Electrical Power and Energy Systems 33 (2011) 147–153

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

Coordinated preventive control of transient stability with multi-contingency in power systems using trajectory sensitivities

Y.H. Li [a,b], W.P. Yuan [a,b], K.W. Chan [a,*], M.B. Liu [b]

[a] Department of Electrical Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, PR China
[b] College of Electric Power, South China University of Technology, Guangzhou 510640, PR China

ARTICLE INFO

Article history:
Received 22 June 2008
Accepted 7 June 2010

Keywords:
Transient stability
Optimal power flow
Generation rescheduling
Trajectory sensitivity
Multi-contingency

ABSTRACT

In this paper, the challenging multi-contingency transient stability constrained optimal power flow problem is partitioned into two sub-problems, namely optimal power flow (OPF) and transient stability control, solved in turn with conventional well trusted power system analysis tools instead of tackling it directly using a complicated integrated approach. Preventive multi-contingency transient stability control is carried out with generation rescheduling based on trajectory sensitivities using results obtained from a conventional transient stability simulation. A new iterative approach is proposed to optimally redistribute the generation from the critical machines to noncritical machines with the help of conventional OPF. Results on the New England 10-machine 39-bus systems demonstrate that the proposed method is capable of handling multiple contingencies and complex power system models effectively with solution quantity and time comparable with conventional integrated approaches.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Transient stability is one of the major threatens for power system operation. With increasing economical pressure and intensified transactions, especially in competitive environment, to maintain transient stability of the economic operation to an acceptable level becomes more important. Preventive control or remedial actions for transient stability enhancement should be taken if credible dangers of instability are detected. Security dispatch is to provide economic operation in the presence of a specific list of contingencies, which becomes more complicated when transient stability concerns are taken into account [1]. In this paper, a new methodology for transient stability dispatch is introduced to reconcile the possible conflict between economy and transient stability simultaneously in an optimal operating point.

Basic formulation for transient stability dispatch is presented preliminarily in [2]. The usual cost function is augmented by including transient stability indices across selected cutsets. A trade-off between optimal economy and steady-state and transient stability is obtained by optimization. Similarly, in [3], instability index is defined with potential energy and algebraic interpretations. Insecurity cost is assigned together with the total system cost. After that, optimal dispatch is taken for real power scheduling.

Generation rescheduling has long been recognized as an effective means to alleviate power system insecurity. For several decades, many efforts, for example, in [4–11], have been made for dynamic security dispatch via preventive control and generation rescheduling. In [4–6], sensitivities of the energy margin to system parameters, such as generation output, are proposed for generation rescheduling. In [4], sensitivity with respect to generation power is studied based on extended equal area criterion and a related transient stability margin. Economic dispatch algorithm is remarked to be extended to transient stability dispatch. In [5], generation rescheduling is carried out by the combination between transient stability constraints and optimization techniques based on the sensitivities of the energy margin. In [6], preventive generation rescheduling is taken based on a structure preserving energy margin sensitivity-based analysis to stabilize a transiently unstable power system. In [7,8], trajectory sensitivities are calculated to provide a preventive rescheduling scheme. In [7], the sensitivity trajectory of the most critical rotor angle, defined as a good coherent index, with respect to the generation outputs is addressed to determine the rescheduling. In [8], optimal dynamic security constrained rescheduling is resolved by introducing power constraints for transient stability, which is produced based on trajectory sensitivities for credible contingencies.

Unlike sensitivity methods, in [9], transient stability dispatch is accomplished by the improvement of the coherence of machines according to the variation rate of generator speeds at fault clearing time. Optimization should be taken into account for the ultimate rescheduling. In [10], generation rescheduling is realized via shifting generation from critical machines to noncritical machines, the amount of which depends on the size of stability

* Corresponding author.
E-mail address: eekwchan@polyu.edu.hk (K.W. Chan).

0142-0615/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2010.06.017

margin determined by the single machine equivalent hybrid transient stability method. In [11], transient stability preventive control is carried out by generation rescheduling using the linear relationships, which is not always true, between critical clearing time and generator rotor angles.

