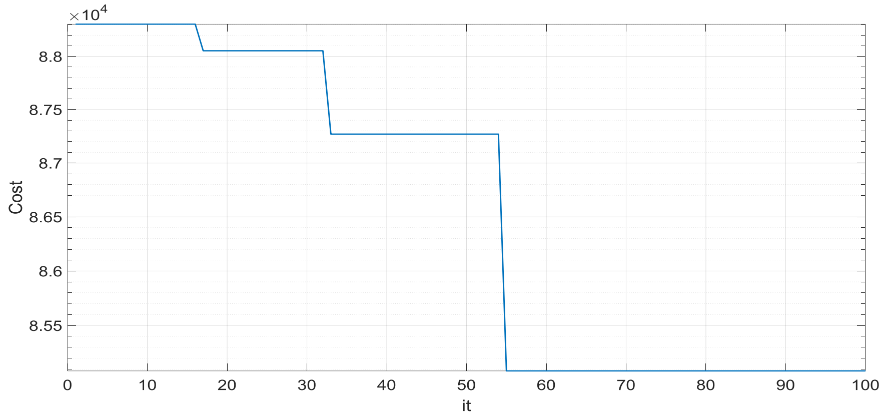
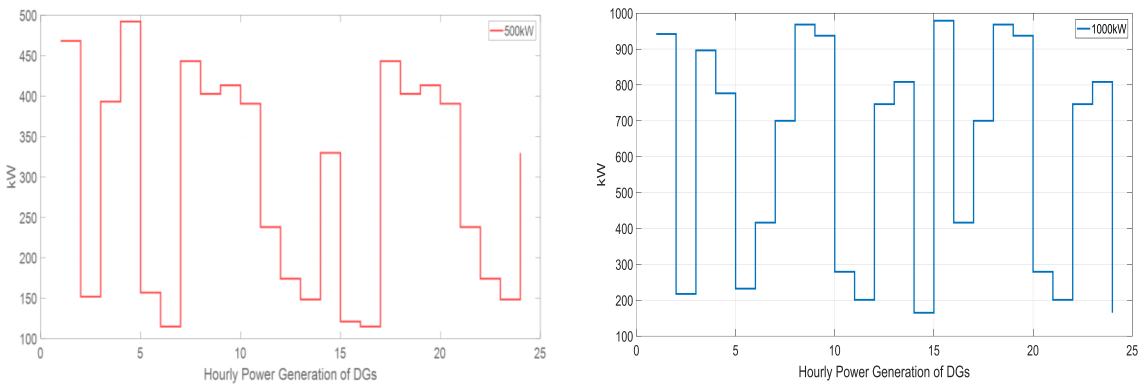


Figure 2: The path of convergence

Details of the objective function due to the implementation of the optimal problem solution are as follows. Obviously, due to the high demand in the micro-grid, and the lack of sufficient capacity for generation, there is a need to import energy from the upstream grid, which leads to an increase in the cost of purchasing energy from the upstream grid. With regards to the nature of the problem, the final answer to the problem is the one-day strategy, which specifies the amount of hourly generation of definite distributed resources, as well as the exchange rate of the hourly parking energy of the micro-grid. In the following figure, the amount of hourly production of distributed generation resources is determined by the installed capacity in the micro-grid. It is clear that the production of units varies in different hours. Also, due to the placement of these units in different micro-grids of the bus, and the importance of technical issues, the production of these units will be different. Factors such as: energy prices, technical issues, the adequacy / inadequacy of solar unit's generation, the need for electric vehicles, etc. affect the amount of definitive effective units of generation (Figure 3).



(a) 500W (b) 1000W

Figure 3: The production of definite dispersed generation sources

As previously mentioned, the proposed method seeks to specify the hourly exchange rate of parking energy with the micro-grid. In the meantime, and similar to the generation of definite resources, the hourly exchange rate of the energy between the parking lot and the micro-grid is different depending on the price of energy, technical constraints and etc. The parking hourly charge / discharge profile is shown in the Figure 4.

