Optimal sizing and location of Multiple Electric Vehicle (EV) Charging Stations with optimal allocation of two types of Distributed Generators (DGs)

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ABSTRACT

Technological advancements have increased global energy demands, necessitating innovative solutions like Distributed Generators (DGs) at the distribution network level. A significant area of focus is electric vehicles (EVs), as they offer a cheaper and cleaner transportation alternative. The strategic planning of EVs involves integrating optimized DGs into the existing system at the distribution level to support the maximum number of EVs. This research proposes optimal sizes and locations for three types of EV charging stations to accommodate three different EV models. The placement of these stations will be determined through the integration of two types of DGs, namely P and P+Q, using the battle royale optimization algorithm. This analysis will be conducted within a 14 bus CIGRE low-voltage distribution network with goals to minimize active power loss, reactive power loss, and total voltage deviation.

1. Introduction

There has been significant research in the field of DG allocation. Previous studies have successfully achieved optimal placement of multiple DGs[1], and others have focused on locating EVCS [2]. However, DG types along with the objectives active power loss, reactive power loss and total voltage deviation have not clearly mentioned. This research to date has managed to optimally allocate multiple types of EVCS concurrently with two types of DGs that is P and P+Q.

2. Method

In the current paper, the optimal allocation of three Electric Vehicle Charging Stations (EVCS) in a distribution system, considering three types of electric vehicles (EVs) with battery capacities of 13.8 kWh, 18.4 kWh, and 24 kWh respectively. We explore two case studies. In the first case, we determine the optimal placement of three EVCS and the number of EVs at each station, considering a P type Distributed Generator (DG) allocation. In the second, the optimal placement of the three EVCS and the number of charging slots at each station are configured alongside the allocation of P+Q DGs respectively. The optimization process aims to minimize active power loss, reactive power loss, and total voltage deviation using the Battle Royale Optimization (BRO) algorithm, which was introduced by Taymaz in 2020[3]. This algorithm is thoroughly described [4] and applied to the optimal DG allocation over a 24-hour period. Additionally, a Multi-Objective Index (*MOI*) that combines all three objectives is considered and detailed in Equation (1).

$$MOI = w1 * API + w2 * RPI + w3 * TVD \qquad (2)$$

Weight indices are $w1$, $w2$ and $w3$ for active power loss index (*API*), reactive power loss index (*RPI*) and total voltage deviation index (*TVD*) 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 *TVD* is given in Eq. (2), Eq. (3) and Eq. (4) respectively.

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

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

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

The acronyms APL_{DG} and RPL_{DG} refer to the active and reactive power losses in the system after incorporating Distributed Generation (DG) and EVs, respectively. In contrast, *APL* and *RPL* represent the active and reactive power losses when DG has not been integrated. *VI* denotes the standard voltage, established at 1.0 per unit (pu), and *Vb* represents the voltage level at bus 'b' following DG integration.

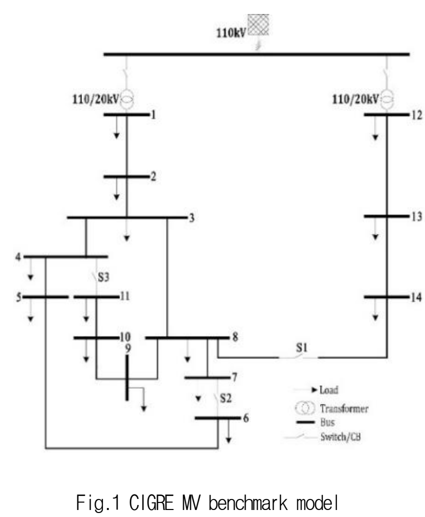


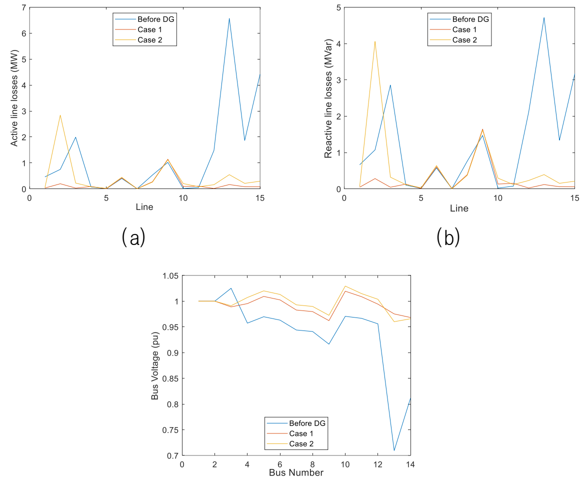
Fig.1 CIGRE MV benchmark model

3. Results 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. Optimization is obtained using 300 population and 300 iterations of BRO algorithm. In case 1, the capacities of EVCS are 676.2 kW, 36.8 kW and 144 kW of type 1, type 2 and type 3 respectively. In case 2, the capacities of EVCS are 41.4 kW, 128.8 kW and 192 kW of type 1, type 2 and type 3 respectively. Based on EVCS capacities the DGs sizes in case 1 are larger than case 2. Also with increased size of DGs, the losses are less in case 1 as compare to case 2. All results are presented in Table 1. Active power line losses, reactive power line losses and bus voltages curves for each is presented in Fig. 2. The results show that DG type 1 have positive response in term of facilitating mire EVs along with less losses and high bus voltages.

Table 1: Overall results for case 1 and case 2

Parameters	Before DG	Case 1	Case 2
MOI	--	0.128915	0.290688
DG location	--	11,12,2	2,12,3
EVCS location	--	11,7,1	7,10,2
Number of EVs	--	49,2,6	3,7,8
EVCS Capacity	--	676.2,36.8,144	41.4, 128.8, 192
DG sizes (kW)	--	606.11,174.44,36.47	353.11,89.73,18.67
Active power loss (MW)	19.655303	2.764587	6.561535
Reactive power loss (KVar)	18.97131	3.727573	8.634818
Max act line losses	6.567	1.144	2.841
Max reactive line losses	4.712	1.645	4.056
Average bus voltage	0.938	0.992	0.997
Min bus voltage	0.71	0.962	0.960



(c)

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

4. Conclusion

In this paper optimal allocation of multiple EVCSs are obtained with maximum number of EVs while placement of two different type of DGs that is type 1: P and type 2: P+Q. It has been determined that DG with type 1 integration facilitate the maximum number of EVs with minimum losses as this is due to active load of EVs.

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