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Unit Commitment Optimization in Smart Grid Environments with implications to Energy Transmission and Carbon Emission

Bapathu.Chennakesava Reddy
M.Tech Student
Department of Eee (Power Systems)
Newtons Institute of Engineering,
Macherla Jntuk.

Bandaru Anjibabu
Assistant Professor
Department of Eee (Power Systems)
Newtons Institute of Engineering,
Macherla Jntuk.

Abstract

Demand Side Resources (DSR), and Carbon Emission Trading(CET), are increasingly becoming significant in the domain of smart grid and hybrid multi-grid environments, for maintaining the power balance of supply and demand. With current trend and awareness in carbon emission and its effects, there has been growing interest in research for new solutions and techniques, that complement and include policy back grounds. This paper proposes a model that not only takes advantage of various resources on the demand side, such as electric vehicles, demand response, and distributed generation, but also reflects the effects of CET on generation schedule. Then, an improved particle swarm optimization (IPSO) algorithm is applied to solve the problem. In numerical studies, we analyze the impacts of DSR and CET on the results of UC, respectively. In addition, two meaningful experiments are conducted to study the approaches to allocate emission quotas and the effects of price transmission mechanism.

INTRODUCTION

One of the most typical features of smart grid is to activate components on the demand side. The Chinese Government has been promoting the popularization of EVs, trying to exploit the potential of DR, and encouraging the applications of grid-connected DG in recent years. In smart grid environment, these demand-side resources (DSR) are invigorated. They will participate in the power balance of supply and demand to a greater extent. Traditional UC models and methods are bound to encounter a great change. Some scholars have done researches in related topics. V2G and its impact on the cost and emission of power system are studied on basis of UC model in. The significance and feasibility of DSR and its role in supply-demand schedule are examined in. economical operation of DG and chance-constrained schedule of active network with DG are researched. These researches have illustrated the potential of DSR to be involved in UC in day-ahead market. However, few researchers have considered all the typical demand-side elements simultaneously with conventional generators to make an overall optimal schedule. On the other hand, since power system is one of the main carbon emitters, smart grid is expected to be low-carbon in various aspects. As for UC, the goal should regard the carbon emission in addition to generating cost. Some remarkable works have been done to combine the cost objective and emission objective. Typical methods are to convert one objective into a constraint, or treat the weighted sum of cost and emission as the overall objective. Nevertheless, cost and emission do not share the same dimension, which poses a challenge to combine them together reasonably and effectively. To solve this issue, CET is worthy of close attention. With the increasing pressure of emissions reduction, many countries are promoting the development of CET.

CET converts the emission to a kind of cost reasonably, so it will effectively strike a balance between pursuing minimum cost and minimum emission in the process of UC. Under this circumstance, a new UC model is indispensable. Researches in this area are quite limited at present. A model with carbon trading to investigate the influence of emission constrains on generation scheduling is built in. The UC problem with carbon trading is translated into an emission-constrained UC in. Moreover, smart grid enables some low-carbon DSR available for commitment, which will enlarge the impacts of CET on power system operation. Conversely, the application of CET will promote the utilization of DSR to get the optimal solution to the daily schedule of power supply-demand balance. To solve the UC problem, more and more researcher stend to utilize intelligent optimization algorithms. Typically ,particle swarm optimization (PSO) has been widely used in recent ten years owing to its good performance in convergence rate and solution precision. However, the main disadvantage of PSO is that it may work out a local optimal solution instead of the global optimal solution. Some scholars have begun to make some modifications to this algorithm to solve the UC problem more accurately. This paper proposes a novel UC model. Not only traditional thermal generators on the supply side but also the DSR, such as V2G, DR, and DG, are considered to make daily generation schedule in the smart grid environment. Furthermore, CET is taken into account in the UC model. We observe CET's impacts on the results of UC and research the effects of approaches to allocate emission quotas and price transmission mechanism, respect tively. In addition, the PSO algorithms improved to have more chances to obtain the global optimal solution to the UC problem.

