Particle Swarm Optimization Algorithm Combined with Genetic Algorithm, Gravitational Search Algorithm and Dynamic Cauchy Mutation for Power Loss reduction

Dr. Kanagasabai Lenin
Professor
Department of EEE
Prasad V.Potluri Siddhartha Institute of Technology,
Kanuru, Vijayawada, Andhra Pradesh -520007.
Email; gklenin@gmail.com

Abstract; In this work particle swarm optimization (PSO) algorithm has been blended with Genetic algorithm (GA), Gravitational search algorithm (GSA), and intermingled with Dynamic Cauchy mutation to solve the reactive power problem. At first PSO merged with GA (called as HGA) then PSO blended with GSA (called as HPG) and PSO intermingle with Dynamic Cauchy mutation (called as HPC) to solve the reactive power problem. In this work to the PSO algorithm three different algorithms has been hybridized to solve the problem and the validity of the algorithms has been tested in standard IEEE 14, 57, 300 bus systems. All the three hybridization successfully solved the reactive power problem. But intermingling of the Cauchy mutation with particle swarm optimization (HPC) has the slighter edge over the other two combined algorithms in reduction of real power loss.

Key words; optimal reactive power, Transmission loss, particle swarm optimization, genetic algorithm, Gravitational search algorithm, Cauchy mutation

I. INTRODUCTION

Reactive power problem plays a key role in secure and economic operations of power system. Optimal reactive power problem has been solved by a various types of methods [1-8]. Nevertheless numerous scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [9-19] are applied to solve the reactive power problem. In this work particle swarm optimization (PSO) algorithm has been blended with Genetic algorithm (GA), Gravitational search algorithm (GSA), and intermingled with Cauchy mutation to solve the reactive power problem. At first PSO merged with GA and it arbitrarily generate population with stochastic acceleration of particle towards most excellent particle of the swarm (called as HGA). Then PSO blend with GSA where the functionality of both algorithms is combined (called as HPG). Both algorithms run in parallel and heterogeneous. Then PSO intermingled with Dynamic Cauchy mutation (called as HPC), many time PSO unable to come out of local solution and to reach the global solution Dynamic Cauchy mutation is incorporated into PSO algorithm. Particularly Dynamic Cauchy mutation could make a particle have a long jump. In this work to the PSO algorithm three different algorithms has been hybridized to solve the problem and the validity of the algorithms has been tested in standard IEEE 14, 57, 300 bus systems. All the three hybridization successfully solved the reactive power problem. But intermingling of PSO with the Cauchy mutation (HPC) has the slighter edge over the other two projected algorithms in reducing the real power loss. .

II. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss:

$$\mathbf{F = P_L = \sum_{k\in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right)} \qquad (1)$$

Voltage deviation given as follows:

$$\mathbf{F = P_L + \omega_v \times Voltage\ Deviation} \qquad (2)$$

Voltage deviation given by:

$$\mathbf{Voltage\ Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \qquad (3)$$

Constraint (Equality)

$$\mathbf{P_G = P_D + P_L} \qquad (4)$$

Constraints (Inequality)

$$\mathbf{P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max}} \qquad (5)$$

$$\mathbf{Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g} \qquad (6)$$

$$\mathbf{V_i^{min} \leq V_i \leq V_i^{max}, i \in N} \qquad (7)$$

$$\mathbf{T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T} \qquad (8)$$

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \qquad (9)$$

III. HYBRIDIZATION OF PARTICLE SWARM OPTIMIZATION WITH GENETIC ALGORITHM

Particle swarm optimization (PSO) is based on social interaction of as bird flocking [20]. It uses a number of particles in the explore space to find most excellent solution. But in their alleyway always look for the most excellent solution. PSO scientifically model as follows:

$$v_i^{t+1} = wv_i^t + c_1 \times rand \times (pbest_i - x_i^t) + c_2 \times rand \times (gbest - x_i^t) \qquad (10)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \qquad (11)$$

Genetic algorithm (GA) is a well-known and frequently used evolutionary computation [21] technique. GA is stimulated by the principles of genetics and evolution, and imitates the reproduction behavior observed in biological populations.

