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Economic and Emission Constrained Load Dispatch Using Genetic Algorithm

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Abstract: The Genetic Method is a self-adaptive algorithm for global search optimization. It is a technique for searching that is based on random probability. It blends an artificial premise, namely Darwin's survival of the fittest, with an abstracted genetic operation from nature to create a durable system that is exceptionally good at discovering optimal solutions to difficult real-world circumstances. This work proposes a GA to manage generation scheduling for Economic load dispatch with emission limits, a topic that has lately gained interest as a result of power industry liberalisation and strict environmental regulation. The issue is written for three distinct generators, each of which is constrained by its own set of constraints. The capacity limits on the generating units are handled as inequality constraints, whereas the generation-demand balance constraint is treated as an equality constraint. This paper presents a novel way for handling equality constraints. The collected data indicate that the evolutionary algorithm has a solution set that is optimal under a range of loading conditions.

Keywords- Genetic Algorithm, Economic Load Dispatch, Economic Emission Dispatch, Reproduction, Crossover, Mutation

I. INTRODUCTION

Economic load dispatch (ELD) is the process of allocating generator output to fulfil electrical demand in a power system in the most cost-effective manner possible while taking all constraints into account. The ELD problem's difficulty is governed by a number of criteria, including the system's size, constraints, and generating characteristics. Economic load dispatch's fundamental objective is to schedule committed producing unit outputs in such a way that they fulfil load demand at the lowest possible operational cost while meeting equality and inequality criteria. Thus, the ELD issue is a large-scale nonlinear optimization problem with severe constraints. Economic emission dispatching (EED) is an alluring short-term strategy for reducing emissions while also lowering fuel expenditures.

II. GENETIC ALGORITHM

GA is an adaptive search technique based on the principles of genetics and natural selection. They are capable of working with string structures. The string is a sequence of binary digits that encodes the control settings associated with a particular problem. Numerous such string constructions are evaluated concurrently, with the best fit obtaining exponentially increasing possibilities of transmitting genetically necessary material to succeeding generations of string structures. Thus, evolutionary algorithms search for a large number of points in the search space simultaneously while gradually reducing the search to the locations with the best observed performance.

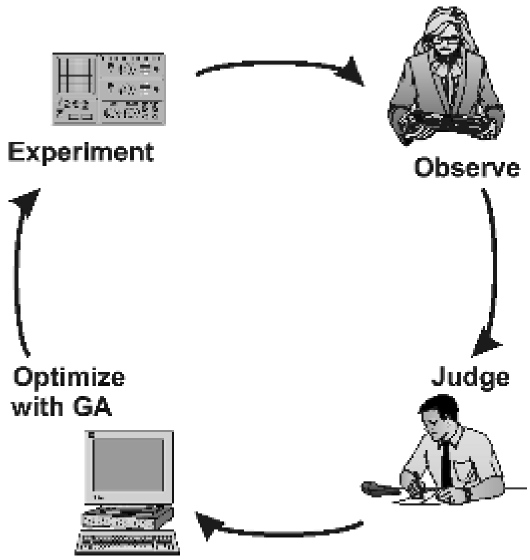

Fig:1 An iterative approach to creativity that combines human judgment with GA.

The basic approach of genetic algorithms is shown as,

1. Determine the coding structure.
2. Determine the fitness function.
3. Determine the selection strategy.
4. Select the control parameters.
5. Design the genetic operators.
6. Determine the terminate criterion.

The basic elements of genetic algorithms are: Reproduction, Crossover and Mutation

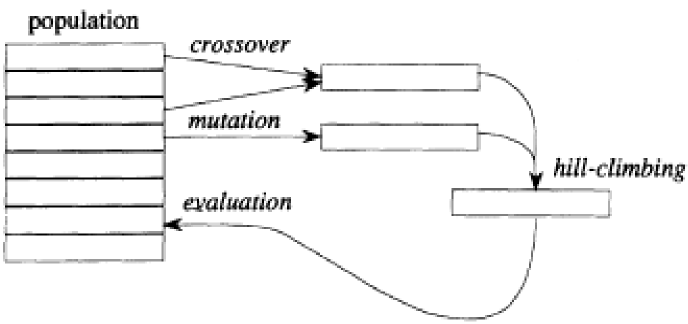

Fig. 2 Simple genetic algorithm procedure

Genetic Algorithm Operators:

1) Reproduction:

The first genetic algorithm operator is reproduction. The reproduction genetic algorithm operator selects good strings in a population and forms a mating pool. So, sometime the operator is also named as the selection operator. The commonly used reproduction operator is the proportionate reproduction operator where a string is selected for the mating pool with a probability for selecting the ith string is

$$f_{av} = \left(\sum_{i=1}^{L} f_i \right) \times \frac{1}{L} \frac{f_i}{\sum_{j=1}^{L} f_j} \quad (1)$$

Where

L is the population size

fi is the fitness of the i^{th} population.

