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SPOT PRICING IN DEREGULATED ELECTRICITY MARKET USING GROUP SEARCH OPTIMIZATION

S.Siva Subramanian, Assistant Professor
Dept. of Electrical and Electronics Engineering
DMI College of Engineering , Pallanchur
Chennai, India
sssincredible@gmail.com

T.Arputhamary, Assistant Professor
Dept. of Electrical and Electronics Engineering
DMI College of Engineering , Pallanchur
Chennai, India
marywilliam1314@gmail.com

Abstract **-** This paper presents a Group Search Optimization algorithm for determination of spot price in deregulated electricity market. The market participants are the power generators, power transmitters and power distributers. Due to the deregulation, several market participants compete to sell electricity price in the competitive electricity market through bids. This makes the Independent System Operator (ISO) to analyze the power system strategies and offers the minimum price that satisfies the demand. The control variables such as generator bus voltages, transformer tap settings and reactive power compensation devices are identified for determining spot price. This procedure is presented in IEEE 30 bus system.

Keywords: Spot price, Group Search optimization, Deregulated electricity market, optimal power flow, Total operating cost

I. INTRODUCTION

Electric power systems have traditionally been operated as regulated monopolies, partly to cope with the complexity of their operation and planning. In recent years, however, there has been a widespread realization that only the transmission of power is a natural monopoly, and that efficiency gains can be made by deregulating and fostering competition within the generation and consumption sectors [4]. In this fully competitive environment, more efficient power producers and distributors will maximize their revenues, while those offering higher prices may have to improve their capabilities in order to lower the cost of power production and / or delivery [5]. More recently it was noticed that the industry could still be reconstituted into a more competitive framework [6]. The objective of the optimal power flow (OPF) is to maximize the social welfare, minimizing the global system costs and thereby maximizing the profit of all market participants [3].The increasing need for OPF to solve problems of today's deregulated industry has caused the working group on operating economics, through task forces, challenges to OPF to evaluate the capabilities of existing OPF, in terms of their abilities [8]. Several optimization methods have been utilized to solve OPF problem viz. Benders Decomposition [9], Interior Point Method [12], Particle Swarm Optimization [14] and Genetic Algorithm [10].

The participants in deregulated power market are independent power producer, Distribution Company, Bids are for supplying loads to because all participants in the power system each other effect. The bids are been received by independent system operator. Independent System Operator (ISO) analyzes the power system situation, develop strategies and define transactions among participants by looking for the minimum price that satisfies the Power demand [6]. In this market, low cost generators would essentially be rewarded. Power pools would implement the economic dispatch and produce a single price known as the spot price for electricity, giving participants clear signal consumption and investment decisions. Winning bidders are paid the spot price that is equal to the highest bid of the winners [18].

This paper focuses on how the solutions of OPF can be utilized to calculate the spot price while minimizing the total operating cost and thereby maximizing the profit in a deregulated electricity market using Group Search Optimization algorithm. The total operating cost is minimized using load flow analysis to optimize the spot price of electricity.

II. SPOT PRICE

A centralized economic dispatch is employed to determine the market clearing price, the power

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generation and demand levels of all units and consumers. The competition in the electricity market must been encourage for investments to the new technology and more productive electrical source. According to many system operations each power production participant defines its own resource scheduling and sends a bid to the ISO for supplying other loads. The participants submit hourly offers that contain quantity and price, and they receive dispatch instructions from the ISO for each 5-min period. ISO determines transaction between participants according to their bids and power demand. Transaction payments are defined as the product of the spot price and power transactions for each participant.

In this spot market, generating companies can choose whether to commit their generators and make it available for dispatch. Once they have decided to commit, they must submit a bid for the opportunity to run their generators. A bid is the "sell offer" submitted for a particular amount of electricity selling at a particular price. Generating companies can change their bids or submit re-bids according to a set of bidding rules. After receiving all the bids, NEM will then selects the generators required to run and when to run at different times of the day, based on the most cost-efficient supply solution to meet specific demand. This ensures electricity is supplied at the lowest possible price. As mentioned above, the spot market allows instantaneous matching of supply against demand [16].

