Turkish Journal of Electromechanics and Energy
ISSN: 2547-975X
Vol:6, No:3, Page 80-87 (2021)
https://www.scienceliterature.com

Turkish Journal of Electromechanics & Energy
an international open access journal
www.scienceliterature.com

Optimization of number and spatial distribution of solar charge stations for electric buses: Case study, Bus Rapid Transit (BRT) lines

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ARTICLE INFO

***Article Type*:**
Research Article

Article History:
Received: 2 May 2021
Revised: 1 September 2021
Accepted: 23 September 2021
Published: 30 December 2021

Editor of the Article:
M. E. Şahin

Keywords:
Electric vehicle, Optimization, Spatial distribution, Solar charge stations

ABSTRACT

As an energy-consuming technology, Electric Vehicles (EVs) create a demand for energy that can be met through renewable energy. In addition to the environmental benefits of this shift, electric transportation benefits from high efficiencies and expands the electrical energy storage system for renewable energy. Meanwhile, solar energy, as one of the most important sources of renewable energy that has a very high potential in Iran, can be used to power EVs. The present study provides a new approach to calculate and optimize the number and location of solar charge stations (SCSs) required for EVs in bus lines all over Tehran. This approach aims to minimize the number of charge stations while covering all bus lines and minimizing the energy loss of transmission in an Electric Vehicle Mobile Energy Network (EV-MEN). Currently, none of the bus lines in Tehran has a charging station. This paper can be a guide in future planning in this area. The results show that if the number of charging stations in Tehran equals six, all bus lines will be covered and energy losses will be minimized.

Cite this article: Y. Noorollahi, R. Moltames, S. Muthusamy, S. C. M. Sundararajan, "Optimization of number and spatial distribution of solar charge stations for electric bus: Case study, BRT lines," *Turkish Journal of Electromechanics & Energy*, 6(3), pp.80-87, 2021.

1. INTRODUCTION

Greenhouse gas emissions led to increased environmental concerns and issues like global warming [1]. On the other hand, the transportation industry has a significant impact on this global warming, so that the transportation sector is considered the second-largest producer of greenhouse gases [2]. According to Figure 1, over the past 15 years, even though the share of the electricity and heat sector in total emissions has stayed constant, the percentage of transportation has grown by 5% [3]. In the last decade, many countries have developed several EVs to reduce greenhouse gas emissions and their global warming effects. Figure 2 shows the increasing trend in the number of electric cars over different years [4]. As can be seen from the figure, the number of EVs increased from about 1 million to 2 million from 2015 to 2016, and this increasing trend is rising [5]. One of the main reasons for this trend is the possibility of recharging and a significant increase in the capacity of batteries. We must keep in mind that EVs and renewable energy resources have emerged to achieve the three primary goals of the present century. These three goals are as follows [2]:

- Utilization of environmentally friendly energy resources
- Sustainable energy supply
- Sustainable development of power systems

Therefore, many studies have been conducted on the development of electric machines in recent years. Some of the most critical actions and the challenges facing this industry are described in this paper.

The question about where to locate plug-in electric vehicle charging stations stems from the general facility location problems, [5], in which a central planner allocates supplies or services to satisfy demand based on nodes in a spatial network, for instance, locations of electric taxi recharging stations [6] and EV charging stations [7].

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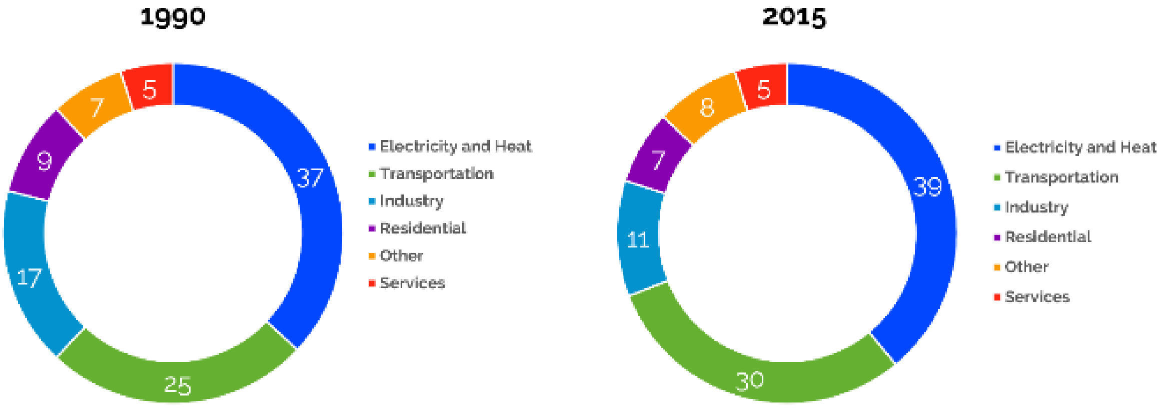

Fig. 1. CO_2 emission by sectors [2].