Both the properties of PSO and GA has been combined to improve the quality of the solution

$$C_1r_1 + C_2r_2 > 0 \qquad (12)$$

$$\frac{C_1r_1+C_2r_2}{2} - \omega < 0.98 \qquad (13)$$

$$\omega < 1 \qquad (14)$$

Knowing that $r_1, r_2 \in [0,1]$, then

$$0 < C_1 + C_2 < 3.96 \qquad (15)$$

$$\frac{c_1+c_2}{2} - 1 < \omega < 1 \qquad (16)$$

Then,

$$\omega^{t+1} = K_W \omega^t \qquad (17)$$

Mutation probability (P_{mi}) is allocated

$$P_{mi} = 0.49\ x \left[\frac{F_{maximum} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i \geq F_{average} \qquad (18)$$

$$P_{mi} = \left[\frac{F_{average} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i < F_{average} \qquad (19)$$

$$x_i^{(1,t+1)} = x_i^{(1,t)} + (r_i - 0.49)\Delta_i \qquad (20)$$

$$\Delta_i = 0.5\, x\, (\max(x_i) - \min(x_i)) \qquad (21)$$

$$\Delta_i = (0.025 \sim 0.075)\, x\, ave\, (x_i) \qquad (22)$$

a. At first Initialization of population are done, and then allotting positions and velocities of particles.
b. pbest with most excellent value is put as gbest
c. For every particle fitness function is computed.
d. Predictable fitness value of every particle is evaluated with its pbest value.
e. Subsequently function value is computed
f. Subsequently, the velocity and location of the particle is modernized according to Equations (10) and (11).
g. Computation is clogged when the greatest number of iteration reached or else loop to step c until convergence.
h. Population size of M particles are combined to form new-fangled pop size particles.
i. Generation = generation + 1, then step c is carried out.
j. Best solution is output.

IV. HYBRIDIZATION OF PARTICLE SWARM OPTIMIZATION WITH GRAVITATIONAL SEARCH ALGORITHM

Gravitational Search Algorithm (GSA) is inspired from is the Newton's theory [22] and GSA was mathematically modeled as follows. Arbitrarily placing all agents in exploration space, algorithm initiated;

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t)\times M_{aj}(t)}{R_{ij}(t)+\epsilon}\left(x_j^d(t) - x_i^d(t)\right) \qquad (23)$$

$$G(t) = G_0 \times \exp(-a \times \frac{iteration}{maximum\ iteration}) \qquad (24)$$

$$F_i^d(t) = \sum_{i=1, j\neq i}^{N} random_j\, F_{ij}^d(t) \qquad (25)$$

$$ac_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \qquad (26)$$

The rapidity and location of agents are calculated as follow:

$$vl_i^d(t+1) = random_i \times vl_i^d(t) + ac_i^d(t) \qquad (27)$$

$$x_i^d(t+1) = x_i^d(t) + vl_i^d(t+1) \qquad (28)$$

a. Obtain the parameters
b. Engender preliminary population,
c. Evaluation of Fitness for the agents,
d. Modernize the values of G(t) and gbest(t),
e. Mass, gravitational constant, force, acceleration are calculated
f. Modernize agents' rapidity and location,
g. Repeat step c to step f until the end criteria is reached,
h. Stop.

V. INTERMINGLING OF PARTICLE SWARM OPTIMIZATION WITH DYNAMIC CAUCHY MUTATION

PSO intermingled with Dynamic Cauchy mutation (called as HPC), many time PSO unable to come out of local solution and to reach the global solution Dynamic Cauchy mutation is incorporated into PSO algorithm. Particularly Dynamic Cauchy mutation could make a particle have a long jump. Velocity update equation turns out to be:

$$\mathrm{V}_{\mathrm{id}}' = \omega \mathrm{V}_{\mathrm{id}} \qquad (29)$$

The fundamental idea is that, the velocity and positions of a particle are modernized according to (10) and (11), and also according to dynamic Cauchy mutation by:

