AUT Journal of Electrical Engineering

AUT J. Elec. Eng., 50(2) (2018) 149-156
DOI: 10.22060/eej.2018.13801.5191

Optimal DC Fast Charging Placing And Sizing In Iran Capital (Tehran)

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ABSTRACT: DC fast charging (DCFC) and optimal placing of them is a fundamental factor for the popularization of electric vehicles (EVs). This paper proposes an approach to optimize place and size of charging stations based on genetic algorithm (GA). Target of this method is minimizing cost of conversion of gas stations to charging stations. Another considered issue is minimizing EVs losses to find nearest station to recharge batteries. The introduced model forms a mixed-integer non-linear problem and is solved by binary GA and is adopted for finding the optimal place and size of charging stations in Iran capital (Tehran). This practical study proves that the proposed model and method are feasible. Existing gas stations in Tehran are selected as candidate to be converted as DC fast charging. EVs has been outspread throughout of city based on traffic and trips in each municipal districts. The model developed here can be generalized to data set for any region or city and can be used for governmental decision for constructing charging station infrastructure.

Review History:

Received: 2 December 2017
Revised: 29 September 2018
Accepted: 30 September 2018
Available Online: 20 October 2018

Keywords:

Electric Vehicles
Charging Station
Optimal Placing
Binary Genetic Algorithm

1- Introduction

Development of electric vehicles (EVs) technology has been accelerated in the recent years. This attraction is associated with improvements in fuel economy and emissions as well as low electricity energy cost for EVs [1]. Nowadays, about 62% of the refined crude oil is used for the transportation aims in Iran that are equal to 270 Million Barrels of Oil Equivalent (MBOE) in 2013 or 91.6 Billion liters per day [2]. About 27.3 MBOE of this amount is gasoline that a significant part of it is imported and finally consumed by light vehicles. Production and consumption of gasoline in Iran is presented in figure (1) for the years 1989-2014 [3]. Although gasoline import has reduced in recent years due to heavy investments, but Iran is faced with challenges like energy security and air pollution in large cities. So in near years, deployment of EVs must increase considerably as government planned some incentives like elimination custom duties and taxes.

The EVs which are currently available in the market have an all-electric-range (AER) of several hundred kilometers to answer the required energy. There are some charging levels (in North America there is three levels as: level I 120V-AC, level II 240 V-AC, level III DC fast charging) to charge battery of EVs that charging time varies from 20 minutes to 20 hours based on battery capacity, amount of depleted energy, charging level, etc. [4]. An on-board charger is usually deployed inside EVs for slow charging in home and overnights. But there is a need to charge batteries quickly in other places like streets and suburban roads to extend AER. Comparison of the both charging methods is presented in [5]. So lack of time causes DC fast charging and constructing off-board charging station infrastructure to be employed in public places. In this paper, in order to reduce cost and land use, it is considered that DCFCs should be constructed in existing gas stations. Gas stations in Iran's capital, Tehran, are widespread all over the city. Whole gas stations are candidate for conversion as charging stations. Optimal selecting and sizing of these candidates is the objective of this paper.

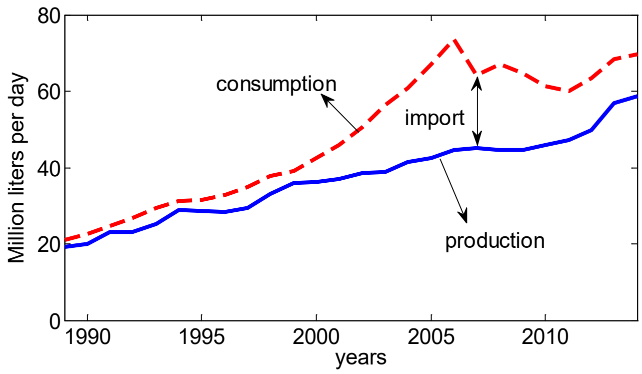

Fig. 1. consumption and production of gasoline in Iran

Many researches are to find the optimal place and size of charging stations. In [6], Chen proposed a new location model based on the set cover model taking the existing traditional gas station network as the candidate sites to determine the distribution of the charging and battery swap stations. In paper [7], a method of locating and sizing the charging stations is proposed based on the grid partition. This method minimizes the losses of EVs on the way to the charging stations. It is performed by zoning the planning area with grid partition method and choosing the best location of charging stations by considering traffic density and the capacity of charging stations constraints. Genetic algorithm is employed to solve the optimization problem. Above papers like many others [8-

