Multi-objective optimization of dynamic load balance on smart grid based on economic dispatch

Li Xin[1]*, Liang Tian[1]

[1]*Shandong Agriculture and Engineering University, Jinan City, Shandong Province, China, 250100*

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Abstract

In this paper, hybrid electric vehicles and renewable energy resources are combined to consider as optimization objective to reduce the remission of greenhouse gas. Electric vehicles can provide assistance to the power grid abbreviated as V2G, which changes single interests of power suppliers under the traditional economic operation mode. The intermittence of renewable energy generation and random charging behaviour of electric vehicles owners needs stronger power grid regulation ability. In this paper, we design a dynamic economic dispatch model for smart grid, which contains the plug-in hybrid electric vehicles and renewable energy power resource. By minimizing of power generation costs including V2G service cost, the lowest charging cost of PHEV owners, least air pollution, and maximizing synthetic load ratio, the model contains four optimization objectives. To solve the multi-objective problem, NSGA-II as a popular method to deal with multi-objectives optimizations is employed. Under the premise of keeping up with the demand of power, dynamically adjust the charging/discharging time and power of plug-in hybrid electric vehicles to match the fluctuations of loads and renewable energy generation. In simulations, we applied this model and methods on a 10-generating-unit system. The simulation results show the rationality and validity of the proposed model.

Keywords: lowest generation costs of power; smart grid; dynamic economic dispatch; multi-objective optimization.

1 Introduction

In current decades, the problem of greenhouse gas has drawn many attentions due to its significant affects in our environments. Vehicle exhaust and some other energy usage problems play an increasingly prominent role on greenhouse gas production. To solve the problem, nowadays, hybrid electric vehicle and renewable energy resource are used to reduce greenhouse gas emissions and improve energy efficiency which is an important part of smart grid development [1-2]. Plug-in hybrid electric vehicle can be connected to the grid to provide ancillary services [3-6]. It is also used to change the single centralized power generation model of traditional power grid. Meanwhile, the unidirectional power flow is turned into bidirectional power flow. All the related researches and applications will impact on smart grid's structure and functions.

With the development of electric vehicles, the charging for a large number of electric vehicles will cause a huge impact on grid [7-10]. Renewable energy including wind and solar is intermittent due to the weather and environmental influences so that the quality of electricity is unwarrantable. [11, 12, 13]. Therefore, it is significant to work on the research to pursue economic dispatch for smart grid.

In previous work, many researchers have already conducted related work. In [14], the authors employed the discharge power of electric vehicle as optimal objective. By minimizing the power generation cost of generators, users could obtain an optimized cost. However, the model does not consider the cost of the battery discharging. In [15], the authors consider two objectives including operating costs of generators and carbon emissions, but the model also did not consider the electric vehicles discharging cost. In [16], the author considers the cost of power generation, carbon emissions and charging cost of electric vehicle as optimization objectives. Nevertheless, the author did not consider the services cost of V2G from the view of power suppliers. Paper considered plug-in hybrid electric vehicle and renewable energy resource generation, but the authors still do not take into account the impact on the environment effects [17-19]. Based on the analysis of the above literatures, this paper established multi-purpose dynamic economic dispatch model including electric vehicles and renewable energy generation. To solve the problems left in mentioned literatures, we established a multi-objectives dynamic economic dispatch model for electric vehicles and renewable energy, which cannot only meet the requirements of electrical vehicles, but also employ the vehicles as energy storages, which is cooperative with renewable resources to guarantee the safety and effectiveness of smart grid. The rest of this paper is organized as follows. In Section 2, the dynamic economic dispatch model is introduced. In Section 3, the design of scheduling of electricity is introduced. The simulations and data analysis are shown in Section 4. We end this paper in Section 5 with conclusions.