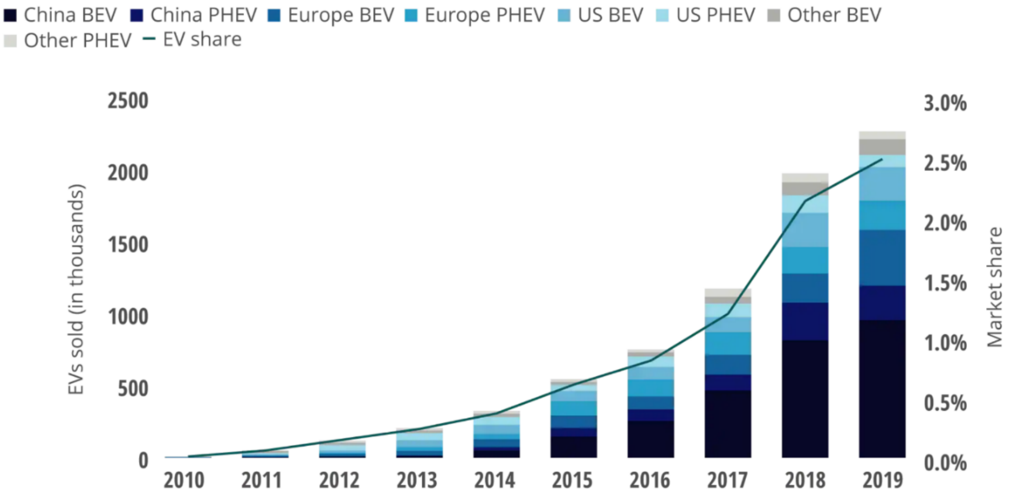

Fig. 2. Evaluation of global electric vehicles [4], [8].

Assignment of an EV charging infrastructure is assigned in Ref. [6]. This paper investigates the power grid impacts in this assignment in Beijing. Their findings reveal that each EV charging infrastructure has its challenges and limitations, which means integration and management are needed to provide a reliable and sustainable charging service [9, 10]. They also found that although electric cars would add an extra load to Beijing's power grid, this overload could be offset by managing the charge time and battery replacement strategy. S. Ge *et al.* [11] proposed a model to plan EV charging stations based on grid partition. They used Genetic Algorithm (GA) to solve the model optimization and considered traffic density and charging station capacity constraints in their model. A practical example showed that their model is viable. H. Wang *et al.* [12] proposed a new EV charging station planning approach. Their multi objective planning model considers affecting factors including EV sustainable development, charging station characteristics, characters of charging consumers, charging demand distribution, characters of the power grid, and municipal planning factors. They used a numerical case based on Chengdu City's background to verify their model. G. Wang *et al.* [13] proposed multi objective planning of EV charging stations based on traffic constraints to ensure a reliable charging service. Their results showed that their proposed model is effective for a case study consisting of a 33-node distribution system and a 25-node traffic network system. Z. A. Padhya and S. S. Bohra [14] investigated a grid-connected photovoltaic system and the impact of electric vehicles on this system. Their study assumes that electric vehicles (under conditions of large numbers) can act as mobile energy storage in the microgrid system. M. Azizi *et al.* [15] studied the utilization of EVs and their batteries for peak-load shifting. In addition to studying the theory, they also showed the system's stability in terms of functionality and experience. Their study showed that the use of electric vehicles and their batteries to support a small-scale energy management system is quite feasible.

Electric cars can store a lot of energy in their batteries. If needed, this energy can be returned to the grid for reuse, creating a concept called Vehicle to Grid (V2G). In V2G systems, EVs can become an extensive storage system [16]. For example, if all cars in the United States were converted into EVs, their battery power could be 24 times that of the entire U.S. power grid. At the same time, EVs can be moved, which causes energy to be transferred from one point to another, which is not possible in conventional power grids. Inspired by the above two concepts, in this paper, we present an electrical network based on EVs, termed EV-Mobile Energy Network (EV-MEN) for energy transportation.

- ✓ To provide a concept for the EV energy network. This network includes EVs, charging stations, and an energy transportation network. In this system, energy can be transferred using EVs from one point to another. On the other hand, energy can be transferred from renewable energy sources to charging stations.
- ✓ To design a specific example of an EV power network. An electric bus company in Tehran is used for this purpose. Buses transmit and distribute energy from renewable energy sources to recharge stations in this concept.
- ✓ To create an optimization model to minimize the number of charging stations and at the same time cover all BRT lines in Tehran. We will prove that the problem is NP-hard and present a greedy algorithm based on a bipartite graph to solve it.

