Received: 20 November 2020 | Revised: 23 January 2021 | Accepted: 25 January 2021

Energy Conversion and Economics

DOI: 10.1049/enc2.12030

ORIGINAL RESEARCH PAPER

Planning and operation of EV charging stations by chicken swarm optimization driven heuristics

Sulabh Sachan[1] | **Sanchari Deb**[2] | **Sri Niwas Singh**[3] | **Pravin Prakash Singh**[4] | **Desh Deepak Sharma**[1]

[1] Electrical Engineering Department, MJP Rohilkhand University, Bareilly, India

[2] ERCIM, VTT Research Centre, Finland

[3] Electrical Engineering Department, IIT Kanpur, India

[4] EED, Tallinn University of Technology (TalTech), Estonia

Correspondence
Sulabh Sachan, Electrical Engineering Department, FET, MJP Rohilkhand University, Bareilly 243006, Uttar Pradesh, India.
Email: sulabh.iitr11@gmail.com

Abstract

Successful deployment of electric vehicles demands for establishment of simple reachable charging stations (CSs). Scheduling and action of CSs is a composite problem and that should not affect the smooth operation of the power grid. The present paper attempts to solve the planning and operation of CSs by a novel chicken swarm optimization-based heuristics. The placement of CS is modelled in a multi-objective framework as cost-effective parameters secures the operation of the power grid. Further, the operation of CSs is examined for three scenarios such as uncoordinated charging, coordinated charging, as well as bidirectional vehicle to grid. The proposed approach is tested on IEEE 33-bus, and on a distribution network of Guwahati, India.

1 | INTRODUCTION

In recent years, researchers and environmentalists are preoccupied with fossil fuel depletion, degradation of air quality, and energy crisis. Electric vehicles (EVs) are a clean mode of transportation and are viable alternatives to deal with the aforementioned problems. However, successful deployment of EVs calls for enlargement of charging station (CS). The planning and operation of CS are critical aspects. Improper planning and operation of CS may be detrimental to the power grid resulting in voltage instability, degraded reliability, increased power losses, and harmonic distortion [1–5].

Globally, the planning and operation of charging stations have attracted much attention from researchers to deal with various problems [6, 7]. Despite their advantages, EVs are not becoming widespread at the desired level since there are no common charging stations, and the reason for this fear is that the private traditional vehicles are on the road [8, 9]. To alleviate this problem, it is assumed that car parks can be used as charging places. Normally, the EVs are not used for a long time as they are often left in parking lots. For this reason, these long times can be measured as a prospect to recharge EVs in smart car parks [10]. The focus of this technology is to prevent damage to the grid by multiple EVs and HEVs being charged simultaneously. The aim of this paper is to ensure the satisfaction of EV and HEV users while eliminating the negative effects [11]. There is a need for a control mechanism to control the power supplied to parked vehicles which is fed from the grid as well as by other forms of electricity production [12–14].

The operation of charging stations signifies the charging strategy that will be adopted in the charging stations such as uncoordinated charging, coordinated smart charging etc. In [15, 16], authors have analysed the advantages of smart charging schemes and found that coordinated charging is beneficial. In [17], authors provided a DR strategy of EV CS by using dynamic programming. In [18], the authors presented a two-stage linear programming-based approach for the operation of charging stations. In [19], authors have proposed an adaptive strategy to manage EV charging load. Further, in [20], the authors presented a load management strategy in EV charging stations in the presence of renewable energy sources.

Researchers have made significant attempts to improve energy efficiency of CSs. In a category, researchers have considered different technologies such as renewable energy sources, ESS and DR programs in studying the operation of energy systems in the presence of EVs. The authors have proposed a

TABLE 1 Summary of relevant research works

Ref.	Aspect	Contributions
[8]	Placement	Scheme for location of CS considering VSI
[9]	Placement	Modelling of CS placement problem as maximisation of profit
[10]	Placement	Modelling of fast CS placement problem as cost, EV flow, and energy losses as the objective functions
[11]	Placement	A robust planning approach for charging stations considering net investment
[12]	Placement	A parking lot allocation scheme for EVs considering cost, power loss, and expected energy not served as objective functions
[13]	Placement	Modelling of the CS citation problem considering net investment and drivers convenience
[14]	Placement	A placement scheme for portable CS considering cost and waiting time
[17]	Operation	A DR strategy of EV CS by using dynamic programming
[18]	Operation	A two-stage linear programming-based approach for operation of charging stations
[19]	Operation	An adaptive strategy to manage EV charging load
[20]	Operation	A load management strategy in EV charging stations in presence of renewable energy sources

multi-objective model for a PV-based, intelligent electric-vehicle CS in connection with a demand–response program in [21] to satisfy both the environmental and economic issues of CSs. A multi-agent approach for coordination of EVs, combined with a renewable-based micro grid, is proposed in [22] for providing vehicle-to-home service. The multi-agent coordination is performed by exchanging information among various control elements. The authors, in [23], have presented a self-supporting model for smart grids to minimise costs during outages by using EV batteries to fulfil the demands of the grid. Accordingly, a multi-agent scheme consisting of a micro grid, home, and EV is designed for managing outages in the smart grid. Also, the penetration of fuel cell technology as a hydrogen-storage system and electrolyze, along with time-of-use DR, have been investigated [24] in conjunction with optimal scheduling of CSs.

