Optimal Placement of Vehicle-to-Grid Charging Station in Distribution System using Particle Swarm Optimization with Time Varying Acceleration Coefficient

Jukkrapun Prasomthong,Weerakorn Ongsakul, *Member, IEEE*and Jan Meyer, *Member, IEEE*

***Abstract*--This paper proposes optimal placement of vehicle to grid (V2G) charging station in a distribution system by using Particle Swarm Optimization with time varying coefficient (PSO-TVAC). While Electric Vehicles (EVs) will be additional load to the distribution system, utilities can use V2G to maximize total benefit including peak power providing, reliability improvement, and power loss reduction within system operating constraints. Charging stations are simulated as loads when they are charging EVs and as distributed generation when they are discharging to the grid. The optimal placement of V2G charging stations and sizes are determined at peak period. Test results on the nine bus test system render a higher total benefit than GA, Basic PSO, and PSO-TVIW.**

***Index Terms*— Electric vehicles (EVs), charging station, Vehicle to Grid (V2G), particle swarm optimization (PSO).**

I. NOMENCLATURE

ω	Inertia factor
k	Number of iteration
k_{max}	Maximum number of iteration
C_1	Weight affecting the cognitive factor
C_2	Weight affecting the social factor
$rand_1$	Coefficient of random that is between 0 and 1
$rand_2$	Coefficient of random that is between 0 and 1
$P_{best,i}^{k}$	The best of personal value that found by particle i
$G_{best,i}^{k}$	The best of global value that found by the entire swarm
X_i^k	Current position of particle i
X_i^{k+1}	Updated position of particle i
V_i^k	Velocity of particle i
V_i^{k+1}	Updated velocity of particle i
$C_{1,i}, C_{1,f}$	Initial and final weight affecting the cognitive factor
$C_{2,i}, C_{2,f}$	Initial and final weight affecting the social factor
$\omega_{min}, \omega_{max}$	Initial and final inertia weights
SOC_i	Initial state of charge of vehicle
ES_i	Battery capacity of EV
P_v	Power rate with which EV is charged
n	Numbers of available vehicles in the parking lot
$r(i)$	Total revenue gained from i^{th} parking lot
$t_{disp}(i)$	Total time that the V2G power is dispatched
P_{rp}	Market price of electricity at peak times
$CF_{cap}(i)$	Capital cost of parking lot i
C_{cap}	Annualized capital cost for each vehicle
$PC(i)$	Capacity of parking lot i
$CF_{Pu,driving}(i)$	Cost of purchased energy to charge vehicles for driving
Pr_{off}	Market price of electricity at off-peak times
$P_{parkc\,h}(i,k)$	Needed power at parking lot for charging vehicles from SOC 0 to SOC 1,
$t(k)$	Time duration at which the output power of parking lot in order to charge EVs
$P_{parkc\,h}(i,k)$	Power for charging EVs
μ_{conv}	Efficiency of inverter
$CF_{pu,V2G}(i)$	Cost of purchased energy to discharge vehicles for V2G power
Pr_{pe}	Purchased energy cost
C_d	Cost of equipment degradation
B	Number of branches in network
C_{inj}	Price of energy not supplied in load level j
γ_b	Failure rate of line section b
L_b	Length of line section b
N_{res}	Number of nodes isolated during fault location
N_{rep}	Number of nodes isolated during fault repair
P_{res}	Loads not supplied during fault location
t_{res}	Duration of the fault location and switching time
P_{rep}	Loads not supplied during fault repair
t_{rep}	Duration of the fault repair
C_{Equipj}	Cost of energy not supplied based on failure in equipment except for branches.
$C_{NS}(j)$	Cost of energy not supplied without V2G
$C_{NS,V2G}(j)$	Cost of energy not supplied with V2G
$price(j)$	Electricity price in load level j
$loss(j)$	Network loss in load level $j$without V2G
$loss_{V2G}(j)$	Network loss in load level j with V2G
R_b	Resistance of branch b
$I_b(j)$	Current of branch b at time interval j

This work was supported in part by PEA-AIT Education Cooperation Project- Royal Thai Government Fellowship Scholarship

JukkrapunPrasomthong and WeerakornOngsakul are with Asian Institute of Technology, KlongLuang, Pathumthani, Thailand (e-mail: Jukkrapun. Prasomthong @ait.asia and ongsakul@ait.asia).

