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Investigation on distribution transformer loss-of-life due to plug-in hybrid electric vehicles charging

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ABSTRACT

This paper is concerned with the adverse influences of electric vehicles battery charging on the distribution system. This crucial issue is of greater importance when these ever-growing vehicles, plug-in hybrid electric vehicles (PHEVs), get charged as extra electric loads from a standard outlet at home. At first, a comprehensive method is proposed in this study to evaluate the damaging impact of several PHEV penetration levels on the loss of distribution transformers life. Next, the proposed method is applied to a real-life distribution system supplying residential customers. Finally, simulation results via MATLAB reveal that the loss-of-life rate during evening peak is 12.21 for a scenario with 40% penetration of PHEVs. In contrast, night-time coordinated charging of PHEVs causes the least harmful effects on the loss of transformer life.

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Distribution network; loss-of-life; plug-in hybrid electric vehicle; transformer

1. Introduction

Tendency of recent engineering objectives toward economic and environmental aspects is creating a new perspective of power systems using the ongoing technology. In this regard, plug-in hybrid electric vehicles (PHEVs) have been of great attention due to their slight pollution emissions and fuel consumptions (Pirouzi et al. 2018a). Eventually, PHEVs will transfer energy demands from crude oil to electricity for the personal transportation sector. Shifting the petroleum use by electric vehicles (EVs) would not only decrease the pollution but also relieve the security worries related to oil extraction, importation and combustion (Wei, Li, and Cai 2018).

The charging of PHEVs affects the distribution system. PHEVs consume a huge amount of electrical energy (Nafisi, Askarian Abyaneh, and Abedi 2014). Therefore, this demand for electrical energy can lead to excessive and undesirable peaks in energy consumption (Nafisi, Askarian Abyaneh, and Abedi 2015; Ruiz-Rodriguez, Hernández, and Jurado 2018). Furthermore, PHEVs are potentially able to transfer power to the grid, in vehicle to grid (V2G) operating mode, to provide auxiliary services such as reducing peak power demand, frequency regulation and voltage control (Nafisi et al. 2016; Niazazari et al. 2014; Abniki et al. 2018). In the literature, significant effort has been devoted to investigate the impacts of different natures that charging of PHEVs and plug-in electric vehicles (PEVs) may have on the power distribution system (Wu et al. 2017; Panwar et al. 2017; Pirouzi et al. 2018; Mehta et al. 2019; Zhang et al. 2018; Gong et al. 2012). Furthermore, several studies have been specifically reported on the impact of PHEVs and fully electric vehicles (FEVs) charging on distribution transformers ageing. The effect of uncoordinated charging of PHEVs, EVs and FEVs on distribution network and distribution transformer ageing are presented in Qian, Zhou, and Yuan (2015); Gourisetti, Kirkham, and Sivaraman (2017); Leemput et al. (2014); Hilshey et al. (2013); Vicini et al. (2012). Moreover, the impacts of smart and coordinated charging of EVs on distribution transformer ageing and overloading have been introduced in Hilshey et al. (2013); Paterakis et al. (2016); Assolami and Morsi (2015); Godina et al. (2016). In Paterakis et al. (2016), the effects of price-incentive-based demand response on a neighbourhood distribution transformer ageing are investigated. The effect of time-of-use prices and charging level of second-generation plug-in battery electric vehicles on distribution transformer ageing were assessed in Assolami and Morsi (2015). Other study (Godina et al. 2016) proposes smart EV charging scheduler for overloading prevention of an industry client power distribution transformer. Meanwhile, Abdelsamad, Morsi, and Sidhu (2015) examined the impact of PEV charging on distribution transformer and loss-of-life (LOL) with considering rooftop photovoltaic (PV).

The transformers' LOL rate is a technical concern which should be precisely studied. However, it seems that further research is still required on the important impacts which have not been acknowledged. In this context, this work presents the impact of PHEV charging on the loss of distribution transformers' life time. It is obvious that an incremental load is imposed on distribution transformers due to PHEVs charging. This incremental load changes the time evolution of the transformers' hottest spot temperature (HST) and their LOL rate. However, there is a knowledge gap about the extent to which LOL rate of distribution transformers is changed, as a function of the penetration of PHEVs and their charging periods.

This paper tries to fill such a knowledge gap by contributing to develop a methodology which is used to investigate the incremental loss of distribution transformer life caused by PHEVs

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