III. PROBLEM FORMULATION

The proposed paper is concerned with the utilization of the optimal power flow (OPF) to minimize the total operating cost in deregulated electricity market subjecting to control constraints in order to determine spot price. GSO technique is adopted for solving this problem. In this approach, generator reactive power settings, tap settings of the transformers and capacitive reactive power settings are chosen as control variables. The objective function to determine the spot price is given as follows:

$$\text{Min } J = (F_i)^{Before} - (F_i)^{After}$$

Where

$(F_i)^{Before}$ - Total Operating cost before optimization

$(F_i)^{After}$ - Total Operating cost after optimization

Subject to

$$V_{i,min} \leq V_i \leq V_{i,max}$$
$$Q_{gi,min} \leq Q_{gi} \leq Q_{gi,max}$$
$$Q_{ci,min} \leq Q_{gi} \leq Q_{ci,max}$$
$$T_{i,min} \leq T_i \leq T_{i,max}$$

where

$V_{i,max}$ and $V_{i,min}$ – the upper and lower limits of bus voltage

$Q_{gi,max}$ and $Q_{gi,min}$ – the upper and lower limits of generator reactive power output

$Q_{ci,max}$ and $Q_{ci,min}$ – the upper and lower limits of compensator reactive power output

$T_{i,max}$ and $T_{i,min}$ – the upper and lower limits of transformer tap positions

IV. GSO ALGORITHM STEPS FOR DETERMINATION OF SPOT PRICE

Group Search Optimization is a recently developed algorithmbased on the searching habits of certain animals like dogs and birds to find food. It is a process of obtaining optimum solution in a search space. The whole population is a group and each individual in the group is a member. It consists of three types of members: producers, scroungers and rangers.

1. Producers

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The member having the best fitness value in the group is selected as the producer. The selected producer finds the optimal position by scanning the search area. The producer will fly into an optimum position having better resource when compared to the current position. It will look for other optimal position by staying in the newly found optimal position. The producer will return back to its original position if it cannot find a better position.

2. Scroungers

The Scroungers will look for the opportunities to keep track of the producers. One among the scroungers will be selected as a producer if the current producer cannot find better optimal position or resource. If the scrounger finds a better position compared to that of previous producer, that scrounger remains being producer. While previous producer and other group members will perform scrounging in the bout.

3. Rangers

The ranging process is performed by group other than producers and scroungers. The proper implementation leads to the strength of the optimization.

V. TESTING CASES, RESULTS AND DISCUSSION

The load flow analysis of the IEEE 30 bus system is performed using optimal power flow method in MATLAB. The base case total operating cost is obtained as 8906.15$/hr. The total operating cost of the generator is reduced to 4577.71 $/hr after optimization. Thus, the spot price obtained is 4328.48$/hr in IEEE 30 bus system using Group Search (GSO) Optimization algorithm technique. The number of variable for IEEE 30 bus system is 18.The number of voltage is 6. The number of generator reactive compensators is 6 and the number of capacitor reactive compensators is 2.The number of transformer tap positions is 4.The voltage levels of the 30-bus system before and after optimization are compared and it is seen that the voltage profile of the system has been improved after optimization using Group Swarm Optimization. The graphical representation of the comparison of voltage levels before and after optimization is in the figure 3.

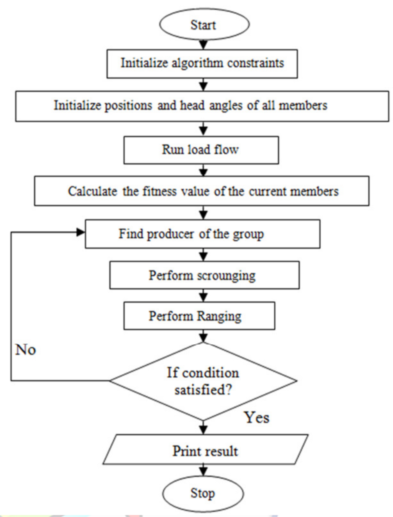

Figure 1:GSO flowchart [7]

The algorithm steps can be summarized as;

1. The load flow analysis is performed for the IEEE-30 bus system and Identify the control variables namely generator voltages,transformer tap settings ,MVAR injected.
2. Calculate the fitness value of current member.
3. Find the producer of the group.
4. Perform producing.
5. Randomly select 80% from the rest members to perform scrounging.
6. Perform scrounging and ranging.
7. Check that there is no violation to the specified constraints.
8. Obtain the optimal Values of the control variables
9. Run the optimal power flow for cost minimization with updated values.
10. If the iteration number exceeds the maximum number of iterations, then output the optimal solution. Otherwise go to step 3.

