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A Genetic Algorithm Based Approach for Solving Optimal Power Flow Problem

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Abstract: *The objective of this paper is to evolve simple and effective methods for the optimal power flow (OPF) problem in thermal units, which are capable of obtaining optimal power generations for a large-scale system. In optimization, GA has some well-known advantages and disadvantages. The classical (derivative based) method is applied as economic dispatch problem with transmission capacity constraints in literature. In this study, a similar investigation for economic dispatch is considered using simple Genetic Algorithm. The performance of results obtained with both of the methods is nearly same but from the viewpoint of calculation time GA is much superior and its effectiveness increases as the constraints of the problem are increased.*

Key Words: Genetic Algorithm, Optimal Power Flow.

1. INTRODUCTION

In a practical power system, the power plants are not located at the same distance from the centre of loads and their fuel costs are different. Also under normal operating conditions, the generation capacity is more than the total load demand and the losses. Thus, there are many options for scheduling generation. In an interconnected power system the objective is to find power scheduling of each power plant in such a way as to minimize the operating cost. This means that the generator's power is allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This is called the optimal power flow problem. The OPF is used to optimize the power flow solution of large scale power system. This is done by minimizing selected objective function while maintaining an acceptable system performance in terms of generator capability limits and the output of compensating devices. The objective functions, also, known as cost functions, may represent economic costs, system security, or other objectives.

The OPF has been studied by many researchers and methods have been presented in several classical papers [2], [3], and [4], and in well established textbooks [5], and [6]. These classical methods require specific assumptions on the objective function such as continuity, differentiability. Moreover, these methods are slowly convergent.

Genetic Algorithms (GA) are general search technique based on the mechanism of natural selection and natural genetics. In GA, genetic strings represent search points. The search process uses probabilistic transition rules instead of deterministic ones as in traditional optimization method. The search is conducted over a population of solutions. Moreover, no specific assumptions on the objective function, such as continuity, differentiability, etc. are required in GA.

Genetic Algorithm is different from traditional or conventional methods in four ways:

1. GA work with a coding of the parameter set, not the parameters themselves.
2. GA search from a population of points, not a single point.
3. GA use payoff (objective function) information, not derivatives or other auxiliary knowledge.
4. GA use probabilistic transition rules, not deterministic rules.

In several papers [1] the optimal power flow problem is solved using GA considering a power plant composed of six generators.

In our paper, analysis is done for any number of buses with any number of generators.

The OPF problem has a nonlinear objective function having many variables and constraints. In this paper GA has been used to solve the OPF problem as it completely replaces classical mathematical programming methods and also it is easy to implement as an optimization procedure.

In view of the above, the main thrust of the research work presented in this paper is to propose a new but effective method for solving OPF using GA. The main objectives of the research work presented are as follows:

1. To present a systematic approach for the design of a new method for solving optimal power flow problem using GA.
2. To compare the performance of the GA based method with the conventionally derivative based methods [1], [2], [4], and [5].

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2. MATHEMATICAL MODEL

Mathematical models are of fundamental importance in understanding any physical system. This section focuses on the modeling of OPF problem and its formulation. The factors influencing power generation at minimum cost are operating efficiencies of generators, fuel cost, and transmission losses. The most efficient generator in the system does not guarantee minimum cost as it may be located in an area where fuel cost is high. Also if the plant is located far from the load center, transmission losses may be considerably higher and hence the plant may be overly uneconomical. Hence the problem is to determine the generation of different plants such that the total operating cost is minimum. In all practical cases, the fuel cost of generator *i* with power output P_i can be represented as a quadratic function of real power generation

$$C_i = \alpha_i + \beta_i P_i + \gamma_i P_i^2$$

where, α_i, β_i, and γ_i represent unit cost coefficients.

The economic dispatch problem is to find the real power generation for each plant such that the objective function (i.e., total production cost) as defined by the equation

$$C_t = \sum_{i=1}^{n} \alpha_i + \beta_i P_i + \gamma_i P_i^2$$

is minimum subject to the inequality constraints given by

$$P_{i(\min)} \le P_i \le P_{i(\max)} \quad i = 1,2,\ldots\ldots, n_g$$

where $P_{i(\min)}$ and $P_{i(\max)}$ are the minimum and maximum generating limits respectively for plant *i*, subject to the constraint that generation should equal total demand plus losses, i.e.,

$$\sum_{i=1}^{n_g} P_i = P_D + P_L$$

where C_t is the total production cost, C_i is the production cost of the *i*-th plant, P_i is the generation of *i*-th plant, P_D is the total load demand, and n_g is the total number of displaceable generating plants and P_L is the total transmission loss as a quadratic function of the generator power outputs given by *Kron's loss formula*

$$P_L = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j + \sum_{i=1}^{n_g} B_{0i} P_i + B_{00}$$

The coefficients B_{ij} are called *loss coefficients*.

