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Hybrid Intelligent Algorithm to Solve Multi Objective Reactive Power Control Problem

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Abstract

Reactive power and voltage control is a minimization problem. In this paper the multi objective function consist of minimization of real power losses, minimization of voltage deviation and minimization of voltage stability index subjected to equality and inequality constraints are considered. This can be achieved by proper adjustment of control variables such as the generator voltages, the transformer tap settings, and the switchable VAR sources that would minimize the real power loss, the voltage deviation and the voltage stability index. In this work, the hybrid intelligent algorithm Genetic Algorithm - Artificial Bee Colony (GA- ABC) are used. The hybrid algorithms used are the combination of best features of two intelligent algorithms. GA has good crossover operator and hence inspires hybridization with ABC to identify the source effectively. The population is evolving iteration by iteration to find global optimal solution. To evaluate the performance of the developed algorithm standard IEEE 30 bus system is used. This hybrid algorithm gives better optimal solution as compared to individual intelligent algorithm.

Keywords: Volt Ampere Reactive, Genetic Algorithm, Artificial Bee Colony, Voltage Stability Index

1 Introduction

Due to the increase in load and various crisis situations, the voltages in all the load bus centers may fluctuate beyond the acceptable level which leads to voltage collapse and increase in system losses. The control centre's has to provide the optimal reactive power where ever necessary to prevent these critical situations.

To supply the convenient amount of reactive power and voltage in the needy region effectively, power flow control is required. Voltage and reactive power must be properly managed and controlled to provide adequate quality service and maintain proper stability of the power system.

Many optimization techniques have been used to solve reactive power control problem. In [5] linear programming is used for voltage profile improvement and the minimization of transmission line losses by adjusting the control variables transformer tap positions and reactive power injection by VAR sources. An efficient program based on sparse matrix technique to solve reactive power control problems presented in [1].Several conventional methods are used to solve reactive power control problem but due to non linearity, non differential, and non convex nature of the reactive power control problem most of the techniques are converged to a local optimum solution. Intelligent techniques have been implemented for reactive power control to overcome these difficulties. In most of the cases single objective function is considered. Recently multi objective reactive power control with hybrid intelligent techniques is more popular. It can effectively control the reactive power control variables and gives optimal solution.

In [4] fuzzy set theory is used for reactive power control with the purpose of improving the voltage stability of a power system. This method is based on the reality that reactive power injections at critical buses of the power system help to drive the system away from a developing voltage collapse. Genetic Algorithm using linear approximation for the selection of corrective control actions for bus voltage and generator reactive power in a power system presented in [7]. Differential Evolution algorithm used to solve optimal power flow problem in [8]. Generator voltage magnitudes, transformer tap settings are considered as control variables and converted into vectors of DE algorithm.DE algorithm gives more importance to mutation, than crossover and selection operation and finds global optimal solution combined with Genetic Algorithm in [6].

2 Objective Functions

Minimization of real power losses

The objective is to minimize the total real power losses in the system. Real power loss in each branch can be calculated from the solution of load flow analysis. This can be calculated as

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

Minimization of voltage deviation

In order to improve the voltage profile the voltage deviation has to be minimized. The objective function minimization of voltage deviation can be calculated by

$$\text{Minimize } VD = \sum_{i=1}^{NL} \left| V_i - 1.0 \right| \tag{2}$$

Minimization of voltage stability index

The formulation of the voltage stability index is discussed below. It uses the information from the load flow analysis by Newton Raphson method. Consider an n-bus system, the relationship between the current and voltage is expressed as

$$\text{Minimize } VSIj = \left| 1 - \sum_{i=1}^{NG} F_{ji} \frac{V_i}{V_j} \right| j = ng + 1, \ldots.., n \tag{3}$$

3 Constraints

Equality Constraints

Power balance equation gives the equality constraints for reactive power control problem. This power balance equation is derived from Newton Raphson power flow analysis which states, generation of real and reactive power should balance real and reactive power demand and losses.

