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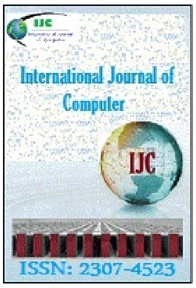

Diminution of Real Power Loss by Using Hybridization of Bat Algorithm with Harmony Search Algorithm

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Abstract

In this paper, a new Hybridization of Bat algorithm with Harmony search algorithm (BAHS) is proposed for solving reactive power dispatch problem. The enhancement includes the addition of pitch modification procedure in HS serving as a mutation operator during the procedure of the bat updating with the aim of speeding up convergence, thus making the approach more feasible for a wider range of real-world applications. The proposed Hybridization of Bat algorithm with Harmony search algorithm (BAHS) algorithm has been tested on standard IEEE 30, IEEE 57 bus test systems and simulation results show clearly the superior performance of the proposed algorithm in reducing the real power loss.

Keywords: Optimal Reactive Power, Transmission loss, harmony search, bat algorithm.

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1. Introduction

Optimal reactive power dispatch (ORPD) problem is mainly to reduce the real power loss and to keep the voltage profile within the limits. Various mathematical methods like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been implemented to decipher the optimal reactive power dispatch problem. Both the gradient and Newton methods have the complication in managing inequality constraints. Also the problem of voltage stability and collapse play a major role in power system planning and operation [8]. Evolutionary algorithms such as genetic algorithm have been already projected to solve the reactive power flow problem [9-11]. In [12], Hybrid differential evolution algorithm is proposed to perk up the voltage stability index. In [13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14], a fuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to solve the optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a non linear interior point method. In [17], a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18], F. Capitanescu proposes a two-step approach to calculate Reactive power reserves with respect to operating constraints and voltage stability. In [19], a programming based approach is used to solve the optimal reactive power dispatch problem. In [20], A. Kargarian et al present a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. This paper proposes a new Hybrid of Bat algorithm with Harmony search algorithm (BAHS) to solve the optimal reactive power dispatch problem. Echolocation is a significant feature of bat behavior and it produce a sound pulse and listens to the echo bouncing back from obstacles whilst flying. This happening has been inspired Yang [21] to build up the Bat Algorithm (BA). The harmony search algorithm [22] is one of the newly developed optimization algorithm and at a same time, it is one the most competent algorithm in the field of combinatorial optimization [23]. This algorithm is attracted by several researchers from various fields particularly those working on solving optimization problems. We merge two approaches to propose a new hybrid meta heuristic algorithm according to the principle of HS and BA. The proposed algorithm Hybrid - BAHS has been evaluated in standard IEEE 30 and IEEE 57 bus test systems. The simulation results demonstrate that our proposed approach outperforms all the entitled reported algorithms in minimization of real power loss.

2. Problem Formulation

The optimal power flow problem is mathematically formulated as follows:

Minimize $f(x, u)$ (1)

subject to $g(x,u)=0$ (2)

and

$h(x,u) \leq 0$ (3)

where f(x,u) is the objective function. g(x.u) and h(x,u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, .., \theta_N, V_{L1}, ., V_{LNL}, Q_{g1}, .., Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \dots, V_{gng}, T_1, .., T_{Nt}, Q_{c1}, .., Q_{cNc}\right)^T \quad (6)$$

Where ng, nt and nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

3. Objective Function

3.1. Active power loss

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which mathematically formulated as follows:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right) (7)$$

or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

whereg_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.

3.2.Voltage profile improvement

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \quad (9)$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (10)$$

3.3.Equality Constraint

The equality constraint g(x,u) of the ORPD problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L \quad (11)$$

3.4.Inequality Constraints

The inequality constraints h(x,u) reflect the limits on components in the power system as well as the limits created to ensure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \qquad (12)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \ , i \in N_g \qquad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max} \ , i \in N \qquad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max} \ , i \in N_T \qquad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max} \ , i \in N_C \qquad (16)$$

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.