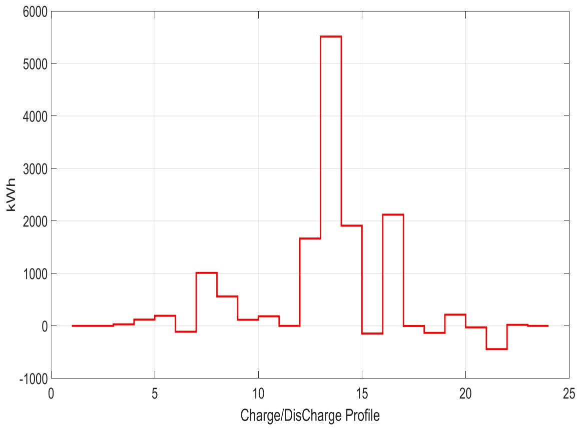


Figure 4: Hourly profile charging / discharging parking.

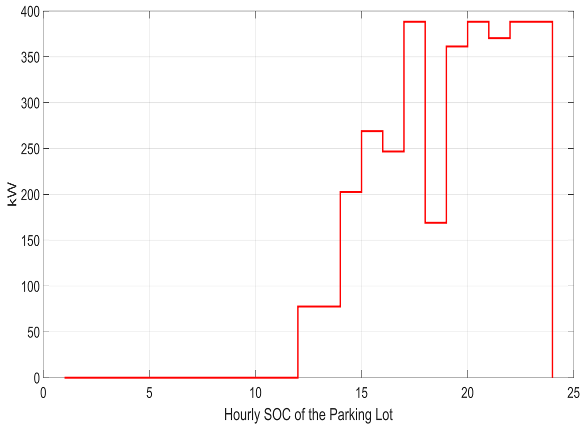


Figure 5: Hourly charge profile in the parking lot

What's on the above mentioned figure is the parking, or charging, discharging, or nothing at any time of the day. It is clear that the charge level in the battery at (t) time is equal to the level in the previous hour and the charging / discharge rate in the hour toward (t) time. However, all constraints regarding to the way of charging / discharging are to be observed. In the figure below, the charge level in the vehicle battery is displayed at different times (Figure 5).

As completely explained, voltage is an important parameter in the operation of the micro-grid. This is the main factor in determining the amount of network losses. Hence, in exploiting the micro-grid, focus should be paid to the extent permitted. The voltage range of all buses at any times and throughout the scenarios is shown in the figure. It is clear that the proposed method has been able to maintain the voltage constraint and keep it within a predetermined range (Figure 6).

