



Variable step-size prediction–correction homotopy method for tracking high-dimension Hopf bifurcations

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ABSTRACT

A new algorithm named prediction–correction homotopy continuation method (PC-HCM) is proposed to track Hopf bifurcations in power systems. To overcome the calculation burden of conventional method, the secant prediction method is proposed to track Hopf bifurcation homotopy path. And the automatic step-size control strategy is produced to implement the step-by-step correction, which ensures the calculation accuracy and speed. Simulation results with WSCC 3-machine 9-bus system and NewEngland 39-bus system indicate that the proposed PC-HCM can trace Hopf bifurcations quickly and accurately.

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1. Introduction

Hopf bifurcations are well known as a kind of local bifurcations that can cause the nominal equilibrium of power systems to lose their structural stability as the parameters pass through the bifurcations [1–3]. Based on the mechanism of Hopf bifurcations, many researches have been accomplished in order to find an excellent method to locate the Hopf bifurcation points [4,5].

Essentially, there are two main kinds of computation methods that are used to calculate Hopf bifurcations of power systems [6]. One is the direct method [7,8], its basic idea is to solve the nonlinear algebraic equations by an iteration method such as Newton method. However, the disadvantages are that the iteration method needs a good initial guess value and also that the solution obtained is just one point, and thus lacks the global information of the local bifurcation boundary. The other method is the continuation method [9], this method was originally developed in mathematical science, in 1990s Ajjarapu and Chiang applied it in power systems load flow equations to analyze the steady-state voltage stability [10,11] then Rajagopalan used it in DAE systems to analyze power systems dynamics [12]. Its basic principle is that it tracks the equilibrium curve of power systems step-by-step as the parameters vary, and then detects and locates the possible local bifurcations by using an interpolation method based on the critical eigenvalues of the related system Jacobian matrix [13,14]. Obviously, this

method need to calculate the critical eigenvalue of a large-scale matrix of power systems at each point on the boundary, of which the calculation burden is much heavy [15].

In this paper, based on the so far developments in this field, a new method named prediction–correction homotopy continuation method (PC-HCM) is proposed to trace Hopf bifurcation points. Since the characteristics of homotopy equations, this method can accurately determine bifurcation points as the direct method does without strict requirement of initial value. On the other hand, the calculation burden of this proposed method, which is not related to matrix inversion computation, is reduced compared with the continuation method. At the same time, the automatic step-size control strategy is used to guarantee the effective implementation of step-by-step correction, which not only ensures the veracity of result but also gives attention to speed.

In summary the contribution of the paper are as follows:

- (1) Propose a prediction–correction homotopy continuation method to calculate Hopf bifurcations of power systems.
- (2) Propose a secant prediction method and half step-size control strategy to trace homotopy path.

This paper is organized as follows. Section 2 provides outlines of Hopf bifurcation analysis model of power systems. Section 3 takes homotopy method into account and proposes the PC-HCM to track Hopf bifurcations. In Section 4, the proposed method is illustrated and tested with the WSCC 9-bus test system and NewEngland 39-bus test system. Finally, in Section 5, conclusions are duly drawn.

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