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A Hybrid Genetic Algorithm Based on Differential Evolution Approach for Optimal Reactive Power Control

KEYWORDS Genetic Algorithm, Differential Evolution, Volt Ampere Reactive

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ABSTRACT *Reactive power and voltage control plays a very important task in proper operation and control of power system. This paper presents a hybrid Genetic Algorithm approach based on Differential Evolution Algorithm for optimal reactive power and voltage control to minimize real power loss in a system. The real power loss has been minimized effectively by the optimal control of control variables based on this approach. In this approach for effective processing the mutation operator of DE is included to avoid the premature convergence. The effectiveness of the proposed approach has been verified on standard IEEE 30 bus test system and it was compared with the existing approach which shows better performance by considerable minimization of real power loss.*

INTRODUCTION

Voltage instability is a very big challenge in power system due to heavily loaded condition. The increase in load may leads to increase in real power losses. This can be remedied by proper distribution of reactive power. Reactive power and voltage control is an important control scheme in power system planning, operation and control. Proper controlling of reactive power and voltage may regulate the system voltage and reduce the real power losses. Several methods have been successfully used in existing system. Most of the techniques converged at local optimal solution.

Many conventional techniques such as gradient-based search algorithms and various mathematical programming methods have been proposed [1]. However, these techniques have severe limitations in handling nonlinear, discontinuous functions and their constraints.

A number of expert systems [2] and a rule based approach [3] based on sensitivity have been presented to minimize the voltage violation problems of low severity. The fuzzy set theory [4] has also been employed to solve those problems. In [5] an approximate reasoning of voltage reactive power control based on a flexible model is proposed. Recently the voltage-reactive power control using fuzzy sets [6] was reported, which aims at the minimization of system real power losses. In [7] the real power loss was minimized by Particle Swarm Optimization algorithm with dynamic weights. In this paper a hybrid Genetic Algorithm and Differential Evolution algorithm is proposed and it is demonstrated in IEEE 30 bus test system which shows better optimal solution.

PROBLEM FORMULATION

Objective Function

The main goal of reactive power and voltage control is to identify the optimal values of control variables which minimize the objective function. The control variables are generator voltages, transformer tap settings and switchable var sources.

In this approach minimization of real power loss is considered as the objective function which satisfies all the equality and inequality constraints. This can be calculated as follows

$$F = \min(P_{Loss}) \tag{1}$$

$$P_{Loss} = \sum_{k=1}^{nl} g_k [V_i^2 + V_j^2 - 2V_i V_j \cos(\delta_i - \delta_j)] \tag{2}$$

Where

nl : the number of branches

g_k : the conductance of the k^{th} line

V_i&V_j : the voltage magnitude at the end buses i & j

δ_i& δ_j : the voltage phase angle at the end buses i & j

Problem Constraints

Equality Constraints

The equality constraints are the real and reactive power balance equations at all the bus bars. The equality constraints can be formulated as

$$P_{gi} - P_{di} = \sum_{j=1}^{n} |V_i| |V_j| |Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \tag{3}$$

$$Q_{gi} - Q_{di} = \sum_{j=1}^{n} |V_i| |V_j| |Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \tag{4}$$

Where

n : the number of buses

Y_{ij} : the mutual admittance between node i and j

δ_i & δ_j : the bus voltage angle of bus i and bus j respectively

θ_{ij} : the admittance angle of line between buses i and j

P_{gi} & Q_{gi} : the real and reactive power generation at bus i

P_{di} & Q_{di} : the real and reactive power demand at bus i

Inequality Constraints

The inequality constraints can be formulated as follows

$$P_s \min \le P_s \le P_s \max \tag{5}$$

Where

$P_s \min$ & $P_s \max$ are the minimum and maximum real powers of slack bus.

$$Q_{gi} \min \le Q_{gi} \le Q_{gi} \max \tag{6}$$

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Where

$Q_{gi}\min \,\&\, Q_{gi}\max$ are the minimum and maximum values of reactive power generation.

$$V_{gi}\min \le V_{gi} \le V_{gi}\max \tag{7}$$

Where

$V_{gi}\min \,\&\, V_{gi}\max$ are the minimum and maximum values of generator voltages.

$$T_i\min \le T_i \le T_i\max \tag{8}$$

Where

$T_i\min \,\&\, T_i\max$ are the minimum and maximum ranges of tap changing transformer.

$$Q_i\min \le Q_i \le Q_i\max \tag{9}$$

Where

$Q_i\min \,\&\, Q_i\max$ are the minimum and maximum outputs of var sources.

HYBRID GA AND DE ALGORITHM

Overview

In this hybrid algorithm the best operators of Genetic Algorithm and Differential Evolution algorithm are combined and implemented. From Genetic Algorithm, the best operator's selection, crossover is selected and in Differential Evolution algorithm, the best operator mutation is selected.

Crossover

Crossover is a recombination operator. It selects genes from parent chromosomes and creates a new offspring. The aim of the crossover operator basically combines the substructure of two parent chromosomes to produce new offspring.

Mutation

The mutation operation of DE applies the vector differentials between the existing population members for determining both the degree and direction of perturbation applied to the individual subject of the mutation operation. The mutation process at each generation begins by randomly selecting three individuals in the population.

