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Modeling and Optimizing the Charge of Electric Vehicles with Genetic Algorithm in the Presence of Renewable Energy Sources

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Abstract- *In recent years, as a result of remarkable increase in energy industry, discrimination between lower and higher loads as well as economic crisis which pestered a majority of countries; hence the usage of power plants became a significant issue. In addition, growing consumption of power and inexistence of valid source in satisfying the requirements has brought different problems such as diminish of fossil fuel resources, adversarial environmental influences, universal growth of Greenhouse Gases (GHGs). The associated issues have created technologies compatible with situations including Electric Vehicles (EVs). Regarding the efficiency of two-side exchange of energy within these vehicles, if there was a connection among the number of them and net under management and intelligent monitor of organization stability, so they can treat like a virtual tiny energy plant with start- up speed and free of cost. This paper presented the modeling and optimizing of the charge of electric vehicles with genetic algorithm in the presence of renewable energy sources. According to the results of this study, the cost of the HEV charge connected to the net is 75.88% less than the EV compared to the payment costs of the car (dis)charge in optimal patterns.*

Keyword: Electric Vehicles (EVs), Genetic Algorithm, Optimizing, Modeling, Renewable Energy Sources.

1. INTRODUCTION

With regard to the reduction of fossil fuel sources and increasing pollution and global warming, the use of renewable energy to generate electricity is one of the best solutions available [1,2]. Regarding to the remarkable increase in human need to maintain power and inexistence of previous sources efficiency to provide a response, high influences of their consumption in environmental issues and investment responses to discover novel power origin which are obvious, so, macro-budgets are enhanced, for instance, 2 billion dollars permitted for EVs in the US [3-5].

In recent years, a majority of studies have been concentrated on the consumption of Renewable Energy Resource (RES). Renewable energy sources are considered as a technological option for generation of clean energy [6]. However, many of key issues have encouraged researchers to substitute EVs for traditional vehicles [7-9]. Due to the fact that high rate of energy is

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consumed on transportation sector which causes irreversible environmental dangers in addition to financial losses [10-12], provision of ancillary services including fine-tuning frequency, supplying spinning reserve and base load, and smoothing the load curve are the application of these vehicles in power systems.

Here, highly relevant works on benefits of EVs regarding the year of publication are provided:

Lund et al. (2008) which modelled a wind turbine applied a range of EVs on Danish national energy which illustrated the growth of Carbon Dioxide (CO_2) pollution. They used EVs to create the higher level of wind [11]. Huston et al. (2008) investigated the battery capacity of Hybrid EVs (HEVs) to conserve electrical power, purchase energy per an hour using a collector to achieve profit [12]. Camus et al. (2009) investigated a series of HEVs connected to the net as a distributable load and smoothed the increase of the load minimum of the load curve system [13]. Simultaneously, Clement et al. suggested a charge method which resulted in minimum loss and maximum load factor [14]. Also, Guille et al. used a model to gather EVs to decrease demand during nonpeak times as a controlled load, and power supplement during peak times [15].

Yousuf Saber et al. (2010) offered a UC-V2G model along with EVs and applied it over an a10-unit system of an IEEE sample. They demonstrated the growth of pollution and cost production [16]. Simultaneously, Sioshansi and colleagues investigated the impacts of HEVs related to the net on the Ohio net and their results ascertain the growth of CO2 pollution [17].Additionally, they offered a set up model of problem in power plants for a series of HEVs linked to the net, as well as showed saving of 200 dollars per a car in a year [18].

With regard to the various scenarios of charge and discharge, Acha at al. (2010) demonstrated that the energy loss can be decreased via monitoring the series of HEVs, linked to the net, and oil transformers [19]. Also, Sekyung han and colleagues presented an aggregator to standardize the frequency. According to the mathematical formulation, its operation was formulated and modelled to bring profit. In addition, a flexible program was used to fix this issue [20]. White (2010) demonstrated that adjustment market can be a great market compared to the peak market for car owners. They suggested a new program to apply a machine technology based on simultaneous usage for both peak and regulation markets. They showed that it has better advantages than both markets [21]. Also, contemporary with them, Kivilouma et al. worked on the intelligent charge and discharge profits over a portfolio system applying UC1 model. They found that the price of intelligent charge and unintelligent charge are 36 and 263 Euros per a car in a year, respectively [22]. As stated in the above, supplement of the base power is one of the applications of EV series. In this research, in order to fix the operational problem of energy plants, EVs were modeled to investigate its efficiency. If you are in the circuit of an energy plant, you should turn on the unit, enhance its speed, coordinate it, and link it, now it can transmit energy into the system.