For more information, the number of BRT lines in Iran includes three cities of Tehran, Tabriz, and Isfahan are 10, the total number of passengers transferred per day is 2,135,000 and the entire length of the lines is about 100 km [17].

The Tehran Bus Rapid Transit lines simulation demonstrates that our algorithm is working efficiently.

2. PROBLEM DESCRIPTION

One of the most important reasons for global warming and climate change is the excessive release of carbon dioxide into the atmosphere. Hence, the use of renewable energy has become a popular option in communities. Among these, solar energy and wind energy are the most important renewable energy sources due to economic justification. However, due to the instability of these energy sources, it is not easy to generate and inject this energy into the electricity grid. Meanwhile, the widespread use of EVs could create a new paradigm for this problem. In this way, electric vehicles can store electrical energy and inject it into charging stations when necessary [18].

The basic idea of an EV-MEN is to use EVs to store and transport energy from renewable energy charge stations to users that need power (e.g., charging stations and houses). An EV-MEN is an energy transmission system that can transport energy from its generation to where users need it for valuable work without using power transmission lines. In Figure 3, the conventional method to transport energy to charge stations is shown. The total efficiency of the traditional transmission (η_{total}) is calculated by the following equation:

$$\eta_{total}(\%) = \eta_{DC/AC} \times \eta_{Pt} \times \eta_{AC/DC} \times 100 \qquad (1)$$

Where $\eta_{DC/AC}$ is the DC/AC conversion efficiency, η_{Pt} is the power transmission efficiency, and $\eta_{AC/DC}$ is the AC/DC conversion efficiency. According to Figure 3, the total efficiency of the conventional transmission is equal to 72.3%. The process includes three steps. The first and the third step are the converters, and the second step is the power transmission system. As the figure shows, 27.7% of the total energy is wasted in this process.

Despite all the advantages of this method, potential users still have concerns. For example, range and charging time are the most critical concerns. Although the charging time of the batteries has been dramatically reduced over the years, it is still more than expected. Battery replacement is one of the methods that can overcome these problems, and automatic battery replacement robots are the best tool for this method. Charging replacement batteries are the most convenient way for users to benefit from EVs. In addition, charging stations can use grid electricity on an off-peak period or renewable energy when available for their needs. Therefore, such methods can help developing countries. The proposed method for power transmission via the EV network is shown in Figure 4. It consists of 2 significant ways as method 1: battery charge stations and method 2: battery replacement stations. According to the figure, the total power loss of the process is 9.78%. Comparing the conventional power transmission and proposed energy network transmission shows that the EV network is more efficient.

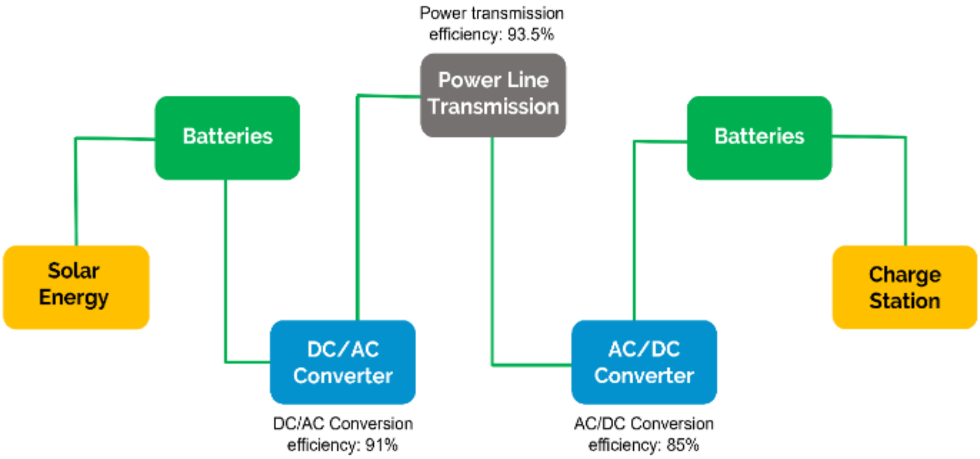

Fig. 3. Conventional power to grid, transmission, and charge station.

