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Comparative Analysis of Congestion Management schemes with Agent Based Simulator (ABS) in Restructured Power System

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ABSTRACT: -In the restructured power market power congestion is one of the major issues. Transmission power congestion leads to market inefficiency. To get rid from it congestion management (CM) mechanism is adopted by power market. This ensures transmission services reliability and economy. In this paper three market based CM schemes namely Locational marginal pricing(LMP), Market splitting(MS) and Flow based market coupling(FBMC) compared with various factors which decides overall social welfare using Agent Based Simulator(ABS). Electricity market is cleared by considering one of the mentioned methods.ABS provide platform for choosing CM scheme for clearing the market. Generator companies generate the power and bid in the market, it may be strategic bid which is Oligopolistic case. Described analysis performed on IEEE 30 bus system for perfect competition and oligopolistic competition case.

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KEYWORDS: Congestion management, Locational marginal pricing, Agent Based Simulator, social welfare

I.INTRODUCTION

The way of operation and business of electricity market changed to open market systemfrom vertically integrated mechanism in beginning of nineties decade [1]. In regulated electric power market previous vertically integrated utility unbundled into separate generation, distribution and transmission utilities. This model characterized by increasing competition among market players and so on providing quality of service while decreasing energy cost. Major issue of restructured power market is power congestion, as had impact on market players and leads to market inefficiency [2].

Various electricity market models and evaluation schemes are available for market this evaluation. A centralized,[1] pool-based trading concept is adopted in thesome parts of the United States, Singapore and Chile.In Europe decentralized structure is adopted. In India[3] Open Access in Inter-state transmission was introduced in May 2004. Universally one Power Exchange trade with physical power delivery operates in one market e.g. European Transmission System Operator (ETSO). Complex Power market structure in India, leads to multiple power exchange which handle physical trade i.e.IEX& PXIL.

Different methods of congestion management are available such as Available transfer capacity(ATC) congestion Management,Price area congestion Management, and Optimal Power Flow (OPF) congestion Management [4] to get rid from power congestion. All market designs are constrained with Transmission network. Every methods comes with own plus points and flows. This paper considers an IEEE 30 bus system network for deciding fluency of CM schemes on pricing methodology. This paper deals with third method as there is an increasing need for market-based pricing concepts in transmission networks. Ideally, this conceptgives correct economic incentives [5] and enable the physical operation of the transmission network.

By considering strategic behaviour of generator[7] for maximizing profit and market power, implementation of ABS for evaluating [8],[9]different schemes is done in this work.Spot market concept [11] provide platform for understanding auctioning in restructured market structure.Difficulties with the zonal pricing system[12] is deciding the zones and zone boundaries and the redistribution effects of the surplus [13] that a zonal pricing system has.An proficient congestion management system is an obligatory condition to remove obstacles to the cross-border trade[14].

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This Cross boarded trading is made possible by using FBMC[15].LMP is conceptually simple and compatible with basic economics; also it is effective in practice [16].The result table framework developed [17] provides the capability of evaluatingthe different CM schemes. OPF based approach in this paper constrained by Power transfer distribution factor (PTDF) matrix.PTDF is a factor which represents the percentage of change in power flow through network[18].Electricity pricing concept [19] contain different parameters and its effects on overall pricing. When congestion occurs pricing is differ to generate revenue. For LMP overall congestion cost is lesser than other methods. The electricity market reform is done for a set of economic reasons rather than the technical improvements [20].

Section II describe algorithm of simulator algorithm as here it is used as analysis tool, section III describe concept of congestion management schemes based on its optimization formulations. Section IV social welfare concept as achieving it is aim of this work finally section V and VI deals with simulator result discussion and conclusion respectively.

II. ALGORITHEM

Agent based simulator can process imperfect information, it allow repetitive actions and learning from previous action of market participants with special attention on gaming and market power. It is possible to evaluate behavior of market participants and their influence of actions on overall market characteristics [5]. Fig.1 shows the algorithm used to simulation of reinforcement learning .

