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REACTIVE POWER PRICING USING GROUP SEARCH OPTIMIZATION IN DEREGULATED ELECTRICTY MARKET

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Abstract - This paper presents a Group Search Optimization (GSO) for reactive power pricing in power systems. In power system, the generator provides both the real and reactive power to the grid. For the efficient transfer of the real power, reactive power flow must be adequate. Due to the increased demand of the real power and insufficient reactive power support, the power system operates under stressed condition. This leads to voltage instability and increased real power loss. This makes the Independent System Operator (ISO) to pay higher amount to the generators. The objective of the reactive power pricing is to minimize the total cost paid by the Independent System Operator (ISO) to the generators in a deregulated electricity market. The generator bus voltages, transformer tap settings and reactive power compensators are determined for minimizing the real power loss in the system. This procedure is presented in IEEE 57 bus system.

Keywords: Reactive power pricing, Group Search Optimization, Deregulated electricity market, Independent System operator

The reactive power plays an important role in transferring the real power across the transmission system. It is a key tool for the secure and reliable operation of the power system. Reactive power is of great significance as it has a close relation with system security through system voltages. The main purpose of the reactive power pricing is to minimize the total cost paid by the ISO to the generators by minimizing the real power loss in the deregulated electricity market. Various conventional optimization techniques such as linear and non-linear programming have been used where several mathematical assumptions are given to simplify the problem. It is a major drawback and consume more time to solve the problem. In order to overcome these drawbacks, various optimization methods like genetic algorithm, differential equation algorithm and simulated annealing and tabu search have been used to solve the reactive power pricing problem.

The proposed paper uses Group Search Optimizer method based on the animal searching behavior. It is based on the producer-scrounger model, which assumes that the group members search for finding or joining opportunities. The animal scanning mechanisms are used for solving the optimization problem.

1 Introduction

1.1 Deregulated Power System

The aim of deregulation in the electric power industry is to optimize the system welfare, by introducing competitive environment, mainly among the suppliers. Developing fair and equitable real and reactive power allocation method has been an active topic of research, particularly in the new paradigm, with many transactions taking place at any time. The current tracing method is chosen because this method is simple and more flexible.

Based on the solving load flow and network parameter, the method converts power injections and line flow into real and imaginary current networks. This current is represented independently as real and imaginary current networks. Since current network are acyclic lossless networks proportional sharing principle and this method is used to trace the relationship between current sources and current sinks. From this relationship of current components of individual generators, it is possible to find real power contribution of each generator.

This method also applied for real power allocation with a few modification. The advantages of the proposed methodologies are demonstrated by commonly used test system and TNB systems. The

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proposed methodologies provide better reliability and minimize the limitation of conventional real power

1.2 Ancillary Services

Ancillary services are those functions performed by electrical generating, transmission, system-control, and distribution- system equipment and people to support the basic services of generating capacity, energy supply, and power delivery. The Federal Energy Regulatory Commission (FERC 1995) defined ancillary services as "those services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system". There are six different kinds of ancillary services:

- scheduling and dispatch
- reactive power and voltage control
- loss compensation
- load following
- system protection
- energy imbalance

2 Problem Formulation

The reactive power pricing problem is concerned with the minimization of the total cost paid by the ISO to the generating companies in deregulated electricity market subjecting to control constraints. GSO technique is adopted for solving this problem.

The total cost paid by the ISO includes the opportunity cost which results from the real power rescheduling when the generator reaches the capability limits. The generator's capability which is also called as the loading capability diagram plays an important role in calculating its opportunity cost.

In the Fig.1 showing the typical loading capability diagram, there are field and armature heating limits. The intersection of armature and field heating limit determine the generators MVA rating.
.

allocation method.

In this approach, a linearized model derived around a given base case state with the generator reactive power settings, tap settings of the transformers and capacitive reactive power settings as control variables.

