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Model-free inertia estimation in bulk power grids through O-splines

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ABSTRACT

This paper proposes a novel methodology to precisely estimate the generation units' inertia constant by using the wide-area monitoring systems (WAMS) information of bulk power grids. The method accurately estimates the rate of change of frequency (RoCoF) and the amplitude of active power deviations through the multivariate O-splines-based differentiators of the discrete-time Taylor–Fourier transform (DTTFT). The proposal utilises active power and frequency measurements that are synchronously collected from WAMS after load changes or generation trips. In the first stage, the Teager–Kaiser energy operator (TKEO) detects the right disturbance instant. Then, the first-order and zero-order O-splines differentiators are applied to the frequency and active power deviation measurements to simultaneously estimate the RoCoF and the amplitude of active power deviations in a sole stage. Thus, the inertia constants of all generation units derived from the second Newton law are estimated using all time-synchronised signals and processing in an exclusive step by the O-splines of the DTTFT in a short time. The attained results and their comparison with a state-of-the-art technique confirm the effectiveness and performance of the proposed strategy for inertia estimates, where simulated signals of two well-known benchmark power grids are tested.

1. Introduction

The active changes in modern power grids have imposed significant challenges on the provision of frequency control, since they have impacted the inertial response traditionally provided by the rotor masses of generation units along the power system. As consequence, power grids have also been exposed to imbalances that alter the reaction of all primary, secondary and supplementary control actions. These problems together with the paradigm about the uncertain knowledge of the total grid inertia [1], advocate the need of disposing of a methodology that estimates the grid inertia, mainly without requiring model information that may be outdated or poorly tuned.

Fortunately, modern grids are equipped with wide-area monitoring systems (WAMS) that provide operators with synchronised large data streams and can be used for grid inertial estimation. Methods that use the WAMS information are model-free (or data-driven), and they require little operator intervention for acquiring assessments, making available valuable information for frequency stability.

1.1. State-of-the-art

There are examples of local inertia estimation, i.e. synchronous generator inertia estimation using synchrophasors [2–5]. These methods do not address the systematic estimation of inertia, considering the cautious time of disturbance detection since it varies as the disturbance propagates across the system. Some of these methods approach the disturbance time detection, like [3,5]. However, such ones are heuristic or depend on user interference. The inertia estimation methods in power grids can be classified according to the type of signals used for assessment. The methods may require pre-determined user injected signals to the grid, i.e. probing signal methods [6]. Typical nominal operation signals, i.e. ambient data methods [7–13]; or signals from severe events, like generation or line trips, i.e. rigorous disturbance methods [14–20].

Probing signal methods use a known and small perturbation to a signal of interest for inertia estimation, usually active power. The

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