Electrical Power and Energy Systems 33 (2011) 1194–1202

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

A new algorithm for analysis of SVC's impact on bifurcations, chaos and voltage collapse in power systems

D. Padma Subramanian [a,*], R.P. Kumudini Devi [b], R. Saravanaselvan [b]

[a] Department of Electrical and Electronics Engineering, SRM Valliammai Engineering College, Kattankulathur-603203
[b] Department of Electrical and Electronics Engineering, College of Engineering, Guindy, Anna University, Chennai-25

ARTICLE INFO

Article history:
Received 2 June 2006
Received in revised form 10 January 2011
Accepted 28 January 2011
Available online 27 March 2011

Keywords:
Continuation algorithm
Bifurcation approach
Voltage collapse
SVC

ABSTRACT

In this paper, a numerical algorithm, based on initial value problem, using local parameterisation continuation technique is proposed for tracing stable and unstable steady state periodic solution branches of power systems. Bifurcation diagrams of steady state solutions are constructed by the application of the proposed algorithm. From the bifurcation diagrams, the existence of various bifurcation points such as, unstable Hopf bifurcation (UHB), stable Hopf bifurcation (SHB), cyclic fold bifurcation (CFB), saddle node bifurcation (SNB) and period doubling bifurcation (PDB) are identified. With the use of tools of nonlinear dynamics, voltage collapse points, and chaotic solutions due to period doublings are unearthed. Simulations have been carried out to analyse the sensitivity of the system with respect to load reactive power and compensating capacitor. The impact of SVC on Hopf bifurcations and occurrence of SNB are investigated. The algorithm is validated by applying it to a standard power system reported in literature and the results obtained are presented.

1. Introduction

Evolution of periodic solutions of power systems may lead to abnormal solutions, viz, chaotic solutions, subharmonic solutions and dynamic voltage collapse points. Hence a numerical method that computes both stable and unstable periodic solutions plays an important role in nonlinear dynamic analysis [1–7]. The packages BIFPACK [5], AUTO [6] and MATCONT [7] have been used successively on a wide range of problems. However, considering the characteristics of periodic solutions of autonomous systems, an alternate, initial value problem based approach is proposed in this paper. In addition, the effect of SVC on Hopf bifurcations, SNB and voltage stability are analysed.

Aprille and Trick [1], proposed a Newton algorithm for determination of a periodic solution and period of autonomous system. Holodniok and Kubíček [2] described an algorithm for the continuation of periodic solutions of the ordinary differential equation based on the shooting method and on the arc-length continuation algorithm DERPAR. Aluko and Chang [3] applied a Euclidean arc-length continuation procedure with adaptive step sizing to the boundary value problem solved by Newton–Fox method that fixes its phase by an automatically determined fixed-component index device. Deodel et al. [4] proposed an integral phase condition that minimizes the changes in the profile of a periodic solution. In the references cited above, [1] describes an approach to get one periodic steady state solution and its period, whereas approach to get continuum of periodic solutions is not given. Refs. [2–7] treat the problem as boundary value problem to obtain range of stable and unstable periodic solutions. The bifurcations and hence chaos exhibited by power systems with the variation in system parameters (e.g., load) have been reported widely in the literature [8,9]. However, in these references, simulation results are obtained using AUTO, subject to initial condition, boundary condition and integral constraints. This paper presents a simple and easy to implement algorithm based on initial value problem for the bifurcation analysis of both stable and unstable steady state periodic solution branches of autonomous systems. By the computation of Floquet multipliers, stability of converged solutions is analysed.

Most of the power systems today are operating under stressed conditions and are threatened by the possibility of voltage instability/collapse. Extensive literature exists on this subject from static as well as dynamic considerations. Static analysis is inadequate when the system dynamics is taken into account. There has been considerable interest in analysis of dynamic voltage instability based on bifurcation approach in recent years. It has been shown [10] that voltage collapse may arise from the existence of Hopf bifurcation, which is prior to the appearance of SNB. With increasing popularity of Flexible AC Transmission System (FACTS) devices and SVC being the well-understood and widely accepted FACTS device, it is worth exploring the effect of SVC on elimination of dynamic bifurcations, chaos and improvement of voltage stability. In [11–17], the effects of FACTS controllers on eliminating Hopf bifurcation and chaos have been studied. The effect of AVR gain

* Corresponding author.
E-mail address: subramanianpads@gmail.com (D. Padma Subramanian).

0142-0615/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2011.01.033