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 θ is set by $360/N_s$ 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

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

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)

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

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

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

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

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

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:

$$Y_0 = LB + random \times (UB - LB) \tag{10}$$

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:

$$Y = \{Y_m\}, m = 1, 2, 3, \ldots, N_d \tag{11}$$

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

$$Y_{n+1}^f = Y_{e(n+1)}^f + exp\left(-\sqrt{\frac{m_{n+1}^f}{d_{n+1}^f}}\right) Y_n^f, n = 0,1,2,3,. \tag{12}$$

Exploding mine bomb location $Y^f_{e(n+1)}$ is defined as:

$$Y^f_{e(n+1)} = d^f_n \times random \times cos(\theta), n = 0,1,2,.. \quad (13)$$

In order to accomplish unvarying search in the domain space the value of θ is set by 360/N_s 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:

$$d^f_{n+1} = \sqrt{\left(Y^f_{n+1} - Y^f_n\right)^2 + \left(F^f_{n+1} - F^f_n\right)^2} n = 0,1,2,.. \quad (14)$$

$$m^f_{n+1} = \frac{F^f_{n+1} - F^f_n}{y^f_{n+1} - y^f_n} n = 0,1,2,... \quad (15)$$

In the solution space exploration is done by:

$$d^f_{n+1} = d^f_n \times (|random\ n|)^2 n = 0,1,2,.. \quad (16)$$

$$Y^f_{e(n+1)} = d^f_n \times cos(\theta), n = 0,1,2,.. \quad (17)$$

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_0 is given as:

$$d^f_n = \frac{d^f_{n-1}}{exp(k/\alpha)} \quad n = 1,2,3,.. \quad (18)$$

Exploration and exploitation progression is given as below:

If μ> k
Exploration
$d^f_{n+1} = d^f_n \times (|random\ n|)^2 n = 0,1,2,..$
$Y^f_{e(n+1)} = d^f_n \times cos(\theta), n = 0,1,2,..$
Else
Exploitation
$Y^f_{e(n+1)} = d^f_n \times random \times cos(\theta), n = 0,1,2,.$
$d^f_{n+1} = \sqrt{\left(Y^f_{n+1} - Y^f_n\right)^2 + \left(F^f_{n+1} - F^f_n\right)^2} n = 0,1,2,..$
$m^f_{n+1} = \frac{F^f_{n+1} - F^f_n}{y^f_{n+1} - y^f_n} n = 0,1,2,...$
$d^f_n = \frac{d^f_{n-1}}{exp(k/\alpha)} \quad n = 1,2,3,..$
End

a. Initialization of parameters
b. Condition of exploration factor (μ) 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 Stepb.

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

$$f(a^1) \leq f(a^2) \ldots\ldots \leq f(a^{HMS}) \;.\; HM = \left[\begin{array}{ccc|c} a_1^1 & \cdots & a_N^1 & f(a^1) \\ \vdots & \ddots & \vdots & . \\ a_1^{HMS} & \cdots & a_N^{HMS} & . \\ & & & f(a^{HMS}) \end{array}\right] \tag{19}$$

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

$$a_i' \leftarrow \begin{cases} a_i' \in \left\{\{a_i^1, a_i^2, \ldots\ldots.. a_i^{HMS}\right\} w.p.HMCR \\ a_i' \in A_i w.p.(1 - HMCR) \end{cases} \tag{20}$$

Decision variables (a_i') are scrutinized and to be tuned with the probability of PAR ∈ [0, 1] by (21)

$$a_i' \leftarrow \begin{cases} Adjusting\ pitch\ w.p.PAR \\ Doing\ Nothing\ w.p.(1 - PAR) \end{cases} \tag{21}$$

$$(a_i') = (a_i') \pm \text{rand}() * \text{bw} \tag{22}$$

$$a' \in HM \wedge a^{worst} \notin HM \tag{23}$$

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

$$\text{PAR(gn)}=\text{PAR}_{\min} + \frac{PAR_{max} - PAR_{min}}{NI} \text{ x } gn \tag{24}$$

$$\text{bw(gn)} = \text{bw}_{\min} + \frac{bw_{max} - bw_{min}}{NI} \text{ x } gn \tag{25}$$

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.

$$x_{i,g+1} = \begin{cases} u_{i,g} if \left(u_{i,g} \leq f(x_{i,g})\right), \\ x_{i,g} otherwise . \end{cases} \tag{26}$$

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:
```

$$y^f_{n+1} = Y^f_{e(n+1)} + \exp\left(-\sqrt{\frac{m^f_{n+1}}{d^f_{n+1}}}\right) Y^f_n, n = 0,1,2,3,..$$