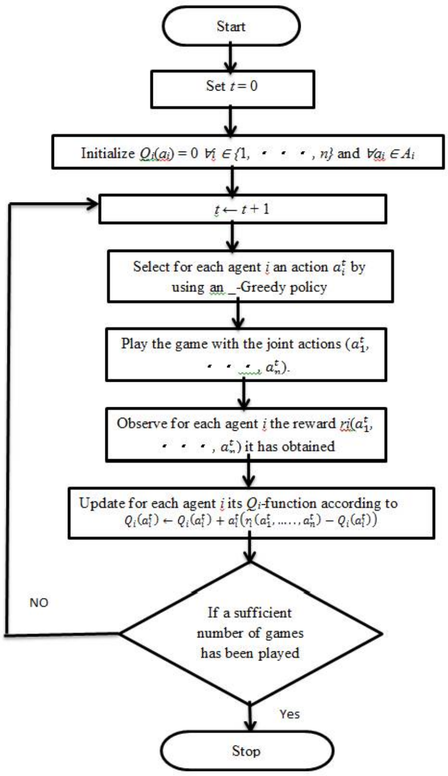

Fig.1 Algorithm for reinforcement learning

III. CONGESTION MANAGEMENT METHODS

Following paragraphs explain general concept of particular congestion scheme along with optimization problems for implementation of locational marginal pricing scheme, market splitting scheme and flow based market coupling scheme.

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A. Locational Marginal Pricing(LMP)

LMP decides the price that consumers would pay for consumed energy in acompetitive power market at particular locations and estimate congestion costs by considering the difference in LMPs between two locations. In [2] this scheme LMPs are calculated at all nodes of the transmission network system depends on bids provided to the power exchanges.

Let $n_k$is the nodal price at node *k*. Following mentioned quadratic programming problem is optimized [6]by independent system operator(ISO) for getting n_k. After the market get cleared, each generator *Gi*is dispatched *PGi*and is rewardedby *nk*per MW produced[1]. Solving this optimization problem is similar to maximizing social welfare[4].

$$(P_{Gi}, \dots, P_{GnbGen}, P_{L1}, \dots P_{LnbLoad}) \in R^{nbGen+nbLoad} \tag{1}$$

That maximizes,

$$\sum_{Lj} \frac{1}{2} m_{Lj} P_{Lj}^2 + n_{Lj} P_{Lj} - \sum_{Gi} \frac{1}{2} s_{Gi}^{bid} P_{Gi}^2 + ic_{Gi}^{bid} P_{Gi} \tag{2}$$

Subject to Constraints,

$$\sum_k P(k, l)(P_{Gi}^k - P_{Lj}^k) \leq P_{flow}^{max}(l) \tag{3}$$

$$P_{Gi} \leq P_{Gi}^{max} \tag{4}$$

$$\sum_i P_{Gi} - \sum_j P_{Lj} = 0 \tag{5}$$

Here,

P_{Gi} =Injected power by generator Gi

P_{Lj} = Withdrawn power by load Lj

P_{flow}^{max} = The maximum power flow allowed on line *l*

P_{Gi}^{max} = Maximum Power generation limit of generator Gi

$P(k, l)$= PTDF matrix.

mLj = The slope of the marginal benefit function of the loads

nLj = The intercept of the marginal benefit function of the loads

sGibid = slope of the linear bid function of the generators

icGibid = The intercept of the linear bid function of the generators.

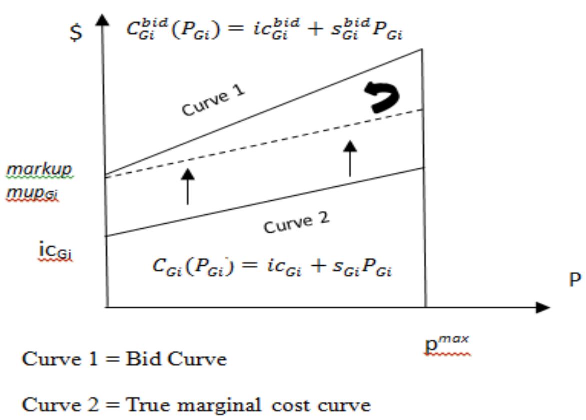

Fig.2. True marginal cost and strategic choice

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Here it is assumed that generators may be differtheir bids from marginal cost for increasing their individual profits. This can be done by two ways as: a) By changing sGi i.e. The slope of the cost function or b) By changing icGi these two strategic choices of the generators$s_{Gibid}$and ic_{Gibid}, which represent the linear bid function of the generators and determined by graph shown in Fig.2.

B. Market Splitting(MS)

In Market splitting Number of nodes are grouped together to form zone. When there is no congestion occurs single clearing price is applicable for entire system network. The market splitting formulation of Bjorndal presented in [12] is adopted.
With two more constraints LMP formulation is extended and solve for MS.

$$s_{Gi}^{bid} P_{Gi} + ic_{Gi}^{bid} = nz_k \qquad k = 1, \dots\dots, nbNodes \qquad (6)$$

$$m_{Lj} P_{Lj} + n_{Lj} = nz_k \quad (7)$$

Here,*Zk*is the allocation of the nodes *k* to the zones.

