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Electrical vehicles planning on incorporation of power production units

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Abstract: The startup issue of the plants has an important role in economical utilization of power systems and also identifying the proper startup or shutdown time of the plants among the possible moods leads to vast economical thriftiness. Moreover, creating proper spinning reserve in power systems, keeps their security in a pleasant status. Incorporating electric vehicles (EVs) to power systems may address both additional demand as well as mobile storage to support electric grid spatially. Charging and discharging of EVs must be scheduled intelligently to prevent overloading of the network at peak hours, take advantages of off peak charging benefits and delaying any load shedding. In this paper, a new structure for Unit Commitment (UC) scheduling associated with V2Gs are suggested, adding of the electrical vehicles into units startup causes to their emission costs decreasing and utilization costs decreasing.
Keywords:electric vehicles, unit commitment, emission, smart grid, generating scheduling

1. Introduction

Nowadays, considering to wasteful energy consumption in the world, the power system do not meet the need of this amount of energy. Therefore, the free capacities of the plants have decreased and planning of units productions faces with problems. Moreover, it should be mentioned if plants can supply this electrical load, the production units as the result of power increasing faces with some difficulties such as environmental emission increasing, fuel limitations and network disability in transferring the requested power.Changing the present structure of power system and its intellectualizing is important for better management and removal of mentioned obstacles. Vehicle to Grids (V2Gs) as one of the new technology can reduce dependencies on small expensive units in new environment which can be used as energy storage. Specially, there are some traditional mathematical methods such as priority list(PL)[1] (Burns RM, 1992; Tomonobu Senjyua, 2006), dynamic planning(DP)[2] (Ouyang Z, 1991), branches and boundary methods(BB)[3] (Cohen AI, 1983), mixed integer planning (MIP)[4] (Carrion M, 2006) and Lagrange release methods(LR)[5] (Ongsakul W, 2004; Wang SJ, 1995). The priority list method is a simple and fast on among them, but generally the quality of the solution is weak. Dynamic planning is flexible but its problem relates to its many dimensions increasing the calculation time. The branches and borders method has some problems in performance while the unit is put into operation. In our case, units startup, the mixed integer planning method leads to defeat when the number of units increases since it needs a high memory so it suffers from big calculation problems. The Langrage releasing method is widely used to solve the issue of units startup in electricity industry. Although this method is a fast one, it suffers from the literal convergence and result quality. Recently new meta heuristic

[1] Priority list
[2] Dynamic programming
[3] Branch Border
[4] Mixed integer programming
[5] Lagrange relaxation

methods such as genetic algorithm(GA)[6](Kazarlis SA, 1996; Srinivasan D, 2004), evolutionary planning(EP)[7] (Hasegawa, 1999), fuzzy logic(FL)[8], artificial neural network(ANN)[9], simulated fusion(SF)[10], and group algorithms like particle swarm(PS) (Gaing, 2003; Tiew-On Ting 2003) have shown more optimistic results. These different meta heuristic optimization methods have attracted special attention to themselves, because their ability in not only for searching the local optimal solutions but also for worldwide optimal solution and they have the ability to deal with different hard non-linear constraints. Anyway, these meta heuristic methods in large scale startup issue need considerable time to find an answer being close to worldwide optimal solutions. Recently, researchers have shown the potential and ability of solving by hybrid solutions(Ongsakul W, 2004; Srinivasan, 2009). These techniques being the combination of the above said techniques even shows better results in comparison to previous methods. In this article the network has been assisted to solve the issue of unit incorporation planning to decrease the total cost of utilization and to do so, the GAMS[11] software has been used. In this issue, the total sustained cost includes production costs of thermal units, startup and shutdown costs and utilization costs of electrical engines which are minimized in the study time of this research.

