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Load Flow Analysis Using Real Coded Genetic Algorithm

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ABSTRACT
This paper presents a Real Coded Genetic Algorithm (RCGA) for finding the load flow solution of electrical power systems. The proposed method is based on the minimization of the real and reactive power mismatches at various buses. The traditional methods such as Gauss-Seidel method and Newton-Raphson (NR) method have certain drawbacks under abnormal operating condition. In order to overcome these problems, the load flow solution based on Real Coded Genetic Algorithm (RCGA) is presented in this paper. Two cross over techniques, Arithmetic crossover and heuristic crossover are used to solve the power flow problem. The proposed method is applied for 3-bus, 5-bus and 6-bus systems and the results are presented.
***Keywords* -** Bus voltages, Load Flow Studies, Real Coded Genetic Algorithm, Real and Reactive Power flows

I. INTRODUCTION

Load flow solution gives the system performance under the steady state condition. It is the determination of the power system operating condition based on the previous knowledge of system parameters. The purpose of load flow study is planning the new system or the extension of an existing system. The load flow solution gives the nodal voltages and phase angles and hence the power injections at all the buses can be determined. The voltage level at the certain buses must be kept within the limits. The line flows can be obtained. The load flow studies most likely to be needed for economic load dispatch, power system stability, short circuit studies and reliability studies. Each power system bus is associated with four variables. These variables are real power (P), reactive power (Q), voltage magnitude ($|V|$) and voltage phase angle ($\boldsymbol{\delta}$).To facilitate this we classify the different buses of the power system as listed below.

For Load Buses, real power P_i and reactive power Q_i are specified, $|V_i|$and δ_i are calculated. For Voltage Controlled Buses, real power P_i and $|V_i|$ are specified,Q_i and δ_i are calculated. For Slack Bus $|V_i|$ and δ_i are specified, real power P_1 and reactive power Q_1 are calculated. Power flow equations represent a set of non-linear simultaneous algebraic equations. There are two famous methods, the Gauss-Sieidel method and the Newton-Raphson Method (NR) [1]-[3]. The NR method has rapid convergence characteristics. However, it has certain limitations [4] when the power system is under heavy loaded conditions. The Jacobian of the power flow equation tends to be singular when the operating condition of power system is near to ceiling point. A higher resistance-to-reactance ratio (R/X) may complicate the load flow convergence, if any extra load is imposed on system beyond the limits voltage collapse may occurs.

To overcome these limitations of the traditional NR method, the proposed Real Coded Genetic Algorithm [5] is introduced. Two cross over techniques, Arithmetic crossover and heuristic crossover are used to solve the power flow problem. The proposed method is applied for 3-bus, 5-bus and 6-bus systems. The output results of RCGA have been compared with the NR method.

II. PROBLEM FORMULATION

Consider an interconnected power system where there are load buses, generator buses and one slack bus. The voltage magnitudes for load buses and voltage phase angles for load and generator buses must be determined in load flow analysis..The load flow equations are:

$$P_i = |V_i| \sum_{k=1}^{n} |V_k|\,|Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i) \quad (1)$$

$$Q_i = -|V_i| \sum_{k=1}^{n} |V_k|\,|Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad (2)$$

Where $Y_{ik} = |Y_{ik}|\angle\theta_{ik}$

$V_i = |V_i|\angle\delta_i$

$V_k = |V_k|\angle\delta_k$

P_i^{cal}, Q_i^{cal} are calculated values of real and reactive powers which are obtained by substituting random values of voltage magnitudes and voltage phase angles. Real powers mismatches are calculated for load and generator buses where as reactive power mismatches are calculated only for load buses. Error is calculated by using following equation

$$\text{Error} = \sum \Delta P_i^2 + \sum \Delta Q_i^2 \quad (3)$$

Where $\Delta P_i = P_i^{spec} - P_i^{cal}$

$\Delta Q_i = Q_i^{spec} - Q_i^{cal}$

The Fitness value F is defined as the square root of sum of squares of power mismatches.

