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GENETIC ALGORIRHM BASED SELECTION OF WHEELING TRANSACTIONS

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ABSTRACT

This paper describes how to select a particular wheeling option among the various feasible transaction options available under de-regulated environment of modern power systems. An efficient GA-optimal power flow (GA-OPF) algorithm has been proposed to determine the optimal selection based on wheeling cost. In this proposed GA-OPF, Newton-Raphson method and GA algorithm have been used for power flow and economic dispatch respectively. Based on the power transfer capability and minimum generation cost, an optimal wheeling option will be suggested to both the owners of private non-utility generator (i.e. independent power producers or co-generators) and the utility. The proposed algorithm is independent of the cost characteristics of non-utility generators (NUGs). The proposed model has been tested on the IEEE 30 bus test system with synthetic imposition of wheeling transactions. The solutions obtained are quite encouraging and useful in the present de-regulated environment.

Keywords: wheeling, optimal power flow, genetic algorithm (GA), NUG.

1. INTRODUCTION

Wheeling is the transmission of electrical energy from a seller to buyer through a transmission network owned by a third party [1].As dependence on electricity grew, regulation on the federal and local level increased as well. The industry essential became a regulated monopoly in 1935.But the need for more efficiency in power production and delivery has led to a restructuring of the power sector in several countries traditionally under control of federal and state governments. The incorporation of transmission in to this competitive framework has proven more complicate and is the subject of going research and debate among utility consumers and suppliers[2-3]. In this new environment of de-regulation, one common problem has been encouraged namely the market activities in electricity trading can exert unprecedented and serve pressure on the existing transmission system. Such networks were originally designed to accommodate certain generation/load pattern.

Under de-regulation the generation patterns resulting from market activities can be quite different from the traditional one. Further since any non-utility generator (NUG) in the system can sell all part of its output to single or multiple buyers located anywhere with in the network, have made the problem very much complicated. NUGs includes both independent power producers (IPPs) and co-generators [4]. There is a need for an optimal system, which may balance the needs of energy providers, the resellers, the large industrial customers and residential consumers [5]. Some methods and mathematical models have been reported in literature for solving above-mentioned problems.

The general concept of wheeling and optimization has been explained in [6,7].The review of the major existing methods of wheeling have been discussed [8] and various existing models are in use in different countries [9].Privatizing and restructuring the state electricity boards has been proposed for the Indian power sector [10] and Norway's power sector[11]. The optimal approach explained in this paper, using GA-OPF, in the proposed hybrid model, is simple and efficient under various complicated situations and system constraints. It can handle the generating plant with non-convex or any other cost characteristics. The proposed approach is free from mathematical complexity and suitable for highly complex environment. Hence GA-OPF has been used to determine most economical and suitable (satisfying various system constraints) options for wheeling transactions under de-regulated environment of power systems. The proposed algorithm is independent of cost characteristics of NUGs. The objective of this paper is to comparing by generator scheduling prediction management technique or stagecoach approach this model is simple and efficient under various complicated situation and systems constraints. And DRM has many advantages; it can handle the generating plant with any other cost characteristics. The proposed approach is free from mathematical complexity and suitable for highly complex environment.

2. MATHEMATICAL FORMULATION

The selection of wheeling transaction is based on optimization of generation cost without violating system constraints. So the optimization of cost of generation has been formulated based on classical OPF. The detailed problem formulation of the proposed approach is as follows:

2.1 Base case (optimal generation without any wheeling transaction)

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For a given power system network, the optimization cost of generation is given by the following equation

$$C = \min \sum_{i=1}^{Ng} f_i(P_{Gi}) \tag{1}$$

Where

C = Optimal cost of generation when the utility supplying its own load.

$f_i(P_{Gi})$ = Generation cost function of the i^{th} generator for P_{Gi} generation.

P_{Gi} = Power generation by the i^{th} generator.

Ng = Number of generator connected network.

The cost is optimized with the following power system constraint

$$\sum_{i=1}^{Ng} P_{Gi} = p_d + p_l \tag{2}$$

Where

P_d = Total load of the system

P_l = Transmission losses of the system (when the utility supplying its own load)

The power flow equation of the power network

$$g(|v|, \phi) = 0 \tag{3}$$

Where

$|v|$ and ϕ is voltage magnitude and phase angles of different buses.

