AN APPROACH TO OPTIMAL DISPATCH OF BILATERAL ELECTRICITY CONTRACTS REGARDING VOLTAGE STABILITY

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Abstract: This paper proposes a methodology for optimal dispatch of bilateral electricity contracts, which may endanger the system voltage stability in light of short-term operational planning of a deregulated power system. In this framework the value that each owner of a transaction is willing to pay will reflect how much the electricity contract is important to be implemented physically. The proposed model dispatches optimally the bilateral transactions regarding the prices offered by owners of bilateral contracts for reactive power and transmission capacity utilization in one hand and, the total operational costs of reactive power resources in the other hand. The model also includes the limits imposed by the physical constraints on the power system such as nodal power flow equations, limits on capacity of resources, voltage stability constraint and etc. The proposed framework is formulated as an AC-OPF problem and is implemented over the IEEE 14 bus test system using CONOPT solver (GAMS) to illustrate the feasibility of the approach.

Keywords: Bilateral contracts, Deregulation, Reactive power, Voltage stability, OPF.

1. INTRODUCTION

Competition in purchasing and selling of a commodity so-called electricity is a new interesting paradigm in deregulated power industries which many countries around the world have found it necessary with their long run economic strategies. The prevalent market models for trading of electricity can be summarized into three groups; decentralized markets, pool or centralized markets and hybrid markets (Cañizares, et al., 2001). The existence of an independent entity named System Operator (SO or ISO) or in some models Market Operator (MO) who should adapt market activities regarding the available transmission network capability is a common feature among the market models. In practice, the transmission capability of power systems is usually restricted by some factors such as equipment thermal limits; available active and reactive power capacities and the limits associated with the network stability problems. Optimal reactive power management can quite increase the available transmission capability as a consequence of the improvement of the network voltage profiles as well as reduction of active and reactive power losses. Therefore in an open electricity market, reactive power support is an ancillary service that plays a significant role in facilitating power transportation (Bhattacharya and Zhong, 2001). This ancillary service becomes very important when the loadability margin of the network diminishes due to high volume of transactions. In this situation ISO needs to follow a transparent procedure for readjusting reactive power resources to provide enough security level in the network. However the electrical transactions should be curtailed at least in some part, once the available reactive power resources are inadequate to achieve this goal. It is important to note that reasonably reactive power resources have different utilization prices in a deregulated power system, which may influence the ISO's selection of reactive power resources to meet system requirements. Up to now some standpoints toward competitive reactive power procurement have been presented in numerous research articles, which can be categorized into three groups. In the first approach, ISO, on the behalf the consumers purchase reactive energy based on the purpose of minimizing the reactive power procurement costs (Lamont and Fu, 1999; Danachi et al., 1996). In this methodology, active power transactions usually are kept constant. Recently a method that incorporates voltage stability criterion into the reactive power market formulation is presented in (Lin, 2003).

In the second approach, active and reactive energy are dispatched simultaneously to meet some purposes such as minimizing active power generation costs (Baughman and Siddiqi, 1991), maximizing social welfare of active power market (Cañizares, et al., 2001), or minimizing total incurred costs of active and reactive power generation (Xie, et al, 2000). This mechanism is usually proposed for hybrid or OPF-based market structure. From the point of this view, a security constraint optimal power flow is used to determine the approved transactions regarding the voltage stability criterion (Cañizares, et al., 2001). Active and reactive marginal prices can also be determined at each location as by-product of optimal dispatch problem.

In the third approach, a reactive power market is designed for a structure in which energy is totally traded through bilateral contracts (Zhong and Bhattacharya, 2003). In this structure, reactive power cost is determined independent of energy market activities with the aim of minimizing deviations from transaction requests and real power loss minimization. In this model, ISO acts on behalf of the consumer in purchasing the reactive power. Transactions are assumed to have the same priority and hence no clear competition can be distinguished among the owners of transactions. Voltage stability problem has not yet been established in this reactive market structure.

In this paper we make an attempt to develop the ideas proposed in (Lin, 2003, Zhong and Bhattacharya, 2003) and, introduce a competitive market structure for reactive power supporting in an open access electricity framework. The optimal power flow equations of the market are modified so as to include voltage stability criterion. The performance of reactive power market structure is evaluated by performing different case studies on the IEEE 14-bus test system and for each case, Locational Marginal Prices of reactive power are calculated at each node.

2. REACTIVE POWER COSTS

Reactive power cost analysis ahs been reported in detail in (Lamont and Fu, 1999; Danachi et al., 1996). Synchronous generators and static VAR compensators are the equipment that their associated reactive power generation costs are reviewed briefly.

2.1 Synchronous Generators

Synchronous generators are the main sources of active power generation in a power system, however they are also able to provide reactive power to fulfill transmission requirements. Active power generation cost of a generator is usually approximated by a second-order polynomial as a function of active power output of the generator. However it is very difficult to determine the cost of reactive power supported by a generator because no fuel is consumed for reactive power production. Reactive power cost determination for a generator is still an open issue for research, which needs further investigation, but we use here the model proposed by (Rider and Paucar, 2004) for generators' reactive power cost calculations as following:

$$C_{gqi}(Q_{gi}) = [C_{gpi}(S_{gi}) - C_{gpi}(P_{gi})]K_{gi} \tag{1}$$

Where:

$C_{gpi}(P_{gi}) = aP_{gi}^2 + bP_{gi} + c$ is active power production cost.

Q_{gi} : is reactive power output of generator i.

S_{gi} : is apparent power output of generator i.

K_{gi} : is profit rate of active power generation, usually between 0.05~0.1

2.2 Static compensators

In general, static reactive devices are used to regulate voltage magnitudes throughout the power network. They have different characteristics in term of dynamics and speed of regulation. Switched capacitors as well as reactors have low installation and operation costs but they are slow in response to a reactive requirement. Static VAR compensators in contrast to fixed reactive devices are able to response to a reactive requirement rapidly, however their installation and operation costs are moderately high. Regardless of considering reactive power quality, in this paper static VAR compensator's costs are modelled in term of their reactive outputs as following (Rider and Paucar, 2004):

$$C_{ci}(Q_{cj}) = r_{cj}Q_{cj} \tag{2}$$

Where:

r_{cj} : is unit cost of reactive power in \$/MVAR.

Q_{cj} : is amount of supplied reactive power in MVAR.

In above equation, it is assumed that a reactive compensator is installed at bus j.

3. THE PROPOSED MARKET FOR REACTIVE POWER

3.1 Electricity market structure

Nowadays electrical energy is provided through electricity market. Market transparency mainly depends on its clearing mechanism. In centralized electricity market, the pool would be the only place for the participants to bid for electricity and ancillary