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Power system transient stability margin estimation using neural networks

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ABSTRACT

This paper proposes a methodology for estimating a normalized power system transient stability margin (ΔV_n) using multi-layered perceptron (MLP) neural network with a fast training approach. The nonlinear mapping relation between the ΔV_n and operating conditions of the power system is established using the MLP neural network. The potential energy boundary surface (PEBS) method along with a time-domain simulation technique is used to obtain the training set of the neural network. Results on the New England 10-machine 39-bus system demonstrate that the proposed method provides a fast and accurate tool to evaluate online power system transient stability with acceptable accuracy. In addition, based on the examination of generators rotor angles after faults, a method is presented to select the power system operating conditions that most effect the ΔV_n for each fault.

1. Introduction

Today's power systems are interconnected networks of transmission lines linking generators and loads into large integrated systems, some of which span entire countries and even continents [1]. The main requirements for the reliable operation of such systems is to keep the synchronous generators running in parallel and with adequate capacity to meet the load demand. In power system stability studies the term transient stability usually refers to the ability of the synchronous machines to remain in synchronism during the brief period following a large disturbance, such as a short circuit on a bus [2]. In large disturbance system nonlinearities play a dominant role. In order to determine transient stability or instability following a large disturbance, or a series of disturbances, time-domain simulation (TDS) method is usually employed to solve the set of nonlinear equations describing the system dynamic. Conclusion about stability or instability can then be drawn from an inspection of the solution [3].

In the actual operation of an electric power system, the parameters and loading conditions are quite different from those assumed at the planning stage. As a result, to ensure power system transient stability against possible abnormal conditions due to contingences (disturbances), the system operator needs to simulate contingences in advance, assess the results, and take preventive control action if required. The TDS technique is the most accurate method for assessing the power system transient stability [4,5]. The TDS approach can be applied to any level of detail of power system models and gives a visual information about state variables. One of the main disadvantages of the TDS approach, except for being time-consuming, is that it does not provide information about the stability margin of the system.

The transient energy function (TEF) method [6,7], and extended equal area criterion (EEAC) [8,9] have also be applied in power system transient stability assessment. However, these methods have some modeling limitations and they still need a lot of computations to determine an index for transient stability analysis [10].

Application of neural networks (NNs) to power systems is an area of growing interest. The main reasons are the ability of NN to learn complex nonlinear relations, and their modular structure, which allows parallel processing [11]. In recent years, pattern recognition techniques have been applied to the transient stability assessment (TSA) problem, with some significant results achieved. In such methods of stability assessment, a relation mapping between the input features and the output results of a stability evaluation is built up, based on a large number of offline simulation results. Neural networks (NNs) have been employed to establish this relation mapping by many researches, e.g., see [12–19].

Sobajic and Pao [12] used NNs for prediction of the critical clearing time (t_{cr}) for a small test power system. Djukanovic et al. [13] used individual energy function normalized by the critical value of global energy function evaluated at fault clearing time to predict energy margin and stability. Pao and Sobajic [14] proposed a combined usage of unsupervised and supervised learning for TSA. Fast pattern recognition and classification of dynamic security states was reported by Zhou et al. [15]. In [15], a feed-forward NN was trained using energy margin and unstable equilibrium point angles of advanced generators as the inputs with power system vulnerability as the output. Hobsen and Allen [16] reported that the NNs have difficulty in returning consistent accurate

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