Optimal Reactive Power Dispatch Using Hybrid Loop-Genetic Based Algorithm

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***Abstract:* -** Reactive power dispatch problem is one of the important issues of the power system in the operation and control. The Optimal Reactive Power Dispatch Problem is the minimization of active power loss in the power system by varying different system control variables, i.e. generator bus voltages or its reactive power output, transformer taps setting, shunt Var compensator etc. The minimization of active power loss will consequently reduce production cost for the requirement of reactive power support. In this paper a new algorithm is presented which is motivated by a hybrid approach called as hybrid Loop-Genetic based algorithm (HLGBA).The hybrid Loop-GA based algorithm (HLGBA) uses the benefits from global search, i.e. the genetic algorithm with less evolution process (only for global search space) and then from local search for refining the solution with the limited computation and time. This algorithm solve ORPD problem more efficiently. This new algorithm verified on standard IEEE_14 bus system to analyze the computation, time and efficiency of algorithm.

Keywords- Optimal reactive power dispatch (ORPD); Genetic Algorithm (GA); Loop Optimization; hybrid Loop-genetic based algorithm (HLGBA).

I. INTRODUCTION

In Power System operation and control the two main short term problem is the optimal reactive power dispatch and optimal active power dispatch. In the present work reactive power dispatch problem has solved. The short term reactive power dispatch problem works on minimization of total active power transmission losses and the voltage profile is also improved with constraints. The operational constraints (state and control variable) contains reactive power source, bus voltages, phase angle and transformer tap setting [1]. ORPD is used to determine the optimal setting of generator voltage or its reactive power output, output of synchronous condenser, shunt capacitor bank, Transformer on Load Tap Changing (OLTC) [1]. The conventional gradient based optimization algorithm is used for decades. Gradient variable is hard to solve because it has many assumptions in the objective function like analytical and differential properties [1]. The gradient based optimization also unable to handle both continuous and discrete variables. In the Last few years different types of new methods are used for optimization problem such as evolutionary programming, genetic algorithm (GA) [2] particle swarm optimization (PSO), simulated annealing [3], ant bee colony (ABC). GA is a part of evolutionary programming. In GA start with random generated population and evolved to better solution using genetic operators (selection, crossover, mutation). Now a days, Evolutionary computation Method has been used in different area of research of the power system.

In Evolutionary algorithm (EA) [4], population of solution is developed with large no of generation to find the optimal solution. Hence designing of optimization problem is more expensive. To reduce computational budget a new approaches i.e. Hybrid Loop-Genetic Based Algorithm proposed in this paper. To improve evaluation process of optimization the important approaches in literature is the hybridization. In hybridization, both global search and local search optimization are combined to improve the efficiency of the proposed algorithm. Local search technique is fast and effective but depends on initial point. For good starting point global search is used. This hybrid approach is also called as mimetic algorithm [5].

In Hybrid loop-Genetic algorithm ,there are two stages firstly uses a genetic algorithm we have to find global search area with less no of iterations because use of GA is only for finding global search. After the genetic algorithm, in second stages, we use the loop algorithm with starting point taken from GA output.

II. PROBLEM FORMULATION

Optimal reactive power dispatch problem optimizes or minimizes the real power losses by setting the control variables generator voltages or its reactive power output of generator, transformer tap and shunt compensator like capacitor etc.

$$\text{Min} \sum p_{kloss} = \sum_{k=1}^{NE} G_k \, (V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij}) \qquad (1)$$

Where k= (i,j); i∈N_B (Total no of buses)

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$\sum p_{kloss}$ = total active power losses in the power system

$G_{k(i,j)}$=conductance of the branch k(in p.u)

Vi, Vj = voltage (pu) of bus i and j respectively

θ_{ij}= load angle between bus i and j (rad)

N_E= total no of branches

Subjected to

Equality constraints:-

Active power flows balance equation at all buses

$$P_{gi}-P_{di}-Vi\sum_{j=Ni} Vj(Gij\ \sin\theta ij + Bij\ cos\theta ij) = 0 \quad (2)$$

Reactive power flow balance equation at all buses

$$Q_{gi}-Q_{di}-Vi\sum_{j=Ni} Vj(Gij\ \sin\theta ij + Bij\ cos\theta ij) = 0 \quad (3)$$

