True power loss reduction by augmented mine blast algorithm

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ABSTRACT

In this paper, Mine Blast Algorithm (MBA) has been intermingled with Harmony Search (HS) algorithm for solving optimal reactive power dispatch problem. MBA is based on explosion of landmines and HS is based on Creativeness progression of musicians–both are hybridized to solve the problem. In MBA Initial distance of shrapnel pieces are reduced gradually to allow the mine bombs search the probable global minimum location in order to amplify the global explore capability. Harmony search (HS) imitates the music creativity process where the musicians supervise their instruments’ pitch by searching for a best state of harmony. Hybridization of Mine Blast Algorithm with Harmony Search algorithm (MH) improves the search effectively in the solution space. Mine blast algorithm improves the exploration and harmony search algorithm augments the exploitation. At first the proposed algorithm starts with exploration & gradually it moves to the phase of exploitation. Proposed Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) has been tested on standard IEEE 14, 300 bus test systems. Real power loss has been reduced considerably by the proposed algorithm. Then Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) tested in IEEE 30, bus system (with considering voltage stability index)– real power loss minimization, voltage deviation minimization, and voltage stability index enhancement has been attained.

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1. INTRODUCTION

In this work the key objective is Actual power loss reduction. Optimal reactive power problem has been solved by a variety of methods [1–6]. However, many technical hitches are found while solving problem due to an assortment of constraints. Evolutionary techniques [7–18] are applied to solve the reactive power problem, but the key problem is some algorithms stuck in local optimal solution & failed to balance the Exploration & Exploitation during the search of global solution. In this paper, Mine Blast Algorithm (MBA) has been intermingled with Harmony Search (HS) algorithm for solving optimal reactive power dispatch problem. MBA is based on explosion of landmines and HS is based on Creativeness progression of musicians–both are hybridized to solve the problem. More first shot points are used and it will increase the initial population. It consequently increases the number of function evaluations and the existing location of a mine bomb. In order to accomplish unvarying search in the domain space the value of \( \theta \) is set by \( 360/N \), and through this amassing of individuals in a specific region of the area search can be prevented. Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) improves the search effectively in the solution
space. Mine blast algorithm improves the exploration and harmony search algorithm augments the exploitation. At first the proposed algorithm starts with exploration & gradually it moves to the phase of exploitation. Proposed Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) has been tested on standard IEEE 14,300 bus test systems. Real power loss has been reduced considerably by the proposed algorithm. Then Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) tested in IEEE 30, bus system (with considering voltage stability index) - real power loss minimization, voltage deviation minimization, and voltage stability index enhancement has been attained.

2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss

\[ F = P_L = \sum_{k\in\text{Nbr}} g_k (V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}) \]  \hspace{1cm} (1)

Voltage deviation given as follows

\[ F = P_L + \omega_v \times \text{Voltage Deviation} \]  \hspace{1cm} (2)

Voltage deviation given by:

\[ \text{Voltage Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \]  \hspace{1cm} (3)

Constraint (Equality)

\[ P_G = P_D + P_L \]  \hspace{1cm} (4)

Constraints (Inequality)

\[ P_{g\text{slack}}^{\text{min}} \leq P_{g\text{slack}} \leq P_{g\text{slack}}^{\text{max}} \]  \hspace{1cm} (5)

\[ Q_{gi}^{\text{min}} \leq Q_{gi} \leq Q_{gi}^{\text{max}}, i \in N_g \]  \hspace{1cm} (6)

\[ V_i^{\text{min}} \leq V_i \leq V_i^{\text{max}}, i \in N \]  \hspace{1cm} (7)

\[ T_i^{\text{min}} \leq T_i \leq T_i^{\text{max}}, i \in N_T \]  \hspace{1cm} (8)

\[ Q_{c}^{\text{min}} \leq Q_{c} \leq Q_{c}^{\text{max}}, i \in N_c \]  \hspace{1cm} (9)

3. MINE BLAST ALGORITHM

Examination of a mine bomb explosion is imitated to design the mine blast algorithm [19-20]. Number of shrapnel pieces (N_s) is considered as the the number of initial population (N_{pop}). First shot point value is generated by a diminutive arbitrarily generated value given as:

\[ Y_0 = LB + \text{random} \times (UB - LB) \]  \hspace{1cm} (10)

More first shot points are used and it will increase the initial population. It consequently increases the number of function evaluations and the existing location of a mine bomb given as:

\[ Y = \{Y_m\}, m = 1, 2, 3, \ldots, N_d \]  \hspace{1cm} (11)

Deliberately N_s shrapnel pieces are created by the mine bomb explosion is the source for another mine to blow up at Y_{n+1} position,

\[ Y_{n+1}^{f} = Y_{e(n+1)}^{f} + \exp \left( -\frac{m_{n+1}}{d_{n+1}^{f}} \right) Y_{n}^{f}/n = 0,1,2,3, \ldots \]  \hspace{1cm} (12)
Exploding mine bomb location $Y_f(n+1)$ is defined as:

$$Y_f(n+1) = d_f n \times \text{random} \times \cos(\theta), n = 0,1,2,..$$ (13)

In order to accomplish unvarying search in the domain space the value of $\theta$ is set by $360/N$, and through this amassing of individuals in a specific region of the area search can be prevented.

