상정사고를 고려하는 최적 조류 계산의 분산 병렬 처리 기법에 관한 연구

김 진호° , 허 돈, 박 종근
서울대학교 전기공학부

김 발호
홍익대학교 전기전자제어공학부

An Efficient Distributed Parallel Processing Method in Security Constrained Optimal Power Flow

Jin-Ho Kim° , Don-Hur, Jong-Keun Park
Seoul National University

Balho H. Kim
Hong-Ik University

Abstract - An operationally secure power system is one low probability of blackout or equipment damage. The power system is needed to maintain a designated security level at minimum operating cost. The inclusions of security make power system problem complex. But, because security and optimality are normally conflicting requirement, the separate treatments of both are inappropriate. So, a unified hierarchical formulation is needed. In this paper, the overview of security constrained optimal power flow (SCOPF) is presented and an introduction of parallel distributed formulation to SCOPF is also presented.

Keywords - security constrained OPF (SCOPF), parallel, distributed

1. Introduction

The most important requirement of power system is the economic and secure operation of electricity. And one of the main difficulties normally found in the practical use of optimal power flow (OPF) is inclusion of the security constraints. Such an important role is done by efficient technologies. This technology is being incorporated into the economy-security functions. The appropriate representation of security constraints may increase of order of magnitude in problem size[1-3].

The security constrained optimal control of an electric power system is extremely difficult task : this difficulty tends to increase with growth in system size, interconnection, and other operating problems.

An optimal power flow solution gives the optimal power dispatch for a static power system. One of the main aspects of system security is steady-state security. This means the ability of the system to operate steady-state-wise within the specified limits of safety and supply quality following a contingency[5].

Some methods use an entirely linearized model, neglecting reactive power and voltage considerations, and accepting the active power flow accuracy limitations of the DC power flow. Others use a linear model for the outage system, so that only approximate outage case MW overload constraints can be reflected into the optimal power flow. Another approach is to apply security-oriented group import/export constraints, which are not easy to define in high interconnected system[1,4].

An extention to conventional OPF is to add constraints that model the limits on components during contingency conditions. That is, "security constraints" or "contingency constraints" allow the OPF to meet pre-contingency limits as well as post-contingency limits[5].

In this paper, the overview of SCOPF is presented and the introduction of parallel distributed algorithm to SCOPF is explained.

2. Security

2.1 Security Concept

The economy-security field is still so evolutionary that a common set of concepts and terminology has not been fully established. In general, "security" used as pertaining to maintenance of supply, that is, the avoidance of loss of load[1,2,5].

Today's on-line security-related functions deal with static snapshots of the power system. This quasi-static approach is to a great extent the only currently do-able one, since dynamic analysis and optimization are more difficult and computationally more time-consuming.

The overall aim of economy-security control is to operate the system at lower cost, with the guaranteed avoidance or survival of emergency conditions. This necessarily means operating the system as close as possible to its security limits.

2.2 Security Level

A formal classification of power system security levels is necessary in order to define the relevant system's actions. Fig.1 illustrate the security level, in which the arrowed lines represent involuntary transitions between level 1 to 5 due to contingencies[1-5].