Fit (i) $=\sqrt{(\sum \Delta P_i^2 + \sum \Delta Q_i^2)}$ (minimization) (4)

Fit1 (i) =1/(1+Fit(i)) (maximization) (5)

Where i=1, 2 . . . nop

By comparing fitness values of different random values considered initially the best sample is determined. Now, modify the random values i.e., according to Real-Coded Genetic Algorithm. We have modified the positions of the chromosome. By using the two cross over techniques, the chromosomes are modified i.e., the random values of voltage magnitude and phase angles are updated. Now the procedure is repeated for this new population of random values and best random value among this new set is determined. This process repeats continuously until the convergence criterion is met.

III. REAL CODED GENETIC ALGORITHM

The Real Coded Genetic algorithm proposed in [5] is used to find the load flow solution. Genetic algorithms were invented by Holland to mimic some of the processes of natural evolution and selection. GA maintains and manipulates a population of solutions and implements a survival of the fittest strategy in their search for better solutions. The fittest individuals of any population tend to reproduce and survive to the next generation thus improving successive generations. The inferior individuals can also survive and reproduce. Implementation of GA requires fundamental issues: Initial population, Fitness evaluation, Termination criterion, Reproduction, Elitism, Crossover and Mutation. Brief descriptions about these issues are provided in the following sections.

Initial population: The RCGA operates on a population of nop chromosomes simultaneously. The initial population of real number vectors is created randomly. Each of these vectors represents one possible solution to the search problem. The population size needs to be selected based on the size of search space.

Fitness evaluation: The fitness value for each member of population is determined. The performance of the algorithm is highly sensitive to the fitness values and the fitness value is the only information available to the GA. As the algorithm proceeds, we would expect to increase the individual fitness of the best chromosome as well as the total fitness of the whole population.

Termination criterion: After the fitness values have been calculated for each chromosome the next step is to check the termination criterion. Termination criterion checks the searching is continue or stop the search.

Reproduction: During the reproductive phase of the GA, good chromosomes (parents) in pairs are selected from the current generation's population for producing offspring and placing them in the next generation's population. Parents are selected randomly from the population using a scheme which favours the more fit individuals. Good individuals will probably be selected several times in a generation; poor ones may not be at all. This can be achieved by many different schemes, but the most common method is the roulette wheel selection.

Elitism: The best population in the current generation's population is copying to the next generation's population is called "Elitism". The implementation of elitism is arranging the population in the descending order according to their fitness value. Here Pe is probability of elitism.

Crossover: The crossover operator is the main search tool. It mates chromosomes in the mating pool by pairs and generates candidate offspring by crossing over the mated pairs with probability Pc There are many types of crossover techniques available in the literature

Mutation: After crossover, some of the genes in the candidate offspring are modified with a small mutation probability Pm. The mutation operator is included to prevent premature convergence by ensuring the population diversity.

IV. ALGORITHM FOR LOAD FLOW SOLUTION

Step 1: Read the line data, bus data & obtain Y_{bus}

Step 2: Initialize the parameters of RCGA.They are **nop, novloc, noaloc, novv** and **noav**. Where **nop** is the initial population size.

novv=no. of voltage variables

noav=no. of angle variables

novloc=voltage locations

noaloc=angle locations

Step 3:$nop \times novv$ Initial population for voltage magnitude is randomly generated between the minimum and maximum limits i.e., v_{min} and v_{max}.

Step 4: $nop \times noav$ Initial population for voltage angles is randomly generated between the minimum and maximum limits i.e., d_{min} and d_{max}.

Step 5: Obtain the calculated values of P_i and Q_i by using (1)&(2)

Step 6: find out the ΔP_i and ΔQ_i

$$\Delta P_i = P_i^{spec} - P_i^{cal} \quad (6)$$

$$\Delta Q_i = Q_i^{spec} - Q_i^{cal} \quad (7)$$

Step 7: calculate the error using the equation

$$\text{Error} = \sum \Delta P_i^2 + \sum \Delta Q_i^2$$

Step 8: find out the fitness value of each population by using the equation (5).

Step 9: Arrange the population in descending order according to their fitness values.