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10] are not surveyed on real condition but analyzed based on assumptions and probabilities. Some researchers studied placing and sizing of charging stations on real conditions and for real cities [11-13]. Since, deployment of EVs in Iran is not matured, conducted researches are really rare. Sadeghi-Barzani in [14] has found optimal placement for a small area in north-west of Tehran. Paper [14] selected candidate charging stations randomly. But in this presented paper, not only Tehran is discussed but also candidate charging stations are selected based on the real existing gas stations.
The rest of paper is organized as follows. Section II describes and formulates the problem as charging stations placing model. In section III, optimizations model and the proposed approach to solve the problem is presented. Case study and simulation results are given in section VI. Applicability of the proposed approach is demonstrated for Iran capital (Tehran). Finally, concluding remarks are provided in section V.

2- Charging station placing model

For optimal placing of DC fast charging stations, the costs should be minimized. The assumed cost consists of two parts, charging station development cost and vehicle displacement cost. Development cost is associated with land cost, transformers, cabling, installation, etc. But vehicle displacement cost is about electric vehicles' losses which vehicles must recharge the batteries till traverse trajectory to attain a charging station. In the following, both costs are discussed.

2- 1- Station development

In this paper, it is considered that the existing gas stations in urban area are equipped to be used as the charging stations due to having facilities like electrical and mechanical installations. Developing the cost of charging stations consists of equipment cost, land cost and fixed cost. Since it is assumed that the existing gas stations will be developed as charging stations, land cost is neglected and just equipment cost and fixed cost are considered. Lack of time entails that the only appropriate charging level is DC fast charging. Development cost of gas station number *i* (SDC_i) can be calculated by equation (1) in $.

$$SDC_i = C_{fix,i} + C_{land,i} + C_{eqp,i} \qquad i=1,...,N \tag{1}$$

In above equation, $C_{fix,i}$ is the initial and fixed cost that is constant for each developed charging station and is related to initial facilities to develop a charging station. $C_{land,i}$ is the cost of land purchasing and varies in different regions of city. In this study, $C_{land,i}$ is neglected. $C_{eqp,i}$ represents equipment cost that is associated with the number of installed charging connectors in charging station number *i* and can be calculated by equation (2).

$$C_{eqp,i} = CN_i \times C_{con} \qquad i=1,...,N \tag{2}$$

In equation (2), CN_i gives the number of installed connectors in charging station number *i* that can change based on the bulk of electric vehicles which are recharging, so it can be considered as the capacity of charging station number *i*. C_{con} is purchasing cost of each connector. Ultimately, total development cost can be obtained by the summation of each development cost via equation (3). In this equation, X_i is a binary decision variable that is related to charging station number *i* and is not null if this charging station is developed.

$$SDC = \sum_{i=1}^{N} (SDC_i) \times X_i \tag{3}$$

2- 2- Vehicle displacement

An important issue in optimal placing is minimizing the distances between commuting electric vehicles and charging stations. Distances from each electric vehicle to each charging station can be calculated and the nearest charging station for every electric vehicle can be achieved. Equation (4) represents the above discussion.

$$D_k = \min(D_{k,1},...,D_{k,n}) \qquad k=1,...,M \tag{4}$$

In equation (4), D_k is the distance between electric vehicle number *k* and charging station number *I,* and the minimum distance is selected as D_k in km. Total number of vehicles is *M*. After calculating minimum distances, the cost of vehicle displacement is derived by using equation (5).

$$VDC_k = EP \times EC \times D_k \qquad k=1,...,M \tag{5}$$

Where *EC* is the electric vehicle average electricity consumption in kWh/km. *EP* in equation (5) represents the electricity price in $/kWh. Total vehicle displacement cost is obtained by the summation of VDC_k via equation (6).

$$VDC = \sum_{k=1}^{M} VDC_k \tag{6}$$

3- Optimization model

The objective of this paper is to minimize total cost which is related to the development of charging stations and electric vehicles displacement losses simultaneously, as it is shown in equation (7).