The objective function is to minimize the total loss which is given as follows:

$$\text{Total Cost Payment Min } J = K_p . P_{loss}$$

Where

K_p = Cost per MW ($)

P_{Loss} = Real Power loss (MW)

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

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

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

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

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

P_{GR} is the real power rating of synchronous generator. At an operating point A, when real power output is less than its rated value i.e., $P_{GA} < P_{GR}$, the field limits on reactive power generation is considered. Otherwise when, $P_{GA} > P_{GR}$, the armature limits on reactive power generation is considered. The shaded region indicates the mandatory amount of reactive power that each generator must provide

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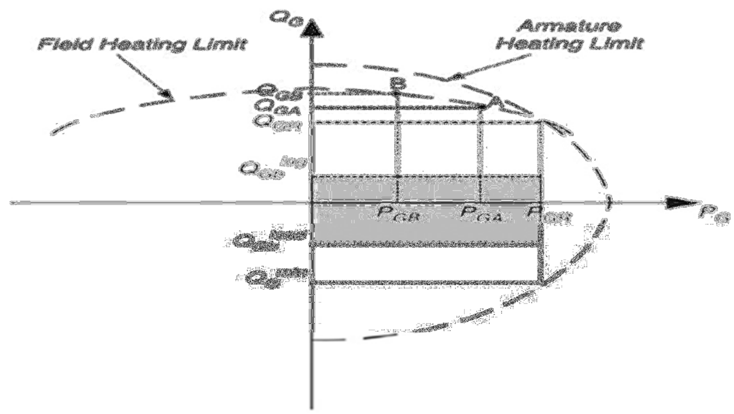

Fig.1. Loading Capability Diagram

3 Group Search Optimization Algorithm

The pseudocode for GSO is as follows

Calculate fitness: Calculate the fitness value of current member f (Xi)

Choose producer: Find the producer Xp of the group

Perform producing:

1) The producer will scan at zero degree and then scan laterally
by randomly sampling three points in the scanning field.

2) Find the best point with the best resource (fitness value). If
the best point has a better resource than its current position,
then it will fly to this point. Otherwise it will stay in its current
position and turn its head to a new angle.

3) If the producer cannot find a better area after *a* iterations,

Perform scrounging: Randomly select 80% from the rest members to perform scrounging

Perform ranging: For the rest members, they will perform ranging:

1. Generate a random head angle.
2. Choose a random distance from the Gauss distribution and move to the new point

The flowchart for GSO is given as follows:

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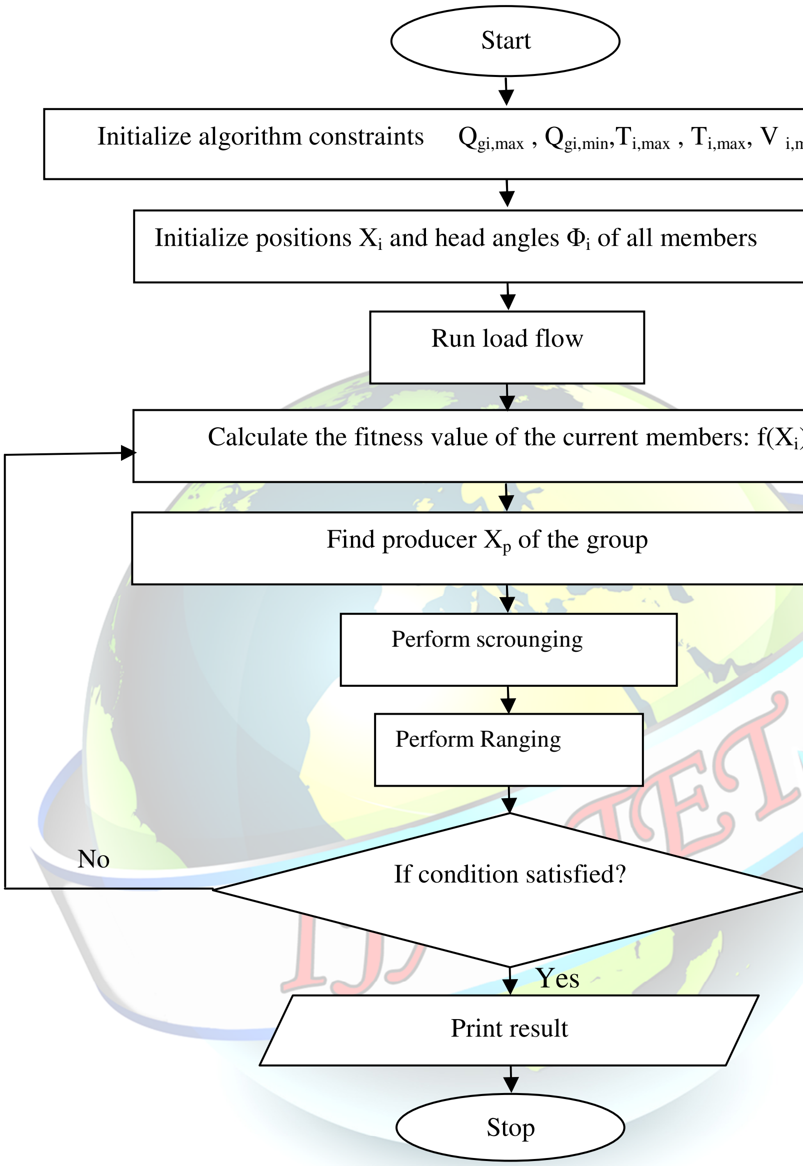