A summary of research works on planning and operation of charging stations is presented in Table 1. From Table 1, it is observed that most of the research works have dealt with placement and operation of charging stations separately. This work considers planning and operation of charging stations under a single framework. Thus, the major contributions of this work are:

- A robust framework has been considered regarding placement and operation of charging stations;
- Multi-objective modelling of charging infrastructure planning has been considered using economic factors as well as the secure operation of power grid;
- A novel chicken swarm optimization (CSO)-based heuristics has been used to solve the planning and operation of charging station problem; and
- Three scenarios such as uncoordinated charging, coordinated charging, as well as bidirectional V2G are examined for the operation of charging stations.

2 | PROBLEM FORMULATION

The charging station scheduling problem is mainly concerned with two activities such as location and operation of CS. The

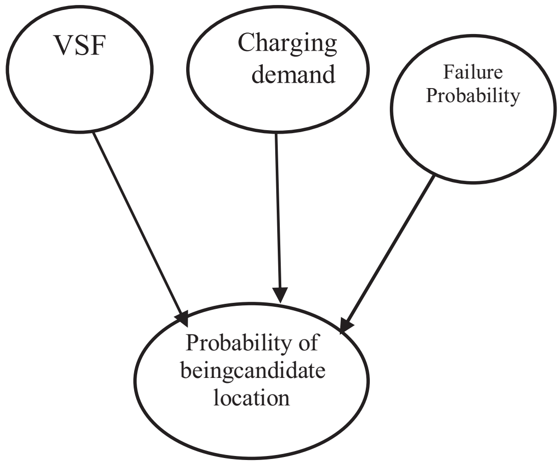


FIGURE 1 BN used to find the cites for the citation of CSs

mathematical formulations of these two activities are elaborated in this section.

2.1 | Placement of charging stations

The CS placement is dealing with the locations and number of CSs to be placed at the respective locations. The placement of CS is divided into two stages. In Stage I, the placements of CSs are screened by using a probabilistic approach based on Bayesian network (BN). In Stage II, optimization is performed to compute the exact location and number of CSs to be placed.

2.1.1 | Stage I

In Stage I, the candidate locations of the power distribution network where charging stations can be placed is screened by BN. The competence and potential of the BN in handling uncertainty and interaction among different events is effectively utilised in [25–27]. The BN used for computing the candidate

TABLE 2 Summary of the nodes of the proposed BN

Node name	Type	States
VSF	Parent	{High (H), Medium (M), Low (L)}
Charging demand	Parent	{Peak (P), Off Peak (OP)}
Failure probability	Parent	{High (H), Low (L)}
Probability of being candidate location	Child	{High (H), Low (L)}

ALGORITHM 1 Pseudo-code for computation of the VSF [25]

Input the bus data and line data;

Run distribution load flow for base case by forward backward method;

For i = 1: total number of bus;

$VSF_{base}(i) = \frac{dV(i)}{dP(i)}$;

End for

$k = 1$;

While k < Realistic loading margin

Increase load in steps;

Run distribution load flow by forward backward sweep algorithm;

If load flow converges

$k = k + 1$;

else

Compute VSF for critical loading;

End if else

End while

locations is as shown in Figure 1. A summary of parent nodes and child nodes of the BN is presented in Table 2. VSF, charging demand, and failure probability are parent nodes. The probability of being a candidate location for placement of CS is dependent on VSF, charging demand, and failure probability. Hence, the probability of being a candidate location is the child node of VSF, charging demand, and failure probability. VSF measures the change in the bus voltage upon increasing the active power or loading and is computed by Algorithm 1. Charging demand of a particular point is computed by an improved random forest algorithm as depicted in Algorithm 2. The failure probability of the buses of the power distribution network can be found in the logbook of the substations [28–30]. The probability of being a candidate location for placement of CS is:

$$P(candidate = yes) = P(candidate|VSF,\ charging\ demand,\ Failure\ Probability) \times P(VSF) \times P(charging\ demand) \times P(Failure\ Probability). \quad (1)$$

2.1.2 | Stage II

In Stage II, optimization is performed to find the optimal cite, number and type of CSs to be placed in the distribution network. The details of the objective function are given in Table 3. It is depicted as:

ALGORITHM 2 Pseudo-code for computing for charging demand [26, 27]

Input historical feature data and corresponding charge of EVs

Step the input charging amount data

Extract n training samples by Bootstrap

Repeatedly extract k training sets

Build decision tree based on the Cart algorithm

If training set traversal is completed

Random forest forecast is completed and input the corresponding feature to forecast

Calculate the average output of the forest

Output amount of charge during the period

Else, build decision tree based on the Cart algorithm

end

end

$$F = \min(\cos t) + \min(VRP\ index) + \max(Accessibility\ index) + \min(waiting\ time). \quad (2)$$

Subject to:

$$F_{\min} < F_p \le F_{\max} \ \text{and} \ f_{\min} < f_p \le f_{\max}, \quad (3)$$

$$S_{\min} < S_p \le S_{\max} \ \text{and} \ s_{\min} < s_p \le s_{\max}, \quad (4)$$

$$P_{gi} - P_{di} - V_i \sum_{j=1}^{N_D} V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) = 0, \quad (5)$$

$$Q_{gi} - Q_{di} - V_i \sum_{j=1}^{N_D} V_j Y_{ij} \sin\left(\delta_i - \delta_j - \theta_{ij}\right) = 0. \quad (6)$$

System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI) are the typical power distribution network reliability indices [28].

