Electric Power Systems Research 80 (2010) 1137–1144

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Estimating parameters of synchronous generators using square-root unscented Kalman filter

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ARTICLE INFO

Article history:
Received 23 September 2009
Received in revised form 4 March 2010
Accepted 16 March 2010
Available online 18 April 2010

Keywords:
Parameter estimation
Power systems
SRUKF
Synchronous generator
Third-order model

ABSTRACT

A new method to estimate the parameters of a synchronous generator using the square-root unscented Kalman filter (SRUKF) is presented in the paper. A third-order model for the parameter estimation of both round rotor and salient generators is developed first and then the SRUKF method is applied to the third-order model to perform the joint estimation of state variables and unknown generator parameters. The simulation results on a test system demonstrated the effectiveness of the proposed method in parameter recognition of a synchronous generator. The estimation processes of generator parameters steadily converge to the estimated values whereas the estimation processes of state variables are consistent with the dynamic responses in the numerical simulations.

1. Introduction

There are three general approaches to building the mathematical model of synchronous generators, namely, white-box modeling, grey-box modeling and black-box modeling [1,2]. The aim of this paper is to recognize the parameters of a third-order grey-box model for synchronous generators using the square-root unscented Kalman filter (SRUKF) method. Considerable researches indicated that a third-order model has sufficient accuracy for simulations on the stability and control of power systems [2,3].

Recognition of generator parameters is an important topic and has been investigated by other researchers [2–7]. Ref. [2] built a state space model of the studied system based on the Prony method and theoretical relations between generator parameters. Ref. [3] derived two nonlinear algebraic-equations for active power and terminal voltage, which can be solved using a nonlinear least squares algorithm. Ref. [4] presented a third-order model for parameter estimation. However, the presented model is based on the assumption of round rotor machines and cannot be applied for salient-pole machines in which X_d is not equal to X_q. Ref. [5] used the extended Kalman filter (EKF) method for joint state and parameter estimation. Refs. [6,7] introduced the evolutionary programming and active identification method for parameter estimation, respectively.

It has been commonly recognized that the Kalman filter can be utilized for the joint state and parameter estimation in which both the state variables and parameters in the model are simultaneously estimated. However, the extended Kalman filter (EKF) method is based on the linear assumption. A successive linearization process must be performed with EKF and this often results in numerical stability problems. The unscented Kalman filter (UKF) method has been proposed in the control theory area to overcome the demerits of EKF [8,9]. The SRUKF is an improved square-root version of the UKF with higher numerical stability and robustness [10]. Compared to the EKF, SRUKF does not require any linearization of nonlinear system equations but keeps the nonlinear feature using a probability distribution concept. The SRUKF has been successfully applied in other research areas [10–12].

The rest of the paper is organized as follows. A third-order model of synchronous generators is developed first for both round rotor and salient-pole machines in Section 2. The SRUKF method in the general control theory is applied to the presented third-order model for joint state and parameter estimation in Section 3. A numerical example is used to demonstrate the application of the presented model and method in Section 4, followed by conclusions in Section 5.

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doi:10.1016/j.epsr.2010.03.007