Figure 2: GSO flowchart

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4 Testing Cases, Results and Discussion

The Newton-Raphson power flow is executed in the base case condition. The number of variable for IEEE 57 bus system is 32. The number of generators is 7. The numbers voltage is 3. The number of reactive compensators is 7 and the number of transformer tap position is 15. The load flow analysis of the IEEE 57 bus system is performed using Newton-Raphson power flow method in MATLAB. The base case real power cost obtained as $2786.4. The figure 5 shows the total cost payment to the generator is reduced to $2481.81. Thus, the results obtained show that the Group Search Optimization has helped in the optimization of the reactive power pricing in IEEE 57 bus system, thus minimizing the total cost paid by the Independent System Operator to the generators.The voltage levels of the 57-buses before and after optimization are compared and it is seen that the voltage profile of the system has been improved after reactive power optimization using Group Search Optimization.The graphical representation of the comparison of voltage levels before and after optimization is as follows:

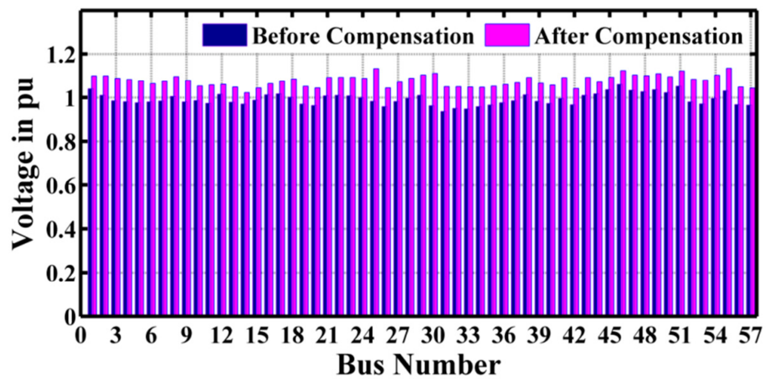

Figure 3: Voltage levels of the 57 buses in IEEE 57 bus system

TABLE 1: LIMITS FOR REACTIVE POWER GENERATION

Bus no.	1	2	3	6	8	9	12
$Q_{g\,min}$ (MVAR)	0	-40	-40	-40	-10	-6	-6
$Q_{g\,max}$ (MVAR)	10	50	50	40	40	24	24

The total cost minimized after optimization using GSO algorithm is obtained to be $2481.81. The optimized result is compared with that of the base case result and the result below.

TABLE 2: COMPARISON OF SIMULATED RESULTS FOR IEEE 57-BUS SYSTEM (REAL POWER LOSS MINIMIZATION)

Cost	GA	GSO
$/hr	$2786.4	$2481.81

The GSO is applied in order to obtain the optimal values of these control variables and the values obtained are shown in Table 3.

