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Comparison of transmission pricing models

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ABSTRACT

In this paper we make a comparison of three transmission pricing models: the Wangensteen model, the optimal power flow model and the Hogan model. The similarities among the models are that all can be used in locational pricing systems. In these systems the prices are calculated as the marginal cost that in turn equals the marginal benefit to load. In the Wangensteen model and the original optimal power flow model, the locational prices are equal to the Lagrange multipliers associated with the power flow equations. On the contrary, Hogan's model and the modified optimal power flow model express the locational prices as equal to the reference bus (node) price, the marginal costs of losses, and the marginal costs of congestion. The Wangensteen model is used for educational purposes and considers elastic load. The optimal power flow model has been widely used in electrical engineering and dispatch of power systems. Load is assumed to be inelastic. Hogan's model is an economist's version of the optimal power flow model and considers elastic load. It also gives an expression for the locational prices in terms of an equilibrium equation.

1. Introduction

The electricity transmission network has an important function in facilitating trade of electricity between geographically dispersed markets. Because many generators are interconnected via the transmission network, together they can provide improved reliability and lower overall generation costs [12]. The complexity of analyzing electricity networks stems from Kirchoff's laws that govern the power flows. The network topology and characteristics together with the joint interaction of transmission congestion, losses, and energy prices from injections and withdrawals of electricity contribute to the formation of electricity prices at different locations. The correct pricing of electricity transmission is crucial in providing signals to the market players for efficient short-run use and long-run capital investments. In the short-run, demand functions are given and the objective is to optimize the use of generation, distribution, and transmission capacity. In the long-run, the objective is to create incentives for the siting of generation and transmission expansion.

In electricity transmission systems there are mainly three short-term cost components that must be considered; the congestion cost, the cost of losses, and the cost of ancillary services such as reactive power [1]. Congestion cost is the cost resulting from scarcity of transmission capacity. Transmission congestion affects the economics of the network in that cheaper generation is replaced by more expensive generation in order to reduce power flows. In the deficit and surplus areas, the optimal price of electricity is equal to the local marginal cost of generation, or to the local willingness to pay. The price of transmission usage between any two locations is defined as the difference in locational prices between those two locations. Marginal losses may give considerable price differences for some of the locations and small deviations from the uncongested case can make even larger effects. These differences could have a significant effect in the siting of generators and loads. Generators provide ancillary services[1] such as regulation[2] and frequency control, spinning reserves, supplemental reserves, backup reserves, voltage control, and black start. It appears that, in many regions, the first four of these services can eventually be provided by many suppliers or customers through competitive markets. The latter two services, by contrast, have locational characteristics that limit potential competition; so it is likely that they will continue to be provided through non-competitive institutional mandates.

2. Transmission pricing methods

There are different methods for pricing transmission: locational (nodal) pricing, zonal pricing, uniform pricing, and Chao–Peck pricing. Locational pricing [8] maximizes social welfare taking into account transmission constraints and losses, and is performed by a

[1] The Norwegian hydro-based power system includes the following ancillary services: primary reserves (frequency control), secondary reserves (manually controlled), reactive power, frequency activated load shedding and generation shedding.

[2] Regulation may be provided by load as reduced demand.

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