2. Model Description and Formulation

Units startup base on the cost is an optimization issue formulated in this way:

2.1 Objective function

The objective is minimizing of the total costs of all units formulated in this way Eq.(1):

$$Min\,TC = OC + EC \qquad (1)$$

In the above formula, OC is the operation cost in Equation(2) and EC is the emission costs of units:

$$OC = FC + SU + SD \qquad (2)$$

The total utilization cost includes Fuel cost (FC) , Start-up cost(SU) and Shut down cost(SD) of the units. The fuel cost of the thermal units is defined as a quadratic equation of output power of the unit in this Eq.(3) :

$$FC(i,t) = c(i)\,P(i,t)^2 + b(i)\,P(i,t) + a(i) \qquad (3)$$

Where: a(i), b(i), c(i) are positive fuel cost coefficients of thermal unit(i), respectively. P(i,t) represents the output power of the ith unit at time t. The operation costs include both cool and warm operation defined in this Eq.(4) :

$$SU(i) = \begin{cases} HSC(i), & MD(i,t) \le TC^{off}(i) \le MD(i,t) + CST(i) \\ CSI(i), & TC^{off}(i) \ge MD(i,t) + CST(i) \end{cases} \qquad (4)$$

Emission is a polynomial equation defined in this Eq.(5) :

$$E(i,t) = \alpha(i).p(i,t)^2 + \beta(i).\,p(i,t) + \delta(i) \qquad (5)$$

And finally the objective equation(TC) is defined in Eq.(6):

$$Min\,TC = \sum_{1}^{N}\sum_{1}^{T}(((SU(i).\,y(i,t) + SD(i).z(i,t)) + FC(i,t) + EC(i,t)) \qquad (6)$$

Shutdown costs *SD(i)* for each unit is fixed and shown by shutdown index Z(i,t) in model (6-4).

The relation among the shutdown index, operation index and units status is defined in this Eq.(7):

$$y(i,t+1) - z(i,t+1) = U(i,t+1) - U(i,t) \qquad (7)$$

Each unit in each time is either on or off and they cannot happen together. It is defined in Equation 8 and 9.

$$y(i,t) + z(i,t) \le 1 \qquad (8)$$

$$0 \le z(i,t) \le 1 \qquad (9)$$

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[6] Genetic Algorithm
[7] Evolutionary programming
[8] Fuzzy logic
[9] Artificial Neural Network
[10] Simulated Annealing
[11] General Algebric Modeling System

The emission cost of the units is defined in Equation 10:

$$EC = \frac{FC(i, P^{max}(i))}{E(i, P^{max}(i))}.E(i,t) \qquad (10)$$

The equation 3 is estimated by a collection of the piecewise blocks and they are formulated in a linear way in Eq.(11) (Sheikh-El-Eslami, 2012):

$$FC(i,t) = F(P^{min}(i,t)).u(i,t) + \sum_{k=1}^{kk} s^{k}(i,t).P^{k}(i,t) \qquad (11)$$

Based on (Sheikh-El-Eslami, 2012), the emission is formulated in a linear way in Eq.(12):

$$E(i,t) = EM(P^{min}(i,t)).u(i,t) + \sum_{m=1}^{m.m} se^{m}(i,t).P^{m}(i,t) \qquad (12)$$

Now we are going to investigate the effect of electrical vehicles on issue. As we know, the utilization cost of electrical vehicles is $P_v.N_{v2g}(t)$. so the objective equation of incorporation of power production units in the presence of electrical vehicles is defined in this Eq.(13):

$$MinTC = \sum_{1}^{N}\sum_{1}^{T}((SU(i).y(i,t) + SD(i).z(i,t)) + (F(P^{min}(i,t)).u(i,t) + \sum_{k=1}^{kk} s^{k}(i,t).P^{k}(i,t)) + \frac{FC(i, P^{max}(i))}{E(i, P^{max}(i))}.(EM(P^{min}(i,t)).u(i,t) + \sum_{m=1}^{m.m} se^{m}(i,t).P^{m}(i,t))) + \sum_{1}^{T}((S.\Phi.P_v.N_{v2g}(t)) \qquad (13)$$

2.2 The constraints of the problem

2.2.1 The power balance constraint

The produced power of thermal units and electrical vehicles should be equal to the total request and casualty defined in Eq.(14):

$$\sum_{i=1}^{N} P(i,t)u(i,t) + (S.\Phi.P_v.N_{v2g}(t) - S.\Phi.P_v.N_{g2v}(t)) = D(t) + \text{losses} \qquad (14)$$

