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Sensitivity analysis of multi-area optimum power flow solutions

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Abstract

The objective of this paper is to formulate a multi-area full AC interconnected power system optimal power flow (OPF) model and develop a methodology for sensitivity analysis of the OPF solution, which can give information of how operation changes as a parameter in the power pool changes, given that optimality is maintained as the parameter varies. Information of these sensitivities is valuable for numerous practical reasons relating to system planning and tariffication.

Keywords: Interconnected system; Multi-area optimal power flow; Sensitivity analysis

1. Introduction

A utility operating area is a portion of an electric power system completely bounded by appropriate metering facilities. Within the area generation is dispatched so that economic and reliable services can be provided to its native customers and the users of its transmission system. It has to generate power for its native load as well as to maintain the total power flow in or out of the control area at a specifically scheduled amount. If no purchases or sales are being made outside the control area, the algebraic sum of the power flowing on the interconnections should be 0.

Interconnection of control areas is almost universal throughout the world [1]. In an interconnected multi-area system, joint operation of generation resources can result in significant operational cost savings and reliability enhancing. A centralized power pool is a formal arrangement, in which the utilities appoint a central dispatcher who makes all the generation and transmission decisions. The central dispatcher has control over the members' facilities and possesses all the necessary information to make the optimal system decision. Both the energy dispatch and the setting up of interchanges are made jointly for all the participating areas in the interconnected multi-area system. Economic power transfers take place when the generators in the pool are dispatched to minimize the aggregated system operating cost.

The most economic arrangement of the pool of course is that the power transfers between areas are free to vary until the total generating cost within the pool is minimized. However, sometimes this practice is not adopted because utilities may want to retain some of their autonomy. For instance, a utility may want to decide a floor on the amount of power it will generate to maintain security according to its own standards. A possible arrangement is that each member, based on its marginal cost curve, submits buy/sell quotations hourly to the central dispatcher. The quotation states the price at which the utility is willing to buy power, the higher price at which it will sell power, and the quantities of power involved. The quotations are based on each potential seller's incremental cost of generating power and each potential buyer's decremental cost (i.e., the amount of own-generation cost that the buyer would save by buying instead of generating power). After the bids have been placed, the central dispatcher will decide the total interchange level for each member.

2. Formulation of pool optimal power flow model

The optimal power flow (OPF) solution described in Refs. [2,3] were originally designed for a single-area system. The aims of the pool OPF model is to extend the single-area OPF solution to the general multi-area case. In the multi-area case the operating cost of an

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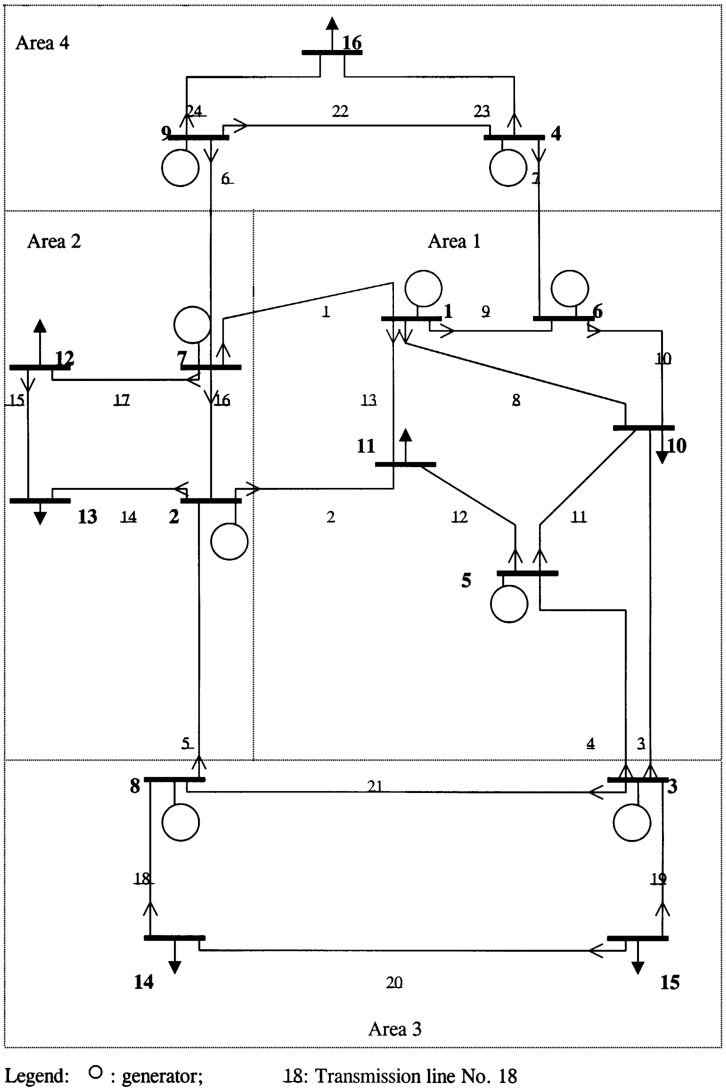

Fig. 1. System diagram.

interconnected power system, constrained by prescribed interchanges between areas is minimized. The scheduled area interchanges act as constraining equations in the economic optimization procedure. Here, the problem is basically the OPF problem which has the objective of minimizing the total cost of operating the spatially separated generating units in the whole interconnected system subject to the set of equations that characterize the interchange of power between areas (sub-systems) and the usual operational constraints such as voltage, power flow and tap-change limits. Notations are given in the Appendix A.

2.1. Objective function:

The objective function may be expressed in the following form:

$$\text{Minimize } C = \sum_{i \in \text{NG}} C_i(P_{Gi}), \quad (1)$$

where $C_i(P_{Gi})$ is the operating cost of producing P_{Gi} units of real power at the generating plant at bus i. There are several constraints to the problem.

Table 1
Generation information in the 16-bus network

Bus no.	Coefficient of cost function			Area
	Quadratic ($/MW^2)	Linear ($/MW)	Constant ($)	
1	0.0100	14.0	800.0	1
2	0.0160	14.0	1000.0	2
3	0.0150	19.0	750.0	3
4	0.0130	21.0	2400.0	4
5	0.0150	18.0	500.0	1
6	0.0180	18.0	700.0	1
7	0.0150	16.0	1600.0	2
8	0.0160	17.0	1300.0	3
9	0.0150	16.0	900.0	4