

Real Power Loss Minimization using Big Bang Big Crunch Algorithm

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ABSTRACT

In power system operation, minimizing the power loss in transmission lines and/or minimizing the voltage deviation at the load buses by controlling the reactive power is referred to as optimal reactive power dispatch (ORPD). ORPD is necessary for secured operation of power systems with regard to voltage stability. In this paper, the nature inspired Big Bang – Big Crunch (BB-BC) algorithm is introduced to solve multi constrained optimal reactive power flow problem in power systems. Generator bus voltages, transformer tap positions and switchable shunt capacitor banks are used as variables to control the reactive power flow. Big Bang – Big Crunch algorithm was tested on standard IEEE 30 bus system and the results are compared with other methods to prove the effectiveness of the new algorithm. The results are quite encouraging and the algorithm is found to be simple and easy to implement.

KEYWORDS

Big Bang – Big Crunch Algorithm, Optimal Reactive Power Dispatch, Loss Minimization, Voltage Deviation Minimization.

1. INTRODUCTION

The increased demand for electric power and the insufficient power generation and transmission facility forces the power system networks is being operated under stressed conditions. The security of a power system is under threat when it is operated at stressed conditions and may result in voltage instability. Nowadays voltage instability has become a new challenge to power system planning and operation. Insufficient reactive power availability or non-optimized reactive power flow may lead a power system to insecure operation under heavily loaded conditions [1]-[2]. By reallocating reactive power generations in the system by adjusting transformer taps, generator voltages and switchable VAR sources, the problem can be solved to a far extent.

Apart from the aforementioned methods, the system losses can also be minimized via redistribution of reactive power in the system for improving the stability of a power system. Large amount of reactive power flow in a system is indicated by the real power loss in the system. Therefore minimizing the real power loss ensures optimized reactive power flow (ORPF) through the lines. Reactive power optimization by real power loss minimization increases the power system economics to some extent. Reactive power optimization by minimization of real power loss has long been attempted for voltage stability improvement [3]-[4].

Optimal reactive power flow is an important tool in terms of secure and operation of power system. It is a powerful concept for power system operation and planning [5]-[6]. In ORPF, the network active power loss is reduced and voltage profile is improved while satisfying a given set of operating and physical

have been exploited for this objective. Techniques such as non linear programming technique [9], gradient based optimization algorithm are used to solve ORPF problem algorithms [10] are used to solve ORPF problem. But it has several disadvantages like large numerical iteration, insufficient convergence properties; which leads to large computation and more execution time.

The recently developed meta-heuristics based algorithms are proving better performance than the conventional methods. They find global best or nearly global best solutions for engineering problems. These algorithms are better utilised for power system optimization. Some of them are Tabu Search [11], Simulated Annealing (SA) [12], Genetic Algorithm (GA) [13], Evolutionary Programming (EP) [14]-[15] Hybrid Evolutionary Programming (HEP) [16], Particle Swarm Optimization PSO [17]-[19], Chaotic Ant Swarm Optimization (CASO) [20], Bacterial Foraging Optimization (BFO) [21], Ant Colony Optimization (ACO) [22], Differential Evolution (DE) [23] and Quantum Genetic Algorithm (QGA) [24] are developed which provides fast and optimal solution.

Conventional methods are sensitive to initial guess of the search point where functions have multiple local minima and not efficient in handling problems of discrete variables [25]. In addition to this a lot of algorithms have been presented to solve optimal reactive power dispatch. Chien-Feng Yang proposed a system for limiting voltage variations by means of switchable shunt reactive compensation and transformer tap setting [26]. Other new optimization techniques are based on using fuzzy logic [27], lagrangian decomposition method [28].

BB-BC algorithm is a recent development and it very simple and easy to implement [29]-[30]. This algorithm has less number of parameters and has good convergence characteristics. In this paper, the BB-BC method is used for ORPD problem. The performance of this method is compared with other algorithms to prove its efficiency.

2. PROBLEM FORMULATION

The objective of this work is to optimize the reactive power flow in a power system by minimizing the real power loss and sum of load bus voltage deviation. An augmented objective function is formed with the two objective components and weights.

2.1 OBJECTIVE FUNCTION

The objective function of this work is to find the optimal settings of reactive power control variables including the rating shunt of var compensating devices which minimizes the real power loss.

