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Impact of the exciter voltage limit to small signal stability region of a three-bus power system

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ABSTRACT

We investigate the influence of non-differential components to the power system small signal stability region in this paper. A method named unified expression function (UEF) is introduced to describe the piecewise, continuous and non-differential function in the small signal stability study. It converts non-differential points of the original function to poles of the UEF's derivative function. Then the derivative at those poles can be approximated by UEF's left-hand or right-hand derivative limits according to the requirement. Based on this method, impact of the exciter voltage limit to power system small signal stability region is then deeply discussed using a simple three-bus power system. We find that the exciter voltage limit can change elements of the system Jacobian matrix so as to cause jump of the system critical eigenvalue. As a result, two new Hopf bifurcation boundaries and a new instability hole emerge in the small signal stability region. When the exciter voltage limit varies, the new instability hole and the new Hopf bifurcation boundaries will change significantly. It makes the topological characteristics of the small signal stability region much more complicated. Since there are many non-differential components in power systems, they should be correctly considered in power system stability studies.

1. Introduction

Power system is a typical nonlinear dynamic system. There are many non-differential components, such as voltage limit of the exciter, discrete tap changing of on load tap changer (OLTC), hysteresis, dead band, and time delays. In the past, many studies have been done to properly consider the impact of such non-differential components in power system stability study. e.g. Refs. [1,2] discussed the impact of various exciter models to power systems small signal stability study. Ref. [3] analyzed the impact of the output limiters to the attraction area (i.e. small signal stability region) in power systems under small disturbance. Ref. [4] discussed the impact of OLTC to power system voltage stability. It was found that the system behavior that OLTC was described by a discrete model was significantly different with the one that OLTC was described by a continuous model. Ref. [5] discussed the influence of time delays on power system small signal stability analysis and small signal stability regions with various time delays were given in the paper. Refs. [6–10] discussed the modeling, influence, evaluation of the hysteresis and dead band in power system stability studies. Some suggestions and recommendations were given.

Small signal stability is the property that dynamic systems can return to the previous steady state condition after some small disturbances. It is essential to keep power system small signal stable in the daily operation. Small signal stable criterion is usually based on the eigen-analysis methods [1,11]. When all eigenvalues of the Jacobian matrix have negative real parts, power system is small signal stable. Once there is at least one eigenvalue with positive real part, power system is unstable. In parameter space, power system small signal stability region is defined as the set that consists of all small signal stable operating points. Since eigen-analysis is not valid at the non-differential points, few studies were performed on the impact of non-differential components to power systems small signal stability studies in the past.

In this paper, we introduce a UEF (unified expression function) method to describe the piecewise, continuous and non-differential functions. Based on the proposed method, we deeply investigate impact of the exciter voltage limit to power system small signal stability region using a three-bus system. It is found that two new Hopf bifurcation curves and a new instability hole in the stability region emerge when exciter voltage limit is considered. So, the exciter voltage limit has significant influence to power system small signal stability region. Since there are many non-differential components in power systems, they should be correctly considered in the stability studies.

Rest of this paper is organized as following: Section 2 gives a brief review to power system small signal stability region with its boundary tracing algorithm and UEF method. Section 3 gives the system model used in this paper. Case studies and discussions are given in Section 4. Conclusions are drawn in Section 5.

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