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Optimal Scheduling of PHEVs with Generating Unit Using Heuristic Optimization Method

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Abstract*: In the power system protection, coordination of PHEV's require much attention. This is required to maintain the reliable operation of electrical energy network. The number of electric vehicle charge and discharge are useful for sub transmission and distribution networks, to provide secre electricity. If the number of either charging or discharging vehile increased at a particular node it resulted in overloading the line, therefore it is also provided with limited number of vehicle at a time to ensure the continuous power supply. This is an important task for power system to schedule with thermal generating units. To solve this optimization problem heuristic optimization techniques is required. In this paper, varying acceleration coefficients particle swarm optimization are used to find the optimal schdelue of generating units with PHEV's. These swarm based techniques are tested on the two test system having 10 and 5 thermal generating units. Time varying acceleration coefficients particle swarm optimization proved to be better among other variants.
Keywords: Economic load dispatch; Electic vehicle; Particle sarm optimization; Time varying acceleration coefficients.

I. INTRODUCTION

Globally the energy reserves are wiped off from the world at the alarming rate. The depleting energy reserve is the prime concern at industry, society, economy and environmental level. The solution to this problem is: 1) the increasing use of highly efficient generating units, 2) the next-generation application for transportation i.e. hybrid electric vehicle and 3) effective strategy and planning of power system [1-2]. From recent published study that transportation sector is responsible for 30% of environment issue. Recently report is published from research laboratory that significant reduction in emission and cost while using PHEV's [2]. This storage device has significant potential to reduce emission and quiet economical. Therefore, more country in the world is setting target of achieving the higher electric vehicle usage. A smart grid is provided ideal platform for interaction between PHEVs and system operator. However, PHEV's is also providing solution to other problem i.e. flexibility, demand response, storage etc. The system flexibility is increased by providing the efficient energy system. Moreover, PHEV's have ability to track the availability of charging station and load demand placing near the charging station [2].Modern power system having efficient generating system i.e. PHEV's and conventional thermal generating plants is increasing the system complexity as shown in Fig. 1. Energy generation in the form of electricity is cannot be stored at higher capacity but can be transported form one place (probably the generating station) to the area of its application instantaneously [3-8]. It can be easily controlled by making efficient generating, transmission and distribution network. Nowadays per capita electric energy consumption is deciding factor of index for standard of living of people in a particular country. Electricity demand is increasing rapidly because of the increased industrialization and its numerous usage for other purposes like home, agriculture, transport etc. Demand for electric energy is increased due to rise in population, increased requirement for housing and rural electrification. The generation cost of electricity includes are[5-15]:

A. Purchasing cost
B. Installation cost,
C. Cost of erection of equipment and auxiliary,
D. Fuel cost
E. Miscellaneous cost like repairing cost, labor cost etc.

The power generation form thermal plant also include fixed cost dependent on investment cost of plant financial rates and operating cost/variable cost covers fuel expenses, labor charges, supervision etc. The total operational cost is included both fixed and operating cost. Traditional, economic load dispatch (ELD) [16] problem is deal with minimization of total operating expenses of power generation with satisfying all the equality and inequality constraints. The constraints of ELD problem are total load requirement including transmission line losses while inequality constraint is generation limit of each thermal unit [16-19]. PSO is an effective tool in solving complicated optimization problems. Recently many researchers in the field of optimization has explored various improved version of PSO which is based on inertia weight and constriction parameter of PSO [20-23]. Adjustability carries a great significance providing a prefect relationship between the quality and quantity of the parameters following the given algorithm. Time varying acceleration coefficient PSO maintain proper balance local and global search [24]. In this paper, optimal scheduling vehile with generatin units is obtained for each hour of day while satisfying all constraints. The constraints for the PHEV's and thermal units with power balance constraints are also satisfied with the help of a popular swarm based technique, PSO and velocity modified variants. The test system is applied on two test system system. The optimizations of the problem and simulation results have been computed in MATLAB.

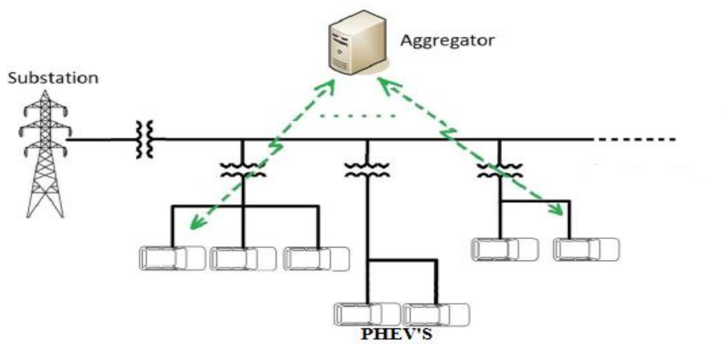

Figure 1: PHEV's connected to aggregators

This paper is organized as follows: Section II describes the mathematical formulation of thermal units and PHEV's. Section III presents a brief overview of PSO and its variants. In section IV the simulation is carried out for two standard test system and result is discussed. In section V the conclusion is given showing the feasible solution of the problem and future work.