The inequality constraint on real power generation P_{Gi} of each generation i

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \tag{4}$$

Where $P_{Gi}^{\min}$ and $P_{Gi}^{\max}$ are respectively minimum and maximum value of real power generation allowed at generator i.

The inequality constraint on voltage of each PQ bus

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{5}$$

Where $V_i^{\min}$ and $V_i^{\max}$ are respectively minimum and maximum voltage at bus i.

Power limit on transmission line

$$MVAf_{p,q} \le MVAf_{p,q}^{\max} \tag{6}$$

Where

$MVAf_{p,q}^{\max}$ is the maximum rating of transmission line connecting bus p and q.

2.2. Overview of Genetic Algorithm

GA is motivated from the simulation of the behavior of social systems such as fish schooling and bird flocking. The GA algorithm requires less memory because of the simplicity inherent in the above systems. The basic assumption behind the GA algorithm is, birds find food by flocking and not individually. This leads to the assumption that information is owned jointly in flocking.

In GA, the potential solutions, called particles, fly through the problem space by the following the current optimum particles .Each particle keeps track of its coordinates in the problem space which are associated with the best solution (fitness) it has achieved so far. (The fitness value is also stored).this value is called p_{best} . When a particle takes all the population as its topological neighbors, the best value is a global best and is called g_{best} .The particle swarm optimization concept consists of , at each time step, changing the velocity of (accelerating) each particle toward its p_{best} . Acceleration is weighted by a random term, with separate random numbers being generated for acceleration towards p_{best} . In past several years, GA has been successfully applied in many research and application areas. It is demonstrated that GA get better results in a faster, cheaper way compared with other methods.

GA learned from the scenario and used it to solve the optimization problems. After finding the two best values, the particle updates its velocity and positions with following equations.

V[ ] = V[ ] + C1* rand ( ) * (p_{best} t [ ] - present[ ]) + C2 * rand ( ) * (g_{best} t[ ] - present[ ])

Present [ ] = present [ ] + V [ ]

Where,

V [ ] is the particle velocity, Present [ ] is the current particle (solution), p_{best} [ ] and g_{best} [ ] are defined as dated before.

Rand ( ) is a random number between (0, 1) and C1, C2 are random numbers

2.3. Parameter selection in GA

2.3.1. Inertia weight

The inertia weight (ω) is employed to control the impact of the previous history of velocity, thus to influence the trade off between global (wide ranging) and local (near by) exploration abilities of the "flying points". In GA, the balance between the global and local exploration abilities is mainly controlled by inertia weights. It often decreases linearly from about 0.9 to 0.4 during the run.

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$$\omega = \omega_{\max} - \left(\frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} \right) * \quad iter \tag{7}$$

Where,

ω = inertia weight factor

$\omega_{\max}$ = maximum value of weighting factor

$\omega_{\min}$ = minimum value of weighting factor

$iter_{\max}$ = maximum number of iterations

$iter$ = current no iteration

2. 3.2. Acceleration constant

The constants C_1 and C_2 represent the weighting factor and are tuned in the process. The constants C_1 and C_2 represent the weighting factor of the acceleration terms that pull each particle toward the p_{best} and g_{best} positions

.

2.3.3. Velocity updation

$$V_{id}^{(t+1)} = \omega V_i^{(t)} + C_1 rand(\,)\,(pbest_{id} - pg_{id}^{(t)} +$$

$$C_2 rand\ (\,)\ gbest_{id} - pg_{id}^{(t)} \tag{8}$$

Where

i = 1, 2, …. n;

d = 1, 2, …. m,

n = population size

m = number of units

ω = inertia weight factor

c_1, c_2 = acceleration constant

rand( ), rand( ) - uniform random value in large [0,1]

$V_i^{(t)}$ = velocity of particle ‘i’ at iteration ‘t’

$V_{id}^{(t+1)}$ = (modified) velocity of particle ‘i’ at iteration ‘t’

