OPTIMAL POWER FLOW EVALUATION OF POWER SYSTEM USING GENETIC ALGORITHM

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Abstract- This paper presents an efficient genetic algorithm for solving non-convex optimal power flow (OPF) problems with bus voltage constraints for practical application. In this method, the individual is the binary-coded representation that contains a mixture of continuous and discrete control variables, and crossover and mutation schemes are proposed to deal with continuous/discrete control variables, respectively. The objective of OPF is defined that not only to minimize total generation cost but also to improve the bus voltage profile.. The proposed method is demonstrated for a IEEE 30-bus four generator ystem, and it is compared with conventional method.The experimental results show that the GA OPF method is superior to the conventional.

I. INTRODUCTION

In todays market due to deregulation of electricity the concept and practices are changed. Better utilization of the existing power system resources to increase capabilities with economic cost becomes essential. The objective of an Optimal Power Flow (OPF) algorithm is to find optimal point which minimizes generation cost, loss etc. or maximizes social welfare, loadability etc. while maintaining an acceptable system performance in terms of limits on generators' real and reactive powers, line flow limits, output of various compensating devices etc [1].

From the viewpoint of an OPF, the maintenance of system security requires keeping each device in the power system within its desired operation range at steady-state. This will include maximum and minimum outputs for generators, maximum MVA flows on transmission lines and transformers, as well as keeping system bus voltages within specified ranges.To achieve this, the OPF will perform all the steady-state control functions of the power system. These functions may include generator control and transmission system control. For generators, the OPF will control generator MW outputs as well as generator voltage. For the transmission system, the OPF may control the tap ratio or phase shift angle for variable transformers, switched shunt control, and all other flexible ac transmission system (FACTS) devices. In general, the OPF is a nonlinear, nonconvex, large-scale, static optimization problem with both continuous and discrete control variables. OPF problem is nonconvex due to the existence of the nonlinear (AC) power flow equality constraints. The presence of discrete control variables, such as switchable shunt devices, transformer tap positions, and phase shifters, further complicates the problem solution.The optimal power flow problem has been discussed since its introduction by Carpentier in 1962 [2]. To solve OPF problem Linear Programming(LP)[3 4], Newton-Raphsons (NR) method, Nonlinear Programming (NLP)[5 6], Quadratic programming(QP) [7], Interior Point (IP) method have been used.

Generally, the OPF problem can be expressed as

$$\left.\begin{array}{l} \text{Min } f(x, u) \\ g(x, u) = 0 \\ h(x, u)\ \_\ 0, \end{array}\right\} \qquad (1)$$

where x is the vector of dependent variables (bus voltage magnitudes and phase angles), u is a vector of control variables (as active power generation and active power flow), g (x, u) is the set of nonlinear equality constraints (power flow equations), and h (x, u) is the set of inequality constraints of the vector arguments x and u.

After introduction in Section II information about GA is given, Section III explain GAOPF, in Section IV problem formulation is given in details, Section V discuss case study and result, Section VI summarizes conclusion.

II. GENETIC ALGORITHM

It is an evolution process based on the theory of survival of the fittest. GAs is used for function / control optimization. It follow a non-systematic search procedure with diversity of population is an important concern.

Genetic algorithms are one of the best ways to solve a problem for which little is known. They are a very general algorithm and so will work well in any search space. All you need to know is what you need the solution to be able to do well, and a genetic algorithm will be able to create a high quality solution. Genetic algorithms use the principles of selection and evolution to produce several solutions to a given problem.

The most common type of genetic algorithm works like this: a population is created with a group of individuals created randomly. The individuals in the population are then evaluated. The evaluation function is provided by the programmer and gives the individuals a score based on how well they perform at the given task. Two individuals are then selected based on their fitness, the higher the fitness, the higher the chance of being selected. These individuals then "reproduce" to create one or more offspring, after which the offspring are mutated randomly. This continues until a suitable solution has been found or a certain number of generations have passed, depending on the needs of the programmer.

Individual - Any possible solution

Population - Group of all *individuals*

Search Space - All possible solutions to the problem

Chromosome - Blueprint for an individual. It store genetic information.