II. MATHEMATIC MODELLING

The present formulation treated PHEV's and economic load dispatch problem which is attempted to optimize the operating expenses, while fulfilling and considering both equality and inequality constraints. The given constraints and objective are take into account for the formulation of ELD problem..

A. Thermal generating units

The given constraints and objective are take into account for the formulation of ELD problem.

The fuel cost function of each thermal generator, is represented as the sum of sine and quadratic function. The fuel cost in terms of generation output can be expressed as:

$$F(P(t)_i) = a_i + b_i \times P(t)_i + C_i \times (P(t)_i)^2 + \left| d_i \sin\left\{ e_i (P_i^{min} - P_i) \right\} \right| \quad (i = 1,2..., ng) \tag{1}$$

1) *Constraints*
2) *Power generation balance constraint:* The total power generation from thermal units must meet the load demand and the real power losses in the transmission lines.

$$\sum_{i=1}^{ng} P(t)_i = PD(t) + \times P_L(t)_i \quad (2)$$

3) *Power generation limit constraint: The* power generation of each thermal unit is under its extreme and least limit.

$$PMIN(t)_i \le P(t)_i \le PMAX(t)_i \quad (3)$$

a_i, b_i, c_i, d_i, e_i	Cost cofficient of i^{th} unit.
F	Fuel cost
p_i	Power generation i^{th} unit.
P_i^{max}	Maximum power generation from i^{th} unit.
P_i^{min}	Minimum power generation from i^{th} unit.

P_D	Power demand
P_L	Transmission line losses
G	Number of generating units

B. PHEV'S Model in Smart Grid Environment

With the development of smart grid, Vehicle to Grid become more active. With the advancement in techniques, it is feasible for electric vehicles to sold electricity back to the grid. There are many basic constraints should be taken into account for PHEV's. Firstly, in case of emergent use of EV's owners, must take care of *SoC* is considered. Secondly, for the sake of safe operation of the gird, an upper limit on total output of EVs at each hour should be stipulated. The details regarding the constraints of V2G with UC problem are given as:

$$\sum_{t=1}^{H} NV2G + NG2V \le N_V^{\max} \quad (4)$$

$$NV2G(t) \le N_{V2G}^{\max}(t) \quad (5)$$

$$NG2V(t) \le N_{G2V}^{\max}(t) \quad (6)$$

$$Pvdish(h) = Pv(\varphi_{pre} - \varphi_{dep}) Nvdish(h) \quad (7)$$

$$Pvch(h) = Pv(\varphi_{pre} - \varphi_{dep}) Nvch(h) \quad (8)$$

$$\varphi_{\min} Pvi \le P_{vch}(h) \le \varphi_{\max} Pvi \quad (9)$$

$$A(i,h) + B(i,h) \le 1 \quad (10)$$

$$Pvch(i,h) \le Pchlimit(i,h) \times A(i,h) \quad (11)$$

$$Pvdish(i,h) \le Pdishlimit(i,h) \times B(i,h) \quad (12)$$

In the above formulations, only predefined forecasted vehicles are considered for the optimum scheduling in UC with V2G as given in Eq. 4. To maintain system reliability, Eq. 5 and 6 describes the number of vehicles connected to grid per hour is limited. The power from PHEV during charging and discharging can be evaluated as Eq. 7 and 8. Here, φ_{pre} and φ_{dep} represents the present and deleted charge of vehicle battery which must satisfy Eq. 9. A vehicle cannot charge and discharge simultaneously as describe in Eq. 10. As a practical approach, the vehicle battery charging/discharging efficiency (η_{vch}/ η_{vdisch}) should be considered. The power generation from charge and discharge of vehicle is limited which is given in Eq. 11 and 12.

