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Security assessment accounting uncertainties in line parameters and control variables with the considerations of transmission line unavailability

Q1 Pushpendra Singh[a,*], L.S. Titare[b], S.C. Choube[c], L.D. Arya[d]

[a] Department of Electrical Engg., Rajkiya Engineering College, Banda, UP 210201, India
[b] Department of Electrical Engg., Govt. Engineering College, Jabalpur, MP 482 011, India
[c] Department of Electrical & Elex., UIT-RGPV, Bhopal, MP 462036, India
[d] Department of Electrical Engg., SGSITS, 23-Park Road, Indore, MP 453331, India

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Abstract

This paper presents a new algorithm for voltage stability security assessment accounting uncertainties in the line parameters and control variables. Security index has been evaluated using Monte-Carlo simulation with & without consideration of unavailability of transmission lines, which is used to perform contingency selection. Further, probabilistic insecurity index at various loading conditions considering voltage stability limit has been obtained using cut-set method for single & double line outages. Static voltage stability limit for various sampled values of system parameters and control variables have been obtained using continuation power flow methodology. Few cases have been used to train back propagation algorithm (BPA). Obtained results for contingency selection based on security index have been compared with well-established methods.

Keywords: Contingency ranking; Probabilistic insecurity index; Artificial neural network; Back propagation algorithm

1. Introduction

The monitoring and analysis of power system security has become an integral part of modern energy management systems (EMS), but its real time implementation is still a challenging task to power system engineers. For secure

Q2 * Corresponding author.
E-mail addresses: erpsingh@rediffmail.com (P. Singh), lstitare@yahoo.co.in (L.S. Titare), scchoube@rgtu.net (S.C. Choube), ldarya@rediffmail.com (L.D. Arya).
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Nomenclature

p_f	Probability of failure
$C_1, C_2, \ldots, C_n$	Minimal cut-sets
P, Q	Real & reactive power flow
$\underline{P}_{gk}, \underline{Q}_{gk}$	Lower bound on active & reactive power generation at k^{th} bus
$\bar{P}_{gk}, \bar{Q}_{gk}$	Upper bound on active & reactive power generation at k^{th} bus
P^o_{gk}, Q^o_{gk}	Active & reactive power generation at k^{th} bus under current operating condition
P^p_{gk}, Q^p_{gk}	Active & reactive power generation at k^{th} bus under predicted load condition
V^o_i	Load bus voltage at i^{th} load bus under current operating condition
V^p_i	Load bus voltage at i^{th} load bus under predicted load condition
$\underline{V}_i, \bar{V}_i$	Lower and upper bound on i^{th} load bus voltage
NG	Number of generator buses
NB	Number of buses
NL	Number of transmission lines
$\hat{p}$	Security index without consideration of unavailability of transmission line
SI	Security index with consideration of unavailability of transmission line
J	Load flow Jacobian
Y	Output of the network
R	Line resistance
X	Line reactance
Bc	Line charging susceptance
R_T	Total line resistance
X_T	Total line reactance
Bc_T	Total line charging susceptance
S_d	Total system load (real & reactive power)

operation of power system, the operating personnel must know which system disturbances or contingencies may cause limit violations and force the system to enter into the emergency state. Security assessment provides information to the system operators about the secure and insecure nature of the operating states in the event of an unforeseen contingency, so that proper control/corrective action can be initiated within the safe time limit. Due to time limitation in real time situations, it is not feasible to carryout detailed analysis of all the possible contingencies. Hence, contingency selection is performed to pick out those contingencies that are potentially harmful to the system and the probability of their occurrence, in order to reduce the number of contingencies. Two popularly used methods for contingency selection are ranking methods and screening methods. Ranking methods involve ranking of contingencies in approximate order of severity which is based on the value of performance index. Performance indices are explicitly expressed in terms of network variables and are directly evaluated. Screening methods use approximate network solutions such as distribution factors, DC load flow, linearised load flow, AC load flow, local solution methods etc. to identify cases causing limit violations (Ejbe et al., 1996; Naik et al., 2015).

Contingency evaluation is one of the most important tasks encountered by planning and operation engineers of power systems. In planning, contingency analysis is used to examine the performance of a power system and the need for new transmission expansion due to load growth or generation expansion. The operation contingency analysis assists engineers to operate the power system at a secure operating point where equipments are loaded within safe limits and power is delivered to customers with acceptable quality standard. The purpose of contingency screening and ranking is to determine which contingencies may cause power system limit violations and/or system instability according to voltage stability criteria. The margin between the voltage collapse point and the current operating point is used as the voltage stability criterion. Several PI-based methods have been suggested and tested for voltage security analysis (Ejbe et al., 1996; Naik et al., 2015; EL-Abiad and Stagg, 1962; Bavghman and Schweppe, 1970; Ejebe and Wollenberg, 1979; Stott et al., 1987; Suzuki et al., 1992; Jasman and Lee, 1993; Moghavvemi and Omar, 1998;

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