Direction of shrapnel pieces $m_f(n+1)$ and distance $d_f(n+1)$ are defined as:

$$d_f(n+1) = \sqrt{(Y_f(n+1) - Y_f(n))^2 + (F_f(n+1) - F_f(n))^2}, n = 0,1,2,..$$ (14)

$$m_f(n+1) = \frac{m_f(n) + m_f(n+1)}{2}, n = 0,1,2,..$$ (15)

In the solution space exploration is done by:

$$d_f = d_f \times (\text{random})^2, n = 0,1,2,..$$ (16)

$$Y_f(n+1) = d_f \times \cos(\theta), n = 0,1,2,..$$ (17)

Initial distance of shrapnel pieces are reduced gradually to allow the mine bombs search the probable global minimum location in order to amplify the global explore capability of the proposed method. Reduction in $d_f$ is given as:

$$d_f = \frac{d_f(n-1)}{\text{exp}(k/a)} , n = 1,2,3,..$$ (18)

Exploration and exploitation progression is given as below:

If $\mu > k$

Exploration

$d_f(n+1) = d_f \times (\text{random})^2, n = 0,1,2,..$

$Y_f(n+1) = d_f \times \cos(\theta), n = 0,1,2,..$

Else

Exploitation

$Y_f(n+1) = d_f \times \text{random} \times \cos(\theta), n = 0,1,2,..$

$$d_f(n+1) = \sqrt{(Y_f(n+1) - Y_f(n))^2 + (F_f(n+1) - F_f(n))^2}, n = 0,1,2,..$$

$$m_f(n+1) = \frac{m_f(n) + m_f(n+1)}{2}, n = 0,1,2,..$$

$$d_f = \frac{d_f(n)}{\text{exp}(k/a)} , n = 1,2,3,..$$

End

a. Initialization of parameters
b. Condition of exploration factor ($\mu$) is checked
c. Calculate the distance of shrapnel pieces and their locations by (16) and (17) once the condition of exploration factor is satisfied if not go to Step i.
d. Direction of shrapnel pieces are calculated by (15).
e. Shrapnel pieces are produced and their improved locations are calculated by (12).
f. For engendered shrapnel pieces constraints limits are checked.
g. Best shrapnel piece is saved as the best sequential solution.
h. If function value than the best temporal solution is greater than the shrapnel piece? If true, swap the position of the shrapnel piece with the best temporal solution. If not go to Step i.
i. Distance of shrapnel pieces and their locations are calculated the using (13) and (14) and then return to Step d.
j. Distance of the shrapnel pieces are reduced by (18).
k. Verify the convergence criteria and if satisfied, the algorithm will be stopped if not return to Step b.

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4. HARMONY SEARCH ALGORITHM

Harmony search (HS) is a new-fangled population-based metaheuristic optimization algorithm [21] that imitates the music creativity process where the musicians supervise their instruments’ pitch by searching for a best state of harmony. The parameters of the HS are: In this step, the solutions are arbitrarily built and reorganize in a reversed order to HM, based on their objective function values such as

\[
\begin{bmatrix}
    f(a_1^1) & \leq f(a_2^1) & \leq \ldots & \leq f(a_{HMS}^1) \\
    f(a_1^2) & \leq f(a_2^2) & \ldots & \leq f(a_{HMS}^2) \\
    \vdots & \vdots & \ddots & \vdots \\
    f(a_1^HMS) & \leq f(a_2^HMS) & \ldots & \leq f(a_{HMS}^{HMS})
\end{bmatrix}
\]

(19)

The following equation concise the two steps i.e. memory consideration and arbitrary consideration.

\[
a_i' \left\{ \begin{array}{ll}
a_i' \in \{a_1^HMS, a_2^HMS, \ldots, a_{HMS}^HMS\} \ w.p. HMC \\
a_i' \in A_i \ w.p. (1 - HMC)
\end{array} \right.
\]

(20)

Decision variables \(a_i'\) are scrutinized and to be tuned with the probability of \(PAR \in [0, 1]\) by \(\) \(a_i'\)

\[
\left\{ \begin{array}{ll}
\text{Adjusting pitch w.p. PAR} \\
\text{Doing Nothing w.p. } (1 - PAR)
\end{array} \right.
\]

(21)

\[
(a_i') = (a_i') \pm \text{rand()} \ast \text{bw}
\]

