Security Constrained Economic Dispatch by Genetic Algorithm

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***Abstract*—The paper aims at solving security constrained economic dispatch problem by Genetic algorithm. The Lagrange multiplier was solved by estimating power generations (Pgi) from binary string structure. A comparison of dispatch & cost was obtained with methods based on classical method. Paper has also evaluated line outages using Genetic algorithm based on security constraint of Pmax (Pgi<=Pmax).In the paper GA parameter fitness was determined based on power balance equation of minimum error. Paper has explained Genetic Algorithm as a successful tool for solving security constrained economic dispatch problem. A global optimization technique known as genetic algorithm (GA) which is a kind of the probabilistic heuristic algorithm has been studied here to solve the power optimization problems.**

***Index Terms*— Economic Load Dispatch, Soft Computing, Genetic Algorithm, Generator constraints, Security constraints**

I. INTRODUCTION

Electrical power is an essential ingredient for industrial and economical development of a region. In any power system, unexpected outages of lines or transformers occur due to faults or other disturbances. These events, referred to as contingencies, may cause significant overloading of transmission lines or transformers, which in turn may lead to a viability crisis of the power system. The principle role of power system control is to maintain a secure system state, i.e., to prevent the power system, moving from secure state into emergency state over the widest range of operating conditions. Modern electric power systems built with nonlinear characteristics are highly interconnected with wide geographical distribution. This demands the optimization of a complex objective function under few practical constraints. Hence power system network optimization involves maximization or minimization of objective function under certain constraints. A saving in the operation of system of small percent represents a significant reduction in operating cost as well as in the quantities of fuel consumed. This formulates the Economic Load Dispatch problem for finding the optimal combination of the output power of all the generating units that minimizes the total fuel cost while satisfying the constraints. The Genetic algorithm is the potential solution methodology due to its inherent ability to address the convex and non convex problems equally.

II. EXISTING METHODOLOGY

The classical methods like Linear Programming Method, Quadratic Programming Method, Network Flow Programming Method etc. are used to analyses security constrained optimal power flow based Economic Dispatch.

In a Linear programming method nonlinear objective function and constraint are linearised and due to linearising original content of the problem is lost, so solution is only approximate of the actual solution. The number of iterations grows exponentially with problem size and Massive computational burden for its large dimensionality. All above existing methodology gives single solution.

To overcome above drawbacks, we require a fast computational technique with multi solutions for Security constraint Economic dispatch and this can be satisfied by Genetic Algorithm.

III. MATHEMATICAL MODEL OF ECONOMIC DISPATCH WITH SECURITY

Adequate power to meet the varying consumer load demand with minimum possible cost under certain constraints leads to the Economic Load Dispatch. Here the power generation is planned for optimality through given set of generating units. It is defined as to minimize the total operating cost while meeting the total load plus transmission losses within generator limits

$$Minimize\ F = \sum_{i\in NG} F_i(P_{Gi})$$

(a) Equality constraint

$$\sum_{i\in NG} P_{Gi} = \sum_{K\in ND} P_{DK} + P_L$$

(b)Unequality constraint

$$P_{Gimin} \leq P_{Gi} \leq\leq P_{Gimax} \quad i \in NG$$

(c) Security constraint

$$|P_{ij}| \leq P_{ijmax} \quad ij \in NT$$

Where,

P_D- real power load, P_{ij} – power flow of transmission line ij,

Pijmax- power limits of transmission line ij, PGi- real power output at generator bus i, P_{Gimin} – minimum real power output at generator i, P_{Gimax} - maximum real power output at generator i, P_L – Network losses, f_i – Cost function of generator i, NT – number of transmission line, NG – number of generator.

The Exact Transmission loss formula has been derived using bus powers and system parameters.

$$P_L = \sum_{i=1}^{NB} \sum_{j=1}^{NB} P_i P_j \left[a_{ij} \left(1 + \frac{Q_i Q_j}{P_i P_j} \right) + b_{ij} \left(\frac{Q_i}{P_i} - \frac{Q_j}{P_j} \right) \right]$$

Where P_L – transmission power loss, P_i, P_j- real power injections at ith and jth buses, Q_i, Q_j- reactive power injections at ith and jth buses respectively.

The above constrained optimization problem is converted into an unconstrained optimization problem. Lagrange multiplier method is used in which the function is minimized with side conditions in the form of equality constraints.

Using Lagrange multipliers, an augmented function is define

Calculate Hessian and Jacobian Matrix elements. Calculate loss using Exact loss formula.