* ***Corresponding author's*** e-mail: lixin_ngy@sina.com

2 Dynamic economic dispatch model based on smart grid

The connection of large-scale plug-in hybrid electric vehicles (PHEVs) and renewable energy resources (RES) to smart grid changes the conventional mode for economic dispatching. Economic dispatch has not only been an optimization objective for power suppliers, but also includes the considerations of owners' interests and requirements of environmental protection [20]. Since the discharge is harmful to battery life, the services cost of V2G is much higher. From the view of power supplier, when V2G service costs is higher than conventional units, generation companies chambers of commerce may abandon V2G power generation and take use of conventional generating units. From the view of owners, if there are no good economic benefits, the owners will be not active in participation in V2G services. In addition, with more and more attentions on environmental protection, using of renewable energy generation and reducing pollution of the environment have become much important. Therefore, economic dispatch for smart grid is a multi-objective with multi-constrained dynamic optimization problem shown as follows.

$$\begin{cases} \min f(x) = \left[f_1(x), f_2(x), f_3(x), f_4(x) \right] \\ s.t. g_i(x) \le 0, i = 1, 2, \dots, q \\ h_j(x) = 0, j = 1, 2, \dots, p \end{cases}, \tag{1}$$

where, $g_i(x)$ is inequality constraint function.

The optimization model can be divided into the four parts. Three of the four parts consider the optimization targets from the view of power generation, while the fourth objective considers the objective from the view of owners.

Generation costs include traditional generator's fuel cost, the cost of start and stop, and include a discharge cost of electric vehicles.

$$\min f_1 = \sum_{t=1}^{N_T} \left(\sum_{i=1}^{N_G} U_i(t) \Big(F_i\left(P_{Gi}(t)\right) + S_i\left(P_{Gi}(t)\right) \Big) + V\left(P_{V2g}(t), r_{V2g1}(t)\right) \right) \tag{2}$$

where, $U_i(t)$, $P_{Gi}(t)$, $F_i\left[P_{Gi}(t)\right]$ and $S_i\left[P_{Gi}(t)\right]$ are commitment statue, unit output, fuel costs and commitment costs functions. N_T is period number, N_G is units' number, $V\left[P_{v2g}(t), r_{v2g1}(t)\right]$ is cost function of using V2G. $P_{v2g}(t)$, $r_{g2v1}(t)$ are out power and discharging price respectively.

Generator sets fuel costs.

$$F_i\left[P_{Gi}(t)\right] = a_i + b_i P_{Gi}(t) + c_i P_{Gi}^2(t) \tag{3}$$

where, a_i, b_i, c_i are parameters of units fuel costs.

Generator sets commitment costs.

$$S_i(t) = \begin{cases} C_i^{hs}, T_i^{off} < X_i^{off}(t) \le H_i^{off} \\ C_i^{cs}, X_i^{off}(t) > H_i^{off} \end{cases}$$
$$H_i^{off} = T_i^{off} + T_i^{cs} \tag{4}$$

where, c_i^{hs}, c_i^{cs}, T_i^{off}, T_i^{cs} are hot start-up costs, cold start-up costs, the minimum allowable downtime and cold start-up time.

Electric vehicles discharge cost. Electric vehicles discharging to the grid will increase the electricity cost of the entire system requirements.

$$V\left[P_{v2g(t)}, r_{v2g}(t)\right] = P_{v2g(t)} r_{v2g}(t) \Delta t \tag{5}$$

Carbon emissions are reduced to the lowest.

Through the economic dispatch of generators can reduce carbon emissions, reduce pollution to the environment.

$$\min f_2 = \sum_{t=1}^{N_T} \left(\sum_{i=1}^{N_G} \left(E_i\left(P_{Gi}(t)\right) \right) \right) \tag{6}$$

Carbon emissions expression is as follow

$$E_i\left(P_{Gi}(t)\right) = \alpha_i + \beta_i P_{Gi}(t) + \gamma_i P_{Gi}^2(t), \tag{7}$$

Where α_i, β_i, γ_i are parameters of units carbon emissions. The power equivalent load rate is up to maximum. Renewable energy generation vulnerability to natural factors and affecting output power fluctuations, and by optimizing the electric vehicle charging and discharging can track power fluctuations, smooth grid load, reduce the impact of intermittent renewable generation to the grid. The higher equivalent load rate is the smaller equivalent load fluctuations of the grid. Equivalent load factor is defined in equation (8).