2.3.4. Limit check

$$V_d^{\min} \le V_{id}^{(t+1)} \le V_d^{\max} \tag{9}$$

The parameter $V^{\max}$ determines the resolution with which regions are to be searched between the present position and the target position. If $V^{\max}$ is too high, particles might fly fast good solutions. If $V^{\max}$ is too small, particles may not explore sufficiently beyond local solutions. Typically,

$$V_d^{\max} = 0.5 P_g^{\max} \quad \text{and} \quad V_d^{\min} = -0.5 P_g^{\min}$$

Where

$P_g^{\max}$ = maximum generating limits

$P_g^{\min}$ = minimum generating limits

E = position modification

$$P_{gid}^{(t+1)} = Pg_{id}^{(t)} + V_{id}^{(t+1)} \tag{10}$$

Where,

$P_{gid}^{(t+1)}$ - modified position of particle ‘i’ at iteration (t +1)

2.3.4. Algorithm for GA

The step by step algorithm for the method is explained as follows:

Step-1: Specify the maximum and minimum limits of generation power of each generating unit, maximum number of iterations to be performed and fuel cost co-efficient of each unit.

Step-2: Initialize randomly the individuals of the population of all units other than the reference unit according to the limit of each unit. Many such population can be generated randomly for better sharing nature.

Step-3: To each individual population of the population array, employ B-coefficient loss formulae to calculate the transmission losses P_L.

Step-4: The individuals of the reference unit is obtained from the equality constraint.

$$P_1 = (P_D + P_L) - (P_2 + P_3)$$

Step-5: Calculate the evaluation value of each population P_g using the evaluation equation (1)

Step-6: Compute the new evaluation function using the equation (1).

Step-7: Compare each population’s evaluation value with its $pbest$. The best evaluation value among the P_{best} is denoted as g_{best}

Step-8: Modify the member velocity V of each individual P_{gi} according to the equation (8)

Step-9: Modify the velocity v of each particle according to the equation

If $V_{id}^{(t+1)} > V_d^{\max}$, then $V_{id}^{(t+1)} = V_d^{\max}$

If $V_{id}^{(t+1)} > V_d^{\min}$, then $V_{id}^{(t+1)} = V_d^{\min}$

Where,

$V_d^{\min}$ - - $0.5\, P_g^{\min}$ and $V_d^{\max}$ - $+ 0.5\, P_g^{\max}$

Step-10: Modify the number position of each individual according to the equation (10).

If P_{gid}^{g+1} violates the constraints then it must be set to the near margin of that particular unit.

Step-11: If the evaluation value of each population is better than the previous P_{best}. The current value is said to be P_{best}. If the best P_{best} is better than g_{best} the value is said to be g_{best}

Step-12: If the number of iterations reaches the maximum then go to step 13, otherwise go to step-3.

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Step-13: The individual that generates the latest g_{best} is the optimal generation power of each unit.

Step-14: After obtaining the global optimum solution, power flow is computed using Newton Raphson method and the calculated MVA of the line flow is compared with the rated MVA of line flow.

Step-15: If the line is found to be found to be overloaded previous g_{best} value is chosen as the global optimum solution.

Step-16: Stop

3. OUTLINE OF DYNAMIC RESCHEDULING ALGORITHM (DRM) METHODOLOGY

Modified Generator rescheduling algorithm has many advantages over the enumeration scheme, the chief advantage being a reduction in the dimensionality of the problem. Suppose we have found unit rescheduling in a system and any combination of them could serve the load. There would be a maximum of 19 combinations in three-generator case to test. The objective of this problem is minimizing the violation in transmission lines. To illustrate the operation of different combinations for relieving congestion management system, an example of three-generator power system is shown in Figure-1.

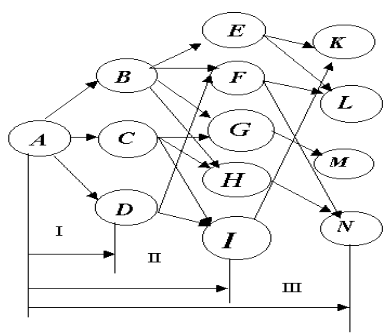

Figure-1. Dynamic generator rescheduling model.

