Electric Power Systems Research 80 (2010) 1033–1041

Contents lists available at ScienceDirect

Electric Power Systems Research

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

Artificial neural networks for load flow and external equivalents studies

Heloisa H. Müller [a], Marcos J. Rider [b,*], Carlos A. Castro [a]

[a] University of Campinas, DSEE/FEEC/UNICAMP, C.P. 6101, 13083-852 Campinas, SP, Brazil
[b] Universidade Estadual Paulista, DEE/FEIS/UNESP, C.P. 31, 15385-000 ILha Solteira, SP, Brazil

ARTICLE INFO

Article history:
Received 14 January 2009
Received in revised form 7 January 2010
Accepted 8 January 2010
Available online 6 February 2010

Keywords:
Artificial neural networks
Load flow
Reactive power limits of generation buses
Load flow with step size optimization
Static external equivalents

ABSTRACT

In this paper an artificial neural network (ANN) based methodology is proposed for (a) solving the basic load flow, (b) solving the load flow considering the reactive power limits of generation (PV) buses, (c) determining a good quality load flow starting point for ill-conditioned systems, and (d) computing static external equivalent circuits. An analysis of the input data required as well as the ANN architecture is presented. A multilayer perceptron trained with the Levenberg–Marquardt second order method is used. The proposed methodology was tested with the IEEE 30- and 57-bus, and an ill-conditioned 11-bus system. Normal operating conditions (base case) and several contingency situations including different load and generation scenarios have been considered. Simulation results show the excellent performance of the ANN for solving problems (a)–(d).

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1. Introduction

The operation of power systems is managed by Energy Management Systems in control centers. Several on-line and off-line network functions are carried out in these control centers. Among those are the generation automatic control, state estimation, external equivalents, and security analysis. Most network functions are heavily based on solving a large number of load flows (LF) [1,2].

The LF consists of computing the steady state operating condition of a power system [1]. Most LFs are solved by the iterative Newton–Raphson (NR) method or its decoupled versions XB and BX [1,2]. Usually, the system's operating point is obtained after a few iterations. However, there are critical situations where the system is ill conditioned, and the NR method fails to converge even though a feasible operating point does exist. In these cases, techniques as the load flow with step size optimization can be used [3,4].

For the sake of illustrating the degree of complexity involved in power systems analysis, consider the contingency analysis, which is one of the most time consuming tasks in real time operation. The post-contingency operating states corresponding to a set of different contingencies must be determined through LF calculations in a few minutes. Many efforts have been done to provide efficient LF methods by using sparse matrices techniques, specialized ordering and factorizing schemes, parallel processing, among others. However, computing all required LF in a small time frame is still a hard task in real time operation [5], even with the current advanced computational resources.

Recently, several artificial intelligence (AI) techniques have been developed and successfully applied to many engineering problems. In the power systems area expert systems and knowledge-based systems have been adopted to perform advanced tasks in control centers, both in real time operation and off-line studies. One of the AI techniques is the artificial neural network (ANN), which has been successfully used in the areas of pattern recognition, classification tasks, and prediction tasks [6].

The multilayer perceptron (MLP) is the most used neural network architecture in engineering, in special for power systems applications [5], and will be adopted in this paper. The MLP-ANN is able to solve complex problems, with difficulty degree similar or larger than the non-linearity associated to the LF problem.

The idea is to use ANNs for obtaining a computational gain in applications such as those of items (a)–(d). These applications are frequently used in control centers during the real time operation. This idea is possible considering that the ANN training process can be carried out off-line and the ANN can be stored. For real time events ANNs are used to obtain the results using simple simulations. Moreover, ANNs do not present convergence problems.

The ANN load flow can be considered as an alternative to the conventional numerical methods. Once trained, an ANN is able to provide an answer in negligible time, since the output is obtained by simple, direct arithmetic operations. Therefore, it could replace the conventional method in environments with very restrictive time constraints, as the real time operation. Also, this paper addresses the consideration of reactive power limits of generation buses in the ANN load flow. To the best of the authors' knowledge, ANN load flow considering limits has not yet been dealt with in the literature. It is well known that one of the main current difficulties of using ANNs is the effort required for training. However, once appropri-

* Corresponding author. Tel.: +55 19 35213708; fax: +55 19 35213866.
E-mail address: mjrider@ieee.org (M.J. Rider).

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doi:10.1016/j.epsr.2010.01.008