# Transient Stability Improvement Through Wide-Area Controlled SVCs

Arash Vahidnia, *Member, IEEE*, Gerard Ledwich, *Senior Member, IEEE*, and Edward W. Palmer, *Member, IEEE*

***Abstract*—This paper presents a wide-area control approach to improve the transient stability of the power systems while also damping the post-fault inter-area oscillations. The proposed approach employs a nonlinear Kalman filter to estimate the inter-area modes using phasor measurement units (PMUs). The wide-area control system then uses the estimated inter-area dynamics through the developed control algorithms to improve the first swing and damping stability of the system. The performance of the proposed approach is evaluated on the simplified Australian test system with different load models including induction motors and the results show significant improvement in the stability of the system by simply adding the wide-area control signals to the available controllers in the system. The application of the proposed wide-area control system is shown to be feasible on realistic systems by improving the system stability and efficiency.**

***Index Terms*—FACTS devices, inter-area oscillations, phsaor measurement units, transient stability, wide-area control.**

## I. Introduction

TRANSIENT stability is an important factor in design and operation of power systems. The recent changes in power networks such as incorporation of renewable energy sources have increased the complexity and uncertainty of the system and pushed the transmission networks to the capacity limits. The increased stress on the power system can lead into a catastrophic failure following a sequence of disturbances in the system. In addition, the power utilities need to increase the utilization of existing transmission networks by improving the transient stability limit of the system [1]. Therefore, there is an increasing value for enhancement methods to maintain and improve the stability of power systems.

The power systems can face severe threats from low frequency inter-area oscillations which are not normally well damped [2]. The investigations by researchers and system operators have concluded in various tools and methods for damping and controlling these modes where few control application based on local measurements have shown good damping stability performance [3], [4]. The recent developments in utilization of synchronized phasor measurement units (PMUs) have provided extensive opportunities for developing wide-area monitoring and control tools [5]. The proposed methods use wide-area signals for damping the inter-area modes using PSS, HVDC, and flexible AC transmission systems (FACTS) controllers [6]–[10].

Despite the importance of damping stability, the power system operators require different controlling algorithms and tools to deal with large disturbances which can threaten the first swing stability of the system [1], [11]. Lyapunov energy function is a widely used tool for assessing the stability of power systems [12], [13] which is also applied for developing controlling algorithms to enhance the first swing and damping stability of the system [3], [14]–[17]. This paper proposes a wide-area control (WAC) approach to address both first swing and damping stability of power system using PMU signals and FACTS devices particularly static VAR compensators (SVC). The approach in [18] demonstrated that the first swing stability of power systems can be assessed by only using the transient energy flow through the critical cutsets between the generators in danger of separation. This approach has been a basis for a model predictive control (MPC) based controller in [19] which has shown a good performance in improving the first swing stability of multi machine systems by applying a control law based on the critical machine groups. These ideas have been developed and utilized in the present paper to design and implement the proposed nonlinear wide-area control approach to improve the first swing and damping stability of the system.

Interpretation of target dynamics from large amount of data captured by wide-area measurements across the network is one of the major limitations in the application of PMU data in wide-area control [20]. It is shown in [21] that the inter-area dynamics can be represented by a wide-area measurement based estimation of the reduced model of the system. The proposed WAC approach uses the aggregated model of the system based on a nonlinear Kalman filter [22] to control the inter-area modes with a limited number of PMU measurements. The application of the proposed approach on the test system which is a representation of a realistic system demonstrates the performance of the proposed wide-area control system in improving the system stability and efficiency. Therefore, the controller is shown to be feasibly applicable on real systems and increase the transfer capacity in tie-lines while damping the inter-area modes.

The paper is organized as follows. Section II describes the nonlinear estimation of inter-area modes based on PMU measurements. The control approach is presented in Sections III and the wide-area controllers are applied on the test system in Section IV. Section V presents the simulation results of the

Manuscript received March 16, 2015; revised July 23, 2015; accepted August 12, 2015. This work was supported in part by the Australian Research Councilunder LP120100302. Paper no. TPWRS-00355-2015.

A. Vahidnia and G. Ledwich are with the School of Electrical Engineering and Computer Science, Queensland University of Technology (QUT), Brisbane, Australia (e-mail: a.vahidnia@qut.edu.au; g.ledwich@qut.edu.au).

E. W. Palmer is with the School of Engineering and Technology, Central Queensland University, Rockhampton, Australia (e-mail: e.palmer@cqu.edu.au).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TPWRS.2015.2473670