2.2.2 The spining reserve constraint

The power system needs acceptable reliability in order to continue service providing to subscribers and decrease the possibility of load disconnection. In order to keep system reliability in a pleasant level, specific amount of load should be provided all the times. On the other hand, spinning reserve requirement must be sufficient enough to prevent any undesirable load shedding in case of an outage or unexpected increasing of demand. It is usually a prespecified amount that is either equal to the largest unit or a given percentage of the forecasted load. It is formulated in Eq.(15) :

$$\sum_{i=1}^{N} u(i,t).P^{max}(i,t) + (S.\Phi.P_v.N_{v2g}(t) - S.\Phi.P_v.N_{g2v}(t)) \geq D(t) + R(t) \qquad (15)$$

2.2.3 The generation unit constraint

The produced power of unit i in each time should be between the minimum and the maximum produced power of the same unit. It is formulated in Eq.(16):

$$P^{min}(i) \leq P(i,t) \leq P^{max}(i) \qquad (16)$$

2.2.4 The maximum increasing or decreasing ramp rate of the units

The maximum increasing ramp rate is the maximum output production that unit i can increase the produced power in an hour based on it ,as Eq.(17). Based on Equation 18, the increasing ramp rate minimize the maximum output capacity of unit i hour t.

$$P^{max}(i) = MIN(P^{max}(i), P(i,t-1) - RD(i)) \qquad (17)$$

$$P(i,t) - P(i,t-1) \leq RU(i) \tag{18}$$

The maximum decreasing ramp rate is the maximum output production that unit i can decrease the produced power in an hour based on it. It is formulate in this Equation(19). Based on Eq.(20), the decreasing ramp rate minimize the maximum output capacity of unit i hour t.

$$P^{min}(i) = MAX\,(P^{min}(i), P(i,t-1) - RD(i)) \tag{19}$$

$$P(i,t-1) - P(i,t) \leq RD(i) \tag{20}$$

2.2.5 The minimum startup/shutdown time

The minimum hours that a unit should be on or active continuously after being started up. The Eq.(21) shows the minimum operation time in a system.

$$TC^{on}(i) \geq (1 - U(\text{i}, \text{t+i})).(MU(\text{i}, \text{t})) \quad \text{if} \quad \text{U(i.t)=1} \tag{21}$$

Based on Eq.(22), the minimum shutdown time of a unit is the minimum hours that unit should be off or inactive continuously after being shut down.

$$TC^{off}(i) \geq (U(\text{i}, \text{t+i})).(MD(\text{i}, \text{t})) \quad \text{if} \quad \text{U(i,t)=0} \tag{22}$$

2.2.6 Discharged vehicles numbers

Based on formula 23, only a specific number of vehicles are modulated for discharge planning. Therefore the total number of vehicles is fixed and all of them are charged by renewable resources:

$$\sum_{t=1}^{T} N_{v2g}(t) = N^{max} \tag{23}$$

Moreover, Based on Eq.(24), all cars cannot be discharged at a specific time:

$$N_{v2g}(t) \leq N_{v2g}^{max}(t) \tag{24}$$

Also, based on Eq.(25), only a few number of cars are modulated for charge planning:

$$\sum_{t=1}^{T} N_{g2v}(t) = N^{max} \tag{25}$$

Furthermore, Based on Eq.(26), all cars cannot be discharged at a certain time:

$$N_{g2v}(t) \leq N_{g2v}^{max}(t) \tag{26}$$

2.3 The state of charge(SOC) of batteries:

One of the important feature of the batteries is the charging status of the machine batteries. This index shows the ratio of the stored energy to battery capacity.

$$E_{v,t} = E_v^{max} \tag{27}$$

2.4 Output

Charging and output of the inverters should be considered.

2.5 Primary conditions

The primary conditions of the generation unit and output power are primary operation and shutdown hours number of the units & primary output power of the units, may limit the startup or shutdown of the units and the output power of the units in schedule scope.

2.6 Vehicles charging and discharging time

It is assumed that each car charges and discharges only once during 24-hour day.

3. Case study simulation

Here, in startup issue of the units without electrical vehicles and with different vehicles is simulated and they are tested on 10 units of IEEE, and different scenarios are solved by GAMS software and they are utilized for 24 hours. The utilization and emission costs of different scenarios are analyzed.
The units specifications of 10-unit system are shown in table (1). Also, the predicted electricity need is presented in table (2).