III. TIME VARYING ACCELERATING COEFFICENTS-PSO

A. Review of PSO

PSO is a metaheuristic technique aiming at obtaining satisfactory results in practical scheduling problem. Thus, above discussed qualities should be desired for such a metaheuristic technique [20]. For the j-dimension of solution area, the location P_i and velocity V_i of i^{th} solution vector is listed as [23]

$$\mu_i = \left[\mu_{i,1}, \mu_{i,2}, \mu_{i,3}, \ldots\ldots \mu_{i,j}\right] \quad (8)$$

$$V_i = \left[V_{i,1}, V_{i,2}, V_{i,3}, \ldots\ldots V_{i,j}\right] \quad (9)$$

The local best value of each particle can be expressed as

$$\mu_i^{best} = \left[\mu_{i,1}^{best}, \mu_{i,2}^{best}, \mu_{i,3}^{best}, \ldots\ldots \mu_{i,j}^{best}\right] \quad (10)$$

The global best value is basically the best solution among all the particles in the swarm which can be expressed as

$$\mu_i^{gbest} = \left[\mu_1^{gbest}, \mu_2^{gbest}, \mu_3^{gbest}, \ldots\ldots \mu_i^{bgest}\right] \quad (11)$$

The solution vector reaches to the improved location as the iteration proceeds using weighted acceleration of its current and past velocity. It is given as [24]

$$V_{j,i}^{k+1} = \begin{bmatrix} w \times V_{j,i}^{k} + C_1 \times ran() \times (\mu_{j,i}^{best} - \mu_{j,i}^{k}) \\ + C_2 \times ran() \times (\mu_i^{Gbest} - \mu_{j,i}^{k}) \end{bmatrix} \quad (12)$$

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The inertia weight is given by [24]

$$w = w_{max} - \lfloor (w_{max} - w_{min}) / it_{max} \rfloor \times it \qquad (13)$$