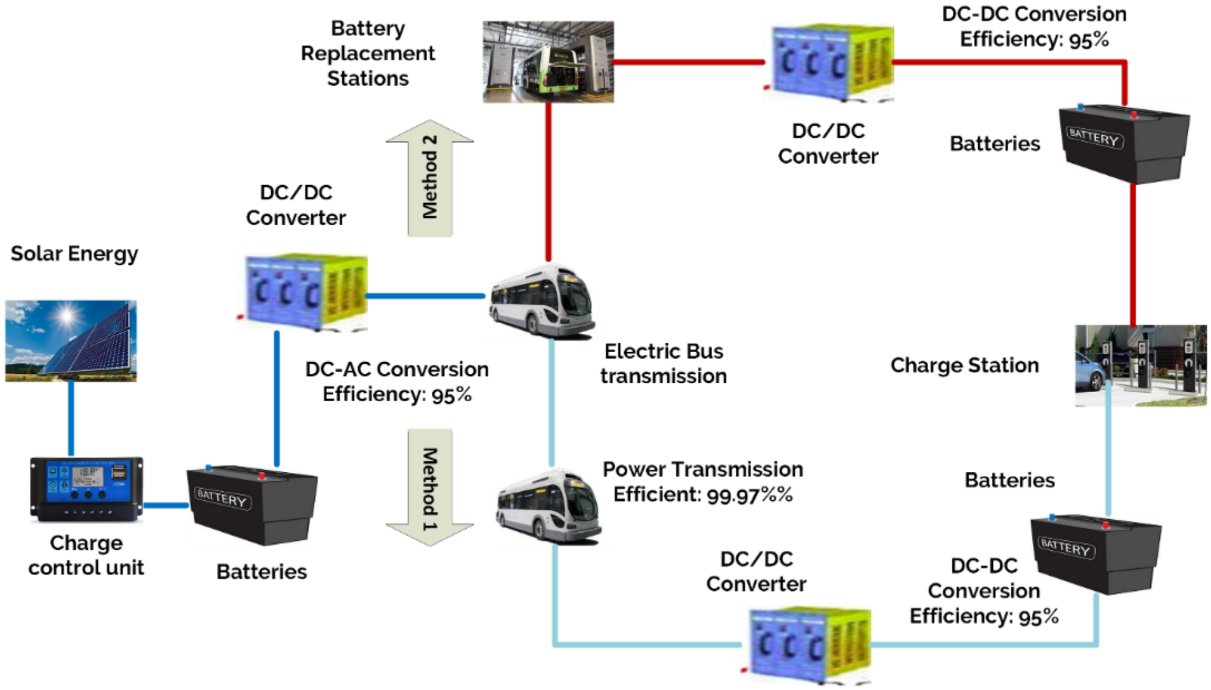

Fig. 4. Proposed energy network transmission system.

3. PROBLEM FORMULATION

Figure 5 and Figure 6 show the BRT lines and the network of bus lines, respectively. The first challenge in building an EV-MEN to support electric buses is how many stations are needed and where they should be located. The first and simplest solution is to set up charging stations at all bus stops. This, however, may incur high costs and take some time to deplete the batteries. Second, instead of charge stations, battery replacement stations are provided to decrease charging time. Rather than wait in line at an official EV charge station and endure 45 minutes to 4 hour wait as batteries are recharged, a swappable battery solution allows EV drivers to pull into battery replacement stations and swap fully-charged ones. To minimize the investment while meeting the needs of fully-electric buses, the minimum number of stations should be built [19]. The second challenge is to solve the problem of reducing energy losses in the transfer of energy from renewable energy sources to stations. Because each charging and discharging process wastes some energy. In the next step, the charging station placement will be described.

The following assumptions are considered in the model:

- $S = \{s1, ... sn\}$ denotes the set of bus stops.
- $L = \{l1, ..., lm\}$ denote the set of bus lines.
- Each bus line contains a set of bus stops.
- $D = \{d1, ..., dl\}$ denote the set of renewable energy sites.

It is assumed that energy generation technologies from renewable energy sources are located in charging stations to simplify the problem. Then $D \subseteq S$. We define a bipartite graph $G = \{S, L, E\}$, in which S is the set of bus stops, L is the set of bus lines, and set $E \in S \times L$ shows the relationship between the two vertex sets. In particular, an edge $(s_i, l_j) \in E$ connects bus stop $s_i \in S$ and bus line $l_j \in L$ if the bus stop is along the bus line. Let Ls denote the set of bus lines that passes bus stop s. That is, $L_s = \{l \mid (s, l) \in E\}$. We also say L_s is the set of bus lines covered by bus stops for ease of exposition.

The energy stored in one bus can be held at a charging station and used by another bus. Charging stations are assumed to be located at bus stop s. Remember that L_s denotes the bus lines that pass bus stop s. Where a charging station is located at a bus stop s, it can be used by all the bus lines in L_s. For ease of exposition, we also say L_s is the set of bus lines covered by charge station s.