Table 1: Unit characteristic of convention 10-unit test system

unit	$p^{min}(i,t)$ (MW)	$p^{max}(i,t)$ (MW)	$c(i)$ ($\$/MWh^2$)	$b(i)$ ($\$/MWh$)	$a(i)$ ($)
1	150	455	0/00048	16/19	1000
2	150	455	0/00031	17/26	970
3	20	130	0/002	16/60	700
4	20	130	0/00211	16/50	680
5	25	162	0/00398	19/70	450
6	20	80	0/00712	22/26	370
7	25	85	0/00079	27/27	480
8	10	55	0/00413	25/92	660
9	10	55	0/00222	27/27	665
10	10	55	0/00173	27/79	670
unit	MD(i) (hr)	MU(i) (hr)	$CST\ (i)$ (hr)	$HSC\ (i)$ ($)	$CSC\ (i)$ ($)
1	8	8	5	4500	9000
2	8	8	5	5000	10000
3	5	5	4	550	1100
4	5	5	4	560	1120
5	6	6	4	900	1800
6	3	3	2	170	340
7	3	3	2	260	520
8	1	1	0	30	60
9	1	1	0	30	60
10	1	1	0	30	60

Table 2: Demand and Price of the predicted electricity for 10-unit systems

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

The vehicles parameters amounts are as follow:
The maximum battery capacity 25KWH, the minimum battery capacity 10 KWH, the average battery capacity P_v=15, the 20 percent of all the vehicles $N_{G2V}^{\max}(t)$, the 10 percent of all the vehicles $N_{V2G}^{\max}(t)$, SOC=50% and output is 85% . The spinning reserve is considered as 10% of load request. First, the table (3) shows the power generation units and table (4) shows operation cost and emission costs of power generation units.

Table (3): The production planning (MW) of power production units

Hour	Unit1 (MW)	Unit2 (MW)	Unit3 (MW)	Unit4 (MW)	Unit5 (MW)	Unit6 (MW)	Unit7 (MW)	Unit8 (MW)	Unit9 (MW)	Unit10 (MW)
1	398	303	0	0	0	0	0	0	0	0
2	425	326	0	0	0	0	0	0	0	0
3	440	344	0	0	66	0	0	0	0	0
4	455	415	0	0	80	0	0	0	0	0
5	455	360	0	119	66	0	0	0	0	0
6	453	348	114	119	66	0	0	0	0	0
7	455	379	119	125	73	0	0	0	0	0
8	453	409	130	130	76	0	0	0	0	0
9	455	440	130	130	85	35	25	0	0	0
10	455	455	130	130	128	65	25	12	0	0
11	455	455	130	130	147	77	25	21	10	0
12	455	455	130	130	162	80	25	33	19	12
13	455	455	130	130	128	65	25	12	0	0
14	455	440	130	130	85	35	25	0	0	0
15	455	409	130	130	76	0	0	0	0	0
16	431	333	114	114	59	0	0	0	0	0
17	409	316	108	108	59	0	0	0	0	0
18	453	348	114	119	66	0	0	0	0	0
19	455	409	130	130	76	0	0	0	0	0
20	455	455	130	130	128	65	25	10	0	0
21	455	440	130	130	85	35	25	0	0	0
22	455	455	0	0	112	53	25	0	0	0
23	455	372	0	0	73	0	0	0	0	0
24	452	348	0	0	0	0	0	0	0	0

Table (4): Utilization and emission costs of power production units in startup issue

unit	Emission cost ($)	Operation cost ($)
1	19624/10	219811/21
2	15961/17	203838/22
3	4314/04	49723/28
4	4569/52	52450/41
5	3729/31	52178/37
6	1885/65	17132/44
7	2038/45	13124/40
8	1056/76	6770/61
9	482/19	2634/04
10	249/58	1269/40

total	53910/76	618932/36

Now the electrical vehicles are added to startup issue of unit based on profit and the problem is solved in three different scenarios with different numbers of vehicles:

Scenario 1: the startup problem of the units is solved with 3000 vehicles and result related to utilization cost of generation units and emission cost of units are presented in table (5).