$$\text{minimize} \quad w_1 \times SDC + w_2 \times VDC \tag{7}$$

In equation (7), SDC and VDC are charging station development cost and vehicle displacement cost, respectively. Coefficients *w1* and *w2* are weights which represent the importance of each objective function SDC and VDC. Equation (7) forms a mixed-integer non-linear problem (MINLP) which should be solved with iterative method. The selected method to solve this minimizing problem is genetic algorithm (GA). Solution feasibility depends on the different constraints represented by the following equations.

$$\sum_{i=1}^{N} X_i > 0 \tag{8}$$

$$CN_i \geq X_i, i=1,...,N \qquad if\ X_i > 0 \tag{9}$$

$$\sum_{k=1}^{P} CN_{i,k} \leq (MAXC) \times X_i \qquad i=1,...,N \tag{10}$$

$$X_i \in \{0,1\} \tag{11}$$

Equations (8) shows that at least one charging station should be developed. Equation (9) indicates that in each developed charging station at least one connector must be considered. Summation of all connectors in charging station number *i* should not exceed the determined maximum connector

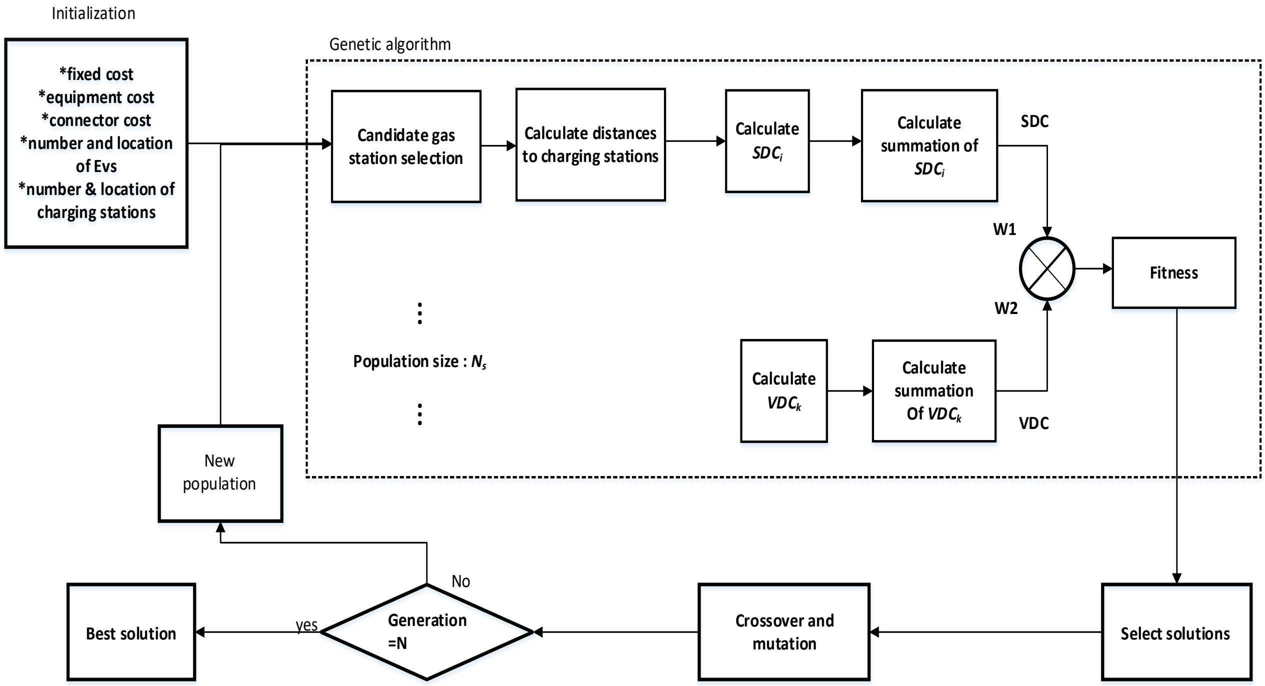

Fig. 2. proposed algorithm via binary GA

(*MAXC*) which is shown in equation (10). Equation (1) gives the feasible zone for the decision-making variable X_i.

