Real Power Loss Minimization by Whirlpool Optimization Algorithm

Dr. K.Lenin
Professor, Dept. of EEE, Prasad V. Potluri Siddhartha Institute of Technology,
Kanuru, Vijayawada, Andhra Pradesh, India

Abstract

In this paper, a new Whirlpool Optimization (WO) algorithm is proposed to solve the reactive power problem. The idea is generally focused on a typical whirlpool flow in nature and enthused from some dynamics that are occurred in the sense of whirlpool nature. In a few words, the algorithm is also a swarm-oriented evolutional problem solution methodology; since it comprises numerous techniques related to removal of feeble swarm members and trying to progress the solution procedure by supporting the solution space through fresh swarm members. In order to evaluate the performance of the proposed Whirlpool Optimization (WO) algorithm, it has been tested in Standard IEEE 57,118 bus systems and compared to other standard algorithms.

Keywords

Reactive power, Transmission loss, Swarm intelligence, evolutional computation, whirlpool optimization.

1. Introduction

Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1, 2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently Global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem [8-14]. In this paper, Whirlpool Optimization (WO) algorithm is proposed to solve the reactive power problem. Goal of this paper is to initiate the idea of a new artificial intelligence based optimization algorithm, which is enthused from the nature [15-16] of whirlpool. As also a bio-inspired computation algorithm, the proposal is commonly focused on a typical whirlpool flow in nature and enthused from some dynamics that are happened in the sense of whirlpool nature. From a common perception, the algorithm is also a swarm-oriented evolutional problem solution methodology; because it includes many methods related to removal of feeble swarm members and trying to perk up the solution procedure by supporting the solution space by means of fresh swarm members. The performance of Whirlpool Optimization (WO) algorithm has been evaluated in standard IEEE 57,118 bus test systems and the results analysis shows that our projected approach outperforms all approaches investigated in this paper.

2. Objective Function

Active power loss

Main aim of the reactive power dispatch problem is to reduce the active power loss in the transmission network, which can be described as:

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

Where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems.

Voltage profile improvement

For minimization of the voltage deviation in PQ buses, the objective function turns into:

$$F = PL + \omega_v \times VD \quad (2)$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Equality Constraint

The equality constraint of the Reactive power problem is represented by the power balance equation, and can be written as, where the total power generation must cover the total power demand and total power loss:

$$P_G = P_D + P_L \quad (4)$$

Where, P_G - Total Power Generation, P_D-Total Power Demand, P_L – Total Power Loss.

Inequality Constraints

Inequality constraints define the limitations in power system components and power system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators are written as follows:

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

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

Upper and lower bounds on the bus voltage magnitudes are described as follows:

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

Upper and lower bounds on the transformers tap ratios are given as follows:

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

Upper and lower bounds on the compensators reactive powers are written as follows:

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

Where N is the total number of buses, N_T is the total number of Transformers; N_c is the total number of shunt reactive compensators.

3. Whirlpool Optimization (WO) algorithm

Foremost facts concerning to usage of whirlpool behaviours for optimization approach has appeared when the following experiences in terms of communications with the nature world:

1. Whirlpool flow comes into sight in water when the plug hole is opened.
2. Whirlpool flows produced by the passageway of plane wing or by an engine of a plane.
3. Whirlpool shapes come into view in the nature; because of dissimilar environmental conditions.

After having information to form a solution methodology for optimization problems, there has been a need for employing some intelligent methods in order to have effectual solution steps based on the power of the artificial intelligence.

Step 1: Describe preliminary parameters (*N* for number of particles; initial *vorticity* (*v*) values of each particle; max. and min. limits (min. limit is the negative of the max. one) for vorticity value (*max_v* and *min_v*) and other values associated to problem; and finally *e* for the elimination rate.

Step 2: Establish the particles arbitrarily within the solution space and compute fitness values for each of them. Modernize the *v* value of the particle with the most excellent fitness value by using an arbitrary value as equation below. Spot this particle as a 'whirlpool' and keep its values as the finest one so far.

the_best_particle_at_first_v_(new) = the_best_particle_at_first_v_(current) + (arbitrary_value * the_best_particle_at_first_v_(current)) (10)

Step 3: Replicate the sub-steps below in the logic of the stop criteria:

Step 3.1: Spot each particle, whose fitness value is equal to or below the common fitness of all particles (minimization problem), as the 'whirlpool'. The other particles are in the 'normal' particle position.