Table (5): Utilization cost of production units and emission cost of units in incorporation of units with 3000 vehicles

unit	Emission cost ($)	Operation cost ($)
1	20314/62	223685/60
2	16613/93	208354/28
3	4452/33	50709/95
4	5196/83	59270/37
5	2902/28	44102/81
6	1870/08	14339/40
7	905/98	6053/20
8	0	191/25
9	0	191/25
10	0	191/25
total	52256/04	605368/10

As it is considered, the utilization cost of the generation units is 618932/36 $ when the unit incorporation problem is solved and its cost is 605368/10$ when the unit incorporation problem with 3000 vehicles is solved and it means that the utilization cost of generation units has decreased for 13564/26$ in comparison to the time that the incorporation problem is solved without electrical vehicles.

Moreover, it can be considered that the emission cost of the production units is 53910/76 $ when the unit incorporation problem is solved and its cost is 52256/04$ when the unit incorporation problem with 3000 vehicles is solved and it means that the emission cost of generation units has decreased for 1654/72$ in comparison to the time that the incorporation problem is solved without electrical vehicles.

Scenario 2: The startup problem of the units is solved with 4000 vehicles and result related to utilization cost of generation units and emission cost of units are presented in table (6).

Table (6): Utilization cost of production units and emission cost of units in PBUC-V2G with 4000 vehicles

Unit	Emission cost ($)	Operation cost ($)
1	20314/62	223749/34
2	16897/03	210281/74
3	4452/33	50773/70
4	5298/08	59887/20
5	2837/66	43673/95
6	1685/87	12229/78
7	679/48	4716/46
8	0	255/00
9	0	255/00
10	0	255/00

Total	52165/07	603782/18

As it is considered, the utilization cost of the generation units is 603782/18 $ when the unit incorporation problem with 4000 vehicles is solved and it means that the utilization cost of production units has decreased for 15150/18$ in comparison to the time that the incorporation problem is solved without electrical vehicles.
Moreover, it can be considered, the emission cost of the production units is 52165/07 $ when the unit incorporation problem with 4000 vehicles is solved and it means that the utilization cost of production units has decreased for 1745/69 $ in comparison to the time that the incorporation problem is solved without electrical vehicles.
Scenario 3: the startup problem of the units is solved with 5000 vehicles and result related to utilization cost of generation units and emission cost of units are presented in table (7).

Table (7): Utilization cost of production units and emission cost of units in PBUC-V2G with 5000 vehicles

unit	Emission cost ($)	Profit ($)
1	20314/62	223813/09
2	16834/46	210261/40
3	4804/12	54361/69
4	5299/39	59957/79
5	2738/03	42215/11
6	1931/72	12874/57
7	0	318/75
8	0	318/75
9	0	318/75
10	0	318/75
total	51922/33	601889/89

fig1:total Emission cost of unit in sec1-3

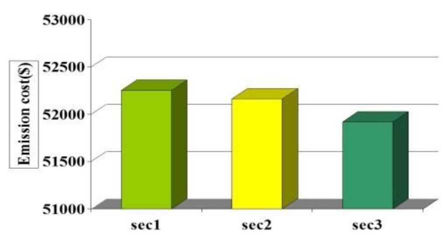

fig1:total Emission cost of unit in sec1-3
As it is considered, the utilization cost of the generation units is 601889/89 $ when the unit incorporation problem with 5000 vehicles is solved and it means that the utilization cost of production units has decreased for 17042/47 $ in comparison to the time that the incorporation problem is solved without electrical vehicles.
Moreover, it can be considered, the emission cost of the production units is 51922/33 $ when the unit incorporation problem with 5000 vehicles is solved and it means that the utilization cost of production units has decreased for 1988/43 $ in comparison to the time that the incorporation problem is solved without electrical vehicles.
With these three scenarios, it can be concluded that electrical vehicles decrease the production costs and emission costs of the production units.

4. Conclusion

The unit incorporation planning problem is an important economical matter in power systems that based on that, it is defined which collection of producing units should incorporate in supplying load need in each hour of planning period how much power each of them should produce in order to provide all system and utilization constraints with minimum possible cost. Due to the non-linear and complex structure of this issue together with its various constraints that create dependence among the problem variables, the optimal solution of units incorporations has changed into a laborious process. In this article a model based on units startup on the basis of costs considering to emission costs and with the incorporation of electrical vehicles was presented. The related constraints are carefully designed and investigated. This model is tested in 10-unit system of IEEE by using of GAMS utilization software and the efficiency of the model has been approved. Moreover, by considering to the results in each scenario, it can be concluded that by adding electrical vehicles to units, the utilization cost and emission cost of the unit decreases.

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