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Adjusted optimal power flow solutions via parameterized formulation

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ABSTRACT

This work proposes a parameterized formulation of the optimal power flow (OPF) problem, which is aimed at preventing the divergence of the OPF iterative process. A parameter, whose function is to adjust the power demand and/or operational limits in case of absence of feasible solutions, is added to the objective function of the original optimization problem. This modified problem is solved through the nonlinear version of the predictor–corrector interior point method. Besides indicating the potential reasons for non-convergence of the iterative process, the proposed methodology also provides the possible actions that could be taken to determine an operational solution. Numerical results obtained with test systems of different sizes illustrate the application of the proposed strategy.

1. Introduction

The wide use of optimal power flow computational programs in the power system industry still has some drawbacks such as the lack of reliability of the convergence. Particularly, if the iterative process fails, alternative OPF solutions or information about the reason for divergence are usually not available.

There are two main reasons for non-convergence of the OPF. The first is the non-existence of a single solution satisfying simultaneously both the equality and inequality constraints. The second is the difficulty of reaching the optimal value of the performance index due to the geometric shape of the objective function. In both cases, some matrices evaluated during the search for the stationary point tend to become singular. If the power demand cannot be supplied under operational conditions, the rank of the Jacobian matrix of the set of equations representing the equality and active inequality constraints becomes deficient and at least one Lagrange multiplier tends to infinity. In this case, the infeasibility could be a consequence of a load level too high or too restrictive conditions imposed by the operating limits [1]. On the other hand, the determination of stationary points of constrained nonlinear functions with local minimum solutions too close is complex because of the oscillations around the optimal solution. In this situation, the drawback to obtain the optimal solution could be attributed to the analytical form of the objective function.

Failures in the OPF iterative process can be studied from the point of view of the maximum loadability of the power system satisfying the operational constraints, here referred to as the *operational maximum loadability*. The determination of this demand level is formulated in [2,3] as a static nonlinear optimization problem. The parameterized demand of each bus is maximized in a pre-specified direction through interior point methods. Alternatively, non-convergence of the OPF problem can be corrected through the restoration of the power system equations solvability, modelled as an optimization problem, as shown in [4,5]. In both cases, the minimum load shedding in a pre-specified direction is determined, such that the adjusted operational solution is obtained. Other methodologies include extra performance indexes in the maximum loadability problem. In [6], the OPF is applied to compute the cost associated to the maximum loadability point. The performance index used in this approach takes into account the distance of the current solution to the point of maximum loadability. Ref. [7] proposes an objective function composed by the summation of the active power generation cost and the maximum loadability parameter. This yields solutions combining the economic aspects of the power generation with the maximum loadability of the power network.

The present work proposes a formulation of the OPF based on the parameterization of the demand and/or the operational limits. The main objective of this strategy is to avoid the divergence of the iterative process and to indicate possible remedial actions to restore the optimal operational solution. For this purpose, the performance index of the problem to be solved is augmented by two terms, one related to the load shedding and the other related to the relaxation of the operational limits. These parameters indicate potential reasons for

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