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Active Power Loss Reduction by Vortex Search Algorithm

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Abstract

In this article, Vortex Search Algorithm (VSA) has been applied to solve the optimal reactive power problem. It is one of the newly projected metaheuristic algorithms which were stimulated from the vertical flow of the stimulated fluids. By using an adaptive step-size adjustment scheme vortex pattern is modelled to do the explore behaviour in VSA. An adaptive step-size modification scheme used in the projected algorithm, the position of the produced candidate solutions is amplified at each iteration. Projected Vortex Search Algorithm has been tested in standard IEEE 14, 57, 300 bus systems and Simulations results show the better performance of the proposed Vortex Search Algorithm (VSA) in reducing the real power loss.

Keywords: ***Real power; Transmission loss; Vortex search.***

1. Introduction

Reactive power optimization problem plays main role in secure and economic operation of the power system. Many conventional methods [1-8] used already for solving the problem. Various drawbacks have been found in the conventional methods and mainly difficulty in handling the inequality constraints. Last two decades many evolutionary algorithms [9-20] have been applied to solve the problem [30-31]. In this work Vortex Search Algorithm (VSA) has been applied for reducing power loss. In order to achieve the better solution its necessary to maintain the balance between exploration and exploitation. It is one of the newly projected metaheuristic algorithms which were stimulated from vertical flow of the stimulated fluids. By using an adaptive step-size adjustment scheme vortex pattern is modelled to do the explore behaviour in VSA. A superior balance between the exploration and exploitation has been maintained. Through number of nested circles vortex pattern is modelled. An adaptive step-size modification scheme used in the projected algorithm, the position of the produced candidate solutions is amplified at every iteration. Candidate solutions are engendered around dissimilar points at each iteration. These points are iteratively updated during the search process. Projected Vortex Search Algorithm has been tested in standard IEEE 14, 57, 300 bus systems and simulations results show the better performance of the proposed Vortex Search Algorithm (VSA) algorithm in reducing the real power loss.

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2. Problem Formulation

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

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

Voltage deviation given as follows:

$$\mathrm{F} = \mathrm{P_L} + \omega_{\mathrm{v}} \times \text{Voltage Deviation} \quad (2)$$

Voltage deviation given by:

$$\text{Voltage Deviation} = \sum_{\mathrm{i}=1}^{\mathrm{Npq}} |\mathrm{V_i} - 1| \quad (3)$$

Constraint (Equality)

$$\mathrm{P_G} = \mathrm{P_D} + \mathrm{P_L} \quad (4)$$

Constraints (Inequality)

$$\mathrm{P_{gslack}^{min}} \le \mathrm{P_{gslack}} \le \mathrm{P_{gslack}^{max}} \quad (5)$$

$$\mathrm{Q_{gi}^{min}} \le \mathrm{Q_{gi}} \le \mathrm{Q_{gi}^{max}}, \mathrm{i} \in \mathrm{N_g} \quad (6)$$

$$\mathrm{V_i^{min}} \le \mathrm{V_i} \le \mathrm{V_i^{max}}, \mathrm{i} \in \mathrm{N} \quad (7)$$

$$\mathrm{T_i^{min}} \le \mathrm{T_i} \le \mathrm{T_i^{max}}, \mathrm{i} \in \mathrm{N_T} \quad (8)$$

$$\mathrm{Q_c^{min}} \le \mathrm{Q_c} \le \mathrm{Q_C^{max}}, \mathrm{i} \in \mathrm{N_C} \quad (9)$$

3. Vortex Search Algorithm

Vortex Search Algorithm (VSA) is one of the newly projected metaheuristic algorithms which were stimulated from the vertical flow of the stimulated fluids. By using an adaptive step-size adjustment scheme vortex pattern is modelled to do the explore behaviour in VSA. A superior balance between the exploration and exploitation has been maintained [21, 22]. Through number of nested circles vortex pattern is modelled. In the search space largest circle is centered at first

$$\mu_o = \frac{upperlimit + lowerlimit}{2} \quad (10)$$

Numbers of neighbour solutions is indicated as Ct (s) and are arbitrarily engendered in the region of the preliminary center μ0 by using a Gaussian distribution in the d -dimensional space. $C_o(s) = \{s_1, s_2, .., s_k\}$ Where k = 1, 2 ,...,n ; it represent a solution and n symbolize the total number of candidate solutions. The common form of the multivariate Gaussian distribution is specified as follows,

$$P(x|\mu, \Sigma) = \frac{1}{\sqrt{(2\pi)^d |\Sigma|}} exp\left\{-\frac{1}{2}(x-\mu)^T \Sigma^{-1}(x-\mu)\right\} \quad (11)$$