Jan Meyer is with Institute of Electrical Power Systems and High Voltage Engineering, TechnischeUniversität Dresden, Dresden, Germany. (e-mail: jan.meyer@tu-dresden.de)

II. INTRODUCTION

A. Vehicle to Grid (V2G)

Vehicle to grid (V2G) is an energy storage technology which flows bidirectional power flow between a vehicle battery and a vehicle operation. For V2G, configuration and parking sites, control and connection between grid and operator and metering are required [1]. The planning of charging infrastructure involves integration between developing of utilities and technology to respond appropriately to the demand. In addition, the power system should be improved to protect the potential impact of EV infrastructure in order to ensure demand growth that is especially peak demand in the future. As a result, system provider should implement strategies and plans by using modeling tools [2]. The development plan of charging stations suggests consideration and investment on EVs and infrastructures. EVs should be used in short range transport, and the electricity rate for charging and price of battery packs also should be considered. Moreover, optimal time of charging should be off-peak period because the price of off-peak rate is cheaper whereas charging in peak period should be avoided [3]. IEC 62196 classified charging into two main characteristics as slow and fast charging. This standard also classified modes of charging into four modes. While either first and second modes focus on slow charging with different socket, third mode focuses on slow and fast charging that based on SAE J1772(connector standard) and IEC 62196 whereas fourth mode focuses on fast charging that uses special charger technologies of CHADEMO [4]. The lithium-ion battery is the promising technology for energy storage due to potential for increasing energy density. Furthermore, lithium-ion batteries have lower weights. As a result, EVs can increase a higher range. However, potential improving is a challenge in order to encourage EVs capability in the future [5]. Because EV charging can cause power loss and voltage deviation in household, the system can minimize loss and voltage deviations with coordinated charging. However, charging in the peak time should be avoided because this period has high impact due to system violation [6]. With single phase charging, Plug-in EV (PEV) can cause high unbalanced load in the system that can result in voltage unbalances, which can exceed defined limits considerably.By contrast, discharging of PEV can reduce unbalanced loads in the system. Accordingly, charging and discharging of PEV should consider condition of unbalanced system loads that cause unbalanced voltages at buses [7].

B. Distributed Generation (DG)

The objective of DG allocation for loss reduction and reliability improvement is searching sites and sizes of DG. While the objective is evaluated with total maximum result between benefits and cost, the objective is evaluated between loss reduction and reliability improvement using DG. With dynamic programing, the procedure of this method use input data to check load flow analysis and ENS evaluation before determining optimal allocation and size. Then, result is checked whethersatisfying of constraints. The results show a total maximum benefit and impact on voltage profile after DGs are placed [8]. Distribution system can be reinforced by adding substation, feeders and DGs. The possible solutions are searched by genetic algorithm (GA) whereas the objective function combining investment, operation and interruption cost is evaluated. [9]. In the same way, DG can be used to improve reliability indices- SAIDI, SAIFI and ENS in distribution system with different conditions such as distance, large-scale DG and small-scale DG. [10]. Analytic hierarchy Process (AHP) can make a decision to search the most desired alternative from several criteria. The criteria are calculated relative weight with comparison pairwise alternative to created weight prioritization [11].

C. Particle Swarm Optimization (PSO)

PSO is used for optimal and placement of DG units which are considered as a constant power source whereas efficiency of PSO depends on memory and speed of processing unit. PSO has a better performance than GA for multi objectives problems. The combination of unit commitment (UC) and V2G can schedule the number of EVs which can charge or discharge in each period by using PSO [12].The optimization problem in [13] applied GA to optimize allocation of parking lots in distribution network by searching total maximum benefits of peak power providing, reliability improvement and power losses reduction within system constraints. In addition, each objective is weighted the prioritization by Analytic Hierarchy Process (AHP). The optimization problem in [14] applied PSO to determine the maximum Plug-in Hybrid EV (PHEV) penetration planning to minimize the total cost within system constraints. The optimization problem in [15] compare different types of PSO models between Basic PSO (BPSO), PSO with time varying inertia weight (PSO-TVIW), PSO with random inertia weight (PSO-RANDIW) and PSO with time varying acceleration constants(PSO-TVAC) to search optimal placement and sizing of static compensator. The result of PSO-TVAC can give the least time to search the result in order to improve smart algorithm and quality solution. The optimization problem in [16] compared the results between ConventionalPSO with time varying acceleration coefficients that are used to solve the optimization problem. PSO-TVAC had high efficiency than BPSO to solve this problem. Meanwhile, PSO-TVAC is also efficiently used to optimize reactive power cost allocation in [17]. Thus, in this paper, PSO-TVAC is proposed for solving optimal placement of V2G charging station in distribution system.