Step 10: The best chromosomes are directly copied to the next generation population to perform the elitism with a probability of Pe, for both voltage variables and angle variables.

Step 11: Parents are selected in pairs by using the roulette wheel selection technique based on their fitness values.

Step 12: Crossover is performed using the two crossover operators. These two crossover operators are the arithmetic crossover and the heuristic crossover. A random number *r* is generated between zero and one. If the random number *r* is less than 0.5 then arithmetic crossover operator is used to produce the offspring, otherwise heuristic crossover operator is used to produce the offspring.

Arithmetic crossover

Arithmetic crossover technique linearly combines two parent chromosomes to produce two new offspring. Two offspring are created according to the following equations.

$$Offspring_1 = a \times parent_1 + (1 - a) \times parent_2 \quad (8)$$

$$Offspring_1 = (1 - a) \times parent_1 + a \times parent_2 \quad (9)$$

Where ***a*** is a random number between zero and one, which is generated before each crossover operation.

Heuristic crossover

A new heuristic crossover operator is proposed based on the evolutionary direction provided by each parent, the fitness ratio of best chromosome and each parent, and the distance between the best chromosome and each parent. The crossover operator can improve the convergence speed of RCGA by using the heuristic information [5].

$$h(i,j)_{new} = K_1 \times h(i,j)_{old} + K_2 \times K_3 \times (parent(1,j) - parent(i,j)) \quad (10)$$

Where $h(i,j)_{new}$ is the latest value of heuristic crossover operator of jth gene of ith parent

$h(i,j)_{old}$ is the old value of heuristic crossover operator of jth gene of ith parent. Initially $h(i,j)_{old}$ is set to zero for all genes of all the chromosomes. $h(i,j)_{new}$ must be within the limits of $(-h(i,j)^{max})$ and $h(i,j)^{max}$. Where $h(i,j)^{max}$ is the maximum allowable step size.

$$-h(i,j)^{max} \geq h(i,j)_{new} \leq h(i,j)^{max} \quad (11)$$

$$K_1 = \{K_1^{max} - [(K_1^{max} - K_1^{min}) \times t/T]\} \quad (12)$$

K_1 is the adjustable coefficient between K_1^{max} and K_1^{min}

t is the current iteration (generation) number

T is the maximum number of iterations

K_2 is the random number between zero and two

K_3 is the ratio of best fitness and fitness of i^{th} parent

$parent(1,j)$ is the j^{th} gene in the best chromosome

$parent(i,j)$ is jth gene of ith parent

$$Offspring(i,j) = parent(i,j) + h(i,j)_{new} \quad (13)$$

Each gene of offspring is produced from each gene of parent using the equation (11).

Step 13: check the iteration count is greater than iteration maximum or not. If it is greater than iteration count then go to step14.

Step 14: After performing the elitism and crossover operators, the new population is generated from the old population. In this present work mutation operator is eliminated. Go to step 6 to repeat the same procedure.

Step 14: Stop the procedure and print the results.

V. SIMULATION RESULTS

The effectiveness of the proposed Real Coded Genetic Algorithm is tested for three, five and six bus systems. Line flows of test system are given in appendix.

Three- Bus System

Comparative results of voltage magnitude, phase angle and total Real and Reactive power losses of Newton Raphson method [1] and RCGA for 3-Bus System are shown in Table 1.

Table 1. Results of 3-bus system

Variable	RCGA Method	NR Method
V_2 (p.u)	0.9717	0.9717
V_3 (p.u)	1.04	1.04
δ_2(deg)	-2.6965	-2.6965
δ_3(deg)	-0.4988	-0.4988
$P_{Total\ Loss}$(MW)	18.423	18.423
$Q_{Total\ Loss}$(MVAR)	37.028	37.028

Five-Bus System

Comparative results of voltage magnitude, phase angle and total Real and Reactive power losses of Newton Raphson method [3] and RCGA for 5-Bus System are shown in Table 2.