Note that,

$$A = \sum P_{Gi}^{0}, B = \Delta P_1, C = \Delta P_2, D = \Delta P_3$$
$$E = \Delta P_2, F = -\Delta P_2, G = \Delta P_3, H = -\Delta P_3, I = -\Delta P_1$$
$$K = \Delta P_3, L = -\Delta P_3, M = -\Delta P_2, N = -\Delta P_1$$

Where,

$\Delta \boldsymbol{P_i} = \Delta \boldsymbol{P_{Gi}} =$ Increase the output of a generator i,

$-\Delta \boldsymbol{P_i} = -\Delta \boldsymbol{P_{Gi}} =$ Decrease the output of a generator I

Here,

$$0 < \Delta \boldsymbol{P_{Gi}} \le \boldsymbol{P_{Gi}^{\max}} - \boldsymbol{P_{Gi}^{0}}$$
and
$$0 < -\Delta \boldsymbol{P_{Gi}} \le \boldsymbol{P_{Gi}^{0}} - \boldsymbol{P_{Gi}^{\min}}$$

Generating units	G1	G2	G3	G4	G5	G6
Generation in MW	192.76	48.44	15.00	11.79	10.00	12.00

To find the line violation-eliminating path, it identifies the stages (I, II, III). At the terminus of each stage, there is a set of choice of nodes $\{x_i\}$ to be chosen. The symbol $V_{ma}(\boldsymbol{A}, \boldsymbol{B})$ represent the path of traversing stage and depends on the starting variables selected from the $\{x_i\}$ and $\{x_{i+1}\}$, noted that 'm' is stage number and 'a' is combination number. It means that A+B.

$f_{1i}(x_1)$ =Eliminating line violation for the stage I is obvious:

$$f_{11}(B) = V_{11}(A, B)$$
$$f_{12}(C) = V_{12}(A, C)$$
$$f_{13}(D) = V_{13}(A, D)$$

$f_{2i}(x_2)$ =Eliminating line violation for the stage II,

$$f_{24}(E) = V_{24}(A, B, E)$$
$$f_{25}(F) = V_{25}(A, B, F)$$
$$\vdots$$
$$f_{212}(I) = V_{212}(A, D, I)$$

$f_{3i}(x_3)$ = Eliminating line violation for the stage III,

$$f_{313}(K) = V_{313}(A, B, E, K)$$
$$f_{314}(L) = V_{314}(A, B, E, L)$$
$$\vdots$$
$$f_{319}(N) = V_{319}(A, D, F, N)$$

Evaluating stages I, II and III,

$$F_1(x_1) = \min_{violation}[f_{11}(B), f_{12}(C), f_{13}(C)]$$
$$F_2(x_2) = \min_{violation}[f_{24}(E), f_{25}(F), \ldots f_{212}(I)]$$
$$F_3(x_3) = \min_{violation}[f_{313}(K), f_{314}(L), \ldots f_{319}(N)]$$

If more than one combination are eliminating violation, find the optimal solution.

4. WHEELING TRANSACTION AND ITS LOADABILITY LIMIT

A simultaneous wheeling transaction has been included in a ' n' bus system . The seller at the bus i and the buyer with a load at bus j. the corresponding wheeling transaction can be represented at WT (i –j), where i and j may be varied from 1 to n and i is not equal to j. let us assume that an IPP is willing to supply the additional load

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demand at bus j through the utility transmission system by a wheeling transaction WT (i-j). Then, run the power flow program with all the generators of the utility being held at fixed optimal setting of base case under these conditions. The amount of wheeled power in the network must be with in the limits of IPP and satisfy the transmission constraints. In general the algebraic sum of power delivered by the non-utility generators/Independent Power Producers is equal to the sum of power taken at different load points.

Suppose now real load is increased at load bus, which is virtually the load increasing at a bus j with unity power factor and it is a function of load parameter λ as

$$P_{dj}=\lambda P_{dj0} \quad (11)$$

The zero subscript indicate base load at the buses. Now the load at bus j is varied until the system no longer has a solution.

Therefore,

$$\lambda \geq \lambda^{\max} \quad (12)$$

The λ is the bifurcation parameter, Where 'λ' is scalar parameter representing the increase in busload.λ=1 corresponds to base case and $\lambda=\lambda^{\max}$ corresponds to the maximum load [13]

5. RESULTS

The PSO algorithm was applied to the IEEE- 30 Bus standard test system.