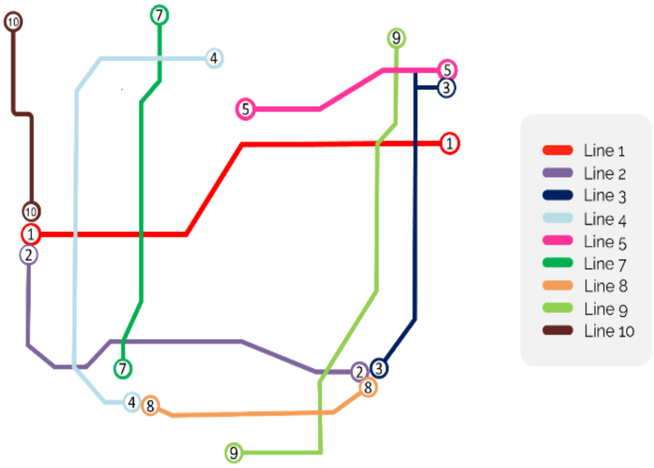

Fig. 5. Diagram of Tehran BRT lines.

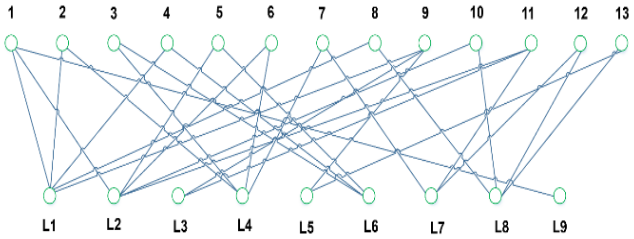

Fig. 6. The network of bus lines and bus stops.

3.1. Problem coverage

The first thing we focus on is finding the least number of charging stations, taking into account the needs of all bus lines, called the Charge Station Cover (CSC) problem. Let $C \subseteq S$ denote the set of charge stations. Then the CSC problem is:

$$Min|C| \qquad C \in S$$
$$s.t: \qquad \begin{cases} L_s = L \\ s \epsilon C \end{cases}$$

In the example of Figure 4, the CSC problem is equivalent to selecting the lowest number of high-level nodes to cover all low-level nodes. It can be easily found that the CSC problem is equal to the minimum set cover problem and hence is a nondeterministic polynomial-time problem that is hard to solve.

3.2. Energy loss

The next step is to find a way to reduce energy losses in transferring energy from renewable energy sources to stations. It is necessary to calculate the shortest energy transfer path from renewable energy sources to the stations to do this. For a renewable energy source $d \in D$ and a charge station $s \in C$, let P (d, c) denote the energy transfer paths from d to c in the bipartite graph G, where all the intermediate bus stops are charge stations. For convenience, let P (d, c) = $\emptyset$ if no such path exists. Then each path in P (d, c) represents a path to transfer energy from the renewable energy source (d) to the charge station (c). Specifically, suppose one path is (d, $l[1]$, $c[1]$, $l[2]$, $c[2]$ . . . , $c[k]$, c). Then it represents that energy from renewable energy source d can be transferred through charge stations $c[1]$, $c[2]$, . . . , $c[k]$, and eventually to charge station c (specifically, buses running on bus line $l[1]$ are charged by d and discharge at $c[1]$, where the energy is picked up by buses running on $l[2]$, which in turn discharge at $c[2]$, and so on). The energy transfer path of a charge station c is defined to be the shortest path from any of the renewable energy sources to c, which shows a path to transfer energy from a renewable energy source to c with the minimum percentage of energy loss.

In the next step, energy loss will be described. For simplicity, only the energy dissipation due to EV discharge is considered here. Let β denote the efficiency of one-time energy charge and discharge for an EV. In the example in Figure 3, $\beta = 0.95 \times 0.95 = 0.90$. The formulation of energy loss has been provided for six lines and nine bus stations. The charge and discharge efficiency for a bus at a time is β, and k_e is the number of bus lines between the renewable energy source and the charge station (c).

The percentile of loss for a bus for one charge and discharge is equal to β-$1k_c$.

For instance, for $A2$, the path is ($A1$, $l1$, $A2$). Therefore, there is just a bus line ($l1$) between the renewable energy source $A1$ and the charge station $A2$ and the amount of loss will be equal to β-1 ($k_c=1$). The mathematical model of the optimization is as follows:
Decision variables: x_{ij} is the link of the graph. It is essential to mention whether a bus stop (charge station) exists or not. As a result, the amount of x_{ij} is between 0 and 1. ($x \in z$, $0 \le x_{ij} \le 1$)
Objective function: It is related to the minimizing of energy loss in the whole system and is shown by the following equation:

