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A novel approach for voltage secure operation using Probabilistic Neural Network in transmission network

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Abstract

This work proposes a unique approach for improving voltage stability limit using a Probabilistic Neural Network (PNN) classifier that gives corrective controls available in the system in the scenario of contingencies. The sensitivity of system is analyzed to identify weak buses with ENVCI evaluation approaching zero. The input to the classifier, termed as voltage stability enhancing neural network (VSENN) classifier, for training are line flows and bus voltages near the notch point of the *P*–*V* curve and the output of the VSENN is a control variable. For various contingencies the control action that improves the voltage profile as well as stability index is identified and trained accordingly. The trained VSENN is finally tested for its robustness to improve load margin and ENVCI as well, apart from trained set of operating condition of the system along with contingencies. The proposed approach is verified in IEEE 39-bus test system.

Keywords: VSENN; ENVCI; PNN; PMU

1. Introduction

The continuous increase in demand of load, limited scope for the expansion of existing conventional generation systems as well as transmission network, modern power systems operate under stressed condition. To this, further load increase and any contingency leads to point of concern for voltage stability (Kundur, 1994). Improper coordination between continuous and discrete controls, insufficient supply of reactive power in terms of size improper planning and location as well as been found to be the reason behind voltage deteriorations (Cutsem and Vournas, 1998). Voltage stability problem can be avoided by VAR placement (Thukaram and Lomi, 2000). For optimal placement and optimal value of VAR planning is done (Minguez et al., 2007). For on-line detection of voltage instability index, a new voltage

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stability index termed as equivalent node voltage collapse index (Wang et al., 2009). The work is emphasized on the design of VSENN classifier based on PNN (Mishra et al., 2008; Tripathy and Behera, 2012). After suitable training of the VSENN, the testing of the same is carried out for various contingencies. Studies carried out when contingencies occur with the system operating very near its voltage stability limit. The results obtained from using the test data of IEEE 39-Bus New England power system (Mishra et al., 2007).

The paper is organized in the following manner. Section 2 describes the sensitivity analysis and Section 3 focuses on the design of VSENN classifier. Section 4 gives the algorithm steps for simulation. Section 5 presents the simulation results and accordingly comparison of the results obtained with as well as without the proposed VSENN. Section 6 explains conclusion.

2. Sensitivity analysis

Even though the conventional methods which rely on actual power flow solution and state estimation of the system are more accurate, still the index evaluation is preferred for their obvious advantages of accuracy, fast calculation and less computation and potential for online applications. The reasons for using ENVCI are enumerated below. ENVCI takes into account the effect of the system external to the bus at which it is evaluated. It avoids the use of continuation method for estimating voltage stability margin. It can be a good index for online control application in large systems where voltage phasor information may be brought with the help of phasor measuring units (PMUs). The equivalent system model is shown in Fig. 1.

The ENVCI values at any bus can be determined by using the following equation,

$$\text{ENVCI} = 2(e_k e_n + f_k f_n) - (e_k^2 + e_n^2) \tag{1}$$

where $\bar{E}_k = e_k + if_k$ and $V_n = e_n + if_n$.

V_n is the voltage of the Nth node. $\vec{E}_k$ is the voltage of the external system. It is to be noted that the ENVCI value of any weak bus lies close to *zero*, and that of a strong bus is close to *one*. The details can be referred from Wang et al. (2009).

3. Methodology adopted for designing the VSENN classifier

The PNN is a class of radial basis function (RBF) network (Specht, 1990), which follows supervised learning. As depicted in Fig. 2, the PNN in its structure consists of a radial basis layer and a competitive layer. Each set of input–output data are trained and classified by their distribution values as probability density function (PDF) expressed in Eq. (2). The input layer consists of S nodes to accept input feature vector (I). As mentioned in Eq. (2) the hth element of the middle layer Hd_h can be evaluated by the Euclidian distance between the ith input feature, I_i and the initialized weight (W_{ih}) connecting I_i to Hd_h.

$$Hd_h = \exp\left(-\frac{||W_{ih} - I||b^2}{\sigma^2}\right) \tag{2}$$

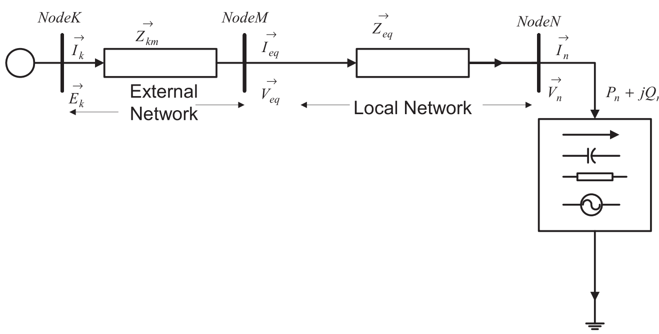

Fig. 1. Equivalent system model.