2) Crossover:

The basic operator for producing new chromosome in the genetic algorithm is that of crossover. In the crossover operator, information is exchanged among string of the mating pool to create new strings. In other words, crossover produces new individuals that have same parts of both parent's genetic materials. It is expected from the crossover operator that good substrings from parent strings will be combined to form a better child offspring. There are three forms of crossover: (i) one point crossover, (ii) multipoint crossover (iii) uniform crossover.

3) Mutation:

Mutation is the important operator, because newly created individuals have no new inheritance information and the number of alleles is constantly decreasing. This process results in the contraction of the population to one point, which is wished at the end of the convergence process, after the population works in a very promising part of the search space. Diversity is necessary to search a big part of the search space. It is one goal of the learning algorithm to search always in regions not viewed before. Therefore, it is necessary to enlarge the information contained in the population. One way to achieve this goal is mutation. Mutation operator changes 1 to 0 and vice versa with a small mutation probability pm. The bit-wise mutation is performed bit-by-bit by flipping the coin with required probability.

Child A: 1 1 1 1 0 1 0

↓

New child A: 1 1 0 1 0 1 0

III. ALGORITHM FOR ECONOMIC LOAD DISPATCH PROBLEM USING GENETIC ALGORITHM

The step-wise procedure is outlined below.

1. Read data, namely cost coefficients, ai, bi, and ci; B- coefficients, Bij (i = 1,2,3....…NG ; j =1,2…,NG). Convergence tolerance, error, step size, alpha and maximum allowed iterations (ITMAX), Length of string l, population size L, probability of crossover pc, probability of mutation pm, pimin and pimax etc.
2. Generate an array of random numbers. Generate the population p_i^j (j = 1,2,…..,L) by flipping the coin. The bit is set according to the coin flip as

$$b_{ij} = \begin{cases} 1 \\ 0 \end{cases}$$

If p =1 OR random 0 <= p and 0 otherwise

3. Set generation counter k=0, BIG =1.0, fmax = 0.0, and fmin = 1.0.
4. Increment the generation counter, k = k +1 and set population counter, j=0.
5. Increment the population counter, j = j +1.
6. Decode the string using function bi2dig (d (i , j)) in Matlab software and find p(i , j)

$$p(i, j) = p\min(i) + \frac{p\max(i) - p\min(i)}{2^l - 1} d(i, j)$$

(i = 1,2,……….NG; j = 1,2,…..L)

Where pmin(i) is the minimum value generation of the ith plant

Pmax(i) is the maximum value of generation of the ith plant.

d (i , j) is the binary coded value of the ith substring

L is the number of strings or population size.

7. Calculate the transmission loss

$$p(L,j)=\sum_{i=1}^{NG}\sum_{k=1}^{NG}P(i,j)*B(i,j)*P(k,j)$$

(j =1,2 ……, L)

8. Using

$$\varepsilon^{j}=\left|pd+p(L,j)-\sum_{i=1}^{NG}p(i,j)\right|$$

9. Find fitness from $$f^{j}=1\div\left(1+(alpha)\frac{\varepsilon^{j}}{pd}\right)$$

(j = 1,2,…….,L) where, alpha is the scaling constant.

If (f(j) > fmax), then set fmax =f(j) and if (f (j) < fmin) then set fmin = f(j)

10. If (j < L) then GOTO step 5 and repeat.
11. Find population with maximum fitness and average fitness of the population.
12. Select the parents for crossover using stochastic remainder roulette wheel selection using algorithm.
13. Perform single point crossover for the selected parents.
14. If (k < ITMAX) then GOTO step 4 repeat.
15. Stop

IV. COMBINED ECONOMIC AND EMISSION CONSTRAINED LOAD DISPATCH PROBLEM FORMULATION

A. Economy Objective:

The fuel cost of a thermal unit is regarded as an essential condition for economic feasibility. The fuel cost curve is assumed to be approximated by a quadratic function of generator power Pg_i as

$$F_1=\sum_{i=1}^{NG}\left(a_iPg_i^{\,2}+b_iPg_i+c_i\right)\quad \text{Rs/h} \qquad (2)$$

Where a_i, b_i and c_i are cost coefficients and NG is the number of generators.

