Journal of Robotics and Control (JRC)
Volume 3, Issue 2, March 2022
ISSN: 2715-5072 DOI: 10.18196/jrc.v3i2.13671

Optimization of Renewable Energy Consumption in Charging Electric Vehicles Using Intelligent Algorithms

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***Abstract*—Today, due to the considerable growth of the power/electricity industry, the high distance between low and high loads, and also economic crisis plagued most of the countries in the world, the operation of power plants has been transformed into a vital issue. Also, increasing use of energy and lack of accountability of conventional resources in response to supply the need has created many problems, including a decrease of fossil fuel sources, adverse environmental impacts, and increase of Greenhouse Gases (GHGs) all around the world. The concerns induced by this problem have caused the technologies consistent with an environment such as Electric Vehicles (EVs) to attract more and more attention. According to the capability of two-side exchange of power in these vehicles, if a significant number of them are connected to a net under management and intelligent control of an institution consistently, they can behave such a virtual small power plant with high start-up speed and without any cost.**

Keywords—Electric Vehicles; PSO; Renewable Energy; Optimization

I. INTRODUCTION

Renewable energy is expanding day by day. The use of renewable energy is increasing day by day, so today, it has found a very important place in electricity generation systems [1-3]. The most important and most widely used use of renewable energy is the production of electrical energy [4-7]. The utilization of renewable energy to supply the required loads of different sectors reduces environmental pollution [8-11]. On the other hand, the use of electric vehicles to prevent the emission of polluting gases in cars has grown significantly [12-15]. According to the significant growth of human need to store energy and lack of conventional resource capability to get a response to it, irreversible impacts of using them on environmental issues and investment answers to find new energy sources are not hidden from anyone. So, macro-budgets are approved and allowed to do this work [16-19].

Recently, much research has been started in the field of using Renewable Energy Resources (RES) and is still ongoing. But one of the most important issues that have occupied researchers' minds is to substitute EVs for traditional vehicles [20-24]. Because a large amount of energy is spent on transportation sectors which creates irreversible environmental dangers in addition to financial losses [25][26]. The presence of these vehicles in power systems has many applications, including the provision of ancillary services such as adjusting frequency, providing spinning reserve and baseload, as well as smoothing the load curve [27-29].

As mentioned before, one of the applications of the EV series is to supply a base power. In this paper, to review the capability of EVs, we model them for the operational problem of power plants. Being in a circuit of a power plant means that you have to turn on the unit, increase its speed, synchronize it, and connect it so that it can inject power into the system. Being in a circuit of a high number of production units is very expensive. So, high savings can be achieved by turning off unnecessary units. Therefore, the aim of the operational problem of power plants is to find an optimal state when the units are on or off so that the required energy of the system can be provided with minimum cost. If many cars are connected to the net, it can be possible to assume a series of these cars as small power plants which have a higher start-up speed and a lower start-up cost than the existing high-speed start-up power plants. So, it seems that the cost of energy produced can be reduced by the management of the series and the use of its benefits. Also, we achieve the main goal of the power consumption decrease with likely planning and home load sharing during critical hours. It should be noted that the decrease of power consumption does not mean not to use home loads, but it means that the consumption level of electrical energy is changed by consumers from the normal amount of their consumption pattern to optimal consumption patterns during critical hours. The optimal consumption patterns are determined by minimizing the objective function and consumer payment costs. So, this optimization is performed by PSO.

II. METHODS

A. System Modeling

Likely planning and home load sharing are done based on the main goal of the power consumption decrease during the critical hours. It is noted that the decrease of power consumption does not mean not to use home loads, but it means to be changed the consumption level of electrical energy by consumers from the normal amount of their consumption pattern to optimal consumption patterns during critical hours. The optimal consumption patterns are determined by minimizing the objective function and consumer payment costs. So, this optimization is performed by PSO in MATLAB software. Participants are informed about an on/off optimal pattern of responsive loads and (dis)charge of EVs during the planning. It should be noted that the planning is done based on the predicted costs the day before in Real-Time Pricing (RTP). As a result, participants decide based on optimal consumption patterns and In-Home Display (IHD) information. So, they are more actively involved in response to load programs.

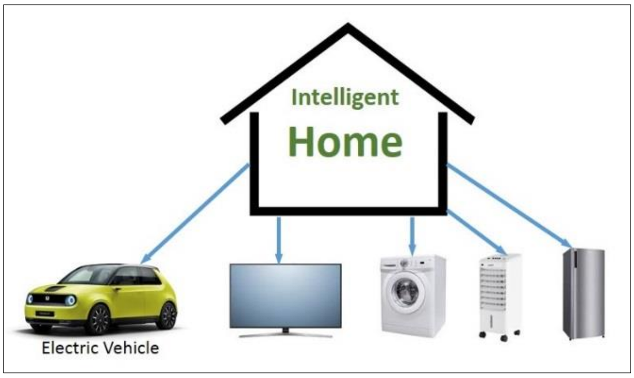

Fig. 1. Intelligent home and load management strategies.