Table 2. Results of 5-bus system

Variable	RCGA Method	NR Method
V_2 (p.u)	1.0474	1.0474
V_3 (p.u)	1.0242	1.0242
V_4 (p.u)	1.0236	1.0236
V_5 (p.u)	1.0179	1.0179
δ_2(deg)	-2.8064	-2.8064
δ_3(deg)	-4.9970	-4.9970
δ_4(deg)	-5.3291	-5.3291
δ_5(deg)	-6.1503	-6.1503
$P_{Total\ Loss}$(MW)	4.587	4.587
$Q_{Total\ Loss}$(MVAR)	-17.421	-17.421

Six-Bus System

Comparative results of voltage magnitude, phase angle and total Real and Reactive power losses of Newton Raphson method [15] and RCGA for 6-Bus System are shown in Table 3.

Table 3. Results of 6-bus system

Variable	RCGA Method	NR Method
V_2 (p.u)	1.05	1.05
V_3 (p.u)	1.07	1.07
V_4 (p.u)	0.9894	0.9894
V_5 (p.u)	0.9854	0.9854
V_6 (p.u)	1.0044	1.0044
δ_2(deg)	-3.6712	-3.6712
δ_3(deg)	-4.2733	-4.2733
δ_4(deg)	-4.1958	-4.1958
δ_5(deg)	-5.2764	-5.2764
δ_6(deg)	-5.9475	-5.9475
$P_{Total\ Loss}$(MW)	7.876	7.876
$Q_{Total\ Loss}$(MVAR)	-30.061	-30.061

VI. CONCLUSIONS

This paper presented a method to find load flow solution using Real Coded Genetic Algorithm. Two cross over techniques Arithmetic and heuristic crossover techniques are used. The proposed method is applied to 3-bus, 5-bus and 6-bus test systems and results are obtained. The RCGA searches the optimal solution in an iterative manner. Finally the results are compared with the results of NR method. The result indicates that this method is an alternative for finding the load flow solution.

REFERENCES

[1] Stagg and El-Abiad, “Computer Method in Power System Analysis”, *McGraw-Hill Inc.*, 1968.

[2] IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis, *IEEE*, STD 399-1997, PP.133-163, September 1997.

[3] Saadat H., Power System Analysis, *Tata McGraw-Hill, New Delhi*, edition 1999-2002.

[4] Hyungchul Kim, Nader Samann, Donggeun Shin, Byeonghun Ko, Gilsoo Jang and Junmin Cha “A New Concept of Power Flow Analysis” *Journal of Electrical Engineering & Technology*, Vol. 2, No. 3, pp. 312-319, 2007.

[5] M. Damodar Reddy, Prof. V.C. Veera Reddy “Optimal Capacitor Placement Using fuzzy And Real Coded Genetic Algorithm For Maximum Savings *“Journal of Theoretical and Applied Information Technology,2005 – 2008.*

[6] Federico Milano “Continuous Newton’s Method for Power Flow Analysis” *IEEE Transactions on Power Systems*, VOL. 24, NO. 1, February 2009.

[7] Hassan A. Kubba and Samir Sami Mahmood “GENETIC ALGORITHM BASED LOAD FLOW SOLUTION PROBLEM IN ELECTRICAL POWER SYSTEMS” *Journal of Engineering*, Number 4, Volume 15, December 2009.

[8] C. M. Wankhade, B. P. Saoji & A. P. Vaidya “Comparative Study of GA Based Optimal Power Flow*” International Journal on Advanced Electrical and Electronics Engineering*,ISSN 2278-8948, Volume-1, Issue-1, 2012.

[9] C.Kumar, Dr. Ch. Padmanabha Raju “ Constrained Optimal Power Flow using Particle Swarm Optimization” *International Journal of Emerging Technology and Advanced Engineering* ISSN 2250-2459, Volume 2, Issue 2, February 2012.

[10] Dharamjit, D.K. Tanti " Load Flow Analysis on IEEE 30 bus System" *International Journal of Scientific and Research Publications*, Volume 2, Issue 11, ISSN 2250-3153, November 2012.

