Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Electric Power Systems Research 77 (2007) 965–972
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

Optimum VAR sizing and allocation using particle swarm optimization

Amgad A. EL-Dib *, Hosam K.M. Youssef, M.M. EL-Metwally, Z. Osman

Electrical Power and Machines Department, Faculty of Engineering, Cairo University, Giza, Egypt

Received 10 June 2005; received in revised form 9 June 2006; accepted 20 August 2006
Available online 12 October 2006

Abstract

This paper proposes a solution technique for finding the optimum location and sizing of the shunt compensation devices in transmission systems. The objective of the formulation is to improve the voltage stability of the system while maintaining acceptable voltage profile. The problem can be formulated as an integer nonlinear optimization problem. The newly developed evolutionary technique particle swarm optimization (PSO) is used to solve this problem. Case studies with the Ward–Hale 6-bus, IEEE 14-bus and 30-bus systems are presented to illustrate the applicability of the algorithm. A comparison with the genetic algorithm (GA) is performed to show the quality of the solutions obtained by PSO.
© 2006 Elsevier B.V. All rights reserved.

Keywords: Voltage stability; Optimum VAR sizing and allocation; Transmission systems; Stability margin; PSO

1. Introduction

One of the most important problems facing any power system is voltage stability; this is due to the increased loading on the system and the difficulty of increasing the transmission capability to cope with this increased demand. This makes the process of identifying the degree of voltage stability of the system very crucial in order to prevent loading the system near or beyond the maximum loading point (MLP). Loading beyond the MLP will cause collapsing of the bus voltages leading to the instability of the system. Not only identifying the state of the system is important for the operator, but also how to modify the operating conditions to increase the stability margin.

The stability margin is the distance between the operating point and the maximum loading point. To identify this margin, numerous approaches have been presented.

In Ref. [1] the use of the convergence in the Newton–Raphson (NR) load flow calculations to estimate the stability limit was proposed. Another technique was suggested in Ref. [2], which is the continuation power flow. This technique is able to find the MLP without facing mathematical problems due to the singularity of the Jacobian matrix. In Refs. [3–5] the MLP was found using an optimization algorithm to maximize the load on the system while satisfying the load flow equations, then the stability margin can be directly determined.

In Refs. [6–8] another type of indicators were used which are the determinant of the Jacobian matrix or its minimum eigenvalue. These two indicators can give a sense of how far is the system from the collapse point.

In Refs. [9–11] the relation between the reactive power generation or the reactive power reserve at the dynamic sources and the degree of voltage stability is investigated. It was shown that to help improving the system security it is required to minimize the reactive power generated to ensure higher stability margin in both pre- and post-contingency states. This can be achieved by using static shunt compensation to supply the required reactive power at the base case.

In general, it is known that the control methods to face the voltage stability problem are classified in two types: preventive controls and corrective controls [12]. The preventive control is carried out before voltage instability actually occurs. The objectives of the preventive control are enhancement of the stability margin and improving the voltage profile. While the corrective control is used to stabilize a power system, directing the system trajectory onto a new stable equilibrium point shortly after a severe contingency.

Particle swarm optimization (PSO) is an optimization technique formulated by Kennedy and Eberhart [13] inspired by the natural behavior of a population of birds or insects. It simulates their performance during the search for food. The PSO has been

* Corresponding author.
E-mail address: amgadeldib10@yahoo.com (A.A. EL-Dib).

0378-7796/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2006.08.023

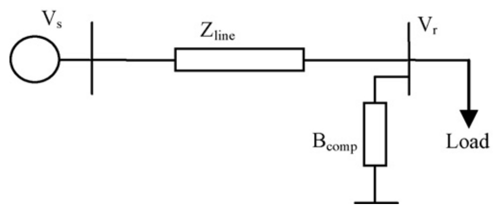

Fig. 1. Two-bus system model.

utilized in different applications in the power system field such as the solution of optimal power flow (OPF) or the reactive power planning problem [14]. It was also used in the design of power system stabilizers. PSO has been applied to calculate the MLP as an optimization problem in Ref. [5].

This paper proposes a solution algorithm for the preventive control problem through finding the optimum location, type and size of the static shunt compensation devices by using PSO to increase the stability margin of the system.

