Solving optimal reactive power problem by improved variable mesh optimization algorithm

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Article Info	ABSTRACT
	In this work Improved Variable Mesh Optimization Algorithm (IVM) has been applied to solve the optimal reactive power problem. Projected Improved VMO algorithm has been modeled by hybridization of Variable mesh optimization algorithm with Clearing-Based Niche Formation Technique, Differential Evolution (DE) algorithm. Mesh formation and exploration has been enhanced by the hybridization. Amongst of niche development process, clearing is a renowned method in which general denominator is the formation of steady subpopulations (niches) at all local optima (peaks) in the exploration space. In Differential Evolution (DE) population is formed by common sampling within the stipulated smallest amount and maximum bounds. Subsequently DE travel into the iteration process where the progressions like, mutation, crossover, and selection, are followed. Proposed Improved Variable Mesh Optimization Algorithm (IVM) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

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1. INTRODUCTION

Reactive power problem plays a key role in secure and economic operations of power system. Optimal reactive power problem has been solved by variety of types of methods [1-6]. Nevertheless, numerous scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7-14] are applied to solve the reactive power problem, but the main problem is many algorithms get stuck in local optimal solution & failed to balance the Exploration & Exploitation during the search of global solution. In this work Improved Variable Mesh Optimization Algorithm (IVM) has been applied to solve the optimal reactive power problem. Projected Improved VMO algorithm has been modeled by hybridization of Variable mesh optimization algorithm with Clearing-Based Niche Formation Technique, Differential Evolution (DE) algorithm. Mesh formation and exploration has been enhanced by the hybridization. Amongst of niche development process, clearing is a renowned method in which general denominator is the formation of steady subpopulations (niches) at all local optima (peaks) in the exploration space. Each niche has a leading (master) individual, i.e. the one with the most excellent fitness. In Differential Evolution (DE) population is formed by common sampling within the stipulated smallest amount and maximum bounds. Subsequent to the launch of generating the population, DE travel into the iteration process where the progressions like, mutation, crossover, and selection, are followed. Proposed Improved Variable Mesh Optimization Algorithm (IVM) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss

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

Voltage deviation given as follows

$$F = P_L + \omega_v \times \text{Voltage Deviation} \tag{2}$$

Voltage deviation given by

$$\text{Voltage Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \tag{3}$$

Constraint (Equality)

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

Constraints (Inequality)

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

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

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

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

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

3. VARIABLE MESH OPTIMIZATION

Variable mesh optimization algorithm (VMO) engendered population is scattered as a mesh. Mesh is poised of Z nodes $(m_1, m_2, .., m_z)$ that symbolize the solutions in the search space [15]. Every node is oblique as a vector of M floating point numbers $m_i = (g_1^i, g_2^i, .., g_j^i, .., g_i^M)$ which designate the solution. In exploration procedure two methodologies called development and narrowing are utilized. During the development, new-fangled nodes are created in the direction of local maximum, comprehensive end and the boundary nodes. Grounded on an elite approach, nodes are prearranged bequeath to their superiority in ascending order. Then clear out adaptive operator is then applied; every node is evaluated to its successor to eradicate those that do not outdo the threshold. Threshold value is computed by

$$\varepsilon_j = \begin{cases} \frac{range(k_j, l_j)}{4} \; if \; d < 0.149 \, \% \, D \\ \frac{range(k_j, l_j)}{8} \; if \; 0.149 \, \% \, D \leq d < 0.29\% \, D \\ \frac{range(k_j, l_j)}{16} \; if \; 0.29 \, \% \, D \leq d < 0.59\% \, D \\ \frac{range(k_j, l_j)}{50} \; if \; 0.59 \, \% \, D \leq d < 0.79\% \, d \\ \frac{range(k_j, l_j)}{100} \; if \; d \geq 0.79\% \, D \end{cases} \tag{10}$$

Maximum number of fitness assessment fixed by D and d symbolize the present number of fitness evaluation. Range (k_j, l_j) indicates the domain borders of every component. Node creation procedure at every cycle has been done.

Commence
For primary mesh randomly construct Z nodes
In primary mesh choose the global best

Replicate
For every node in primary mesh do
Discover adjoining k nodes by the spatial position
Choose the premium neighbour by fitness values
When present node is not the local most excellent then create a new-fangled node towards the local most excellent
End if
End for
For every node in primary mesh however the global most excellent do
Create a fresh node towards the global most excellent
End for
Engender nodes from the mesh boundary nodes
According to fitness values categorize the nodes
An adaptive clearing operator splodge
Choose Z best nodes to construct the primary mesh for the successive iterations
If essential capriciously engender new-fangled nodes to form the preliminary mesh for the subsequent iteration
When end criterion is met, process will be stopped
End

4. CLEARING-BASED NICHE FORMATION TECHNIQUE

Amongst of niche development process, clearing is a renowned method in which general denominator is the formation of steady subpopulations (niches) at all local optima (peaks) in the exploration space. Each niche has a leading (master) individual, i.e. the one with the most excellent fitness [16]. To a certain niche an individual fit in when its distance to the leading (master) individual is less than a given threshold called as clearing radius. This process share the possessions of a niche among a set of winners (individuals to be profited by clearing), whereas it sets to zero then the fitness of all erstwhile individuals will be in the same niche. Those restrained by the winner are deceitfully separated from the population. Subsequently reiterate this method for a definite number of iterations, then all winners will come into view.

