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Decomposition–coordination strategy to improve power transfer capability of interconnected systems

M.K. Kim [a,1], D. Hur [b,*]

[a] Department of Electrical Engineering, Dong-A University, 840 Hadan 2-dong, Saha-gu, Busan 604-714, Republic of Korea
[b] Department of Electrical Engineering, Kwangwoon University, Kwangwoon-ro 20, Nowon-gu, Seoul 139-701, Republic of Korea

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A B S T R A C T

The maximum power transfer across critical corridors or interfaces is limited by various system constraints such as thermal, voltage, and stability limits. In an open transmission access environment, these constraints would be deeply influenced by the interactions among the path flows in different control areas. In particular, small signal stability, commonly in the form of low frequency oscillations, is considered a crucial factor since it limits the power transfer capability of transmission paths in interconnected multi-area systems. Based on such considerations, the focal point of this paper will be a new approach to coordinating the path transfers across multiple control areas, giving exclusive attention to the small signal stability. The differential eigenvalue method is used to derive the damping ratio constraints for satisfying the small signal stability criteria which are linear inequality constraints expressed in terms of the control parameter. Using Bender's decomposition, the proposed methodology is formulated as a master problem and a set of sub-problems, each associated with one area motivated by the improvement of the overall computational efficiency via parallel processing. The performance of the decomposition–coordination method is illustrated with a 68-bus system from which it might be deduced that inter-area transfer margin could be improved by reasonable rescheduling of the neighboring tie-line flows.

1. Introduction

The deregulation in the electricity market leads to higher loading of the transmission network, resulting in the operations of power systems that require many sophisticated forms of security constraints to be met during a variety of possible operational conditions. These include static constraints such as thermal limits of the circuits as well as dynamic constraints, for example voltage, transient, and small signal stability limits. By and large, the dynamic constraints of a system may become more restrictive than the static limits, depending on its operational conditions. Most prominently, a good knowledge of the effects of violating these constraints is very important in operating the system closer to its stability limits by preventing the vulnerable states and obeying the allowable system's operational ranges.

Since a modern power grid consists of multiple entities interconnected tightly with each other [1], interconnected multi-area systems undergo the processing of more transactions across different control areas as the power systems get more stressed with increasing or varying loads. Thus, a power system interconnected with multiple areas needs to be operated in a coordinated manner for maintaining the overall system reliability and ensuring economic operation although each area has its own system operator. Moreover, interconnected multi-area systems are usually decomposed into areas based on various criteria and the operations and control of the whole network of interconnections are undertaken by all the ISOs responsible for their respective areas. To keep the security of the network at a desired level, a higher level of coordination among the ISOs is indispensable and, at the same time, it is necessary to evaluate the path transfer capability by considering the interactions with all the other parts of the entire power grid.

Because of the inherent tradeoff between increasing utilization of the grid and security of the operation, various mathematical techniques using optimal power flow (OPF) have been employed for enhancing the transfer capability without violating dynamic security constraints [2–4]. Traditionally, researches in the area of dynamic security have fully focused on voltage and transient stability. Attempts to provide practical models for OPF subject to voltage and transient stability constraints have been aimed towards the development of new methods for calculating the transfer capability; in this regard, many methods have been developed [5–8]. With the increased generation capacities, different areas in the power system network are combined with their own inertias, making the system prone to inter-area oscillations. As a result, the issue

* Corresponding author. Tel.: +82 2 940 5473; fax: +82 2 940 5141.
E-mail addresses: mkkim@dau.ac.kr (M.K. Kim), dhur@kw.ac.kr (D. Hur).
[1] Tel.: +82 51 200 7745; fax: +82 51 200 7743.

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