The act of staying in the circuit off upper rate of generation unit's costs highly. Hence, high reservation can be obtained through turning off unneeded units. So, the purpose of the set up problem in energy plants is finding an ideal state in on and off condition of units, so that the needed power of the system can be presented with minimum price. If there were more connections of cars to the net, postulating of a series of these cars as tiny energy plants is possible which is along with operation speed and lower operation cost compared to the existing upper speed operation energy plants.

Therefore, the price of energy generated can be decreased by the control of serious and application of its advantages. Additionally, the basic purpose of the energy usage incline is achieved by planning and home load sharing at the rush hours. It values to mention that diminish of energy use is not restricted to the home load application, but also the consumption level of electrical power is altered by energy users from the normal amount of their consumption pattern to optimal consumption patterns during rush hours. In order to determine the ideal pattern for use, the objective function and consumer payments expenses were diminished. Consequently, Genetic Algorithm (GA) was used for optimization.

2. METHODOLOGY

2.1. System modeling

Since, programming and home load sharing will reduce during rush hours, based on the basic purpose of the energy usage, it can be mentioned that, diminish of energy usage not also is not restricted to the home heads, but also alters the use level of electrical power by energy users from normal rate of their use model to ideal usage models at the time of restricted hours. The ideal use models are assigned through decreasing the aim function and user payment expenses. Therefore, Genetic Algorithm (GA) in MATLAB software was used to perform optimization. In this algorithm, each participant is informed about the on/off optimal pattern of loads, and (dis)charge of EVs during the programming. It can be mentioned that the programming is fulfilled regarding the forecasted expenses the day before in Real-Time Pricing (RTP). Consequently, all participants take decision on the basis of optimal use pattern In-Home Display (IHD) information. Then, they will be more active in giving response to the load programs.

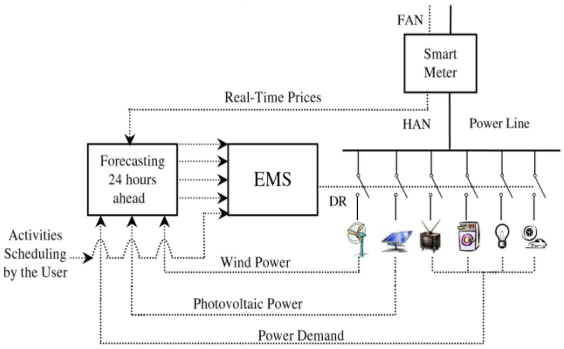

Fig. 1. Intelligent home and load management strategies

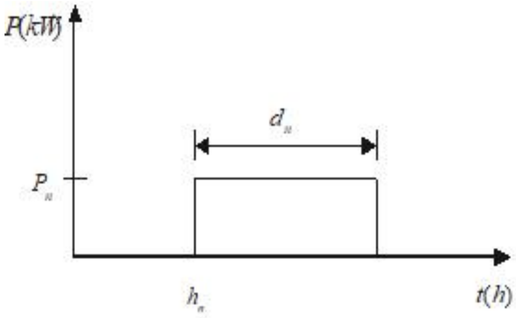

Fig. 2. The characteristic of home appliances

Simultaneous intelligent management system of home appliances or planning and home load as well as EVs categorized in four stages

2.2. System design

The Figure 3 showed the intelligent home. Washing machine and EVs were the loads involved in the planning.

In this research, the feed-in tariff of power is created based on the RTP. The feed-in tariffs applied for setting a price associated to the electricity market in 2018 during a summer day (Figure 4) [13]. The forecasting of price was paid highly in this kind of pricing. As it can be observed in figure 4, there is a small difference between real cost and forecasted cost.

The depicted pattern was used on a 10-unit system. It is a regular system and the rate of rotating reservation in this system is 10% of the hourly load. We considered the existence and lack in the network to investigate the impact of the set of vehicles and the results were shown in Table 1.

Few postulations were applied to solve the issue. If there were complexes, the cars will be charged from renewable energy sources and discharged to the grid. Additionally, car charging status = 50%, car efficiency = 85% and total available car power = 310 MW.