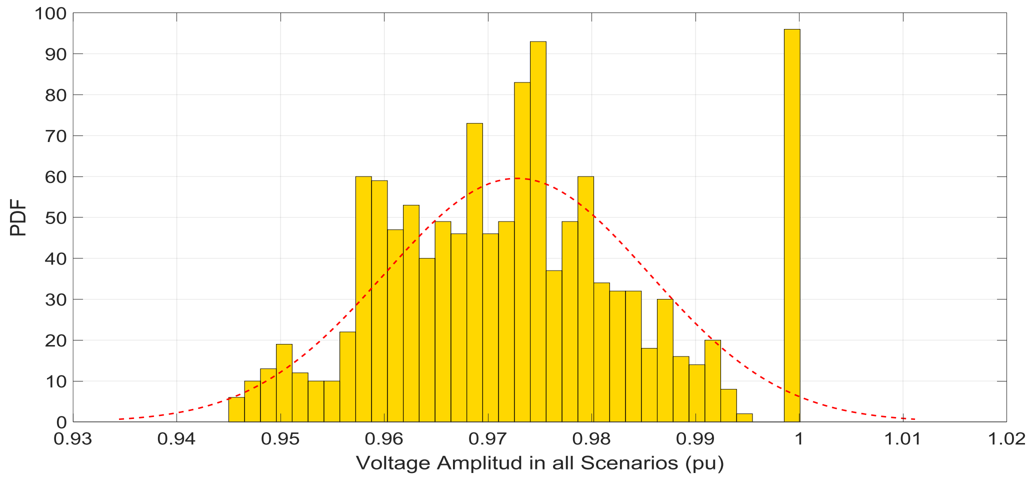


Figure 6: The voltage amplitude in all scenarios

Considering the loss amount effect, as well as the amount of micro-grid energy purchased from the upstream network in the proposed target function and ultimately the final strategy for implementation, the frequency distribution of these parameters, taking into account the numerical values of these parameters at all times and during all scenarios in the Figures 7 and 8.

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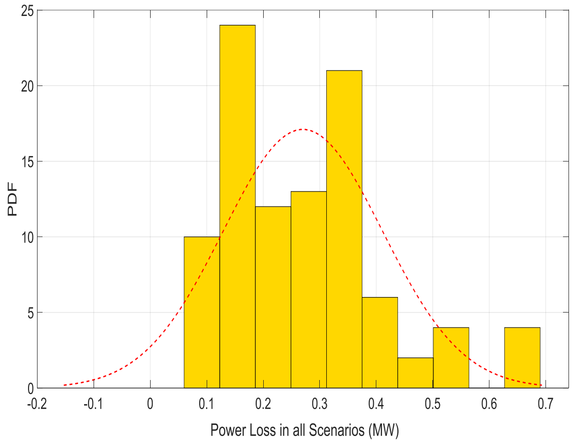

Figure 7: Power loss in all scenarios.

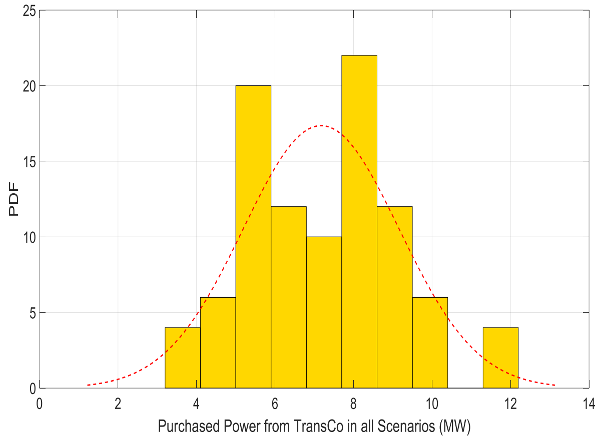

Figure 8: Purchased power from Transco in all scenarios.

Regarding to the aim of the problem of the operation of the micro-grid in the presence of the uncertainty of electric vehicle parking [18], the uncertainty of the solar resources, the energy price and load demand using the genetic optimization algorithm, the proposed scheme for solving the problem is detailed and the results of the presentation turned out. The discussion of the results implies the effectiveness of the proposed method and the accuracy of the modeling.

The new generation of electric vehicles with bilateral capability of power exchanging with the network [11], due to the variable location, time and charge rates of these vehicles, have led to various challenges and opportunities for the power system, which requires the acquisition of their imagined interests management and benefit in an accurate and principled vector of them. On the other hand, the high influence of renewable energy resources on smart distribution networks with an alternative nature of their generation has doubled the complexity of network utilization. A micro-grid [MG] control system can interact positively and effectively with the presence of distributed energy resources [DER] and their uncertainties.

5. CONCLUSION

Hence, in this study, the optimal operation of the micro-grid with the presence of the uncertainty of electric vehicles and the uncertainty of photovoltaic resources has been targeted as a predominant source of small-scale energy resource. The proposed method intends to supply customers at the possible lowest cost by maintaining the network utilization constraints. In the proposed scheme, genetic algorithm has been used as an efficient and effective tool for finding optimum solutions. Computational simulation on a sample micro-grid [MG] and analyzing its results indicates the effectiveness and accuracy of the proposed scheme.

6. DATA AVAILABILITY STATEMENT

The used or generated data and the result of this study are available upon request to the corresponding author.

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