Impact of Solar Panels on Power Quality of Distribution Networks and Transformers
Impact de panneaux solaires sur la qualité des réseaux de distribution et de transformateurs de puissance

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***Abstract*— This paper presents an investigation on the impact of solar panels (SPs) on the power quality of distribution networks and transformers. Both solar farms and residential rooftop SP are modeled with the distribution network according to Canadian Utility data. Total harmonic distortion of voltages and currents on both sides of the distribution transformer are monitored under different operation conditions. A laboratory setup employing a single-phase inverter and three-phase transformer is used to test system performance in the presence of phase unbalance and harmonics. Core and winding temperatures are measured under various loads. Simulation and experimentation results show that the performance of distribution networks and transformers under the impact of SPs is within standard limits.**

***Résumé*— Cet article présente une enquête sur l'impact des panneaux solaires (PS) sur la qualité des réseaux de distribution et de transformateurs de puissance. Les fermes solaires ainsi que les toits avec des PS résidentiels sont modélisés avec le réseau de distribution basé sur les données canadiennes de services publics. Les distorsions harmoniques totales des tensions et des courants sur les deux côtés du transformateur de distribution sont contrôlées sous différentes conditions de fonctionnement. Une installation de laboratoire utilisant un onduleur monophasé et un transformateur triphasé est utilisée pour mesurer la performance du système de test avec un déséquilibre de phase et d'harmoniques. Les températures du noyau et d'enroulement sont mesurées avec différentes charges. Les résultats de simulation et expérimentaux montrent que la performance des réseaux de distribution et des transformateurs sous l'impact des PS respecte les standards.**

***Index Terms*— Distribution networks, distribution transformers, harmonics, solar panels (SPs).**

I. Introduction

SOLAR photovoltaic (PV) energy is one of the most rapidly developing renewable sources. Solar cells are made of semiconductor materials which convert light energy of the sun into dc electricity. Therefore, the usage of inverters with solar panels (SP) becomes inevitable before solar power can be used by local loads or transmitted into the grid. SPs are normally installed in distribution networks, rather than the generation or transmission levels of power systems. Both small rooftop SP installations and large solar farms create voltage harmonics and inject current harmonics into the distribution network by the associated inverters. On the other hand, distribution transformers are subject to second-quadrant operation (i.e., when the active power flow is reversed) under light load conditions when SP operate at or close to full capacity.

Although power system harmonics are known to be consequences of nonlinear loads, accurate measurement of voltage and current harmonics is quite tricky [1]. Tracking down harmonic sources is also challenging as well as effective filtering and mitigation techniques [2]. A few publications in the literature have considered the effects of SP on distribution networks. Impact of the SP at the Sydney Olympic Village on accommodating network is addressed in [3], where voltage and current total harmonic distortion (THD) remain within standard limits even if all SP operate simultaneously. In a weak network supplied by SP, the replacement of incandescent lamps by compact fluorescent lamps—for energy saving—increases voltage THD [4]. The initial THD of 3.14% can reach 10.15%, 22.2%, and 34% if 30%, 60%, and 90% of the lighting load is replaced, respectively. In [5], the effects of SP on power grids of two small Greek islands are studied and compared with the case of Diesel generator supplies. Although voltage THD with SP operation is higher than the Diesel generator case, yet, it remains under standard limits.

With the combination of linear and nonlinear loads on a transformer, an expansion of the standard K-factor evaluates the composite harmonic current [6]. Rad *et al.* [7] report

Manuscript received February 27, 2014; revised May 29, 2014; accepted September 15, 2014. Date of current version March 31, 2015. This work was supported by Hydro One Networks Inc., Toronto, ON, Canada, through the Centre for Urban Energy, Ryerson University, Toronto.

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Associate Editor managing this paper's review: Davood Yazdani.

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Digital Object Identifier 10.1109/CJECE.2014.2359111