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Improved Oniscus Granulatus Algorithm for solving optimal reactive power problem

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ABSTRACT

In this paper, an Improved Oniscus Granulatus Algorithm (IOSA) is proposed to solve optimal reactive power problem. The behaviour of Oniscus Granulatus has been imitated to formulate the proposed algorithm. Exploration & Exploitation has been amplified in proposed Improved Oniscus Granulatus Algorithm (IOSA). IOSA has been tested on standard IEEE 30 bus test system and simulation results show clearly the good performance of the proposed algorithm in reducing the real power loss and voltage variables are within the limits.

1. INTRODUCTION

Main objective of optimal reactive power problem is to minimize the real power loss and bus voltage deviation. Different conventional techniques [1-8] have been already implemented to solve the optimal reactive power problem. Due to the difficulty in managing inequality constraints many algorithm fail to reach the global solution. Recently many types of Evolutionary algorithms have been used to solve optimal reactive power flow problem [9-11], & some algorithms good in exploration & some better in exploitation alone. Proposed algorithm equally balances the exploration & exploitation in the search of global solution in optimal reactive power problem. In this paper, an Improved Oniscus Granulatus Algorithm (IOSA) is proposed for solving optimal reactive power problem. IOSA is inspired by the behaviour of Oniscus Granulatus. In standard IEEE 30 bus test system proposed Improved Oniscus Granulatus Algorithm (IOSA) has been tested and simulation results show the excellent performance of the IOSA in reducing the real power loss and voltage variables are within the specified limits.

2. PROBLEM FORMULATION

2.1 Active power loss

Key objective is to minimize the active power loss in the transmission network & described as,

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

where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems. P_d: is the total active power demand, P_{gi}: is the generator active power of unit i, and P_{gsalck}: is the generator active power of slack bus.

2.2 Voltage profile improvement

In order to minimize the voltage deviation, the above equation is rewritten as,

$$F = PL + \omega_v \times VD \tag{2}$$

where ω_v: is a weighting factor of voltage deviation.
Voltage deviation (VD) is calculated by,

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \tag{3}$$

2.3 Equality constraint

In equality constraint Power balance equation represented by,

$$P_G = P_D + P_L \tag{4}$$

2.4 Inequality constraints

Limits on components (slack bus, and reactive power of generators) in power system are given by the inequality constraints.

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \tag{5}$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \tag{6}$$

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \tag{7}$$

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \tag{8}$$

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \tag{9}$$

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 [22].

3. ONISCUS GRANULATUS ALGORITHM

Oniscus Granulatus algorithm (OGA) is inspired by the behaviour of Oniscus Granulatus & it is a species of woodlice [21]. Normally Oniscus Granulatus live in groups, seen in moist, dark & cool places. But they can also survive in extremely harsh environment. When they sense by sensory receptors in the body about the surroundings conditions if it is not favourable for their living then they will move on to find a good place for their living.

The most important formula of the OGA approach is given by,

$$y_i^{k+1} = y_i^k - (1-\lambda)\left(y_k^i - arg \min_{y_i^k}\{f(y_j^k)\}\right) + \lambda Q\tau \quad (10)$$

where λ ∈ (0, 1), τ is a vector & each element being an arbitrary number.

Where Q is defined as,

$$Q = \frac{f(y_i^k+\tau) - min(f(y_i^k+\tau))}{max(f(y_i^k+\tau)) - min(f(y_i^k+\tau))}$$

Objective function f(y), y = [y1, y2... yd]^T

Generate initial position of Oniscus Granulatus y_i^0 (i = 1, 2,…, N)

Surrounding condition S_y at position y is determined by f(y)

For decision based on aggregation set weighted parameter λ

F* has been initialized to an exceptionally large value

Each element of vector y* ∈ Rd has been initialized to an arbitrary value

While k < Maximum; step do

With the best surrounding condition, position will be obtained i.e., y_b = arg $\min_{y_i^k}\{f(y_j^k)\}$ at the existing time in the midst of the group of Oniscus Granulatus

If $\min_{y_i^k}\{f(y_j^k)\}$< F* then

y* = y_b

F* = $\min_{y_i^k}\{f(y_j^k)\}$ end if

Direction has been chosen arbitrarily τ = [τ1, τ2,…, τd]^T to identify.

Spot the most excellent surrounding condition min {Sy} & most awful surrounding condition max{Sy} at position y_i^k+ τ for i = 1: N all N Oniscus Granulatus ; for i = 1: N all N Oniscus Granulatus do

With respect to the position decide the difference as collective i.e., y_i^k− arg $\min_{y_i^k}\{f(y_j^k)\}$

Exploration has to be identified (pτ) & it has to be shift to a new-fangled position

Output y* and the analogous function value F*

4. IMPROVED ONISCUS GRANULATUS ALGORITHM

In the improved Oniscus Granulatus Algorithm $og_j(y) \le 0$ (j = 1, 2, · , m) is introduced into the function. Penalty methodology has been utilized, and a new-fangled function will be acquired as below,

$$\breve{f}(y) = f(y) + \gamma \textstyle\sum_{i=1}^{m} og_i^2(y) h(og_i(y)) \quad (11)$$

where $h(og_i(y))$ is defined as,

$$h(og_i(y)) = \begin{cases} 1, & if\, og_i(y) > 0 \\ 0, & if\, 0g_i(y) \le 0 \end{cases}$$, γ ≫ 1 is penalty parameter.

The expression $\gamma \sum_{i=1}^{m} og_i^2(y) h(og_i(y))$ takes a foremost role in the function. When $og_i(y) \le 0$ (i = 1, 2,..., m) is fulfilled, then $h(og_i(y)) = 0$, ∀i, thus $\breve{f}(y) = f(y)$.