4. Bat Algorithm

Bats utilize sonar echoes to sense and keep away from obstacles. They use time delay from emission to reflection and utilize it for navigation. They typically release short loud, sound impulse and the rate of pulse is usually 10 to20 times per second. Bats uses inbound frequencies (20,500) kHz. By execution [24-25], Pulse rate can be determined fro range (0-1). Pulse rate can be simply determined from range 0 to 1, where 0 means there is no emission and by 1, bats are emitting maximum , By utilizing above actions new bat algorithm can be formulated. The three comprehensive rules for bat algorithm are:

a) All bats utilize echolocation to sense distance, and they also guess the difference between food and background barriers in some magical way.

b) Bats fly arbitrarily with velocity ϑ_i at position x_i with a predetermined frequencyf_{min}, varying wavelength λ and loudness A_0 to search for prey. They can routinely adjust the wavelength of their emitted pulses and regulate the rate of pulse emission $r \in [0; 1]$, depending on the propinquity of their target.

c) Even though the loudness can vary in many ways, we presume that the loudness varies from a large (positive) A_0 to a minimum constant valueA_{min} .

Bat Algorithm

```
a: Objective function $f(x), x = (x_1, .., x_d)^T$

b: Initializing the bat population $x_i$ and $v_i$ for i = 1…n

c: Delineate pulse frequency $Q_i \in [Q_{min}, Q_{max}]$

d: Initialize pulse rates $r_i$ and the loudness $A_i$

e: while (t <$T_{max}$) // number of iterations

f: Breed new solutions by adjusting frequency, and

g: Renew velocities and locations/solutions

h: if (rand (0; 1) >$r_i$ )

i: Choose a solution among the best solutions

j: Create a local solution around the best solution

k: end if

l: Create a new solution by flying randomly

m: if (rand (0; 1) < $A_i$ and $f(x_i) < f(x)$)

n: Recognize the new solutions
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o: Augment $r_i$ and reduce $A_i$
p: end if
q: Categorize the bats and find the current best
r: end while
```

The creation of new solution has been performed by moving virtual bats according the following equations:

$$Q_i^{(t)} = Q_{\min} + (Q_{\max} - Q_{\min}) \cup (0,1),(17)$$

$$v_i^{(t+1)} = v_i^t + (x_i^t - \text{best})Q_i^{(t)}, \qquad (18)$$

$$x_i^{(t+1)} = x_i^{(t)} + v_i^{(t)}(19)$$

Where U (0; 1) is a uniform distribution.

An arbitrary walk with straight exploitation is used for local search that modifies the current best solution according to equation:

$$x^{(t)} = \text{best} + \epsilon A_i^{(t)}(2U(0,1) - 1), (20)$$

Where ϵ is the scaling factor, and $A_i^{(t)}$ the loudness. The local explore is launched with the propinquity depending on the pulse rate r_i and the new-fangled solutions established with some propinquity depending on parameter. In natural bats, where the rate of pulse production r_i augments and the loudness Ai diminishes when a bat finds a prey. The above characteristics can be written by the following equations:

$$A_i^{(t+1)} = \alpha A_i^{(t)}, r_i^{(t)} = r_i^{(0)}[1 - \exp(-\gamma\epsilon)], (21)$$

Where α and γ and are constants.

5. Harmony Search Algorithm

Harmony search (HS) is a new-fangled population-based metaheuristic optimization algorithm, that imitates the music inventiveness process where the musicians manage their instruments' pitch by searching for a ideal state of harmony. HS imitates the natural occurrence of musicians' behavior when they assist the pitches of their instruments together to achieve a fantastic harmony as measured by artistic standards. This musicians' extended and intense method led them to the ideal state. It is a very successful metaheuristic algorithm that can explore the search space of a given data in parallel optimization environment, where every solution (harmony) vector is created by intelligently exploring and exploiting a search space . It has many features that make it as a preferable technique not only as standalone algorithm but also to be combined with other metaheuristic algorithms.

The similarity between improvisation and optimization is likely as follows :

1. Every musician corresponds to every decision variable;

2. Musical instrument’s pitch range corresponds to the decision variable’s value range;

3. Musical harmony at a certain time corresponds to the solution vector at certain iteration;

4. Audience’s aesthetics corresponds to the objective function.

Just like musical harmony is improved time after time, solution vector is enhanced iteration by iteration.

In general, HS has five steps and they are described as follow:

The optimization problem is defined as follow:

minimize $f(a)$,

Subject to $a_i \in \mathbf{A}_i$, i= 1,2,..,N (22)

where $f(a)$ is an objective function; a is the set of each decision variable(a_i);A_i is the set of possible range of values for each decision variable, $L^{ai} \leq \mathbf{A}i \geq U^{ai}$; and N is the number of decision variables.