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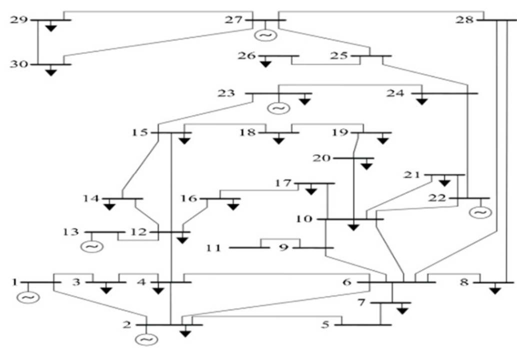

Figure 2:IEEE 30 bus system

TABLE I: LIMITS FOR REACTIVE POWER GENERATION

Bus no.	1	2	5	8	11	13
$Q_{g\,min}\,(MVAR)$	0	-40	-40	40	10	-6
$Q_{g\,max}\,(MVAR)$	10	50	50	40	40	24

TABLE II: LIMITS FOR VOLTAGE AND TAP-SETTING (in p.u.)

V_G^{max}	V_G^{min}	V_{load}^{max}	V_{load}^{min}	T_k^{max}	T_k^{min}
1.1	0.95	1.1	0.95	1.05	0.95

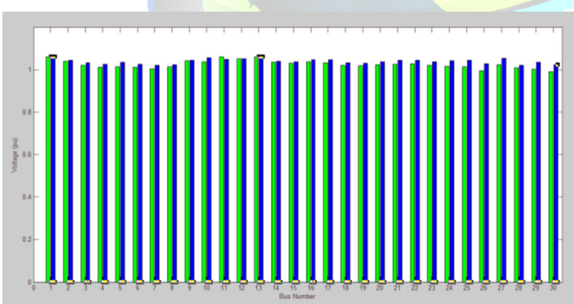

Figure 3:Voltage levels of 30 buses in IEEE 30 bus system

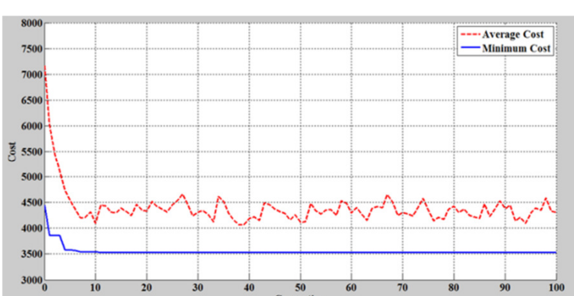

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Figure 4: Convergence diagram of optimized cost of IEEE 30 bus system

TABLE II: OPTMAL VALUES OF THE CONTROL VARIABLES OBTAINED AFTER OPTIMIZATION

V_1	1.09815
V_2	1.0996
V_5	1.07548
V_8	0.97431
V_{11}	1.085541
V_{13}	0.971535
Q_{C10}	41.7147
Q_{C24}	9.79285
T_1	0.998186
T_2	1.03094
T_3	0.9548196
T_4	0.954899
Q_1	49.1203
Q_2	-39.872
Q_5	-29.7-47
Q_8	35.2195
Q_{11}	22.6065
Q_{13}	39.9935

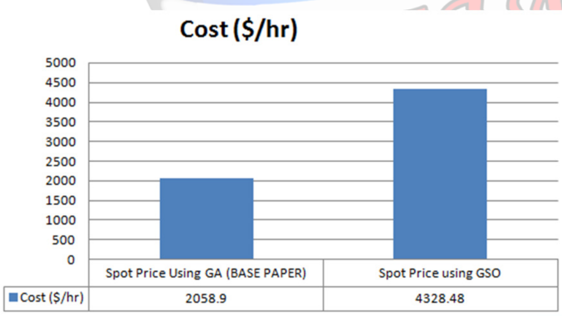

Figure 5:Comparison of the spot prices

VI. CONCLUSION

In this paper, spot pricing using Group Search Optimization method is presented. The market participants are the power generators, transmitters and power distributers. Due to the deregulation, several market participants compete to sell electricity price in the competitive electricity market through bids. This makes the Independent System Operator (ISO) to analyze the power system strategies and offers the minimum price that satisfies the demand. The generator bus voltages, transformer tap settings and reactive power compensation devices are determined for determining spot price. This procedure is presented in IEEE 30 bus system. This proposed work determines the spot price by determining the total operating cost after

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optimization using GSO and subtracting from the initial operating cost. The GSO algorithm is executed for spot pricing problem using MATLAB 7 programming in Intel CORE i3 system and run for 50 trials. The convergence time of the GSO was found to be 2 minutes 13 seconds when worked on IEEE 30 bus system.

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