(22)

\[a_i' \in HM \land a_{\text{worst}} \notin HM\]

(23)

The PAR value is linearly increased in iteration’s of HS by using the following equation,

\[
PAR(gn) = PAR_{\text{min}} + \frac{PAR_{\text{max}} - PAR_{\text{min}}}{NI} \times gn
\]

(24)

\[
bw(gn) = bw_{\text{min}} + \frac{bw_{\text{max}} - bw_{\text{min}}}{NI} \times gn
\]

(25)

Step a: preliminary population are arbitrarily generated and calculate the fitness of each individual;  
Step b: determine the best and the worst individuals in the existing population in HM;  
Step c: control a new-fangled harmony: first, engender a novel vector; secondly, adjust the vector through HS;  
Step d: modify harmony memory, which is same to selection.

\[
x_{i,g+1} = \begin{cases} 
    u_{i,g} \text{if } (u_{i,g} \leq f(x_{i,g})) \
    x_{i,g} \text{otherwise.}
\end{cases}
\]

(26)

Step e: authenticate the stopping criterion: \(|f(best) - f(worst)| < \varepsilon = 1 \times 10^{-16}|.

5. HYBRIDIZATION OF MINE BLAST ALGORITHM WITH HARMONY SEARCH ALGORITHM

The hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) improves the search effectively in the solution space. Mine blast algorithm improves the exploration and harmony search algorithm augments the exploitation. At first the proposed algorithm starts with exploration & gradually it moves to the phase of exploitation.

Parameters are initiated  
Initial bandwidth of each shrapnel piece will be determined  
At first Dynamic Harmony Memory will be nil and in later phases arbitrarily it will be engendered  
Objective function has been calculated for the first shot point & Best has been found
While (t < Maximum Iterations)
For i = 1: N
If t < μ; Exploration Phase is done by the MBA
Estimate the modernized position of landmines using:
\[ y_{n+1} = Y_{0(n+1)} + \exp \left( -\frac{m}{\sqrt{z_{n+1}}} \right) V_{n, n} = 0,1,2,3,.. \]
Else
% (HS is embedded in this Exploitation Phase,)
jrandom = floor(D × rand(0, 1));
End for
For j ∈ 1, ..., D do
If random(0, 1) ≤ CR or j == jrand) then
\[ u_j = x_j; r_0 + F \times (x_j; r_1 - x_j; r_2); \]
Else
\[ u_j = x_j; i; \]
End if
End for
Else
Compute the location of explode landmine by the following
\[ X_{e(n+1)} = d_{n} \times \text{rand} \times \cos(\theta), n = 0,1,2,.. \]
Estimate the Euclidean distance & compute the modernized position of shrapnel pieces
End if
End for
End if
End while

6. SIMULATION RESULTS
At first in standard IEEE 14 bus system the validity of the proposed hybridized algorithm (MH) has been tested & comparison results are presented in Table 1. Figure 1. Provide the details of Comparison of real power loss.

| Control variables | ABCO [22] | IABCO [22] | Projected MH |
|-------------------|-----------|------------|--------------|
| V1                | 1.06      | 1.05       | 1.04         |
| V2                | 1.03      | 1.05       | 1.02         |
| V3                | 0.98      | 1.03       | 1.03         |
| V6                | 1.05      | 1.05       | 1.01         |
| V8                | 1.00      | 1.04       | 0.90         |
| Q9                | 0.139     | 0.132      | 0.110        |
| T36               | 0.979     | 0.960      | 0.920        |
| T47               | 0.950     | 0.950      | 0.900        |
| T49               | 1.014     | 1.007      | 1.000        |
| Ploss (MW)        | 5.92892   | 5.50031    | 4.82426      |

True power loss reduction by augmented mine blast algorithm (Kanagasabai Lenin)
Then IEEE 300 bus system [18] is used as test system to validate the performance of the hybridized algorithm (MH). Table 2 shows the comparison of real power loss obtained after optimization. Figure 2 gives the comparison of real power values. Real power loss has been considerably reduced when compared to the other standard reported algorithms.

Then hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) has been tested in IEEE 30 bus system [25] with considering voltage stability index. It has a sum of active and reactive power consumption of 2.834 and 1.262 per unit on 100 MVA base. Table 3 gives the constraints of control variables; Table 4 gives the system parameters; then Table 5 gives the real power loss comparison. Comparison of different algorithms with reference to voltage stability improvement has been given in Table 6. Then Comparison of values with reference to Voltage Deviation Minimization has been given Table 7. Finally, Comparison of values with reference to Multi – objective formulation is given in Table 8.