2.1 Real power loss minimization (PL)

The total real power of the system can be calculated as follows

$$P_{loss} = \sum_{k=1}^{N_L} G_k [V_i^2 + V_j^2 - 2|V_i||V_j|\cos\delta_i - \delta_j] \quad (1)$$

Where, N_L is the total number of lines in the system; G_k is the conductance of the line 'k', V_i and V_j are the magnitudes of the sending end and receiving end voltages of the line; δ_i and δ_j are angles of the end voltages.

2.2 Constraints

The minimization problem is subject to the following equality and inequality constraints

2.2.1 Equality constraints

Load Flow Constraints:

The equality constraints represent the load flow equations, which are given below for i_{th} bus:

$$P_{gi} - P_{Di} = \sum_{j=1}^{NB} V_i V_j Y_{ij} \cos(\delta_{ij} + \gamma_j - \gamma_i) \quad (2)$$

$$Q_{gi} - Q_{Di} = \sum_{j=1}^{NB} V_i V_j Y_{ij} \sin(\delta_{ij} + \gamma_i - \gamma_j) \quad (3)$$

where P_{gi} , Q_{gi} are the active and reactive power of i_{th} generator, P_{Di} , Q_{Di} the active and reactive power of i_{th} load bus.

2.2.2 Inequality constraints

Generator constraints.

Generator voltage and reactive power of i_{th} bus lies between their upper and lower limits as given below:

$$\begin{cases} V_{gi}^{min} \leq V_{gi} \leq V_{gi}^{max} & i=1,2,...,NG \\ Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} & i=1,2,...,NG \end{cases} \quad (4)$$

Where V_{gi}^{min} , V_{gi}^{max} are the minimum and maximum voltage of i_{th} generating unit and Q_{gi}^{min} , Q_{gi}^{max} are the minimum and maximum reactive power of i_{th} generating unit.

Load bus constraints.

$$V_{L1}^{min} \leq V_{L1} \leq V_{L1}^{max} \quad i=1,2,...,NL \quad (6)$$

Where V_{L1}^{min} , V_{L1}^{max} are the minimum and maximum load voltage of i_{th} unit.

Transmission line constraints.

$$S_{L1} \leq S_{L1}^{max} \quad i=1,2,...,NTL \quad (9)$$

Where S_{L1} is the apparent power flow of i_{th} branch and S_{L1}^{max} is the maximum apparent power flow limit of i_{th} branch.

Transformer tap constraints.

Transformer tap settings are bounded between upper and lower limit as given below:

$$T_i^{min} \leq T_i \leq T_i^{max} \quad i=1,2,...,NT \quad (10)$$

Where T_i^{min} , T_i^{max} are the minimum and the maximum tap setting limits of i_{th} transformer.

Shunt compensator constraints.

Shunt compensation are restricted by their limits as follows:

$$Q_{C1}^{min} \leq Q_{C1} \leq Q_{C1}^{max}, \quad i=1,2,...,NC \quad (11)$$

Where Q_{C1}^{min} , Q_{C1}^{max} are the minimum and maximum VAR injection limits of i_{th} shunt capacitor.

3. BIG BANG – BIG CRUNCH ALGORITHM

3.1 OVERVIEW

A new nature inspired optimization technique which has low computational time and high convergence speed called BB-BC is introduced recently [29]-[30]. It has two phases, Big bang phase and Big crunch phase.

In Big Bang phase, candidate solutions are randomly distributed over the search space. The main features of Big Bang phase is that the energy dissipation produces disorder and randomness and in a Big Crunch phase, randomly distributed particles are drawn into an order.

The Big Bang-Big Crunch optimization method generates random points in the Big Bang phase and shrinks these points to a single point in the Big Crunch phase after a number sequential Big Bangs and Big Crunches.

The Big Bang phase is followed by the Big Crunch phase. The Big Crunch is a convergence operator that has many inputs but only one output, which is named as the ‘‘centre of mass’’, since the only output has been derived by calculating the centre of mass. The point representing the centre of mass that is denoted by X_c is calculated according to the following equation.

$$\vec{X}_c = \frac{\sum_{i=1}^N \vec{f}_i}{\sum_{i=1}^N 1}$$

where X_i is a point within an D-dimensional search space generated, $f(X_i)$ is a fitness function value of this point, NP is the population size in Big Bang phase. The convergence operator in the Big Crunch phase is different from ‘exaggerated’ selection since the output term may contain additional information (new candidate or member having different parameters than others) than the participating ones, hence differing from the population members. This one step convergence is superior compared to selecting two members and finding their centre of gravity. This method takes the population members as a whole in the Big Crunch phase that acts as a squeezing or contraction operator; and it, therefore, eliminates the necessity for two-by-two combination calculations.