PROBLEM FORMULATION

A. Smart Grid Environment

With the development of smart grid, DSR become more active. They may play an increasingly essential part in power system operation. In this paper, V2G, DR, and DG are considered in the UC model.*1) V2G:* Smart grid is an ideal platform for the interactions between the system operators and EVs. With the related techniques getting mature, it is feasible for EV to sold electricity back to the grid. There is supposed to be an aggregator to communicate between the system operator and a great number of EV owners. If an EV is inactive for a certain period, its owner can sign a contract with the system operator for commit ent via the load aggregator. The sum of V2G can be treated as a special unit. Considering there is an increasing marginal cost to involve more EV owners, the cost function of V2G is assumed to be a quadratic function

$$V2GC\,(V2G_t) = a_{\mathrm{V2G},t} + b_{\mathrm{V2G},t} V2G_t + c_{\mathrm{V2G},t} V2G_t^2.$$

Some basic constraints should be taken into account. Firstly, in case of emergent use of EV's owners, a lower limit of *SoC* is considered (2). Secondly, for the sake of safe operation of the gird, an upper limit on total output of EVs at each hours hould be stipulated (4). Thirdly, now that EV may not be connected to the grid all the 24 h, it is sensible to set a time range limit when EV is available for the system operator (5).Fourthly, the available capacity of V2G at each hour has an upper limit, respectively

$$SoC_{t,j} \geq SoC_{min}$$

$$SoC_{t,j} = \frac{C_{0,j} + \sum_{u=1}^{t} G2V_{u,j} - \sum_{u=1}^{t} V2G_{u,j}}{C_j}$$

$$V2G_t = \sum_{j=1}^{m} V2G_{t,j} \leq V2G_{max}$$

$$V2G_{t,j} = 0,\ t \notin [\mathrm{t}_1, \mathrm{t}_2]$$

$$V2G_t \leq V2G_{t,max}.$$

2) DR: By virtue of smart meter, electric power consumers are able to have a bidirectional communication with the grid. It is possible for them to have a response, such as load curtailment, to the incentive signal and price signal. This paper focuses on the incentive-based DR considering current state of electricity market. A load aggregator exists to interact with tens of thousands of scattered power users.It gathers all the distributed DR resources and signs contract with the system operator. Consequently, the total contribution of DR is treated as a special unit in our UC model. DR's cost function is also assumed to be a quadratic function

$$DRC\,(DR_t) = a_{\mathrm{DR}} + b_{\mathrm{DR}} DR_t + c_{\mathrm{DR}} DR_t^2.$$

There are two constraints on DR in our model for the sake of power users' habits and interests. Upper limits are set on demand curtailment at each hour and within a day as follows:

$$DR_t \leq DR_{t,max}$$

$$\sum_{t=1}^{24} DR_t \leq DR_{dmax}.$$

3) DG: In smart grid environment, the power system has a higher tolerance for DG. With more DG connecting to the grid, they should be taken into consideration in UC model. DG is divided into two types. One is direct use by the power consumers, noted as *DGa*in this paper, leading to reduction of load demand in UC problem. The other one is the power can be sold to the grid, denoted by *DGb*. In this situation, the sum of DG acts as a special unit if an aggregator is considered as discussed in. This special unit has its own cost coefficients and cost function

$$DGC\left(DGb_t\right) = a_{DGb} + b_{DGb}DGb_t + c_{DGb}DGb_t^2.$$

Two constraints of DG are taken into account. Firstly, since DG's output is subject to natural resource and weather condition, so an upper limit on available DG at each hour is considered (11). Secondly, now that DG tends to be in termittent and volatile, an upper limit on its penetration rate should be set (12), to ensure a reliable operation of the power system

$$DGb_t \leq DGb_{t,max}$$

$$\eta_t = \frac{DGb_t}{\sum_{i=1}^{N}\left(P_{i,t}I_{i,t}\right) + V2G_t + DGb_t} \leq \eta_{max}.$$