III. PROBLEM FORMULATION

In this paper, the required time for EV charging is:

$$t(k) = \left(\frac{(1-SOC_i)\times ES_i}{P_v}\right) \quad (1)$$

The output power of the parking lot can be represented as:

$$P_{park} = P_v \times n(2)$$

First Benefit: peak power providing

Net revenue: Charging station can purchase energy from EVs' owner and supply peak power to the grid with a high rate.

$$r(i) = Pr_p \times P_{park}(i) \times t_{disp}(i) \quad (3)$$

Capital cost:

$$CF_{cap}(i) = C_{ac} \times PC(i) \quad (4)$$

Cost of V2G power purchasing:

$$CF_{Pu,driving}(i) = \sum_{k=1}^{t_n} \frac{Pr_{off}}{\mu_{conv}} \times P_{parkc\ h}(i,k) \times t(k) \quad (5)$$

Cost of purchased energy for driving purposes:

$$CF_{pu,V2G}(i) = Pr_{pe} \times P_{park}(i) \times t_{disp} \quad (6)$$

The equation for calculating Pr_{pe} includes a purchased energy term and an equipment degradation term:

$$Pr_{pe} = \frac{Pr_{off}}{\mu_{conv}} + C_d \quad (7)$$

More details about calculating cd are given in [1].

Benefit 2: reliability improvement benefit

Cost of energy no supply:

$$C_{NS}(j) = \left[\sum_{b=1}^{B} C_{inj} \times \gamma_b \times L_b \times \left(\sum_{res=1}^{N_{res}} P_{res} \times t_{res} + \sum_{rep=1}^{Nrep} P_{rep} \times t_{rep}\right)\right] + C_{Equip,j} \quad (8)$$

$$DC_{NS}(j) = C_{NS}(j) - C_{NS,V2G}(j) \quad (9)$$

Benefit 3: power loss reduction benefit

Power loss reduction:

$$DC_{loss}(j) = price(j) \times (loss(j) - loss_{V2G}(j)) \quad (10)$$

$$loss(j) = \sum_{b=1}^{B} R_b \times I_b^2(j) \times t(k) \quad (11)$$

The maximum of total benefits is fitness function that contains three objectives or six function that are the following:

$$MAX\ F = \sum_{i=1}^{N_{V2G}} (w_1 \times r(i)) - \left(w_2 \times CF_{cap}(i) + w_3 \times CF_{Pu,driving}(i) + w_4 \times CF_{pu,V2G}(i)\right) + \sum_{j=1}^{J} (w_5 \times DC_{NS}(j) + w_6 \times DC_{loss}(j)) \quad (12)$$

The six objectives of fitness function are given the weight with Analytic Hierarchy Process (AHP) to deal priority [13]. The fitness function is subject to system constraints when EVs are charged and discharged. These constraints are the following:

Capacity constraint:

$$0 \le CP_n \le CP_{max} \quad (13)$$

whereCP_{max} is the maximum number of charging lot which EVs can be charged or discharged. $CP_n$is available number of EV in charging station.

Voltage constraints:

$$|V_i|_{min} \le |V_i| \le |V_i|_{max} \quad ; \quad i = 1,2,\dots,n \quad (14)$$

where $V_{i,min}$, $V_{i,max}$ are the minimum and maximum of acceptable voltage limit. $i$is the number of bus.

Line flow constraint and line current flow constraint:

$$|P_{ij}| \le S_{ij,max} \quad (15)$$

$$|I_{ij}| \le I_{ij,max} \quad (16)$$

Where,P_{ij} is power flow between node i to j, and $S_{ij,max}$ is the maximum power of line flow between node i to j. I_{ij} is lime current flow between node i to j, $I_{ij,max}$ is the maximum capacity of line current flow between node i to j,

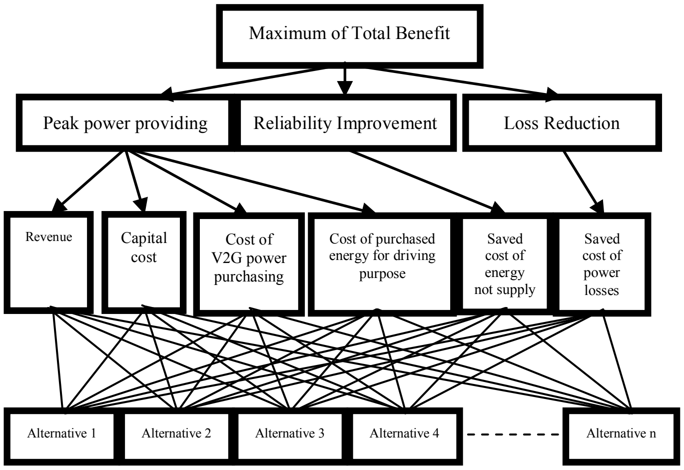

Fig.1 Graphical representation of the fitness function and optimization process

IV. METHODOLOGY

A. Basic Particle Swarm Optimization (BPSO)

PSO is a stochastic optimization technique inspired byswarm behaviour approximate solutions for complicated numeric maximization or minimization problems. Each particle of PSO searches for a possible solution by representation current position and velocity. Velocity of each agentcan be updated as:

$$V_i^{k+1} = \omega^k \times V_i^{k+1} + rand_1 \times \left(P_{best,i}^k - X_i^k\right) + C_2 \times rand_2 \times \left(G_{best,i}^k - X_i^k\right) \quad (17)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (18)$$

