Optimum Scheduling of Generators Using Genetic Algorithm

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Summary
Variation in load demand does not allow a fixed number of generators working in parallel to share the load in proportion to their capacity and therefore lead to an uneconomical operating cost. Presently the economic load dispatch in a group of generators is decided by the criteria of constant derivative state achieved among all the generators in the group of generators. Thus with n-generators operating together the partial derivatives of fuel cost F to the capacity of generator P, should always prevail with equality for each of the generators. Since the derivative approach for economic load dispatch suffers from the draw back of local maxima, the present work has implemented genetic algorithm, which yields global maxima. Also it has been found that the scheduling of generators with regard to its operation on maxima and minima of their capacity in a particular hour over 24 hours is decided by genetic algorithm GA. It is proved that the GA approach for optimum scheduling of generators, Yields a substantial saving/ economy in operating cost over the derivative approach. Software has been developed to implement GA for selection of best string. Here the best string refers to the optimum scheduling of generators in a group.

Key words:
Genetic algorithm, Reproduction, crossover, Mutation, chromosomes, total objective function (TOF), Generations.

1.0. Introduction

The modern power system needs to operate its generating units in parallel to meet the specific load demand under variable operating conditions. The maintenance engineer is always under a pressure to ensure economic dispatch of load. The engineer has always to plan about the generators that will remain in operation at a given time and under given load conditions. The economic dispatch involves two separate steps namely the unit commitment and the online economic dispatch. By the term Unit Commitment [3] its meant that the load will be supplying by the generator at minimum cost and besides it the generator will keep a specified margin known as operating reserve. By the online economic dispatch provides for proper load allocation to different generating units in such a manner as to minimize the total cost of supplying the load. The operating cost is mainly the cost of fuel, which is a non-linear function of plant generation given by

$$Ci = \alpha i \quad + \beta i\, Pi + \gamma i\, Pi^2$$

Since the cost of generation is a nonlinear function of the power generated by any generating unit. The use of mathematical model for solving optimal operating conditions doesn't yield a global optimal conditions, rather its provides local optimal conditions, in order to overcome this difficulty the most versatile which was noticed after study the GENETIC ALGORITHM.

1.1 Why Genetic Algorithm?

Basically Genetic Algorithm popularly known as GAs, are search algorithms based on the mechanics of natural selections and natural genetics. GA combined survival of the fittest string among string structures with structure randomize information exchange to form a search algorithm. Genetic algorithm has been developed by John Holland at university of Michigan. It was aimed to abstract and give a rigorous explanation to adaptive processes in natural systems. He also aimed to design artificial system software that strictly follows the basic mechanism of natural system. This powerful tool is going to prove wonders in the field of search, optimization and machine learning.

The objective of genetic algorithm is to ensure robustness [2] of the best fit generation. It strikes a balance between two or more competing features for example effectiveness and power. Consider a function that varies in a pattern as shown in figure.

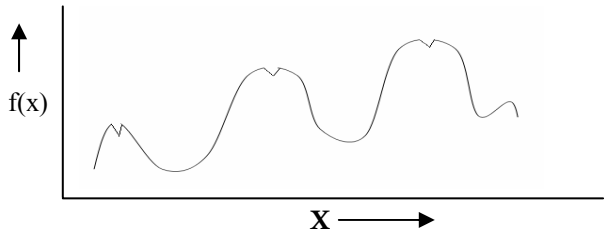

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Figure 1.

It can be seen that characteristics shows no. of maximas and minimas. The efforts are made using calculus for determining the optimal conditions the result gives either local maxima or local minima. This may not be the ultimate or global minima/maxima. The genetic algorithm is not a victim to this approach because the search doesn't stop till all the maximas and minimas present in the function are not tested. It therefore gives global maxima and global minima besides the local maxima and local minima. Though the tool of genetic algorithm is time consuming yet it is reliable and comprehensive.

