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Full Length Article

A novel hybrid Particle Swarm Optimizer with multi verse optimizer for global numerical optimization and Optimal Reactive Power Dispatch problem

Pradeep Jangir [a], Siddharth A. Parmar [a], Indrajit N. Trivedi [b], R.H. Bhesdadiya [a]

[a] *Department of Electrical Engineering, Lukhdhirji Engineering College, Morbi, Gujarat 363641, India*
[b] *Department of Electrical Engineering, Government Engineering College, Gandhinagar, Gujarat 389001, India*

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ABSTRACT

Recent trend of research is to hybridize two and more algorithms to obtain superior solution in the field of optimization problems. In this context, a new technique hybrid Particle Swarm Optimization (PSO)-Multi verse Optimizer (MVO) is exercised on some unconstraint benchmark test functions and the most common problem of the modern power system named Optimal Reactive Power Dispatch (ORPD) is optimized using the novel hybrid meta-heuristic optimization algorithm Particle Swarm Optimization-Multi Verse Optimizer (HPSO-MVO) method. Hybrid PSO-MVO is combination of PSO used for exploitation phase and MVO for exploration phase in uncertain environment. Position and Speed of particle is modernised according to location of universes in each iteration. The hybrid PSO-MVO method has a fast convergence rate due to use of roulette wheel selection method. For the ORPD solution, standard IEEE-30 bus test system is used. The hybrid PSO-MVO method is implemented to solve the proposed problem. The problems considered in the ORPD are fuel cost reduction, Voltage profile improvement, Voltage stability enhancement, Active power loss minimization and Reactive power loss minimization. The results obtained with hybrid PSO-MVO method is compared with other techniques such as Particle Swarm Optimization (PSO) and Multi Verse Optimizer (MVO). Analysis of competitive results obtained from HPSO-MVO validates its effectiveness compare to standard PSO and MVO algorithm.

1. Introduction

At the present time, hybridize of two and more algorithms to obtain superior solution in the field of optimization problems and application in The Optimal Reactive Power Dispatch (ORPD) is very significant problem and most focused objective for power system planning and operation [1]. The ORPD is the elementary tool which permits the utilities to identify the economic operational and much secure states in the system [2,3]. The ORPD problem is one of the utmost operating desires of the electrical power system [4]. The prior function of ORPD problem is to evaluate the optimum operational state for Bus system by minimizing each objective function within the limits of the operational constraints like equality constraints and inequality constraints [5]. Hence the Optimal Reactive Power Dispatch problem can be defined as an extremely non-linear and non-convex multimodal optimisation problem [6].

From the past few years too many optimization techniques were used for the solution of the Optimal Reactive Power Dispatch (ORPD) problem. Some traditional methods are used to solve the proposed problem have been suffered from some limitations like converging at local optima, not suitable for binary or integer problems and also have the assumptions like the convexity, differentiability, and continuity [7]. Hence these techniques are not suitable for the actual ORPD situation [8,9]. All these limitations are overcome by meta-heuristic optimization methods like genetic algorithm (GA), Particle Swarm Optimization algorithm (PSO), ant colony algorithm (ACO), differential evolution algorithm (DEA) and harmony search algorithm (HSA) [10,11].

In the present work, a newly introduced hybrid meta-heuristic optimisation technique named Hybrid Particle Swarm Optimization-Multi Verse Optimizer (HPSO-MVO) is applied to solve the Optimal Reactive Power Dispatch problem. HPSO-MVO comprises of best characteristic of both Particle Swarm Optimization [12] and Multi Verse Optimizer [13] algorithm. The

E-mail addresses: pkjmtech@gmail.com (P. Jangir), saparmar92@gmail.com (S.A. Parmar), forumtrivedi@gmail.com (I.N. Trivedi), rhblec@gmail.com (R.H. Bhesdadiya).

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capabilities of HPSO-MVO are finding the near global solution, fast convergence rate due to use of roulette wheel selection, can handle continuous and discrete optimization problems.

In this work, the HPSO-MVO is implemented to unconstraint bench mark function and standard IEEE-30 bus test system [14] to solve the ORPD [15–20] problem. There are five objective cases considered in this paper that has to be optimize using HPSO-MVO technique are Fuel Cost Reduction, Voltage Stability Improvement, Voltage Deviation Minimization, Active Power Loss Minimization and Reactive Power Loss Minimization. The result shows the optimal adjustments of control variables in accordance with their limits. The results obtained using HPSO-MVO technique has been compared with standard Particle Swarm Optimisation (PSO) and Multi Verse Optimizer (MVO) techniques. The results show that HPSO-MVO gives better optimization values as compared to other methods which proves the effectiveness of the proposed algorithm.

The structure of the paper can be given as follow: – Section 1 consists of Introduction, Section 2 includes description of participated algorithms, Section 3 consists of competitive results analysis of unconstraint test benchmark problem and ORPD problem finally acknowledgement and conclusion based on results is drawn.

