Abstract

Motivated by the important role of electrical energy in the quality of life in cities, the electric power flow management, scheduling and optimization is a critical task especially in large scale power systems. The power flow equations as the heart of power system operation translate the power injections and voltages steady-state relationship. The nonlinearity of the power flow equations makes the optimal power flow (OPF) problem a nonconvex NP-hard optimization problem any may have multiple optima. Complexity of the OPF problem increases significantly as the size of power system increases, so obtaining an optimal solution for OPF problem within a reasonable time is one of the main challenge in optimization of power system research area.

Therefore, a variety of deterministic and non-deterministic techniques have been applied to OPF problem over the last 50 years of research on power networks. Although the mature deterministic algorithms are usually able to quickly find a solution but they do not guarantee global optimality of the obtained solution and they may get trapped in any local optima and no additional information is provided regarding the solution. Certifiably obtaining the global solution is important for certain applications of OPF problems.

In this thesis, first a metaheuristic optimization approach, fully informed water cycle algorithm (FIWCA), is proposed with the idea of exchanging global and local information among the individuals in the populations with the goal of achieving a reasonable solution

within smaller number of iterations and also avoid trapping in any local optima.

Many global optimization techniques, such as semidefinite programming (SDP), compute an optimality gap that compares the achievable objective value corresponding to the feasible point from a local solution algorithm with the objective value bound from a convex relaxation technique. Rather than the traditional practice of completely separating the local solution and convex relaxation computations. This thesis next proposes a method that exploits information from a local solution to speed the computation of an objective value bound using a semidefinite programming (SDP) relaxation. The improvement in computational tractability comes with the trade-off of reduced tightness for the resulting objective value bound.

Recent development in power industry leads to a more complicated optimization problem to solve. Conventional way of solving static OPF problem is unsuitable for power networks, especially at the distribution level with the renewable energy sources (RES), energy storage systems (ESS) and flexible loads (FL), due to the time-coupled and stochastic dynamics. On the other hand, convex relaxation approaches are not suitable for distribution grids due to their high line resistance. This thesis next proposes a computationally efficient approach for solving receding horizon control (RHC) based multi-objective Alternating Current OPF problem in energy grids having intermittent renewable energy generation, storage devices and flexible loads. The method decomposes the solution into two stages. A Direct Current OPF (DCOPF) problem is solved using a RHC approach at the first stage by embedding forecasts on renewable generation and demand. A single-period ACOPF to optimize both line-losses and operating cost is solved at the second stage with the storage and flexible loads fixed at the optimal values computed in the first stage. In addition, hot-start is provided to the second stage optimization problem using the generation schedule computed at the first stage.

List of Publications

- Alireza Barzegar, Daniel K. Molzahn, Rong Su, , “A Method for Quickly Bounding the Optimal Objective Value of an OPF Problem using a Semidefinite Relaxation and a Local Solution”, IEEE Transaction on Power Systems, (Manuscript under review).
- Alireza Barzegar, Ali Sadollah, Rong Su, Seshadhri Srinivasan, “Fully Informed Water Cycle Algorithm for Solving Optimal Power Flow Problem in Energy Grids”, Journal of Experimental and Theoretical Artificial Intelligence, (The revised manuscript has been submitted).
- Alireza Barzegar, Ali Sadollah, Leila Rajabpour, and Rong Su, “Optimal power flow solution using water cycle algorithm,” 14th International Conference on Control, Automation, Robotics and Vision (ICARCV), IEEE, pp. 1-4, 2016.
- Alireza Barzegar, Rong Su, Changyun Wen, Leila Rajabpour, Yicheng Zhang, Amit Gupta, Chandana Gajanayake, and Meng Yeong Lee, “Intelligent power allocation and load management of more electric aircraft,” in Power Electronics and Drive Systems (PEDS), 2015 IEEE 11th International Conference on Power Electronics and Drive Systems (PEDS), IEEE, pp. 533-538, 2015.