3- 1- Genetic algorithm

In this paper, binary genetic algorithm is adopted to optimize number and location of charging stations which can charge electric vehicles' batteries via DC fast charging. Another considered issue in optimizing the problem is the number of installed connectors in selected charging stations to find optimal size of each. Optimizing problem is based on the number of connectors and location of charging stations to reduce investment cost vehicle losses with considering constraints mentioned in equations (8-11). The binary GA randomly generates a solution population consisting of a certain number of gas stations that can be candidate as active charging stations. Each solution contains binary numbers that represent a chromosome. Each number indicates that related gas station can be developed as a charging station or not. Fitness functions for this paper is presented in equations (3-6). After calculating fitness values, selecting best solutions, crossover, and mutation, the new solutions can be got that is included both the old and the new solutions. After judging whether the expected generation number has been satisfied or not, the best solution can be obtained and then the new solutions can be generated again. Since selecting the best gas station to be developed and optimal number of installed connector are desired variables in our scheme and the constraint parameters are set in the beginning, we assume that the total fitness function is equation (7). Referring to the selection process, a roulette selection method is used in which the solution with a better fitness value that is calculated via equation (3,6) has a higher probability to be selected for further processing. The proposed algorithm via binary GA is presented in figure (2).

4- Case study

In this research Tehran is selected to survey feasibility of proposed approach. City of Tehran is divided into 22 municipal districts, and there are near 1.2 million moving vehicles in roads, based on the latest census performed in Iran in 2006 [15]. Map of Tehran is shown in figure (3) based on [16]. In this figure, 22 municipal districts urban area are presented by colorful area.

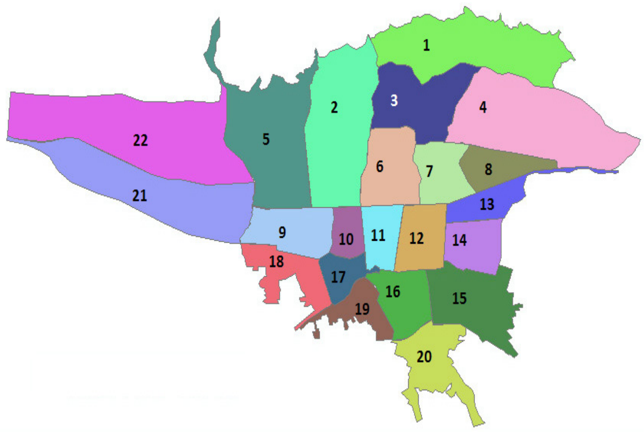

Fig. 3. Tehran municipal districts

The information of 2006 census in Iran for Tehran city shows vehicle ownership in each district [15]. Table (1) gives vehicle possession and shares in Tehran based on districts in 2006. Also population, area and number of gas stations in each district is shown in table (1). Another issue that is presented in table (1) is some information about the absorbed and produced trips that can be used as criteria for considering traffic flow derived from [17]. As it is shown in 22 districts of Tehran, there is totally 149 gas stations [18].

Population of 5 districts number 1-5 is about 2781190 that is about 36% of total, but near more than 47% of vehicles is in this region. Area of 5 districts numbers 6, 7, 10, 11, 12 is about

Table 1. Information of municipal districts of Tehran

District No.	District area (km^2)	District population	Gas station Numbers	Vehicle Numbers	Vehicle share (%)	Absorbed trips	Produced trips	Total trips	Trip shares (%)
1	64	379962	11	77657	6.95	440881	485793	926674	5.44
2	64	608814	10	125440	11.23	600993	727965	1328958	7.8
3	31.2	290726	9	61313	5.49	515442	433802	949244	5.57
4	61.4	822580	9	130736	11.7	644082	881330	1525412	8.95
5	54.7	679108	10	130244	11.66	510202	760135	1270337	7.46
6	35.2	237292	9	41549	3.72	937669	426428	1364097	8.01
7	15.3	310184	6	44361	3.97	407101	366596	773697	4.54
8	13.2	378725	3	58660	5.25	277163	402180	679343	3.99
9	19.6	165903	5	18598	1.66	219615	175713	395328	2.32
10	8.2	315619	3	33286	2.98	202189	301730	503919	2.96
11	12.1	275241	5	31211	2.79	430704	337172	767876	4.51
12	17	248048	8	23603	2.11	1004840	406623	1411463	8.28
13	12.8	245724	9	38595	3.45	195739	266361	462100	2.71
14	22	483432	4	64379	5.76	287793	449944	737737	4.33
15	35.4	644259	9	61441	5.5	417160	575814	992974	5.83
16	16.5	291169	4	26230	2.35	223596	245948	469544	2.76
17	8.2	256022	0	20175	1.8	175975	200560	376535	2.21
18	18.1	317188	4	29877	2.67	300813	335739	636552	3.74
19	20.7	249786	11	23406	2.1	155028	212800	367828	2.16
20	23	335634	8	34551	3.1	298750	306794	605544	3.55
21	51.6	159793	7	24152	2.16	167715	163219	330934	1.94
22	70.8	108674	5	17773	1.6	57407	104907	162314	0.94
total	675	7803883	149	1117237	100	8470857	8567553	17038410	100