Genes - Possible aspect of an individual

Allele - Possible settings for genes

Locus - The unique position of a gene on the chromosome

Genome - Collection of all chromosomes for an individual

Selection

While there are many different types of selection In roulette wheel selection, individuals are given a probability of being selected that is directly proportionate to their fitness. Two individuals are then chosen randomly based on these probabilities and produce offspring.

Crossover

After the selection of individuals it is supposed to somehow produce offspring with them, directly either copied or by crossover.

Parent 1

0 1 0 0 1 1 1 0	1 1 0 0 1 0 0 1

Parent 2

1 0 1 1 0 1 0 0	0 0 1 0 1 1 0 1

Child 1

0 0 1 0 1 1 0 1	0 1 0 0 1 1 1 0

Child 2

1 1 0 0 1 0 0 1	1 0 1 1 0 1 0 0

Mutation

After selection and crossover new population full of individuals is available . Some are directly copied, and others are produced by crossover. In order to ensure that the individuals are not all exactly the same, you allow for a small chance of mutation. You can either change it by a small amount or replace it with a new value. The probability of mutation is usually between 1 and 2 tenths of a percent

Before Mutation

1 0 0 1 1 0 1 1	0 1 1 0 1 1 1 0

After Mutation

1 0 0 1 1 0 1 1	0 1 1 0 1 0 1 0

III. GA - OPF

The Genetic Algorithm Optimal Power Flow (GAOPF) problem is solved based on the use of a genetic algorithm load flow, and to accelerate the concepts, it is proposed to use the gradient information by the steepest decent method. The GAOPF method is not sensitive to the starting points and capable to determining the global optimum solution to the OPF for a range of constraints and objective functions. In Genetic Algorithm approach, the control variables modelled are generator active power outputs and voltages, shunt devices, and transformer taps. Branch flow, reactive generation, and voltage magnitude constraints have treated as quadratic penalty terms in the GA Fitness Function (FF). GA is used to solve the optimal power dispatch problem for a multi-node auction market. The GA maximizes the total participants' welfare, subject to network flow and transport limitation constraints.

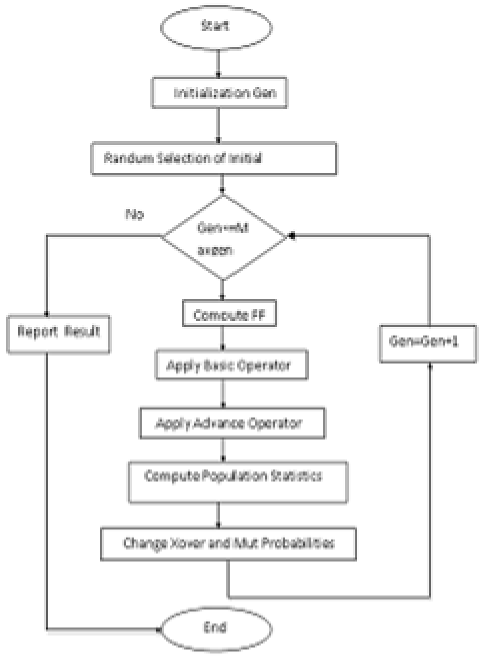
A simple Genetic Algorithm is an iterative procedure. During each iteration step, (generation) three genetic operators (reproduction, crossover, and mutation) are performing to generate new populations (offspring), and the chromosomes of the new populations have evaluated via the value of the fitness, which is related to cost function. Based on these genetic operators and the evaluations, the better new populations of candidate solution are formed. If the search goal has not been achieved, again GA creates offspring strings through above three operators and the process is continued until the search goal is achieved.

3.1 Coding and Decoding of Chromosome

Gas perform with a population of binary string instead the parameters themselves. This study used binary coding.