B. CET

1) Carbon Emission Quotas: CET is also called cap-and-trade, which reveals that setting a cap is the step in the first place [30]. The cap of all the generators in this paper is supposed to be a certain proportion of the original overall emissions. Each generator gets an emission quota. The actual emission of a unit may be greater or lower than its cap, because of the quota trades. A key point is how to allocate the quotas among different units. This paper assumes that the emission quota of a unit mainly depends on its emission intensity, i.e., the average eamount of emission for generating one unit of electricity. Two concrete approaches are proposed. For each method, it is essential to solve the UC problem without CET and calculate the total output and emissions of each unit in advance. Then, emission intensity of each unit will be determined. After that, classify units into several groups according to their emission intensity level from high to low. The keynote of the first approach is to make the quotas of all the units less than or equal to their original emission level. The second approach is to reduce the emission quotas of units in high emission groups, while raise the quotas of units in low emission group. These two methods share the same gist: the sum of the quotas of all the units should be equal to the overall cap. Additionally, V2G causes some emissions because the electricity in the EV may come from thermal power generation. Hence, the aggregator of V2G should be considered in CET market. Since it is quite a new resource with different operating features and development scales with generators in supply side, the quota of V2G is determined independently.

2) Price of Carbon Emissions Rights:

Since there will bea great quantity of companies in various sectors in the CETmarket, this paper assumes that the quantity is so large thatthe CET of generator units will not affect the trading prices.We use the average price in four CET markets in India onFeb. 14th, 2014, i.e., 450Rs per ton. It is $7.708 per ton considering the exchange rate on that day. Calculations in this paper are based on this price named *pr*. In UC problem, CET means that an "emission cost" should be determined

$$EC = \sum_{i=1}^{N}\left[\left(\sum_{t=1}^{24} E_{i,t} - Eq_i\right) \times pr_e\right] + \left(\sum_{t=1}^{24} E_{V2G,t} - Eq_{V2G}\right) \times pr_e.$$

Evidently, the overall emission cost consists of the cost of generators and the cost of V2G. The cost appears when their emissions get higher than their quotas, which means they have to spend money to buy extra emission quotas. The emission of a thermal unit is usually presented as a quadratic function of its power output

$$E_{i,t}\left(P_{i,t}\right)=\alpha_i+\beta_i P_{i,t}+\gamma_i P_{i,t}^2.$$

The emission caused by V2G is assumed to be its output multiplied by the average emission intensity of all the generators in this paper, since it is impossible to figure out which generator the electricity in EVs' batteries comes from.

C. UC Model

A novel UC model considering DSR and CET is proposed.*1) Objective:* The general objective of UC is to minimize the *TC* to achieve the supply-demand balance of power. The *FC*s and *SC*s of thermal units are counted as follows [1]:

$$FC_i\left(P_{i,t}\right)=a_i+b_iP_{i,t}+c_iP_{i,t}^2$$

$$SC_{i,t}=\begin{cases} h-cost_i & MD_i\le X_i^{off}\le H_i^{off}\\ c-cost_i & X_i^{off}>H_i^{off}\end{cases}$$

$$H_i^{off}=MD_i+Cshour_i.$$

In view of V2G, DR and grid-connected DG, the cost objective in this paper should also include the three sorts of costs presented in (1), (7), and (10). Besides, the emission cost defined in (13) is also taken into account in the objective function. The *TC* of UC is

$$TC=\sum_{t=1}^{24}\sum_{i=1}^{N}\left[FC_i\left(P_{i,t}\right)I_{i,t}+I_{i,t}\left(1-I_{i,t-1}\right)SC_{i,t}\right]$$
$$+\sum_{t=1}^{24}\left[DRC\left(DR_t\right)+V2GC\left(V2G_t\right)+DGC\left(DGb_t\right)\right]$$
$$+EC.$$

2) Constrains: UC model usually contains power balance constraint, spinning reserve constraint, generation limits constraint, minimum *on*/*off* time constraint and network security constraint as follows

$$\sum_{i=1}^{N}\left(P_{i,t}I_{i,t}\right)=Load_t-DR_t-V2G_t-DGa_t-DGb_t+PL_t.$$