2.2 | Charging strategy

Three charging strategies via uncoordinated charging, coordinated charging, as well as bidirectional vehicle to grid (V2G) are examined in this work. An overview of the aforementioned charging strategies is provided in Table 4.

3 | METHODOLOGY

The placement and operation problem reported in Section 2 is solved by a novel CSO-based heuristics approach elaborated in [31]. CSO is a bio-stimulated procedure that mimics the

TABLE 3 Objective functions

Objective function	Significance	Formulation
Cost	This takes into account the installation ($Cost_{installation}$), operating ($Cost_{operation}$) and maintenance ($Cost_{maintennace}$) cost of charging stations	$Cost = Cost_{installation} + Cost_{operation} + Cost_{maintainence}$ $Cost_{installation} = \left\{ \left(\sum_{i=1}^{m} F_i \times f_i \right) \times C_{fast} \right\} + \left\{ \left(\sum_{i=1}^{m} S_i \times s_i \right) \times C_{slow} \right\}$ $Cost_{operation} = \left\{ \left(\sum_{i=1}^{m} F_i \times f_i \right) \times CP_{fast} \right\} + \left\{ \left(\sum_{i=1}^{m} S_i \times s_i \right) \times CP_{slow} \right\} \times P_{elec}$ $Cost_{maintenance} = \left\{ \left(\sum_{i=1}^{m} F_i \times f_i \right) \times CM_{fast} \right\} + \left\{ \left(\sum_{i=1}^{m} S_i \times s_i \right) \times CM_{slow} \right\}$
Voltage stability index	Voltage stability index (VSI) is regarded as a tool for evaluating the proximity of a given operating point to voltage instability	$V = \frac{VSI_l}{VSI_{base}}$ $VSI_{base} = \sum_{i=1}^{N_D} 2V_i^2 V_{i+1}^2 - 2V_{i+1}^2 (P_{i+1} r_i + Q_{i+1} x_i) - \lvert z \rvert^2 \left(P_{i+1}^2 + Q_{i+1}^2 \right)$ $P'_p = P_p + \{(F_p \times f_p) \times CP_{fast}\} + \{(S_p \times s_p) \times CP_{slow}\}$ $VSI_l = \sum_{i=1}^{N_D} 2V'^2_i V'^2_{i+1} - 2V'^2_{i+1} (P'_{i+1} r_i + Q'_{i+1} x_i) - \lvert z \rvert^2 \left(P'^2_{i+1} + Q'^2_{i+1} \right)$
Reliability	The probability of a system under which it operates satisfactorily is termed as reliability	$R = w_1 \frac{SAIFI_l}{SAIFI_{base}} + w_2 \frac{SAIDI_l}{SAIDI_{base}} + w_3 \frac{CAIDI_l}{CAIDI_{base}}$
Power loss	Power loss refers to the I^2R losses of the system	$P = \frac{P_{loss}^{l}}{P_{loss}^{base}}$

