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Determination of Mean and Variance of LMP Using Probabilistic DCOPF and T-PEM

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***Abstract*—The Locational Marginal Pricing (LMP), calculated based on deterministic load flow and Optimal Power Flow (OPF), is used in power markets studies. In this paper, an algorithm has been proposed to calculate the mean and variance of LMP. The proposed method is based on Two Point Estimate Method (T-PEM). The probabilistic LMP can be used to have a good estimation for LMP.**

***Keywords*—LMP; Mean Value; Variance Value; Power Market; Probabilistic DCOPF; Probability Theory; T-PEM**

I. Introduction

The Locational Marginal Pricing (LMP) is a dominant approach in energy market operation and planning to identify the nodal price and to manage the transmission congestion. The LMP can be calculated by the Optimal Power Flow (OPF) and DCOPF-based simulations. The DCOPF has been used by many utilities for price forecasting and system planning. In [1], a DCOPF-based algorithm has been presented with the Fictitious Nodal Demand (FND) model to calculate the LMP.

Considering the uncertainties associated with the input data of load flow [2], the LMP can be considered as a stochastic variable. In probability theory, it is well known that the mean and variance value of each variable, which should be forecasted, must be determined. So, the mean and variance of LMP, as a probabilistic variable in power markets, must be determined, too.

In this paper, the optimum generation of power plants, is calculated using an iterative probabilistic DCOPF-based algorithm with the Fictitious Nodal Demand (FND) model [1]. The probabilistic LMP is calculated based on T-PEM. The effect of uncertainty of system parameters can be considered, too. The proposed LMP mean and variance calculation method is applied to the PJM 5-bus system [3] and the results have been compared with the deterministic calculations results. The LMP mean and variance calculation can be used by LMP simulator for price forecasting and system planning.

II. Probabilistic DCOPF Considering Losses

The DCOPF can be modeled as the minimization problem of the total production cost subject to energy balance and transmission constraints. It is assumed that the demand elasticity is equal to zero [1]. According to [1], the minimization procedure, including losses, can be expressed by the following equations:

$$Min \sum_{i=1}^{N} c_i \times G_i. \tag{1}$$

$$s.t. \sum_{i=1}^{N} DF_i^{est} \times G_i - \sum_{i=1}^{N} DF_i^{est} \times D_i + P_{Loss}^{est} = 0 \tag{2}$$

$$F_k = \sum_{i=1}^{N} GSF_{k-i} \times (G_i - D_i - E_i^{est}) \le Limit_k \qquad for\, k = 1,2,...,M \tag{3}$$

$$G_i^{\min} \le G_i \le G_i^{\max} \qquad for\, i = 1,2,...,N \tag{4}$$

where, N = number of buses, M = number of lines, c_i = generation cost at Bus i (\$/MWh), G_i = generation dispatch at Bus i (\$/MWh), $G_i^{\max}, G_i^{\min}$ = maximum and minimum generation output at Bus i (MWh), respectively, D_i = demand at Bus i (\$/MWh), GSF_{k-i} = generation shift factor from Bus i to line k, $Limit_k$ = transmission limit of Line k (MW), DF_i^{est} = estimated delivery factor. It should be noted that we have:

$$DF_i = 1 - LF_i = 1 - \frac{\partial P_{Loss}}{\partial P_i}, \quad P_{Loss} = \sum_{k=1}^{M} F_k{}^2 \times R_k \tag{5}$$

$$\frac{\partial P_{Loss}}{\partial P_i} = \sum_{k=1}^{M} 2 \times R_k \times GSF_{k-i} \times (\sum_{j=i}^{N} GSF_{k-j} \times P_j) \tag{6}$$

$$E_i = \sum_{k=1}^{M_i} 0.5 \times F_k^2 \times R_k \tag{7}$$

In the equation (6) the GSF_{k-i} shows the relationship between the pure injection of bus i and power flow of the line k. This point can be written as follows:

$$B \times \theta = G - D \tag{8}$$

where, $B = imag(Y_{bus})$, $G = 1 \times N$ generation matrix, $D = 1 \times N$ demand matrix, $\theta = 1 \times N$ voltages angles matrix and $Y_{bus} = N \times N$ network admittance matrix. According to the DC load flow formulation, we have:

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