Then, the parameters of the HS are initialized. These parameters are:

1. Harmony Memory Size (HMS)

2. Harmony Memory considering Rate (HMCR), where HMCR ∈ [0, 1];

3. Pitch adjust Rate (PAR),

Where PAR ∈ [0, 1];

4.Stopping Criteria (i.e. number of improvisation (NI));

5.1. Initialize harmony memory

The harmony memory (HM) is a matrix of solutions with a size of HMS, where every harmony memory vector represents one solution. In this step, the solutions are arbitrarily constructed and rearranged in a reversed order to HM, based on their objective function values such as

$f(a^1) \leq f(a^2) \ldots\ldots \leq f(a^{HMS})$.

$$HM = \left[\begin{array}{ccc|c} & & & f(a^1) \\ a_1^1 & \cdots & a_N^1 & . \\ \vdots & \ddots & \vdots & . \\ a_1^{HMS} & \cdots & a_N^{HMS} & . \\ & & & f(a^{HMS}) \end{array}\right] \qquad (23)$$

This step is the heart of the HS algorithm and the foundation stone that has been building this algorithm. In this step, the HS generates a new harmony vector,

$a' = (a'_{1,} a'_2 \ldots\ldots a'_N)$. It is based on three operators: memory consideration; pitch adjustment; or arbitrary consideration. In the memory consideration, the values of the new-fangled harmony vector are arbitrarily inherited from the historical values stored in HM with a probability of HMCR. Therefore, the value of decision variable$(a'_1)$is selected from $(a_1^1, a_1^2, \ldots\ldots a_1^{HMS})$that is (a'_2) is selected from $(a_2^1, a_2^2, \ldots\ldots a_2^{HMS})$ and the other decision variables, $(a'_3, a'_4, a'_5, \ldots\ldots)$,are selected consecutively in the same manner with the probability of HMCR ∈ [0, 1]. The usage of HM is similar to the step where the musician uses his or her memory to produce an exceptional tune. This collective step ensures that high-quality harmonies are considered as the elements of new-fangled Harmony vectors. Out of that, where the additional decision variable values are not selected from HM, according to the HMCR probability test, they are arbitrarily chosen according to their possible range,$a'_1 \in$ Ai . This case is referred to as arbitrary consideration (with a probability of (1−HMCR)), which augments the diversity of the solutions and drives the system further to explore various diverse solutions so that global optimality can be attained. The following equation summarized these two steps i.e. memory consideration and arbitrary consideration.

$$a'_i \leftarrow \begin{cases} a'_i \in \left\{\{a_i^1, a_i^2, \ldots\ldots\ldots a_i^{HMS}\right\} w.p. HMCR \\ a'_i \in A_i w.p. (1 - HMCR) \end{cases} \qquad (24)$$

Furthermore, the additional search for high-quality solutions in the search space is achieved through tuning each decision variable in the new-fangled harmony vector,$a' = (a'_{1,} a'_2 \ldots\ldots a'_N)$ inherited from HM using PAR operator. These decision variables(a'_i) are examined and to be tuned with the probability of PAR ∈ [0, 1] as in Eq. (25).

$$a'_i \leftarrow \begin{cases} Adjusting\ pitch\ w.p. PAR \\ Doing\ Nothing\ w.p. (1 - PAR) \end{cases} \qquad (25)$$

If a createdarbitrary number rnd ∈ [0, 1] within the probability of PAR then, the new decision variable (a'_i) will be adjusted based on the following equation:

$$(a'_i) = (a'_i) \pm \text{rand}() * \text{bw} \qquad (26)$$

Here, bw is an arbitrary distance bandwidth used to perk up the performance of HS and (rand()) is a function that produces anarbitrary number ∈ [0, 1]. Actually, bw determines the amount of movement or changes that may have occurred to the components of the new-fangled vector. The value of bw is based on the optimization problem itself i.e. continuous or discrete. In general, the way that the parameter (PAR) modifies the components of the new-fangled harmony vector is an analogy to the musicians' behavior when they slightly change their tone frequencies in order to get much superior harmonies. Consequently, it explores more solutions in the search space and perk up the searching abilities.

5.2. Update the harmony memory

In order to update HM with the new produced vector $a^{'} = (a_1^{'}, a_2^{'}, \dots \dots a_N^{'})$,,the objective function is computed for each new-fangled Harmony vector f $(a^{'})$. If the objective function value for the new vector is better than the worst harmony vector stored in HM, then the worst harmony vector is replaced by the new vector. Otherwise, this new vector is ignored.