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TABLE 3: OPTMAL VALUES OF THE CONTROL VARIABLES OBTAINED USING GSO

V_1	1.1	Q_{C25}	14.0779	T_7	0.98121	T_{15}	0.973481
V_2	1.1	Q_{C53}	10.6718	T_8	0.95	Q_{G1}	8.16912
V_3	1.09393	T_1	1.04986	T_9	1.0151	Q_{G2}	36.8901
V_6	1.07365	T_2	1.00994	T_{10}	0.95	Q_{G3}	7.85802
V_8	1.9724	T_3	0.95	T_{11}	0.950007	Q_{G4}	32.9213
V_9	1.08889	T_4	0.950385	T_{12}	1.04986	Q_{G5}	31.1122
V_{12}	1.07376	T_5	0.95	T_{13}	0.95178	Q_{G6}	17.2714
Q_{C18}	10.897	T_6	0.95	T_{14}	0.975272	Q_{G7}	1.06576

TABLE 4: 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

5 Conclusion

In this paper, reactive power pricing using Group Search Optimization method is presented. Due to the increased demand of the real power and insufficient reactive power support, the power system operates under stressed condition. This leads to voltage instability and increased real power loss. This makes the Independent System Operator (ISO) to pay higher amount to the generators The simulation results using MATLAB are carried out. From the result analysis, the total cost paid by the Independent System Operator (ISO) is minimized with the minimization of the real power loss (P_{Loss}). This algorithm is tested on IEEE-57 bus system for various control parameters of GSO. This proposed work minimizes the total loss of opportunity cost paid by the system operator to the generating company for providing required reactive power support. This paper gives the reactive power dispatch model and re-scheduling of real power of generators exceeding its maximum limit of reactive power

REFERENCES

1. C.A.Canizares, K.Bhattacharya, El-Samahy, H.Haghighat and Pan C.Tang, "Re-defining the Reactive Power Dispatch Problem in the context of Competitive Electricity Markets", IET Generation, Transmission and Distribution, 2010, Volume 4
2. I.El-Samahy, K.Battacharya, C.A.Canizares, M.Anjos, J.Pan "A Procurement Market Model for Reactive Power Services considering System Security", IEEE Tractions on Power System, 2008,23.
3. I.El-Samahy, C.A.Canizares, K.Bhattacharya, J.Pan "An Optimal Reactive Power Dispatch Model for Deregulated Electricity Markets" , Proceedings in IEEE Power engineering Society General Meeting, June 2007
4. Lin.J, David A.K, "A novel market - based reactive power management scheme", *Electrical power and Energy Systems.*,28, pp127-132, 2006.
5. El-Samahy, K.Bhattacharya, C.A.Canizares, "A Unified Framework for Reactive Power Management in Deregulated Electricity Markets" Proc. IEEE-PES Power Systems Conference Exposition (PSCE), October 2006
6. Allen J. Wood, Bruce F. Wollenburg "Power Generation Operation and Control", 2012, JohnWiley&sons.
7. US-Canada Power System Outage Task Force: "Final Report on the August 14, 2003

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ISSN 2394-3785 (Online)
Available online at www.ijartet.com

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Blackout in the United States and Canada: Causes and Recommendations", April 2004

8. V. Ajjarapu, P. L. Lau, and S. Battula, "An Optimal Reactive Power Planning Strategy Against Voltage Collapse" ,*IEEE Trans. Power Syst.*,Vol. 9, No. 2, pp. 906 – 917, May 1994.
9. Kwang Y. Lee, Xiaomin Bai and "Optimization Method for Reactive Power Planning by Using a Modified Simple Genetic Algorithm" , IEEE Transactions on Power Systems, Vol. 10, No. 4, November 1995
10. M. Sedighizadeh, A. Rezazadeh and M. Seyed Yazdi "Pricing of Reactive Power Service in Deregulated Electricity Markets Based on Particle Swarm Optimization" International Journal of Computer and Electrical Engineering, Vol.2, No.6, December, 2010 1793-8163