B. PSO with time-varying inertia weight (PSO-TVIW)

PSO-TVIW varies inertia weight by setting initial inertia and final weight iteration whereas acceleration coefficients are still constant.Velocity and inertia weight of each agentcan be updated by:

$$V_i^{k+1} = \omega^k \times V_i^{k+1} + rand_1 \times \left(P_{best,i}^k - X_i^k\right) + C_2 \times rand_2 \times \left(G_{best,i}^k - X_i^k\right) \quad (19)$$

$$\omega^k = \omega_{max} - \frac{(\omega_{max} - \omega_{min})}{k_{max}} \times k \quad (20)$$

C. PSO with time-varying acceleration coefficients (PSO-TVAC)

PSO-TVAC set a new aspect of coefficients to perform optimization process by adjusting acceleration to both cognitive and social factors. The updating equations of PSO-TVAC that include initialization, fitness function, updating particles, and updating best particles, are

$$V_i^{k+1} = \omega^k \times V_i^{k+1} + rand_1 \times \left(P_{best,i}^k - X_i^k\right) + C_2 \times rand_2 \times \left(G_{best,i}^k - X_i^k\right) \quad (21)$$

$$\omega^k = \omega_{max} - \frac{(\omega_{max} - \omega_{min})}{k_{max}} \times k \quad (22)$$

$$C_1 = \left(C_{1,f} - C_{1,i}\right) \times \frac{k}{k_{max}} + C_{1,i} \quad (23)$$

$$C_2 = \left(C_{2,f} - C_{2,i}\right) \times \frac{k}{k_{max}} + C_{2,i} \quad (24)$$

V. SCOPE AND LIMITATION

The nine buses of radial system from [13] is used as test system as shown in Fig. 3. The data and information of this system are given in [8]. The distribution test system includes high voltage distribution substation 132–33 kV which feeds eight load points.Charging stations are simulated as loads when EVs charge. On the other hand, charging stations are simulated as DGs when EVs discharge.In addition, batteries of vehicles are charged with a constant power of 15 kW and their capacities are assumed to be 50 kWh. For PSO parameters, inertia weight (ω) and cognitive acceleration factors (C_1,C_2) of are given [14], [15], [16] and [17] in Table 1.

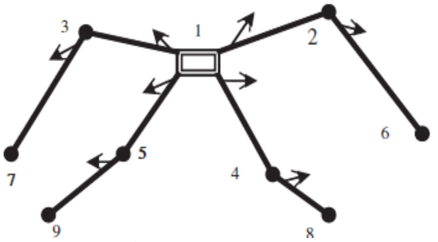

Fig.2.Test System

TABLE 1 PARAMETERS OF PSO

Type of PSO	ω	C_1	C_2
BPSO	[1.2,1.2]	2.05	2.05
PSO-TVIW	[0.4,0.9]	2.0	2.0
PSO-TVAC	[0.4,0.9]	[2.5,0.5]	[0.5,2.05]

In addition, AHP deal priority for each function in case of the same priority weights as W_{ahp1}=[0.167, 0.167, 0.167, 0.167, 0.167,0.167] and case of the differentpriority weight asW_{ahp2} =[0.0625, 0.1875, 0.0625, 0.0625, 0.1875, 0.437]

VI. NUMERICAL RESULTS AND DISCUSSIONS

Firstly, only bus 2, 3, and 6 are candidate buses with the same priority weight (Case 1) and different priority weight (Case 2). In Table 2, PSO-TVAC renders almost the same benefit of peak power providing as GA[13], BPSO and PSO-TVIW. For the second benefit, PSO-TVAC benefit of reliability improvement of 31,692.870 ishigher than GA by 336.87 (1.07%), BPSO by 94.58 (0.298%) and PSO-TVIW by 25.27 (0.08%). For the last benefit, PSO-TVAC benefit of power loss reduction of 39,355is higher than GA by 650 (1.68%),BPSO by 188.3 (0.48%) and PSO-TVIW by 151.63 (0.39%). For the total maximum of benefit, PSO-TVAC total maximum benefit of 482,687.853 ishigher than GA by 987.85 (0.205%), BPSO by 188.3 (0.039%) and PSO-TVIW 176.91 (0.037%).