```
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
uj= xj;r0 + F*(xj;r1- xj;r2);
Else
uj= xj;i;
End if
End for
Else
Compute the location of explode landmine by the following
```

$$X^f_{e(n+1)} = d^f_n \times \text{rand} \times \cos(\theta), n = 0,1,2,..$$

```
Estimate the Euclidean distance & compute the modernized position of shrapnel pieces
End if
End for
End if
```

Determine objective function of engendered shrapnel pieces and class the shrapnel pieces
Choose the most excellent shrapnel piece

```
// Harmony memory considering: arbitrarily select any variable-i pitch in HM
if (rand(0, 1) ≤ HMCR then
if (round(0, 1) ≤ PAR then
//Pitch adjusting: arbitrarily adjust uj within a small bandwidth,
±rand(0, 1) *BAND
if(round(0, 1) ≤ 0.5 then
vj= uj+ random(0, 1) *BAND
else
vj= uj- random(0, 1) *BAND
end if
end if
else
//Random playing: arbitrarily select any pitch within upper uj and lower bounds lj
vj= lj+ rand(0, 1) *(uj- lj)
End if
End for
if vjis better than the worst harmony in HM, xworst, then
Replace xworst with vj in HM, then sort HM
End if
Until (best) - f(worst)| < ε
End for
End if
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.

Table 1. Comparison results

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
T56	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

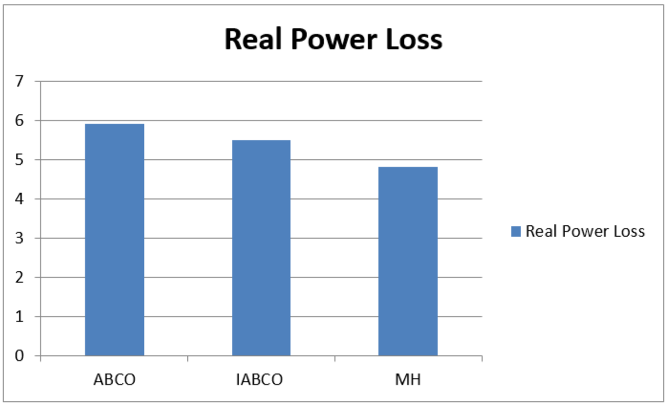

Figure 1. Comparison of real power loss

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.

Table 2. Comparison of real power loss

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

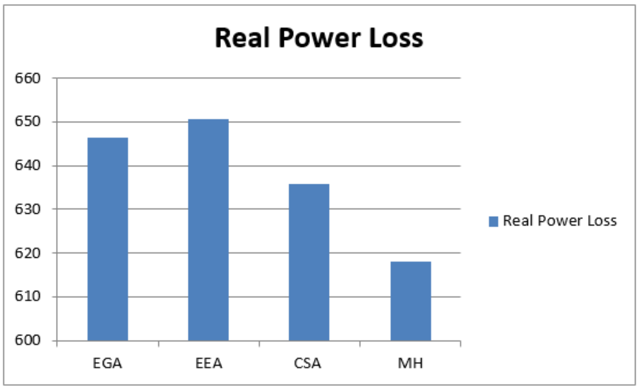

Figure 2. Real power loss comparison

Table 3. Constraints of control variables

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

Table 4. System parameters

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 5. Comparison of real power loss with different metaheuristic algorithms

	DE [26]	GSA [27]	APOPSO [28]	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	4.3722	5.000	5.000
QC 15	5	0.1199	4.879	4.783
QC 17	5	2.0876	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	1.3839	4.654	4.501
QC 29	2.5979	0.0000	2.175	2.160
T11 (6-9)	1.04	1.0985	1.029	1.014
T12 (6-10)	0.9097	0.9824	0.911	0.905
T15 (4-12)	0.98	1.095	0.952	0.946
T36 (28-27)	0.9689	1.0593	0.958	0.943
PLoss (MW)	4.555	4.5143	4.398	4.214
VD (PU)	1.9589	0.87522	1.047	1.031
L-index (PU)	0.5513	0.14109	0.1267	0.1202

Table 6. Comparison of different algorithms with reference to voltage stability improvement

	DE [26]	GSA [27]	APOPSO [28]	MH
VG1	1.01	0.983	1.011	1.024
VG2	0.99	1.044	1.001	1.012
VG5	1.02	1.020	1.014	1.013
VG8	1.02	0.999	1.009	1.014
VG11	1.01	1.077	0.954	0.935
VG13	1.03	1.044	1.000	1.003
QC 10	4.94	0	4.102	4.102
QC 12	1.0885	0.4735	2.124	2.121
QC 15	4.9985	5	4.512	4.493
QC 17	0.2393	0	0.000	0.000
QC 20	4.99	5	5.000	5.000
QC 21	4.90	0	5.000	5.000
QC 23	4.9863	4.9998	5.000	5.000
QC 24	4.9663	5	5.000	5.000
QC 29	2.2325	5	4.120	4.134
T11 (6-9)	1.02	0.9	0.998	0.976
T12 (6-10)	0.9038	1.1	0.822	0.805
T15 (4-12)	1.01	1.051	0.954	0.933
T36 (28-27)	0.9635	0.9619	0.958	0.942
PLoss (MW)	6.4755	6.9117	5.698	5.411
VD (PU)	0.0911	0.0676	0.087	0.062
L-index (PU)	0.14352	0.1349	0.1377	0.1310