Objective function,

$$L(P_{gi}, \gamma) = F(P_{gi}) + \gamma \left(P_D + P_L - \sum_{i=1}^{NG} P_{gi} \right)$$

Where L is Lagrangian Multiplier.

IV. GENETIC ALGORITHM OPTIMIZATION APPROACH

A Global optimization technique known as a genetic algorithm has emerged as a candidate due to its flexibility and efficiency for many optimization application. It is a stochastic searching algorithm.

In Genetic Algorithm, each iteration, or 'generation', a population of possible solutions is evaluated and the top-ranking solutions are selected as 'parents' of the next generation. The next generation of solutions is created by the recombination of elements from their parents, along with occasional random alterations or 'mutations'. The process is repeated so that the 'fitness' of subsequent populations increases. In this way, the likelihood that the population contains the optimal solution also increases.

Considering the network losses P_L , and selecting unit N as the slack bus unit, then the real power balance equation can be written as

$$P_{GN} = P_D + P_L - \sum_{i=1}^{N-1} P_{gi}$$

The network security constraints can be written as

$$|P_{ij}| \leq P_{ijmax} \quad ij = 1,2 \ldots\ldots NL$$

Adding penalty factors h_1, h_2 to the violation of power output of the slack bus unit and h_3 to the violation of line power, we get the augmented cost

$$F_A = \sum_{i=1}^{N} F_i(P_{gi}) + h_1(P_{GN} - P_{GNmax})^2 + h_2(P_{GNmin} - P_{GN})^2 + h_3 \sum_{ij=1}^{NL} (|P_{ij}| - P_{ijmax})^2$$

where P_{GNmin} , P_{GNmax} are the lower and upper limits of the power output of the slack bus unit, respectively. The value of the penalty factors should be large so that there is no violation for unit output at the final solution. Since GA is designed for the solution of maximization problems, the GA fitness function is defined as the inverse of above equation

$$F_{fitness} = \frac{1}{F_A}$$

In the economic dispatch problem, the problem variables correspond to the power generations of the units. Each string represents a possible solution and is made of substrings, each corresponding to a generating unit. The length of each substring is decided based on the maximum/minimum limits on the power generation of the corresponding unit and the solution accuracy desired. The string length, which depends on the length of each substring, is chosen based on a trade - off between solution accuracy and solution time. Longer strings may provide better accuracy but result in more solution time.

V. GENETIC ALGORITHM IMPLEMENTATION.

Step-1:
Read data: NG is the number of buses having generators, NB is the number of buses, NV is the number of PV buses. V,
For slack bus, Pdi, Qdi, Vi for PV buses, a,b,c cost coefficients etc.

Step-2:
Obtain YBUS and by inverting it obtain ZBUS.
Compute the initial values λ.

Step-3:
Select the parameters related to GA such as population size, number of generations, substring length, and number of trials.
Generate initially random coded strings as population members in the first generation.

Step-4:
Decode the population to get power generations of the units in the strings. e.g. for 5 bit strings
PG = Pmin +[(Decimal value of string)* (Pmax – Pmin)]/ 32

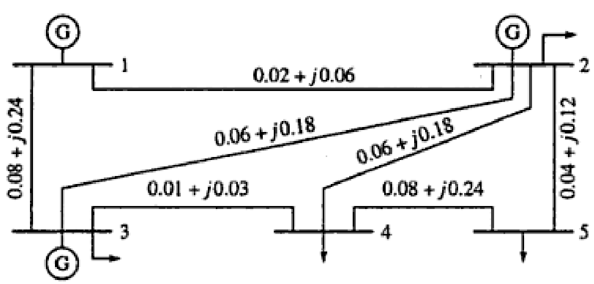
Step-5:
Calculate Hessian and Jacobian Matrix elements.Calculate loss using Exact loss formula.

Step-6:
Perform power flow analysis considering the unit generations so that GA is able to evaluate system transmission loss, slack bus generation, line flows, and hence any violation for the slack bus generation and violation for the line flow Limits. Check whether the equality constraint condition is satisfied. If yes, obtain the solution parameters. If No, go to step 4.

Step-7:
Compute the optimal total System Lambda, Total Generation, cost F, loss PL , etc. Evaluate the fitness of population members (i.e., strings).