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

$$Q_{gi} - Q_{di} = \sum_{j=1}^{n} |V_i| \, |V_j| |Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \tag{5}$$

Inequality Constraints

In this reactive power control problem the control variables and dependent variables has lower and upper limits and also the limits on power flow in the transmission lines form inequality constraints.

$P_s\min \leq P_s \leq P_s\max$ (6)

$Q_{gi}\min \leq Q_{gi} \leq Q_{gi}\max$ for i=1to NG (7)

$V_{gi}\min \leq V_{gi} \leq V_{gi}\max$ for i=1to NG (8)

$T_i\min \leq T_i \leq T_i\max$ for i=1to NT (9)

$Q_{ci}\min \leq Q_{ci} \leq Q_{ci}\max$ for i=1to NC (10)

Where,

nl	-	number of transmission lines
g_k	-	conductance of the k^{th} line
n	-	Number of buses
ng	-	number of generator buses
V_i & V_j	-	voltage magnitude at the buses i and j
Y_{ij}	-	mutual admittance in between the node i and j
δ_i & δ_j	-	angle of bus voltages of bus i and bus j respectively
θ_{ij}	-	admittance angle between the buses i and j
P_{gi} & Q_{gi}	-	real and reactive power generation at bus i
P_{di} & Q_{di}	-	real and reactive power demand at bus i
NL	-	number of load buses
NG	-	number of generator buses
NT	-	number of tap setting transformer
NC	-	number of capacitors

4 Implementation of Hybrid GA - ABC for Reactive Power Control

ABC mimics the behavior of honey bees. The location of the nectar source shows the probable solution of reactive power optimization problem. The amount of nectar from the source shows the quality (fitness) of the associated solution represented by that food source. To improve the investigation of search space crossover is introduced. The excellence of this solution is formulated by combining GA and ABC to form hybrid GA-ABC algorithm.GA-ABC is a population based heuristic algorithm, the location of the nectar source shows the achievable results of this optimization problem. The nectar quantity of the food source is the quality (fitness) of the associated solution. The quantity of the employed bees is equal to the solutions of the problem in that population.

At the first step, an arbitrarily dispersed initial population (food source positions) is generated. After initialization, the population was subjected to repeat the cycles of the search processes of the employed, onlooker, and scout bees, in that order. An employed bee produces an adaptation on the source position in her memory and searching a new food source position. To identify the source effectively the crossover operator of GA is introduced. The bee memorizes the new source position and forgets the old one. Once the employed bees completed their search process, they can share the information about location of the sources with the onlooker bees in the dancing area. The onlooker bees evaluate the nectar information taken from all employed bees and then choose a food source depending on the nectar amount of the sources. In the case of the employed bee, she produces an adaptation on the source position in her memory and checks its nectar amount. Provided that its nectar is higher than that of the previous one, the bees memorize the novel position and forget the old one. The source discarded was determined and new sources are randomly produced to be replaced with the discarded ones by artificial scouts.

Hybrid GA-ABC algorithm is used to solve reactive power control problem in this section. For the considered test case, 6 generator bus voltages, 4 transformer tap position and 5 switchable VAR sources are taken as the candidate solution. The number of the employed bees is equal to the number of solutions in the population. This population is evolving iteration by iteration to find global optimal solution. The maximum number of iteration it may evolve is taken as 100 iterations and the population selected is 30.In this work single point cross over is used and cross over constant value 0.7 is considered. Hybrid GA-ABC algorithm gives good optimal solution as compared to all other developed algorithm.

5 Results and Discussions

To evaluate the performance of the developed algorithms standard IEEE 30 bus system is used. The minimum and maximum limits of control variables are for generator bus voltages between 0.95 and 1.05 p.u, for transformer tap position between 0.90 to 1.1p.u, for shunt capacitor between 1 and 5 p.u and for slack bus real power between 50 and 200 MW. The first step of this approach is run the Newton Raphson power flow for IEEE 30 bus system under stressed condition. The stress is created by 125 percentage of load applied in all the load buses i.e., the real and reactive power of all the load buses multiplied by 1.25.The VSI for all the load buses are calculated. The voltage stability index value ranges from 0 to 1. The bus with highest value of VSI is considered as most vulnerable bus. Identify the most five weakest buses. From this computation the highest value of VSI is 0.1978 found in bus 30 and the most five weakest buses are 30,29,26,25 and 24. Inject reactive power in these weakest buses by connecting shunt capacitors across it. The optimal solutions of the objective functions can be calculated by apply the developed algorithms.