Table 7. Comparison with reference to Voltage Deviation Minimization

	DE [26]	GSA [27]	APOPSO [28]	MH
VG1	1.09	1.1	1.043	1.031
VG2	1.09	1.1	1.061	1.053
VG5	1.09	1.1	1.061	1.034
VG8	1.04	1.1	1.057	1.033
VG11	1.09	1.1	1.048	1.042
VG13	0.95	1.1	1.091	1.070
QC 10	0.69	5	0.040	0.041
QC 12	4.7163	5	0.039	0.032
QC 15	4.4931	5	0.038	0.033
QC 17	4.51	5	0.040	0.030
QC 20	4.48	5	0.037	0.031
QC 21	4.60	5	0.009	0.014
QC 23	3.8806	5	0.019	0.013
QC 24	3.8806	5	0.011	0.010
QC 29	3.2541	5	0.001	0.004
T11 (6-9)	0.90	0.9	0.919	0.911
T12 (6-10)	0.9029	0.9	0.924	0.900
T15 (4-12)	0.90	0.9	0.938	0.913
T36 (28-27)	0.936	1.0195	0.924	0.915
PLoss (MW)	7.0733	4.9752	4.478	4.206
VD (PU)	1.419	0.21579	1.8579	1.8200
L-index (PU)	0.1246	0.13684	0.1227	0.1159

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

	APOPSO [28]	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 (6-9)	1.042	1.044
T12 (6-10)	0.909	0.902
T15 (4-12)	1.023	1.011
T36 (28-27)	0.958	0.925
PLoss (MW)	4.842	4.722
VD (PU)	1.009	1.001
L-index (PU)	0.1192	0.1179

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.

