Renewable and Sustainable Energy Reviews 38 (2014) 572–580

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Transmission management for congested power system: A review of concepts, technical challenges and development of a new methodology

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ARTICLE INFO

Article history:
Received 27 June 2012
Received in revised form
12 May 2014
Accepted 24 May 2014

Keywords:
Transmission congestion and management
Network losses
Economic dispatch
Optimal power flow
Shift factor
Electricity market
Locational marginal price (LMP)

ABSTRACT

Transmission networks have some constraints that should be addressed in order to ensure sufficient control to maintain the security level of a power system while maximising market efficiency. The most obvious drawback of transmission constraints is a congestion problem that becomes an obstacle to perfect competition among the market participants since it can influence spot market pricing. As the power flow violates transmission constraints, redispatching generating units is required and this will cause the price at every node to vary. This manuscript presents concepts, technical challenges and methodology for investigating an alternative solution to the redispatch mechanism and then formulates LMP scheme using an optimisation technique that may well control congestion as the main issue. The LMP scheme are varied and improved to take into account the energy price, congestion revenue, cost of losses, as well as the transmission usage tariff by utilising shift factor-based optimal power flow (SF-OPF), which is derived from the well-known DC optimal power flow (DC-OPF) model.

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http://dx.doi.org/10.1016/j.rser.2014.05.089
1364-0321/

1. Introduction

In deregulated electricity markets, transmission networks hold an essential role in supporting interaction between producers and customers because it should provide an unbiased environment for all participants [1]. Furthermore, bottlenecks in transmission lines are an obstacle for perfect competition among market participants [2]. One obvious drawback of transmission constraint is congestion. The system is said to be congested when both parties agree to produce and consume a particular amount of electric power but fails to do this because of a transmission network exceeding its thermal limits. This eventually brings further impacts to exercise market power that can cause price volatility beyond the marginal costs [3]. Therefore, an efficient congestion management becomes one of the most important indicators of the design of a power market to display the network capability in a competitive market.

The fundamental issue in a competitive market is the market clearing price (MCP) mechanism. As the power flow violates transmission constraints, redispatch of generating output is required and this causes different prices at every node. This phenomenon is defined as locational marginal prices (LMPs), also known as *load pocket* [4]. Based on these facts, the relationship between MCP and transmission management has a strong relationship, which needs to be assessed in order to obtain an efficient and transparent price to satisfy all market participants.

The DC-OPF has been used widely to primarily manage congestion through computing LMPs, due to its speed and strength. However when the LMP scheme takes line losses into account the advantageous features of the DC-OPF based LMP mode are diminished.

Therefore, this paper examines an advanced solution for the re-dispatch mechanism, which not only improves the computation of congestion and losses, but also formulates a new LMP scheme using an optimisation technique that considers congestion as the crucial problem. The LMP schemes are adapted and improved to take into account the cost of losses, congestion revenue, energy prices, as well as an embedded cost, called the transmission usage tariff (TUT). The objective is to support the development of a standard market design in managing transmission systems which promotes economic efficiency, lowers delivered energy costs, maintains power system reliability and mitigates exercising market power. Accordingly, three schemes of the LMP are introduced, namely LMP-lossless, LMP-loss and LMP–TUT. The LMP-lossless model has two components, namely, energy price and transmission congestion revenue. The second scheme in this LMP modeling, LMP-loss, includes three components: energy price, transmission congestion revenue and transmission losses cost. LMP–TUT is formulated based on the LMP-loss but takes into account a tariff for transmission usage as well. These schemes are developed to evaluate the performance of the proposed method of shift factor-based optimal power flow (SF-OPF), which is derived from the DC-OPF model.

This manuscript is organised as follows. Section 2 elaborates issues surrounding transmission management in the electricity industry. Section 3 gives an overview of economic dispatch and optimal power flow. Section 4 explores the congestion and supply/demand equilibrium and Section 5 presents a generic LMP scheme for congestion management. Section 6 proposes an improved method of OPF for LMP. The basic tasks of the improved method and its conceptual flowchart are presented in Section 7. Finally, the conclusion of this paper is presented in Section 8.

2. Issues surrounding transmission management in electricity industry

Within an open access environment transmission management holds a vital role in supporting transactions between producers and customers. Bottlenecks in the line transmission for example, will be an obstacle to perfect competition among the market participants. Hence the operation and planning of a transmission network system should be planned in an effective manner [5,6]. Fig. 1 shows some issues faced due to transmission management in a deregulated environment.

One obvious drawback of transmission constraint is congestion problems. Congestion is a result of transmission constraints limiting network capacity that interferes with power transfer from a set of power transactions [7]. Two other significant issues that should also be addressed in transmission management are transmission usage tariff and transmission losses [8–10]. Transmission usage tariff is defined as embedded cost in [6], while [11] classified it as the use of transmission system charge. This is to convert standard operating and maintenance costs into a transmission charge cost, which refers to the previous capital cost acquired in the transmission infrastructure development and maintenance. The last aspect in transmission management is the cost of losses. Transmission losses are simply defined as the difference between the total power supply from generation and the total power accepted (demand) by customers in the system. Even though the impact of losses may be small compared to other potential sources of market inefficiency they must be considered as well [12]. To meet the required demand

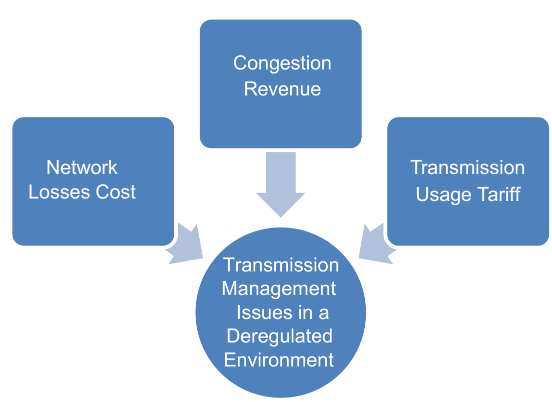

Fig. 1. Issues surrounding transmission management in a deregulated environment.