Thus, positional coordinates of each of the particle in swarm is expressed as

$$\mu_{j,i}^{k+1} = \mu_{j,i}^{k} + V_{j,i}^{k+1} \qquad (16)$$

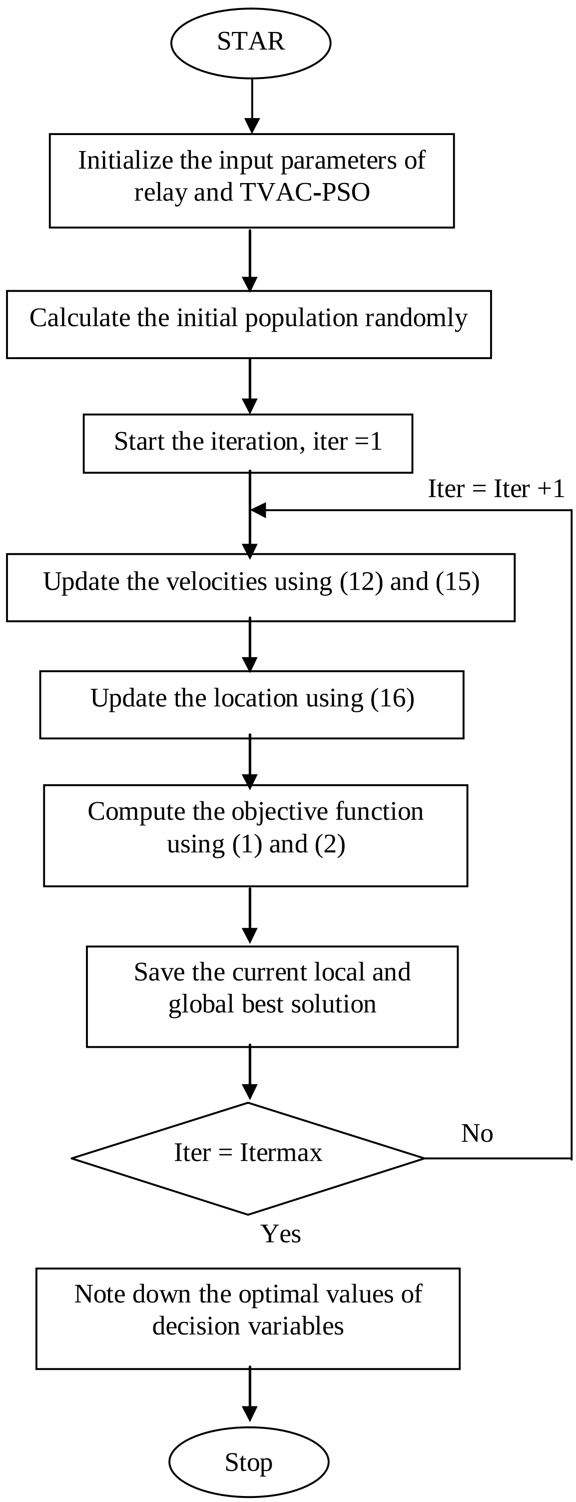

Figure 2. Flow-Chart for TVAC-PSO

In PSO when search process reaches the local search area then convergence the rate slow for exploitation and does not find best solution. The rate of convergence is greatly affected by the variable acceleration coefficients. This leads to the implementation of time varying acceleration coefficients PSO (TVAC-PSO). The flow chart for TVAC-PSO is shown in Fig. 1. The acceleration coefficients are constants in conventional PSO. These coefficients are needed to be updated to improve the solution. The cognitive parameter is of declining and social parameter is of inclining behavior as iteration proceeds. Comparatively large value of the social parameter relating to cognitive parameter corresponds to the false convergence at some local value while comparatively large values of cognitive parameter increase the global search ability of the technique [27].

$$C_1 = C_{1\min} + \left[\left(C_{1\max} - C_{1\min}\right) / it_{\max}\right] \times it \quad (17)$$

$$C_2 = C_{2\min} + \left[\left(C_{2\max} - C_{2\min}\right) / it_{\max}\right] \times it \quad (18)$$

where C_{1min}, C_{1max}, C_{2min} and C_{2max} are minimum and maximum values for the cognitive and social parameters..

IV. RESULT AND DISCUSSION

The TVAC-PSO have been applied for the reduction of the total operating cost for scheduling the genertating units and PHEV's. This optimum scheduling with satisfied constraints is the main purpose of this paper. The TVAC-PSO are applied on a two test system. Test system 1 contains 10 thermal generating units [1], and 50000 electric vehicles. Test system 2 contains 5 thermal generating units [11], and 50000 electric vehicles. Furthermore, the minimum and maximum number of electric vehicle charge and discharge at each hour is 2500 and 4000, respectively.

The settings for number of charging and discharging is considered as to minimum load on transmission line from electric vehicle and provide flexibility to system. It shows that, test system 1 consists 10 X 24 decision variables (10, generating units for 24 hours) and Demand, NG2V and NV2G constraints (3 X 24 for 24 hours, respectively). A group of codes in the form of program is written on the computer for testing the prescribed algorithms.

Fortran PowerStation 4.0 by Microsoft Dev Studio is used for the simulation purpose. Test system is solved using optimization technique and check the usefulness of given algorithms. The results are represented in the tabular as well as graphical form. Table I and II shows the schedule of power generation for 24 hours schedule period with number of electric vehicle charge and discharge for both test systems.

Figure shows the typical layout of varying power generation from one time interval to another interval for the applied test system. Figure 3 shows the optimum power generation from each thermal unit for 24 hour schedule period of objective function value for TVAC-PSO for test system 2.

The obtained results shows that all the constraints are fully satisfied and within their ranges. Figure 4 shows the optimum power generation from each thermal unit for 24 hour schedule period of objective function value for TVAC-PSO for test system 2. The obtained results shows that all the constraints are fully satisfied and within their ranges.

Table i. Power generation from thermal units and number of phev's charge and discharge in test system 1.

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hrs	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	NV2G	NG2V
1	150	135	170	60	73	160	93	47	80	55	4000	2500
2	150	135	73	300	73	57	130	120	20	55	51	2500
3	185	135	73	300	243	57	130	47	20	55	1321	1334
4	150	135	185	238	243	57	130	120	80	55	923	2500
5	217	222	73	300	243	160	130	47	20	55	4000	2500
6	223	135	340	300	73	160	130	120	80	55	2193	4
7	303	135	340	196	243	160	130	47	80	55	4000	16
8	150	460	340	300	73	57	130	120	80	55	4000	2500
9	226	460	340	300	73	160	130	120	47	55	4000	2500
10	245	460	340	300	243	160	130	47	80	55	35	2500
11	309	396	340	300	243	160	130	120	80	55	4000	2500
12	423	460	340	300	243	57	130	120	80	55	1947	2500
13	456	460	188	300	243	160	130	47	20	55	9	2500
14	188	36	340	300	243	160	130	47	52	55	110	2500
15	150	460	85	300	243	160	110	120	80	55	4000	32
16	155	135	340	300	243	57	130	47	80	55	4000	2500
17	150	222	339	241	73	57	130	120	80	55	95	2500
18	223	135	340	300	73	160	130	120	80	55	1362	2500
19	379	460	195	241	73	57	130	120	52	55	4000	2500
20	208	460	340	300	243	160	93	120	80	55	45	2500
21	226	460	340	97	243	160	130	120	80	55	65	2500
22	226	396	185	89	172	160	130	120	80	55	1808	1097
23	150	460	80	187	73	57	93	85	51	55	4000	2500
24	226	222	73	234	73	57	93	85	51	55	30	2500