TABLE 2 TOTAL BENEFITS COMPARISON WITH THE SAMEPRIORITY WEIGHT (CASE 1)

Benefits	GA[13]	BPSO	PSO-TVIW	PSO-TVAC
Benefit of peak power providing ($)	411,640.00	411,639.98	411,639.984	411,639.984
Benefit of reliability improvement($)	31,356.00	31,598.29	31,667.596	31,692.870
Benefit of loss reduction ($)	38,705.00	39,166.70	39,203.366	39,355.000
Total benefits ($)	481,700.00	482,404.97	482,510.946	482,687.853

TABLE 3 COMPARISON OF OPTIMAL NUMBER OF EV WITHTHE SAME PRIORITY WEIGHT (CASE 1)

bus	GA[13]	BPSO	PSO-TVIW	PSO-TVAC
2	375	327	333	330
3	375	375	375	375
6	225	272	267	270
Total	975	974	975	975

In Table 3, the total number of EV of PSO-TVIW and PSO-TVAC is the same as GA whereas BPSO is just one less. For PSO-TVAC, there are more number of EV at bus 6 and less number of EV at bus 2 than GA. In addition, charging station at bus 2, 3 and 6 can also improve voltage profiles as shown in Fig 3.

In Table 4, with different relative weights, PSO-TVIW and PSO-TVAC render the same benefit of peak power providing of 103,381.447 which is higher than GA by41,817.447 (67.925%) and BPSO by 103,353.3 (0.027%).For the second benefit, PSO-TVIW and PSO-TVAC benefits of reliability improvement of 12,312.895are lower than GA by 21,040.457 (63.08%), but higher than BPSO by 3.35 (0.027%). For the last benefit,PSO-TVIW and PSO-TVAC benefits of power loss reduction of 17,018.234 arehigher than GA and BPSOby 7,254.03 (21.75%), 3.352 (0.027%),respectively. For the total maximum of benefit,PSO-TVIW and PSO-TVAC total maximum benefits of 132,712.576arehigher than GA by 28,034.38 (26.78%) and BPSO by 34.93 (0.026%).

TABLE 4 TOTAL BENEFITS COMPARISON WITH DIFFERENT PRIORITY WEIGHT (CASE 2)

Benefits	GA [13]	BPSO	PSO-TVIW	PSO-TVAC
Benefit of peak power providing ($)	61,564.00	103,353.301	103,381.447	103,381.447
Benefit of reliability improvement($)	33,350.00	12,309.543	12,312.895	12,312.895
Benefit of power loss reduction ($)	9,764.20	17,014.804	17,018.234	17,018.234
Total benefits ($)	104,678.20	132,677.648	132,712.576	132,712.576

In Table 5, BPSO, PSO-TVIW and PSO-TVAC render the same totalnumber of EV at bus 6which is more than GA by 25. In Figure 4, charging station at bus 6 can improve voltage profiles. Note voltage profile at bus 2 has been improved because buses 2 and 6 are located at the same feeder.

Since voltage at bus 8 in the first and second case is still below acceptable limit, reactive power compensation such as capacitor bank should be installed to improve voltage profile. Reactive power compensation of 3.3 MVARat bus 8 can improve voltage profiles as shown in Figures5 and 6.

TABLE5 OPTIMAL NUMBER OF EV COMPARISON WITHDIFFERENT PRIORITY WEIGHT (CASE 2)

bus	GA[13]	BPSO	PSO-TVIW	PSO-TVAC
2	25	0	0	0
3	50	0	0	0
6	150	245	245	245
Total	225	245	245	245