Inequality constraints:-

Reactive power generation limit for each bus

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \quad i \in Ng \quad (4)$$

Voltage magnitude limit voltages for each bus

$$V_i^{min} \leq V_i \leq V_i^{max}, \quad i \in N_B \quad (5)$$

Transformer tap setting limits

$$T_i^{min} \leq T_i \leq T_i^{max}, \quad i \in N_T \quad (6)$$

Reactive power source installation

$$Q_{ci}^{min} \leq Q_{ci} \leq Q_{ci}^{max}, \quad i \in N_c \quad (7)$$

Where B_{ij} represents the mutual susceptance in bus i and j. P_{gi} and Q_{gi} represents the active power and reactive power generation of bus i.

P_{di} and Q_{di} are the active power and reactive power demand of bus i. V_i is the voltages of the buses,V_i^{max} and V_i^{min} is the upper and lower limits of the voltages. T_i transformer tap in branch k, T_i^{max} and T_i^{min} is the upper limit and the lower limit of transformer tap setting. Q_{ci} represents the reactive power source installation and upper limit and lower limit value is Q_{ci}^{max} and Q_{ci}^{min}. N_B and N_g is the no of system buses and generator buses respectively.N_C and N_T is the no of reactive source installation and no of transformer tap.

The equation (1) represents the total transmission loss in the system. Equality constraints equation (2) to equation (4) satisfied by load flow and inequality constraints equation (4) to equation (7) satisfied by limit the variables.

III. PROPOSED HYBRID LOOP-GENETIC BASED ALGORITHM

Several classical method and stochastic method are used to solve reactive power dispatch problem, e.g. linear and non-linear programming, Gradient non-linear quadratic programming etc. Now days due to advancement of EA, genetic algorithm, PSO, differential evolution is used. The intention of proposed algorithm is to refine and improve efficiency of optimal reactive dispatch solution by taking the advantage (Fast & Effective, Refine the solution quickly) of Local Search and removing the disadvantage not feasible with bad initial point of local search by identifying good region for search space i.e. give good initial point using Global Search. If we able to identify good region for search space its gives always good initial point which is possible through Global search. As discussed with good initial point local search is best solution for ORPD. So if we combined global search and local search it will be best solution for ORPD with significant computational cost.

The algorithm based on the local search with global search. The two key approaches are used.

1. Global search :- The fist key approaches of the proposed algorithm is global search using genetic algorithm with less no of generation than the actual genetic algorithm because GA find global search only. The output of GA is optimal value of control variable with all constraints.
2. Local Search: - Now perform the local search using loop optimization method. In this method for each control variable, loop are used with all constraints. Now constraints variable limits are taken from global search space i.e. output of GA.

A. Genetic Algorithm

Genetic algorithm is categorised as a global search heuristic technique to find exact or approximate optimized solution. It is inspired from evolution process such as selection crossover and mutation. The GA starts from a population of randomly generated individuals [6]. In each generation find the fitness value of each population and now select the population for next according to the fitness value after selection different genetic operator i.e. crossover, mutation etc., are used.

Algorithm: Genetic Algorithm to Solve ORPD

1. Read the system input data (branch data, bus data from IEEE-14 Bus system)

2. Initialize the parameter for Genetic Algorithm population size, Maximum no of generation, the probability of crossover, and probability of mutation.

3. Set the control variable, i.e. Generator voltage and transformer tap and shunt capacitor bank.

4. Start generation(gen=0)
5. gen=gen+1
6. population=0
7. population=population+1
8. Randomly generate the population of control variables (generator voltage and transformer tap) within limits to form a single string.
9. For each population run the load flow using Newton Raphson Method
10. If optimal power flow is not converged, then go to step 8.
11. Replace valid chromosome in the initial population.
12. Calculate the fitness value (1/ (total active power loss)) from valid chromosome.
13. If the (population<=population size) then go to step 7.
14. Find the best fitness value from all the fitness value and store the corresponding total active loss and control variable (bus data and branch data).
15. For producing the new population for next generation. Select the parent for reproduction using roulette wheel selection.
16. Perform five point crossovers from randomly selected parent.
17. Perform the mutation from randomly selected parent.
18. If (gen<=Max gen) go to step 5.
19. Display minimum active power loss and control variable
20. Stop.