VI. IMPLEMENTATION ON TEST SYSTEM AND SIMULATION RESULTS

Case Study : Three Unit System



Problem Parameters

Number of generators=3
Load Demand=150 MW

Unit operating ranges are:

10 MW < P1 < 85 MW
10 MW < P2 < 80 MW
10 MW < P3 < 70 MW

Cost Functions:

F1=0.008P12+ 7 P1+200 Rs/hr
F2=0.009P22 +6.3P2 +180 Rs/hr
F3=0.007P32 + 6.8P3 +140 Rs/hr

Bus Data:

Bus No	Load		Generator			
	MW	MVAR	MW	MVAR	Qmin	Qmax
1	0	0	0	0	10	50
2	20	10	40	30	10	50
3	20	15	30	10	10	40
4	50	30	0	0	0	0
5	60	40	0	0	0	0

Line Data:

Line	R (pu)	X (pu)	1/2 B (pu)
1--2	0.02	0.06	0.03
1--3	0.08	0.24	0.025
2--3	0.06	0.18	0.02
2--4	0.06	0.18	0.02
2--5	0.04	0.12	0.015
3--4	0.01	0.03	0.01
4--5	0.08	0.24	0.025

Result And Analysis:
1. Table 1 indicates solution by GA for security constraint economic load dispatch & comparision with classical method.
2. Table 2 indicates results obtained with line outages based on security constraint.
3. Table 3 indicates multisolution based on GA with min error.
4. Solution of Security constraint Economic dispatch by classical method is obtained for sample test system.
Solution of Security constraint Economic dispatch by Genetic Algorithm method is obtained for sample test system.
Comparison of classical method and Genetic Algorithm method is obtained. Similar results are obtained by classical method and Genetic Algorithm method.

VII. CONCLUSION

The paper has successfully obtained economic load dispatch solution based on equality constraint, inequality constraint & security constraint. Paper has made comparison of security constraint economic load dispatch solution with classical methods. Line outages and power transfer violations were estimated based on GA method. Thus Security constrained Economic Dispatch problem can be solved by Genetic Algorithm Method. Compare to various classical methods GA gives better results and multiple solution.

VIII. ACKNOWLEDGEMENT

The authors are thankful to authorities of Faculty of Engg and Tech., M.S. University of Baroda, Vadodara for providing all facilities to complete this work.

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Table:1 Comparision of result by GA and classical Method

Parameter	Classical Method	Proposed Method(GA using 5 bit string)
PG1	23.55 MW	24.06 MW
PG2	69.55 MW	64.37 MW
PG3	59.03 MW	62.5 MW
∑ PG	152.13 MW	150.93 MW
System Loss	2.15 MW	0.9384 MW
Generation cost	1596.96 Rs/h	1588.27 Rs/h
System Lambda	7.759 Rs/MWh	7.511 Rs/MWh

Table :2 Result on line outages based on security constraint

Line Outage	PG1 (MW)	PG2 (MW)	PG3 (MW)	∑ PG	Loss (MW)	Cost Rs/h	Lambda Rs/MWh
1—2	10	75.4606	67.1864	152.647	2.64978	1606.05	7.880535
1—3	26.1378	67.9242	58.0657	152.1277	2.12816	1596.32	7.745762
2—3	23.1354	69.7648	59.2322	152.1324	2.13334	1596.89	7.761737
2—4	10	75.6657	66.7558	152.4215	2.42228	1604.16	7.858068
3—4	10	80	65.6569	155.6569	5.65808	1629.05	8.158212
4—5	10	80	62.9192	152.9192	2.92019	1607.97	7.84874

Table:3 Multisolution based on GA

Error	0.0058	0.0023	0.0176	0.0178	0.0131	0.0109	0.0199	0.0053	***0.0009***	0.0151	0.0175
PG1	75.625	70.9375	82.6563	68.5938	61.5625	68.5938	35.7813	73.2813	***24.0625***	52.1875	49.8438
PG2	62.5	60.625	38.125	45.625	41.875	30.625	56.875	17.5	***64.375***	36.25	34.375
PG3	12.1875	18.75	29.6875	36.25	47.1875	51.5625	58.125	60.3125	***62.5***	62.5	66.875
Loss	0.3183	0.3148	0.4511	0.451	0.6119	0.7704	0.8012	1.099	***0.9384***	0.9526	1.0762
Cost	1607.9	1601.8	1614.6	1599.7	1597.3	1608.4	1587	1624.5	***1588.3***	1599.6	1602
FA	2370.3	2364.1	2376.9	2361.9	2359.6	2370.7	2349.3	2386.8	***2350.6***	2361.9	2364.3
Fitness	0.000422	0.000423	0.000421	0.000423	0.000424	0.000422	0.000426	0.000419	***0.000425***	0.000423	0.000423