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Transient stability improvement by nonlinear controllers based on tracking

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ABSTRACT

This paper deals with the control problem in multi-machine electric power systems, which represent complex great scale nonlinear systems. Thus, the controller design is a challenging problem. These systems are subjected to different perturbations, such as short circuits, connection and/or disconnection of loads, lines, or generators. Then, the utilization of controllers which guarantee good performance under those perturbations is required in order to provide electrical energy to the loads with admissible stability margins. The proposed controllers are based on a systematic strategy, which calculate nonlinear controllers for generating units in a power plant, both for voltage and velocity regulation. The formulation allows designing controllers in a multi-machine power system without intricate calculations. Results on a power system of the open research indicate the proposition's suitability. The problem is formulated as a tracking problem. The designed controllers may be implemented in any electric power system.

1. Introduction

Electric power systems (EPS) exhibit two major problems: (a) loss of synchronism or angle instability, and (b) terminal voltage instability or collapse due to over loading in transmission lines, reactive constraints, and faults. The generators' controllers must keep the terminal voltage and frequency close to the reference value and provide sufficient damping to the power oscillations at all admissible operating points.

For economical reasons, EPS are becoming more complex due to the increment in load demand. These changes have produced big uncertainties and have pushed the networks closer to their operational limits. Then, EPS will require the application of advanced control technologies. Proper design of these control systems is imperative to guarantee robustness over wide operating conditions. Likewise, EPS are affected by diverse perturbations and it must remain stable and maintain the reference terminal voltage under all such perturbations.

EPS models are complex large-scale nonlinear systems, subjected to variations as a result of changes in system's loading and configurations. Thus, the controller design for these systems is a challenging problem.

Nowadays, attention of researchers has been focused on the design of modern nonlinear controllers for EPS that allow reduce the effect of internal and/or external perturbations. The main features that those controllers must satisfy are described in the following:

i. *Nonlinear model and controllers*. The mathematical models are not linearized. This means that results are not limited to an equilibrium point's neighborhood.
ii. *Robustness*. The designed controller must guarantee good performance in steady state and in presence of perturbations such as parametric variations or faults.
iii. *Tracking*. The controllers are able to track the terminal reference voltage.
iv. *Bounded control signals*. All the non-linearities are considered within the controllers' design, including limits for the control input.
v. *Fast dynamics*. Fast and non-modelled dynamics may be analyzed to reduce their negative effects.

In order to improve the EPS stability, several control techniques have been applied. As a summary, the some of the main strategies are outlined as follows:

(a) *Adaptive control*. The control objective is the controller parameters' modification while the system conditions are varying. Adaptive control has been utilized to design conventional controllers in [1–3]. In [4,5], the adaptive control technique is combined with feedback linearization in an infinite machine bus system.
(b) *Feedback linearization*. In this case, the nonlinear models are linearized by a feedback loop in such a way that linear techniques can be utilized. The basics of this methodology can be found in [6], while the applications to infinite machine bus systems are described in [7,8]. In [9,41] feedback linearization is applied to multi-machine EPS. Nevertheless, this technique does not offer robustness. Combination of

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