B. Loop Optimization

Loop optimization is a basic search optimization method for solving problem which has good initial points i.e. it has good search space. In this optimization method nested loop are used to refine the solution after GA, for each variable a, for loop are used with very small increment. This optimization search is like pattern search so it is called as local search optimization method [7].

Algorithm: Solve ORPD Using Loop Optimization

1. Read the system input data(branch data, bus data from IEEE-14 Bus system) Control variable limits taken from Global Search Space i.e. GA.
2. Initialize the parameter for Loop optimization method and the initial value is taken from GA output.
3. Now set the control variable (5 generator Bus) and for each control variable for-loop are used.
4. For each and every increment of variable, run the load flow (N-R) method.
5. Check if power flow is converged then find and store the control variable and active power loss, go to 4.
6. Set the active power loss with high value.
7. After terminating the loop, find the minimum active power loss and corresponding control variable.
8. Stop.

V. SIMULATION AND RESULT

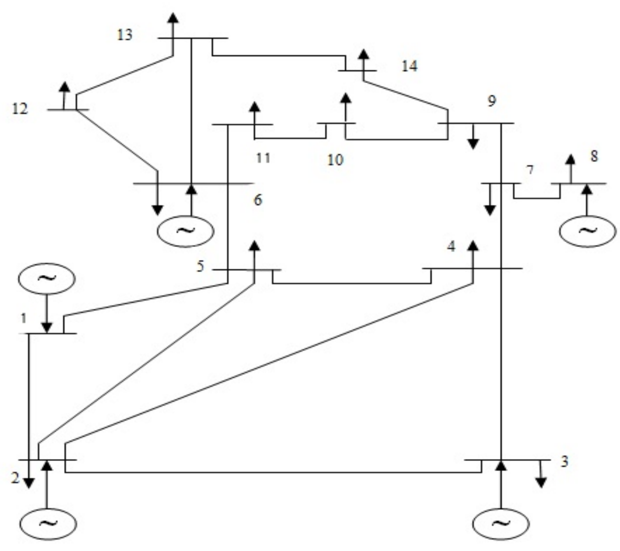
The standard IEEE_14 Bus System is used to test the system to prove the accuracy and efficacy of the new algorithm for Optimal Reactive Power Dispatch problem. The single line diagram of IEEE_14 system is in fig 1. Description of IEEE 14 Bus System is given in table 1 [9].Constraints of the variables is given in table 2. Using MATLAB Code (MATLAB 2012a) hybrid Loop-Genetic based algorithm was simulated and then run on a PC. The results show the accuracy of the proposed algorithm and application of the algorithm.

It is simulated for two different case types -

Case 1: ORPD Problem solved by proposed method with 5 control variable (5 Generator Buses).

Case 2: ORPD Problem solved by proposed method with 8 control variable (5 Generator Buses and 3 Transformer Tap).

Firstly the total power loss for optimal load flow is calculated using N-R method. The total power losses found 13.4014 MW [6] for the 14 bus IEEE standard test system.



INPUT PARAMETER (Generator Voltage)	CONSTRAINTS (Initial Limits taken from GA)
V1	1.070 – 1.090
V2	1.020 – 1.055
V3	1.000 – 1.500
V6	1.020 – 1.050
V8	1.020 – 1.050

S. No.	Description	Values
1	Buses	14
2	Branches	20
3	Generators	5
4	Generator or buses	9
5	Tap-Changing transformers	3

No.	Variables constraints	Units	Lower Limits	Upper Limits
1	Voltage Load Bus	Pu	0.95	1.05
2	Voltage Generator Bus	Pu	0.90	1.10
3	Trans. Tap Setting	Pu	0.10	1.00

Fig: 1. IEEE 14 Bus Systems

TABLE 1. DESCRIPTION OF BUS SYSTEMS

TABLE 2. CONSTRAINTS OF VARIABLES

Case 1:

In this case, the ORPD of IEEE 14 bus system is optimized using hybrid loop-GA method with 5 control variables (5 Generator bus voltages). This problem solved by optimal setting of generator bus voltages using the proposed algorithm. Genetic parameter values are given in the table 3.