$$V'_{id} = V_{id}\exp(\delta) \qquad (30)$$

$$X'_{id} = X_{id} + V'_{id}\delta_{id} \qquad (31)$$

Dynamic Cauchy mutation operator used in this work is

$$Ng_{best} = g_{best} + \alpha\,.\,\mathrm{cauchy}(\,) \qquad (32)$$

$\mathrm{cauchy}(\,)$ is an arbitrary number generated by the Cauchy distribution function with scale factor t=1, and α is a dynamic weight which is defined by,

$$\alpha = \alpha_{low} + \frac{\text{maximum number of iterations} - \text{iterations}}{\text{iterations}}\,.\,\alpha_{up} \qquad (33)$$

$$\alpha_{up} = \frac{|x_{maximum} - x_{minimum}|}{50} \qquad (34)$$

a: engender the preliminary particles by arbitrarily generating the position and velocity for each particle.
b: particle’s fitness are calculated
c: if fitness is smaller than its preceding, then update Pid .
d: if fitness is smaller than the most excellent one, then update Pgd.
e: For each particle, do
    aa). By equation (10) and (11) engender a new particle t
    bb). By equation (30) and (31) produce a new-fangled positions and velocity
    cc) evaluate t ;
f: subsequent generation is engendered
g: if the end criterion is fulfilled, then end, else go to Step c.

VI. SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed algorithms has been tested & comparison results are presented in Table 1. Real power loss has been considerably reduced & vital parameters are within the limits.

Table 1 Comparison of Real Power Loss

Control variables	ABCO [23]	IABCO [23]	HGP	HPG	HPC
V1	1.06	1.05	1.05	1.03	1.04
V2	1.03	1.05	1.04	1.03	1.02
V3	0.98	1.03	1.05	1.01	1.04
V6	1.05	1.05	1.05	1.04	1.02
V8	1.00	1.04	0.90	0.90	0.90
Q9	0.139	0.132	0.100	0.100	0.100
T56	0.979	0.960	0.900	0.900	0.900
T47	0.950	0.950	0.900	0.900	0.900

T49	1.014	1.007	1.000	1.000	1.000
Ploss (MW)	5.92892	5.50031	4.22512	4.22138	4.16864

Then **the** Performance of the projected algorithms has been validated by tested in standard IEEE 57 bus system [24]. Total active and reactive power demands in the system are 1248.23 MW and 334.16 MVAR. Generator data the system is given in Table 2. The optimum loss comparison is presented in Table 3.

Table 2. Generator Data

Generator No	Pgi minimum	Pgi maximum	Qgi minimum	Qgi maximum
1	25.00	50.00	0.00	0.00
2	15.00	90.00	-17.00	50.00
3	10.00	500.00	-10.00	60.00
4	10.00	50.00	-8.00	25.00
5	12.00	50.00	-140.00	200.00
6	10.00	360.00	-3.00	9.00
7	50.00	550.00	-50.00	155.00

Table 3. Comparison of Losses

Parameter	CLPSO [26]	DE [25]	GSA [25]	OGSA [27]	SOA [26]	QODE [25]	CSA [28]	HGP	HPG	HPC
PLOSS (MW)	24.5152	16.7857	23.4611	23.43	24.2654	15.8473	15.5149	14.1286	14.0897	13.5941

Then the performance of the proposed Algorithms has been tested in standard IEEE 300 bus system [24]. Table 4 shows the comparison of power loss.

Table 4 Comparison of Real Power Loss

Parameter	EGA [29]	EEA [29]	CSA [28]	HGP	HPG	HPC
PLOSS (MW)	646.2998	650.6027	635.8942	625.1964	624.9812	623.5864

VII. CONCLUSION

In this work particle swarm optimization (PSO) algorithm has been blended with Genetic algorithm (GA), Gravitational search algorithm (GSA), intermingled with Dynamic Cauchy mutation and productively solved the optimal reactive power problem. Through the hybridization exploration, exploitation has been improved. Validity of the projected algorithms has been tested in standard IEEE 14, 57, 300 bus systems. All the three hybridization successfully solved the reactive power problem. But intermingling of the Cauchy mutation particle swarm optimization (HPC) has the slighter edge over the other two projected algorithms in reducing the real power loss.

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