Start
Arrange the population Pp in decreasing order with respect to the fitness values
For $i = 0$ to S - 1
If (*Fitness* ($Pp[i]$) ≠ 0); *nbWinners* = 1
Generate a new-fangled niche, being $Pp[i]$ its master
For $j = i + 1$ **to** $S - 1$; if (*Fitness* ($Pp[j]$) ≠ 0 and *Distance* ($Pp[i]$, $Pp[j]$) <σ)
If (*nbWinners* < κ) *nbWinners* = *nbWinners* + 1
Place the individual $Pp[j]$ in the present niche
Else
Fitness ($Pp[j]$) = 0
End if
End for
End

5. DIFFERENTIAL EVOLUTION

In Differential Evolution (DE) population is formed by common sampling within the stipulated smallest amount and maximum bounds [17]. Subsequent to the launch of generating the population, DE travel into the iteration process where the progressions like, mutation, crossover, and selection are followed.

"DE/best/1"

$$D_i = Y_{best} + H(Y_{s1} - Y_{s2})$$ (11)

"DE/current-to-best/1"

$$D_i = Y_i + H(Y_{best} - Y_i) + H(Y_{s1} - Y_{s2})$$ (12)

"DE/best/2"

$$D_i = Y_{best} + H(Y_{s1} - Y_{s2}) + H(Y_{s3} - Y_{s4}) \tag{13}$$

"DE/rand/1"

$$D_i = Y_{s1} + H(Y_{s2} - Y_{s3}) \tag{14}$$

"DE/current-to-rand/1"

$$D_i = Y_i + H(Y_{s1} - Y_i) + H(Y_{s2} - Y_{s3}) \tag{15}$$

DE/rand/2"

$$D_i = Y_{r1} + H(Y_{s2} - Y_{s3}) + H(Y_{s4} - Y_{s5}) \tag{16}$$

Improved strategy of the binomial crossover described as follows

$$g_{ij} = \begin{cases} d_{i,j} \, if \, rand(0,1) \leq E_r \, or \, l = l_{rand} \\ y_{i,j} otherwise \end{cases} \tag{17}$$

$$Y_i = \begin{cases} G_i \, if \, fitness(G_i) \leq fitness(Y_i) \\ Y_i otherwise \end{cases} \tag{18}$$

Begin
Population are initialized
Calculate the primary population
For i=0 to max-iteration do
Select capricious trial vectors
Create off spring's population
Combine parent and offspring population
If an offspring is greater than its parent then exchange the parent by offspring in the succeeding generation
End if
End for
End

6. IMPROVED VARIABLE MESH OPTIMIZATION ALGORITHM

In this work Improved Variable Mesh Optimization Algorithm (IVM) has been hybridized with Clearing-Based Niche Formation Technique, DE algorithm. Mesh formation and exploration has been enhanced through the hybridization.

Commence
For primary mesh randomly construct Z nodes
In primary mesh choose the global best
Replicate
For every node in primary mesh do
Discover adjoining k nodes by the spatial position
Choose the premium neighbour by fitness values
When present node is not the local most excellent then create a new-fangled node towards the local most excellent
End if
End for
For every node in primary mesh however the global most excellent do
Create a fresh node towards the global most excellent
End for
Engender nodes from the mesh boundary nodes

Apply the clearing-based niche formation technique
For each identified niche do
Sort nodes according to their fitness values
Apply the adaptive clearing operator
End for
According to fitness values categorize the nodes
An adaptive clearing operator splodge
Choose Z best nodes to construct the primary mesh for the successive iterations
If essential capriciously engender new-fangled nodes to form the preliminary mesh for the subsequent iteration
DE call using VMO population
When end criterion is met, process will be stopped
End

7.   SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed Improved Variable Mesh Optimization Algorithm (IVM) has been tested & comparison results are presented in Table 1.

Table 1. Improved Variable Mesh optimization algorithm (IVM)

Control variables	ABCO [18]	IABCO [18]	IVM
V1	1.06	1.05	1.02
V2	1.03	1.05	1.03
V3	0.98	1.03	1.01
V6	1.05	1.05	1.00
V8	1.00	1.04	0.90
Q9	0.139	0.132	0.100
T56	0.979	0.960	0.900
T47	0.950	0.950	0.900
T49	1.014	1.007	1.000
Ploss (MW)	5.92892	5.50031	4.0986

Then IEEE 300 bus system [19] is used as test system to validate the performance of the Improved Variable Mesh Optimization Algorithm (IVM). Table 2 shows the comparison of real power loss obtained after optimization.

Table 2. Comparison of real power loss

Parameter	Method EGA [20]	Method EEA [20]	Method CSA [21]	IVM
PLOSS (MW)	646.2998	650.6027	635.8942	613.1240

8.   CONCLUSION

In this work Improved Variable Mesh Optimization Algorithm (IVM) has been successfully solved the optimal reactive power problem. Mesh formation and exploration has been enhanced by the hybridization. Amongst of niche development process, clearing is a renowned method in which general denominator is the formation of steady subpopulations (niches) at all local optima (peaks) in the exploration space. In Differential Evolution (DE) population is formed by common sampling within the stipulated smallest amount and maximum bounds. Proposed Improved Variable Mesh Optimization Algorithm (IVM) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

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