In reality transient stability dispatch appears to be an extended OPF problem with add-on transient stability constraints. Mathematically, the extended OPF can be formulated as a semi-infinite programming (SIP) problem with finite dimension for optimal variables but infinite dimension for transient stability constraints in time domain. Up to now the application of SIP in power systems has made some progress in two directions. In [12–16], infinite-dimensional constraints, such as differential-algebraic equations describing the system dynamics and transient stability constraints, are discretized, which transforms the SIP problem to conventional finite programming problem. In [17–20], infinite-dimensional constraints are transcribed to require integration over the regions where the infinite dynamic constraints are violated. However, the first direction suffers the inefficiency resulted from higher-dimensional constraints by discretization and tactical grid selection strategies; the second direction can keep the number of constraints low, but the accurate evaluation of the integrals arises huge time-consuming computation and is not attractive. As a result, an alternative approach based on intelligent methods such as genetic algorithm and particle swarm optimization have been proposed [21,22]. Though this approach is time-consuming, its results were encouraging.

In this paper, the partition approach presented in [8] is adopted, extended and enhanced to deal with complex power system models and multi-contingency. The challenging multi-contingency transient stability constrained optimal power flow problem is partitioned into two sub-problems, namely optimal power flow (OPF) and transient stability control, solved in turn with conventional well trusted power system analysis tools instead of tackling it directly using a complicated integrated approach. Preventive multi-contingency transient stability control is carried out with generation rescheduling based on trajectory sensitivities calculated with accurate initial values using results obtained from a conventional transient stability simulation. A new iterative approach is proposed to optimally redistribute the generation from the critical machines to noncritical machines with the help of conventional OPF. Results on the New England 10-machine 39-bus systems demonstrate that the proposed method is capable of handling multiple contingencies and complex power system models effectively with solution quantity and time comparable with conventional integrated approaches.

2. Mathematical model

2.1. Definition of trajectory sensitivities

Dynamic process of a power system can be described by the following differential-algebraic equations:

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{y}, \lambda), \quad \mathbf{x}(t_0) = \mathbf{x}_0 \tag{1}$$

$$\mathbf{0} = \mathbf{g}(\mathbf{x}, \mathbf{y}, \lambda), \quad \mathbf{y}(t_0) = \mathbf{y}_0 \tag{2}$$

where $\mathbf{x}$ is a vector consisting of state variables such as generators rotor angles and velocities; $\mathbf{y}$ is a vector consisting of algebraic variables such as voltage magnitudes and angles; $\boldsymbol{\lambda}$ is a vector consisting of parameters such as mechanical power of generators.

Subsequently, trajectory sensitivities ($\partial x/\partial \boldsymbol{\lambda}$ and $\partial y/\partial \boldsymbol{\lambda}$) can be calculated as follows [8,23,24]:

$$\frac{\partial \dot{\mathbf{x}}}{\partial \boldsymbol{\lambda}} = \mathbf{f}_{\mathbf{x}}(\mathbf{x}, \mathbf{y}, \lambda)\mathbf{x}_{\lambda} + \mathbf{f}_{\mathbf{y}}(\mathbf{x}, \mathbf{y}, \lambda)\mathbf{y}_{\lambda} \tag{3}$$

$$\mathbf{0} = \mathbf{g}_{\mathbf{x}}(\mathbf{x}, \mathbf{y}, \lambda)\mathbf{x}_{\lambda} + \mathbf{g}_{\mathbf{y}}(\mathbf{x}, \mathbf{y}, \lambda)\mathbf{y}_{\lambda} \tag{4}$$

For convenience, the initial values $\mathbf{x}_{\lambda}(t_0)$ and $\mathbf{y}_{\lambda}(t_0)$ were set to zero in [8,24]. However, as illustrated in the following section, $\mathbf{y}_{\lambda}(\bullet)$ and $\mathbf{x}_{\lambda}(t_0)$ can be derived conveniently to obtain a more accurate trajectory sensitivities, and hence, to improve the performance of OPF [25].

