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"Implementation of Optimal Power Flow Based Nodal Pricing for Deregulated Power System"

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***Abstract*— Generation companies (GENCO) participate in day-ahead power pool trading to maximize their profit in the energy market. The self-scheduling of the GENCOs in the day ahead market is based on the operating constraints. Since the self-scheduling problem is complex conventional methods for optimizing may suffer excessive computational burden. The self-scheduling of the generators is a function of LMP. In the case of LMP forecasting, the main challenge is to forecast the volatile prices accurately in a day-ahead market. The optimum power flow (OPF) in an interconnected grid system is an important operation with respect to transmission loss and other operational constraints of the power system. Moreover, with the deregulation of the power industry there has been a huge change in the process of operation and control strategies of optimum power flow (OPF). The increase in power transaction with respect to real time increase in demand and for satisfying those demand the competition of the market players (GENCOs), are creating stress on the power system and preventing normal flow of power. Thus, leading to power congestion in the system. This project incorporates the method for determining the locational marginal pricing with and without congestion due to over load and rescheduling of generators is carried out accordingly in the deregulated energy market using Power World Simulator (PWS) software for IEEE-9, IEEE-14 and IEEE-30 bus system.**

***Keywords*— LMP Locational marginal pricing LP Linear programming.**

I. INTRODUCTION

Locational Marginal Pricing (LMP) is the marginal cost of supplying an increment of electrical demand at a specific location on the electrical network, considering both supply and demand offers as well as the transmission constraints. The term LMP can also be generally used for the price of a load aggregation point. Deregulated markets are the complex markets with many participants who buy and sell electricity. The optimal scheduling of a power system is the determination of the generation for every plant such that the total cost for generation is minimum while satisfying the system constraints. An important point to note is that the restructuring process is not uniform in all countries. In many instances, it started with the breaking up of a large vertically integrated utility. In certain other instances, restructuring was characterized by the opening up of small regional monopolies to create competition. In a deregulated electricity market, a single company, normally referred to as utility, owns all the infrastructure that stores and distributes electricity. That same utility is also responsible for buying the electricity from electricity-generation companies, selling the electricity to public, and distributing the electricity to homes. Energy deregulation is good for consumer choice but not every country is deregulated. In the competitive market, the process of the power system such as generation, transmission and distribution are distinct entities and the market participants participate in the power-pool trading to maximize their profit. In the power pool trading, Restrictions will be applied to the transmission systems for the power-pool traders for maximizing its profit in a deregulated power system.

II. TYPES OF ELECTRICITY MARKETS

There are two types of energy markets namely real-time market and day-ahead market. These markets use the nodal pricing (LMP) scheme. One of the objectives of the LMP scheme is to provide both short-term and long-term price signals to market participants 11 so that market participants can make appropriate economic decisions in a market setting. The short-term price signals are typically provided by nodal prices from both day-ahead and real-time markets. The long-term price signals are provided by a longer-term capacity auction market. Those prices reflect the results of complex combination of economic decisions made by market participants, through offers and bids, based on the relevant system (network) topology while the independent market operator (PJM) ensures that there is sufficient generation supply available to meet the desired demand in the least-bid manner. The LMPs from the day-ahead market form the forward prices while the LMPs from the real-time market form the spot prices. Although the day-ahead market financially binds the market participants it also allows them to secure some price certainty. This is because the volatility observed in the real-time market is generally higher than the volatility observed in the day-ahead market. Undoubtedly, the certainty of market prices is very important to any market participant. The more volatility the market prices exhibit, the more uncertainty the market participants will experience. That, in turn, will create greater risks for them. For that reason, the energy volume traded in the day-ahead market is much larger than the energy volume traded in the real-time market.

A. Day-ahead market

Day-ahead market is a forward market in which hourly clearing prices (LMPs) are calculated for each node in the system, for each hour of the next operating day. The computation of locational marginal pricing is based on generation offers, demand bids, virtual (financial) bids and bilateral transaction schedules submitted into the day-ahead market.

B. Real-time market

The real-time market is a spot market in which locational marginal pricing (LMPs) are computed for each node in the system, based on actual system operating conditions on near real-time basis. As of today, the real-time market is cleared at five-minute intervals. Hence, the real-time market conditions can be affected by the actions of system operators who would occasionally intervene or take drastic actions necessary to maintain system reliability. The real-time market is also known as the Balancing Market.

III. MATHEMATICAL FORMULATION

The Optimal Power Flow (OPF) has been applied to obtain a secure and economic operation in power system. LMP is obtained by using OPF. Mathematically, LMP at any bus is the Lagrangian multiplier for the bus equality constraint in OPF. Nodal power balance illustrates that sum of injections and withdrawals at that bus is equal to zero.