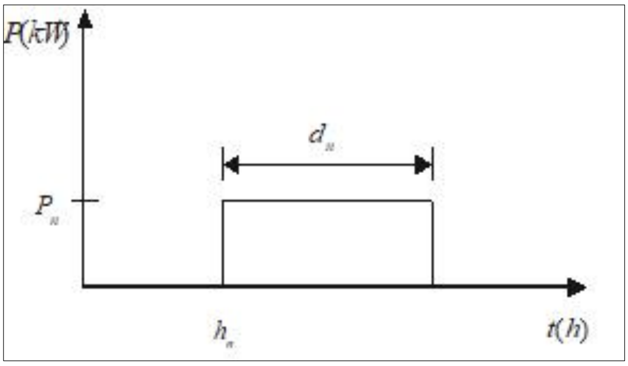

Fig. 2. The characteristic of home appliances.

In the following, likely planning and home load or, in other words, the simultaneous intelligent management system of home appliances and that of EVs is implemented in four stages.

B. System Design

The intelligent home is shown in Fig. 3. The loads involved in the planning are washing machines and EVs.

The feed-in tariff of electricity in this paper is based on the RTP. The feed-in tariffs used for this kind of pricing are related to the electricity market in 2018 during a summer day which has been shown in Fig. 4. In this kind of pricing, the prediction of cost has much more importance. As you see in this figure, the difference between real cost and the predicted cost is very low.

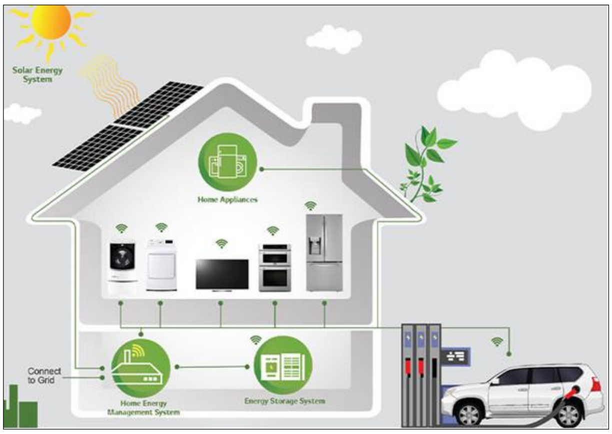

Fig. 3. An intelligent home.

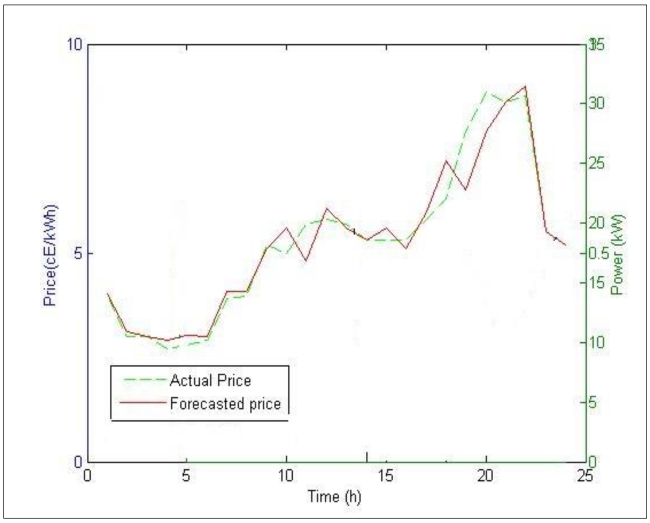

Fig. 4. The predicted costs and real-time.

The designed model is implemented on a 10-unit system. This system is a standard test system, and the amount of rotating reservations in this system is 10% of the hourly load. In order to analyze the effect of the set of vehicles in the network, two different assumptions based on their presence and absence in the network are considered, which are shown in Table 1.

TABLE I. TWO DIFFERENT ASSUMPTIONS BASED ON THEIR PRESENCE AND ABSENCE IN THE NETWORK

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

For this purpose, some assumptions have been made to solve the problem. In the presence of the complex, the cars are charged from renewable energy sources and discharged to the grid. Also, car charging status = 50%, car efficiency = 83% and total available car power = 310 MW.

C. Renewable Energy Sources

In Table 2, the geographical characteristics of the study area can be seen to design the system. Also, in Fig. 5 and Fig. 6, the intensity of solar radiation and wind can be seen for the study area.

