Abstract

In recent years, distributed energy resources (DER) systems have increasingly played an important role in electric power distribution system. Nevertheless, they also concurrently introduce new characteristics to the distribution system, such as bi-directional power flows, unstable power supply, unintentional islanding and voltage profile issues. The evolvement of distribution networks necessitates rapid and accurate distribution network monitoring. Phasor Measurement Unit (PMU) has contributed greatly to power system state estimation because of its ability to directly measure voltage and current phase angle. However, so far PMUs have been used almost exclusively in transmission systems monitoring.

This thesis discusses the application of PMUs in distribution networks, with a focus on their optimal PMU placement (OPP) . Many OPP algorithms have been well documented. However, most of them are designed and tested on transmission networks, and very studies have been conducted on distribution networks. Distribution networks have very different topology from transmission networks, and hence there is a need to study how the PMUs can be optimally placed. In this thesis, we have proposed algorithms that take advantage of radial topology of distribution networks, to solve the OPP problem in an exhaustive manner yet without much computational burden. The proposed algorithms have been tested on several networks. Results show that for similar scale networks, distribution networks take much less time than transmission networks using the proposed exhaustive algorithms. The computational burden of this method dramatically decreases due to the radial topology of distribution networks.

Besides the above mentioned exhaustive method, integer linear programming has been investigated in this thesis. Compared to exhaustive algorithm, integer linear programming is much faster in solving the OPP problem. However, it can only give limited solutions, while in practice it is possible that there are multiple solutions that can satisfy the given constraints. Identifying all alternative solutions enables the

decision maker to examine them and choose the overall best solution. This thesis also introduces an OPP method using integer linear programming algorithm to identify all alternative optimal placements that satisfy certain constraints. The proposed method uses integer linear programming to identify multiple solutions, where the network buses are classified into three categories based on those multiple solutions. By further analyzing certain buses which belong to one of the three categories, the proposed method is able to identify all alternative optimal solutions. This method is efficient in determining the solution when applied to large-scale power system.

State estimators applied in transmission networks usually use positive sequence model. On the other hand, distribution networks usually contain unbalanced loads. In order to deal with imbalance in distribution networks, a three phase state estimator is also developed and tested in this thesis. We have shown that assuming there are sufficient number of PMUs to make the system observable, the state estimator is linear and can be solved in a non-iterative manner.

Publications

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