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Optimal scheduling of electrical power in energy-deficient scenarios using artificial neural network and Bootstrap aggregating

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ABSTRACT

In a developing country like Pakistan, where the electrical power demand is more than the generated power, maintaining the power system stability is a big challenge. In such cases it becomes, thus, essential to shed just the right amount of load to keep a power system stable. This paper presents a case study of Pakistan's power system where the generated power, the load demand, frequency deviation and the load shed during a 24-h duration have been provided. The data have been analyzed using two techniques; the conventional artificial neural network (ANN) by implementing feed forward back propagation model and the Bootstrap aggregating or bagging algorithm. The simulation results reveal the superiority of the Bootstrap aggregating algorithm over a conventional ANN technique using feed forward back propagation model.

Introduction

The demand of power is increasing with each passing day which requires more resources of generation and construction of new grids. The developing countries that do not have sufficient resources have to perform load shedding in order to achieve 'power system stability'. When the load increases, the generators connected to a power system start slowing down that in turn results in reduced electrical frequency. The minimum threshold value for frequency in Pakistan is 49.5 Hz. When frequency decreases below its threshold value due to a sudden increase in load or tripping of major power plants (or transmission lines), the whole system becomes vulnerable to losing its stability. The tripping of one major generator (or power plant) or a transmission line results in the re-distribution of load on other generators or transmission lines and if they are not able to bear this increased load (particularly in case when they already are operating near their rated capacities), the whole system could collapse. This condition is known as cascaded failure or blackout [1].

The cascaded failures are a major threat to power systems. They should not be allowed to happen as they can prove detrimental to the equipment and personnel. One of the earliest blackout occurred in 1965 popularly known as Northeast Blackout, which left more than 30 million people without electricity for almost 6 days. The biggest cascaded failure that affected more than 300 million people occurred in India on 30 July 2012. In the last decade Pakistan also suffered with three major cascaded failures.

Optimal load shedding means shedding of just minimum load which can guarantee the system stability [2]. There are two worse-case scenarios in a power system:

(i) When the system generation is less than the load demand, frequency falls which could ultimately cause the generators to shut down.
(ii) When system generation is greater than the load demand, the speeding up of the generators will increase the system frequency and in the absence of a control mechanism will make the generators lose synchronism with the rest of the power system.

The upper threshold value of the frequency in Pakistan is 50.5 Hz. Fig. 1 presents a beautiful illustration, in the form of a balance, of the variation of frequency with the change in load or the generation: 50 Hz will be the frequency when generation exactly matches with the load, ignoring losses. Increasing power generation above the balance point will increase the frequency, whereas increased load will result in the decrease of the frequency.

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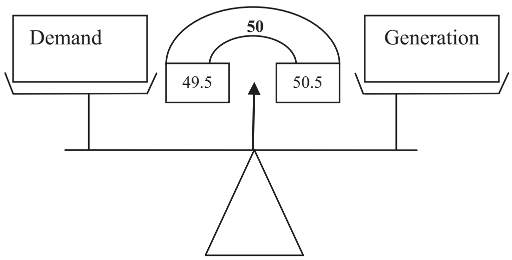

Fig. 1. Effect of supply and demand on system frequency.

Automatic generation control (or load–frequency control) mechanism, equipped with every generator, completely solves the second problem (when generation is more than the load demand by a governor action to decrease the flow of steam in case of steam-driven generators and water in case of hydel generators) but partially in the first scenario (when the load demand is more than the generation). In this case the control mechanism tries to adjust the speed of a generator by increasing the flow of steam, in case of a steam-driven generator for example, to compensate for the slow speed of the machine. However, if the machines are already operating at their maximum limits (generally the rated values) then the only option left is shedding some load to avoid a cascaded failure [3]. There are numerous ways to shed load such as breaker-interlock method, under-frequency relay, programmable logic controller based and intelligent load shedding scheme. The problems with these methods are that they are too slow and not efficient to calculate the correct amount of load needed to be shed.