Objective Function: $X_{A1} \times l_1 \times 0 + X_{A2} \times l_2 \times 0 + X_{A4} \times l_4 \times 0 + X_{A2} \times l_1 \times (1-\beta) + X_{A2} \times l_2 \times (1-\beta) + X_{A2} \times l_5 \times \left(1-\beta^2\right) + X_{A3} \times l_1 \times (1-\beta) + X_{A3} \times l_6 \times (1-\beta) + X_{B1} \times l_2 \times (1-\beta) + X_{B1} \times l_4 \times (1-\beta) + X_{B2} \times l_2 \times (1-\beta) + X_{A1} \times l_1 \times 0 + X_{B2} \times l_5 \times \left(1-\beta^2\right) + X_{B3} \times l_2 \times (1-\beta) + X_{B3} \times l_6 \times (1-\beta) + X_{C1} \times l_3 \times (1-\beta) + X_{C1} \times l_4 \times (1-\beta) + X_{C2} \times l_3 \times (1-\beta) + X_{C2} \times l_5 \times \left(1-\beta^2\right) + X_{C3} \times l_3 \times 0 + X_{C3} \times l_6 \times 0$

Constraints:

$$\begin{cases} 1)\ X_{A1} \times l_1 + X_{A2} \times l_1 + X_{A3} \times l_3 = 1 \\ 2)\ X_{A1} \times l_2 + X_{A2} \times l_2 + X_{B1} \times l_2 + X_{B3} \times l_2 = 1 \\ 3)\ X_{C1} \times l_3 + X_{C2} \times l_3 + X_{C3} \times l_3 = 1 \\ 4)\ X_{A1} \times l_4 + X_{B1} \times l_4 + X_{C1} \times l_4 = 1 \\ 5)\ X_{A2} \times l_5 + X_{B2} \times l_5 + X_{C2} \times l_5 = 1 \\ 6)\ X_{A3} \times l_6 + X_{B3} \times l_6 + X_{C3} \times l_6 = 1 \\ 7)\ 0 \le X_{ij} \le 1 \end{cases}$$

4. PROBLEM SOLUTION

In Section 2, it is proved that the optimization problem is of type NP-Hard. This section presents an innovative solution to the CSC problem. In this algorithm, a set of charging stations is provided to cover all bus lines, and its purpose is to use the least number of charging stations and minimize energy losses.

The concept of the mentioned algorithm is as follows: Initially, let a set of charge stations, C, be an empty set. At each step, we construct a bipartite graph G = (S', L', E') where L' represents the yet to be covered bus lines and S' the bus stops associated with these lines that have not been chosen to be transfer stations (initially, $L'= L$ and $S'= S$). Let T be the set of potential charge stations. We will first add all the renewable energy sources to T to reduce energy loss. Among the nodes in T, the node with the most significant degree (the degree refers to the degree in G') is selected as the charge station and removes all the bus lines covered by this charge station. Then this step is repeated until all the bus lines are covered, or T is empty. If T is empty, the bus stops that are one hop away from the renewable energy sources to T are added and repeated. If T becomes empty and some bus lines remain covered, the bus stops that are one hop away from the renewable energy sources to T are added. The above procedure continues until all the bus lines are covered. Firstly, all renewable energy sources are added to T to reduce energy loss. Among the nodes in T, the node with the largest degree (the degree refers to the degree in G') is selected as a charge station and removes all the bus lines covered by this charge station from the graph. Then, this step is repeated until all the bus lines are covered, or *T* is empty. If *T* is blank, then the bus stops that are one hop away from the renewable energy sources to *T* are added and repeat the above process. If *T* becomes empty and some bus lines remain covered, the bus stops that are one hop away from the renewable energy sources to *T* are added. The above procedure continues until all bus lines are covered.

The proposed algorithm using the TBRT in Tehran is illustrated in Figure 7. Firstly, the renewable energy sources, 1 and 13, added to the *T*. The degree of the 1 is three, and the degree of the 13 is two. In the first select one as the charge station. The bus lines that node one covers are *L1*, *L2*, and *L9*. We remove one from set *T* and remove *L1*, *L2*, and *L9* from *L/*. Then, we select 13 as the charge station and remove the bus lines that it covers (i.e., *L5* and *L8*) from *L/*. Afterwards, since *T* is empty and four bus lines remain (i.e., *L3*, *L4*, *L6*, and *L7*) to be covered. We add bus stops that are one hop away from the renewable energy sources to *T*. Namely, and we add 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 to *T*. Now the degree of 9 is three, and the degree of other nodes is two. We select two as a charge station, which covers *L4*. Then, node nine is chosen to cover *L3*. After that, we choose seven to cover *L7*. Next, by selecting node three, all the bus lines are covered, and the algorithm terminates.

5. SIMULATION AND RESULTS

The charge station algorithm performance using empirical data is assessed in this section. It should be mentioned that our analysis is based on the BRT bus map in Tehran. There are nine bus lines and 200 bus stops in Tehran. The bus stop that serves at least two bus lines is selected; in other words, the bus stop with the highest number of nodes, then repeated and isolated bus stops are removed. After, the bus lines that are not covered are four.