Here the active generation power set of n-bus system (PG1, PG2, PG3, …., PGn) would be coded as binary string (0 and 1) with length L1, L2, ……,Ln. Each parameter PGi has upper bound *bi* ( ) and lower bound *ai* ( ). The choice of L1, L2, ……,Ln for the parameters is concerned with the resolution specified by the designer in the search space. In this method, the bit length Bi and the corresponding resolution Ri is associated by,

This transforms the PGi set into a binary string called *chromosome* with length ΣLi and then the search space has to be explored. The first step of any GA is to generate the initial population. A binary string of length L is associated to each member (individual) of the population. This string usually represents a solution of the problem. A sampling of this initial population creates an intermediate population.



3.2 Genetic Operator: Reproduction

Reproduction is based on the principle of survival of the fittest. It is an operator that obtains a fixed number of copies of solutions according to their fitness value. If the score increases, then the number of copies increases too. A score value is associated with a given solution according to its distance from the optimal solution (closer distances to the optimal solution mean higher scores).

3.3 Fitness Function

The cost function has defined as:

To minimize F(x) is equivalent to getting a maximum fitness value in the searching process. A chromosome that has lower cost function should be assigned a larger fitness value. The objective of OPF has to be changed to the maximization of fitness to be used in the simulated roulette wheel. The fitness function is used as follows:

$$Fitness\ Function\ (FF) = \frac{1}{1 + f^2} \qquad (3)$$

Where

$$f = f_c + p_{1\left(\sum c_{ineq}^2\right)} + p_{2\left(\sum c_{eq}^2\right)}$$

C_{ineq} - Inequality constraint violation

C_{eq} - Equality constraint violation

Where *C* is the constant; *Fi* (*PGi*) is cost characteristics of the generator *i*; *wj* is weighting factor of equality and inequality constraints *j*; *Penaltyj* is the penalty function for equality and inequality constraints *j*; *h j* (*x*, *t*) is the violation of the equality and inequality constraints if positive; *H* (.) is the Heaviside (step) function; *N*c is the number of equality and inequality constraints. The fitness function has been programmed in such a way that it should firstly satisfy all inequality constraints by heavily penalizing if they have been violated. Then the equality constraints are satisfied by less heavily penalizing for any violation. Here this penalty weight is not the price of power. Instead, the weight is a coefficient set large enough to prevent the algorithm from converging to an illegal solution. Then the GA tries to generate better offspring to improve the fitness.

IV. OPTIMAL POWER FLOW PROBLEM STATEMENT

In proposed method, from equation 1 where the state variable x are used as a control variables given as

$x = [\ V_{Gen}\ \ P_{Gen}\ ]^T$

$u = [\ P_{Line}\ \ Q_{line}\ V_{load}\ \theta_{load}\ Q_{Gen}\ ]^T$

where V_{Gen} is the Generator voltage ,

P_{Gen} is the generated power

No PV-PQ switching is applied and maximum generator capacity bus is considered as slack bus.

The nonexistence of a feasible solution, means that too many constraints added to the problem and no solution exists which obeys all of the constraints. Implement inequality constraints in the form of penalty functions can avoid this problem. For the inequality constraints, the penalty functions offer a viable option. So, penalty functions are added to the objective function of the OPF. Ideally, a penalty function will be very small, near a limit and increase rapidly as the limit is violated more. The penalty function is zero when the inequality constraint are not violated and as the constraint begins to be violated, the penalty function quickly increases and reduces on reduction in violation limits.

VI. CASE STUDY

The proposed method was tested on IEEE 30 Bus, four generator system.

Generator Operating Data is given in Table1

Table1 – Generator Operating Data

Gen. Bus	G1	G2	G3	G4
Pmin	1.10	0	0.5	0.4
Pmax	1.6	0.5	1.0	0.8
Qmin	0.0448	0	0.386	0.0232
Qmax	0.5	0.5	0.5	0.5
Vmin	101	95	95	95S
Vmax	105	105	105	105
a	0.14	0.20	0.14	0.20
b	20.240	19.30	20.240	19.30
c	5	5	5	5

The chromosome of the gene comprises the generator real power P_{Gi}, generator reactive power Q_{Gi} , Shunt compensation $T_{sh,}$, Transformer tap setting T_p. Each variable is coded in binary form and length of 8 bit. The total length of chromosome will be 32 bit. The chromosome will be as follows is shown in fig.2

