ABSTRACT

The foremost task for implementing the Wide Area Measurement System (WAMS) is determination of locations of Phasor Measurement Units (PMUs) in the power system in order to get desired measurements with least number of PMUs. The installation cost of PMUs is too high, therefore, it is uneconomical to install the PMUs at all the buses and make the system observable. Several algorithms and approaches have been reported in the literature for the optimal PMU placement (OPP) in power system. Such approaches can broadly be classified as conventional and evolutionary methods. The most of the reported methods pay attention to produce the optimal number of PMUs and their locations in the system. Some of the methods have included the full and maximum observability in the objective function. However, the observability may be altered if the locations of the PMUs are changed even if the optimal number remains same.

In the present work, the PMU placement problem has been formulated such that the PMUs are placed at minimum number of locations producing the full and maximum observability of the system. Therefore, the problem has been formulated with two objectives. First objective is to minimize the number of PMUs in the system and second is to maximize the observability of the system. Thus the PMU placement problem has been expressed as a multi-objective problem. The effect of presence of zero injection buses (ZIB) has also been incorporated in this work. Besides, single PMU outage and single line outage cases in the presence of zero injection buses have been investigated as a contingency. However, which of the above contingencies has occurred may not be known a priory. This necessitates formulation of the PMU placement problem such that none of the buses is left unobservable to take care of uncertainty. The case of the uncertainty of PMUs has not been paid proper attention in the literatures. Therefore, the PMU and line outages have been dealt with separately in this work. The above mentioned issues have been addressed as constraint of the OPP problem retaining the same objective function. The basic law of Gravitational Search Algorithm (GSA) has been adopted to solve the above OPP problem. The OPP problem deals with discrete binary variables. Therefore, basic concepts of GSA need to incorporate discrete binary variables. A modified GSA

to incorporate binary variables called Binary Gravitational Search Algorithm (BGSA) has been proposed in this work to solve OPP problem.

A huge amount of data collected by PMUs need to be transferred over the communication channels to the control center where monitoring and control actions are taken. Thus, the installation cost of PMUs is not only depends upon the cost of PMUs, but it also depends upon the cost of communication infrastructure (CI) such as cost of fiber optics, cost of switches, cost of labors etc. Various methods have been employed in the past to determine the optimal locations of devices to retain the observability of the system. However, the cost of CI from Phasor Data Concentrator to PMUs has not been given suitable consideration. In order to address this issue, the PMU placement problem has been formulated incorporating the cost of CI also in this work. For this, a novel multi-objective function has been proposed. Different contingency cases have also been studied to improve the reliability of the method. Besides, the case of effects of presence of preinstalled PMUs have been considered.

Series of blackouts in recent years have occurred because either of voltage or angle instability or both together could not be detected within time. Many methods have been reported in past for the voltage stability monitoring using PMUs. In this work, a faster voltage stability assessment method using real time Phasor Measurement has been presented. For this, it is assumed that all the buses of the system are fully observable by using the proposed OPP techniques. As the slope of the P-V curve increases, the voltage stability limit of a bus decreases. This observation has been utilized to evaluate an index defined as Voltage Stability Predictor Index (VSPI). The VSPI has been evaluated using voltage phasor obtained from PMU measurement in this work. The value of VSPI at the bus varies from 0 to 1. A value approaching unity indicates that the bus is tending to be unstable. However, a value approaching zero is indicator of voltage stable bus. In order to demonstrate this method, the voltage phasors have been determined using Continuous Power Flow (CPF) for varying load. The VSPI has been calculated at various loading conditions. It has been observed that the VSPI proceed towards unity as the loading is increased. Moreover, the VSPI rightly revealed the system status at all load in respect of voltage stability.