1.2 Genetic Algorithm a better Way !

- The genetic algorithm is preferred over traditional methods because they work with coding and are free from limitations like continuity, derivation and unimodality.
- It provides a model free approximation of the problem and has proved to be best technique in obtaining the best solutions.
- Genetic algorithm search from population of point rather then a single point. Its known as build as well as robust tool for maxima.
- Genetic algorithm use payoff information not derivation or other auxiliary knowledge.
- Genetic algorithm use probabilistic transmission rules instead of deterministic ones. Therefore it can search a non-convex area to find the global optimum.

1.3 How GA Works ?

GAs work from a rich database of points simultaneously (a population of strings), climbing many peaks in parallel; thus, the probability of finding a false peak is reduced over methods that go from point to point. The mechanics of a simple genetic algorithm involves nothing more complex than to copy strings and swap partial strings. The explanation of why this simple process works is subtle and yet it is extremely powerful. Simplicity of operation and the power of the effect (speed and accuracy) are two of the main attractions of genetic algorithms. A simple genetic algorithms that yields good results in many practical problems is composed of three operators [5]

1. Reproduction
2. Crossover
3. Mutation

Reproduction is a process in which individual strings are selected according to their objective function value f (biologists call this function - the fitness function). Intuitively, we can think of the function f as some measure of profit, utility, or goodness that we want to maximize. Selecting strings according to their fitness values means that strings with a higher value have a higher probability of contributing offspring to the next generation. After reproduction, **crossover** proceeds in two steps. First, members of the newly reproduced strings in the mating pool are mated at random. Second, each pair of strings undergoes crossover as follows: an integer position k along the string is selected uniformly at random between 1 and the string length less one [1, l-1]. Two new strings are created by swapping all characters between position k+1 and l inclusively. Mutation plays a decidedly secondary role in the operation of genetic algorithms. **Mutation** is needed because, despite the fact that reproduction and crossover search and recombine existent notions, occasionally they may lose some potentially useful genetic material. The mutation operation involves periodically selecting one individual at random, selecting one position on the chromosome string and transposing it from 0 to 1 or vice-versa. Mutation restores diversity but does not provide a logical approach to optimization. Its use should be restricted to situations where a a local minimum (or maxima) has trapped the algorithm and a new population member is required to trigger the crossover operator on to a better result.

2.0. Proposed Work

1. To collect the data showing the number and sizes of generating units and their fuel cost.
2. To collect the data showing the daily load variation in a power system.
3. To develop a software for implementing genetic algorithm.
4. To test the data for generating units and load variations on the developed software.
5. To analyse the results.

2.1 Expected Result

It is expected that the solution of optimization of cost of operation would yield a better economy over the traditional approach.

3.0 The Problem

To establish that the GA approach is more reliable method of reducing the cost of generation than any other approach, the problem of the present research work includes

- To identify load variation.
- To identify number and sizes of generating units.
- To develop an objective function.
- To develop a software for obtaining optimal solutions using genetic algorithm, GA.
- To solve the problem by using derivative approach.

- To obtain and analyze the results.

4.0 The Solution

The solution is obtained by using the

- GA software approach
- Derivative Approach &
- There Comparision

4.1 Development of GA Software Approach

To workout GA software approach following have been considered.

- Load variation can be identified by using data received from Load dispatch centre as shown in table 5.1.
- Available number and sizes of generators are given in table 5.2.
- Objective function is given by[8]

$$F=\sum_{l=1}^{K}\sum_{n-1}^{N}(a_n+b_nP_{nl}+c_nP_{nl}^2)$$

here F represents the total objective function, a_n , b_n & c_n are the coefficients of the input-output curve of generating units, Pnl is the power of the n^{th} unit for the l^{th} hour, N & h are the number of units and the load duration in hour respectively. Eq. represents the total objective function (TOF) to be minimized by the GA.

- Construct a flowchart as shown in Fig.2.
- Algorithm developed is as given below [1]

Step 1: Represent the problem variable domain as a chromosome of a fixed length, choose the size of a chromosome population N, the crossover probability pc and the mutation probability pm.