B. Environmental Objectives:

The emission curves can be directly related to the cost curve through emission rate which is a constant factor for a given type of fuel. Therefore, the amount of NO_x emission is given as a quadratic function of generator output Pg_i, i.e.

$$F_2 = \sum_{i=1}^{NG} \left(d_{1i} Pg_i^2 + e_{1i} Pg_i + f_{1i} \right) \text{ kg/h} \qquad (3)$$

Where d_{1i}, e_{1i}, and f_{1i} are NO_x emission coefficients

'Similarly the amount of SO_2 emission is given as a quadratic function of generator output Pg_i, i.e.

$$F_3 = \sum_{i=1}^{NG} \left(d_{2i} Pg_i^2 + e_{2i} Pg_i + g_{2i} \right) \quad \text{kg/h} \qquad (4)$$

Where d_{2i}, e_{2i} and f_{2i} are SO_2 emission coefficients

The amount of CO_2 emission is also represented as a quadratic function of generator output Pg_i, i.e.

$$F_4 = \sum_{i=1}^{NG} \left(d_{3i} Pg_i^2 + e_{3i} Pg_i + f_{3i} \right) \text{ kg/h} \qquad (5)$$

Where d_{3i}, e_{3i} and f_{3i} are CO_2 emission coefficients

C. Constraints:

To ensure a real power balance, an equality constraint is imposed, i.e.

$$\sum_{i=1}^{NG} Pg_i - (P_D + P_L) = 0 \qquad (6)$$

Where

P_D is the load demand

P_L is the transmission losses, which are approximated in terms of loss-coefficients as

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} Pg_i B_{ij} Pg_j \text{ MW} \tag{7}$$

The inequality constraints imposed on generator output are

$$Pg_i^{min} \leq Pgi \leq Pg_i^{max} \qquad (i = 1, 2, \ldots..NG)$$

Where P_i^{min} is the lower limit, and P_i^{max} is the upper limit of generator output.

Aggregating equations., the multi-objective optimization problem is defined as

Minimize $[F_1(Pg), F_2(Pg), F_3(Pg), F_4(Pg),]^T$

Subject to $$a = \sum_{i=1}^{NG} Pg_i - (P_D + P_L) = 0 \tag{8}$$

$$Pg_i^{min} \leq Pgi \leq Pg_i^{max} \qquad (i = 1, 2, \ldots, NG)$$

Where F_1 (Pg), F_2(Pg), F_3(Pg), and F_4(Pg) are the objective functions to be minimized over the set of admissible decision vector Pg. [10]

V. ALGORITHM FOR COMBINED ECONOMIC & EMISSION CONSTRAINED LOAD DISPATCH USING GENETIC ALGORITHM

The step-wise procedure is outlined below.

1. Read data, namely cost coefficients, ai, bi, and ci, emission coefficients of gases CO_2,NOx and Sox, B- coefficients, Bij (i = 1,2,3...….NG ; j =1,2…,NG). Convergence tolerance, alpha and maximum allowed iterations (ITMAX), Length of string l, population size L, probability of crossover pc, probability of mutation pm, pimin and pimax etc.
2. Generate an array of random numbers. Generate the population p_i^j (j = 1,2,…..,L) by flipping the coin. The bit is set according to the coin flip as

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$$p(i,j) = p\min(i) + \frac{p\max(i) - p\min(i)}{2^{l} - 1} d(i,j)$$

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8. Using

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9. Find fitness from

$$f^{j} = 1 \div \left(1 + (alpha) \frac{\varepsilon^{j}}{pd} \right)$$

(j = 1,2,…….,L) where, alpha is the scaling constant.