TABLE II. GEOGRAPHICAL CHARACTERISTICS OF THE STUDIED AREA

Parameter	Quantity	Unit
Location	Tehran	-
Latitude	+35.41	°
Longitude	+51.23	°

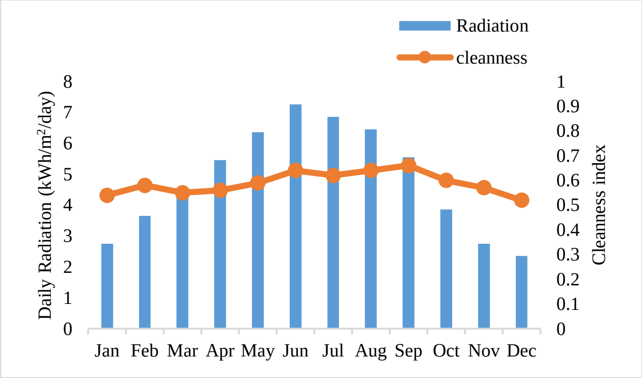

Fig. 5. The intensity of solar radiation.

The intensity of the sun's rays for different days of the year is shown in Fig. 5. As can be seen in this figure, the highest intensity of solar radiation is related to July with a value of 405 W/m₂ and the lowest intensity of radiation for this year is related to December with a value of 35 W/m^2. The intensity of the wind for one year after different days can be seen in Fig. 6.

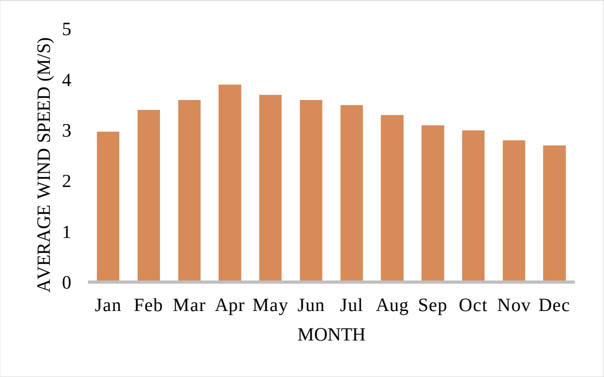

Fig. 6. Wind intensity.

As can be seen from Fig. 6, the highest wind speed is related to the month of February with a value of 18 meters per second, and the minimum wind speed for this region is related to the month of December with a value of 1.2 meters per second.

D. System Optimization

The amount of electrical power generated by a wind turbine depends on several factors. The most important of these factors are air density, wind speed, and wind turbine blade radius. The power generation capacity of wind turbines can be obtained by Equation (1) [30].

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

In relation to (1), V_W is wind speed, R is the blade radius, β is the blade angle, ρ is the air density, C_P is the turbine power factor and a function of λ and β. Also, the amount of electrical power produced by the photovoltaic cell can be obtained by Equation (2).

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

Where R is the intensity of solar radiation, R_C is the specific intensity of radiation, usually 150 W/m^2, R_{STD} is the intensity of radiation in standard conditions, usually 1000 W/m^2, P_{rs} is the power output of the solar cell, P_{SCG} is the total output power. The objective function related to the optimization problem is defined as follows:

$$\begin{aligned} F = \sum_{i=1}^{i=24}\Bigg[&\sum_{n=1}^{n=N} VUA_n(i)\,PDCA_n(\alpha_n.i) \\ &+ \sum_{k=1}^{k=K} VUV_K(i)\,PDCV_K(\beta_K.i) \\ &- EP(i)\left(\sum_{n=1}^{n=N} DCA_n(\alpha_n.i)\,P \right. \\ &\left. + \sum_{k=1}^{k=K} PDCV_K(\beta_K.i)\right)\Bigg] \end{aligned} \tag{3}$$

If a wind turbine and photovoltaic (PV) panels are used in a residential house, the objective function is defined as follows:

$$\begin{aligned} F = \sum_{i=1}^{i=24}\Bigg[&\sum_{n=1}^{n=N} VUA_n(i)\,PDCA_n(\alpha_n.i) \\ &+ \sum_{k=1}^{k=K} VUV_K(i)\,PDCV_K(\beta_K.i) \\ &- EP(i)\left(\sum_{n=1}^{n=N} PDCA_n(\alpha_n.i)\right. \\ &\left. + \sum_{k=1}^{k=K} PDCV_K(\beta_K.i)\right) \\ &+ EP(i)(WP(i) + PVP(i))\Bigg] \end{aligned} \tag{4}$$

Where $PVP(i)$ and $WP(i)$ are the produced power of wind turbine and that of PV panels for i hour, respectively.

