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Voltage Magnitude State Estimation By ANNs with Reduction of PMUs

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Abstract. In this paper, the relationship between the number of installed PMUs and the accuracy of the monitoring system has been studied. In the best case, all buses are observable. In this paper, it is assumed that the economical saving or failure of PMUs can result in unobservable buses. In this case, Artificial Neural Network (ANN) has been used to estimate the voltage of unobservable buses. The proposed method has been applied to IEEE 14-Bus system. Based on single contingencies analysis, it is shown that in small scale networks, such as IEEE 14-Bus system, the ANN can estimate the unobservable buses with neglectable error.

Key words

State Estimation, PMU, Incomplete Observability, Artificial Neural Network.

1. Introduction

PMUs can get the magnitude and phase of voltage of the bus that is connected to, and the magnitude and phase of current of lines that are connected to that bus. One of the important questions related to PMUs is the determination of the minimum number of required PMUs, which should be installed in the power system, because they are expensive devices and cannot be installed on all buses. In [1], it is shown that the PMU placement is a NP-Complete (Nondeterministic Polynomial time) problem and there is no closed form solution for it.

In [2] and [8], an algorithm based on Integer Linear Programming (ILP) has been presented to find the minimum number of PMUs that are required to make all grid buses observable. In [2], an algorithm has been presented for multistage installation of PMUs, too. This problem has been solved by Binary ILP (BILP) [3] and [6]. In [4], the concept of unobservability has been studied and a solution for the PMU placement problem has been presented.

In [7], a virtual data elimination preprocessing method and a matrix reduction algorithm has been suggested, to reduce the scale of a placement problem.

In [9], [10] and [11], the state estimation problem has been solved for PMUs. The PMU can measure voltage phasors of the PMU node and the current phasors of the branches, which are connected to this node. So, state variables of these nodes are known.

In this paper, the main object is the reduction of PMU installation cost, by the reduction of the number of installed PMUs. After applying this strategy, some of network buses will be unobservable. As a result, this strategy has negative effects on monitoring or efficient control of the power system. To overcome this problem, unobservable buses voltages must be estimated. The reduction of installed PMUs decreases the accuracy of the monitoring system. As a result, this strategy can be used, when the maximum error of the estimation of system states is small enough and negligible. In this paper, ANN (Artificial Neural Network) has been used to estimate voltages of unobservable buses. It should be noted that the proposed method can be used for the case when one PMU has failed or its communication system has interrupted.

2. Estimation by ANN

In this paper, PMUs will be optimally placed considering two important points; the first point is the installation cost of PMUs and the second one is the error of the estimation. If a power system needs an accurate monitoring system, it should have enough installed PMUs. The reduction of the number of PMUs results in unobservable buses. In this paper, the ANN has been used to estimate the voltages of unobservable buses. The power network has been simulated by DIgSILENT software and the ANN has been carried out in MATLAB software. As it is mentioned before, this idea can be used when there is complete observability but one of PMUs or its communication system has failed. From this point of view, the ANN related to each PMU has been trained, and when one PMU fails, the ANN related to that PMU can be used and the voltages of buses, which are unobservable can be estimated by ANN.

The ANN should be trained by the results of the load flow analysis. The scenarios have been randomly selected for different load or generation levels, which are generated by using Mont-Carlo method. In this method, a random number (N) between 1 and N_b (the