TABLE 4 Overview of charging strategies

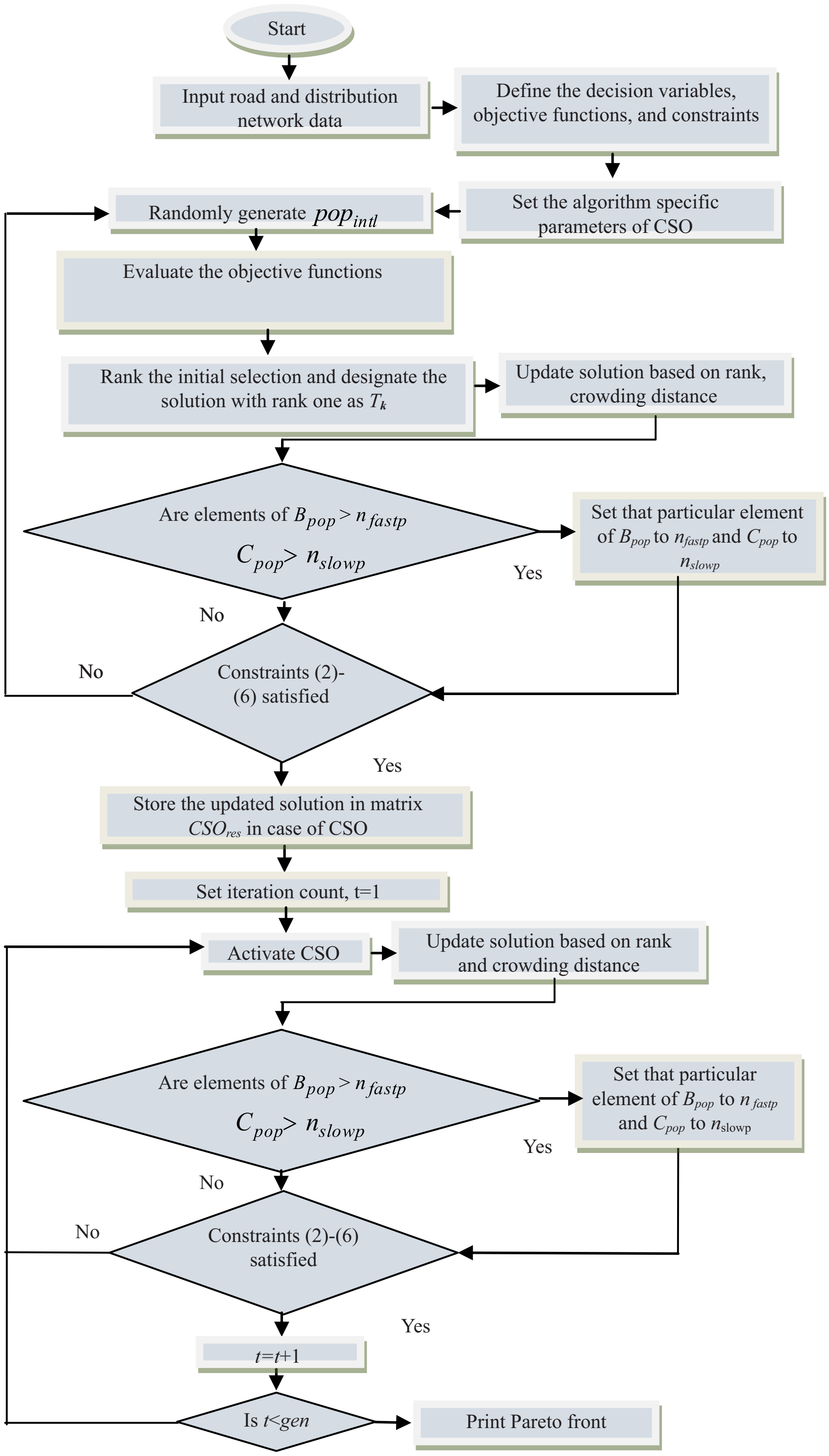
		Mapping					
					Complexity		
Strategy	Description	ToU tariff	Bi-directional flow	Control system requirement	Low	Medium	High
Uncoordinated charging	Under uncoordinated scheme, the batteries of the EVs takes power immediately when arrived at stations and plugged in (even during peak hours)				•		
Coordinated charging	In coordinated charging, the EV charging can be shifted to off peak time. EVs participate in this scheme by adapting the rate of power at which the battery is charged	•		•		•	
V2G	In V2G, EVs can provide grid services by sending power back to the grid, by bidirectional power flow	•	•	•			•

food searching phenomenon of chicken in a swarm. The swarm is divided into dominant roosters that lead the food searching process, hens following the roosters, and chicks following the mother hen. The algorithm also mimics the competition between hens in the quest for food. The main advantage of CSO is that it utilises the intelligence of chicken swarm in an effective manner and maintains a good balance between randomness and determinacy while finding the optimal solution. A multi-objective modelling considering economic and security issues jointly has made the problem more complex. However, the proposed model is more realistic and considers planning and operation of charging stations simultaneously. The CSO-based heuristics proposed in the work has the capacity to take into account the computational burden of the proposed model by sustaining a stability among exploration and manipulation. The detailed solution procedure is shown in Figure 2.

4 | NUMERICAL ANALYSIS

The proposed formulation is validated on IEEE 33-bus and distribution network of Guwahati as depicted in Figures 3 and 4, respectively. The bus, line, outage data of the two test systems shown in Figures 3 and 4 can be found in [4, 32, 33]. As elaborated in Section 2, the first step of the placement problem

FIGURE 2 Flowchart elaborating solution methodology



involves screening of candidate locations for charging station allocation by BN with voltage sensitivity factor (VSF), charging demand, and failure probability as the parent nodes. The VSF of the two test systems are evaluated by Algorithm 1 and depicted in Figures 5 and 6. Also, it is observed that bus 14 and bus 19 are the weakest buses of test system 1 and test system 2, respectively. The charging demands of the test systems are computed by Algorithm 2 and depicted in Figures 7 and 8. The failure probability of test system 1 can be found in [4] and the failure probability of test system 2 is taken from the logbook of substations.

The probabilities of being candidate locations for the placement of charging stations computed by BN are depicted in Figures 9 and 10. It can be observed that locating the

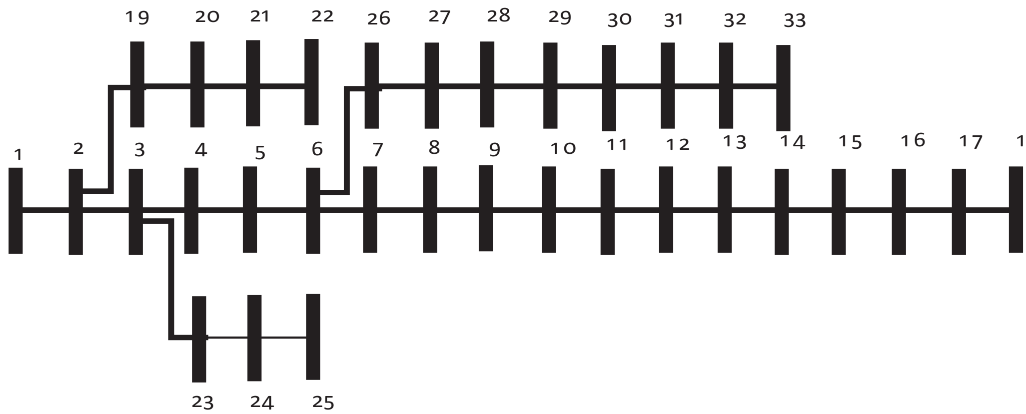


FIGURE 3 Test system 1 [4]