TABLE 3. GA PARAMETERS FOR 5 CONTROL VARIABLE

Sl. No.	Parameters	Values
1	Length of Chromosome	25
2	No of Generation	50
3	Population Size	25
4	String Length	25
5	Crossover Probability	0.9
6	Mutation Probability	0.2

Due to randomness nature of GA, The program runs for 20 times to reduce the effect of randomness. After result of GA, loop optimization method used to refine the solution whose limits of control variables taken from GA (best value and worst value taken as a lower and upper limit) and initial value initialized by the best value of GA presented in Table 4.

The optimal values of control variables (seen in dark), active power loses and reactive power loses obtained from GA and result of HLGBA are presented in Table 5.

TABLE 4. CONSTRAINTS(5 CONTROL VARIABLES) FOR LOOP OPTIMIZATION METHOD

TABLE 5. RESULT OF ORPD USING GA AND HLGBA FOR 5 CONTROL VARIABLE

Parameter		O/P Using GA	O/P Using HLGBA
BUS VOLTAGES (Pu)	**V1**	**1.0645**	**1.0900**
	V2	**1.0400**	**1.0550**
	V3	**1.0100**	**1.0200**
	V4	1.0073	1.0197
	V5	1.0099	1.0238
	V6	**1.0432**	**1.0500**
	V7	1.0351	1.0417
	V8	**1.0500**	**1.0500**
	V9	1.0297	1.0373
	V10	1.0245	1.0320
	V11	1.0302	1.0373
	V12	1.0281	1.0350
	V13	1.0232	1.0302
	V14	1.0084	1.0159
Active Power Loss(MW)		13.2198	13.1229
Reactive Power Loss (MVAR)		53.9376	53.4699

The total active power loss of ORPD using GA is 13.2198 MW. The voltage profile is improved after GA which can be seen in fig 2. Proposed algorithm(HLGBA) is applied to minimize the active power loss in the system it can varies the control variable such as total active power losses decreases from 13.40 MW to 13.1229 MW, which is equal to % 2 saving and the voltage profile is also improved, it can be seen in fig 3. The reactive power loss is also improved from 56.4234(N-R Method) to 53.4699 MVAR.

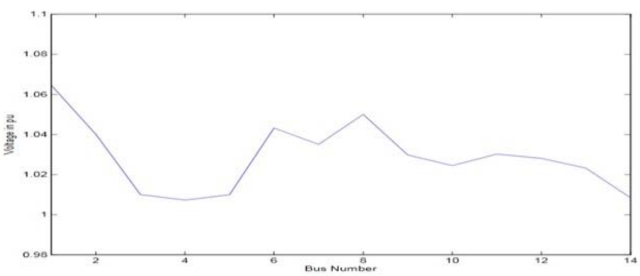


Fig 2: Using GA Voltage Profile of Bus Voltages (5 control variables)

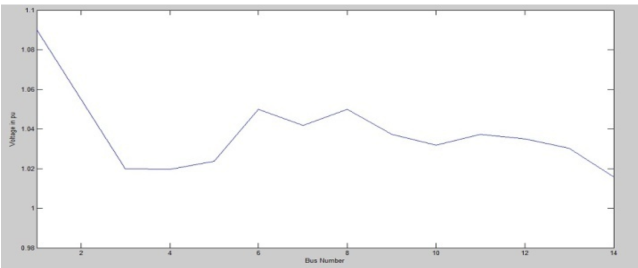


Fig 3: Using HLGBA Voltage Profile of Bus Voltages
(5 control variables)

Case 2:

In this case, The ORPD problem is optimized by hybrid loop-GA algorithm with 8 control variables (5 Generator buses and 3 transformer tap). This problem solved by optimal setting of generator bus voltages and trans. tap using the proposed algorithm. Genetic parameter values are given in the Table 6. Due to randomness nature of GA, The program runs for 20 times to reduce the effect of randomness [6]. After result of GA, loop optimization method used to refine the solution whose limits of control variables taken from GA output (worst and best value) and initial value initialized by the best value of GA presented in Table 7.