P_{G} 1		P GN	Q G1		Q GN	T_S H1		T_S HN	T_P 1		T_P N

$\underbrace{\qquad\qquad}_{P_{Gi}}\ \underbrace{\qquad\qquad}_{Q_{Gi}}\ \underbrace{\qquad\qquad}_{T_{sh}}\ \underbrace{\qquad\qquad}_{T_P}$

Keeping crossover probability at 0.6 and mutation rate very low at 0.01 and varying the population size from 50 to 150 in a step of 50 and taking 10 run of each step size, the voltage profile at each bus is almost following the same pattern as that of classical method. The voltage pattern is shown in fig. 3

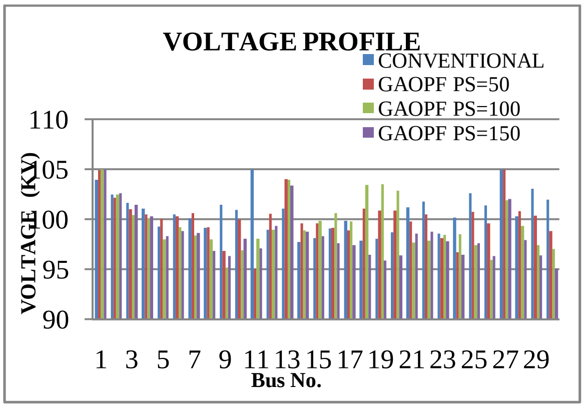


Fig.3 Voltage Profile of various bus

In conventional method all four generators are not supplying power as per their rating, as in case of GAOPF all generator except G2 supplying power as per the rating, as generator G2is supplying zero power so that the operating cost of generator becomes low as compared to conventional method and it is shown in fig.4

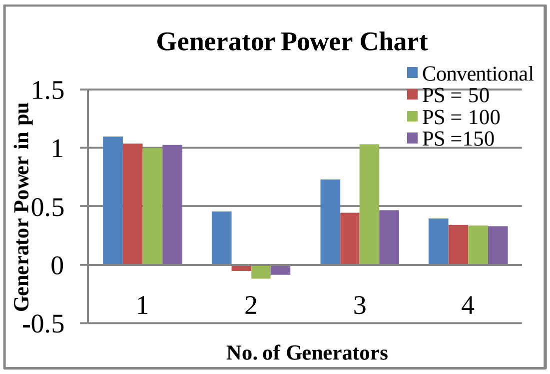


Fig.4 Generation power chart

Computational time is less when population size is 100 but the operating cost is less at population size of 150.It is shown in Table 2

Table 2 – Cost table

Population Size	Cost($)	Computational Time (sec)
Conventional	74.30	---
50	75.3	194.3
100	68.53	83.22
150	67.78	681.45
200	68.50	662.00

At population size of 150, crossover probability 0.6 and mutation rate 0.01 is the combination which gives the minimum operating cost with improved voltage profile and proper loading of each generator. The result is shown in the fig.3

Table 3 – Result Table

Variables	Conventional	GAOPF
P_{G1}	1.10 pu	1.027
P_{G2}	0.4569 pu	-0.082
P_{G3}	0.7356 pu	0.0470
P_{G4}	0.4 pu	0.334
Q_{G1}	0.0448	0.273722
Q_{G2}	0.1634	0.399211
Q_{G3}	0.0386	-0.01668
Q_{G4}	0.0232	0.398031
V_{G1}	104.00	104.9999
V_{G2}	102.47	102.6461
V_{G3}	101.84	98.78998
$V_{G4`}$	105	102.0239
Cost($)	74.30	67.78
Computational Time (sec)	681.45	----

VII. CONCLUSION

In this paper, a GAOPF approach is developed. It's found that the GAOPF method offers, the lowest fuel cost and when compared to conventional method the control parameters obtained by the proposed method confirms the robustness. The implementation has been performed on a standard IEEE 30 Bus system it's found that the proposed method is highly promising.

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