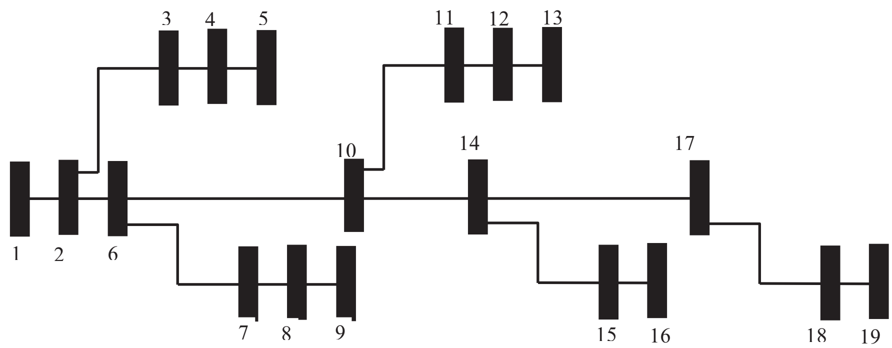


FIGURE 4 Test system 2 [32, 34]

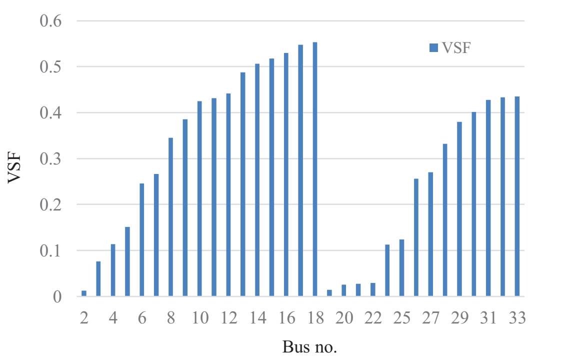


FIGURE 5 VSF of all the buses for IEEE 33-bus distribution network

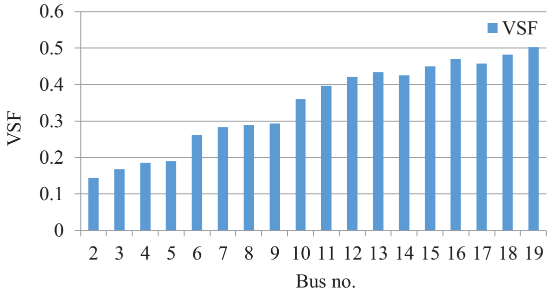


FIGURE 6 VSF of all the buses for distribution network of Guwahati

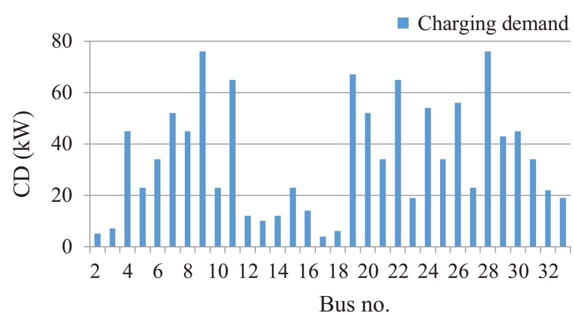


FIGURE 7 Charging demand for IEEE 33-bus distribution network

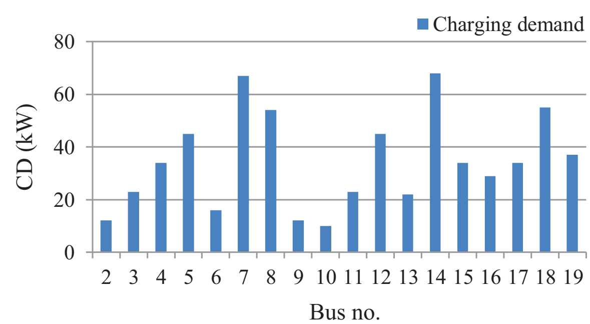


FIGURE 8 Charging demand for distribution network of Guwahati

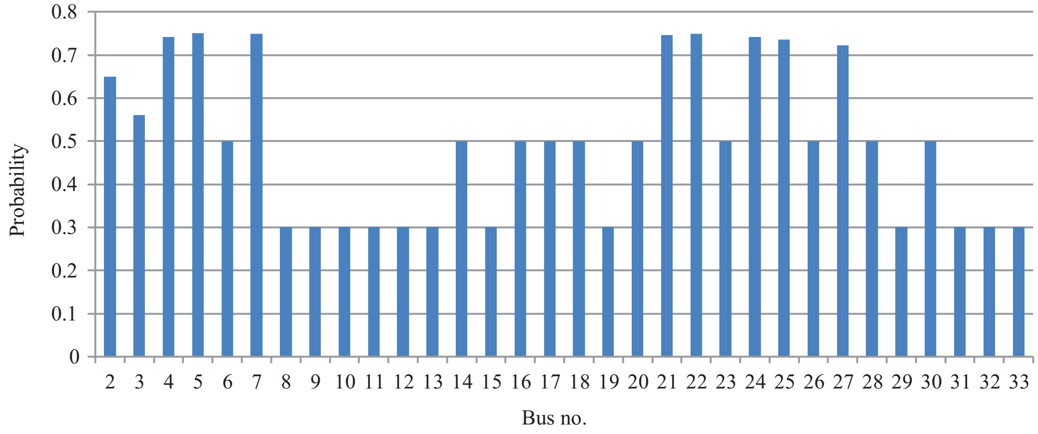


FIGURE 9 Probability of being charging station for IEEE 33-bus distribution network

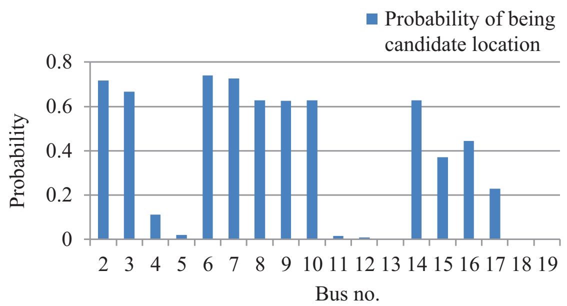


FIGURE 10 Probability of being charging station for distribution network of Guwahati

TABLE 5 Candidate locations

Test system	Location
1	{2, 4, 5, 7, 21, 22, 24, 25, 27}
2	{2, 3, 6, 7, 8, 9, 10, 14}

charging stations at various buses is better than concentrating on few buses which will create voltage deviation, reliability problem and increased losses. If any node has no space for charging the vehicles, the neighbouring bus can be selected. Accordingly, another favourable position for appropriating the charging station is making the charging station available to a bigger number of EVs handling in various routes. This will decrease the congestion of the particular routes in which charging stations are concentrated.

The set of candidate locations having probability more than 0.6 is shown in Table 5. The optimization problem reported in Section 2 is solved by CSO. The input parameters of the optimization problem are same as in [31]. The general as well as algorithm-specific parameters of CSO are also taken from [31]. The optimization