3. GENETIC ALGORITHM

Genetic algorithms are computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection. They combine the survival of the fittest among string structures with a structured yet randomized information exchange to form search algorithm with some of the innovative flair of human search. In every generation, a new set of artificial creatures (strings) is created using bits and pieces of the fittest of the old; an occasional new part is tried for good measure. While randomized, genetic algorithms are no simple random walk. They efficiently exploit historical information to speculate on new search points with expected improved performance [7], and [8].

3.1 General Structure of GA

The sequential steps for searching optimal solution of PSS parameters using GA is shown in Fig.1.

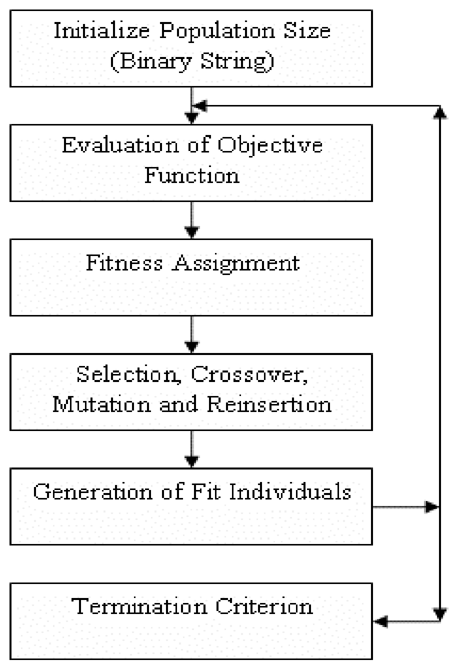

Fig. 1 Computational flow chart.

3.2 Design Methodology

The design problem can be formulated as the following optimization problem:

1. Minimize the objective function $C_i = \alpha_i + \beta_i P_i + \gamma_i P_i^2$ subjected to constraint $P_{\min} \le P_i \le P_{\max}$. Here the fitness

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function $f = C_i - C_{i(0)}$ is taken and it is to be minimized.

2. An initial population of 256 individuals is generated each of 8 bits with the following equations. So, *N=8.*

(a) First the accuracy with following parameters is chosen:

$$Accuracy = \frac{X^U - X^L}{2^N - 1};$$

where $X^U = P_{\max}$ and $X^L = P_{\min}$.

(b) *Chromosome/Individual value* = *Accuracy*$*S_i$ where S_i*=0,1,2,…,255.*

3. From this initial population of 256, 128 individuals are taken randomly for every generation.
4. Roulette Wheel Method of reproduction is used.
5. Single cross-site of crossover is used with crossover rate 0.5 and mutation rate 0.05.
6. As a terminating condition number of generation is chosen to be 100.

4. COMPARATIVE STUDY OF GA BASED SOLUTION WITH CONVENTIONAL SOLUTION

To evaluate the effectiveness of the proposed GA based OPF problem solution examples from [5] are taken as reference, the performance of the GA is examined under different conditions

1. Economic dispatch neglecting losses and generator limits (Example 7.4).
2. Economic dispatch neglecting losses and including generator limits (Example 7.6).
3. Economic dispatch including losses and generator limits (Example 7.7).

Comparative results are given in the following tables: (Table 1, Table 2, and Table 3)

Table 1: Comparison of classical and genetic based optimal dispatch of generation problem neglecting losses and generator limits.

	Classical	**Genetic**
P1(MW)	400.0000	398.4313
P2(MW)	250.0000	250.9803
P3(MW)	150.0000	150.5882
Cost ($/h)	6682.20	6682.51
Time(sec)	50.765	0.9677

Table 2: Comparison of classical and genetic based optimal dispatch of generation problem neglecting losses and including generator limits.

	Classical	**Genetic**
P1(MW)	450.0000	447.3529
P2(MW)	325.0000	325.0000
P3(MW)	200.0000	202.6470
Cost ($/h)	8236.25	8237.66
Time(sec)	105.765	1.0103

Table 3: Comparison of classical and genetic based optimal dispatch of generation problem including losses and generator limits.

	Classical	**Genetic**
P1(MW)	35.0907	31.1764
P2(MW)	64.1317	67.0588
P3(MW)	52.4767	50.0000
Cost ($/h)	1592.65	1566.45
Time(sec)	250.765	1.723

From the tables it is evident that GA based solutions are faster than the traditional derivative based methods and the computational time differences are much more prominent as the constraints are increased.

5. CONCLUSION

A new approach for solving the challenging optimal load flow problem is presented. The model for solving the mentioned problem is formulated and solved at various conditions. The results are compared with the results obtained using traditional methods. The results are quite similar except that GA is much faster than the traditional ones. This indicates that the GA approach is quite promising and deserves serious attention because of its probabilistic transition rules, not deterministic ones.

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