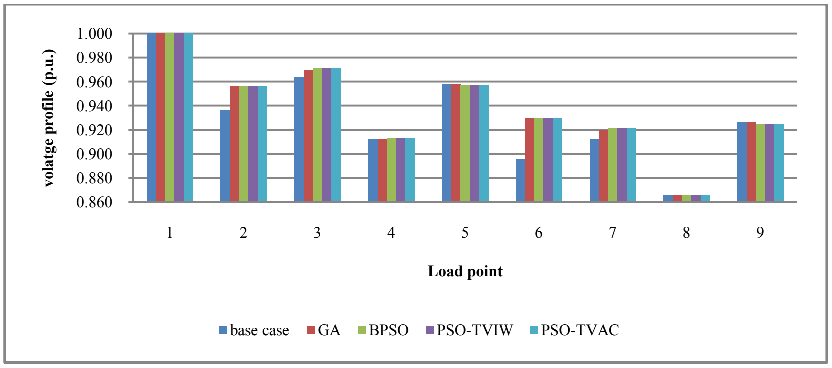

Fig.3.Voltage profiles in Case1

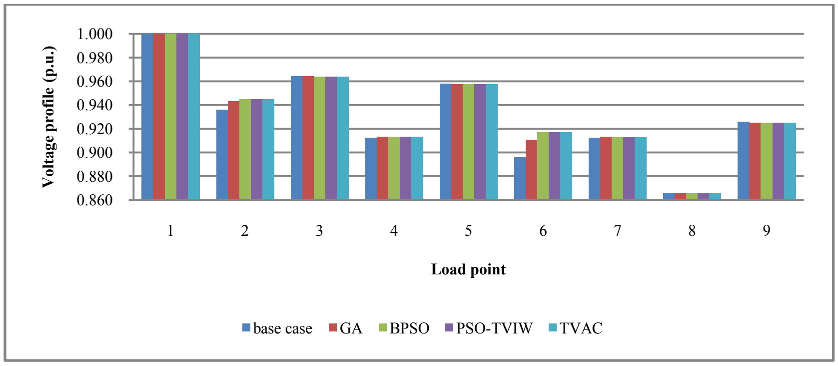

Fig.4.Voltage profiles in Case 2

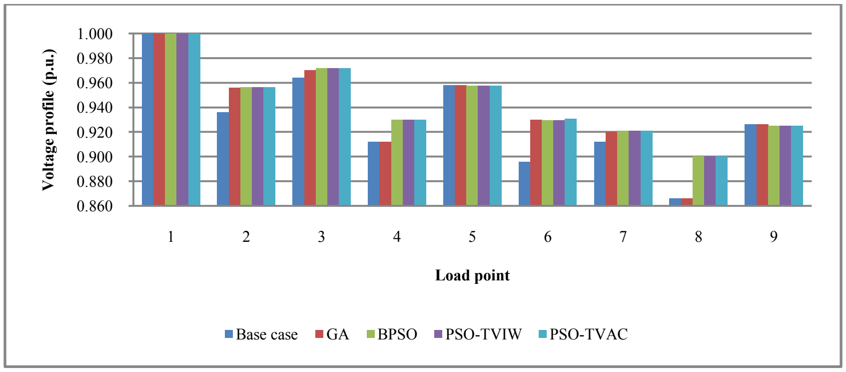

Fig.5.Voltage profiles in Case 1 with reactive power compensation at bus 8

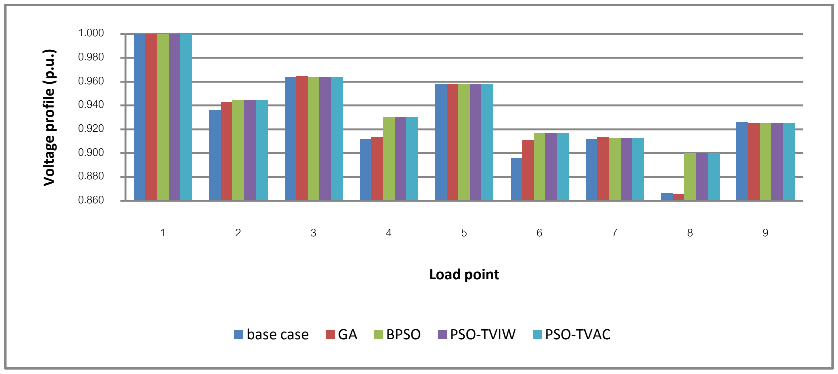

Fig.6.Voltage profiles in Case 2 with reactive power compensation at bus 8

For Case 3, all buses (1-9) are candidate buses with the same priority weight. In Table 6, PSO-TVIW and PSO-TVAC peak power providing benefits of 730,397 are higher than BPSO by 703.66. For the second benefit, PSO-TVACbenefit of reliability improvement of 1,729,353.107 is higher than BPSO by 15,373.58 (0.9%) and PSO-TVIW by 241.68 (0.14%). For the third benefit, PSO-TVAC benefit of power loss reduction of 90,120.542 is higher than BPSO by 297.27 (0.33%) and PSO-TVIW by 4.05 (0.004%). Finally, PSO-TVAC total benefit of 2,549,870.748is higher than BPSO by 16,374 (0.643%), and PSO-TVIW by 245.73 (0.01%). In Table 7, only buses 2, 3, 5, 7, and 8 are placed with V2G charging stations. Similarly, V2G can also improve voltage profiles at each bus as Figure 7.

TABLE 6 TOTAL BENEFITS COMPARISON WITH THE SAME PRIORITY WEIGHT (CASE 3)

Benefits	BPSO	PSO-TVIW	PSO-TVAC
Benefit of peak power providing ($)	729,693.442	730,397.100	730,397.100
Benefit of reliability improvement($)	1,713,979.525	1,729,111.419	1,729,353.107
Benefit of power loss reduction ($)	89,823.276	90,116.496	90,120.542
Total benefits ($)	2,533,496.243	2,549,625.015	2,549,870.748

TABLE7OPTIMAL NUMBER OF EV COMPARISON WITH THE SAME PRIORITY WEIGHT (CASE 3)

bus	BPSO	PSO-TVIW	PSO-TVAC
2	600	600	600
3	199	188	188
4	0	0	0
5	375	375	375
6	0	0	0
7	174	187	187
8	380	380	380
9	0	0	0
Total	1728	1730	1730