yielded six non-dominant solutions (NDSs) as reported in Tables 6 and 7. The selection of the best plan among the six alternatives depends upon user requirements. Further, three charging scenarios namely uncoordinated charging, coordinated charging and V2G are compared based on

TABLE 6 Optimal allocation of CS for test system I

NDS	p	F_p	S_p	f_p	s_p	NDS	p	F_p	S_p	f_p	s_p
1	4	1	1	8	6	4	21	1	1	3	9
	24	1	1	9	6		5	1	2	5	9
	2	1	1	4	13		2	1	1	6	7
2	2	1	1	8	13	5	2	1	1	10	7
	7	1	1	4	10		7	1	1	10	7
	25	1	1	6	10		24	1	1	6	16
3	5	1	1	4	8	6	7	1	1	6	9
	2	1	2	3	6		4	1	3	5	14
	7	1	1	4	5		22	1	1	6	11

TABLE 7 Optimal allocation of CS for test system II

NDS	p	F_p	S_p	f_p	s_p	NDS	p	F_p	S_p	f_p	s_p
1	2	1	1	3	6	4	2	2	2	5	10
	3	1	2	3	6		7	1	2	5	10
	8	1	1	3	6		8	2	2	5	10
2	2	2	2	5	10	5	2	1	2	4	7
	9	2	2	5	10		6	1	2	5	9
	10	2	2	5	10		7	1	2	3	16
3	2	2	2	4	8	6	2	1	2	5	10
	8	1	2	4	8		3	1	1	5	7
	9	2	2	4	8		10	1	2	3	10

VRP index proposed in [4]. A novel index named VRP index taking into account the voltage stability, reliability and power loss is also formulated. The novelty of VRP index lies in the fact that it has the capability of considering voltage stability, power loss, and reliability together under a common frame. The VRP indices for two test systems in case of the three aforementioned scenarios are shown in Figures 11 and 12, respectively. The advantages of coordinated charging and V2G

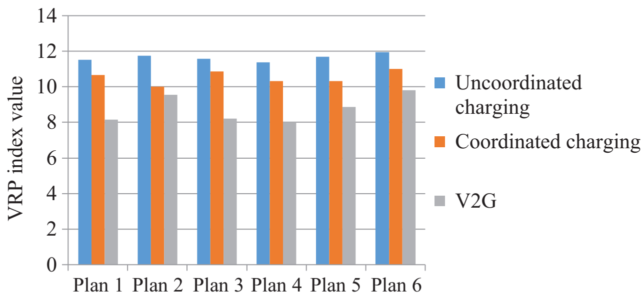


FIGURE 11 VRP index value for three scenarios in case of IEEE 33-bus distribution network

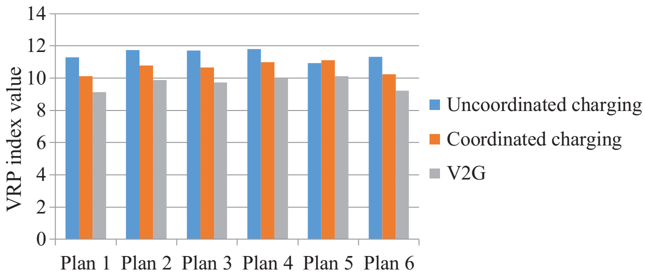


FIGURE 12 VRP index value for three scenarios in case of distribution network of Guwahati

over uncoordinated charging are prominent from the simulation results.