$$\max f_3 = P_{s1d}^{av} / P_{s1d}^{\max} \tag{8}$$

$$P_{s1d}^{av} = \frac{1}{N_T} \sum_{t=1}^{N_T} P_{s1d}(t) \tag{9}$$

$$P_{s1d}^{\max} = \max\left(P_{s1d}(0), \dots, P_{s1d}(T)\right) \tag{10}$$

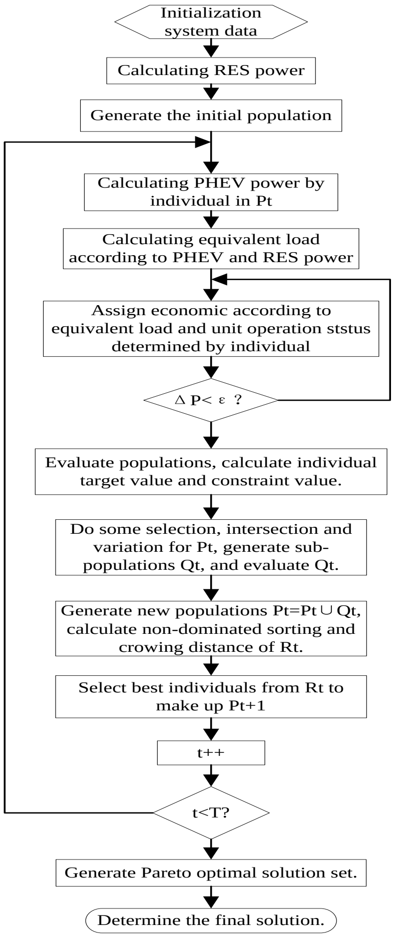


FIGURE1. NSGA-II flow chart

$$P_{s1d}(t)=P_{1d}(t)+P_{g2v}(t)-P_{v2g}(t)-P_{wd}(t)-P_{pv}(t),\quad(11)$$

where, $P_{sld}(t),P_{ld}(t),P_{g2v}(t),P_{wd}(t),P_{pv}(t)$ are equivalent load power, load power, the electric vehicles' charging power, wind power and light power.

Goals need to be converted to the minimum target.

$$\min f_3=1-\frac{P_{s1d}^{av}}{P_{s1d}^{\max}}\quad(12)$$

Allow electric vehicles to participate in V2G service should ensure the maximization of owners economic benefits, so owners participate actively.

$$\min f_4=\sum_{t=1}^{N_r}\left(r_{g2v}P_{g2v}(t)\Delta t-r_{v2g2}P_{v2g}(t)\Delta t\right)\quad(13)$$

Where, $r_{g2v}(t)$ is the preferential charging prices, $r_{v2g2}(t)$ is prices paid by service providers to owners.

After electric vehicles and renewable energy generation connect to network, will change the traditional turbine output, and effect system power balance.

$$\sum_{t=1}^{N_G}P_{Gi}(t)u_i(t)+P_{v2g}(t)+P_{wd}(t)+P_{pv}(t)=\\P_{1d}(t)+P_{g2v}(t)+L(t)\quad(14)$$

Electric car battery power should meet the owner's driving needs, which is the most basic function of electric vehicles, must be met.

$$\sum_{t=1}^{N_T}\left[\left(p_{g2v}(t)\cdot\eta_c-p_{v2g}(t)/\eta_d\right)\cdot\Delta t\right]=E\cdot\left(S_{OC}^a-S_{OC}^d\right),\quad(15)$$

where, $p_{g2v}(t)$ and $p_{v2g}(t)$ are the charging and discharging power of a single vehicles. η_c and η_d are the charging and discharging efficiency of battery. E is battery rated capacity. S_{OC}^a and S_{OC}^d are states of charge. When connected to the grid, the conditions to meet the battery charge and discharge each time.

$$E\cdot S_{OC}(t+1)=E\cdot S_{OC}(t)+\\p_{g2v}(t)\cdot\Delta t\cdot\eta_c-p_{v2g}(t)\cdot\Delta t/\eta_d,\quad(16)$$

Where, $S_{OC}(t)$ is state of battery charge at t.