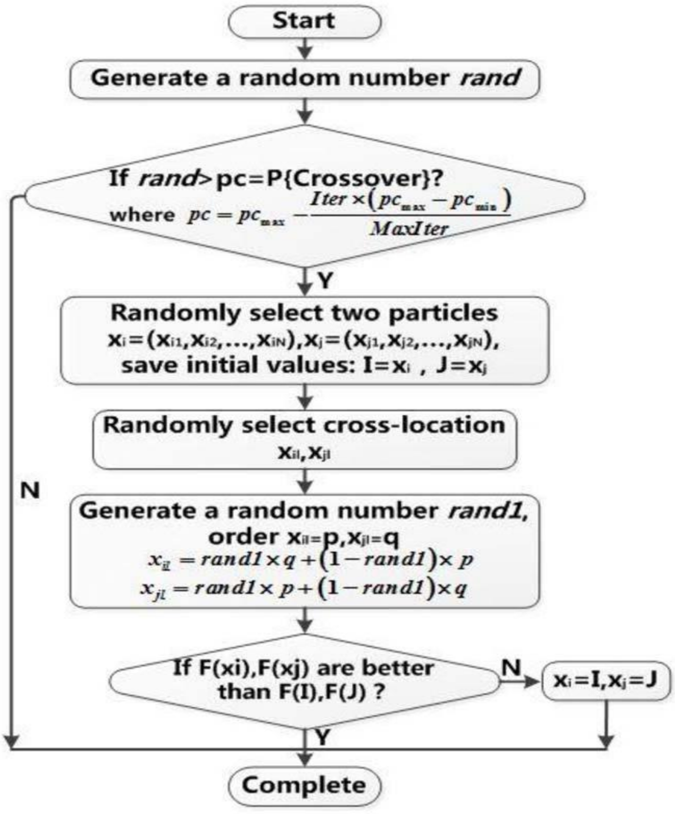
$$\sum_{i=1}^{N}\left(P_{i,t,max}I_{i,t}\right)+V2G_{t,max}+DR_{t,max}\ge Load_t+PL_t+R_t.$$

$$P_{i,min}\le P_{i,t}\le P_{i,max}.$$
$$\left.\begin{array}{rl}\left(1-I_{i,t+1}\right)MU_i\le X_{i,t}^{on} & I_{i,t}=1\\ I_{i,t+1}MD_i\le X_{i,t}^{off} & I_{i,t}=0\end{array}\right\}.$$
$$-K_{ij}\le\sum_{b\in B}L_{ij}^b\left(\sum_{i\in G_b}P_{i,t}+V2G_t^b+DGb_t^b-Load_t^b\right.$$
$$\left.+\ DR_t^b+DGa_t^b\right)\le K_{ij},\forall(i,j)\in\varepsilon.$$

In light of V2G, DR and DG, it is indispensable to add the constraints of these resources as shown in (2), (4)–(6), (8), (9), (11), and (12) to the general UC optimization model.

III. SOLUTION METHODOLOGY

PSO was proposed by Kennedy and Eberhart in 1995.Each particle in PSO has a specific position that represents generators in this paper, since it is impossible to figure out which generator the electricity in EVs' batteries comes from.