5 | CONCLUSION

In recent years, both limited fossil fuels and environmental factors have forced automotive manufacturers to produce more efficient and greener vehicles. In this context, the production and use of hybrid and electric vehicles are increasing rapidly. With this rapid change in vehicle technology, user habits have raised important issues, such as the need to increase the numbers of charging stations, updating the electricity grid and increasing their capacities. It will, therefore, become inevitable that existing traditional car parks and fuel stations will have to be equipped with charging units and smart energy management algorithms will have to be developed to ensure their effective use. The formulations consider economic factors as well as secure operation of the power network. Further, the framework compares three charging strategies such as uncoordinated charging, coordinated charging and V2G. The solution methodology is based on a CSO driven heuristics. The simulation consequences indorse the efficacy of the anticipated framework and the advantages of coordinated charging and V2G over uncoordinated charging. The important issues such as quantitative analysis of charging strategies, operation of V2G enabled CSs, techno-economic analysis of smart charging as well as V2G will be addressed in future work.

NOMENCLATURE

Abbreviations

EV	Electric vehicle
CS	Charging station
DR	Demand response
BN	Bayesian network
CSO	Chicken Swarm Optimization
V2G	Vehicle to Grid
ESS	Energy storage system
VSF	Voltage Sensitivity Factor
VRP	Voltage stability, Reliability & Power loss (VRP) index

Decision variables

p	Cite for the placement of CS
F_p, S_P	fast/slow CS at location p
f_p, s_P	fast/slow servers at location p
P_{loss}^{base}	Base value of power loss
$F_{\max}, f_{\max}$	number of fast CS and sockets
$S_{\max}, s_{\max}$	number of slow CS and sockets
$F_{\min}, f_{\min}$	Min fast CS and charging points
$S_{\min}, s_{\min}$	Min slow CS and charging points

Constant parameters

C_{fast}	fast CS cost
C_{slow}	slow CS cost
CP_{fast}	fast CS capacity
CP_{slow}	slow CS capacity
CM_{fast}	Maintenance cost
P_{elec}	Per-unit cost of electricity
VSI_{base}	voltage stability index
$SAIFI_{base}$	(SAIFI)
$SAIDI_{base}$	(SAIDI)
$CAIDI_{base}$	(CAIDI)

Variables

P_{gi}	Active power at i^{th} bus
P_{di}	demand at i^{th} bus
Q_{gi}	Reactive power at i^{th} bus
V_j	Voltage of j^{th} bus
Y_{ij}	admittance matrix
θ_{ij}	Angle of Y_{ij}
δ_i	angle of i^{th} bus
δ_j	angle of j^{th} bus

ACKNOWLEDGEMENTS

The authors are thankful to TEQIP-III, govern by NPIU, MHRD India for CRS ID-1–5742567271.

ORCID

Sulabh Sachan https://orcid.org/0000-0003-0309-5001

REFERENCES

1. Dubey, A., Santoso, S.: Electric vehicle charging on residential distribution systems: Impacts and mitigations. IEEE Access 3, 1871–1893 (2015)