For Case 4, all buses (1-9) are candidate buses with different priority weight. In Table 8, PSO-TVIW and PSO-TVAC benefits of peak power providing of 730,397.100are higher than BPSO by 2,786.49 (0.38%). For the second benefit, PSO-TVAC benefitof reliability improvement of1,964,454.209 is higher than BPSO by 22,200 (1.14%) and PSO-TVIW by 6530.3 (0.333%). For the third benefit, PSO-TVAC of 108,747.050is higher than BPSO by 301.95 (0.28%) and PSO-TVIW by 0.559. Finally, PSO-TVAC total benefit of 2,800,480.983 is higher than BPSO by 35,628 (1.28%), and PSO-TVIW by 8,068.32 (0.29%).In Table 9, only buses 5, 6, 7, 8, and 9 are placed with V2G charging stations. V2G can also improve voltage profiles at each bus within acceptable range as shown in Figure 8.

TABLE 8TOTAL BENEFITS COMPARISON WITH DIFFERENT PRIORITY WEIGHT (CASE 4)

Benefits	BPSO	PSO-TVIW	PSO-TVAC
Benefit of peak power providing ($)	727,610.614	730,397.100	730,397.100
Benefit of reliability improvement($)	1,942,254.209	1,957,923.856	1,964,454.209
Benefit of power loss reduction ($)	108,445.104	108,746.491	108,747.050
Total benefits ($)	2,764,852.758	2,792,412.664	2,800,480.983

TABLE 9OPTIMAL NUMBER OF EV COMPARISON WITHDIFFERENT PRIORITY WEIGHT (CASE 4)

bus	BPSO	PSO-TVIW	PSO-TVAC
2	0	0	0
3	0	0	0
4	0	0	0
5	160	187	187
6	600	600	600
7	375	375	375
8	380	380	380
9	209	188	188
Total	1724	1730	1730

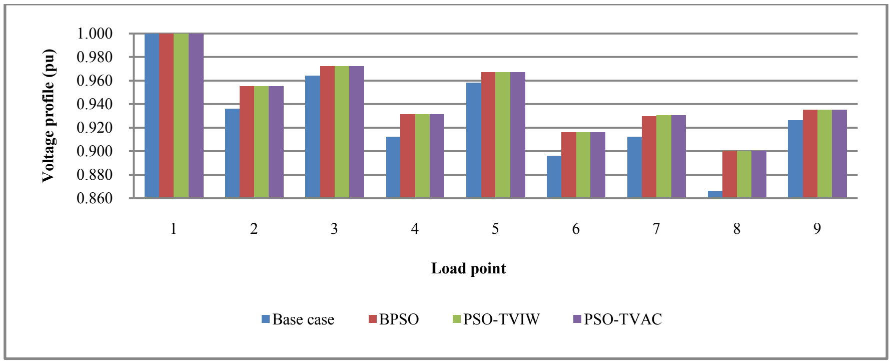

Fig.7.Voltage profiles in Case 3

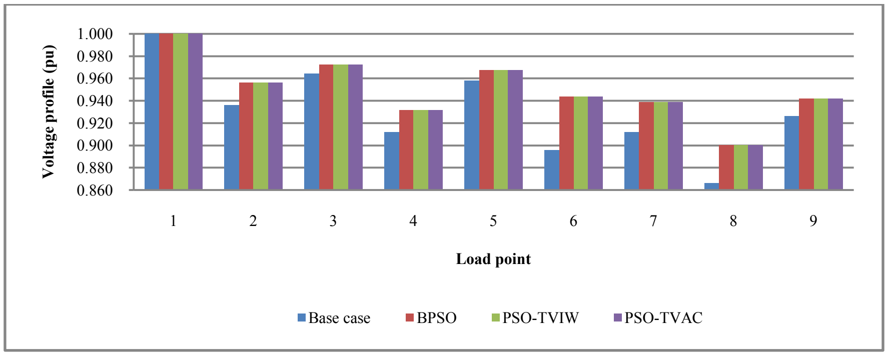

Fig.8.Voltage profiles in Case 4

VII. CONCLUSION

In this paper, the optimal charging station and size are efficiently determined to obtain the total maximum benefit including peak power providing, reliability improvement and power loss reduction. Test results on thenine bus system indicate that the total maximum benefit of PSO-TVAC is more than those of GA, BPSO and PSO-TVIW, leading to peak reduction, reliability improvement, and power loss reduction.

VIII. REFERENCE

[1] Kempton, W., Tomi, J., 2005. Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. Journal of Power Sources 144 (2005), page 268–279.

[2] Clean Energy Coalition, Plug-in ready michiganelectric vehicle preparedness plan,(2012).

[3] Grdic, I., Kirincic, V., Skok, S., 2013. The development of charging stations for electric vehicles: A solution or a problem?, Information & Communication Technology Electronics & Microelectronics (MIPRO) 36th, (2013), pp 1226-1230.

