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The Active and Reactive Power Dispatch for Charging Station Location Impact Factors Analysis

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Abstract

With the increasing number of Electric Vehicles (EVs) in modern society, a number of challenges and opportunities are presenting themselves. For example, how to choose charging station locations to minimize the Distribution Network's (DN) power loss when a large number of EVs are connected to the DN. How impact factors, such as different load patterns, EVs' charging locations and network topology, affect charging station location is becoming vital. In this paper a new charging station location methodology informed by impact factor analysis is proposed by using the Active and Reactive Power Dispatch of charging stations in terms of power loss minimization. Results for the 36 DN with three different scenarios are presented. In addition, a more realistic model based on EV's daily travel patterns is built to illustrate how these impact factors affect charging station location. It is demonstrated that the optimal charging station location in terms of power loss minimization can be found by using the new methodology, and it is not affected by the EVs' charging location and load patterns, it is affect by the network topology.

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Keywors: electric vehicle, distribution networks, impact factors, charging stations

1. Introduction

Modern power systems are suffering pressures from government, large industries and investors. Especially when new type of loads are emerging, such as EVs. These new technologies make life easier and more comfortable. However, they also challenge the traditional power system. For example with a large level of EV penetration, are there enough charging stations to facilitate EVs' charging. How do we choose charging stations' locations, and how the impact factors such as different load patterns, EVs' charging locations and network topology affect this. This is becoming vital not only for power system operators, but also for EVs' users.

In [1] the authors developed a mixed-integer programming model to determine the optimal location of charging station by considering the EVs' parking demands, local jobs and a community's population density. In [2] the authors considered the impacts of limiting EV's full state of charge on the total charge energy for charging station planning.

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Reference [3] considered the environmental factors and service radius for charging station location choice by using a two-step screening method. Reference [4] proposed a new charging station model, which is influenced by the electricity consumption along the roads in cities and oil sales. Reference [5] considered how traffic flow and EVs' battery capacity affect a charging station's location choices and size.

Unlike these papers, the proposed method in this paper uses the active and reactive optimal power flow to analysis how the charging station locations change as a consequence of changing the network's resistance, reactance and EV's charging locations, which can be chosen at any bus in test 36 DN. The structure of this paper is as follows: In section two a theoretical analysis of this method is given, the charging station structure and the base case are also introduced for the cases studies and the results are discussed. In section three, two cases based on several scenarios are given and simulation results are discussed. In the final section, the conclusions of this paper are given.

2. Theoretical Analysis

The main focus of this paper is to analyse how the impact factors such as loads and network resistance and reactance affect optimal charging station location choice in terms of power loss minimization. In order to quantify the impacts on the DN, the optimal charging station location was obtained by using the active and reactive power approach. The EV to grid concept is not considered in this paper.

2.1. Charging Station Introductions

The charging station plays an essential role in EVs' power supply chain. It consists of a Battery Energy Storage System (BESS), which can not only provide the energy to EVs, but also can provide energy to local electricity customers. The BESS consists of batteries and Power Conditional Systems (PCS) [6][7].

A PCS has several electronic devices such as capacitors, diodes and transformers, the structure can be seen in [6].

It has two operation modes. The first operation is called discharging mode. In this operation mode BESS is being discharged to supply the active and reactive power to loads. The second operation mode is called charging mode. In this operation mode BESS is being charged, absorbing both active and reactive power from the DN. The active and reactive power discharge of the BESS should not exceed the maximum apparent power S_{ESSmax} of the BESS [8][9].

$$P_{dis}^2 + Q_{dis}^2 \leq S_{BESSmax}^2 \quad (1)$$

$$P_{char}^2 + Q_{disc}^2 \leq S_{BESSmax}^2 \quad (2)$$

The active power for charging and discharging must be positive values

$$P_{char(k,h)} \geq 0, \qquad P_{dis(k,h)} \geq 0 \quad (3)$$

$$S_{ESSmax(k,h)}^2 \geq Q_{dis\,(k,h)} \quad (4)$$

Moreover the upper and lower bound of the storage capacity should satisfy

$$E_{min} \leq E_{Low}, \qquad E_{Up} \leq E_{max} \quad (5)$$

The EVs power demand at each time slot can be calculated by using the equation

$$P_i(t) = \frac{[b_i - x_i(t)] \times C_i}{E_i \times H_{charging}}, \forall i, t \quad (6)$$

where $P_i(t)$ is the power demand of EVs at any time slot. b_i is the desired State of Charge (SOC) in this paper is 100%. $x_i(t)$ is the SOC at the beginning of t is 20%. C_i is the capacity of EV. E_i is the battery charging efficiency of EVs, $H_{charging}$ is the average charging period of all four types of EV. It is assume one charging station can charge 100 EVs simultaneously [10].

2.2. Base case and model explanation

The base case is the original network in this paper. It is the 36-bus DN [11] without any modifications, and it is assumed that there are two charging stations in the DN, charging station one's has already been installed in bus two because the system largest loss occurs there. The 36-bus DN voltage is 11KV and the total active reactive load are 3.97MW and 2.08Mvar. The system's topology is shown in Fig.1 and reference [11]. Also in order to analyse the power flow between each busbar, a simple π line model is