Application of Support Vector Network for Power System Static Security Evaluation

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ABSTRACT

This paper uses Support Vector Network (SVN) to examine whether the power system is secured under steady-state operating conditions. A system is considered operationally reliable if the load bus voltages do not fall below a certain limit and if the power flow through lines does not exceed the corresponding allowable values. SVN determines the minimum bus voltage and maximum ratio of line-flow to permissible line-flow. The input variables to the network are the active power of the load buses, power factor of the loads and the net generated powers of the generating buses. IEEE 14-bus system has been taken as an example. The proper kernel function and optimal value of C i.e. penalty parameter has been calculated. A comparison of the performance of SVN and ANN with those calculated by fast decoupled load flow is carried out. Results of the SVN closely agree with that obtained by fast decoupled load-flow and ANN in the case of proportional input vector. ANN is not suitable in the case of disproportionate input vector whereas SVN overcomes this disadvantage.

Keywords: Artificial Neural Network (ANN), Kernel Methods, Machine Learning, Static Security, Support Vector Network

1. INTRODUCTION

The static security of the power system is defined as the ability of the system, following a contingency, to reach an operating state within the specified safety and supply quality (Kirschen, 2002). The present trend towards deregulation has forced electric utilities to operate their systems under stressed operating condition closer to their security limits. Important criteria for security assessment are violation of constraints for voltages, power flows etc. The load flow study is the basic requirement for planning and operation of a power system (Wood & Wollenberg, 1996). It gives the voltage profile and line flows in a system. The fast and efficient methods available at present solve with ease load flow problem of a large system, provided required data are available. However, to study the operational reliability, i.e. to see whether

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the system is secured or not, the detailed load flow results are not necessary.

In recent years soft computing techniques are used to solve power system problems (Arya, Mathur, & Gupta, 2012; Bhaskar, Srinivas & Maheswarapu, 2011; Kurbatsky, Sidorov, Tomin & Spiryaev, 2014; Milani, & Mozafari, 2011; Sadeghi & Hosseini, 2013). The application of machine learning methods for security assessment has been proposed by many researchers. For static security assessment Artificial Neural Network (ANN) (Neibur & Germond, 1991; Ray, Chakravorti, & Mukherjee, 1994; Shanti, 2008; Zhou, Davidson & Foud, 1994; Wehenkel, 1998; Kim and Singh, 2005) have been suggested. ANN has the ability to classify patterns and its good accuracy in comparison with other machine learning methods, so Artificial Neural Network is the most popular method suggested. Disadvantages of ANN are:

ANN requires selecting of a number of tunable parameters like the number of neurons in the hidden layer, momentum constant, learning rate parameter, and number of iterations to converge a given set of data in a feature space within a specified error limit.

Recently, Support Vector Network (SVN), based on statistical learning theory, have been used in different areas of machine learning, computer vision, pattern recognition and other practical applications (Banerjee, Lahiri & Bhattacharyya, 2007; Burges, 1998; Guo, Niu & Chen, 2006; Moulin, Alves da Silva & El-Sharkawi, 2004; Platt, 1998; Sansom, Downs & Saha, 2002; Turkay & Demren, 2011; Vapnik, 1999). There are several causes for the superior performance of the SVN models to the artificial neural networks (ANN) models. First the SVN model has nonlinear mapping capabilities and, thus, can more easily capture electricity load data patterns than can the ANN models. Second, the SVN model performs structural risk minimization rather than minimizing the training errors. Compared with the ANN models, minimizing the upper bound on the generalization error improves the generalization performance.

In addition, the SVN regression is to map nonlinearily the original data into a higher dimensional feature space, it will be equivalent to solving a linear constrained quadratic programming problem so that the solution of SVN is always unique and globally optimal. The over-fitting problem can be easily controlled by the choice of a suitable data separation margin.

To see whether the system is statically secured or not, the detailed load flow study is being done at present to find out all bus voltages and line flows. Further, for evaluation of contingency due to loss of generating units, outage of line or transformer etc. load flow solution is necessary. For both the above cases, usually fast load flow algorithm, such as d.c. load flow or fast decoupled load flow is employed.

In this study IEEE 14 - bus system has been taken as an example. Load flow data are used as training data sets. The input variables to the network are the active powers of the load buses, power factor of the loads, assumed to be same for all load buses, and generated power of the generator buses except the slack bus. It is assumed that the hourly load distribution pattern of the different buses is similar, i.e. the loads at buses vary proportionately as load demand changes under normal condition. Same is assumed for net generated power at the generator buses. The output values are the minimum load bus voltage and the maximum or permissible line flow. For training, the output values are obtained from the fast decoupled load flow. A comparison of the performance of SVN and ANN with those calculated by fast decoupled load flow is carried out.

2. SUPPORT VECTOR NETWORK

SVN was originally introduced by Vapnik (1995) in the area of statistical learning theory and structural risk minimization. SVN performs the task of classification by first mapping the input data to a high-dimensional feature space and then constructing an optimal hyperplane classifier separating the two classes with maxi-
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