The conditions capacity before battery running is as follow.

$$E\cdot S_{oc}^a=E\cdot S_{OC}^b-\Delta E\cdot L\quad(17)$$

Where, ΔE is power consumption per unit distance. L is driving distance.

Inequality constraints that the units should meet are as follows.

$$\sum_{i=1}^{N_G}p_{Gi}^{\max}u_i(t)+p_{v2g}\left(N_{ev}-N_{v2g}(t)-N_{g2v}(t)\right)+\\p_{v2g}N_{v2g}(t)+P_{wd}(t)+P_{pv}(t)>\\p_{g2v}N_{g2v}(t)+P_{1d}(t)+L(t)+R(t),\quad(18)$$

where, $R(t)$ is the reserve requirement at t. N_{ev} is the number of electrical vehicles. $N_{g2v}(t),N_{v2g}(t)$ are charging and discharging numbers of vehicles.

$$\begin{cases}\left[X_i^{on}(t)-T_i^{on}\right]\left[u_i(t)-u_i(t+1)\right]\geq 0\\\left[X_i^{off}(t)-T_i^{off}\right]\left[u_i(t+1)-u_i(t)\right]\geq 0\end{cases},\quad(19)$$

where, T_i^{on},T_i^{off} are the shortest running time allowed and the minimum downtime allowed respectively. $X_i^{on}(t),X_i^{off}(t)$ Are continuous operation time and continuous downtime respectively.

Upper and lower unit output constraints.

$$P_{Gi}^{\min}u_i(t)\leq P_{Gi}(t)\leq P_{Gi}^{\max}u_i(t)\quad(20)$$

Units' ramp rate constraints are as follows.

$$R_{di} \le P_{Gi}(t+1) - P_{Gi}(t) \le R_{ui} \quad (21)$$

Considerate for the protection of battery life, when the battery connected to the grid power is neither all done or overcharge, that battery charge should meet the following conditions:

$$E_{\min} < E \cdot S_{OC}^{a} + \Delta t \cdot \sum_{j=1}^{t}\left(p_{g2v}(j)\cdot\eta_c - p_{v2g}(j)/\eta_d\right) < E_{\max}, t = 0,1,\ldots,N_T \quad (22)$$

where, $E_{\min}$ and $E_{\max}$ are the minimum and maximum battery capacity

Charge-discharge power of the electric vehicle should be less than the rated charge and discharge power:

$$\begin{cases} p_{g2v}(t) < P_{EVC} \\ p_{v2g}(t) < P_{EVD} \end{cases}, \quad (23)$$

where, p_{EVC}, p_{EVD} are rated charges and discharge electric power of electric vehicles respectively.

To meet the time constraints, charge and discharge time should meet the owner's driving needs.

$$t \in (T_a \sim T_d) \quad (24)$$

Where, T_a is arrive time, T_a is start time.

3 Model solutions

The traditional economic allocation considers economic dispatch of many periods. It is a dynamic optimization problem. In this paper, a multi-constrained processing algorithm NSGA-II [22-23] is employed to solve this multi-objective, multi-constrained dynamic optimization problem. NSGA-II algorithm is one of the best evolutionary multi-objective optimization algorithms so far. It uses fast non-dominated sorting method based on a new classification and proposes the concept of crowding distance as well as introduces the elite retention mechanism. It greatly reduced the computational complexity, which makes Pareto optimal solutions distribute more uniform and the diversity of solutions better. In this paper, we use binary and decimal mixed encoding method, individual making up with (Ng + 1) NT-dimensional matrix, where: Ng × NT dimensional matrix represents the status of each unit. 1 represents run operation and 0 represents stop operation. 1×NT dimensional matrix represents the number of charging and discharging of electric vehicles (integer). NSGA-II totally includes two layers optimization modules, outer layer optimization is unit commitment and inner layer optimization is load economic allocation. Outer layer optimization module generates status of commitment unit and the electric vehicles number of charging and discharging, and passes it to the inner optimization module, the overall optimization is run by NSGA-II, to guide the direction of evolution of individual by selection, crossover and mutation; inner optimization modules assign the load economic for each unit according to the status of unit passed from outer module, and the result carried to outer module for individual assessment. Calculation process is shown in FIGURE 1. In the actual calculation, if random initialize the start and stop state of the unit by using binary numbers directly, optimization led to a long time, hard to find or cannot find a solution. For this reason this paper improves NSGA-II algorithm, modifies the generator set start and stop initialization method, the specific process is as follows:

$$P_{Gi}^{0}(t) = rnd\left(0, P_{Gi}^{\max}\right) \quad (25)$$

Calculate the total power of each unit.