TABLE 6. GA PARAMETER FOR 8 CONTROL VARIABLE

Sl. No.	Parameters	Values
1	Length of Chromosome	46
2	No of Generation	50
3	Population Size	25
4	String Length	46
5	Crossover probability	0.9
6	Mutation probability	0.2

TABLE 7. CONSTRAINTS (8 CONTROLVARIABLES) FOR LOOP OPTIMIZATION METHOD

INPUT PARAMETER (Generator Voltage)	CONSTRAINTS (Initial Limits from GA)
V1	1.070-1.080
V2	1.050-1.060
V3	1.025-1.030
V6	1.040-1.050
V8	1.020-1.025
T1	0.600-0.700
T2	0.500-0.600
T3	0.900-1.000

TABLE 8. RESULT OF ORPD USING GA AND HLGBA FOR 8 CONTROL VARIABLES

Parameter		O/P Using GA	O/P Using HLGBA
Transformer tap`	T1	**0.4173**	**0.6787**
	T2	**0.9690**	**0.5700**
	T3	**0.9320**	**0.9291**
BUS VOLTAGES (Pu)	V1	**1.0894**	**1.0781**
	V2	**1.0426**	**1.0600**
	V3	**1.0048**	**1.0268**
	V4	1.0080	1.0177
	V5	1.0145	1.0209
	V6	**1.0503**	**1.0413**
	V7	1.0234	1.0287
	V8	**1.0184**	**1.0242**
	V9	1.0239	1.0266
	V10	1.0209	1.0215
	V11	1.0319	1.0277
	V12	1.0343	1.0260
	V13	1.0285	1.0211
	V14	1.0074	1.0056
Active Power Loss (MW)		12.4645	12.4645
Reactive Power Loss (MVAR)		51.5754	51.5754

The total active power loss of ORPD using GA is 12.4645 MW. The voltage profile is improved after GA which can be seen in fig 4. Proposed algorithm (HLGBA) is applied to minimize the active power loss in the system it can varies the control variable such as total active power losses 12.4645 MW, which is same as GA output, but the voltage profile is improved which can be seen in the fig 5 and the active power loss is decreases from 13.40 MW to 12.4645 MW Which is %7 saving of the active power loss. It can be seen in figure 5. The reactive power loss is also improved from 56.4234(N-R Method) to 51.5754 MVAR.

The optimal values of control variables (seen in dark), active power loses and reactive power loses obtained from GA and result of HLGBA are presented in Table 8.

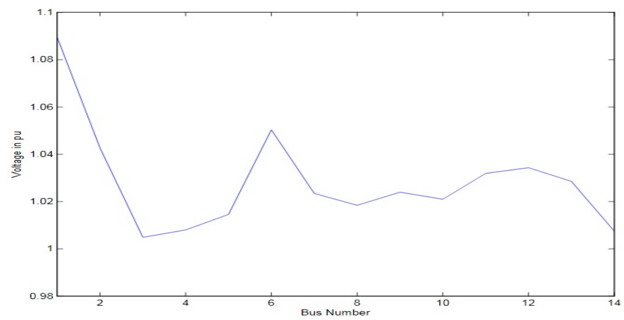


Fig 4- Using GA Voltage Profile of Bus Voltages
(8 control variables)

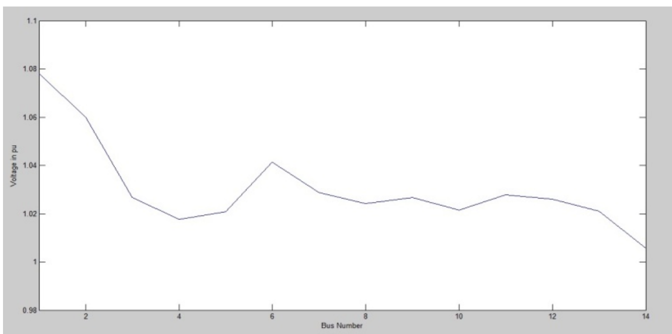


Fig 5-Using HLGBA Voltage Profile of Bus Voltages
(8 control variables)

VI. CONCLUSION

The paper presented a new approach: Loop-GA based algorithm to solve ORPD problem and it is tested on IEEE 14 bus system. The most important advantages of hybrid Loop-genetic based algorithm over other modern heuristics are less computational time fast convergence and more accurate than other method. It can be easily coded on MATLAB 2012 a. Using HLGBA the total active power loss found 13.1229 MW (5 generator bus voltages as control variables) and 12.4645 MW(5 Gen. bus voltages and 3 trans. tap setting as control variables) which is reducing %2 and % 7 of 13.40 MW value in optimal power flow. Hence we can say that HLGBA approach can be accepted to solve this kind of problem for future studies.

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