Table 1. The set of vehicles and the results

Condition	Details
1	Absence of car collection
2	Presence of 5 sets of cars

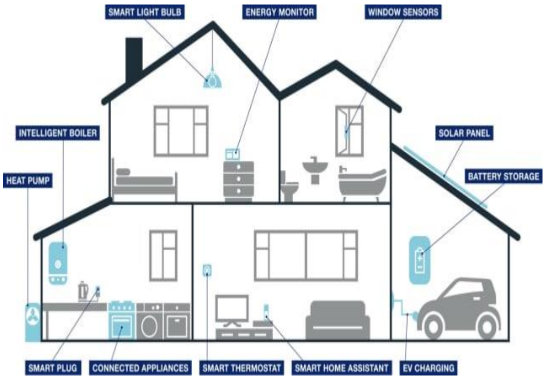

Fig. 3. An intelligent home

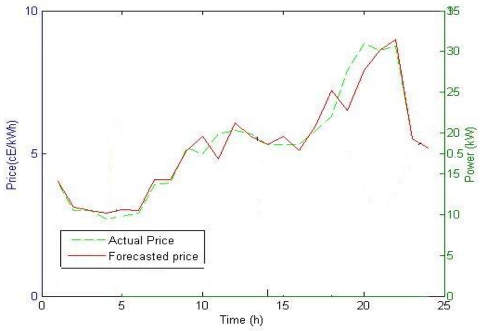

Fig. 4. The forecasted costs and real time

2.3. Renewable Energy Sources

The geographical characteristics of this research to design the system were provided in Table 2. Similarly, Figures 5 and 6 showed the intensity of solar radiation and wind, respectively. Figure 5 illustrated the intensity of the sun's rays for different days annually. Accordingly, the highest intensity of solar radiation was associated to July with a value of 405 W/m2 and the lowest intensity of radiation annually was associated to December with a value of 35 W/m2. Figure 6 showed the intensity of the wind for one year within different days. According to the figure 6, the highest wind speed was in February with a value of 18 meters per second, and the minimum wind speed was in December with a value of 1.2 meters per second.

Table2. Geographical characteristics of the studied area

Parameter	Quantity	Unit
Location	Hamedan	-
Latitude	+35.44	°
Longitude	+44.23	°
Altitude	1803	M

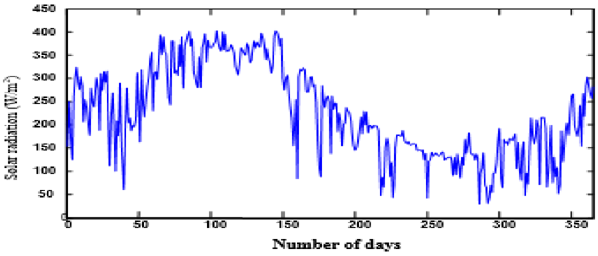

Fig. 5. The intensity of solar radiation

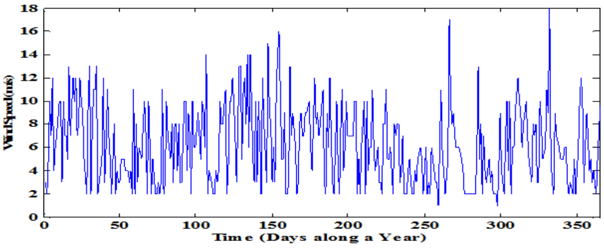

Fig. 6. Wind intensity

2.4. System Optimization

The procedure of optimization was performed based on a genetic algorithm. It is a non-deterministic method, so it enables a wider exploration of the solutions space considering to other optimization techniques, avoiding possible convergence on local optima. Moreover, it is relatively simple derivate a solution that is sufficiently close to theglobal optimum of the problem.

The generation rate of electrical power by a wind turbine was dependent on several factors. Among them, air density, wind speed, and wind turbine blade radius were the most significant factors. Equation 1 was used for the power generation capacity of wind turbines:

$$P_W = \frac{1}{2}\rho\pi R^2 V w^3 C_P(\lambda, B) \qquad (1)$$

In which 1, V_W is wind speed, R is the blade radius, β is the blade angle, ρ is the air density, C_P stands for the turbine power factor and a function of λ and β. Similarly, Equation 2 showed the amount of electrical power which was produced by the photovoltaic cell:

$$P_{SCG} = \begin{cases} P_{rs} & if\ v \le R < R_C \\ P_{rs}\dfrac{R}{R_{STD}R_C} & if\ RC \le R < RSTD \\ P_{rs} & if\ R_{STD} \le R \end{cases} \qquad (2)$$