If (f(j) > fmax), then set fmax =f(j) and if (f (j) < fmin) then set fmin = f(j)

10. If (j < L) then GOTO step 5 and repeat.
11. Find population with maximum fitness and average fitness of the population.
12. Select the parents for crossover using stochastic remainder roulette wheel selection using algorithm.
13. Perform single point crossover for the selected parents.
14. Calculate the total cost of the generation.
15. Calculate the emission of NOx, SOx and CO2 using the value of different unit generation.

16. If (k < ITMAX) then GOTO step 4 repeat.
17. Stop
18.

VI. PROGRAM RESULTS

PROGRAM RESULT FOR ECONOMIC LOAD DISPATCH PROBLEM:

Consider three generator system, the fuel cost co-efficient and the operating Generator limits are given in appendix. Determine the Economic Load Dispatch for load of 300 MW respectively.

Program inputs:-

The length of string l= 30
The population size L = 60
The probability of crossover pc = 0.9
The value of load demand in MW = 300

Program results

fmax = 0.990234
pg1= 124.589330 MW
pg2= 147.153552 MW
pg3= 36.283370 MW
Total generation = 308.026252 MW
Transmission losses are = 10.984991 MW
Total cost of generation is = 3656.225311 Rs/h

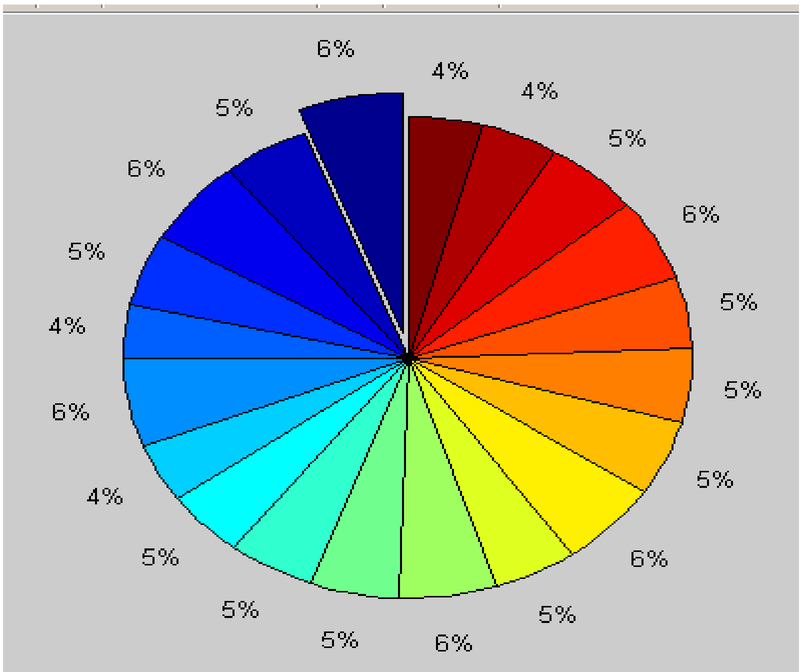

Fig.:3 Roulette wheel selection for the problem

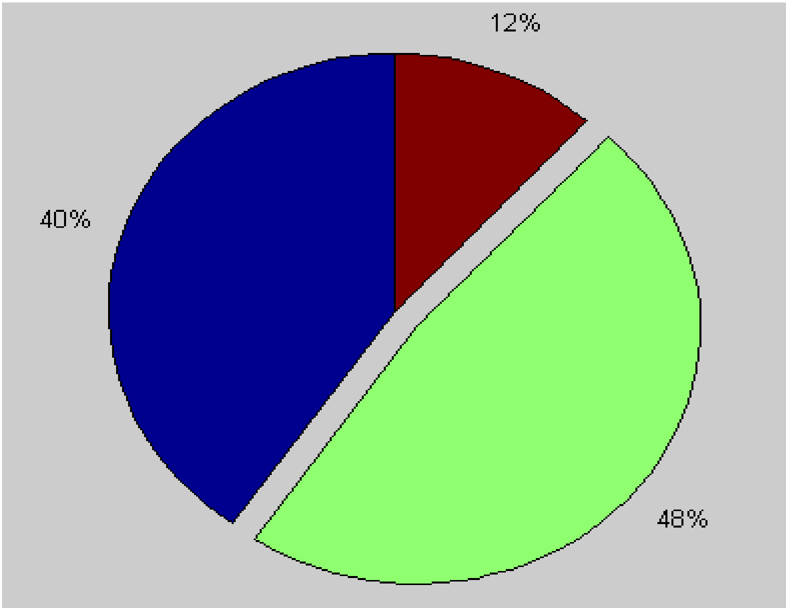

Fig.:4 Percentage of generation for three generators

PROGRAM RESULTS FOR COMBINED ECONOMIC AND EMISSION CONSTRAINED LOAD DISPATCH PROBLEM:

Now for the generation at three generators both economic and emission constraints are considered. The results are shown for three different cases for different parameter change considered.