Physically, the Lagrangian multiplier is the cost of re-dispatching one additional MW at a certain bus. While minimizing the dispatch cost, the two formulations used to consider it as DCOPF are

3.3.1 Problem formulation 1

$\min c^T * P - b^T * PD$

S.t $PDmin \leq PD \leq PDmax$

$K * PLv - x * P + y * PD = 0$

$PLR = \omega a - \omega b \, xab$

$Pgmin \leq Pg \leq Pgmax$

$|Pl| \leq PLmax$

3.3.2 Problem formulation 2

If Shift Factor (SF) is used i.e., sensitivity of a line flow to a bus generation increments the LMP can be calculated using the following

$\min c^T * P - b^T * PD$

S.t $\sum PD,m \, m - \sum Pn \, n = 0$

$PDmin \leq PD \leq PDmax$

$Pmin \leq P \leq Pmax$ (3.10) $-PLv = -SF * (x * P - y * PD) \leq PLmax$

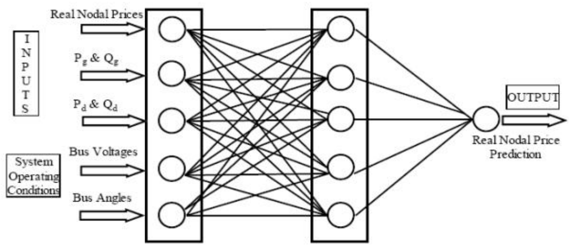
$PLv = SF * (x * P - y * PD) \leq PLmax$

So, $LMP = \lambda - SFT * (\pi + - \pi -)$,

13 $LMPenergy = \lambda$

$LMPcongestion = -SFT * (\pi + - \pi -)$

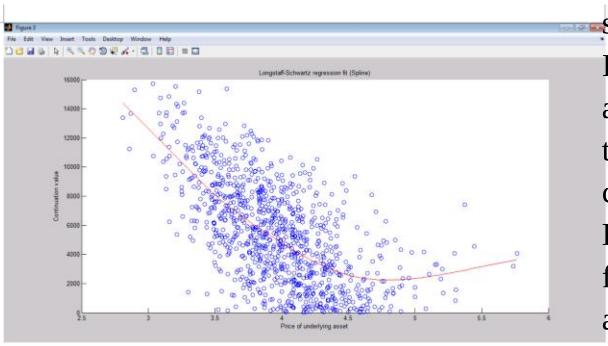
IV. BLOCK DIAGRAM



In power industry the upshot of deregulation has reformed the electricity prices of the electric distribution system where pricing schemes are controlled by rules and regulations of market operation. Nodal price is a method to determine the prices at which the market clearing prices are calculated for various locations of the transmission network called nodes, it can also be implemented to distribution systems. This work depicts the study of nodal pricing in power distribution system with probabilistic load and the impact of wind power assimilation on nodal prices is perceived. The current method utilizes marginal loss coefficients (MLC) technique to obtain nodal prices, and compares the results with deterministic and probabilistic loads, these are again examined with wind power integration. The whole study is carried out on a IEEE 69 bus radial distribution system using MATLAB 7.0.4

Prior to the degradation of fossil fuels, renewable energy resources have been formulated as the exception to fossil fuel-based power plant such as biomass, solar and wind. Many large power stations are forbidden due to the environmental issues for which government agreed to promote the energy industry. The DG penetration may affect the distribution system operation in both economic and environmental ways. The beneficial impacts include power loss reduction, reliability, voltage profile improvement and dynamic stability. Renewable energy is endorsed with various DG's due to its low cost and environmental viability. MLC technique had been employed to calculate locational marginal prices in the transmission network [1]. It is noticed that this technique can be even adopted in distribution network [2]. A multi-objective performance index is used with distributed generation that considers various technical issues [3]. The integration of renewable energy into dispatchable DG minimizes energy losses compared to non-dispatchable DG units at optimal power factor [4]. We make use ofAmp-mile tariff and nodal pricing with the impact of wind power for the distribution network [5]. The penetration of wind and solar power is assumed to be dominated over conventional resources [6]. The determination of nodal prices with realistic ZIP loads is carried out using MLC's [7]. The renewable energy sources are considered as an alternative for generation of power which are eco-friendly and economically efficient [8]. The US2PM method is used for handling the uncertainties caused by the proliferation of wind turbines and solar panels [9]. A PPF Algorithm is applied to estimate the uncertainties PV generation by considering correlation among input random variable [10]. CSI's are capable of providing only active power can be generated by VSI [11].

V. OUTPUT GRAPH



VI. CONCLUSION

In this project the locational marginal pricing of generators for IEEE 9-bus, IEEE 14-bus and IEEE 30-bus system is calculated using power world simulator software. As congestion in electricity market is a complex problem, it will lead to drastic effects on the power flow of the transmission system. Here the analysis was performed on IEEE 9-bus, IEEE 14-bus, IEEE 30-bus systems. The analysis was mainly focused on congestion alleviation following optimal power flow method. When power flow in the line exceeds the line limits it leads to congestion. Optimal power flow analysis is done on the system to alleviate congestion in the power world simulator software and the values of locational marginal pricing are obtained for IEEE 9-bus, IEEE 14-bus and IEEE 30-bus systems by rescheduling of generators and hence the total cost of generation is obtained. Results have been included comparing both the total cost of generation with and without congestion. Generally, congestion in the system may arise due to sudden increase of load, generator outage and line outage. In this project line outage has considered as a serious problem due to its frequency of occurrence. Hence this project mainly focusses on congestion alleviation due to line outage considering losses which is a practical system because transmission losses do occur in a system.

VII. FUTURE SCOPE

In future, this project can be applied for higher bus systems[redacted] IEEE 57-bus system, IEEE 62-bus, IEEE 1[redacted] Indian utility system for more in depth analysis[redacted] finding locational marginal prices. Also this pr[redacted] can be extended for various causes of congest[redacted]like generator outage, increase of load etc. Differe[redacted] methodology can be proposed to find m[redacted] accurate values of congestion and to alleviat[redacted]

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