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Prediction of transmission line overloading using intelligent technique

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Abstract

With the worldwide deregulation of power system, fast line flows or real power (MW) security assessment has become a challenging task for which fast and accurate prediction of line flows is essential. Since last few years, limit violation of voltage and line loading has been responsible for undesirable incidents of power system collapse leading to partial or even complete blackouts. Accurate prediction and alleviation of line overloads is the suitable corrective action to avoid network collapse. The control action strategies to limit the transmission line loading to the security limits are generation rescheduling/load shedding. In this paper, an intelligent technique based on cascade neural network (CNN) is presented for identification of the overloaded transmission lines in a power system and for prediction of overloading amount in the identified overloaded lines. The effectiveness of the proposed CNN based approach is demonstrated by identification and prediction of line overloading for different generation/loading conditions in IEEE 14-bus system. Once the cascade neural network is trained properly, it provides accurate and quick results for previously unseen loading scenarios during testing phase.
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Keywords: Cascade neural network; Counterpropagation neural network; Identification module; Prediction module; Overloading prediction; Dominant class; Subordinate class; Modified BP algorithm; Power flows

1. Introduction

Power system security and reliability have become challenging issues in the present restructured scenario. The problem of monitoring the power flows and bus voltages in a power system is very important in maintaining system security and fast prediction is essential for controlling these quantities. As power systems have become more stressed due to increased loading and large interconnections, there will be an increase in cases of voltage limit violation and line loading limit violation, particularly in contingency conditions like line outage, generator outage etc. Under emergency conditions, power system operator has to take quick decisions without caring much for the optimality of the operating condition. Under this condition, a direct approach could be line-overloading alleviation with minimum number of control actions i.e. rescheduling of generators/load shedding in the affected power system.

For real power flow security assessment of power system, it is important to find out which line is overloaded (line overloading identification) and what is the amount of overloading in these lines [1]. This is essential that power flows in all the branches respect their specified limits not only in base case condition but also in stressed/line outage conditions. The most severe violation in a line flow limit can be due to different contingencies. Therefore an immediate need arises to take corrective action for alleviation of line overloads in the overloaded lines of the system. There are several methods based on optimal power flow (OPF) for the corrective and preventive control actions along with economy and security function.

Power system is a dynamic system as the operating state of it continually changes with respect to time. The emergency state of line overloading may occur as a result of sudden increase in system demand, outages of generator or transmission line or failure in any of the system components. Alleviation of the emergency due to transmission line overload is a crucial problem in power system operation.

Accurate as well as fast computation of lines flows, identification of overloaded lines and prediction of line

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overloading in different overloaded branches are essential for secure and reliable operation of power system. In other words, fast security assessment of power system is of paramount importance in modern power system to provide reliable and secure electricity supply to its consumers.

In reference [2], a corrective switching algorithm has been proposed which relieves overloads and voltage violations as well. Ioannis and Konstantinos [3] developed a model and some initial results of a dynamical model for blackouts in power transmission systems. The traditional form of load control (shedding) is quite disruptive to consumers and so often avoided. In reference [4], a non-disruptive load control method has been developed to switch small pieces of load, so that interruptions are effectively unnoticed by consumers.

Several power flow methods are available to compute line-flows in a power system like Gauss Seidel iterative method, Newton-Raphson method, fast decoupled power flow method and dc power flow method but these are either approximate or too slow for on-line implementation [5,6,11].

With the development of artificial intelligence based techniques such as artificial neural network, fuzzy logic etc. in recent years, there is growing trend in applying these approaches for the operation and control of power system [7–11]. Artificial neural network systems gained popularity over the conventional methods as they are efficient in discovering similarities among large bodies of data and synthesizing fault tolerant model for nonlinear, partly unknown and noisy/corrupted system.

Artificial neural network (ANN) is an intelligent technique, which mimics the functioning of a human brain. It simulates human intuition in making decision and drawing conclusions even when presented with complex, noisy, irrelevant and partial information. The information going to the input layer neurons of artificial neural network is recoded into internal representation and the outputs are generated by the internal representation rather than by the input pattern [10]. ANN can model any non-linear function without knowledge of the actual model structure and during testing phase, it gives extremely fast response. Properly trained ANNs are able to provide accurate results for the patterns that are not far different from the training patterns. A neural network consists of a number of neurons, which are elementary processing units that are connected together according to some pattern of connectivity.

In this paper, a cascade neural network based approach [11] is proposed for fast identification and prediction of transmission line overloading. The developed cascade neural network is a combination of an Identification module (ANN1) and a Prediction module (ANN2). All the training patterns are applied to the identification module, which is trained to classify them either in overloaded class or in under-loaded class using a modified BP algorithm. The identified overloaded cases are then passed to the prediction module (which is a feed-forward counterpropagation neural network) for prediction of line overloading.

The input features for CNN are taken from the set of real power injections at generation (*PV*) and load (*PQ*) buses, and reactive power injections at *PQ* type buses as these independent and known variables (prior to power flow analysis) influence the line flows most. Due to large number of such variable in any practical power system, it is not possible to consider all these variables as inputs to an ANN, as it will increase the input dimension, the size of the neural network i.e. the number of interconnection weights and ultimately the training time. So to overcome this difficulty, the variables are grouped into different clusters and from each cluster one representative variable is selected as the input feature to the proposed neural network. In this paper, angular distance based clustering [12] is applied for the selection of input features. Since only one Cascade neural network is trained for identification and prediction of line overloading in a number of lines, a topology in the form of admittance *Gij* and susceptance *Bij* corresponding to each line between buses *i* and *j* is also applied along with the input features to train the neural networks (ANN1 and ANN2). Optimal training of the CNN has been achieved by iteration wise monitoring the error patterns for the training set and the validation set.

The proposed neural network based technique is applied for overloading identification and prediction at different loading/generation conditions in IEEE-14 bus system.

2. Methodology

The block diagram of the proposed Cascade neural network is shown in Fig. 1. By perturbing the load at all the buses randomly in wide range of system operating conditions, a large number of load patterns have been generated and full ac power flow analysis has been carried out for each case to calculate real line-flow in each line of the power system. Angular distance based clustering [12] is applied for selection of input features from the set of real power injections at generation and load buses, and reactive power injections at load buses. An identification module which is a three-layered feed-forward neural network with single clamped output as shown in Fig. 2, is developed to classify the transmission lines condition either in overloaded or in under-loaded class taking into consideration the real power flows and the maximum power flow limits in different lines.

The identification module is trained using modified BP algorithm [11,13] such that its target output is high (0.9) when presented with a sample from overloaded class (C_1), and low (0.1) when presented with a sample from under-loaded class (C_2). During training, the outputs of the identification module greater than 0.9 are clamped to 0.9, similarly outputs smaller than 0.1 are clamped to 0.1 to reduce the likelihood of the network getting stuck in local minima.

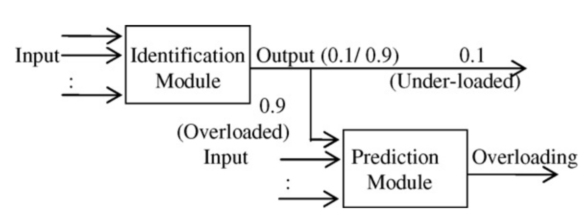

Fig. 1. Cascade neural network for identification and prediction of overloading.

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