5.1 Base Case (optimal generation of 6-generating plants)

For the base case the optimal generation (MW) of the generating units of the utility are presented in the Table-1. The total cost of generation for the base case optimal schedule is C = 790.1037 \$/hr.

Table 1- Base Case

5.2 Loadability limit for a wheeling transaction

Let us assume that Independent of 44MW maximum capacity is connected at bus no.24. (It may be installed at any other bus). Then run the power flow program with all the generators of the utility being held at fixed optimal setting of base case under these conditions. It is described in section 3. 2. Now the question is whether it can sell full 44 MW to the buyer through the utility or not. If not what amount of power it can sell. In For this analysis a pseudo generator of very high cost characteristics is connected to the load point bus (at which this additional power is to sell).

Fig 2 represents the maximum allowed load that can be supplied by the non-utility generator/Independent Power Producer through different wheeling transaction at different load points.Tthe power flow program with all generatora is to installed under these conditions.the pseudo generator of very high characteristics is connected to the load point.

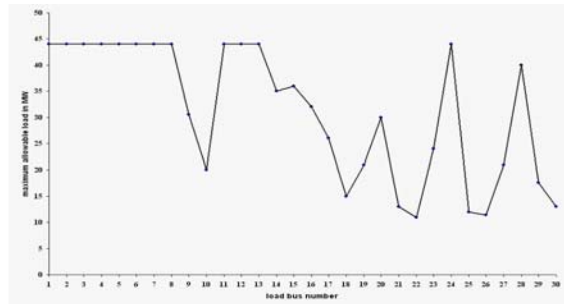

Figure-2. Maximum allowed load supplied by IPP (NUG) through wheeling transactions.

For the present study, reactive power demand at load buses has been taken constant. The losses are assumed to be supply by the slack bus generator at bus no.1. The study is carried out by computing optimal generation subject to various wheeling transaction. The model described in section 3 is used to carry out a case study to examine the operation of the DRM and its role in removing the congestion in the system. The system has 6 generators and one NUG.

Table-2. Selection of wheeling transaction option.

Bus No.	Optimal cost in \$/hr		Transactions option selected
	Option 1: GA-OPF	Option 2: DRM	
1	791.3938	793.879	1
2	791.3938	810.007	1
3	791.3938	699.980	2
4	790.1037	791.091	1
5	791.3938	832.009	1
6	791.3573	739.087	2
7	791.3573	790.111	2
8	790.1037	879.999	1
9	791.3938	678.990	2
10	791.3938	729.009	2
11	791.3573	834.008	1
12	791.3573	786.009	2
13	791.3573	800.008	1
14	791.3938	798.004	1
15	790.1037	790.113	1
16	790.1037	723.002	2
17	791.3938	810.009	1
18	791.3938	821.987	1

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19	790.1037	798.987	1
20	791.3573	768.904	2
21	791.3573	790.009	2
22	790.1037	801.008	1
23	791.3573	812.098	1
24	791.3573	790.001	2
25	790.0997	699.999	2
26	790.1037	799.990	1
27	791.3938	754.912	2
28	791.3938	768.678	2
29	791.3573	799.901	1
30	791.3938	796.001	1

5.3. Option 1

If the NUG is supplying the increased demand of 1 MW and additional losses and the utility generators are set at their original optimal point. The results shows that at bus number 4,8,15,16,19,22,25,26 the generating fuel cost is lesser than other buses.

5.4. Option 2

If the utility makes an agreement with the NUG and all seven generators (including NUG) are supplying the increasing load demand. The increment in the optimal cost is shown in Table-2.

6. CONCLUSIONS

A Genetic Algorithm based approach for optimal selection of wheeling option from the various feasible options of power system considering various system constraints has been proposed under de-regulated environment.

The concept of pseudo transactions and generator has been used to determine the validity of the proposed HOPF. The performance of the GA algorithm has been demonstrated using IEEE-30 bus test system. From the results shown in table, it is very much clear that for most of wheeling option 1 (i.e. the NUG supplying the increased load demand and additional losses due to the wheal) has least increment in cost, where as for some other transactions option 2 (i.e. the increased load supplied by the combined operation of the utility and NUG) is most economical. Hence before a wheeling transaction is allowed, this analysis is very much necessary to find out most economical decision.

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