$a^{'} \in \ HM \wedge a^{worst} \notin \ HM(27)$

However, for the diversity of harmonies in HM, other harmonies can be considered. Also, the maximum number of identical harmonies in HM can be considered in order to prevent premature HM.

5.3.Check the stopping criterion

The iteration procedure is terminated when the maximum number of improvisations (NI) is reached. Finally, the best harmony memory vector is chosen and is considered to be the best solution to the problem under investigation.

5.4.Harmony search characteristics

The other important strengths of HS are their improvisation operators, memory consideration; pitch adjustment; and arbitrary consideration, that play a key rule in attaining the preferredequilibrium between the two major extremes for any optimization algorithm, Intensification and diversification . Fundamentally, both pitch adjustment and random consideration are the key components of achieving the preferred diversification in HS. In arbitrary consideration, the new-fangled vector's components are produced at arbitrary mode, has the similar level of efficiency as in other algorithms that handle randomization, where this property permits HS to discover new regions that may not have been visited in the search space. While, the pitch adjustment adds a new way for HS to augment its diversification aptitude by tuning the new-fangled vector's component within a given bandwidth. A littlearbitrary amount is added to or subtracted from an existing component stored in HM. This operator, pitch adjustment, is a enhancement process of local solutions that ensures that good local solutions are retained, while it adds a novel room for exploring new solutions. Further to that, pitch adjustment operator can also be considered as aninstrument to support the intensification of HS through controlling the probability of PAR. The amplification in the HS algorithm is represented by the third HS operator, memory consideration. Anelevated harmony acceptance rate means that good solutions from the memory are more likely to be selected.

This is equivalent to a certain degree of superiority. Observably, if the acceptance rate is too low, solutions will converge more slowly.

5.5.Variants of harmony search

Harmony search algorithm got the awareness of many researchers to solve many optimization problems such as engineering and computer science problems. Consequently, the interest in this algorithm led the researchers to perk up and expand its performance in line with the requirements of problems that are solved. These developments primarily cover two aspects: (1) development of HS in term of parameters setting, and (2) development in term of hybridizing of HS components with other meta heuristic algorithms. This section will emphasize these developments and improvements to this algorithm in the ten years of this algorithm's age.

5.6.Variants based on parameters setting

The suitable selection of HS parameter values is considered as one of the exigent task not only for HS algorithm but also for other metaheuristic algorithms. This difficulty is a consequence of different reasons, and the most significant one is the lack of general rules governing this aspect. Actually, setting these values is problem dependant and therefore the investigational trials are the only guide to the best values. However, this matter guides the study into new variants of HS. These variants are based on adding some additional components or idea to make part of these parameters energetically adapted. The projected algorithm includes dynamic adaptation for both pitch adjustment rate (PAR) and bandwidth (bw) values. The PAR value is linearly increased in each iteration of HS by using the following equation:

$$\text{PAR(gn)} = \text{PAR}_{\min} + \frac{PAR_{max} - PAR_{min}}{NI} \text{ x } gn \quad (28)$$

WherePAR(gn)is the PAR value for each generation, $\text{PAR}_{\min}$ and $\text{PAR}_{\max}$ are the minimum pitch adjusting rate and maximum pitch adjusting rate respectively. NI is the maximum number of iterations and gn is the generation number. The bandwidth (bw) value is exponentially decreased in each iteration of HS by using the following equation:

$$\text{bw(gn)} = \text{bw}_{\min} + \frac{bw_{max} - bw_{min}}{NI} \text{ x } gn \qquad (29)$$

where bw (gn)is the bandwidth value for each generation, $\text{bw}_{\max}$ is the maximum bandwidth, bwmin is the minimum bandwidth and gn is the generation number.