$$P_G(t) = \sum_{i=1}^{N_G} P_{Gi}^{0}(t) \quad (26)$$

Calculate the proportion of power generating units.

$$r_{Gi}(t) = P_{Gi}^{0}(t) / P_{Gi}(t) \quad (27)$$

$$P_{Gi}^{0}(t) = P_{1d}(t) \cdot r_{Gi}(t) \quad (28)$$

Adjust the power output of each unit by power constraints.

$$P_{Gi}^{0}(t) = \begin{cases} P_{Gi}^{\max}, P_{Gi}^{0}(t) > P_{Gi}^{\max} \\ P_{Gi}^{0}(t), P_{Gi}^{\max} \ge P_{Gi}^{0}(t) \ge P_{Gi}^{\min} \\ 0, P_{Gi}^{0}(t) < P_{Gi}^{\min} \end{cases} \quad (29)$$

Set unit commitment status by each unit generating power.

$$u_i^{0}(t) = \begin{cases} 1, P_{Gi}^{0}(t) > 0 \\ 0, P_{Gi}^{0}(t) = 0 \end{cases} \quad (30)$$

4 Numerical examples

In this paper, analysing 10-generating unit system based on the above optimization model, the parameters of the unit are shown in Table I, 24 h load data is shown in Table II, and the system spinning reserve is set to 10%.

Assuming that there are 50,000 electric vehicles can be scheduled in the power grid, to simplify the analysis, the average charge-discharge power is set as 2 kW, after continuous charging 6 h can be filled. Electric vehicles are traveling on the road during 7: 00-8: 00 and 17: 00-18: 00; it can be charged and discharged in accordance with scheduling flexibility at other times. SOC is 100% at 7:00, after a charge-discharge cycle it can be back to the original

SOC. The average round-trip distance is 30 miles and consumes 4 miles / kW. H, single trip power consumption is about 30%. Assuming installed capacity of stroke power and photovoltaic power generation in power grid were 26MW and 13 MW. FIGUREs 2 and 3 are wind speed and light intensity data respectively. Modeling for wind power and photovoltaic power generation by using Weibull [24] and beta [25] distribution probability model, active output data generated in FIGURE 4. Simulate 10-generating unit with the model and optimization method proposed above, parameters in NSGA-II are set as follows. Population size is N = 100, evolution algebra is T = 200, crossover probability is Pc = 0.9, mutation probability is Pm = 0.1. Frontier solution set of Pareto is shown in FIGURE 5. The final plan can be selected according to the actual needs among the Pareto solution sets. In this paper, the final plan selection principle is reducing the power generation cost at first, so that power producers will priority use V2G services rather than small and expensive units. Secondly, to encourage owners to participate in V2G service, charge costs should be reduced, then reduce environmental pollution. Finally, take advantage of renewable energy generation, improve grid equivalent load factor. That preference order of the optimization goal is set to f1-f3-f2-f4. After sorting options, unit optimal combination scheme is shown in FIGURE 6 (each column contains the unit 24h's output power), electric vehicle charging and discharging optimization program is shown in FIGURE 7. As can be seen from FIGURE 6, the unit 1-4 bear the base load of the system where units 1, 3 and 4 have lower electricity cost in large and medium scale units, so they almost always at full power state. Others adjust the power output according to the load flexibility, units 6-10 as small units have less generation power, generally only invest in peak load periods. As can be seen from FIGURE 7, the discharge power of electric vehicles is small, this is due to the high cost of electric vehicles discharge, is not suitable for release big power to replace the large power units who bear base load, but is suitable to replace some of the small power units with high cost in peak load period. From Table II and FIGURE 4 and 7 can be seen, grid load is low and the wind is very rich from 22: 00 to next days' 7:00, you can take advantage of this time to charge in order to meet the travel needs in the morning, while the grid load rate improved. Electric vehicles traveling on the road during 7: 00 to 8: 00, the battery SOC decline after running. Renewable energy power generation increased during 8: 00 to 15: 00, but at this time electric vehicle does not charging. This is because it is the peak load period of the power grid, load can up to 1500MW, while the wind generation is small compared to the total power generation (up to only about 35 MW), solar energy can provide limited power, so in this time electric car not involved in the charge but transport energy to the grid along with the wind and light to reduce the load pressure and improve power quality. In addition, the owners charge with high prices in the peak load time, but the discharge benefits a lot, so in the meantime electric vehicles involved in the discharge. During 16: 00-17: 00 loads decline a lot, the reduction is 150 MW at 16:00 PM compared with 15:00, charging price is lower than that in peak load time, ideal for charging, electric vehicles charging to meet travel demand. During 17: 00-18: 00 electric cars running on the road, cannot charge and discharge. During 18: 00-19: 00 electric cars have arrived home, at this time grid load is low and electric vehicles continue to charge. During 19: 00-21: 00, grid load rise, wind power is reducing; electric cars release electricity to the grid to reduce the grid pressure. To illustrate the proposed optimization model results, three kinds of operation mode are defined, and give a comparative analysis. Don't consider renewable energy generation, electric vehicles only as a load involved in the regulation of the power grid. Don't consider renewable energy generation, electric vehicles can involved in a grid ancillary services be used as the load and power. Consider renewable energy generation, electric vehicles can involved in a grid ancillary services be used as load and power.