Optimal load shedding has been studied using various conventional and artificial intelligence techniques. Traditional methods take more time than that by artificial neural network (ANN) to calculate the correct amount of load to be shed [3,4]. The convergence rate and execution time of ANNs are faster than those of many other artificial intelligence techniques [5,6]. The error in the learning of artificial neural network can be reduced by Bootstrap aggregating, also called bagging, algorithm that will increase the accuracy of a system [7]. The objective of this study is to explore optimal load shedding by using bagging algorithm. Power generation, power demand and the rate of change of frequency will play key roles in the training of neural networks, and to shed the correct amount of load. After training the neural network, a comparison of the target and the neural network output has been made which shows that there still was a significant difference between the two. Bagging technique is then used to reduce this error.

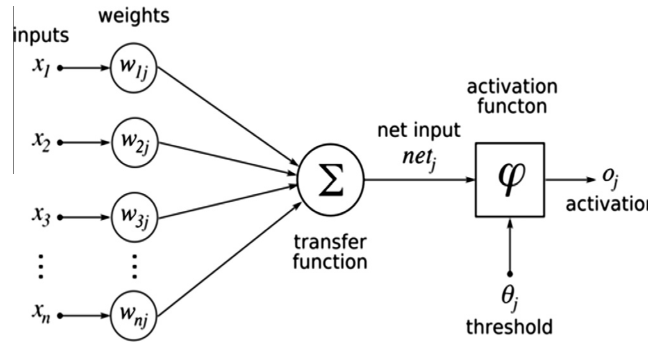

Fig. 3. Data propagation in an ANN.

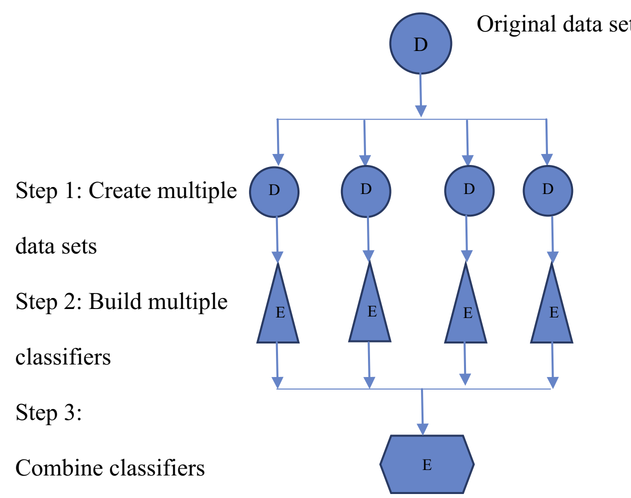

Fig. 4. General idea of bagging.

Levenberg–Marquardt back-propagation artificial neural network

A biological neural network forms the basic design of an artificial neural network. ANN is, however, not as complex as biological neural networks but the way of information processing resembles with those of biological neural systems. ANN is an interconnected system which is able to solve highly non-linear functions in a short time. The structure of an ANN is shown in Fig. 2.

Suitable data are required to extract enough information between input and output to train an ANN. The selection of the

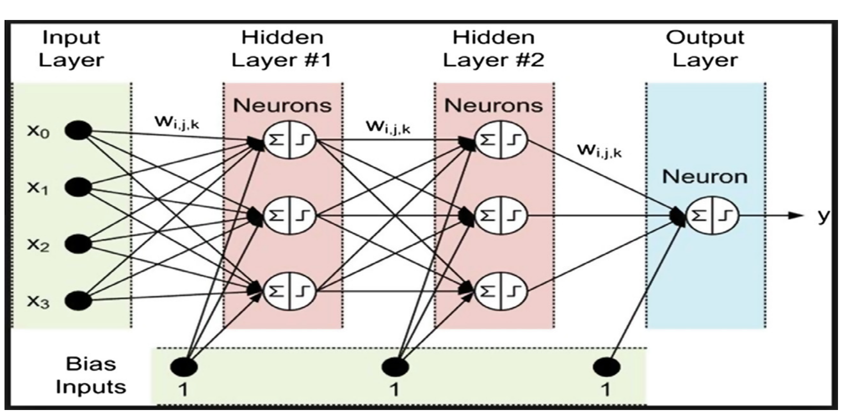

Fig. 2. Structure of an ANN.