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Network Losses-Based Economic Redispatch for Optimal Energy Pricing in a Congested Power System

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Abstract

An efficient, low-cost and reliable operation of a power system by adjusting the available electricity generation resources to supply demand of the system is required to ensure satisfied economic plant dispatching. This paper proposes a scheme for economic redispatch model considering the transmission issues such as transmission congestion and network losses, in order to obtain an optimal energy price in supporting competitive electricity market under deregulated environment of a power system.

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Keywords: Economic dispatch, transmission congestion, electricity market, locational marginal prices, optimal power flow, DC-OPF, nodal price, energy price, deregulated power system.

1. Introduction

Competitive structure in deregulated electricity market is supposed to have the potential to promote economic efficiency of the electricity industry [1, 2]. However, as the power flow violates transmission constraints, redispatching generating units is required and this causes the price at every node to vary. Hence, transmission management should be assessed carefully in order to obtain an efficient and transparent price but satisfying all market participants [3-5]. However, congestion can cause the market players to exercise market power that is able to result in price volatility beyond the marginal costs [6-8]. In order to alleviate the system from further cascading failure, either preventive or protective actions must be taken such as load shedding strategy and DG penetration within congested zone [9-11].

Therefore, efficient, low-cost and reliable operation of a power system by adjusting the available electricity generation resources to supply demand of the system is needed to ensure economic plant dispatching. The main idea of the importance of economic dispatch is to minimize the total cost of generation while meeting the operational constraints of the available generation resources.

This manuscript introduces a scheme for economic redispatch model considering the transmission issue in order to obtain an optimal energy price, especially when transmission congestion occurs. A proposed scheme is presented to briefly review the main idea behind the energy price calculation, which is represented by locational marginal price (LMP), and further discuss the techniques used to incorporate transmission congestion taking into account network losses minimization into the model.

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2. Economic Dispatch Considering Network Losses

The definition of economic dispatch as cited in [12] is "*the operation of generation facilities to produce energy at the lowest cost to reliably serve customers, recognizing any operational limits of generation and transmission facilities*". The production cost of generation is analysed during the dispatch, subject to data that is concerning fuel cost and electrical power output [13-15]. A quadratic equation is utilised to approximate the cost function along with several cost coefficients. The key objective of the economic dispatch problem is to find a set of active power delivered by the committed generators to satisfy at any time the required demand subject to the unit technical limits and at the lowest production cost. For this reason, it is of great importance to solve this problem as fast and precisely as possible. The configuration of the economic dispatch problem with network losses considered is slightly more intricate to set up compared to the dispatching ignoring losses. This is because the network losses are added as an additional constraint to the equation. Figure 1 illustrates a thermal power generation system connected to an equivalent load bus through a transmission network.

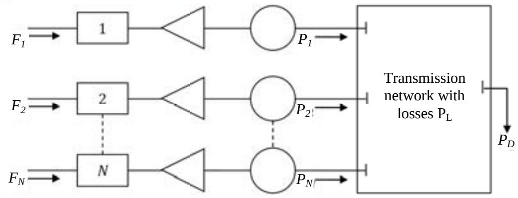

Fig. 1 *N* thermal units serving load through transmission network

The objective function of the system operation, F_T, is the same as that defined in the previous section. However, the equation must now include the network losses P_L as a constraint. Therefore, the optimization problem considering network losses may be stated as

Minimize

$$F_T = F(P_{gi}) = F_1 + F_2 + F_3 + \dots + F_N = \sum_{i=1}^{N} F_i(P_{Gi}) \tag{1}$$

Subject to:

- The energy balance equation $(\mathcal{E} = 0 = P_D + P_L - \sum_{i=1}^{N} P_{Gi})$
- and the inequality constraints $(P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$ for $i = 1,2, \dots, N)$

The same procedure involving Lagrange function is also performed in order to establish the required condition for the solution of the minimum operating cost, hence,

$$\mathcal{L}(P_{Gi}, \lambda) = F(P_{Gi}) + \lambda \left(P_D + P_L - \sum_{i=1}^{N} P_{Gi} \right) \tag{2}$$

The set of equations involving the computation of network losses is more difficult to solve than the set of equations with no losses. Nonetheless, there are two general approaches to solve this problem [14]. The first approach is the *loss-formula* method that generates a mathematical expression for the losses in the network only, as a function of the power output of each unit. The second approach is by integrating the load–flow equations as crucial constraints in the formal establishment of the optimization problem which is known as the *optimal power flow.*

2.1. Network Losses Model

Generally, the power loss is represented in the terms of active power generation only. This is called the *B-coefficient* method and was first developed by Kron in 1951, then popularized by Kirchmayer in 1958 and extended by Happ and Meyer [13]. The transmission losses is given by

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} P_{Gi} B_{ij} P_{Gj} \tag{3}$$

Where, P_{Gi}, P_{Gj} is the real power generation at i and j plants and B_{ij} are the power loss coefficients which are constant under assumed conditions. Then the loss equation based on bus impedance matrix and current vector is given by