2. Deb, S., Kalita, K., Mahanta, P.: Review of impact of electric vehicle charging station on the power grid. In: 2017 International Conference on Technological Advancements in Power and Energy (TAP Energy), pp. 1-6 (2017). https://doi.org/10.1109/TAPENERGY.2017.8397215
3. Deb, S., Kalita, K., Mahanta, P.: Impact of electric vehicle charging stations on reliability of distribution network. In: 2017 International Conference on Technological Advancements in Power and Energy (TAP Energy), pp. 1-6 (2017). https://doi.org/10.1109/TAPENERGY.2017.8397272
4. Dharmakeerthi, N.M., Saha, T.K.: Impact of electric vehicle fast charging on power system voltage stability. Int. J. Electr. Power Energy Syst. 57, 241–249 (2014)
5. Esmaili, M., Goldoust, A.: Multi-objective optimal charging of plug-in electric vehicles in unbalanced distribution networks. Int. J. Electr. Power Energy Syst. 73, 644–652 (2015)
6. López, M.A., et al.: Demand-side management in smart grid operation considering electric vehicles load shifting and vehicle-to-grid support. Int. J. Electr. Power Energy Syst. 64, 689–698 (2015)
7. Shareef, H., Islam, M.M., Mohamed, A.: A review of the stage-of-the-art charging technologies, placement methodologies, and impacts of electric vehicles. Renew. Sust. Energ. Rev. 64, 403–420 (2016)
8. Sachan, S., Kishor, N.: Optimal location for centralized charging of electric vehicle in distribution network. In: 2016 18th Mediterranean Electrotechnical Conference (MELECON), pp. 1–6 (2016)
9. Janjic, A.: Two-step algorithm for the optimization of vehicle fleet in electricity distribution company. Int. J. Electr. Power Energy Syst. 65, 307–315 (2015)
10. Yao, W., et al.: A multi-objective collaborative planning strategy for integrated power distribution and electric vehicle charging systems. IEEE Trans. Power Syst. 29(4), 1811–1821 (2014)
11. Zhao, J., et al.: Robust distributed generation investment accommodating electric vehicle charging in a distribution network. IEEE Trans. Power Syst. 33(5), 4654–4666 (2018)
12. Rahmani-Andebili, M., et al.: Planning and operation of parking lots considering system, traffic, and drivers behavioral model. IEEE Trans. Syst. Man Cybern. Syst. 49(9), 1879–1892 (2018)
13. Zhang, Y., et al.: GIS-based multi-objective particle swarm optimization of charging stations for electric vehicles. Energy. 169, 844–853 (2019)
14. Parastvand, H., et al.: A graph automorphic approach for placement and sizing of charging stations in EV network considering traffic. IEEE Trans. Smart Grid 11, 4190–4200 (2020)
15. Sachan, S., Deb, S., Singh, S.N.: Different charging infrastructures along with smart charging strategies for electric vehicles. Sustain. Cities Soc. 60, 102238 (2020)
16. Sachan, S., Adnan, N.: Stochastic charging of electric vehicles in smart power distribution grids. Sustain. Cities Soc. 40, 91–100 (2018)
17. Wu, Y., et al.: Demand side energy management of EV charging stations by approximate dynamic programming. Energy Convers. Manag. 196, 878–890 (2019)
18. Faridpak, B., et al.: Two-step LP approach for optimal placement and operation of EV charging stations. In: 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe), Bucharest (2019)
19. Wang, B., et al.: Adaptive operation strategies for electric vehicle charging stations. In: 2019 IEEE Industry Applications Society Annual Meeting, Baltimore (2019)
20. Cheng, Y., et al.: Electric bus fast charging station resource planning considering load aggregation and renewable integration. IET Renew. Power Gener. 13(7), 1132–1141 (2019)
21. Jensen, F.V.: An Introduction to Bayesian Networks. UCL Press, London (1996)
22. Williams, B.: A bucket elimination approach for determining strong controllability of temporal plans with uncontrollable choices. In: Proceedings of the AAAI Conference on Artificial Intelligence, Cambridge (2012)
23. Deb, S., Ghosh, D., Mohanta, D.K.: Reliability analysis of PV cell, wind turbine and diesel generator by using Bayesian network. In: 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, India (2016)
24. Ghosh, D., Deb, S., Mohanta, D.K.: Reliability evaluation and enhancement of microgrid incorporating the effect of distributed generation. In: Handbook of Distributed Generation, pp. 685–730. Springer, Cham (2017)
25. Rupa, J.M., Ganesh, S.: Power flow analysis for radial distribution system using backward/forward sweep method. Int. J. of Electr. Comput. Electron. Commun. Eng. 8(10), 1540–1544 (2014)
26. Lu, Y., et al.: The application of improved random forest algorithm on the prediction of electric vehicle charging load. Energies 11(11), 3207 (2018)
27. Chen, J., et al.: A parallel random forest algorithm for big data in a spark cloud computing environment. IEEE Trans. Parallel Distrib. Syst. 28(4), 919–933 (2016)
28. Chowdhury, A., Koval, D.: Power Distribution System Reliability: Practical Methods and Applications. John Wiley & Sons, Hoboken, NJ (2011)
29. Nahman, J.M., Perić, D.M.: Radial distribution network planning under uncertainty by applying different reliability cost models. Int. J. Electr. Power Energy Syst. 117, 105655 (2020)
30. Sachan, S.: Integration of electric vehicles with optimum sized storage for grid connected photo-voltaic system. AIMS Energy 5(6), 997–1012 (2017)
31. Deb, S., et al.: A hybrid multi-objective chicken swarm optimization and teaching learning based algorithm for charging station placement problem. IEEE Access 8, 92573–92590 (2020). https://doi.org/10.1109/ACCESS.2020.2994298
32. Singh, M., Kumar, P., Kar, I.: Implementation of vehicle to grid infrastructure using fuzzy logic controller. IEEE Trans. Smart Grid 3(1), 565–577 (2012)
33. Sachan, S., Amini, M.H.: Optimal allocation of EV charging spots along with capacitors in smart distribution network for congestion management. Int. Trans. Electr. Energ. Syst. 30, e12507 (2020)
34. Gupta, V., et al.: Multi-aggregator collaborative electric vehicle charge scheduling under variable energy purchase and EV cancelation events. IEEE Trans. Industr. Inform. 14(7), 2894–2902 (2017)

How to cite this article: Sachan, S., et al.: Planning and operation of EV charging stations by chicken swarm optimization driven heuristics. Energy Convers. Econ. 2, 91–99 (2021). https://doi.org/10.1049/enc2.12030