6. Hybrid-BAHS

The Hybrid bat algorithm with harmony search (BAHS) alters the solutions with poor fitness in order to add diversity of the population to perk up the search efficiency. In general, the standard BA algorithm is dexterous at exploiting the search space, but at times it may ensnare into some local optima, so that it cannot achieve global search well. For BA, explore depends entirely on arbitrary walks, so a rapid convergence cannot be guaranteed. In order to increase the diversity of the population for BA so as to keep away from trapping into local optima, a key enhancement of adding pitch adjustment operation in HS serving as a mutation operator is made to the BA with the aim of speeding up convergence, thus making the approach more practicable for a wider range of realistic applications while preserving the attractive characteristics of the basic BA. In this paper, a hybrid meta heuristic algorithm by inducing the pitch alteration operation in HS as a mutation operator into bat algorithm, so-called hybrid of Bat algorithm with Harmony search algorithm (BAHS), is used to solve optimal reactive power dispatch problem. The difference between BAHS and BA is that the mutation operator is used to perk up the original BA generating a new solution for each bat. In this way, this technique can explore the new search space by the mutation of the HS algorithm and exploit the population information with BA, and therefore can stay away from trapping into local optima in BA. In the following, we will show the algorithm BAHS which is an enhancement of HS and BA. The noteworthy operator of BAHS is the hybrid harmony search mutation operator, which composes the inventiveness of harmony in HS with the BA. The core idea of the projected hybrid mutation operator is based on two considerations.

Firstly, poor solutions can take in many new-fangled used features from good solutions. Secondly, the mutation operator can perk up the exploration of the new-fangled explore space. In this way, the muscular exploration abilities of the original HS and the exploitation abilities of the BA can be fully developed. For bat algorithm, as the search relies entirely on random walks, a fast convergence cannot be guaranteed. Described here for the first time, a key progress of adding mutation operator is made to the BA, including three minor improvements, which are made with the aspire of speeding up convergence, thus making the method more practical for a wider range of applications, but without losing the striking features of the original method.

The first enhancement is that we use fixed frequency $f$and loudness Ainstead of various frequency $f_i$andA_i^t. Alike to BA, in BAHS, each bat is defined by its position x_i^t, velocityv_i^t, the emission pulse rate $r_i^t$and the predetermined frequency$f$, and loudness Ain a d-dimensional search space. The new solutions x_i^t and velocities v_i^t at time step $t$are given by,

$$v_i^t = v_i^{t-1} + (x_i^t - x_*)f \;, \qquad (30)$$

$$x_i^t = x_i^{t-1} + v_i^t \qquad (31)$$

Where $x_*$is the current global best location which is located after comparing all the solutions among all the $n$bats. In our investigation, we make f = 0.5. The second progress is to add mutation operator in an effort to augment diversity of the population to perk up the search efficiency and to speed up the rate of convergence. For the local search part, once a solution is selected among the current best solutions, a new solution for each bat is generated locally using arbitrary walk. When $\xi$is larger than pulse rate r, that is, ξ>r, where $\xi\in$ [0,1] is a arbitrary real number drawn from a uniform distribution; while when $\xi \le r$, we use pitch modification operation in HS serving as a mutation operator updating the new-fangled solution to augment diversity of the population to perk up the search efficiency.

Hybrid – BAHS algorithm for solving reactive power dispatch problem.

Commence

Step 1: Initialize. Set the generation counter t = 1; initialize the population of NP bats P arbitrarily and every bat corresponding to a budding solution to the given problem; define loudness A; set frequency Q, the initial velocities V, and pulse rate r; set the harmony memory consideration rate HMCR, the pitch modification rate PAR and bandwidth bw; set utmost of elite individuals retained KEEP.

Step 2: calculate the quality f for each bat in P determined by the objective function (x).

```
Step 3: While the termination criterion is not satisfied or $t$<Max Generation do
Arrange the population of bats $P$ from most excellent to nastiest by order of quality $f$ for every bat.
Stockpile the KEEP best bats as KEEPBAT.
for $i$ = 1:NP (all bats) do
    $v_i^t = v_i^{t-1} + (x_i^t - x_*)Q$
    $x_i^t = x_i^{t-1} + v_i^t$
if(rand >$r$) then
    $x_u^t = x_* + \alpha\varepsilon^t$
end if
for $j$ = 1:$D$(all elements) do //Mutate
if(rand <HMCR) then
r_1 =[NP *rand]
    $x_v(j) = x_{r1}(j) where r_1 \epsilon (1,2,..,HMS)$
if(rand <PAR) then
$x_v(j) = x_v(j)$ + bw× (2 × rand − 1)
end if
else
$x_v(j) = x_{min,j}$+ rand × ($x_{max,j} - x_{min,j}$)
```

```
end if
end for j
Calculate the fitness for the off springs $x_u^t, x_i^t, x_v^t$
choose the offspring $x_k^t$ with the best fitness among the off springs $x_u^t, x_i^t, x_v^t$
if(rand< A) then
    $x_{r1}^t = x_k^t$ ;
end if
Reinstate the KEEP worst bats with the KEEP best bats KEEPBAT stored.
end for i
t = t + 1;
Step 4: end while
```

