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Optimal PMU Placement for Tamil Nadu Grid under Controlled Islanding Environment

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Abstract

This paper proposes an optimal phasor measurement Unit (PMU) placement model considering power system controlled islanding so that the power network remains observable under controlled islanding condition as well as normal operation condition. The optimization objectives of proposed model are to minimize the number of installed PMUs and to maximize the measurement redundancy. These two objectives are combined together with a weighting variable so that the optimal solution with minimum PMU number and maximum measurement redundancy would be obtained from the model. At last, IEEE-14 bus standard systems and the Tamil Nadu state power grid (83 bus system) are employed to test the presented model. Results are presented to demonstrate the effectiveness of the proposed method.

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Keywords: Controlled islanding; integer linear programming; measurement redundancy; optimal phasor measurement unit (PMU) placement.

1. Introduction

Synchronized phasor measurement unit (PMU) is essentially a digital recorder with synchronized capability. It can be a stand-alone physical unit or a functional unit within another protective device. By measuring the magnitude and phase angles of currents and voltages a single PMU can provide real-time information about power system events in its area, and multiple PMU can enable coordinated system-wide measurements. PMU also can time-stamp, record, and store the phasor measurements of power system events [1]. This capability has made PMU become the foundation of various kinds of wide area protection and control schemes. Synchrophasors are precise measurements

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of the A lot of PMU potential applications in power system monitoring, protection, and control have been studied since it was introduced in mid-1980s. Specially, in recent years, PMUs have been and extensively used or proposed to be used in many applications in the area of power system protection and control with the cost reduction of PMUs and power systems and are obtained from PMUs. PMUs measure voltage, current, and frequency in terms of magnitude and phasor angle at a very high speed (usually 30 measurements per second)[2]. Each phasor measurement recorded by PMU devices is time-stamped based on universal standard time, such that phasors measured by different PMUs installed in different locations can be synchronized by aligning time stamps.

However, PMU and its associated communication facilities are costly. Furthermore, the voltage phasor of the bus incident to the bus with PMU installed can be computed with branch parameter and branch current phasor measurement [3]. So it is neither economical nor necessary to install PMUs at all system buses. Thus, one of the important issues is to find the optimal number and placement of PMUs.

Optimal PMU placement (OPP) is firstly attempted in [4], formulating as a combinatorial optimization problem of minimizing the PMU number for system observability. In [5], an integer programming formulation of OPP problem is proposed with the presence of conventional measurements. A generalized integer linear programming (ILP) formulation for OPP is presented in [6]. Generally, the existing OPP models concerns about the determination of minimum number and optimal location set of PMUs, ensuring that the entire power system remains a single observable island [7]. In another word, these models can only handle the cases in which the power system is operated as a single and integrated network. However, some severe faults may lead parts of the network to angle, frequency or voltage instability. In that case, trying to maintain system integrity and operate the system entirely interconnected is very difficult and may cause propagation of local weaknesses to other parts of the system [8]. As a solution, controlled islanding (CI) is employed by system operators, in which the interconnected power system is separated into several planned islands prior to catastrophic events [9], [10]. After system splitting, wide area blackout can be avoided because the local instability is isolated and prevented from further spreading [11]. In order to operate each island with power balancing and stability after controlled islanding, it is essential to provide an OPP scheme which can keep the network observable for the post-islanding condition as well as normal condition.

In this paper , an ILP model of OPP considering controlled islanding (OPP-CI) is proposed. This model is able to determine the minimal number and optimal location set of PMUs in order to provide the full network observability in normal operation as well as in controlled islanding scenario. To distinguish multiple optimal solutions, measurement redundancy is incorporated into the optimization objective. The performance of the proposed new model is assessed using IEEE-14 bus standard systems and a Tamil Nadu state power grid system.

2. OPP using integer linear programming

Integer Linear Programming (ILP) is a mathematical optimization method for getting an optimal outcome from a given mathematical objective function, subject to some linear inequality constraints. In this paper ILP is used for finding the minimum set of PMUs for a given power grid to achieve its complete observability. The objective of the PMU placement problem is that a bus will be reached by at least one PMU. Two assumptions are made before applying ILP for PMU placement. First, there is no constraint on the number measuring channels for the PMU, i.e., a PMU can measure the current phasors from any number of branches that are connected to it. Second, there are no problems with the availability of the communication system. i.e., all buses are well equipped with communication facilities for the transfer of data from PMUs .

The Program for objective function and constraints of IEEE-14 Bus test systems for complete observability is to create a matrix U_{PMU}, in such a way that, its entries are defined as

$$u_{i,j} = 1, \text{ (if i and j are connected)} \tag{1}$$

In a power system network, the PMU placement at a bus can be seen as a binary decision variable defined as

$$u_i = \begin{Bmatrix} 1 \;\; if \; PMU \; is \; placed \; at \; bus \; i \\ 0 \;\; otherwise \end{Bmatrix} \tag{2}$$

For a system with buses, therefore, the optimal PMU placement problem can be formulated as an integer linear programming problem as follows:

$$min \; F_J = \sum_{i=1}^{n} CiUi \tag{3}$$

subject to constraints

$$f_i = \sum_{j=1}^{n} a \; i,j \; u \; j \;\; \geq 1 \qquad i = 1,2,\ldots,n \tag{4}$$