After the Big Crunch phase, the algorithm must create new members to be used as the Big Bang of the next iteration step. This can be done in various ways, the simplest one being jumping to the first step and creating an initial population. The algorithm will have no difference than random search method by so doing since latter iterations will not use the knowledge gained from the previous ones; hence, the convergence of such an algorithm will most probably be very low. In this work, the new candidates are generated around the centre of mass and knowledge of centre of mass of previous iteration is used for better convergence. The parameters to be supplied to normal random point generator are the centre of mass of the previous step and the standard deviation. The deviation term can be fixed, but decreasing its value along with the elapsed iterations produces better results.

3.2 BIG BANG BIG CRUNCH APPLIED TO ORPF:

Big Bang Big Crunch algorithm involves the steps shown below in reactive power optimization

Step 1: Form an initial generation of NP candidates in a random

manner respecting the limits of search space.

Step 2: Calculate the fitness function values of all candidate solution by running the NR load flow. *Step 3:* Determine the centre of mass which has global best fitness using equation (10).

Step 4: Calculate new candidate around the centre of mass by adding/subtracting a normal random number according to equation (11).

Step 5: Return to step 2 until stopping criteria has been achieved.

Flow chart :

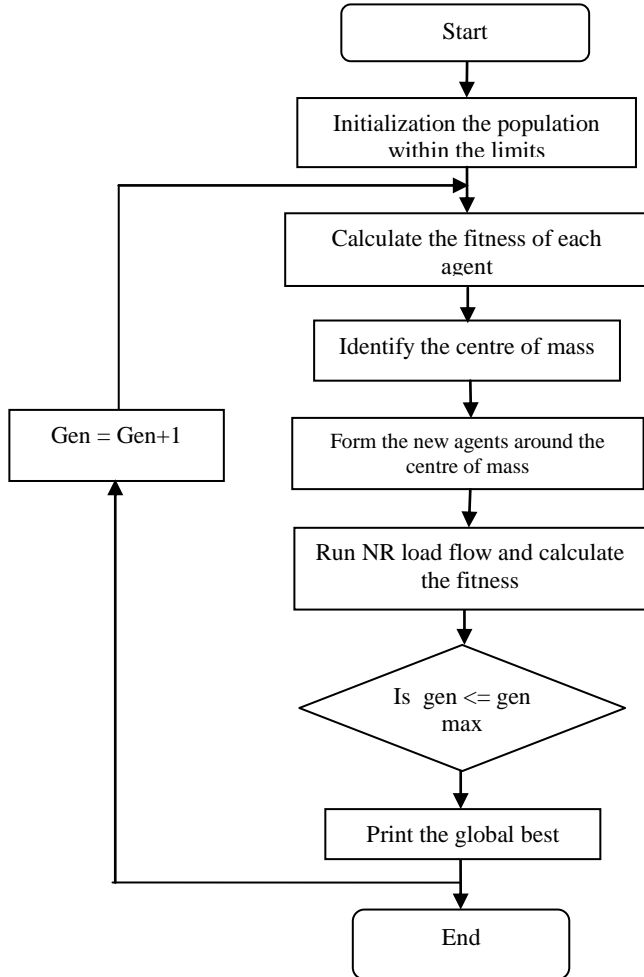


Fig 1.Flow chart for BB-BC algorithm

4. NUMERICAL RESULTS AND DISCUSSIONS

The performance of the proposed BB-BC algorithm based reactive power optimization method is tested in the medium size IEEE 30 bus system. The algorithm is coded in MATLAB environment and a Core 2 Duo, 2.8 MHz, 2GB RAM based PC is for the simulation purpose.

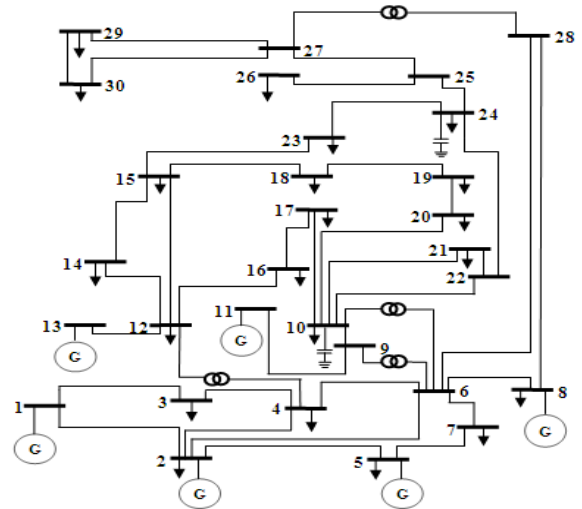


Figure 2. Single line diagram of IEEE-30 bus system.