Step 2: Define a fitness function to measure the performance, or fitness, of an individual chromosome in the problem domain. The fitness function establishes the basis for selection of chromosomes that will be mated together during reproduction.

Step 3: Randomly generate an initial population of chromosomes of size N: x1, x2, . . . , xN

Step 4: Calculate the fitness of each individual chromosome: f (x1), f (x2), . . . , f (xN)

Step 5: Select a pair of chromosomes for mating from the current population. Parent chromosomes are selected with a probability related to their fitness. Highly fit chromosomes have a higher probability of being selected for mating than less fit chromosomes.

Step 6: Create a pair of offspring chromosomes by applying genetic operators crossover and mutation.

Step 7: Place the created offspring chromosomes in the new population.

Step 8: Repeat Step 5 until the size of the new chromosome population becomes equal to the size of the initial population, N.

Step 9: Replace the initial (parent) chromosome population with the new (offspring) population.

Step 10: Go to Step 4, and repeat the process until the termination criterion is satisfied.

• A software is developed in C language to ensure economic load dispatch by implementing GA operators.

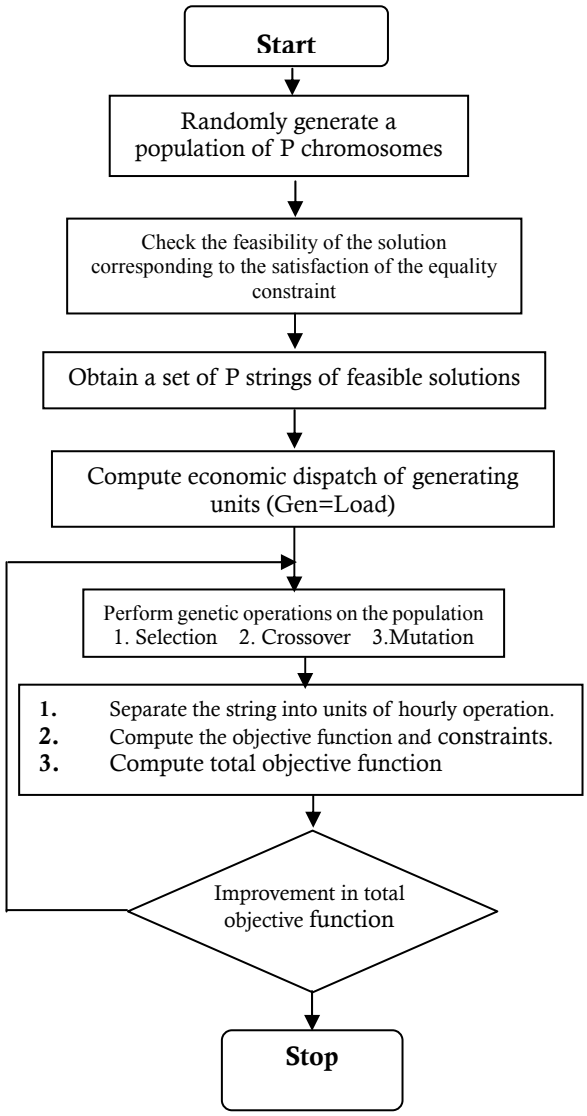

Fig 2. flowchart of GA approach

4.2 Derivative Approach

Traditionally so far optimal value has been find using derivative approach. This approach doesn't provide global maxima but gives the solution at a local point.

Total cost per hour of plants 1 and 2 are given as

$F1=0.2P_1^2+40P_1+120$ Rs/hr

$F2=0.25P_2^2+30P_2+150$ Rs/hr

Condition for Optimal load dispatch can be obtained by differentiating F (Fuel Input) w.r.t. the generation P and equating this value for two units, i.e.