R stands for the intensity of solar radiation, R_C stands for the particular intensity of radiation, usually 150 W / m^2, R_{STD} shows the intensity of radiation in standard circumstances, usually 1000 W / m^2, P_{rs} stands for the power output of the solar cell, P_{SCG} is the total output power. The following equation is the definition of objective function:

$$F = \sum_{i=1}^{i=24}\begin{bmatrix} \sum_{n=1}^{n=N} VUA_n(i)PDCA_n(\alpha_n.i) + \\ \sum_{k=1}^{k=K} VUV_K(i)PDCV_K(\beta_K.i) - \\ EP(i)\begin{pmatrix} \sum_{n=1}^{n=N} DCA_n(\alpha_n.i)\,P + \\ \sum_{k=1}^{k=K} PDCV_K(\beta_K.i) \end{pmatrix} \end{bmatrix} \qquad (3)$$

If a wind turbine and Photovoltaic (PV) panels were used in a residential house, the objective function will be:

$$F = \sum_{i=1}^{i=24}\begin{bmatrix} \sum_{n=1}^{n=N} VUA_n(i)PDCA_n(\alpha_n.i) + \\ \sum_{k=1}^{k=K} VUV_K(i)PDCV_K(\beta_K.i) - \\ EP(i)\begin{pmatrix} \sum_{n=1}^{n=N} PDCA_n(\alpha_n.i) + \\ \sum_{k=1}^{k=K} PDCV_K(\beta_K.i) \end{pmatrix} \\ +EP(i)(WP(i) + PVP(i)) \end{bmatrix} \qquad (4)$$

$PVP(i)$ is the produced power of wind turbine and $WP(i)$ is that of PV panels for i hour.

Table 3. 10-unit system production program in the absence of vehicles

Time (h)	unit 1 (MW)	Unit 2 (MW)	unit 3 (MW)	unit 4 (MW)	unit 5 (MW)	unit 6 (MW)	unit 7 (MW)	unit 8 (MW)	unit 9 (MW)	unit 10 (MW)	Reserve (MW)	Demand (MW)
1	455	245	0	0	0	0	0	0	0	0	210	700
2	455	295	0	0	0	0	0	0	0	0	160	750
3	455	370	0	0	25	0	0	0	0	0	222	850
4	455	455	0	0	40	0	0	0	0	0	122	950
5	455	390	130	0	25	0	0	0	0	0	202	1000
6	455	360	130	130	25	0	0	0	0	0	232	1100
7	455	410	130	130	25	0	0	0	0	0	182	1150
8	455	455	130	130	30	0	0	0	0	0	135	1200
9	455	455	130	130	85	20	25	0	0	0	197	1300
10	455	455	130	130	162	33	25	10	0	0	152	1400
11	455	455	130	130	162	73	25	10	10	0	157	1450
12	455	455	130	130	162	80	25	43	10	10	160	1500
13	455	455	130	130	162	33	25	0	10	0	152	1400
14	455	455	130	130	85	20	25	0	0	0	197	1300
15	455	455	130	130	30	0	0	0	0	0	132	1200
16	455	310	130	130	25	0	0	0	0	0	282	1050
17	455	260	130	130	25	0	0	0	0	0	332	1000
18	455	360	130	130	25	0	0	0	0	0	232	1100
19	455	455	130	130	20	0	0	0	0	0	132	1200
20	455	455	130	130	162	33	25	0	10	0	152	1400
21	455	455	130	130	85	20	25	0	0	0	197	1300
22	455	455	130	0	25	20	25	0	0	0	267	1100
23	455	425	0	0	0	20	0	0	0	0	90	900
24	455	345	0	0	0	0	0	0	0	0	110	800

Table 4. 10-unit system production program in the presence of a set of vehicles

Time (h)	unit 1 (MW)	Unit 2 (MW)	unit 3 (MW)	unit 4 (MW)	unit 5 (MW)	unit 6 (MW)	unit 7 (MW)	unit 8 (MW)	unit 9 (MW)	unit 10 (MW)	Reserve (MW)	Demand (MW)	Vehicles (MW)
1	455	245	0	0	0	0	0	0	0	0	210	700	0
2	455	295	0	0	0	0	0	0	0	0	160	750	0
3	455	370	0	0	0	0	0	0	0	0	110	850	25
4	455	360	0	130	0	0	0	0	0	0	100	950	5
5	455	390	0	130	25	0	0	0	0	0	202	1000	0
6	455	455	0	130	194/51	0	0	0	0	0	661/119	1100	805/8
7	455	410	130	130	25	0	0	0	0	0	182	1150	0
8	455	455	130	130	25	0	0	0	0	0	142	1200	5
9	455	455	130	130	92	20	0	0	0	0	001/148	1300	001/18
10	455	455	130	130	142	20	25	0	0	0	001/183	1400	001/43
11	455	455	130	130	162	40	25	10	0	0	001/168	1450	001/43
12	455	455	130	130	162	806/77	25	10	10	0	389/197	1500	195/45
13	455	455	130	130	142	20	25	0	0	0	001/183	1400	001/43
14	455	455	130	130	92	20	0	0	0	0	001/148	1300	001/18
15	455	455	130	130	25	0	0	0	0	0	142	1200	5
16	455	310	130	130	25	0	0	0	0	0	282	1050	0
17	455	260	130	130	25	0	0	0	0	0	332	1000	0
18	455	360	130	130	25	0	0	0	0	0	232	1100	0
19	455	455	130	130	25	0	0	0	0	0	142	1200	5
20	455	455	130	130	162	20	0	10	10	0	001/178	1400	001/28
21	455	455	130	130	92	20	0	0	0	0	001/148	1300	001/18
22	455	365	130	130	0	20	0	0	0	0	150	1100	0
23	455	425	0	0	0	20	0	0	0	0	90	900	0
24	455	345	0	0	0	0	0	0	0	0	110	800	0