![Real Power Loss](image1)

**Figure 1. Comparison of real power loss**

![Real Power Loss](image2)

**Figure 2. Real power loss comparison**

| Parameter | Method EGA [24] | Method EEA [24] | Method CSA [23] | Projected MH |
|-----------|----------------|----------------|----------------|--------------|
| PLOSS (MW) | 646.2998 | 650.6027 | 635.8942 | 618.0414 |

| Variables | Minimum (PU) | Maximum (PU) |
|-----------|--------------|--------------|
| Generator Voltage | 0.95 | 1.1 |
| Transformer Tap | 0.9 | 1.1 |
| VAR Source | 0 | 5 (MVAR) |

| Description | IEEE 30 bus |
|-------------|-------------|
| NB – number of buses | 30 |
| NG - Number of generators | 6 |
| NT - number of transformers | 4 |
| NQ - number of shunt | 9 |
| NE - Number of branches | 41 |
| PLoss (base case) MW | 5.66 |
| Base care for VD (PU) | 0.58217 |
Table 7. Comparison with reference to Voltage Deviation Minimization

|         | DE   | GSA  | APOPSO | MH   |
|---------|------|------|--------|------|
| VG1     | 1.1  | 1.071| 1.100  | 1.093|
| VG2     | 1.09 | 1.022| 1.084  | 1.040|
| VG5     | 1.07 | 1.040| 1.056  | 1.024|
| VG8     | 1.07 | 1.051| 1.076  | 1.041|
| VG11    | 1.1  | 0.977| 1.091  | 1.083|
| VG13    | 5    | 0.968| 1.100  | 0.970|
| QC 10   | 5    | 1.653| 5.000  | 4.962|
| QC 12   | 5    | 4.372| 5.000  | 5.000|
| QC 15   | 5    | 0.1199| 4.879 | 4.783|
| QC 17   | 5    | 2.087| 4.976  | 4.971|
| QC 20   | 4.41 | 0.357| 3.821  | 3.705|
| QC 21   | 5    | 0.2602| 4.541 | 4.662|
| QC 23   | 2.8004| 0.0000| 2.354 | 2.400|
| QC 24   | 5    | 1.839| 4.654  | 4.501|
| QC 29   | 2.5979| 0.0000| 2.175 | 2.160|
| T11     | 1.04 | 1.0985| 1.029 | 1.014|
| T12     | 0.9097| 0.9824| 0.911 | 0.905|
| T15     | 0.98 | 1.095| 0.952  | 0.946|
| T36     | 0.9689| 1.0593| 0.958 | 0.943|
| PLoss   | 4.555 | 4.5143| 4.398 | 4.214|
| VD (PU) | 1.9589| 0.87522| 1.047 | 1.031|
| L-index | 0.5513| 0.14109| 0.1267| 0.1202|

Table 8. Comparison of values with reference to Multi – objective formulation

|         | APOPSO | MH   |
|---------|--------|------|
| VG1     | 1.020 | 1.012|
| VG2     | 1.033 | 1.013|
| VG5     | 1.000 | 1.000|
| VG8     | 1.004 | 1.001|
| VG11    | 1.032 | 1.013|
| VG13    | 1.028 | 1.014|
| QC 10   | 0.051 | 0.035|
| QC 12   | 0.002 | 0.001|
| QC 15   | 0.044 | 0.023|
| QC 17   | 0.009 | 0.002|
| QC 20   | 0.048 | 0.021|
| QC 21   | 0.041 | 0.020|
| QC 23   | 0.033 | 0.016|
| QC 24   | 0.050 | 0.037|
| QC 29   | 0.015 | 0.018|
| T11     | 1.042 | 1.044|
| T12     | 0.909 | 0.902|
| T15     | 1.023 | 1.011|
| T36     | 0.958 | 0.925|
| PLoss   | 4.842 | 4.722|
| VD (PU) | 1.009 | 1.001|
| L-index | 0.1192| 0.1179|

True power loss reduction by augmented mine blast algorithm (Kanagasabai Lenin)
7. CONCLUSION
In this work Mine Blast Algorithm (MBA) has been intermingled with Harmony Search (HS) algorithm successfully solved the optimal reactive power dispatch problem. The hybridized algorithm (MH) improves the search effectively in the solution space. Mine blast algorithm improves the exploration and harmony search algorithm augments the exploitation. At first the proposed algorithm starts with exploration and gradually it moves to the phase of exploitation. At first the proposed algorithm starts with exploration & gradually it moves to the phase of exploitation. Proposed Hybridized algorithm (MH) has been tested on standard IEEE 14, 300 bus test systems. Real power loss has been reduced considerably by the proposed MH algorithm. Then Hybridized Mine Blast Algorithm with Harmony Search algorithm (MH) are tested in IEEE 30, bus system (with considering voltage stability index) - real power loss minimization, voltage deviation minimization, and voltage stability index enhancement has been attained.

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True power loss reduction by augmented mine blast algorithm (Kanagasabai Lenin)