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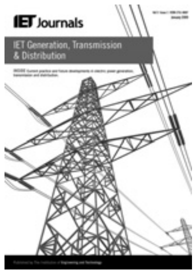

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Real-time transient stability assessment based on centre-of-inertia estimation from phasor measurement unit records

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Abstract: Several smart grid applications have recently been devised in order to timely perform supervisory functions along with self-healing and adaptive countermeasures based on system-wide analysis, with the ultimate goal of reducing the risks associated with potentially insecure operating conditions. Real-time transient stability assessment (TSA) belongs to this type of applications, which allows deciding and coordinating pertinent corrective control actions depending on the evolution of post-fault rotor-angle deviations. This study presents a novel approach for carrying out real-time TSA based on prediction of area-based centre-of-inertia (COI) referred rotor angles from phasor measurement unit (PMU) measurements. Monte Carlo-based procedures are performed to iteratively evaluate the system transient stability response, considering the operational statistics related to loading condition changes and fault occurrence rates, in order to build a knowledge database for PMU and COI-referred rotor-angles as well as to screen those relevant PMU signals that allows ensuring high observability of slow and fast dynamic phenomena. The database is employed for structuring and training an intelligent COI-referred rotor-angle regressor based on support vector machines [support vector regressor (SVR)] to be used for real-time TSA from selected PMUs. Besides, the SVR is optimally tuned by using the swarm variant of the mean-variance mapping optimisation. The proposal is tested on the IEEE New England 39-bus system. Results demonstrate the feasibility of the methodology in estimating the COI-referred rotor angles, which enables alerting about real-time transient stability threats per system areas, for which a transient stability index is also computed.

1 Introduction

In recent years, a number of factors such as transitioning energy policies, market pressures, slow transmission expansion, bulk power transfers over long distances and increasing environmental constraints, have pushed power systems to be frequently operated close to their technical limits [1]. Under these conditions, some critical contingencies may lead to major consequences, including widespread disruptions or even blackouts, whose root causes are occasionally attributed to large rotor-angle deviations [2]. Thus, real-time assessment of large-disturbance rotor-angle stability (i.e. transient stability—TS), which is concerned with the ability of a power system to maintain synchronism after being subjected to a large disturbance, is receiving a renewed interest from power system community [3].

Traditionally, transient stability assessment (TSA) has been conducted by using offline dynamic simulations for a given set of credible contingencies. This framework has been widely used for the designing and tuning of protective and control systems and to provide guidelines for secure operations as well. By contrast, real-time TSA is appropriate for evaluating the progress of actual transient phenomena occurring in a power system [4]. In view of this, several smart grid applications have been developed to improve monitoring, protection and control tasks in real time, which are mainly based on emerging technologies such as phasor measurement units (PMUs) and wide-area monitoring, protection and control systems [5–7]. The use of PMUs facilitates the measurement of electrical quantities at high sampling rates, hence it allows tracking post-fault transient evolution in real time [5]. In this connection, several research works have been carried out in order to predict and assess possible transient instability in real time from PMU measurements [4–26]. Moreover, post-contingency corrective control actions could be also executed within real time as long as reliable TSA is previously guaranteed [5].

For instance, the so-called piecewise constant-current load equivalent (PCCLE) approach is presented in [8] whose aim is to perform on-line TSA. In [9], the research work introduced in [8] has been extended for proposing two