Level 1 has the ideal security : the power system survives any of the relevant

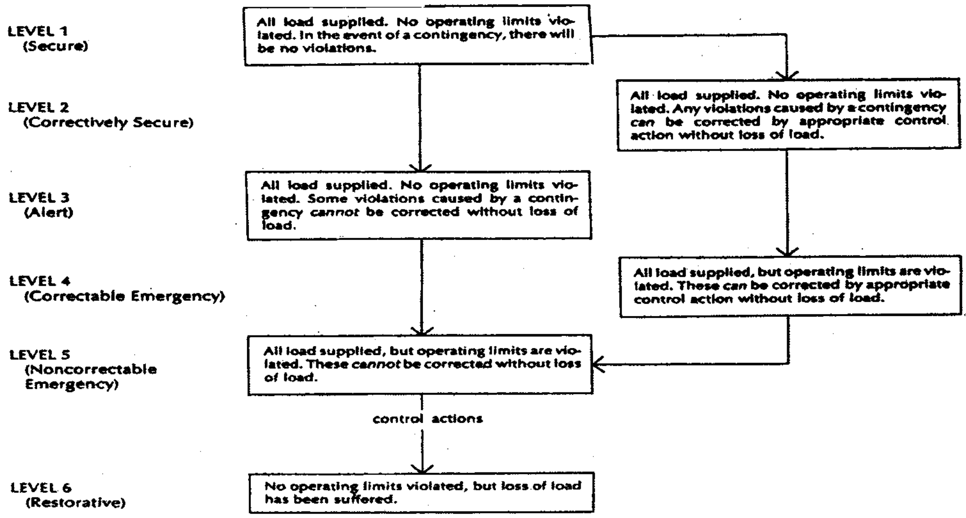

Fig. 1. Power system static security levels.

contingencies without relying on any post contingency corrective actions. Level 2 is more economical, but it must remove violations without loss of load, within a specified period of time. Level 2 concept applies primarily to post-contingency control.

The removal of violations from level 4 generally requires "corrective rescheduling" or "remedial action", bring the system to level 3. Once level 3 has been reached, further "preventive rescheduling" must be performed to return the system to either level 1 or 2.

3. Contingency Analysis

Security Assessment and Security Control are main function of economy-security fields. The former determines the security level of the system operating state. The latter calculates the appropriate security-constrained scheduling needed to optimally achieve the target security level[5].

As indicated in Fig.1, the static security level of a power system is characterized by the presence or otherwise of emergency operating conditions in its actual (pre-contingency) or potential (post-contingency) operating states. System security assessment is the process whereby any such violations are detected.

Security assessment has two main functions. The first is violation detection in the actual system operating state. The second function of security assessment is contingency analysis.

3.1 Purpose of contingency analysis

Contingency analysis is performed on a list of credible contingency cases. Those contingencies that, if they occurred, would create steady-state emergencies must be identified and ranked in the order of severity. The power system operator and/or an automated security-constrained schedules should respond to each insecure contingency case in decreasing order of severity[2,8,9].

3.2 Approaches to contingency analysis

Each contingency should be simulated on the base-case model of the power system. Then the calculated post-contingency operating state is checked for operating limit violations. In practice, there are several difficulties. The first is to establish the appropriate power system model. The second is to determine which contingency cases to consider. The third difficulty is the fact that processing power-flow solutions for large numbers of contingencies, usually at frequent interval of time, requires an enormous computational effort.

The general approach now widely adopted is to separate on-line contingency analysis into three distinct stages : contingency definition, selection, and evaluation.

In contingency definition, contingencies whose probability of occurrence is deemed sufficiently high are listed.

The purpose of contingency selection is to shorten the original long list of contingencies by eliminating that vast majority of cases having no violations. On the basis of these result, the contingency cases are ranked in rough order of severity.

Contingency evaluation is performed on the successive individual cases in decreasing order of severity. The process is continued up to the point where no post-contingency violations are encountered[5,8,9].

4. Security-Constrained OPF

The purpose of an on-line OPF function is to schedule the power system controls to achieve operation at a desired security level, while optimizing an objective function such as cost of operation.

The ultimate real-time goal is to have the security-constrained scheduling calculation initiated, completed, and dispatched to the power system entirely automatically, without human intervention.