Three kinds of operation modes equivalent load and equivalent load factor are shown in FIGURE 8 and 9. As can be seen, in the original load, grid trough periods have not been fully utilized, the biggest difference existing between peak and load, load rate equivalent is the lowest. Mode 1, although electric vehicles charge in off-peak hours, but not release electrify to power grid in the peak load, so grid peak load has not been reduced.

Mode 2, the electric car is not only charge in low hours, and can be discharged to the grid at peak load times, to some extent, can reduce the peak load, but the high cost of electric vehicles discharge not suitable for large-scale discharge, so grid peak load has not decreased significantly.

Mode 3, renewable energy power generation, electric vehicles charge at late night when the wind power is rich, discharge into the grid at peak load, electric vehicles and renewable energy provide power to the grid at the same time, thus clipping effect is obvious, equivalent load rate is the highest.

Table III compared optimization target of the three ways. Mode 1, because the original load and electric vehicle charging load is borne by generators, electric cars are not involved in the discharge, and therefore the cost of electricity and owners' charge cost is the highest, serious pollute the environment. Mode 2, the electric vehicles can replace small and expensive generators to discharge the grid, thus reducing the cost of electricity, the owners also benefit by discharge and reducing the charge-discharge costs. Mode 3, due to the introduction of renewable energy power generation and electric vehicles involved in the discharge, reducing the cost of electricity effectively, and further reducing emissions, the owner charging costs to a minimum extent.