$\partial F_1/\partial P_1=\partial F_2/\partial P_2$ (1)

P1+P2=load at that hour (2)

Find P1 & P2 by solving equations 1 & 2. Calculate F1 & F2. Now cost of generation for that hour is obtained by addition of F1 & F2

The derivative approach when applied on two generators unit problem it gave certain minimum optimum value. This is shown in the following illustration.

5.0 Illustration

GA parameters are as shown in table 1.

Table 1. GA Parameters

S. No.	*Parameter*	
1	No. of generating units	2
2	String population size	2
3	No. of generations	21
4	Load duration hours	24
5	Probability of mutation	0.4
6	String length	48

Generator capacity and operating constants are given in table 2.

Table 2. Generator Data

Unit	Pmax	Pmin	an	bn	cn
1	100	25	120	40	0.2
2	100	25	150	30	0.25

Load pattern of 24 hours are as shown in table 3.

Table 3. Load Pattern

Hour	Load (MW)	Hour	Load (MW)	Hour	Load (MW)
1	60	9	100	17	170
2	50	10	180	18	165
3	50	11	180	19	190
4	50	12	165	20	140
5	70	13	150	21	150
6	70	14	180	22	100
7	60	15	100	23	80
8	60	16	170	24	60

5.1 Output from GA software approach

Output from the GA software approach is as given below. Here TC is total minimum cost among three strings

GENERATION: 1
11111011011111101111110111110101000110111111110
11111011111011111011111111111001110101111111111
10111111011011111111011111110010000011111111110
TC = 1,39,255

GENERATION: 2
11011111111111111111011110111110101000110111111
11111001111100111111111111111100100000111111111
11101111111111011111111101111111001110101111111
TC = 1,38,921
.
.
.
GENERATION: 21
00011111111111101111111111011111100111010111111
11011111101111111011111110111111010100011011111
11101111111111101111111101111111001000001111111
TC = 1, 35, 670

5.2 Output from Derivative approach

Results obtained from derivative approach is found to be 1,36,955 Rs. / Day.

6.0 Results & Analysis

- Using derivative approach cost of operation of two generating units is found to be Rs. 1,36,955 / Day.
- The cost was initially found out by Genetic Algorithm. There after by increasing the number of generations it continuously follow decreasing

trend and finally attained a minimum constant value.

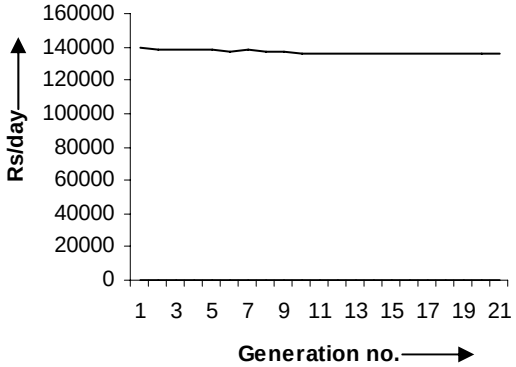

Figure 3. Plot between Rs/day & generation no.

- Results obtained from derivative approach is found to be 1,35,670 Rs./ Day.
- It has been established that by the use of genetic algorithm for obtaining optimal number of generating units under given load conditions, leads to a high profit in the running cost of the order of approximately rupees 1200 per day. It amounts to a net profit of Rs 4,38,000 per annum.

6. Conclusion

The most optimal/economic dispatch condition is strongly decided by the factors like selection of strings, crossover followed by mutation. However improper string, mismatched crossover and undesired mutation leads to a very weak outcome with the result that it becomes impossible to obtain the economic dispatch status of load. A study has been carried out to understand and practically implement the use of operators like string formation, crossover and mutation. The genetic algorithm has been applied on power system with two generating units. It has been established that the use of genetic algorithm for obtaining optimal number of generating units under given load conditions, leads to a high profit in the running cost of the order of approximately rupees 1200 per day. It amounts to a net profit of Rs 36,000 per annum. The profit multiplies with increase in number of units. The only drawback of this technique is that it takes a very long processing time. It is hoped that this will also reduced with the advent of high-speed processors in computers.

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