C. Flow-based Market Coupling (FBMC)

'Market coupling' means the information regarding relation of price and net transactions in each area that market considered for settlement.In contrast to market splitting there are no zonal constraints for the optimization of above quadratic problem. The mathematical formulation is same as LMP. Equal zonal prices are identified by using of one PTDF for all nodes contained by one zone (country). For FBMC one country assumed as one zone. As per proposal of ETSO [14] and the regulation of the European Directorate-General Energy and Transport, in [13] point out the following key features of FBMC:

- Price zones identified by country borders
- Intrazonalpower flows are not represented i.e.it is assumed that of there is absence of intrazonal congestion
- Cross-border lines are combined into one equivalent interconnector for each neighboring country (zone)

IV. SOCIAL WELFARE ANALYSIS

Social welfare is the equilibrium price or market clearing price at this which everyone in the market has to be satisfied *i.e*buyers and sellers. It is the sum of the consumer's surplus and the producer's surplus is called global welfare. It counts the overall benefit that arises from the trading.Simulator permits the comparison of above mentioned CMschemes for IEEE 30 bus system. Here perfect competition and oligopolistic competition market conditions are considered for analysis.

In case of perfect competition it is considered thatany generators does not behave strategically [4] i.e. they bid with ic_{Gi}. The market equilibrium can be determined through solving the optimization problems defined in section II. Here it is assumed that *markupmup*$_{Gi}$is 10% of its original intercept value for oligopolistic competition case.

V. RESULT AND DISCUSSION

A. Welfare Analysis (Perfect Competition)

Following result table format adopted from [16]. In this comparison LMP considered as a base method. In table third column i.e %Change shows difference between LMP and MS. Fifth column in table shows % Change between LMP and FBMC.

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TABLE I
Results for Perfect competition case

	LMP	MS	%Change	FBMC	%change
Total Demand	4140	4167.3	-0.6594	4365.4	-5.444
Consumer Surplus	2807748	2826300	-0.6607	2960600	-5.444
Prod Surplus	2001979	1763500	11.9122	1642420	17.960
Congestion cost	2700568	2794100	-3.4634	2828400	-4.734
Overall welfare	7510295	7383900	1.6830	7431420	1.050

From the result table I, the following observations are obtained,

- Highest Total demand shows for FBMC and it is low for LMP.
- Production surplus is more for FBMC.
- Congestion cost is less for LMP
- Overall welfare is more for LMP and it decreased by 1.683% for MS and by 1.05% for FBMC

B. Welfare Analysis (Oligopolistic Competition)

TABLE II
Results for Oligopolistic competition case

	LMP	MS	%Change	FBMC	%change
Total Demand	4130.8	4159.1	-0.6851	4364.2	-5.650
Consumer Surplus	2807600	2826100	-0.6589	2960500	-5.446
Prod Surplus	2051900	1824400	11.0873	1646700	19.748
Congestion cost	2875400	2893900	-0.6434	2928300	-1.840
Overall welfare	7734900	7544400	2.462863	7535500	2.578

From the results table II, the following observationsare noted,

- As in the perfect competitive case, LMP has the highest overall welfare, followed by market splitting and FBMC.
- Comparing the change of welfare for the oligopolistic case itself we find that there are stronger reductions with LMP as reference. For market splitting there is a drop of 2.462863 %; for FBMC welfare reduces by 2.578%.
- In comparison with the competitive case for all CM schemes producer's surplus increases while consumer surplus decreases. This effect seems to be due to generators exercising market power.
- For FBMC the prices increase compared with LMP and market splitting and compared with the competitive case.

VI.CONCLUSION

Q-learning algorithmis used with agent models to analyse competition in oligopolistic structures, where power Supplier Company can bid strategically by deviating their bids from their original marginal cost functions. The related optimization problems for locational marginal pricing(LMP), market splitting(MS) and flow-based market coupling(FBMC) to be realized in the proposed multi agent framework, which suggest that LMP method results in better social welfare than other methods. Using aIEEE30 bus system, market characteristics such as the social welfare, congestion cost, total demand etc.are analysed. The analysis has been carried outfor perfect and oligopolistic competition.

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