Value of S can be calculated by using zero covariance along with equal variances by,

$$\Sigma = \sigma^2 . [I]_{dxd} \quad (12)$$

Preliminary standard deviation σ_o of the distribution is computed by

$$\sigma_o = \frac{maximum(upperlimit) - minimum(lower\ limit)}{2} \quad (13)$$

The solutions which going beyond the boundary is brought back by following equation,

$$S_k^i = \begin{cases} random(upperlimit^i - lowerlimit^i) + lowerlimit^i, S_k^i < lowerlimit^i \\ S_k^i \, , lowerlimit^i \leq S_k^i \ \leq upperlimit^i \\ random(upperlimit^i - lowerlimit^i) + lowerlimit^i, S_k^i > upperlimit^i \end{cases} \quad (14)$$

Gamma function t commonly arises in probability theory, and particularly in those applications involving the chi-square distribution given by,

$$\gamma(x, a) = \int_o^x e^{-t} \, t^{a-1} \ dt \ \ a > o \quad (15)$$

Preliminary radius r0 can be computed by,

$$r_o = \sigma_o . \left(\frac{1}{x}\right) . gammaincinv(x, a_o) \quad (16)$$

Common equation to obtain the value of the radius at each iteration as follows,

$$r_1 = \sigma_o . \left(\frac{1}{x}\right) . gammaincinv(x, a_1) \quad (17)$$

Every iteration, a value of "a" is calculated by the following,

$$a_t = a_o - \frac{1}{maximum\ iteration} \quad (18)$$

Preliminary centre μ_0 is computed

Preliminary radius r_0 is computed by utilizing equation (16)

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$f(S_{best})$ Most excellent solution fitness value has to be found
t=0
Engender the candidate solution by using the Gaussian distribution
Engender $C_t(s)$
If the boundaries are crossed then bring back the values by using equation (14)
Choose the best solution from $C_t(s)$ to replace the current centre $\mu_t$
$s' = choose\ C_t(s)$ ; if $f(s') < f(S_{best})$then $S_{best} = s'; f(s') = f(S_{best})$
Else
Keep the best solution so far
End
Center is shifted to the excellent solution found so far
$\mu_{t+1} = S_{best}$
Reduce the radius value in subsequent iterations
$r_{(t+1)} = Reduce\ r_t$
t=t+1
When maximum number of iterations reached output the most excellent solution
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4. Simulation study

At first in standard IEEE 14 bus system the validity of the proposed algorithm has been tested and comparison results are presented in Table 1. Comparison of loss shown in Figs 1 to 3. Real power loss has been considerably reduced and vital parameters are within the limits.

Table 1: Comparison of Real Power Loss.

Control variables	**ABCO [23]**	**IABCO [23]**	**VSA**
V1	1.06	1.05	1.02
V2	1.03	1.05	1.00
V3	0.98	1.03	1.00
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	4.10016

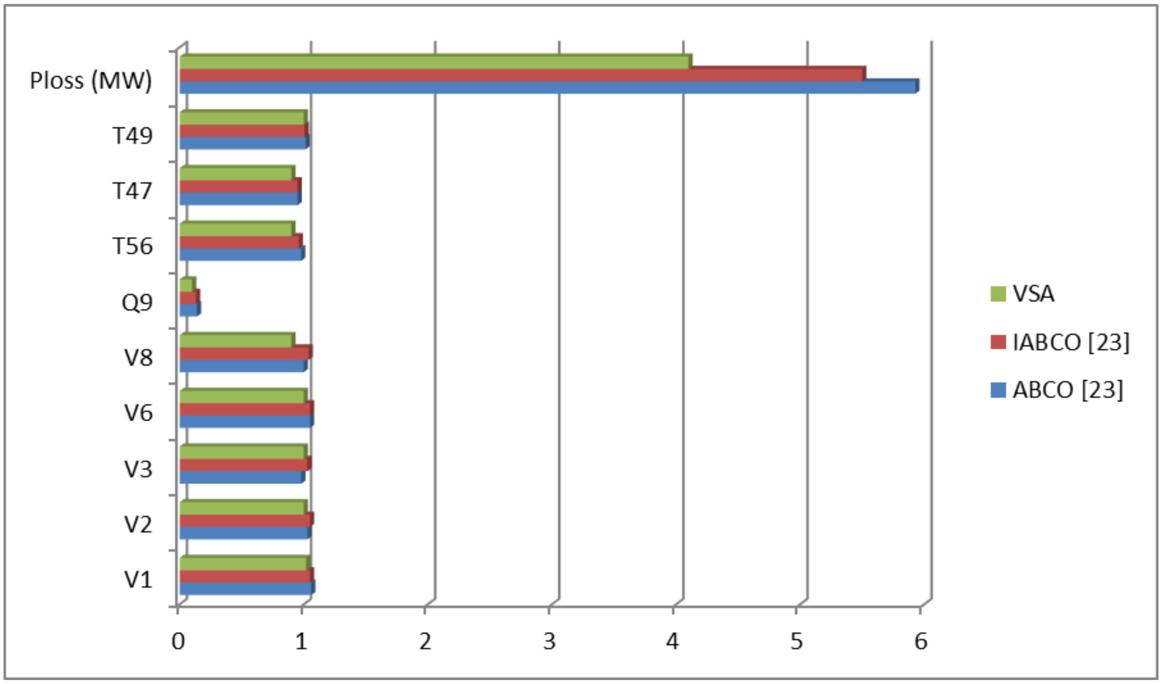

Figure 1: Comparison of parameters

Then the Performance of the projected algorithm 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]	VSA
PLOSS (MW)	24.5152	16.7857	23.4611	23.43	24.2654	15.8473	15.5149	12.1992