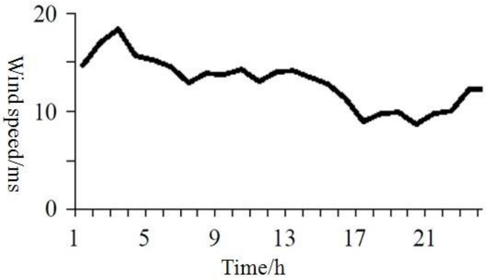


FIGURE 2 Wind speed curve

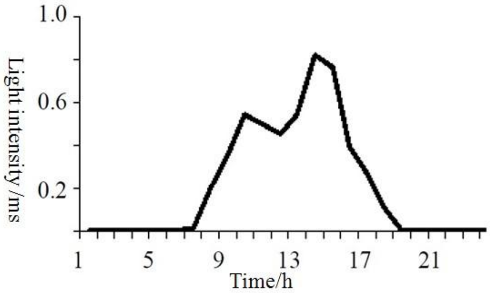


FIGURE 3 Light intensity curve

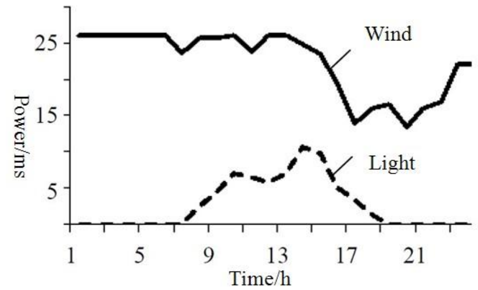
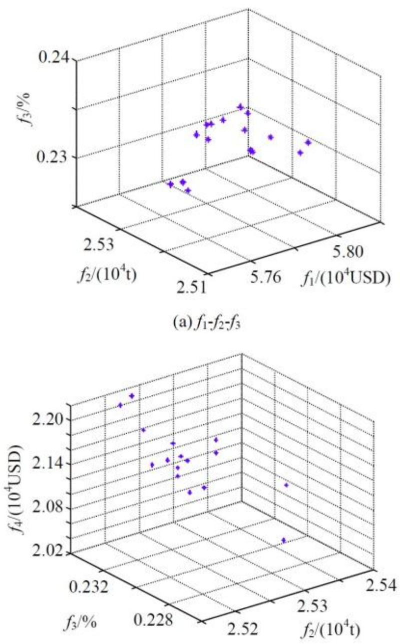
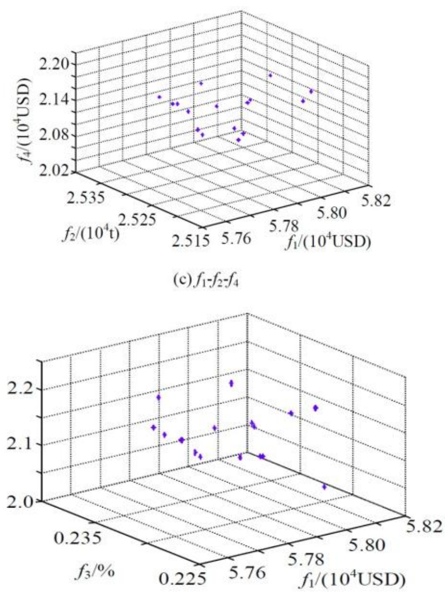