Table ii. . Power generation from thermal units and number of phev's charge and discharge in test system 2.

hrs	P1	P2	P3	P4	P5	NV2G	NG2V
1	11	100	112	126	50	4000	2500
2	10	20	175	195	50	0	2500
3	10	100	175	40	139	4000	2500
4	10	98	97	40	300	0	2500
5	74	99	114	125	141	555	129
6	29	125	30	124	300	0	240
7	10	96	30	250	229	4000	2500
8	59	20	175	250	139	4000	2500
9	65	125	175	40	300	0	2500
10	37	20	175	250	229	0	1296
11	10	100	175	125	300	4000	2500
12	13	125	175	125	300	2697	2500
13	10	125	175	250	133	4000	2500
14	65	125	175	40	300	0	2500
15	74	31	175	125	238	4000	2500
16	10	125	175	124	135	2000	2500
17	10	124	30	250	140	413	69
18	16	20	175	250	140	3497	2500

19	43	98	112	250	139	4000	2500
20	10	20	175	250	229	3627	592
21	10	98	175	110	300	0	2291
22	10	88	174	40	300	1209	2500
23	22	20	175	250	50	4000	2500
24	67	124	112	124	50	0	2500

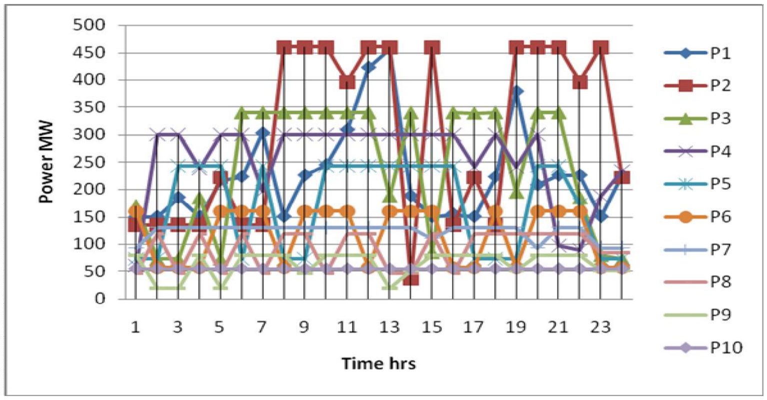

Figure 3. Power generation from generating units for test system 1.

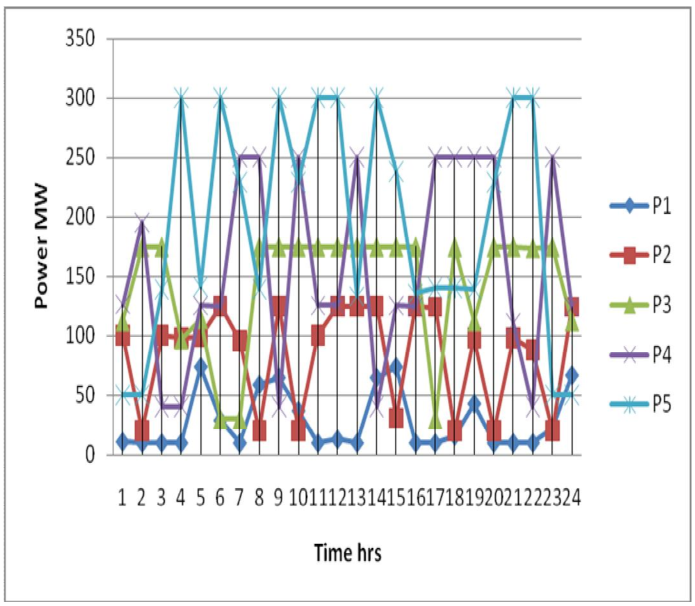

Figure 4. Power generation from generating units for test system 2.

The objective function value for test system 2 is $ 46428.970000 while for test system 1 is $1069848.

V. CONCLUSION

In this paper, time varying acceleration coefficients particle swarm optimization is tested on the problem of scheduling of generating units with electric vehicle . The output of simulation shows that it provide feasible solution for the input data of generating units and electric vehicles. This paper presented the continuous parameter solution in terms of power generation and number electric vehicle charge and discharge. The test system used for the testing purpose is IEEE 10 unit and 5 unit test system. Particle swarm optimization is a popular swarm based technique. TVAC-PSO provide the better results in comparison to conventional and PSO. This work can be continued to the larger number of bus system and using more variants of PSO.

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