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Particle Swarm Optimization trained recurrent neural network for voltage instability prediction

Amr M. Ibrahim [a,*], Noha H. El-Amary [b]

[a] *Electrical Power and Machines Engineering Dept., Ain Shams University, Cairo, Egypt*
[b] *Electrical Power and Control Engineering Dept., Arab Academy for Science and Technology, Egypt*

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Abstract

Voltage instability is considered as a major problem that faces the power systems during its operation. Voltage instability prediction is necessary for avoiding voltage collapse. This paper investigates the performance of recurrent neural network (RNN) in voltage instability prediction. A recurrent neural network trained with Particle Swarm Optimization (PSO) is proposed in this paper. The proposed method is examined on 14-bus and 30-bus IEEE standard systems. These systems are simulated using MATLAB/Power System Toolbox program. Also, a detailed comparison between PSO algorithm and Backpropagation (BP) algorithm is discussed. The results proved the effectiveness of the proposed method.

Keywords: Backpropagation algorithm; Particle Swarm Optimization technique; Recurrent neural network; Voltage instability predictor; Voltage stability

1. Introduction

Voltage instability problems play a great role in power systems planning and operation. Nowadays, power systems are operated near to their capacity borders because of the environmental and the economic aspects. Preserving a steady-state process of the power system is a vital matter. Therefore, it is highly suggested to monitor the voltage stability in the electrical networks.

Many researchers study the power system voltage stability from different points of view. The excessive loading of transmission lines is one of the essential factors causing voltage instability.

The research progress is started with defining and identifying the voltage stability circumstances, factors, indices and problems. Some articles are performed to improve and enhance the voltage stability index (Khatua and Yadav, 2015; Mohandas et al., 2015; Murty and Kumar, 2015; Angelim and Affonso, 2016). Also, many techniques are used in voltage instability detection (Nakawiro and Erlich, 2008; El-Amary et al., 2008; Kamalasadan, 1998).

Phasor measurement units (PMUs) are vital devices in monitoring and collecting data from the electrical grid that helps in many applications and problems (Zhang et al., 2009; Lin et al., 2004; Laverty et al., 2009). The correlation

* Corresponding author.
E-mail address: amrmohamedhassan@yahoo.com (A.M. Ibrahim).

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between PMUs and GPS provide high capability to synchronize the measurable data of voltage and current signals from several positions that located at the electrical grid (Phadke, 2002; Depablos et al., 2004). This work employs PMUs to give accurate measurements of voltage phase angle of each bus in the studied networks.

Early prediction of voltage instability is helped in avoiding voltage collapse of the power systems. This is can be achieved by monitoring the changes in phase difference between each two consecutive buses of the electrical networks instead of focusing on the voltage magnitudes. This is because voltage magnitudes, at certain loading conditions, may not detect voltage collapse in an early phase.

In this article, voltage instability prediction is accomplished by recurrent neural network (RNN). Recurrent neural network is a powerful learning algorithm. Several studies on electrical power systems using RNN have been conducted, including applications in induction motor speed estimation (Goedtel et al., 2006), islanding detection for distributed generation (Bayrak, 2009), wind speed and power forecasting (Barbounis and Theocharis et al., 2006), and design of power system stabilizer (Chen and Chen, 2006).

Recurrent neural networks consist of different layers of neurons organized in input, output and hidden layers. The neurons are connected to each other by synaptic weights. During the learning process, the network weights are adapted until a minimum error is achieved. Neural networks training process took the attention of many researchers in the last few years (Janson and Frenzel, 1993; Alpaydin et al., 2002; Mendes and Cortez et al., 2002; Salerno, 1997; Gudise and Venayagamoorthy, 2003).

The application of various population-based search algorithms in the training of neural networks has been enabled due to a recent growth in evolutionary computation mechanisms.

One of the most famous evolutionary computation techniques is Particle Swarm Optimization (PSO) which based on swarm intelligence. The PSO has been found to be fast and robust in solving many nonlinear optimization problems (Angeline, 1998; Clerc and Kennedy, 2002; Trelea, 2003). One of the first implementation of PSO was that training neural networks (Kennedy and Eberhart, 2001). The comparative simplicity of PSO in training neural networks is the main advantage of its usage over other optimization algorithms.

This paper represents a comprehensive study using RNN for voltage instability prediction. PSO algorithm is proposed to train a recurrent neural network for prediction of voltage instability. To prove the effectiveness of the proposed method a comparison has been established with a method using Backpropagation (BP) algorithm in training RNN.

The rest of the paper is organized as follows: Section 2 presents an explanation about the voltage stability. Section 3 describes in details two algorithms used in training recurrent neural network (RNN): Backpropagation (BP) training algorithm and Particle Swarm Optimization (PSO) algorithm. Section 4 evaluates the results of voltage instability predictor when applied on 14-bus and 30-bus IEEE standard systems, also this section investigates the performance of the training algorithms. Finally, Section 5 introduces the extracted conclusion.

2. Voltage stability

Voltage stability is defined as the system ability to supply appropriate reactive power support, in order to preserve voltage magnitudes of the load within particular operating boundaries for both balanced and transient conditions. From the load point of view, voltage stability can be defined as the load ability to give more power as the loading is increased without voltage dips beyond the limits.

This research follows the strategy of voltage instability prediction through monitoring the change in phase difference between each two consecutive buses of the power system. Fig. 1 shows the voltage phasors $V_a \llcorner \delta_a$ and $V_b \llcorner \delta_b$ of two

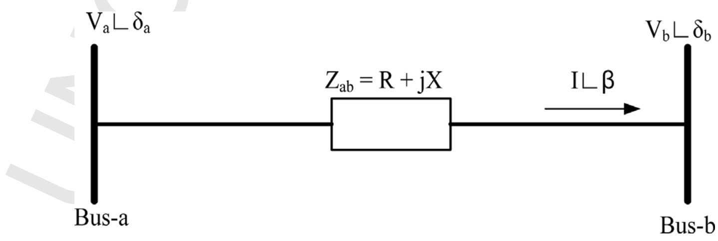

Fig. 1. Two-bus system.