Chapter 18
Application of Teaching Learning-Based Optimization to the Optimal Placement of Phasor Measurement Units

Abdelmadjid Recioui
University of Boumerdes, Algeria

ABSTRACT

In recent years, the placement of phasor measurement units (PMUs) in electric transmission systems has gained much attention. This chapter presents a binary teaching learning based optimization (BTLBO) algorithm for the optimal placement of phasor measurement units (PMUs). The optimal PMU placement problem is formulated to minimize the number of PMUs installation subject to full network observability at the power system buses. The efficiency of the proposed method is verified by the simulation results of IEEE14-bus, 30-bus, 57-bus-118 bus systems, respectively. The results show that the whole system can be observable with installing PMUs on less than 25% of system buses. For verification of our proposed method, the results are compared with some newly reported methods which show the method as a novel effective solution to obtain system measurements with the least number of phasor measurement units.

MOTIVATION

Wide Area Measurement System (WAMS) based on synchronized phasor measurement technology has been gaining increasingly interest due to its great value in power system dynamic monitoring, potential applications in system modeling and validation and system wide protection and control (Valenti and Feliachi, 2002). Phasor Mesurment units (PMUs) can offer accurate node voltage and current phasors referring to the same time-space coordinate. They can enhance many applications such as state estimation and bad data detection (Rahman et al., 2012), stability control (Barley and Winn, 1996), remedial action schemes and disturbance monitoring (Barley and Winn, 1995). As the voltage and current phasors
are measured, the equations of state estimation problem become linear and the solution can be obtained straightforward (Xu and Abur, 2005).

It is neither economical nor feasible to install a PMU at each bus of a wide-area power network. As a result, the problem of optimal PMU placement (OPP) concerns with where and how many PMUs should be implemented to a power system to achieve full observability at minimum number of PMUs (Xu, 2006). Using the data provided by PMUs installed in some appropriate bus nodes of a power network, one can construct a new type of measuring system to improve the observability and the precision of the power system state estimator. The observability depends on the type, the number and the geographic distribution of measurements (Xu et al., 2008).

Observability analysis has so far been accomplished by the help of either topological or numerical approaches. The topological approach makes use of the graph theory and determines network observability strictly based on the type and location of the measurements. It does not use any floating point arithmetic and needs to be implemented independent of the state estimation solution itself (Phadke and Thorp, 2008). The numerical approach is based on the decoupled measurement Jacobian and the associated gain matrix. It uses an iterative scheme to determine all the observable islands if the system is found to be unobservable (Mosavi et al., 2012).

In this chapter, a binary version of the teaching learning based optimization (BTLBO) algorithm for the optimal placement of phasor measurement units (PMUs) is presented. The optimal PMU placement problem is formulated to minimize the number of PMUs installation subject to full network observability at the power system buses.

RELATED WORKS

Several works have been done to efficiently place phasor measurement units (PMUs) in terms of both measurement accuracy and cost effectiveness. The problem has been addressed in (Baldwin, 1993). (Phadke et al., 2008) explored the possibility of providing all the nodes of the system with PMU’s for state estimation purpose. The problem which has been defined in (Phadke, 1993) is to determine the placement of the minimal set of PMU’s which makes the system observable. Attention has been also drawn to the use of evolutionary heuristic algorithms in optimal PMU placement. In (Nuqui and Phadke, 2005) a modified bisecting search and simulated annealing method based on topological observability have been used. In (Melosovic and Begovic, 2003), a genetic algorithm is used to find the optimal PMU locations. In (Ku and Abur, 2004) and (Xu and Abur, 2005), the authors use integer programming to find the minimum number and locations of PMUs. In (Chakrabarti and E. Kyriakides, 2007) and (Chakrabarti and E. Kyriakides, 2008) the authors propose an exhaustive search based methodology to determine the minimum number and optimal locations of PMUs for complete observability of the power system. The particle swarm optimization (PSO) technique has been used successfully in a number of power system applications (Hajian et al., 2007; Sharma and Tyagi, 2011).

Recently, nature inspired evolutionary algorithms which have earned their place because of their simplicity, no mathematical analysis, larger solution space and faster convergence. Recently, the teaching learning based optimization (TLBO) technique proposed by (Rao et al., 2011; Rao et al.,2012; Rao and Savsani, 2012; Rao and Patel, 2012) has been used successfully in a number of N-P optimization problems. The TLBO proposed in the previous references does not have a binary version that is able to optimize binary problems, and since PMU placement is a binary optimization problem, a binary