The test system taken has six generating units connected to buses 1,2,5,8,11 and 13. There are 4 regulating transformers connected between bus numbers 6-9, 6-10, 4-12 and 27-28. Two shunt compensators are connected in bus numbers 10 and 24. The system is interconnected by 41 transmission lines. The control variables are generator's voltages, tap settings of the regulating transformers and var injection of shunt capacitors.

The upper and lower bounds of the different control variables are given in table 1.

Table 1. Control variable limits

S. No	Control Variable	Limit
1.	Generator voltage (V_G)	(0.9-1.1) p.u.
2.	Tap setting(T_p)	(0.9 -1.1) p.u.
3.	Static Var compensators (Q_{svc})	(0-25) MVAR

4.1 Minimization of real power loss

The real power transmission loss minimization is the major component of reactive power optimization and it needs more attention. This case takes only the real power loss minimization as the objective function. The optimal control variables of the overall system obtained by BB-BC algorithm for this case are shown in table 4.

Table 4. Optimal parameter values.

Sl no	Parameter	Initial value	Optimal Value [BB-BC]
1	V_{G1}	1.05	1.1000
2	V_{G2}	1.04	1.0957
3	V_{G5}	1.01	1.0760
4	V_{G8}	1.01	1.0782
5	V_{G11}	1.05	1.0495
6	V_{G13}	1.05	1.1000
7	T_{6-9}	1.078	1.0376
8	T_{6-10}	1.069	0.9083
9	T_{4-12}	1.032	0.9749
10	T_{27-28}	1.068	0.9709
11	Q_{10}	0.0	23.5205
12	Q_{24}	0.0	7.3395

In this case the BB-BC algorithm better optimizes real power loss as shown in table 5. The reduction in loss indicated by BB-BC algorithm is highly encouraging and it is only 4.807 MW.

Table 5. Minimization of objective terms.

Sl No	Parameter	Initial value	BB-BC	BBO [1]	PSO [1]
1.	P_{loss}	5.744	4.807	4.9650	5.09219

The good convergence characteristics of BB-BC In the objective of real power loss minimization is plotted in figure 6.

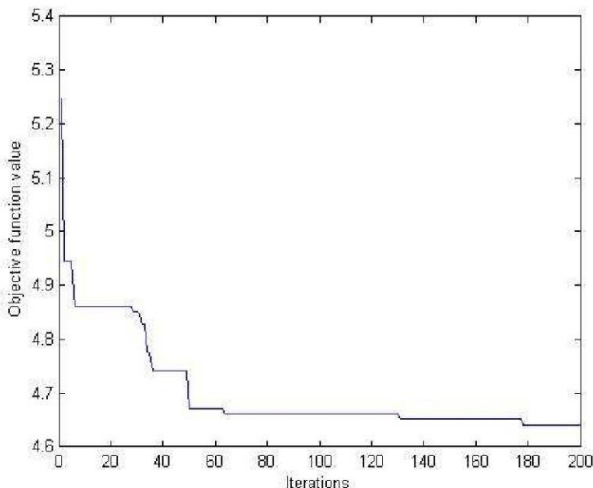


Figure 6. Convergence characteristics of BB-BC

5. CONCLUSIONS

In this paper, a novel BB-BC Based optimization algorithm is proposed to solve multi-objective optimal reactive power flow

problem. The performance of the proposed algorithm for solving ORPF problems is demonstrated using IEEE-30 bus system. The results are compared to those of other algorithms like PSO and BBO. The test results clearly demonstrate that BB-BC outperforms other reported methods in terms of solution quality. The superiority of the proposed BB-BC method is more pronounced for large system as is evident from IEEE-30 bus system. From all simulation results it may finally be concluded that among all the algorithms, BB-BC based optimization method is capable of achieving global optimal solution. This paper shows that such excellent results with different objective functions shows that makes the proposed BB-BC optimization technique is good in dealing with power system optimization problems.

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