[11] Firas M. Tuaimah, Montather F. Meteb "A Particle Swarm Optimization based Optimal Power Flow Problem for Iraqi Extra High Voltage Grid" *International Journal of Computer Applications*,Volume 59– No.8, December 2012.

[12] Bhupender Sharma, Shivani Sehgal, Ajay Nain "Particle Swarm Optimization and Genetic Algorithm based Optimal Power Flow Solutions" *International Journal of Application or Innovation in Engineering & Managemen*t, Volume 2, Issue 7, July 2013

[13] N.G. Shankarwar, V.A. Deodhar-Kulkarni "Load Flow Study of six bus System by Digital Computer" *International Journal of Engineering and Advanced Technology* ISSN 2249 – 8958, Volume-2, Issue-3, February 2013.

[14] Shilpa S. Shrawane, Dr. M. Diagavane "Application of Genetic Algorithm for Power Flow Analysis" *International Journal of Engineering Research & Technology* ISSN:2278-0181 Vol. 2 Issue 9, September – 2013.

[15] Camilla Paes Salomon, Germano Lambert-Torres Luiz Eduardo Borges da Silva, Maurilio Pereira Coutinho and Carlos Henrique Valerio de Moraes"A Hybrid Particle Swarm Optimization Approach For Load Flow Computation" *International Journal of Innovative Computing, Information and Control*,Volume 9, Number 11, November 2013.

APPENDIX

Line Flow And Losses For 3-Bus System Using RCGA Method

FROM BUS	TO BUS	P (MW)	Q (MVAR)	FROM BUS	TO BUS	P (MW)	Q (MVAR)	LINE LOSS MW	LINE LOSS MW
1	2	179.362	118.734	2	1	-170.968	-101.947	8.393	16.787
1	3	39.061	22.118	3	1	-38.878	-21.569	0.183	0.548
2	3	-229.032	-148.053	3	2	238.878	167.746	9.847	19.693
							TOTAL LOSS	18.423	37.028

Line Flow And Losses For 5-Bus System Using RCGA Method

FROM BUS	TO BUS	P (MW)	Q (MVAR)	FROM BUS	TO BUS	P (MW)	Q (MVAR)	LINE LOSS MW	LINE LOSS MVAR
1	2	88.864	-8.579	2	1	-87.453	6.149	1.410	-2.431
1	3	40.723	1.158	3	1	-39.531	-3.014	1.192	-1.855
2	3	24.694	3.546	3	2	-24.343	-6.784	0.352	-3.238
2	4	27.936	2.962	4	2	-27.495	-5.928	0.441	-2.966
2	5	54.823	7.343	5	2	-53.698	-7.167	1.125	0.176
3	4	18.874	-5.202	4	3	-18.838	3.212	0.036	-1.990
4	5	6.333	-2.285	5	4	-6.302	-2.833	0.031	-5.118
							TOTAL LOSS	4.587	-17.421

Line Flow And Losses For 6-Bus System Using RCGA Method

FROM BUS	TO BUS	P (MW)	Q (MVAR)	FROM BUS	TO BUS	P (MW)	Q (MVAR)	LINE LOSS MW	LINE LOSS MW
1	2	28.690	-15.419	2	1	-27.785	12.819	0.905	-2.600
1	4	43.585	20.120	4	1	-42.497	-19.933	1.088	0.188
1	5	35.601	10.255	5	1	-34.527	-13.450	1.074	-2.195
2	3	2.930	-12.269	3	2	-2.890	5.728	0.040	-6.541
2	4	33.091	46.054	4	2	-31.586	-45.125	1.505	0.929
2	5	15.515	15.353	5	2	-15.017	-18.007	0.498	-2.653
2	6	26.249	12.399	6	2	-25.666	-16.011	0.583	-3.612
3	5	19.117	23.174	5	3	-18.023	-26.095	1.094	-2.921
3	6	43.773	60.724	6	3	-42.770	-57.861	1.003	2.863
4	5	4.083	-4.942	5	4	-4.047	-2.785	0.036	-7.727
5	6	1.614	-9.663	6	5	-1.565	3.872	0.050	-5.791
							TOTAL LOSS	7.876	-30.061