This paper is organized as follows: Sections 2 and 3 describe the basic concept and the formulation of the allocation problem as an optimization problem. In Section 4, a background on the PSO technique is introduced and the modification used to make the PSO handle integer variables. Section 5 describes the application of the PSO to solve the allocation problem. In Section 6, the proposed method is applied on the Ward–Hale 6- and IEEE 14- and 30-bus test systems. Finally, the performance of PSO is compared to the genetic algorithm (GA) as one of the evolutionary optimization techniques suitable for this kind of a problem. Conclusion of the obtained results is then introduced in Section 7.

2. Basic concept

The effect of shunt compensation on the voltage profile and the stability margin can be demonstrated using a two-bus system model as given in Fig. 1.

Fig. 2 shows three *P–V* curves: the solid one is the curve without shunt compensation, the dashed one is with capacitive

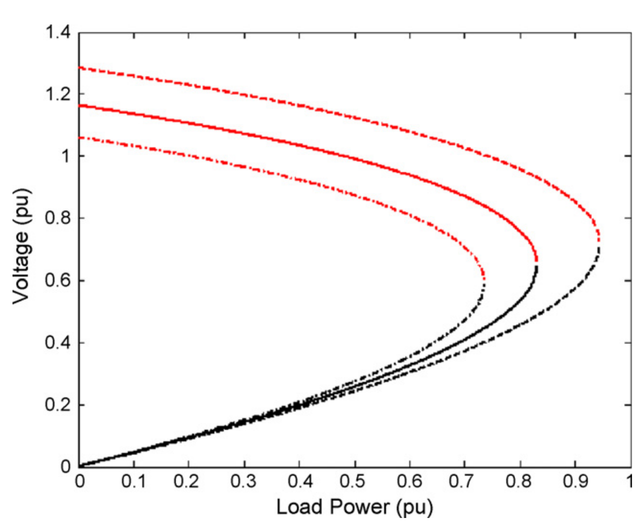

Fig. 2. Effect of compensation on *PV*-curves.

compensation and the dash–dot curve is with inductive compensation.

From these curves, it is evident that:

1. The capacitive compensation increases the stability margin but also increases the no load or base case voltage.
2. The inductive compensation has exactly the opposite effect of the capacitive compensation.

The same effect for both types of compensation can be shown for larger systems. Therefore, to achieve the required target which is to increase the stability margin while maintaining the acceptable voltage profile, e.g. (±5%), both types of compensation may be required.

3. Problem formulation

The problem of preventive control has been tackled in many papers. In Ref. [15] it is required to increase the stability margin by first identifying the saddle node bifurcation point by the direct equilibrium tracing approach. After that, the margin sensitivity for different controls is calculated. According to this sensitivity analysis, the best controls are chosen to participate in an optimization problem to find minimum amount of control to achieve the required margin. Ref. [16] proposes a method for identifying dispersed reactive power (VAR) supply that will enhance power systems pre- and post-contingency voltage security subject to technical and economic constraints. The problem is formulated in two stages. The first stage involves a nonlinear optimization problem that minimizes the amount of reactive supply. The second stage employs a mixed-integer linear program, which optimizes the number of candidate buses for VAR support. In Ref. [9] a method is based on the fact that the increase in reactive reserves is effective for enhancement of voltage stability margins of pre- and post-contingency states. Ref. [10] uses the sensitivity methods for reactive support allocation using the minimum singular values of the Jacobian matrix and the total generated reactive power as indicators of the stability margin. In Ref. [17] an interior point method was implemented to solve the optimal reactive dispatch (ORD) problem. Since the problem of maximizing the stability margin is a special case of the ORD the same concept can be applied. Ref. [18] introduced a method of determining the minimum amount of shunt reactive power (VAR) support which indirectly maximizes the real power transfer before voltage collapse is encountered. The problem is solved using a relaxation strategy that operates with a predictor-corrector optimization scheme. In Ref. [19] a hybrid tool is presented to assist the operator in reactive power dispatching for voltage profile improvement. Advantage is taken of both numerical and heuristic (knowledge-based) methods in order to find a practical number of control variables which can be effectively used to solve voltage violations. Evolutionary techniques were also used in solving the problem of reactive power optimization. In Ref. [20] an approach to optimal reactive power planning is introduced based on the genetic algorithm. In Refs. [21,22] the evolutionary programming technique was used to solve the reactive power planning problem. As stated before

Download English Version:

https://daneshyari.com/en/article/705808

Download Persian Version:

https://daneshyari.com/article/705808

Daneshyari.com