7. Simulation Results

At first Hybrid-BAHS algorithm has been tested in IEEE 30-bus, 41 branch system. It has a total of 13 control variables as follows: 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is the slack bus, 2, 5, 8, 11 and 13 are taken as PV generator buses and the rest are PQ load buses. The considered security constraints are the voltage magnitudes of all buses, the reactive power limits of the shunt VAR compensators and the transformers tap settings limits. The variables limits are listed in Table 1.

Table 1: Initial Variables Limits (PU)

Control variables	Min. value	Max. value	Type
Generator: Vg	0.91	1.10	Continuous
Load Bus: VL	0.94	1.04	Continuous
T	0.94	1.04	Discrete
Qc	-0.11	0.35	Discrete

The transformer taps and the reactive power source installation are discrete with the changes step of 0.01. The power limits generators buses are represented in Table 2. Generators buses are: PV buses 2,5,8,11,13 and slack bus is 1 and the others are PQ-buses.

Table 2: Generators Power Limits in MW and MVAR

Bus n°	Pg	Pgmin	Pgmax	Qgmin
1	98.00	51	202	-21
2	81.00	22	81	-21
5	53.00	16	53	-16
8	21.00	11	34	-16
11	21.00	11	29	-11
13	21.00	13	41	-16

Table 3 summarizes the Values of Control Variables after Optimization and Active Power Loss by BAHS method.

Table 3: Values of Control Variables after Optimization and Active Power Loss

Control Variables (p.u)	BAHS
V1	1.0660
V2	1.0569
V5	1.0339
V8	1.0468
V11	1.0869
V13	1.0660
T4,12	0.00
T6,9	0.02
T6,10	0.91
T28,27	0.90
Q10	0.11
Q24	0.10
PLOSS	4.9198
VD	0.9099

The proposed approach succeeds in keeping the dependent variables within their limits.

Table 4 summarizes the results of the optimal solution obtained by PSO, SGA and BAHS methods. It reveals the reduction of real power loss after optimization.

Table 4: Comparison Results of Different Methods

SGA[26]	PSO[27]	BAHS
4.98 Mw	4.9262Mw	4.9198 Mw

Secondly the proposed hybrid BAHS algorithm for solving ORPD problem is tested in standard IEEE-57 bus power system. The IEEE 57-bus system data consists of 80 branches, seven generator-buses and 17 branches under load tap setting transformer branches. The possible reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. In this case, the search space has 27 dimensions, i.e., the seven generator voltages, 17 transformer taps, and three capacitor banks. The system variable limits are given in Table 5. The initial conditions for the IEEE-57 bus power system are given as follows:

P_{load}= 12.419 p.u. Q_{load} = 3.346 p.u.

The total initial generations and power losses are obtained as follows:

$\sum P_G$ = 12.7737 p.u. $\sum Q_G$ = 3.4567 p.u.

P_{loss}= 0.27479 p.u. Q_{loss} = -1.2265 p.u.

Table 5: Variables limits for IEEE-57 bus power system (p.u.)

reactive power generation limits							
bus no	1	2	3	6	8	9	12
Q_{gmin}	-1.2	-.014	-.02	-0.06	-1.2	-0.01	-0.1
q_{gmax}	2	0.3	0.4	0.21	2	0.06	1.53
voltage and tap setting limits							
v_{gmin}	v_{gmax}	v_{pqmin}	v_{pqmax}	t_{kmin}	t_{kmax}		
0.7	1.2	0.94	1.04	0.7	1.2		
shunt capacitor limits							
bus no	18	25	53				
q_{cmin}	0	0	0				
q_{cmax}	10	5.6	6.1				

Table 6 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after BAHS based optimization which are within their acceptable limits. In Table 7 comparison of optimum results obtained from proposed BAHS with other optimization techniques for ORPD mentioned in literature for IEEE-57 bus power system is given. These results indicate the robustness of proposed BAHS approach for providing better optimal solution in case of IEEE-57 bus system.

Table 6: control variables obtained after optimization by BAHS method for IEEE-57 bus system (p.u.)