4.1 Formulation of SCOPF

Original formulation of SCPOF is

$$\min\ f(u,x)$$
$$\text{s.t. } g(u,x)=0\ ,\ h(u,x)\geq 0 \quad (1)$$

In this paper, we are going to introduce the decomposition technique, so called, auxiliary problem principle. In this method, original problem is decomposed into regions by duplicating the border variables and imposing coupling constraints between two variables. For the purpose of distributing the computation, the formulation of original problem is like (2)[5,9].

$$(x^{k+1},\ y^{k+1}{}_a) = \arg\min\{F(x,y_a)\},\ (x,y_a)\in A \quad (2)$$
$$F(x,y_a) = f_a(x) + \frac{\beta}{2}\|y_a - y^k{}_a\| + \gamma y_a(\ y^k{}_a - y^k{}_b) + \lambda^k y_a$$

By locating each processor physically in its assigned region, the communication time would be on the order of the radius of the region[9].

In trying to optimize only a portion of an interconnected system, there is fundamental problem of how much the scheduling is allowed to affect the neighbors. One approach is to assume that any scheduling within the internal system shall not alter the flows or voltages at the boundaries with external system. In this case, the external system is simply not modeled. Preoptimized values are fixed. It does not take advantage of the mutual-assistance benefits of interconnection[5].

A somewhat less restrictive approach is to model the boundary buses as generators with fixed MVARs, but it may be difficult to predefine realistic values for these ranges.

The most common and straightforward approach is to provide detailed power flow modeling of the external network in a buffer zone around the optimized part of the system.

4.2 Solutions of SCOPF

Contingency constraints are basic element of economy-security control. The total number of the contingency constraints to be imposed on the OPF calculation is enormous. Depending on the power system size, each contingency case may involve hundreds or even thousands of inequalities. But, fortunately, very few of these constraints will be binding in the solution.

The general approach to the solution of SCOPF is as follows.

First, contingencies are selected at the current operating points. Second, selected constraints are incorporated into OPF. Third, OPF problem is solved subject to the both base case and post contingency case[1,2,5,9]

5. Discussion & Conclusion

In this paper, a distributed parallel formulation for the solution of security constrained OPF using decomposition method, auxiliary problem principle, is proposed.

To take advantages of the parallel computation, original problem is decomposed into regions.

We are going to develop the interior-point-method for finding optimal point(s) of SCOPF.

Until now, we are developing the distributed mechanism for the run of SCOPF software and we established UNIX environment, and its platform is SunSolaris.

As we are in the initial state of research, the results of case studies are not presented as yet.

[REFERENCE]

[1] O. Alsac, B. Stott, "Optimal Load Flow with Steady-State Security", IEEE Trans. on PAS, Vol. 93, pp 745-751, May/June 1974.

[2] A.Monticelli, M.V.F. Pereira, S. Granville, "Security-Constrained Optimal Power Flow with Post-Contingency Corrective Rescheduling", IEEE Trans. on Power System, Vol. PWRS-2, No. 1, February 1987.

[3] M.Rodrigues, O.R.Saavedra, A.Monticelli, "Asynchronous Programming Model for the Concurrent Solution of the Security Constrained Optimal Power Flow Problem", IEEE Trans. on Power System, Vol.9, No. 4, November 1994.

[4] Balho H. Kim and Ross Baldick, "Coarse-grained Distributed Optimal Power Flow", Trans. on Power System, May 1997

[5] Allen J. Wood, Bruce F. Wollenberg, 'Power Generation, Operation and Control', John Wiely & Sons, INC, 1996.

[6] Arthur R. Bergen, 'Power System Analysis', Prentice-Hall, INC, 1970

[7] Alex Papaleexpoulos, Shangyou Hao, "Cost /Benefit Analysis of an Optimal Power Flow: The PG&E Experience", IEEE Trans. on Power System, Vol. 9, No. 2, May 1994.

[8] O. Alsac, J.Bright, M.Paris, B.Stott, "Further Development in LP-Based Optimal Power Flow", IEEE Trans. on Power System, Vol.5, No.3, August 1990

[9] Guy Cohen, "Optimization by Decomposition and Coordination : A Unified Approach", IEEE Trans. on Automatic Control, Vol.AC-23, No.2, April 1978