87.8 km^2 that is about 13% of whole area, but 29% of total trips occurred in this region. Location of existing gas stations and considered electric vehicles are simulated and shown in figure (4) as red plus (+) and black dot (.), respectively.

It is assumed that 5 percent of the vehicles in widespread of city be as electric vehicles and just one third of them is charged in every day, so every day 18620 electric vehicles can be charged in developed gas stations as charging stations. In this study, the number of vehicles is determined based on vehicle possession but share of vehicles in each district can be chosen based on share of trips. Share of trips is calculated by the summation of absorbed and produced trips and divided by total.

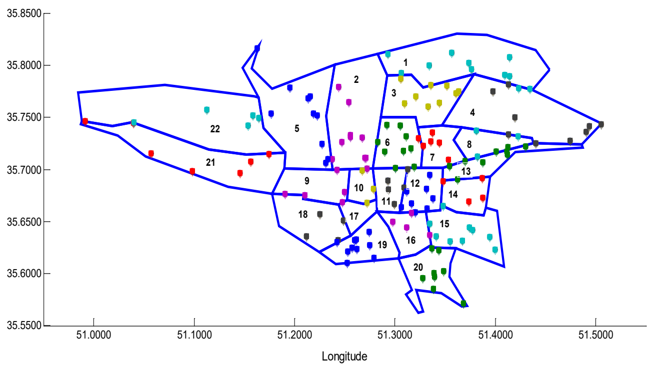

Fig. 4. Location of simulated gas stations

In the following, two scenarios are defined and discussed as scenario (A) and (B) to solve the placing and sizing problem. These scenarios can be performed with proposed approach.

4- 1- Scenario (A)

In scenario (A), cost of charging station development is neglected and assumed that government and the existing gas station owners undertake the cost as partnership. In this case, coefficient weight *w1* will be zero and objective function forms as equation (12).

$$\text{minimize} \sum_{k=1}^{M} VDC_k \tag{12}$$

The proposed approach is adopted to solve equation (12) and to find optimal place and size of developed charging stations. Capacity of each installed connector is limited by parameter *MC* which represents maximum electric vehicles that can be charged via this connector during 24 hours. Maximum installable connectors for each charging station is presented by parameter *MAXC* and is determined to be 25. So each station is able to have 25 connectors in maximum. Other parameters like number of electric vehicles and number of

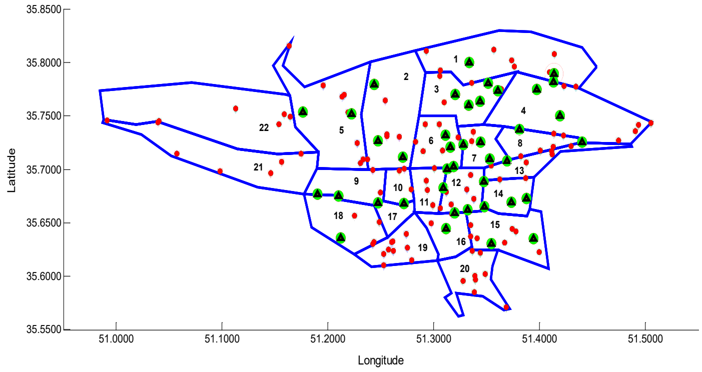

Fig. 5. Optimal placing for scenario A

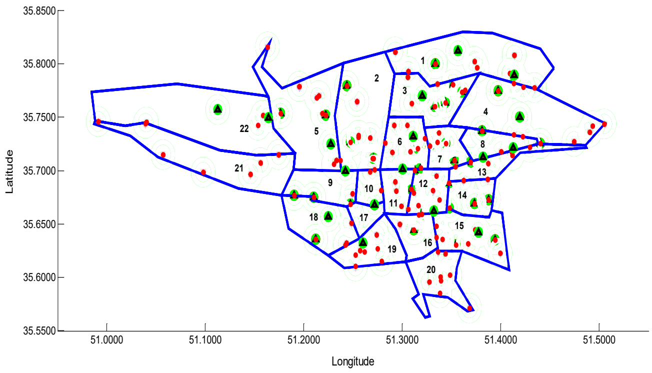

Fig. 6. Optimal placing for scenario B

candidate stations which used in this study are shown in table (2). Parameters which are used to solve the binary GA are presented in table (3).