Control Variables	BAHS
V1	1.2
V2	1.079
V3	1.069
V6	1.059
V8	1.079
V9	1.049
V12	1.059
Qc18	0.0852
Qc25	0.345
Qc53	0.0637
T4-18	1.020
T21-20	1.069
T24-25	0.969
T24-26	0.943
T7-29	1.089
T34-32	0.949
T11-41	1.014
T15-45	1.069
T14-46	0.939
T10-51	1.049
T13-49	1.069
T11-43	0.919
T40-56	0.909
T39-57	0.969
T9-55	0.979

Table 7: Comparative Optimization Results for IEEE-57 Bus Power System (P.U.)

S.No.	Optimization Algorithm	Best Solution	Worst Solution	Average Solution
1	NLP [28]	0.25902	0.30854	0.27858
2	CGA [28]	0.25244	0.27507	0.26293
3	AGA [28]	0.24564	0.26671	0.25127
4	PSO-w [28]	0.24270	0.26152	0.24725
5	PSO-cf [28]	0.24280	0.26032	0.24698
6	CLPSO [28]	0.24515	0.24780	0.24673
7	SPSO-07 [28]	0.24430	0.25457	0.24752
8	L-DE [28]	0.27812	0.41909	0.33177
9	L-SACP-DE [28]	0.27915	0.36978	0.31032
10	L-SaDE [28]	0.24267	0.24391	0.24311
11	SOA [28]	0.24265	0.24280	0.24270
12	LM [29]	0.2484	0.2922	0.2641
13	MBEP1 [29]	0.2474	0.2848	0.2643
14	MBEP2 [29]	0.2482	0.283	0.2592
15	BES100 [29]	0.2438	0.263	0.2541
16	BES200 [29]	0.3417	0.2486	0.2443
17	Proposed BAHS	0.22379	0.23542	0.23145

8. Conclusion

Hybrid –BAHS algorithm has been efficiently applied for ORPD problem. The Hybrid - BAHS based ORPD is tested in standard IEEE 30, IEEE 57 bus system. Performance comparisons with well-known population-based algorithms give positive results. Hybrid – BAHS emerges to find high-quality solutions when compared to that of other algorithms. The simulation results presented in previous section prove the ability of Hybrid -BAHS approach to arrive at near global optimal solution.

References

[1] O.Alsac,and B. Scott, “Optimal load flow with steady state security”,IEEE Transaction. PAS -1973, pp. 745-751.

[2] Lee K Y ,Paru Y M , Oritz J L –A united approach to optimal real and reactive power dispatch , IEEE Transactions on power Apparatus and systems 1985: PAS-104 : 1147-1153.

[3] A.Monticelli , M .V.F Pereira ,and S. Granville , “Security constrained optimal power flow with post contingency corrective rescheduling” , IEEE Transactions on Power Systems :PWRS-2, No. 1, pp.175-182,1987.

[4] Deeb N ,Shahidehpur S.M ,Linear reactive power optimization in a large power network using the decomposition approach. IEEE Transactions on power system 1990: 5(2) : 428-435

[5] E. Hobson ,’Network consrained reactive power control using linear programming, ‘ IEEE Transactions on power systems PAS -99 (4) ,pp 868-877, 1980

[6] K.Y Lee ,Y.M Park , and J.L Oritz, “Fuel –cost optimization for both real and reactive power dispatches” , IEE Proc; 131C,(3), pp.85-93.

[7] M.K. Mangoli, and K.Y. Lee, “Optimal real and reactive power control using linear programming” , Electr.Power Syst.Res, Vol.26, pp.1-10,1993.

[8] C.A. Canizares, A.C.Z.de Souza and V.H. Quintana , “ Comparison of performance indices for detection of proximity to voltage collapse ,’’ vol. 11. no.3, pp.1441-1450, Aug 1996.

[9] S.R.Paranjothi, and K.Anburaja, “Optimal power flow using refined genetic algorithm”, Electr. Power Compon.Syst , Vol. 30, 1055-1063,2002.

[10] D. Devaraj, and B. Yeganarayana, “Genetic algorithm based optimal power flow for security enhancement”, IEE proc-Generation. Transmission and. Distribution; 152, 6 November 2005.

[11] A. Berizzi, C. Bovo, M. Merlo, and M. Delfanti, “A ga approach to compare orpf objective functions including secondary voltage regulation,”Electric Power Systems Research, vol. 84, no. 1, pp. 187 – 194,2012.

