Inertial Response of Isolated Power Networks with Wind Power Plants

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***Abstract*— The constant increase of power generation provided by renewable energy source (RES) power plants is causing a progressive reduction of the overall inertia of the power systems. Especially in the case of small, isolated power networks, the replacement of conventional generation plants with RES power plants can affect significantly the frequency response of the system. The critical low-inertia conditions can be improved by the introduction of specific additional controls to the RES power converters. These control schemes are known as “synthetic inertia” or “virtual inertia” controls. The paper analyzes the impact of a derivative-based inertial control on a small, isolated power system, with a relevant share of power supplied by a wind power plant. The inertial response control is added to the standard IEC wind turbine active power controller of type WT4A. Simulations performed on the dynamic model of the system indicate the appearance of frequency oscillations in response to the applied power unbalance. A comprehensive analysis of the observed phenomenon is given, and a tuning of the inertial control parameters is then proposed. Simulations repeated with the proposed tuning of the controller prove the validity of the applied modifications, and show a satisfactory transient response of the system, even in the case of critical low-inertia conditions.**

***Keywords*— synthetic inertia, virtual inertia, low-inertia power systems, frequency response, system stability, wind turbine, IEC 61400-27.**

I. INTRODUCTION

Isolated power systems such as the ones of geographical islands rely on local, concentrated power plants. These power plants are typically traditional, fuel-based generation plants. According to the worldwide current trend, the need of clean energy is leading more and more to the substitution of traditional thermal and gas power plants with renewable energy sources (RES). Current technology provides these RES power plants to be connected to the grid through full-scale power converters. Since rotating machines directly connected to the grid are substituted with generation sources interfaced through static power converters, the system experiences a reduction of the overall inertia. This phenomenon becomes more and more relevant as the sharing of RES power plants over the total generation increases: for small, isolated power systems, the impact of this phenomenon can become critical much more easily than for large, interconnected grids. The transient response of the system in such low-inertia conditions can be supported by specific additional controls in the power converters of the RES power plants. These control actions are known in literature as “synthetic inertia” or “virtual inertia”, and they aim to let the power converters participate to the inertial response of the system. The paper takes an existing island’s power network as reference system for the assessment of these inertial controls. A detailed model of the system is developed in a power systems analysis tool. The model is suitable for the dynamic analysis of the system, i.e. for performing transient stability and small signal stability simulations. The base case is compared with the scenario of the integration of a wind power plant in the system: this scenario is characterized by a reduction of the overall system inertia. The response of the system in such low-inertia conditions is examined also when an inertial response control is introduced into the wind turbine power converter. The implemented scheme is a derivative-based control, and it is added to the active power control of the wind turbine model. The system is subjected to a generation outage as perturbation of the initial steady-state, which causes power unbalance and consequent frequency deviations. The transient response of the system and the effects of the inertial response control are then examined.

II. OVERVIEW

In order to study the inertial response of a small power system with a relevant amount of power supplied by wind power plant, a detail model of an existing island power network is developed. The model is based on the Differential Algebraic Equations (DAE) structure and it is suitable for performing dynamic analysis and modal analysis of the system. The system model is developed using the power systems analysis tool NEPLAN. A schematic representation of the base case system is shown in Figure 1. The wind power generator and all the corresponding controllers are simulated according to the models specified in the standard IEC 61400-27. The wind power plant is type WT4A, equipped with the corresponding active power controller, reactive power controller, reactive power limitation and current limiter controller. A specific inertia control is added to the standard active power WT controller. The considered inertial response method realizes a derivative control of the system frequency, and it is intended to provide the so called synthetic or virtual inertia to the system under transient conditions.

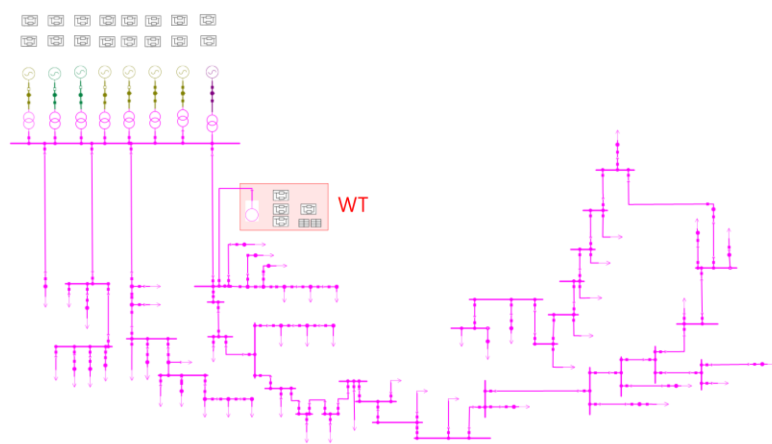

Fig. 1. Schematic network representation.

The results of the simulations are shown in Figure 2. As expected, the presence of the WT power plant in the low-inertia scenario produces a worsening of the overall frequency response, in terms both of minimum frequency and RoCoF. The introduction of the inertial response action has on the other side a clear, positive impact on the transient response. The appearance of the oscillations is analyzed and discussed more in details in the paper. The study includes also the modal analysis of the system and the sensitivity analysis of the inertial control.

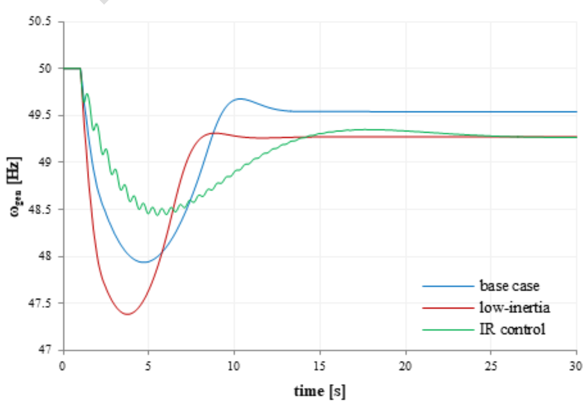

Fig. 2. Angular speed of the reference synchronous machine in the three simulated scenarios.