2. Standard PSO and standard MVO

2.1. Particle Swarm Optimization

The Particle Swarm Optimization algorithm (PSO) was discovered by James Kennedy and Russell C. Eberhart in 1995 [12]. This algorithm is inspired by simulation of social psychological expression of birds and fishes. PSO includes two terms P_{best} and G_{best}. Position and velocity are updated over the course of iteration from these mathematical equations:

$$v_{ij}^{t+1} = wv_{ij}^{t} + c_1R_1(Pbest^t - X^t) + c_2R_2(Gbest^t - X^t) \quad (1)$$

$$X^{t+1} = X^t + v^{t+1}(\mathrm{i} = 1, 2\ldots\mathrm{NP}) \text{ And } (\mathrm{j} = 1, 2\ldots\mathrm{NG}) \quad (2)$$

where

$$w = w^{\max} - \frac{(w^{\max} - w^{\min}) * iteration}{\max iteration}, \quad (3)$$

$w^{max} = 0.4$ and $w^{min} = 0.9$. v_{ij}^{t}, v_{ij}^{t+1} Is the velocity of jth member of ith particle at iteration number (t) and ($t + 1$). (Usually $C_1 = C_2 = 2$), r_1 and r_2 Random number (0, 1).

2.2. Multi-verse optimizer

Three notions such as black hole, white hole and wormhole shown in Fig. 1 are the main motivation of the MVO algorithm. These three notions are formulated in mathematical models to evaluate exploitation, exploration and local search, respectively. The white hole assumed to be the main part to produce universe. Black holes are attracting all due to its tremendous force of gravitation. The wormholes behave as time/space travel channels in which objects can moves rapidly in universe. Main steps uses to the universes of MVO [13]:

I. If the inflation rate is greater, the possibility of presence of white hole is greater.
II. If the inflation rate is greater, the possibility of presence of black hole is lower.
III. Universes having greater inflation rate are send the substances through white holes.
IV. Universes having lesser inflation rate are accepting more substances through black holes.

The substances/objects in every universe can create random movement in the direction of the fittest universe through worm holes irrespective to the inflation rate. The objects are move from a universe having higher inflation rate to a universe having lesser inflation rate. It can assure the enhancement of the average inflation rates of the entire cosmoses with the iterations. In each iteration, the universes are sorted according to their inflation rates and select one from them using the roulette wheel as a white hole. The subsequent stages are used for this procedure. Assume that

$$U = \begin{bmatrix} x_1^1 & x_1^2 & \cdot & \cdot & x_1^d \\ x_2^1 & x_2^2 & \cdot & \cdot & x_2^d \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ x_n^1 & x_n^2 & \cdot & \cdot & x_n^d \end{bmatrix} \quad (4)$$

Where, d shows the No. of variables and n shows the No. of candidate solutions:

$$x_i^j = \begin{cases} x_k^j; & r1 < NI(Ui) \\ x_i^j; & r1 \geqslant NI(Ui) \end{cases} \quad (5)$$

where, x_i^j shows the jth variable of ith universe, U_i indicates the ith universe, $NI(U_i)$ is normalized inflation rate of the ith universe, $r1$ is a random No. from [0,1], and x_k^j shows the jth variable of kth universe chosen through a roulette wheel. To deliver variations for all universe and more possibility of increasing the inflation rate by worm holes, suppose that worm hole channels are recognized among a universe and the fittest universe created until now. This mechanism is formulated as:

$$x_i^j = \begin{cases} \begin{cases} X_j + TDR \times ((ub_j - lb_j) \times r4 + lb_j); r3 < 0.5 \\ X_j - TDR \times ((ub_j - lb_j) \times r4 + lb_j); r3 \geqslant 0.5 \end{cases}; r2 < WEP \\ x_i^j; r2 \geqslant WEP \end{cases} \quad (6)$$

where X_j shows jth variable of fittest universe created until now, lb_j indicates the min limit of jth parameter, ub_j indicates max limit of jth parameter, x_i^j shows the jth parameter of ith universe, and r2, r3, r4 are random numbers from [0, 1]. It can be concluded by the formulation that wormhole existence probability (WEP) and travelling distance rate (TDR) are the chief coefficients. The formula for these coefficients are given by:

$$WEP = \min + l \times \left(\frac{\max - \min}{L}\right) \quad (7)$$

Where, l shows the present run, and L represent maximum run number/iteration.

$$TDR = 1 - \frac{l^{1/p}}{L^{1/p}} \quad (8)$$

Where, p states the accuracy of exploitation with the iterations. If the p is greater, the exploitation is faster and more precise. The complexity of the MVO algorithms based on the No. of iterations, No. of universes, roulette wheel mechanism, and universe arranging mechanism. The overall computational complexity is as follows:

$$O(MVO) = O(l(O(Quicksort) + n \times d \times (O(roulette\_wheel)))) \quad (9)$$

$$O(MVO) = O(l(n^2 + n \times d \times \log n)) \quad (10)$$

Where, n shows No. of universes, l shows the maximum No. of run/iterations, and d shows the No. of substances.

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