[12] C.-F. Yang, G. G. Lai, C.-H.Lee, C.-T. Su, and G. W. Chang, “Optimal setting of reactive compensation devices with an improved voltage stability index for voltage stability enhancement,” International Journal of Electrical Power and Energy Systems, vol. 37, no. 1, pp. 50 – 57,2012.

[13] P. Roy, S. Ghoshal, and S. Thakur, “Optimal var control for improvements in voltage profiles and for real power loss minimization using biogeography based optimization,” International Journal of Electrical Power and Energy Systems, vol. 43, no. 1, pp. 830 – 838, 2012.

[14] B. Venkatesh, G. Sadasivam, and M. Khan, “A new optimal reactive power scheduling method for loss minimization and voltage stability margin maximization using successive multi-objective fuzzy lp technique,”IEEE Transactions on Power Systems, vol. 15, no. 2, pp. 844 –851, may 2000.

[15] W. Yan, S. Lu, and D. Yu, “A novel optimal reactive power dispatch method based on an improved hybrid evolutionary programming technique, ”IEEE Transactions on Power Systems, vol. 19, no. 2, pp. 913 –918, may 2004.

[16] W. Yan, F. Liu, C. Chung, and K. Wong, “A hybrid genetic algorithm interiorpoint method for optimal reactive power flow,” IEEE Transaction son Power Systems, vol. 21, no. 3, pp. 1163 –1169, aug. 2006.

[17] J. Yu, W. Yan, W. Li, C. Chung, and K. Wong, “An unfixed piece wise optimal reactive power-flow model and its algorithm for ac-dc systems,”IEEE Transactions on Power Systems, vol. 23, no. 1, pp. 170 –176, feb.2008.

[18] F. Capitanescu, “Assessing reactive power reserves with respect to operating constraints and voltage stability,” IEEE Transactions on Power Systems, vol. 26, no. 4, pp. 2224–2234, nov. 2011.

[19] Z. Hu, X. Wang, and G. Taylor, “Stochastic optimal reactive power dispatch: Formulation and solution method,” International Journal of Electrical Power and Energy Systems, vol. 32, no. 6, pp. 615 – 621,2010.

[20] A. Kargarian, M. Raoofat, and M. Mohammadi, “Probabilistic reactive power procurement in hybrid electricity markets with uncertain loads,”Electric Power Systems Research, vol. 82, no. 1, pp. 68 – 80, 2012.

[21] X.S. Yang. Bat algorithm for multi-objective optimisation. International Journal of Bio-Inspired Computation, 3(5):267– 274, 2011

[22] Geem Z (2006) Improved harmony search from ensemble of music players. In: Gabrys B, Howlett RJ, Jain L (eds) Knowledge-based intelligent information and engineering systems. Springer, Heidelberg, pp 86–93.

[23] Geem Z (2007a) optimal scheduling of multiple dam system using harmony search algorithm. In: Computational and ambient intelligence. Springer, Berlin, pp 316–323

[24] P.W. Tsai, J.S. Pan, B.Y. Liao, M.J. Tsai, and V. Istanda. Bat algorithm inspired algorithm for solving numerical optimization problems. Applied Mechanics and Materials, 148:134–137,2012.

[25] X.S. Yang. Review of meta-heuristics and generalised evolutionary walk algorithm. International Journal of Bio-Inspired Computation, 3(2):77–84, 2011.

[26] Q.H. Wu, Y.J.Cao, and J.Y. Wen. Optimal reactive power dispatch using an adaptive genetic algorithm. Int. J. Elect. Power Energy Syst. Vol 20. Pp. 563-569; Aug 1998.

[27] B. Zhao, C. X. Guo, and Y.J. CAO. Multiagent-based particle swarm optimization approach for optimal reactive power dispatch. IEEE Trans. Power Syst. Vol. 20, no. 2, pp. 1070-1078, May 2005.

[28]Chaohua Dai, Weirong Chen, Yunfang Zhu, and Xuexia Zhang, “Seeker optimization algorithm for optimal reactive power dispatch,” IEEE Trans. Power Systems, Vol. 24, No. 3, August 2009, pp. 1218-1231.

[29] J. R. Gomes and 0. R. Saavedra, “Optimal reactive power dispatch using evolutionary computation: Extended algorithms,” IEE Proceedings on Generation Transmission Distribution. Vol. 146, No. 6. Nov. 1999.

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