Case 1:- Population of random number generation change

Program inputs

The population size L = 60

The probability of crossover pc = 0.85

The value of load demand in MW = 300

Program results

fmax = 0.958142

pg1= 188.336846 MW

pg2= 84.830911 MW

pg3= 53.115575 MW

Total generation = 326.283331 MW

Transmission losses are = 13.177285 MW

Total cost of generation are = 3772.621222 Rs/h

Total emission of NOx are = 502.676182 kg/kWh

Total emission of SOx are = 2321.091468 kg/kwh

Total emission of CO_2 are = 6417.652802 kg/kwh

Result Analysis:- Comparing these two results we can say that generation combination are different but yet they all results satisfy the require fitness of value, which is depending on selection of length of string *l*, probability of crossover pc and the population of random number generation.

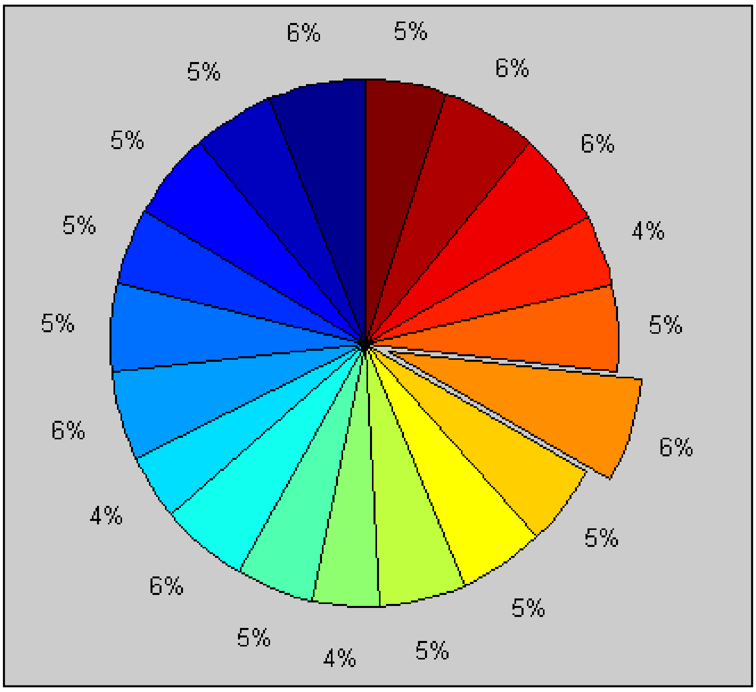

Fig.:5 Roullete Wheel Selection for the problem

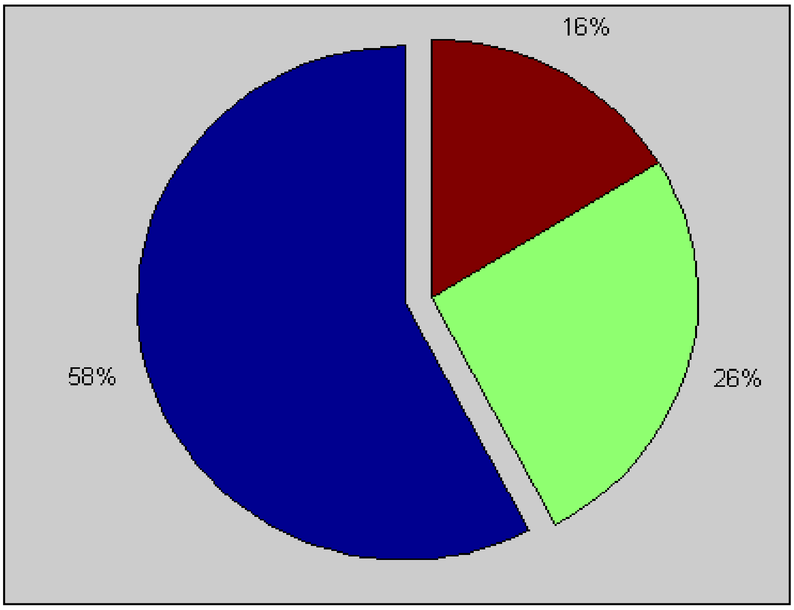

Fig.:6 Percentage of generation for three generators

Case 2 :- Change in length of string

Program inputs

Enter the length of string l= 30

Enter the population size L = 60

Enter the probability of crossover pc = 0.85

Enter the value of load demand in MW = 300

Program results

fmax = 0.987220

pg1= 148.058827 MW

pg2= 70.835285 MW

pg3= 91.323236 MW

Total generation = 310.217348 MW

Transmission losses are = 14.101038 MW

Total cost of generation are = 3604.351915 Rs/h

Total emission of NOx are = 394.827530 kg/kwh

Total emission of SOx are = 2219.445452 kg/kwh

Total emission of CO_2 are = 5616.998094 kg/kwh

Result Analysis:-

In this case we have changed the length of string from 24 to 30, keeping other parameters same. As we select a longer string the result will be more fit. Now the efficiency of the result increases from 95% to 98%.