Figure (5) shows the results for scenario (A). As it is shown, 40 gas stations are selected optimally to be developed as charging stations. More information about the selected gas stations and optimal size and cost of whichever is represented in table (4) and appendix (A). Total number of installed connectors is 313 and total cost is about 20690 $ that is just associated with electric vehicles' losses.

Table 2 used parameters in objective function

Parameter	*Value*	*Unit*
N	149	—
M	18620	—
EC	7 [19]	km/kWh
EP	90	$/kWh
C_{fix}	70000 [20]	$
C_{con}	20000 [20]	$
MC	36	—
MAXC	25	—

4- 2- Scenario (B)

In this scenario, not only the cost of vehicle displacement, but also the cost of charging stations development is considered. In this case, participation of private sector in investment in charging stations development is assumed. So coefficient weights w1 and w2 are non-zero and the objective function is formed as equation (7). Results for the new considered condition is presented in figure (6). Table (4) gives the sizes and the number of selected gas stations to be developed. Parameters used for solving the problem and adopting the binary GA are represented in table (2) and table (3), respectively.

Total installed connectors in scenario (A) is about equal in scenario (B), because this parameter is associated with the number of electric vehicles that in both scenarios is constant. In table (4), in each scenario, the number of selected gas stations to be developed is given and in parentheses, the number of the installed connector is presented. Coordination of gas stations in each region is presented in appendix A. Cost of charging stations development and electric vehicles displacement are achieved separately which in scenario (A) the cost of charging stations development is neglected.

Table 3. results for implementation of scenario A and B

	Scenario A	Scenario B
Selected gas stations to be developed (number of connectors)	3 (6), 9 (7), 12 (13), 16 (8), 17 (12), 19 (9), 20 (6), 22 (6), 23 (5), 24 (8), 27 (6), 28 (7), 30 (6), 31 (5), 39 (9), 45 (10), 47 (10), 50 (7), 52 (11), 55 (5), 56 (6), 57 (7), 62 (7), 65 (7), 66 (6), 69 (11), 70 (15), 75 (13), 76 (7), 78 (7), 79 (8), 84 (4), 90 (7), 92 (7), 93 (6), 94 (6), 97 (9), 100 (8), 102 (12), 109 (6).	3 (10), 4 (25), 24 (25), 27 (8), 42 (25), 46 (25), 52 (25), 69 (25), 70 (25), 79 (25), 86 (15), 87 (11), 99 (23), 106 (10), 112 (25), 132 (5), 133 (7).
Cost of charging stations development ($)	—	7960000
Cost of vehicles displacement ($)	20690	42027
Total cost ($)	20690	8002027
Total installed connectors	315	313
Total selected charging stations	40	17

Ultimately, total cost of developement and losses for 17 charging stations in scenario (B) is about 18 million $. The major cost in scenario (B) is associated with the development cost. In scenario (A), regarding the neglected cost of charging stations development, the number of selected stations is much more than scenario (B), but cost of electric vehicles displacement increased twofold from 20690 $ to 42027 $. This is because of reduction in the number of the developed gas stations in scenario (B) that enhances the vehicle displacement losses.

Table 4. used parameters in binary GA

Parameter	Value (scenario A)	Value (scenario B)
w1	0	1
w2	1	1000
Ns	100	100
Pc	0.85	0.85
Pm	0.15	0.15
Ng,max	100	200

5- Conclusion

This paper proposes an approach for optimal placing and sizing of electric vehicle charging stations. After definition of problem, Tehran, is selected for studying the feasibility of approach via two scenarios. The aim of the first scenario is minimizing vehicle displacement losses of EVs on the way to charging stations. In the second scenario, minimizing vehicle losses is assessed with the consideration of stations' development cost, simultaneously. The proposed approach adopted binary GA to solve the explained problem via considering location of the existing gas stations and random widespread vehicles based on the traffic density. This practical example proves that the model is feasible. However, electric grid is one of the important issues that should be considered in the study based on the voltage profile and stability constraints, which can change the results.