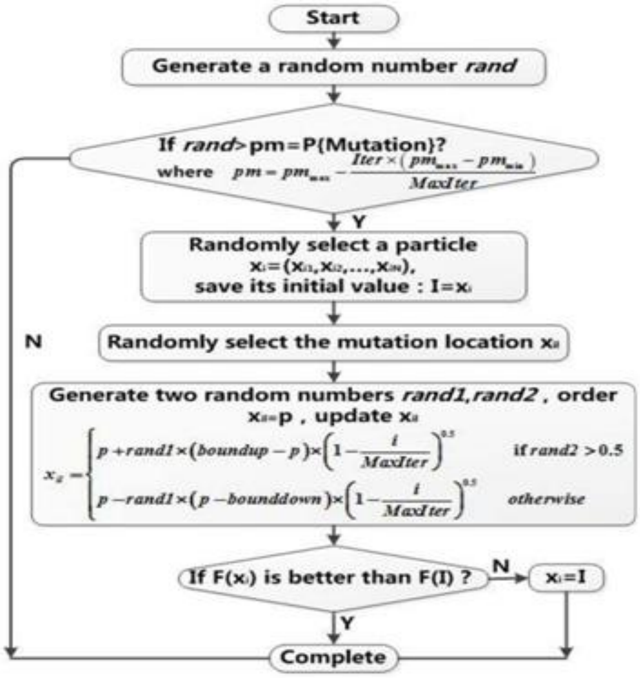
Flow chart of the cross-over operator a potential solution to the optimization problem. All the particles keep updating their velocity so that their positions may change after each iteration. Since the particles never stop trying to move to better positions, they are expected to find the best position in the space. However, PSO has a principal drawback that particles tend to lose themselves in local optimal solution [22]. After a number of iterations, particles may lack the motivation to search the space that is wide enough to cover the global optimal position, particularly when they are very close to local optimal positions. The adverse effects tend to be more serious to solve multidimensional problems. Some scholars have made some modifications to resolve the drawback [21]–[23]. Authors have improved the general PSO algorithm by employing cross over operator and mutation operator that are similar to those typical operators in genetic algorithm (GA). This modified algorithmis called improved particle swarm optimization (IPSO). Theaim is to enhance the probability of particles to find the global optimal position. Crossover and mutation operators will be conducted with a specified probability at the end of each iteration. Specific steps of these two operators are illustrated inFigs. 1 and 2, respectively.

IV. NUMERICAL STUDIES

The studies have been conducted on the ten-unit system and the IEEE 30 bus system. The program is coded in MATLAB 8.2 on a computer with Intel Core i5 and 8 GB RAM.

A. Ten-Unit Case

Firstly, we do a relatively simple case study on the ten-unit system to verify the effectiveness and the superiority of the novel algorithm in this paper, the IPSO. The ten-unit system is one of the most popular choices in the papers related to UC and it is especially suitable to test the algorithm

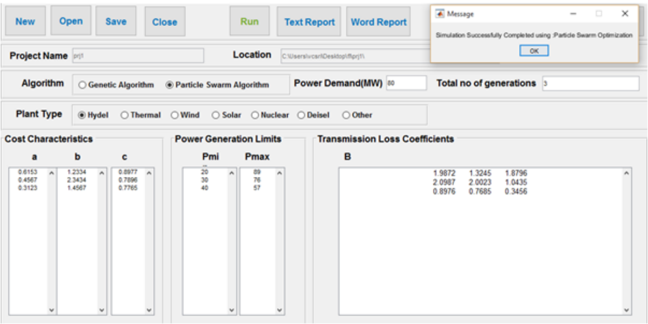


Flowchart of the mutation operator.

V. CONCLUSION

This paper develops a novel UC model in smart grid environment considering V2G, DR, DG as well as CET. The UC optimization problem is solved by the IPSO algorithm. Numerical studies verify the capability of DSR to participate in the power supply-demand balance. The *TC* and the total emission decrease evidently by virtue of DSR. The effect is more obvious if CET is carried out, because DSR offer great options for system operator to replace the high carb on traditional generators that are under pressure of CET. Thanks to CET, generators with relatively low emission intensity and DSR are more likely to be dispatched. Then, this paper researches two typical points on CET policy. One is how to allocate the emission quotas. The conclusion is that we should make the quotas of some low carbon units greater than their original emission level, instead of providing all the units with quotas that are less than or equal to their original emissions. The other is the importance of price transmission mechanism. CET raises the price of utilizing fossil energy. If the change in generating cost can be transferred to the electricity sales price, the effect of CET on the emission reduction of power sector will be better.