Reproduction

The Roulette approach is used to select the strings. Only the selected strings with smallest values are allowed to crossover and mutate for further generations.

IMPLEMENTATION OF HYBRID ALGORITHM

Initialization

Generate initial value for each chromosome in the population. Each chromosome has 14 genes and 30 chromosomes form a population. In each chromosome there are 5 genes of generator bus voltage magnitude, 4 genes of transformer tap position and 5 genes of switchable var sources. For each chromosome the Newton Raphson power flow is executed. From the results of power flow solutions obtain the dependent and independent variables and verifies all the constraints within the limit. If it is not within the limit the particular chromosome will be eliminated from the population.

Selection

From the values of dependent and independent variables the objective function minimization of real power loss is calculated. Based on the objective function the chromosomes are arranged in ascending order. Apply the Roulette wheel approach and select the parent chromosome for crossover. The selected parents are kept in the parent pool.

Crossover

Select two parents from the parent pool randomly and perform single point crossover with the crossover rate of 0.7. The result of the crossover is new offspring.

Mutation

Mutation is done for all chromosomes in the population. In this approach the mutation constant is selected as0.01.

The key parameters selected for the optimization of reactive power control based on Hybrid intelligent Algorithm in real power loss minimization is as follows.

Number of decision variables	= 14
Number of populations	= 30
Number of generations	= 100
Scaling factor	= 0.9
Cross over rate	= 0.4
Mutation constant	= 0.01

RESULTS AND DISCUSSIONS

The proposed Hybrid algorithm has been tested on standard IEEE 30-bus test system. The system having 41 transmission lines, 4 tap changing transformers, 6 generators and 5 static var sources. The line data bus data and initial setting of control variables of IEEE 30 bus test system is taken from [8].In this optimization problem the optimal solution of the proposed algorithm can be demonstrated under the stressed condition of 125 % load in IEEE 30 bus test system. Run the load flow and find the most vulnerable buses. Select the most critical five buses, the buses are load bus 30, 29, 26, 24 and 25. Inject the reactive power in these particular buses by var sources. Apply the proposed algorithm and obtain the optimal settings of control variables to get the best solution. After the implementation of the proposed algorithm the real power loss is minimized and compared with the existing approach [9]. Hence it is observed that the performance of the system is improved. Figure.1 shows the convergence characteristics of real power loss minimization.Table-1 shows the optimal settings of control variables for the proposed approach to IEEE-30 bus test system.

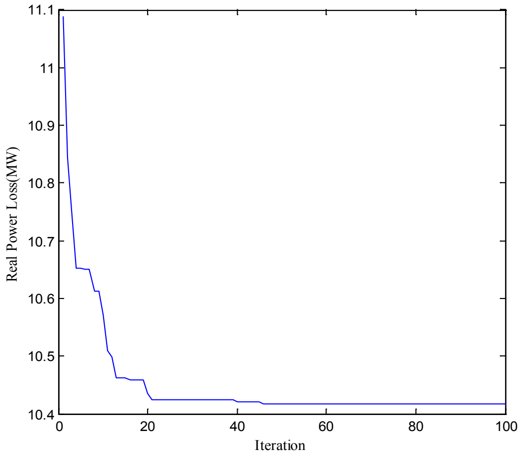

Figure.1Convergence characteristics of real power loss minimization

TABLE – 1
OPTIMAL SETTINGS OF CONTROL VARIABLES FOR IEEE-30 BUS TEST SYSTEM

Control variables	Min limit	Max limit	Initial Setting	Min of P-Loss (GA)	Min of P-Loss (DE)	Min of P-Loss (Hybrid)
Vg1	0.95	1.05	1.0500	1.0500	1.0500	1.0500
Vg2	0.95	1.05	1.0400	1.0256	1.0353	1.0410
Vg3	0.95	1.05	1.0100	1.0063	1.0106	1.0250
Vg4	0.95	1.05	1.0100	0.9895	1.0050	1.0500
Vg5	0.95	1.05	1.0500	1.0584	1.0034	1.0080
Vg6	0.95	1.05	1.0500	1.0806	1.0246	1.0500
T1	0.9	1.1	0.9780	1.0500	0.9600	0.9830
T2	0.9	1.1	0.9690	0.9000	0.9680	0.9670
T3	0.9	1.1	0.9320	0.9250	0.9000	0.9210
T4	0.9	1.1	0.9680	0.9500	0.9432	0.9714
Q30	0	5	0	5	2	5
Q29	0	5	0	5	4	5
Q26	0	5	0	5	4	2
Q25	0	5	0	1	3	3
Q24	0	5	0	3	4	2
P Loss			10.76	10.55	10.50	10.41

Conclusion

In this paper a hybrid intelligent technique has been developed and successfully applied to solve reactive power control problems. This problem has been formulated with the objective function minimization of real power loss. It is found that the hybrid algorithm can effectively utilize the reactive power control variablesand satisfies all the equality and inequality constraints. In this approach the optimal solution of real power loss is reduced to 10.41 MW. The effectiveness of the proposed approach has been examined on standard IEEE 30 bus test system and verified by comparing the test results with the base case, GA and DE based reactive power control optimization problem.

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