Refrences

[1] J. Saarenpää, M. Kolehmainen, H. Niska, Geodemographic analysis and estimation of early plug-in hybrid electric vehicle adoption, Applied Energy, 107 (2013) 456-464.

[2] I.R.o.I.M.o. Energy, Iran energy balance 1392, (Aug 2015).

[3] N.I.O.P.D.C. (NIOPDC), consumption of petrolium products statistics – 1393, (Nov 2015).

[4] H. Quebec, Electric Vehicle Charging Stations Technical Installation Guide, in, no. August, 2015.

[5] C. Botsford, A. Szczepanek, Fast charging vs. slow charging: Pros and cons for the new age of electric vehicles, in: International Battery Hybrid Fuel Cell Electric Vehicle Symposium, 2009.

[6] C. Chen, G. Hua, A new model for optimal deployment of electric vehicle charging and battery swapping stations, International Journal of Control & Automation, 8(5) (2014).

[7] S. Ge, L. Feng, H. Liu, The planning of electric vehicle charging station based on grid partition method, in: Electrical and Control Engineering (ICECE), 2011 International Conference on, IEEE, 2011, pp. 2726-2730.

[8] M. Jin, R. Shi, N. Zhang, Y. Li, Study on multi-level layout planning of electric vehicle charging stations based on an improved genetic algorithm, International Journal of Smart Grid and Clean Energy, 2(2) (2013) 277-282.

[9] H. Xu, S. Miao, C. Zhang, D. Shi, Optimal placement of charging infrastructures for large-scale integration of pure electric vehicles into grid, International Journal of Electrical Power & Energy Systems, 53 (2013) 159-165.

[10] Z. Liu, F. Wen, G. Ledwich, Optimal planning of electric-vehicle charging stations in distribution systems, IEEE Transactions on Power Delivery, 28(1) (2013) 102-110.

[11] C. Dharmakeerthi, N. Mithulananthan, T. Saha, A comprehensive planning framework for electric vehicle charging infrastructure deployment in the power grid with enhanced voltage stability, International Transactions on Electrical Energy Systems, 25(6) (2015) 1022-1040.

[12] Z.-f. Liu, W. Zhang, X. Ji, K. Li, Optimal planning of charging station for electric vehicle based on particle swarm optimization, in: Innovative Smart Grid Technologies-Asia (ISGT Asia), 2012 IEEE, IEEE, 2012, pp. 1-5.

[13] S. Mehar, S.M. Senouci, An optimization location scheme for electric charging stations, IEEE SaCoNet, (2013) 1-5.

[14] P. Sadeghi-Barzani, A. Rajabi-Ghahnavieh, H. Kazemi-Karegar, Optimal fast charging station placing and sizing, Applied Energy, 125 (2014) 289-299.

[15] S. center, final results for Tehran (22regions), (2007).

[16] G. Maps, Tehran Accessed Nov 2, (2015).

[17] T.c.t.a.t. co, selected data and information of urban transportation in Tehran – 1392, (2013).

[18] N.I.O.p.d.c.N.-T. region, address and phone of gas stations in Tehran based on region, (Nov 2015).

[19] C. Cities, Plug-In Electric Vehicle Handbook for Public Charging Station Hosts, US Department of Energy Publication No. DOE/GO-102012-3275, (2012)

