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Optimal distribution of primary control participation with respect to voltage stability

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ABSTRACT

In competitive electricity markets the transmission system will at times be heavily loaded. At these occasions prevention of voltage instability is an important objective that the system operator has to meet. In this paper a method for finding the primary control participation that maximizes the margin from an operating point to the saddle-node bifurcation surface is proposed. The arising optimization problem is solved using a steepest descent method. The proposed method can find its applications both in generation planning and in real-time operation of electric power systems.

1. Introduction

In today's power systems it is often desirable to utilize the power grid in an efficient way. To maximize the utilization of the power grid it is advantageous to steer the power system equipment in order to be able to increase the utilization but still keep the same small risk of system failure.

Much work has been put on the placement and coordination of control devices to enhance the stability margins of operating points [1–6]. In this paper we consider the relation between the distribution of the primary frequency control and the voltage stability properties of a power system. The distribution of the primary control participation will be chosen to maximize the margin to voltage instability in injected power space. By using this optimally distributed participation it is possible to operate the system in a more efficient way without running an unacceptably high risk of voltage instability.

To represent the margin to voltage instability we have chosen the distance from an operating point to the saddle-node bifurcation boundary under a given metric ρ. The choice of an appropriate metric ρ will depend on the uncertainties in future injected power. The uncertainties to be considered here will be the uncertainties in injected power in the very near future, since the primary control will be relieved within a short time period by the secondary or tertiary control [7]. Hence, the measure of the distance, *i.e.* the metric ρ, will be based on the probability distribution of the injected power within a certain specified time and can be deduced from historical system data and predictions.

In this paper it is assumed that at the present loading point p_0 the frequency equals the nominal frequency, *i.e.* that no primary control reserve is used. This restriction is just to make the calculations simpler and can be omitted without causing substantial difficulties. It will be shown how to find the distribution of the primary control participation that maximizes the distance from p_0 to the saddle-node bifurcation surface under the metric ρ. It will be assumed that $\nabla_y \rho(p,y)$ exists for all p and y of interest in $\mathbb{R}^n$, where n is the number of nodes where injected power is to be considered as uncertain.

Some of the primary control might not be dispatchable in a power system, therefore, constraints for the distribution of the primary control participation must be formulated. The method used to solve the optimization problem at hand will be able to deal with this type of restrictions by restricting the search path of the algorithm.

The paper begin with a detailed declaration of the problem to be solved, in Section 2. In Section 3 we give a definition of the saddle-node bifurcation set and explain how to calculate the normal vector of the saddle-node bifurcation surface using the method presented in [8]. Included in this section is also a discussion on generator reactive power limitations. In Section 4 an explanation of the metric ρ is given. Here, a reasonable definition of ρ is given. Section 5 is devoted to finding the distance to the saddle-node bifurcation surface under the metric ρ. This will be done using an iterative method, taking steps in the tangent plane to the saddle-node bifurcation surface. After taking a step in the tangent plane a projection onto the surface will give the next point. In Section 6 an iterative method that finds the distribution of the primary control partici-

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