[4] IEC 62196-1:2003. Charging of electric vehicles up to 250 A a.c.and 400 A d.c.

[5] Clement-Nyns, K., Haesen, E., Driesen, J., 2010. The Impact of Charging Plug-In Hybrid ElectricVehicles on a Residential Distribution Grid, IEEE Transactions on power systems, vol.25, NO. 1, Febuary, 2010.

[6] Jimenez, A. Garcia, N., 2012. Unbalanced three-phase power flow studies of distribution systems with plug-in electric vehicle, North American Power Symposium (NAPS), 2012.

[7] Falaghi, H., Singh, C., Haghifam, M.-R., M. Ramezani, 2011. DG integrated multistage distribution system expansion planning. Electrical Power and Energy Systems 33 (2011) 1489–1497.

[8] Khalesi, N., Rezaei, N., Haghifam, M.-R., 2011. DG allocation with application of dynamic programming for loss reduction and reliability improvement. Electrical Power and Energy Systems 33 (2011) 288–295.

[9] Waseem, I.; Pipattanasomporn, M. ; Rahman, S.,2009. Reliability benefits of distributed generation as a backup source. Power & Energy Society General Meeting, 2009. PES '09. IEEE (2009).

[10] Jin, J., Rothrock Ling, McDermott, P. L., Barnes, M., 2010. Using the Analytic Hierarchy Process to Examine Judgment Consistency in a Complex Multi attribute Task. IEEE Transaction on systems, man, and cybernetics—PART A: SYSTEMS AND HUMANS, Vol. 40, NO. 5, September 2010.

[11] Coello Coello, C. A., Lechuga, M.S., 2002. MOPSO: A proposal for multiple objective particle swarm optimization. Evolutionary Computation, 2002. CEC '02. Proceedings of the 2002 Congress. (2002), page 1051 – 1056.

[12] Viral, R., Khatod, D.K.,2012. Optimal planning of distributed generation systems in distribution system: A review, Renewable and Sustainable Energy Reviews, volume 16, issue 7, September 2012, pages 5146-5165.

[13] Moradijoz, M., Moghaddam, M. P., Haghifam, M.R., Alishahi,

E., 2012. A multi-objective optimization problem for allocating parking lots in a distribution network. Electrical Power and Energy Systems 46 (2013) 115–122.

[14] Khedkaw S., 2012. Robust combined-objective particle swarm optimization for planning transition to plug-in hybrid electric vehicles. School of Environment, Resources and Development, Asian Institute of Technology, Thailand. May 2012.

[15] Salhi, A., Naimi, D. and Bouktir, T.201, 2013. TVAC based PSO for solving economic and environmental dispatch considering security constraint. Renewable and Sustainable Energy Conference (IRSEC), 2013 International. page 396-401.

[16] Achayuthakan, C. Ongsakul W. ,2009. TVAC-PSO based optimal reactive power dispatch for reactive power cost allocation under deregulated environment. Power & Energy Society General Meeting, 2009. PES '09. IEEE, page 1-9.

[17] Varshney S., Srivastava L., Pandit M., 2011. Comparison of PSO Models for Optimal Placement and Sizing of Statcom. Chennai and Dr.MGR University Second International Conference on Sustainable Energy and Intelligent System (SEISCON 2011), page 346-351.

IX. ACKNOWLEDGEMENT

I would like to thank Dr. Jan Meyer (Institute of Electrical Power Systems and High Voltage Engineering, TechnischeUniversität Dresden, Dresden, Germany) for hosting me forresearch internship during May to August 2013.

X. BIOGRAPHIES

JukkrapunPrasomthongreceived the B.Eng. degree in electrical engineering from Kasetsart University (Bangkhen Campus), Bangkok, Thailand in 2010. He is currently aM.Eng. candidate in Electrical Engineering at Energy Field of Study, School of Environment, Resources and Development, Asian Institute of Technology, Thailand.

WeerakornOngsakul received the M.S. and Ph.D. degrees in electrical engineering from Texas A&M University, College Station, USA in 1991 and 1994, respectively. He is currently an Associate Professor at Energy Field of Study, and former Dean of School of Environment, Resources and Development, Asian Institute of Technology, Thailand. His current interests are in AI applications to power systems, and power system restructuring and deregulation, micro grid and smart grid.

Jan Meyer received the Dipl.-Ing. and Ph.D. from TechnischeUniversität Dresden (Germany). Since 1995, he is with the Institute of Electrical Power Systems and High Voltage Engineering at the TechnischeUniversität Dresden. He is member of several national and international working groups related to Power Quality and EMC. His fields of interest are all aspects of design and management of large power quality monitoring campaigns and theory of network disturbances, especially harmonics.