2.2. Detailed derivation of trajectory sensitivities and the determination of their initial values

Classical second-order model for synchronous machines is adopted here as an example. It is assumed that $\boldsymbol{\lambda}$ represents mechanical input power of generators and other system's parameters remain invariant. The trajectory sensitivity equation of generator i with respect to generator k's mechanical input power is given as:

$$\begin{aligned} M_i \frac{\partial \dot{\omega}_i}{\partial P_k} = &- \sum_{j=1, j\neq i}^{n} (E_i E_j B_{ij} \cos\delta_{ij} - E_i E_j G_{ij} \sin\delta_{ij}) \left(\frac{\partial \delta_i}{\partial P_k} - \frac{\partial \delta_j}{\partial P_k} \right) \\ &- \sum_{j=1, j\neq i}^{n} \left[(B_{ij} \sin\delta_{ij} + G_{ij} \cos\delta_{ij}) \left(\frac{\partial E_i}{\partial P_k} E_j + \frac{\partial E_j}{\partial P_k} E_i \right) \right] \\ &+ \frac{\partial P_i}{\partial P_k} + 2E_i \frac{\partial E_i}{\partial P_k} G_{ii} \end{aligned} \tag{5}$$

$$\frac{\partial \dot{\delta}_i}{\partial P_k} = \frac{\partial \omega_i}{\partial P_k} \tag{6}$$

where $Y_{ij} = G_{ij} + jB_{ij}$ is the ijth element of the reduced admittance matrix when only internal generator buses are preserved; M_i is an inertia constant of generator i; δ_i and δ_j are generator i and j's rotor angle, respectively; $\delta_{ij} = \delta_i - \delta_j$; E_i and E_j are generator i and j's internal voltages, respectively, which represent trajectory sensitivity algebraic variables y as discussed in this paper; the initial values of $\partial P_i/\partial P_k$ and $\partial \omega_i/\partial P_j$ are given, respectively, as follows:

$$\frac{\partial P_i}{\partial P_k} = \begin{cases} 1, & i = k \\ 0, & i \neq k \end{cases} \tag{7}$$

$$\frac{\partial \omega_i}{\partial P_j} = 0 \tag{8}$$

In pre-fault period, the mechanical input power P_i of a generator equals to its electrical one as shown in Fig. 1.

$$P_i = P_{ei} = \frac{E_i V_i}{x'_{di}} \sin(\delta_i - \theta_i) \tag{9}$$

Firstly, the expression of $\partial E_i/\partial P_k$ is derived. Since $\partial E_i/\partial P_k$ equals to zero when $k \neq i$, only $\partial E_i/\partial P_i$ is needed to be derived. Differentiating both sides of (9) with respect to P_i yields:

$$\begin{aligned} 1 = &\frac{\partial E_i}{\partial P_i} \cdot \frac{V_i}{x'_{di}} \cdot \sin(\delta_i - \theta_i) + \frac{E_i \cdot V_i}{x'_{di}} \cdot \cos(\delta_i - \theta_i) \cdot \frac{\partial \delta_i}{\partial P_i} + \frac{\partial V_i}{\partial P_i} \cdot \frac{E_i}{x'_{di}} \\ &\cdot \sin(\delta_i - \theta_i) - \frac{E_i \cdot V_i}{x'_{di}} \cdot \cos(\delta_i - \theta_i) \cdot \frac{\partial \theta_i}{\partial P_i} \end{aligned} \tag{10}$$

The computation of $\partial E_i/\partial P_k$ is then become the determination of $\partial V_i/\partial P_i$ and $\partial \theta_i/\partial P_i$. Additionally, network equation during the pre-fault period is given as:

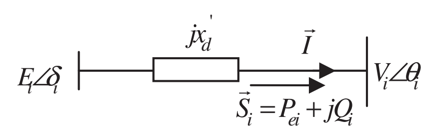

Fig. 1. Equivalent circuit of a generator.

Download English Version:

https://daneshyari.com/en/article/399016

Download Persian Version:

https://daneshyari.com/article/399016

Daneshyari.com