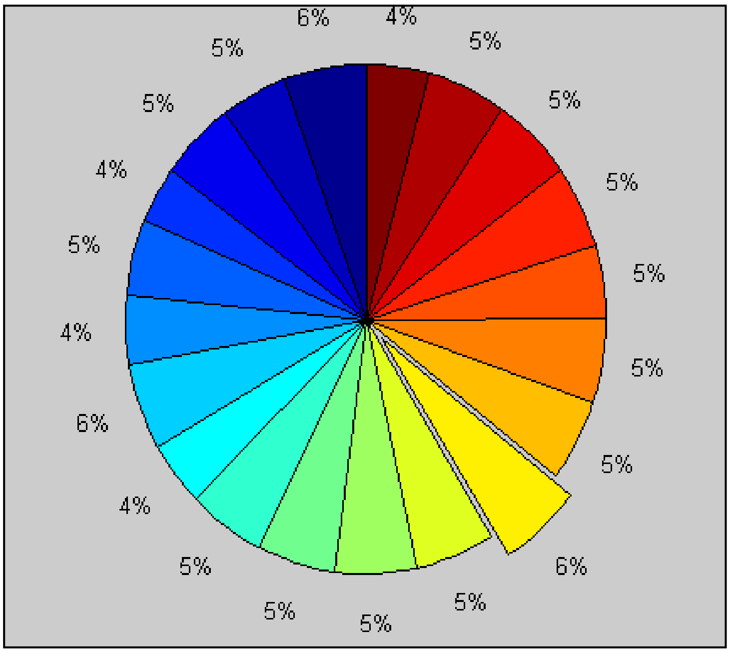

Fig.: 7 Roullete Wheel Selection for the problem

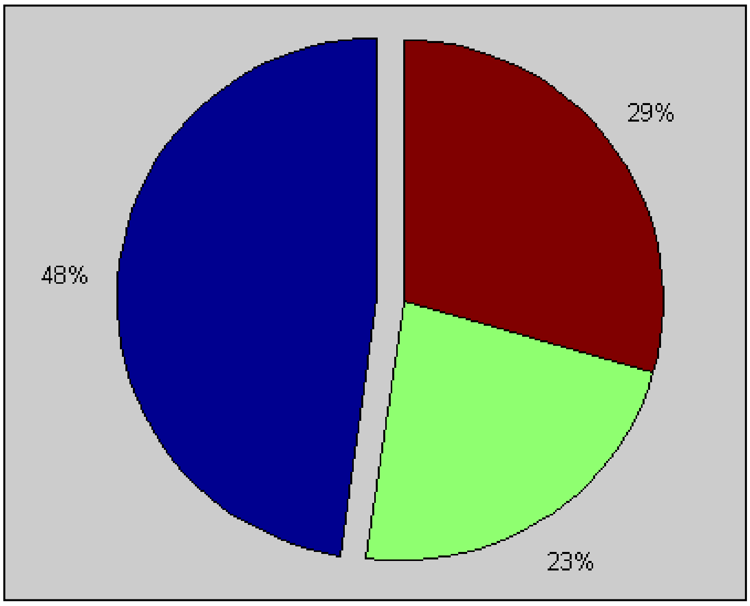

Fig.:8 Percentage of generation for three generators

Case 3 :- Change in probability of crossover

Program inputs

The length of string l= 24

The the population size L = 60

The probability of crossover pc = 0.9

The value of load demand in MW = 300

Program results

fmax = 0.992966

pg1= 145.705121 MW

pg2= 113.086923 MW

pg3= 50.923730 MW

Total generation = 309.715775 MW

Transmission losses are = 11.840936 MW

Total cost of generation are = 3623.543986 Rs/h

Total emission of NOx are = 445.070223 kg/kwh

Total emission of SOx are = 2199.824267 kg/kwh

Total emission of CO_2 are = 5177.323065 kg/kwh

Result Analysis:-