3. RESULTS AND DISCUSSION

The results of the absence of electric vehicles for charging can be seen in Table 3. To explain this, it was assumed that there are 10 stations for generating electricity, two of which are related to renewable systems, including wind turbines and photovoltaic cells.

First model: A washing machine and a HEV connected to a net according to a 5 kW contour (The charge of the car and the performance of the appliance do not synchronize). The evaluation of the GA program performance has been depicted in Figure 7.

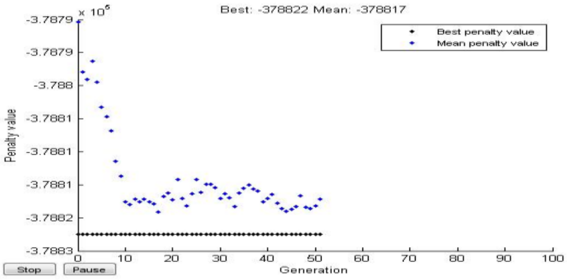

Fig. 7. Results of the GA performance

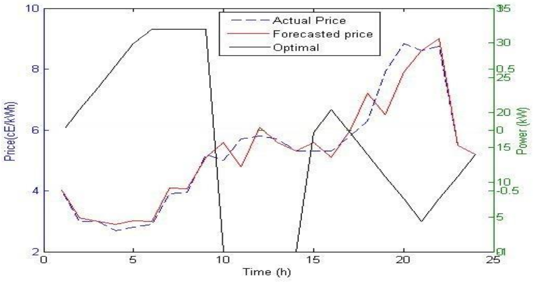

Fig. 8. The optimal pattern of a car

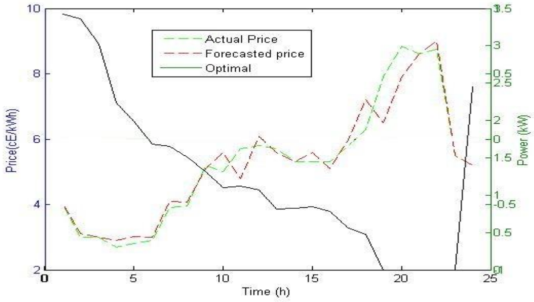

Fig. 9. Optimal electric vehicle charging pattern

The most optimal conditions of car demand can be seen in Figure 8. After locating the optimal values on the objective function, the value of the optimal charge was obtained for an EV (Figure 9).

In an optimal charge of the EV, the payment cost of the consumer was based on the predicted costs of 109 Euros. If a car owner leaves a parking lot at 8 am, and returns to it at 13 pm, the payment cost will be 145 Euros. The change of a consumption pattern from the usual pattern to the optimal pattern causes the monthly electricity bill to decrease about 24%.

The results of the study by Longo et al. in 2019 showed that the use of EVs in the district introduces considerable savings with respect to the Base Case [23]. Moreover, Petrusic and colleagues in their study in 2021 concluded that it is possible to maximize the exact renewable energy share when charging an EV. Other criteria that are simultaneously optimized are the total costs of the system (consisting of battery installation and operation costs, and costs of importing the energy from the grid) and battery degradation rate [24].

4. CONCLUSIONS

This paper presented an optimization methodology of the charge of electric vehicles with genetic algorithm in the presence of renewable energy sources. After doing this program, calculation of payment costs and the percentage of the cost decrease are observed the day before planning that the RTP causes the energy consumption and costs to decrease. This means that this pricing has a positive effect on the likely planning and home load sharing. In other words, the cost of the HEV charge connected to the net is 75.88% less than the EV compared to the payment costs of the car (dis)charge in optimal patterns.

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