Stability Constrained Optimal Power Flow

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***Abstract*— In this paper, traditional and stability constrained optimal power flow problems are presented with and without detailed generator and exponential load models. The formulations and models are compared using results obtained from benchmark test systems; interior point methods are used to obtain numerical solutions of the associated optimization problems.**

***Index Terms*— Optimal Power Flow, Modeling, Voltage Stability, Interior Point Methods.**

I. Introduction

As MORE and more power systems are becoming deregulated around the world, market influences are demanding greater attention to operating cost in comparison to the stability margin. In other words, more and more power systems are being operated closer to their stability limit as the open access market principles are being applied to them, resulting in higher loading conditions. A number of voltage collapse events around the world indicate this decreasing stability margin [1]. Therefore, it is evident that voltage collapse and system stability criteria and tools are of increasing importance in power systems.

Generally, voltage collapse is associated with the loss of an equilibrium point due to a contingency, which can be classified into saddle-node bifurcation (SNB) or limit-induced bifurcation (LIB) [2]. In recent years, there has been increasing interest in using optimization techniques in the study of stability problems. As a result, new analysis tools that incorporate optimization to maximize the stability margin are being introduced.

The use of optimization for stability purposes was first suggested. A survey of recent technical literature reflects the increasing interest in the application of optimization to stability problems. In [3], the voltage collapse problem was first formulated as an optimization problem. Interior Point Methods are used to determine the reactive power margins to voltage collapse and the maximum loadability of a power system in [4] and [5], respectively. In [6] the distance to a saddle-node bifurcation point is maximized using the optimal compensation parameter settings, and in [7] the distance to a voltage collapse is maximized using the optimal PV generator setting. The aforementioned algorithms only included constraints on the current operating point. In [8], a goal programming approach is used to incorporate stability and cost objectives.

In [7], a new technique to incorporate stability into traditional Optimal Power Flow (OPF) is introduced. Theoretical and numerical discussion for the application of optimization techniques to voltage collapse studies. A Lagrangian based proof to show that optimization techniques allow to compute the maximum loading point for both SNBs and LIBs is also presented here.

In [9], the current loading point and the maximum loading points are considered in the several Stability Constrained Optimal Power Flow (SC-OPF) formulations proposed in the paper. In [10], the balance between system security and "social benefits" is controlled by the market operators and participants via the weighting factors of the objective equation (associated with the 2 aforementioned objectives.) In [11], voltage stability indicators (L-indicators) are used to measure the voltage instability proximity of the current operating point. This method avoids the calculation of the information at the collapse point.

The current paper provides a thorough analysis of the application of optimization techniques in stability studies, followed by the incorporation of stability constraints into a traditional OPF. Also, the effect of detailed system modeling on the optimization solution is presented. Finally, a multi-stage Stability-Constrained OPF (SC-OPF) techniques is presented and is compared with the single stage SC-OPF solutions.

As shown in [12], [13], [14], traditional system models can be very inaccurate when modeling the system near its stability limit. Therefore, detailed generator and load models are incorporated into the simulations in order to improve the results. When constructing the generator models, special attention was paid to the generator reactive power limits since these limits have been shown to be a significant discrepancy between detailed and non-detailed generator models [13] and they have also been shown to play a very significant role in voltage collapse scenarios [2], [15], [16], [17].

Load models are also a key factor in stability analysis [12]. A numebr of different load models are presented in this paper and the volatge-dependent load model is used in the different OPF formulations to study their effects on costs and sysmtem stability.

The numerical results are obtianed by using the IEEE 30, 57 and 118 test systems, which are based on IEEE test systems that model portions of the American Midwest power system in the early sixties [18].

This paper is structured as follows: In Section II, the concepts of bifurcation and voltage stability are reviewed. Also, the background behind the OPF problem along with the methodology for calculating stability based on optimization techniques is presented. The Multi-stage optimization technique used in this paper is also presented in this section. In Section IV, a biref discussion of the generator and load models are presented. Numerical results from the traditional OPF and various stability-constrained OPF's are presented in Section V. A discussion of the detailed system modelling effects are

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