$l_j \le y_j \le u_j$ with j = 1, 2, · , d, for simple bounds are hold by two system. The preliminary position of each Oniscus Granulatus is initially set, to convince the simple bounds, by the following equation:

$$y_{i,j}^0 = l_j + (u_j - l_j) \times random\ (0,1) \quad (12)$$

where $y_{i,j}^0$ denote the preliminary value of the jth variable of the position vector of the ith (i = 1, 2,..., N) Oniscus Granulatus; random (0, 1) indicate an arbitrary number in the region (0, 1).

The customized evolution rule is projected as follows:

$$y_i^{k+1} = Q_\Omega\left(y_i^k - (1-\lambda)\left(y_k^i - arg \min_{y_i^k}\{f(y_j^k)\}\right) + \lambda Q\tau\right) \quad (13)$$

Algorithm for the assessment of QΩ(y) with y = [$y_1, y_2,..., y_d$]^T

For i = 1: d do

If $y_1 < l_i$ then

$y_i = l_i$

End if

If $y_i > u_i$ then

$y_i = u_i$

End if

End for

Return y = [$y_1, y_2,…, y_d$]^T

Improved Oniscus Granulatus Algorithm (IPSA) for solving reactive power problem

Cost function f(y), y = [y1, y2,... yd]^T

Generate initial position of Oniscus Granulatus y_i^0 (i = 1, 2,…, N)

Surrounding condition S_y at position y is determined by f(y)

For decision based on aggregation set weighted parameter λ

F* has been initialized to an exceptionally large value

Each element of vector y* ∈ Rd has been initialized to an arbitrary value

While k < Maximum step do

With the best surrounding condition, position will be obtained i.e., y_b = arg $\min_{y_i^k}\{f(y_j^k)\}$ at the existing time in the midst of the group of Oniscus Granulatus

If $\min_{y_i^k}\{f(y_j^k)\}$< F* then

y* = y_b

F* = $\min_{y_i^k}\{f(y_j^k)\}$ end if

Direction has been chosen arbitrarily τ = [τ1, τ2,…, τd]^T to identify.

Identify the most excellent surrounding condition min {Sy} & most awful surrounding condition max{Sy} at position y_i^k+ τ for i = 1 : N all N Oniscus Granulatus ; for i = 1: N all N Oniscus Granulatus do

With respect to the position decide the difference as collective i.e., y_i^k− arg $\min_{y_i^k}\{f(y_j^k)\}$

Exploration has to be identified (pτ) & shift to a new-fangled position

Shift to a new-fangled position & where $Q\Omega(y)$ has to be evaluated
End for
End while
Output y^* and the analogous function value F^*

5. SIMULATION RESULTS

Validity of proposed Improved Oniscus Granulatus Algorithm (IOSA) has been verified by testing it in standard IEEE 30-bus, which has 41 branches, 6 generator-buses, 4 transformer-tap settings, 2shunt reactive compensators. Bus 1 is considered as slack bus. 2, 5, 8, 11 and 13 are taken as PV buses & remaining as PQ buses. Control variables limits are given in Table 1.

Table 1. Key variable limits (Pu)

List of Variables	Minimum	Maximum	Type
Generator Bus	0.950	1.10	Continuous
Load Bus	0.950	1.050	Continuous
Transformer-Tap	0.90	1.10	Discrete
Shunt Reactive Compensator	-0.110	0.310	Discrete

In Table 2 Generators power limits are listed.

Table 2. Generators power limits

Bus	Pg	Pgminimum	Pgmaximum	Qgminimum	Qgmaximum
1	96.000	49.000	200.000	0.000	10.000
2	79.000	18.000	79.000	-40.000	50.000
5	49.000	14.000	49.000	-40.000	40.000
8	21.000	11.000	31.000	-10.000	40.000
11	21.000	11.000	28.000	-6.000	24.000
13	21.000	11.000	39.000	-6.000	24.000

Table 3. Control variables values after optimization

List of Control Variables	IOSA
V1	1.041900
V2	1.041000
V5	1.020600
V8	1.031000
V11	1.070400
V13	1.050000
T4,12	0.0000
T6,9	0.0000
T6,10	0.9000
T28,27	0.9000
Q10	0.1000
Q24	0.1000
Real power loss (MW)	4.2348
Voltage deviation	0.9089

Table 4. Narration of projected IOSA algorithm

No. of Iterations	28
Time taken	7.74
Real power loss (MW)	4.2348

Table 5. Evaluation of outcome

List of Techniques	Real power loss (MW)
SGA [23]	4.98
PSO [24]	4.9262
LP [25]	5.988
EP [25]	4.963
CGA [25]	4.980
AGA [25]	4.926
CLPSO [25]	4.7208
HSA [26]	4.7624
BB-BC [27]	4.690
MCS [28]	4.87231
Proposed IOSA	4.2348

Table 3 gives the control variables obtained after optimization.Table 4 presents the performance of the proposed IOSA. Table 5 list out the overall comparison of real power loss.

6. CONCLUSION

In this paper, an Improved Oniscus Granulatus Algorithm (IOSA) is successfully solved optimal reactive power problem. IOSA approach is inspired by the behaviour of Oniscus Granulatus. Potential of exploration & exploitation has been amplified by the Improved Oniscus Granulatus Algorithm (IOSA). Proposed IOSA has been tested on standard IEEE 30 bus test system and simulation results show clearly the good performance of the proposed algorithm in reducing the real power loss and voltage variables are within the limits.

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