In this case we have changed the probability of crossover from 0.85 to 0.9, keeping other parameters same. As we select the different probability of crossover the site for the single point crossover at the binary string will be changed.

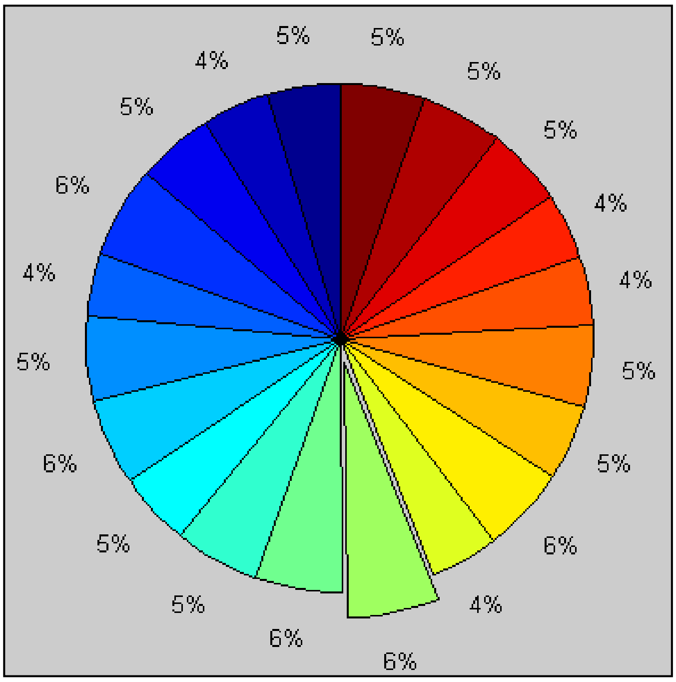

Fig.:9 Roullete Wheel Selection for the problem

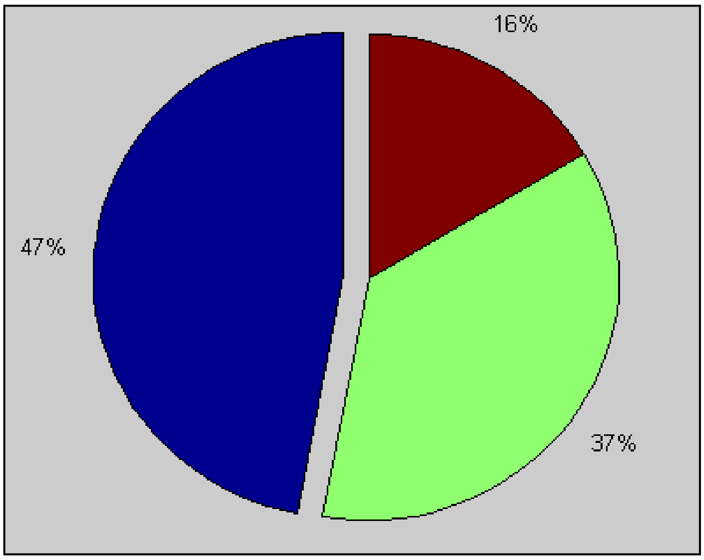

Fig.:10 Percentage of generation for three generators

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VI. CONCLUSION

In this paper MATLAB M-file programming has been used to obtain the multi objective generation scheduling using genetic algorithm. From the program results we conclude that in every time generation combination are different but yet all results satisfy the require fitness of value, which is depending on selection of length of string l, probability of crossover pc and the population of random number generation.

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