The number of renewable energy sources is assumed to be varied from 1 to 9. 100 settings are generated for each set by randomly placing renewable energy sources using independent random seeds and obtaining 95% confidence intervals. Figure 8 shows the proposed algorithm programmed in MATLAB, compared to the performance of an algorithm that randomly selects charging stations.

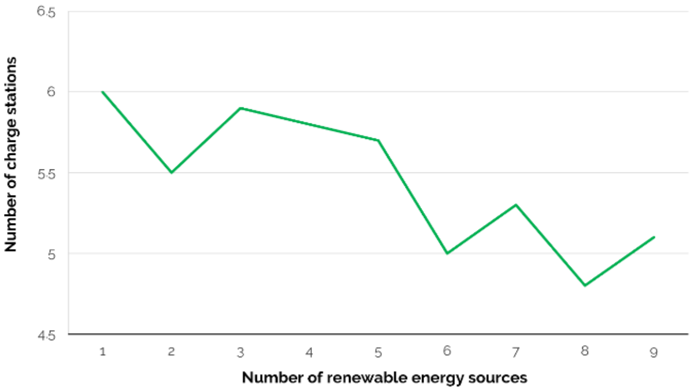

Fig. 8. The algorithm obtains the number of charge stations.

According to Figure 8, the proposed algorithm's average number of charge stations is 5.33. Notably lower than the number of charge stations obtained by the random algorithm. Thus, the number of solar energy sources affects energy loss. In conclusion, the number of charge stations to cover all the bus lines decreases; consequently, the energy loss will reduce. In other words, the total number of charge stations to cover the whole city is six. In general, the algorithm proposed in this paper is much more efficient than the basic algorithm because it requires fewer charging stations and much lower energy losses.

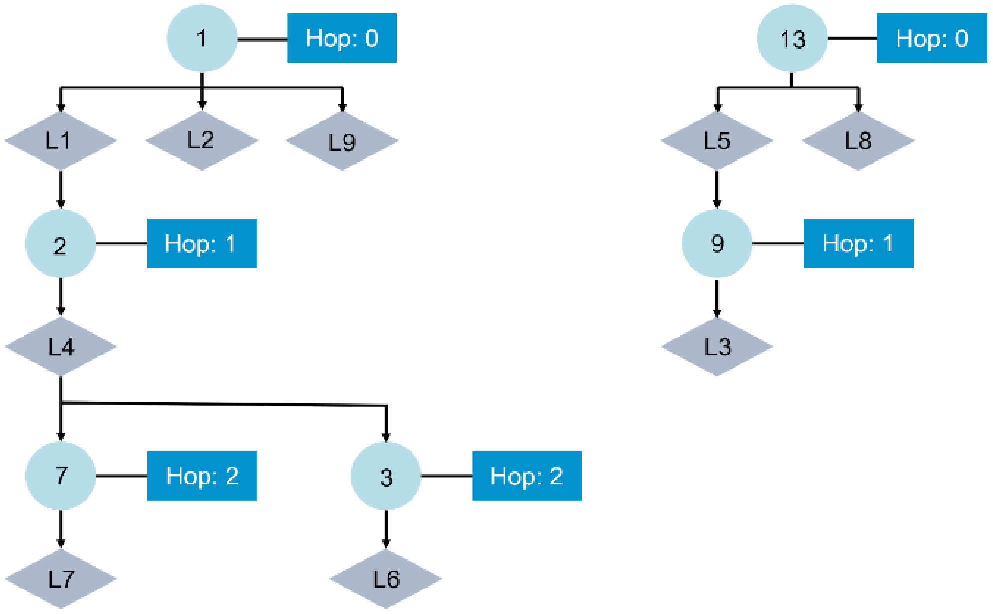

Fig. 7. Description of the proposed algorithm.

3. CONCLUSION

Increasing energy consumption and greenhouse gas emissions have caused many problems in today's world. The second-largest CO_2 emitter is the transportation sector. Hence, the tendency to research and develop electric vehicles has increased. To this end, a new approach to finding the least number of solar charging stations with the minor energy loss to cover all bus lines in Tehran for EVs is presented in this paper. The proposed approach aimed to minimize the number of charge stations while protecting all bus lines and minimizing the energy loss of transmission in an Electric Vehicle Mobile Energy Network.

The results obtained from the developed algorithm indicated that the number of charge stations to cover all the bus lines in Tehran is 6 to minimize the energy loss.

References

[1] M. Mohammadi, Y. Noorollahi, B. Mohammadi-ivatloo, and H. Yousefi, “Energy hub: From a model to a concept – A review,” *Renewable and Sustainable Energy Reviews*, vol. 80, pp. 1512–1527, December 2017.

