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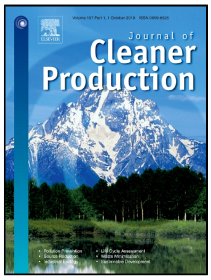

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Dynamic control strategy in partially-shaded photovoltaic power plants for improving the frequency of the electricity system

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ABSTRACT

When large-scale photovoltaic power plants (PV-PPs) operate under partially-shaded conditions, their power output can be extremely fluctuating. This situation may compromise the energy balance of the electricity grid, which in turn threatens its secure operation from a frequency control viewpoint. In this context, the development of control strategies to reduce the variability of the power generated by PV-PPs is a key issue towards reaching sustainable electric systems. With this purpose, this paper proposes a novel control strategy to reduce the negative effects that PV-PPs operating under partially-shaded conditions may cause on the frequency control of electricity grids. The control operates the PV-PP in deload mode, i.e. keeping power reserves. The deload level of the PV-PP is set dynamically during the day considering a 10-minutes forecast of solar generation. The forecast is performed with artificial neural networks, first predicting the day-type (sunny, cloudy, overcast) and then the solar power. The controller continuously monitors the condition of the PV-PP: when the plant is under non-uniform shaded conditions, it deploys the power reserves to smooth the PV power. The proposed control was applied to a Chilean case study focused on the Atacama Desert, testing different control rules for the deload level. The obtained results show that the implementation of the proposed control considerably improves the frequency performance of the electricity grid. Although operating in deload mode implies energy losses in the PV-PP, the use of a dynamic deload level minimizes these losses when compared to a constant deload level. Altogether, the dynamic simulations show that such a control can play a relevant role for frequency control in electrical power systems with high shares of photovoltaic power. Our findings give important insights to electricity regulators about the technical requirements that they should impose to large-scale PV-PPs in electric power systems dominated by renewables energies.

1. Introduction

The deployment of large-scale photovoltaic power plants (PV-PPs) has been remarkable during the last years. The worldwide installed capacity of PV generation exceeded 300 GW in 2016 with a yearly growth rate of 70 GW (REN21, 2017). Chile contributed with an installed capacity of around 2 GW. Towards a more sustainable society, the penetration of solar power plants, together with other renewables technologies (Hašková, 2017; Mardoyan and Braun, 2015), will need to keep on growing. Chile is particularly interesting given its relevance in the worldwide copper market, an essential material for renewable technologies. Higher shares of renewable technologies would consequently also imply a cleaner copper production (McLellan et al., 2012; Moreno-Leiva et al., 2017).

However, large shares of renewable generation technologies may significantly affect the operation of electric power systems (Carvalho et al., 2011; Jones, 2017). For a satisfactory operation of the electricity grid, the frequency should remain nearly constant around its nominal value (50 Hz in Europe). This means that at each point in time, electric power systems must keep the total energy production equal to the total consumption. In case of a generation surplus, the grid frequency increases; for generation deficits, the opposite happens. This balance management is called frequency control or frequency regulation. An energy imbalance can trigger the disconnection of key system components, which in turn may lead to a system blackout. Accordingly, frequency control represents a vital task for ensuring the security of the electricity supply.

The variability and uncertainty of solar power impose different challenges to transmission system operators (TSOs) (Faranda

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