Optimal Allocation and Strategy for Multiple Electric Vehicles (EV) Charging Stations in Conjunction with Distributed Generators (DGs) Distribution

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Abstract

Technological advancements have escalated the global energy demand, necessitating innovative solutions like Distributed Generators (DGs) at the distribution level. Concurrently, the surge in Electric Vehicle (EV) usage, favored for its cost-effectiveness and zero-emission transportation, has led to a growing need for optimally allocated Electric Vehicle Charging Stations (EVCS). This research introduces an approach for optimally allocating Electric Vehicle Charging Stations (EVCS) with various numbers of charging slots, considering the increasing demand for electric vehicles. We focus on integrating Distributed Generators (DGs) into a 14 bus CIGRE low-voltage distribution system, analyzing the system's capacity with one, two, and three DGs. The battle royale optimization algorithm determines the best placement for DGs and EVCS. To enhance the efficiency and reliability of this integrated system, the role of advanced communication technologies is considered crucial. Communication networks can facilitate real-time data exchange, demand-response management, and coordinated control between DGs and EVCS. This integration ensures optimal energy distribution, improved system stability, and enhanced user experience in EV charging. The inclusion of a robust communication framework is vital for the scalability and adaptability of DG and EVCS integration, addressing future energy demands and technological evolutions.

Ⅰ. Introduction

People have done a lot of research in DG allocation. Researchers have obtained optimal allocation of multiple DGs [1] while study [2] have obtained allocation of EVCS. However, none of the study obtained the optimal allocation of multiple types of EVCS along with optimal allocation of DGs. In current paper, simultaneous optimal allocation of various types of DGs and EVCS is obtained.

Ⅱ. Method

In the current paper, three EVCS is allocated optimally in the distribution system while considering three types of EVs (battery capacity of type 1= 13.8kWh, type 2=18.4kWh, type 3= 24kWh). Three case studies are considered. In case 1, optimal allocation of three EVCS and number of EV at each EVCS is obtained in the presence of single optimal DG allocation (size and location). In case 2 and case 3, optimal allocation of three EVCS and number of EV slot at each EVCS is obtained in the presence of two and three optimal DGs allocation (size and location) respectively. Optimization is obtained by minimizing active power loss, reactive power loss and voltage deviation using Battle Royale Optimization (BRO) algorithm presented by Taymaz in 2020[3]. The algorithm is expressed in [4] detail and implemented for optimal DG allocation for 24 hours. Multi objective index (MOI) is considered which is the combination of all three objectives and presented in Eq. (1).

$$MOI = w1 * API + w2 * RPI + w3 * VDI \quad (1)$$

Weight indices are w1, w2 and w3 for active power loss index (API), reactive power loss index (RPI) and voltage deviation index (VDI) respectively. While values for w1, w2 and w3 indices are 0.5, 0.25 and 0.25 respectively.

The mathematical equation for API, RPI and VDI is given in Eq. (2), Eq. (3) and Eq. (4) respectively.

$$API = [APL_{DG} / APL] \quad (2)$$

$$RPI = [RPL_{DG} / RPL] \quad (3)$$

$$VDI = max_{b=1}^{n}\left(\frac{|V_I| - |V_b|}{|V_I|}\right) \quad (4)$$

The term APLDG and RPLDG represent the active and reactive power losses in the system following the integration of Distributed Generation (DG), respectively. Conversely, APL and RPL denote the active and reactive power losses in the absence of DG integration. VI signifies the standard voltage, set at 1.0 per unit (pu), whereas Vb indicates the voltage level at bus 'b' after the integration of DG."

Ⅲ. Result and discussion

CIGRE mv benchmark model is considered as test system which consists of 14 buses which is presented in Fig. 1. The model consists of various types of pre-installed renewable and non-renewable DGs. Three EVCS are optimally placed in the system with maximum number of slots. Each EVCS will be have total capacity equal to sum of its EV slots.

Table.1: Overall Results				
DG types	Before DG	Case 1	Case 2	Case 3
MOI	-	0.2932	0.2259	0.2419
DG location	-	12	12,1	12,8,1
EVCS location	-	3,6,12	9,9,12	12,5,9
Number of EVs		14,22,25	33,20,38	38,33,13
DG sizes (k)	-	64.04	84.91, 130.81	81.68,10.14, 154.64
Active power loss (MW)	21.26	7.52	5.92	6.36
Reactive power loss (KVar)	21.36	8.71	7.38	7.88
Max act line losses	6.54	1.53	1.61	1.67
Max reactive line losses	4.70	2.07	2.31	2.39
Average bus voltage	0.93	1.026	1.06	1.071
Min bus voltage	0.70	0.9435	1	1

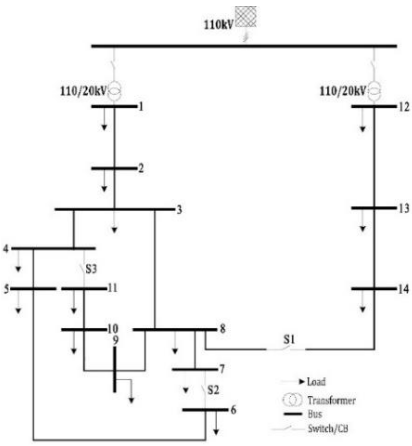

Fig.1 CIGRE system

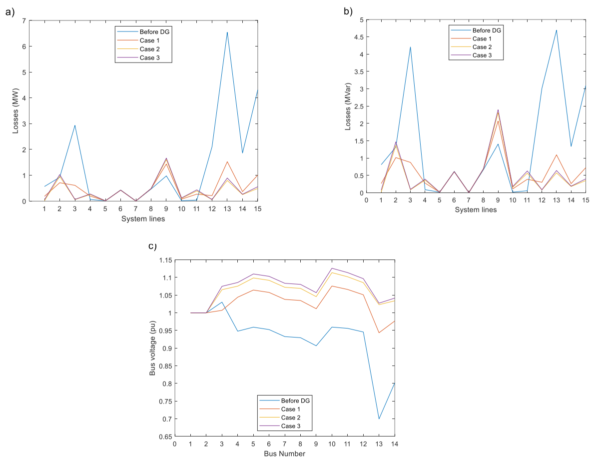

Fig.2 (a)Active power losses, (b) Reactive power losses and (c) Voltage across each bus

Optimization is obtained using 300 population and 300 iterations of BRO algorithm. All results are presented in Table.1. The results show that increasing number of DGs causes variation in the number of EV slots in EVCS. Case 1, case 2 and case 3 carry 65, 91 and 13 total EV slots in all three types of EVCS respectively.

The results also show that case 2 has better performance as compare to case 1 and case 3 in term of active and reactive power losses. The results also show that increasing number of DG power injection does not lead to increasing number of EVs. If the optimal size and location is not obtained for DG, it led to more active and reactive losses. Active power line losses, reactive power line losses and voltage across each bus is presented in Fig. 2(a), Fig. 2(b) and Fig. 2(c) respectively.

Ⅳ. Conclusion

In this paper optimal allocation of multiple EVCSs are obtained in the presence of one, two and three optimal placements of DGs. It has been determined that the growth in the quantity and power output of Distributed Generators (DGs) does not necessarily correlate with an increase in Electric Vehicles (EVs) and a reduction in system losses. To support a substantial number of EV DGs efficiently and with minimal losses, it is crucial to identify the optimal number and placement of DGs in the system.

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