FIGURE 4 Daily power of RES



(a) f_1-f_2-f_3

(b) f_2-f_3-f_4



(c) f_1-f_2-f_4

(d) f_1-f_3-f_4

FIGURE 5 Pareto front sets

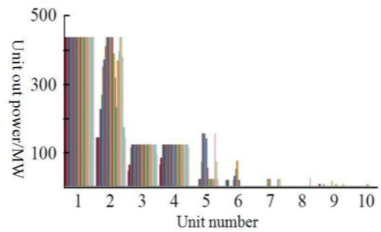


FIGURE 6 Optimal unit commitment

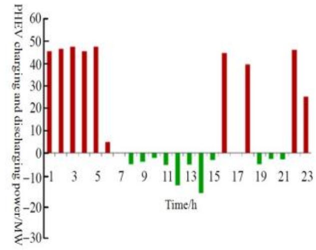


FIGURE 7 Optimal charging and discharging power of PHEV

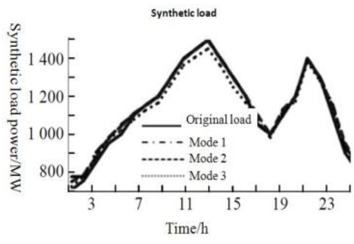


FIGURE 8 Synthetic load curve

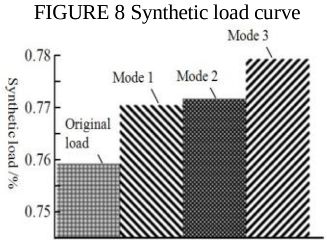


FIGURE 9 Synthetic load ratio curve

TABLE 1 Generator parameters of a 10-generating unit system

Parameters	U1	U2	U3
P_{MAX}/MW	455	455	130
P_{MIN}/MW	150	150	20
a/(USD/h)	1000	970	700
b/(USD/MW.h)	16.19	17.26	16.6
c/(USD/MW^2.h)	0.00048	0.00031	0.002
α/(t/ h)	10.33908	10.33908	30.0391
β/(t/MW h)	-0.24444	-0.24444	-0.40695
γ(t/MW^2 h)	0.00312	0.00312	0.00509
T_{on}/h	8	8	5
T_{off}/h	8	8	8
C_h/h	4500	5000	550
C_c/h	9000	10000	1100
T_{cs}/h	5	5	4
Tinit/h	8	8	-5

TABLE 2 Generator parameters of a 10-generating unit system

U4	U5	U6	U7
130	162	80	85
20	25	20	25
680	450	370	480
16.5	19.7	22.26	27.74
0.00211	0.00398	0.00712	0.0079
30.0391	32.00006	32.00006	33.00056
-0.40695	-0.38132	-0.38132	-0.39023
0.00509	0.00344	0.00344	0.00465
5	6	3	3
5	6	3	3
560	900	170	260
1120	1800	340	520
4	4	2	2
-5	-6	-3	-3

TABLE 3 Generator parameters of a 10-generating unit system

Parameters	U8	U9	U10
P_{MAX}/MW	55	55	55
P_{MIN}/MW	10	10	10
a/(USD/h)	660	665	670
b/(USD/MW.h)	25.92	27.27	27.79
c/(USD/MW^2.h)	0.00413	0.00222	0.00173
α/(t/ h)	33.00056	35.00056	36.00012
β/(t/MW h)	-0.39023	-0.39524	-0.39864
γ(t/MW^2 h)	0.00465	0.00465	0.0047
T_{on}/h	1	1	1
T_{off}/h	1	1	1
C_h/h	30	30	30
C_c/h	60	60	60
T_{cs}/h	0	0	0
Tinit/h	-1	-1	-1

TABLE 4 Daily load data

Period	Load/MW	Period	Load /MW	Period	Load /MW
1	700	9	1300	17	1000
2	750	10	1400	18	1100
3	850	11	1450	19	1200
4	950	12	1500	20	1400
5	1000	13	1400	21	1300
6	1100	14	1300	22	1100
7	1150	15	1200	23	900
8	1200	16	1050	24	800

TABLE 5 Objections comparison

Mode	Generation costs/USD	Emissions/t	Owners charging/USD
1	598485.68	26261.72	23154.72
2	588194.31	25981.05	22196.81
3	575466.14	25256.74	21939.20

5 Conclusions

This paper establishes a dynamic economic dispatch model for the smart grid, which considers both of plug-in hybrid electric vehicle and renewable energy resource generation. The model that includes many objectives changes the conventional way of economic dispatching. Simulation analysis of 10-generating unit indicates that the model can well match the load and power fluctuations of renewable energy generation and improve the power grid equivalent load factor. The design and modeming reduce the impact of renewable generation intermittent to the grid. The connection of plug-in hybrid electric vehicles (PHEVs) and renewable energy resources (RES) is helpful to reduce both of the cost of electricity and the production of greenhouse gas. In addition, the owners can get economic benefits and reduce charging costs.

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Author

< Li Xin >, <1976.04 >, < Jinan County, Shandong Province, China>

Current position, grades: A lecturer of Shandong Agriculture And Engineering University, China.
University studies: received his Computer science education from Shandong Normal University in China. He received his M.Sc. from Shandong Normal University in China.
Scientific interest: His research interest fields include computer application and the computer network.
Publications: more than nine papers published in various journals.
Experience: He has teaching experience of Sixteen years, has completed four scientific research projects.

< Liang Tian>, <1982.01>,< Jinan County, Shandong Province, China>

Current position, grades: A lecturer of Shandong Agriculture And Engineering University, China.
University studies: received her Software engineering from Shandong University in China. She received her M.Sc. from Shandong University in China.
Scientific interest: She research interest fields include computer application and software engineering.
Publications: more than four papers published in various journals.
Experience: She has teaching experience of eight years, has completed three scientific research projects.