REFERENCES

[1] K. Y. Lee, et al, “Fuel-cost minimisation for both real and reactive-power dispatches,” *Proceedings Generation, Transmission and Distribution Conference*, vol. 131, no. 3, pp. 85-93, 1984.
[2] N. I. Deeb, et al., “An efficient technique for reactive power dispatch using a revised linear programming approach,” *Electric Power System Research*, vol. 15, no. 2, pp. 121–134, 1988.
[3] M. R. Bjelogrlic, M. S. Calovic, B. S. Babic, et. al., “Application of Newton’s optimal power flow in voltage/reactive power control”, *IEEE Trans Power Syste*m, vol. 5, no. 4, pp. 1447-1454, 1990.
[4] S. Granville, “Optimal reactive dispatch through interior point methods,” *IEEE Transactions on Power System*, vol. 9, no. 1, pp. 136–146, 1994.
[5] N. Grudinin, “Reactive power optimization using successive quadratic programming method,” *IEEE Transactions on Power System*, vol. 13, no. 4, pp. 1219–1225, 1998.
[6] Wei Yan, J. Yu, D. C. Yu and K. Bhattarai, “A new optimal reactive power flow model in rectangular form and its solution by predictor corrector primal dual interior point method”, *IEEE Trans. Pwr. Syst*., vol. 21, no. 1, pp. 61-67, 2006.
[7] Aparajita Mukherjee, Vivekananda Mukherjee, “Solution of optimal reactive power dispatch by chaotic krill herd algorithm", *IET Gener. Transm. Distrib, ,* vol. 9, no. 15, pp. 2351–2362, 2015.
[8] Mahaletchumi A/P Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman, Mahfuzah Mustafa and Rosdiyana Samad, “Computational intelligence technique for static VAR compensator (SVC) installation considering multi-contingencies (N-m)”, *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no. 22, 2015.
[9] Mohd Herwan Sulaiman, Zuriani Mustaffa, Hamdan Daniyal, Mohd Rusllim Mohamed and Omar Aliman, “Solving Optimal Reactive Power Planning Problem Utilizing Nature Inspired Computing Techniques”, *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no. 21, pp. 9779-9785. 2015.
[10] Mohd Herwan Sulaiman, Wong Lo Ing, Zuriani Mustaffa and Mohd Rusllim Mohamed, “Grey Wolf Optimizer for Solving Economic Dispatch Problem with Valve-Loading Effects”, *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no. 21, pp. 9796-9801, 2015.
[11] Pandiarajan, K. & Babulal, C. K., “Fuzzy harmony search algorithm based optimal power flow for power system security enhancement”. *International Journal Electric Power Energy Syst.*, vol. 78, pp. 72-79. 2016.
[12] Sulaiman, M.H., Mustaffa, Z., Mohamed, M.R., Aliman, O., “An application of multi-verse optimizer for optimal reactive power dispatch problems,” *International Journal of Simulation: Systems, Science and Technology*, vol. 17, vol. 41, pp. 1-5 2017.
[13] Mahaletchumi A/P Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman, Mahfuzah Mustafa and Rosdiyana Samad, “Multi-Objective Evolutionary Programming (MOEP) Using Mutation Based on Adaptive Mutation Operator (AMO) Applied for Optimal Reactive Power Dispatch,” *ARPN Journal of Engineering and Applied Sciences*, vol. 11, no. 14, 2016.
[14] Rebecca Ng Shin Mei, Mohd Herwan Sulaiman, Zuriani Mustaffa, “Ant Lion Optimizer for Optimal Reactive Power Dispatch Solution,” *Journal of Electrical Systems*, Special Issue AMPE2015, pp. 68-74, 2016.
[15] Mahaletchumi Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman, Mahfuzah Mustafa, Rosdiyana Samad, “Benchmark Studies on Optimal Reactive Power Dispatch (ORPD) Based Multi-objective Evolutionary Programming (MOEP) Using Mutation Based on Adaptive Mutation Adapter (AMO) and Polynomial Mutation Operator (PMO),” *Journal of Electrical Systems*, 12-1, 2016.
[16] Rebecca Ng Shin Mei, Mohd Herwan Sulaiman, Zuriani Mustaffa, Hamdan Daniyal, “Optimal Reactive Power Dispatch Solution by Loss Minimization using Moth-Flame Optimization Technique,” *Applied Soft Computing*, vol 59, pp. 210-222, 2017.
[17] Chandragupta Mauryan Kuppamuthu Sivalingam1, Subramanian Ramachandran, Purrnimaa Shiva Sakthi Rajamani, “Reactive power optimization in a power system network through metaheuristic algorithms,” *Turkish Journal of Electrical Engineering & Computer Science,* vol. 25, pp. 4615-4623, 2017.
[18] IEEE, “The IEEE-test systems”, (1993).
[19] A. Sadollah, A. Bahreininejad, H. Eskandar, M. Hamdi, “Mine blast algorithm foroptimization of truss structures with discrete variables,” *Computers & Structures*, vol. 102–103, pp. 49–63, 2012.

[20] Ali Sadollaha, ArdeshirBahreininejada, HadiEskandarb, Mohd Hamdia, Mine blast algorithm, "A new population-based algorithm for solving constrained engineering optimization problems," *Applied Soft Computing*, vol. 13, pp. 2592–2612, 2013.
[21] Z. W. Geem, J. H. Kim, and G. V. Loganathan, "A new heuristic optimization algorithm: Harmony search," *J. Simul.,* vol. 76, no. 2, pp. 60–68, Feb. 2001.
[22] Chandragupta Mauryan Kuppamuthu Sivalingam1, Subramanian Ramachandran, Purrnimaa Shiva Sakthi Rajamani, "Reactive power optimization in a power system network through metaheuristic algorithms," *Turkish Journal of Electrical Engineering & Computer Science,* vol. 25, pp. 4615–4623, 2017.
[23] S. Surender Reddy, "Optimal Reactive Power Scheduling Using Cuckoo Search Algorithm," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 5, pp. 2349-2356. 2017.
[24] S.S. Reddy, "Faster evolutionary algorithm based optimal power flow using incremental variables," *Electrical Power and Energy Systems*, vol. 54, pp. 198-210, 2014.
[25] Illinois Center for a Smarter Electric Grid (ICSEG). Available online: https://icseg.iti.illinois.edu/ieee-30-bussystem/ (accessed on 25 February 2019).
[26] El Ela, A.A.; Abido, M.A.; Spea, S.R, "Differential evolution algorithm for optimal reactive power dispatch," *Electr. Power Syst. Res*, vol. 81, pp. 458–464, 2011.
[27] Duman, S.; Sönmez, Y.; Güvenç, U.; Yörükeren, N., "Optimal reactive power dispatch using a gravitational search algorithm," *IET Gener. Transm. Distrib*, vol. 6, pp. 563–576, 2012.
[28] Aljohani, T.M.; Ebrahim, A.F.; Mohammed, O, "Single and Multiobjective Optimal Reactive Power Dispatch Based on Hybrid Artificial Physics–Particle Swarm Optimization," *Energies*, vol. 12, no. 12, pp. 2333, 2019.