APPENDIX.A: Coordination of gas stations in each region

Region No.	No.	Latitude	Longitude	No.	Latitude	Longitude
1	1	35.777456	51.534582	7	35.802150	51.473384
	2	35.778073	51.523258	8	35.812120	51.456541
	3	35.789496	51.514115	9	35.799751	51.433901
	4	35.790850	51.509132	10	35.792648	51.406145
	5	35.807893	51.514137	11	35.810793	51.392953
	6	35.796444	51.476069			
2	12	35.779512	51.343735	17	35.726622	51.347294
	13	35.764587	51.354045	18	35.709858	51.337350
	14	35.730661	51.367430	19	35.700815	51.372022
	15	35.732942	51.355662	20	35.711248	51.371038
	16	35.731560	51.355452	21	35.711397	51.369778
3	22	35.775283	51.463620	27	35.760137	51.433248
	23	35.773417	51.460622	28	35.769887	51.420548
	24	35.780313	51.451702	29	35.763214	51.409765
	25	35.781262	51.435747	30	35.787345	51.405767
	26	35.763821	51.444133			
4	31	35.781935	51.513303	36	35.727492	51.574591
	32	35.774863	51.497709	37	35.735854	51.590335
	33	35.733880	51.513159	38	35.741623	51.593704
	34	35.750204	51.519334	39	35.743403	51.605171
	35	35.725482	51.540225			
5	40	35.816011	51.262959	45	35.753503	51.318858
	41	35.778680	51.295160	46	35.753573	51.276404
	42	35.770306	51.315500	47	35.724864	51.327394
	43	35.768443	51.313284	48	35.706304	51.330812
	44	35.752044	51.322433	49	35.709752	51.333271
6	50	35.70163	51.400688	55	35.726308	51.382633
	51	35.702512	51.419128	56	35.732126	51.411044
	52	35.717345	51.389854	57	35.742304	51.405114
	53	35.717686	51.408426	58	35.742668	51.392058
	54	35.720548	51.415696			
7	59	35.709514	51.453252	62	35.726782	51.435783
	60	35.72292	51.428189	63	35.730255	51.423229
	61	35.725569	51.444475	64	35.735607	51.43726
8	65	35.737335	51.481012	67	35.731853	51.522713
	66	35.712353	51.482104			
9	68	35.67674	51.290383	71	35.678384	51.349524
	69	35.67523	51.309987	72	35.699477	51.342091
	70	35.668617	51.347426			
10	73	35.667837	51.372166	75	35.698939	51.367429
	74	35.681579	51.378352			
11	76	35.667067	51.399114	79	35.70058	51.412611
	77	35.680982	51.393718	80	35.689559	51.392954
	78	35.682627	51.409116			

12	81	35.663925	51.406056	85	35.672468	51.437866
	82	35.659228	51.420131	86	35.679031	51.4119
	83	35.662441	51.4322	87	35.681764	51.431337
	84	35.667419	51.416388	88	35.694755	51.434763
13	89	35.703593	51.454357	94	35.721273	51.512719
	90	35.690788	51.46214	95	35.722169	51.529955
	91	35.708056	51.469713	96	35.717012	51.511594
	92	35.706719	51.487389	97	35.714089	51.511798
	93	35.717595	51.500598			
14	98	35.688606	51.447687	100	35.669433	51.473628
	99	35.692079	51.4868	101	35.672992	51.487685
15	102	35.664982	51.447959	107	35.642166	51.477547
	103	35.647985	51.434757	108	35.635278	51.494324
	104	35.63575	51.440802	109	35.623112	51.499771
	105	35.630823	51.454652	110	35.631981	51.467087
	106	35.644448	51.474234			
16	111	35.658621	51.416648	113	35.644726	51.411799
	112	35.637361	51.434798	114	35.649934	51.397509
18	115	35.657116	51.325142	117	35.632202	51.343393
	116	35.651166	51.348576	118	35.635751	51.311978
19	119	35.639956	51.374168	125	35.623929	51.361924
	120	35.632707	51.361443	126	35.61051	51.352663
	121	35.632069	51.360086	127	35.621184	51.352783
	122	35.63214	51.360035	128	35.62518	51.357373
	123	35.627226	51.374945	129	35.630693	51.342337
	124	35.615181	51.37932			
20	130	35.622513	51.443729	134	35.597242	51.439184
	131	35.624144	51.436534	135	35.595933	51.427801
	132	35.60232	51.448309	136	35.585459	51.438202
	133	35.600719	51.438895	137	35.571574	51.468474
21	138	35.696867	51.245799	142	35.715231	51.157117
	139	35.707555	51.256146	143	35.746192	51.091206
	140	35.714768	51.274251	144	35.74444	51.13933
	141	35.698397	51.197943			
22	145	35.74938	51.264236	148	35.757226	51.212392
	146	35.751671	51.258604	149	35.745177	51.140014
	147	35.742194	51.253593			

Please cite this article using:

M. Mosstafayi, M. Abedi, Gh. H. Riahy , Optimal DC Fast Charging Placing And Sizing In Iran Capital (Tehran), *AUT J. Elec. Eng.*, 50(2) (2018) 149-156.

DOI: 10.22060/eej.2018.13801.5191