Step 3.2: Modernize *v* value of each particle (*i*) by using the following equations:

$$\text{Particle}_i\text{\_v\_(new)} = \text{particle}_i\text{\_v\_(current)} + (\text{arbitrary\_value} * (\text{global\_best\_v} / \text{particle}_i\text{\_v\_(current)})) \qquad (11)$$

Step 3.3: Update the *v* value of each whirlpool particle (except from the best particle so far) by using an arbitrary value by equation below,

$$\text{Particle}_i\text{\_v\_(new)} = \text{arbitrary\_value} * \text{particle}_i\text{\_v\_(current)} \qquad (12)$$

Step 3.4: Modernize position of each particle (excluding from the best particle so far) by using the following equation:

$$\text{particle}_i\text{\_position\_(new)} = \text{particle}_i\text{\_position\_(current)} + (\text{arbitrary\_value} * (\text{particle}_i\text{\_v\_(current)} * (\text{global\_best\_position} - \text{particle}_i\text{\_position\_(current)}))) \qquad (13)$$

Step 3.5: compute fitness values according to fresh positions of each particle. Spot the particle with the best value as a 'whirlpool' (if it is not a whirlpool yet) and keep its values as the finest so far.

Step 3.6: If number of non-whirlpool particles is equal to or under the value of e, remove all non-particles from the solution space and produce fresh particles according to number of separated particles. Establish these new particles arbitrarily within the solution space. Return to the Step 3.1, if the stopping criterion has not been reached.

Step 4: The most excellent values obtained within the loop is the near to global optimum solution.

4. Simulation Results

At first Whirlpool Optimization (WO) algorithm has been tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 1.

The preliminary conditions for the IEEE-57 bus power system are given as follows:

P_{load} = 12.104 p.u. Q_{load} = 3.052 p.u.

The total initial generations and power losses are obtained as follows:

$\sum P_G$ = 12.434 p.u. $\sum Q_G$ = 3.3158 p.u.

P_{loss} = 0.25893 p.u. Q_{loss} = -1.2071 p.u.

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed methods with other optimization techniques. These results indicate the robustness of proposed approaches for providing better optimal solution in case of IEEE-57 bus system.

Table 1. Variable Limits

Reactive Power Generation Limits							
Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50
Voltage And Tap Setting Limits							
vgmin	**Vgmax**	**vpqmin**	**Vpqmax**	**tkmin**	**tkmax**		
0.9	1.0	0.91	1.05	0.9	1.0		
Shunt Capacitor Limits							
Bus no	18	25	53				
Qcmin	0	0	0				
Qcmax	10	5.2	6.1				

Table 2. Control variables obtained after optimization

Control Variables	**WO**
V1	1.1
V2	1.039
V3	1.038
V6	1.029
V8	1.020
V9	1.009
V12	1.018
Qc18	0.0664
Qc25	0.200
Qc53	0.0474
T4-18	1.009
T21-20	1.047
T24-25	0.868
T24-26	0.876
T7-29	1.050
T34-32	0.870
T11-41	1.014
T15-45	1.030
T14-46	0.910

T10-51	1.020
T13-49	1.060
T11-43	0.910
T40-56	0.900
T39-57	0.950
T9-55	0.950

Table 3. Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [17]	0.25902	0.30854	0.27858
2	CGA [17]	0.25244	0.27507	0.26293
3	AGA [17]	0.24564	0.26671	0.25127
4	PSO-w [17]	0.24270	0.26152	0.24725
5	PSO-cf [17]	0.24280	0.26032	0.24698
6	CLPSO [17]	0.24515	0.24780	0.24673
7	SPSO-07 [17]	0.24430	0.25457	0.24752
8	L-DE [17]	0.27812	0.41909	0.33177
9	L-SACP-DE [17]	0.27915	0.36978	0.31032
10	L-SaDE [17]	0.24267	0.24391	0.24311
11	SOA [17]	0.24265	0.24280	0.24270
12	LM [18]	0.2484	0.2922	0.2641
13	MBEP1 [18]	0.2474	0.2848	0.2643
14	MBEP2 [18]	0.2482	0.283	0.2592
15	BES100 [18]	0.2438	0.263	0.2541
16	BES200 [18]	0.3417	0.2486	0.2443
17	Proposed WO	0.22044	0.23008	0.22298

Then Whirlpool Optimization (WO) algorithm has been tested in standard IEEE 118-bus test system [19].The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 - 1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 4, with the change in step of 0.01.

Table 4. Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 5 and the results clearly show the better performance of proposed Whirlpool Optimization (WO) algorithm in reducing the real power loss.

Table 5. Comparison results

Active power loss (MW)	BBO [20]	ILSBBO/ strategy1 [20]	ILSBBO/ strategy1 [20]	Proposed WO
Min	128.77	126.98	124.78	116.95
Max	132.64	137.34	132.39	120.02
Average	130.21	130.37	129.22	117.92

5. Conclusion

In this paper Whirlpool Optimization (WO) algorithm has been used to solve reactive power dispatch problem. The idea is generally focused on a typical whirlpool flow in nature and enthused from some dynamics that are occurred in the sense of whirlpool nature. The effectiveness of the proposed Whirlpool Optimization (WO) algorithm has been demonstrated by testing it in standard IEEE 57,118 bus systems and simuation results expose about the decrease of real power loss when compared with other standard algorithms and mainly volatge profiles are within the limits .

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