Hybrid GA-ABC is iterated for 100 iterations as shown Figure-1 and converged around 54th iteration. By this approach a minimum real power loss of 10.3918 MW, a minimum voltage deviation of 0.2102 p.u. and a minimum voltage stability index of 0.1708 is obtained.

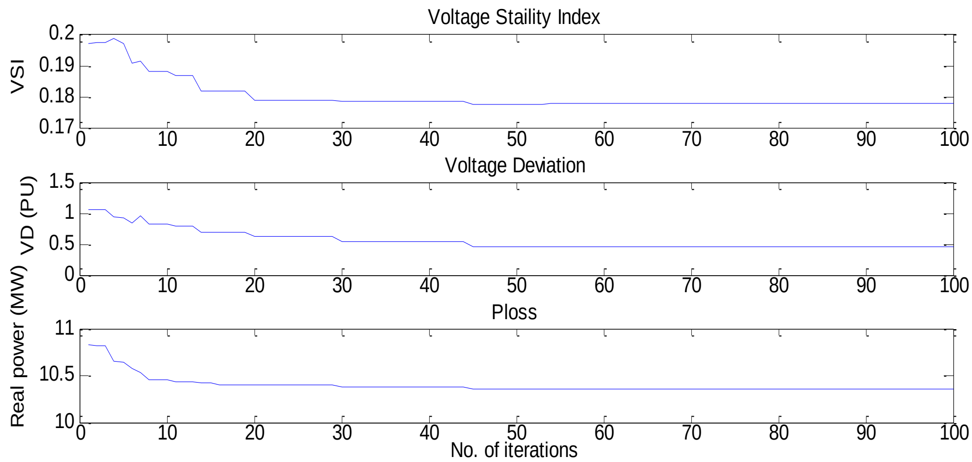

Figure 1 Convergence Curve – hybrid GA-ABC

In this approach all the control variables are within the limits and a best solution is achieved for all the objective functions. In this computation it satisfies all the equality constraints and inequality constraints. Compared to other intelligent techniques applied [3] the hybrid GA-ABC gives the optimal solution.

Table - 1 Control variable limits and optimal solution

Sl. No.	Control variables	Initial settings	GA	GA-ABC
1	V_1	1.050	1.050	1.0500
2	V_2	1.040	1.025	1.0410
3	V_3	1.010	1.006	1.0250
4	V_4	1.010	0.989	1.0500
5	V_5	1.050	1.005	1.0080
6	V_6	1.050	1.080	1.0500
7	T_1	0.978	1.050	0.9830
8	T_2	0.969	0.900	0.9670
9	T_3	0.932	0.925	0.9210
10	T_4	0.968	0.950	0.9714
11	Q_{30}	0	5	5
12	Q_{29}	0	5	5
13	Q_{26}	0	5	2
14	Q_{25}	0	1	3
15	Q_{24}	0	3	2
P Loss(MW)		10.76	10.55	**10.3918**
VSI		0.1978	0.1807	**0.1708**
Voltage Deviation(p.u)		0.2334	-	**0.2102**

6 Conclusions

The hybrid algorithm GA-ABC provides better results for this problem. ABC has no cross over operation and the solution may improved by adding cross over with it, since GA has better cross over ABC is hybrid with GA. The hybrid GA-ABC approach has faster convergence compared to other algorithm the number of iteration is less and also attains a better solution. This hybrid algorithm gives best results compared to other algorithms and satisfies all the equality and inequality constraints for the same test case IEEE 30 bus system with same constraints.

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