[2] B. Mohan and M. V. Ramesh. "Optimal DG placement under standard market design using GA," *2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management*, 2012, pp. 148–153.

[3] Y. Noorollahi, A. Aligholian, A. Golshanfard, “Stochastic energy modeling with consideration of electrical vehicles and renewable energy resources-A review” *Energy Management and Technology (JEMT)*, Vol. 4, pp. 13-26, 2017, pp. 1598-1604.

[4] Y. Noorollahi, A. Golshanfard, A. Aligholian, B. Mohammadi-ivatloo, S. Nielsen, and A. Hajinezhad, “Sustainable Energy System Planning for an Industrial Zone by Integrating Electric Vehicles as Energy Storage,” *J. Energy Storage*, vol. 30, p. 101553, 2020.

[5] S. Y. Ge, L. Feng, H, Liu, L. Wang, " The Planning of Electric Vehicle Charging Stations in the Urban Area," *2012 Proceedings of the 2nd International Conference on Electronic & Mechanical Engineering and Information Technology*, 2012

[6] J. Liu, “Electric vehicle charging infrastructure assignment and power grid impacts assessment in Beijing,” *Energy Policy*, vol. 51, pp. 544–557, Dec. 2012.

[7] Y. Huang and K. M. Kockelman, “Electric vehicle charging station locations: Elastic demand, station congestion, and network equilibrium,” *Transp. Res. Part D Transp. Environ.*, vol. 78, p. 102179, Jan. 2020.

[8] R. Irle, "Deloitte analysis: Automotive planning solutions, IHS Markit, The electric vehicle world sales database," 2021, Online, [Available]: https://www.ev-volumes.com/, {Accessed 11 December 2021]

[9] P. A. Østergaard, N. Duic, Y. Noorollahi, H. Mikulcic, and S. Kalogirou, “Sustainable development using renewable energy technology,” *Renew. Energy*, vol. 146, pp. 2430–2437, Feb. 2020.

[10] P. A. Østergaard, N. Duic, Y. Noorollahi, and S. A. Kalogirou, “Recent advances in renewable energy technology for the energy transition,” *Renew. Energy*, 175(1), pp. 877–884, 2021.

[11] S. Ge, L. Feng, and H. Liu, "The planning of electric vehicle charging station based on Grid partition method," *2011 International Conference on Electrical and Control Engineering*, 2011, pp. 2726–2730.

[12] H. Wang, Q. Huang, C. Zhang, and A. Xia, "A novel approach for the layout of electric vehicle charging station," *The 2010 International Conference on Apperceiving Computing and Intelligence Analysis Proceeding*, Chengdu, 2010, pp. 64–70.

[13] G. Wang, Z. Xu, F. Wen, and K. P. Wong, “Traffic-constrained multiobjective planning of electric-vehicle charging stations,” *IEEE Trans. Power Deliv.*, 28(4), pp. 2363–2372, 2013.

[14] Z. A. Padhya, S. S. Bohra, “Power management analysis for V2G (Vehicle-to-Grid) applications in a microgrid with photovoltaic source," *Turkish Journal of Electromechanics and Energy*, Vol. 5, pp. 61-73, 2020.

[15] M. Aziz, T. Oda, T. Mitani, Y. Watanabe, and T. Kashiwagi, “Utilization of electric vehicles and their used batteries for peak-load shifting,” *Energies*, 8(5), pp. 3720–3738, 2015.

[16] M. Mohammadi, Y. Noorollahi, B. Mohammadi-ivatloo, M. Hosseinzadeh, H. Yousefi, and S. T. Khorasani, “Optimal management of energy hubs and smart energy hubs – A review,” *Renew. Sustain. Energy Rev.*, vol. 89, pp. 33–50, Jun. 2018.

[17] P. Parvazi, S. Mohammadi, F. Nouruzi Fard, "Intelligent BRT in Iran," *Journal of Automation, Mobile Robotics & Intelligent Systems*, Vol. 6, pp. 49-52, 2012.

[18] P. A. Østergaard, N. Duic, Y. Noorollahi, H. Mikulcic, and S. Kalogirou, “Sustainable development using renewable energy technology,” *Renewable Energy*, vol. 146, pp. 2430–2437, Feb. 2020.

[19] Y. Noorollahi, A. Aligholian, and A. Golshanfard, "Stochastic energy modelling with consideration of electric vehicles and renewable energy resources-A review," *J. Energy Manag. Technol.*, 4(1), pp. 13–26, 2020.

Biographies

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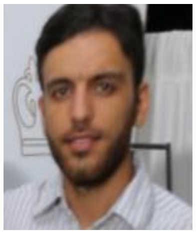

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