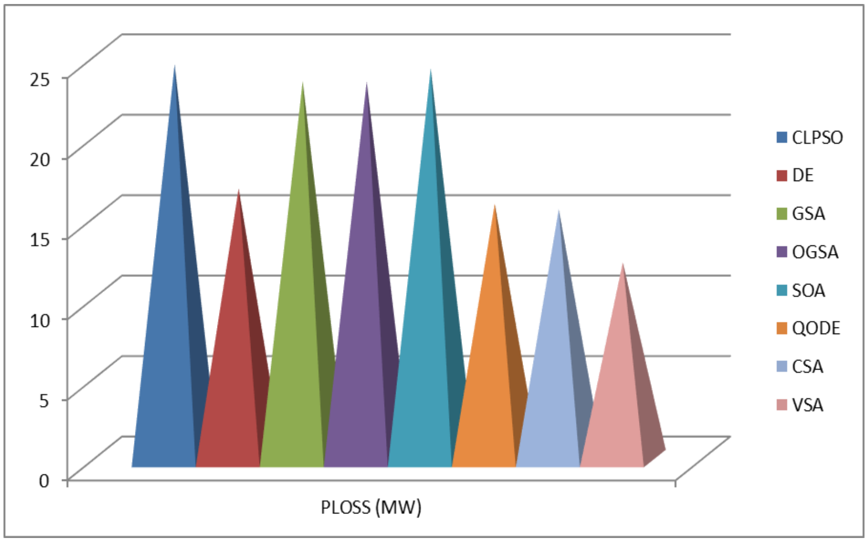

Figure 2: Comparison of loss

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

5. Simulation Results

At first in standard IEEE 14 bus system [19] the validity of the proposed Moth Search Algorithm (MSA) and Intermingled algorithm (IA) has been tested, Table 1 shows the constraints of control variables. Table 2 shows the limits of reactive power generators and comparison results are presented in Table 4.

Table 4: Comparison of Real Power Loss.

Parameter	EGA [29]	EEA [29]	CSA [28]	VSA
PLOSS (MW)	646.2998	650.6027	635.8942	622.9872

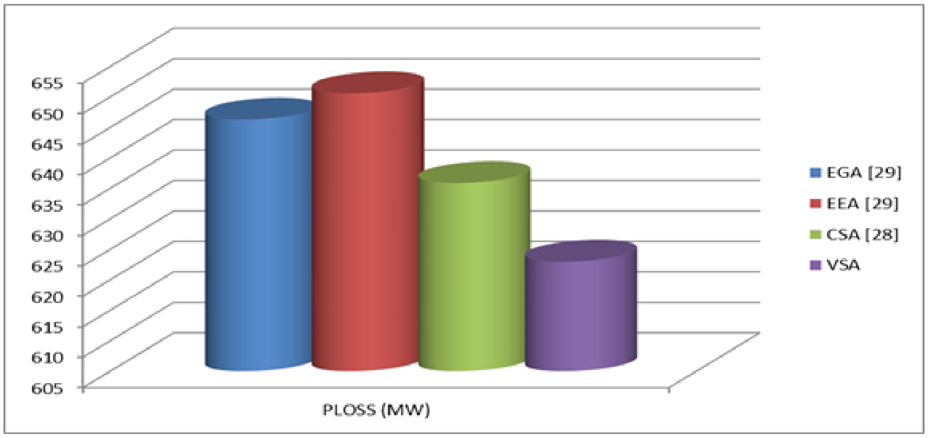

Figure 3: Loss comparison

6. Conclusion

In this article Vortex Search Algorithm (VSA) has been successfully solved the optimal reactive power problem. Mainly an adaptive step-size modification scheme vortex pattern is modelled to do the explore behaviour. In the search both the exploration and exploitation has been improved. Projected Vortex Search Algorithm has been tested in standard IEEE 14, 57, 300 bus systems and simulations results show the better performance of the proposed Vortex Search Algorithm in reducing the real power loss.

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Author Biography

Kanagasabai Lenin received the B.E. degree in electrical and electronics engineering from the University of Madras, the M.E. degree in power systems from Annamalai University and receive the PhD in electrical engineering from the Jawaharlal Nehru Technological University, Hyderabad, India. He is currently working as a Professor in Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, Andhra Pradesh, India. He has published more than 300 international journal research papers.

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