The Main Interface for Input Parameters



Simulation Successfully Completed using :Particle Swarm Optimization

Project Name prj1

Location C:\Users\vcsrl\Desktop\f\prj1\

Algorithm ○ Genetic Algorithm ● Particle Swarm Algorithm

Power Demand(MW) 80

Total no of generations 3

Plant Type ● Hydel ○ Thermal ○ Wind ○ Solar ○ Nuclear ○ Deisel ○ Other

Cost Characteristics

a	b	c
0.6153	1.2334	0.8977
0.4567	2.3434	0.7896
0.3123	1.4567	0.7765

Power Generation Limits

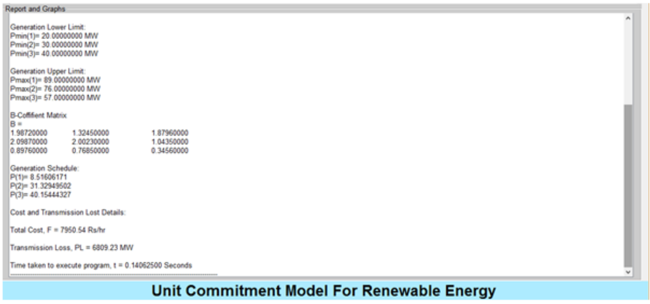
Pmi	Pmax
20	89
30	76
40	57

Transmission Loss Coefficients

B

1.9872	1.3245	1.8796
2.0987	2.0023	1.0435
0.8976	0.7685	0.3456

Text Report



```
Generation Lower Limit:
Pmin(1)= 20.00000000 MW
Pmin(2)= 30.00000000 MW
Pmin(3)= 40.00000000 MW

Generation Upper Limit:
Pmax(1)= 89.00000000 MW
Pmax(2)= 76.00000000 MW
Pmax(3)= 57.00000000 MW

B-Coffifent Matrix
B =
1.98720000      1.32450000          1.87960000
2.09870000      2.00230000          1.04350000
0.89760000      0.76850000          0.34560000

Generation Schedule:
P(1)= 8.51606171
P(2)= 31.32949502
P(3)= 40.15444327

Cost and Transmission Lost Details:

Total Cost, F = 7950.54 Rs/hr

Transmission Loss, PL = 6809.23 MW

Time taken to execute program, t = 0.14062500 Seconds
```

References:

[1] Ning Zhang, Zhaoguang Hu, Daihong Dai, Shuping Dang, Mingtao Yao & Yuhui Zhou, Unit Commitment Model in Smart Grid Environment Considering Carbon Emissions Trading, IEEE Transactions on Smart Grid (Volume: 7, Issue: 1, Jan. 2016)

[2] A.Rajesh, K.Sudheer & M.Balasubbareddy, Optimum AC-DC Interconnected Grid Control, IJMETMR, Vol. No: 1(2014), Iss No: 11 (November) , http://www.ijmetmr.com/olnovember2014/ARajesh-KSudheer-MBalasubbareddy-58.pdf

[3]R. H. Lasseter and P. Paigi, “Microgrid: A conceptual solution,” in Proc. IEEE 35th PESC, Jun. 2004, vol. 6, pp. 4285–4290.

[4]S. A. Daniel and N. Ammasai Gounden, “A novel hybrid isolated generating system based on PV fed inverter-assisted wind-driven induction generators,” IEEE Trans. Energy Conv., vol. 19, no. 2, pp. 416–422, Jun. 2004.

[5] Booth, R.R. Power System Simulation Model based on Probability Analysis. IEEE Transactions, vol. PAS-91, pgs. 62-69, 1972.

[6] Dupacova, J.; N. Growe-Kuska, and W. Romisch. Scenario reduction in stochastic programming: An approach using probability metrics. Math Programming, vol. 95, no. 3, pgs. 493-511, 2003.

[7] Poria Hasanpor Divshali and Bong Choi, "Electrical Market Management Considering Power System Constraints in Smart Distribution Grids", Energies, vol. 9, pp. 405, 2016, ISSN 1996-1073.