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RESEARCH ARTICLE - ELECTRICAL ENGINEERING

Network Security Perspectives of Plug-in Hybrid Electric Vehicles

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Abstract Plug-in hybrid electric vehicles (PHEVs) are becoming more popular. The batteries of these electric vehicles may be charged from a standard outlet at home. These extra electrical loads have several impacts on distribution networks. This paper presents a methodology to quantify the impact that charging of different penetration levels of PHEVs may have on the security of distribution network. The network security is reflected through the well-known N-1 contingency analysis before and after charging PHEVs at home. The proposed methodology is applied to a realistic distribution network. The results show that network security may be remarkably degraded as the penetration of PHEVs increases. However, the extent of network security degradation largely depends on the charging period of PHEVs. As revealed by the results, daytime charging, from hour 06:00 to 14:00, may have the most adverse effect on the network security.

Keywords Plug-in hybrid electric vehicle · Power distribution lines · Power system security

الخلاصة

لقد أصبحت السيارات الكهربائية الهجينة التي توصل بالكهرباء (PHEVs) أكثر شعبية. ويمكن شحن البطاريات في هذه المركبات الكهربائية من مقبس قياسي في المنزل. إن هذه الأحمال الكهربائية الإضافية لديها العديد من التأثيرات في شبكات التوزيع. وتعرض هذه الورقة العلمية منهجية لقياس أثر شحن مستويات مختلفة من اختراق السيارات الكهربائية الهجينة في أمن شبكة التوزيع. وينعكس أمن الشبكة من خلال تحليل الطوارئ ن-1 المعروف جيدا قبل وبعد شحن السيارات الكهربائية الهجينة في المنزل. وقد طُبقت المنهجية المقترحة لشبكة توزيع واقعية، وبينت النتائج أن أمن الشبكة قد يتدهور بشكل ملحوظ عندما تزداد اختراقات السيارات الكهربائية الهجينة. ومع ذلك، فإن مدى تدهور أمن الشبكات يعتمد إلى حد كبير على فترة شحن السيارات الكهربائية الهجينة. ويتضح من النتائج أن الشحن خلال النهار، من الساعة 6:00 حتي 14:00، قد يكون له تأثير أكثر سلبية في أمن الشبكة.

1 Introduction

The fast technological developments in the automotive sector, together with the growing environmental concerns and the increase of oil prices, have triggered the appearance of vehicles with diversified energy sources. This is the case of plug-in electric vehicles (PEVs). Basically, these vehicles have two models: pure battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), which essentially work with a combination of two power sources, i.e., batteries and gasoline. The latter are an extended version of current hybrid electric vehicles including a battery with larger autonomy and able to connect to the distribution network to be charged [1].

The charging of PHEVs has several impacts on distribution networks because these vehicles consume a large amount of electrical energy and this extra demand of electrical power can lead to large and undesirable peaks in the electricity consumption [2]. In the literature, much effort has been devoted to the study of PHEVs charging impacts on

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