III. RESULTS AND DISCUSSION

The results of the absence of electric vehicles for charging can be seen in Fig. 7 and Fig. 8. To explain this, it is assumed that there are 10 stations for generating electricity, two of which are related to renewable systems, including wind turbines and photovoltaic cells.

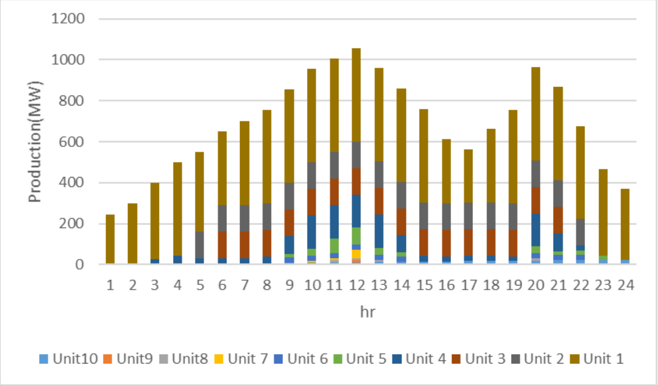

Fig. 7. 10-unit system production program in the absence of vehicles.

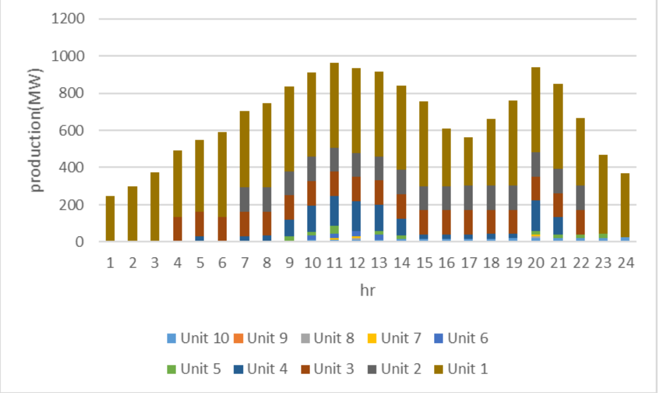

Fig. 8. 10-unit system production program in the presence of a set of vehicles.

First model: A washing machine and an 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 most optimal conditions can be seen in Fig. 9 car demand.

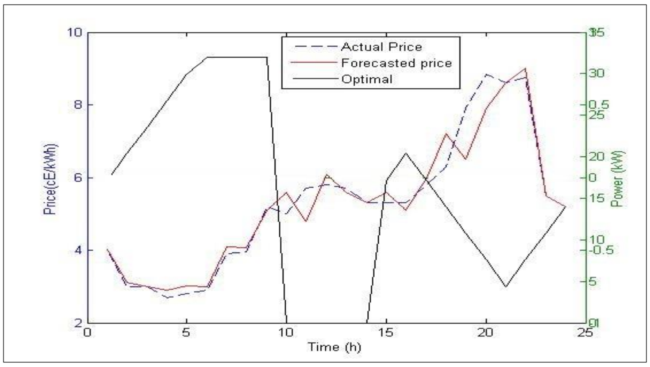

Fig. 9. The optimal pattern of a car.

After locating the optimal values on the objective function, the value of the optimal charge is obtained for an EV (see Fig. 10).

In an optimal charge of the EV, the payment cost of the consumer is based on the predicted costs of 109 Euros. If a car owner leaves a parking lot at 8 am, normally, 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 by about 24%.

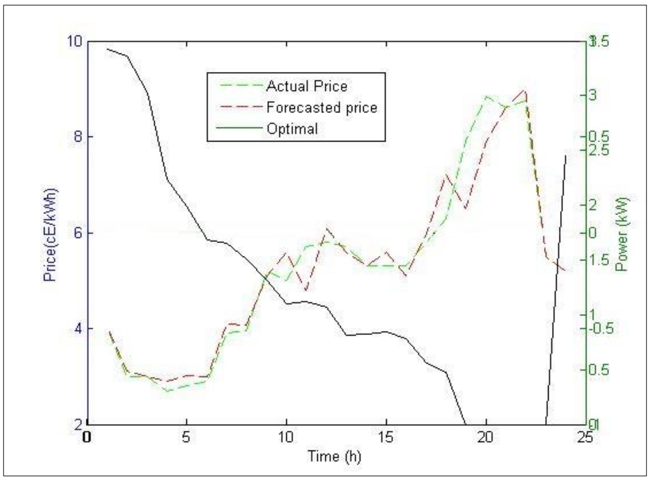

Fig. 10. Optimal electric vehicle charging pattern.

IV. CONCLUSION

After doing this program, calculation of payment costs and the percentage of the cost decrease is 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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