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# Economic Dispatch with Valve Point Effect Using Improved Bat Algorithm

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**ABSTRACT:** This paper presents application of Improved Bat Algorithm(IBA) for solving Economic Load Dispatch problem considering Valve point loading effect. Bat algorithm is an optimization algorithm motivated by the echolocation behaviour of natural bats in finding their foods. Potency of the algorithm is tested on forty unit system. The promising results show the quick convergence and effectiveness of the Bat algorithm.

**KEYWORDS:** Economic Load Dispatch, Valve point loading effect, Bat algorithm.

## I. INTRODUCTION

Nowadays, the planning and operating power system is a challenging task for power engineers because of its complexity and to satisfy the demand for electric energy of the area served by the system with Continuity of service and reliability. An elite objective here is to perform the service at the lowest possible cost. The role of soft computing techniques has influenced a lot in the field of power system especially in solving optimization problems because of their reliability, speed of convergence and robustness [1]. The ELD problem, one of the different non-linear programming commitment in power system, is about minimizing the fuel cost of generating units for a specific period of operation so as to accomplish optimal generation dispatch among operating units and to satisfy the system load demand and generator operation constraints with ramp rate limits and prohibited operating zones [2]. S.K.Dash [3] was presented a new method to solve the problem of optimal generation dispatch with multiple fuel options using a Radial basis function neural network along with a heuristic rule based search algorithm and a Hopfield neural network. Dr .G. Srinivasan, et al. [4] solved economic load dispatch problem with Valve point effects and multi Fuels using particle swarm algorithm with chaotic sequences and the crossover operation to improve the global searching capability by preventing premature convergence through increased diversity of the population. Radhakrishnan Anandhakumar, et al. [5]was proposed a non-iterative direct Composite Cost Function method, to solve economic dispatches of the online units with less Computation time. Umamaheswari Krishnasamy,et al. [6] presented a Refined Teaching-Learning Based Optimization Algorithm for Dynamic Economic Dispatch of Integrated Multiple Fuel integrated with Wind Power Plants.R.Balamurugan, et al. [7] proposed a self-adaptive mechanism isused to change these control parameters during the evolution process. These control parameters are applied at the individual levels in the population to solve economic dispatch with valve point and multi fuel options. Xin-She Yang. [8] proposed the Bat algorithm and its characteristic with implementation of various functions for global optimization.

In this paper, Economic load Dispatch problem with inclusion of valve point effect has been solved by using the Improved Bat Algorithm. The Bat algorithm approach has been verified by applying it to forty unit system. The performance of the proposed Improved Bat algorithm is analysed and its parameters was self tuned. Because this parameter plays a major role in controlling the searching process of algorithm.

## II. FORMULATION OF ECONOMIC LOAD DISPATCH PROBLEM

**TOTAL COST FUNCTION:-**

The main objective of Economic Load Dispatch in electrical power system is to reduce the overall production cost of supplying loads while satisfying constraints. The total cost function can be formulated as the following equation.

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$$F_t = \sum_{i=1}^{N} F_i(P_i) = \sum_{i=1}^{N} a_i + b_iP_i + c_iP_i^2 \quad (1)$$

where $F_i(P_i)$ is the cost function of $i_{th}$ generator and is usually expressed as a quadratic polynomial; $a_i$, $b_i$ and $c_i$ are the fuel cost coefficients of $i_{th}$ generator; N is the number of generators , $P_i$ is the real power output of $i_{th}$ generator. The Economic Load Dispatch problem minimizes $F_t$ subject to the following constraints and effects.

**EQUALITY CONSTRAINTS:-**

The power balance equation is given by

$$\sum_{i=1}^{N} P_i = P_D \quad (2)$$

where, $P_D$ is the power demand of the system. $B_{ij}$, $B_{0i}$, and $B_{00}$ are transmission loss coefficients.

**INEQUALITY CONSTRAINTS:-**

The upper and the lower operating region of the generator is given by the equation

$$P_i^{min} \leq P_i \leq P_i^{max} \; i \in N \quad (3)$$

Where $P_i^{min}$ and $P_i^{max}$ are the minimum and maximum power outputs of generator i, respectively. The maximum output power of generator is limited by thermal consideration and minimum power generation is limited by the flame instability of a boiler.

**VALVE-POINT EFFECTS:-**

The generator cost function is obtained from a data point taken during “heat run” tests when input and output data are measured as the unit slowly varies through its operating region. Wire drawing effects, which occur as each steam admission valve in a turbine starts to open, produce a rippling effect on the unit curve. To consider the accurate cost curve of each generating unit, the valve point results in as each steam valve starts to open, the ripples like the cost function addressing valve-point loadings of generating units is accurately represented as

$$F_t = \sum_{i=1}^{N} F_i(P_i) = \sum_{i=1}^{N} a_i + b_iP_i + c_i + \left|d_i \times \sin\{e_i \times (p_i^{min} - P_i\}\right| \quad (4)$$

## III. BAT ALGORITHM

Bat algorithm is an optimization algorithm motivated by the echolocation behaviour of natural bats in finding their foods. It is introduced by Yang and is used for solving many real world optimization problems. Each virtual bat in the initial population employs a homologous manner by doing echolocation for updating its position. Bat echolocation is a perceptual system in which a series of loud ultrasound waves are released to produce echoes. These waves are returned with delays and various sound levels which make bats to discover a specific prey as shown in Fig-1. Some guidelines are studied to enhance the structure of BAT algorithm and use the echolocation nature of bats.

- Each bats identify the distance between the prey and background barriers using echolocation.
- Bats fly randomly with velocity $v_i$ at position $x_i$ with a fixed frequency $f_{min}$(or Wavelength λ), varying wavelength λ (or frequency f) and loudness $A_o$ to search for prey. They can naturally adopt the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r ∈ [0, 1], depending on the closeness of their prey;
- Although the loudness of the bats can be modified in many ways, we consider that the loudness varies from a large (positive) $A_o$ to a minimum value $A_{min}$ according to the problem taken.

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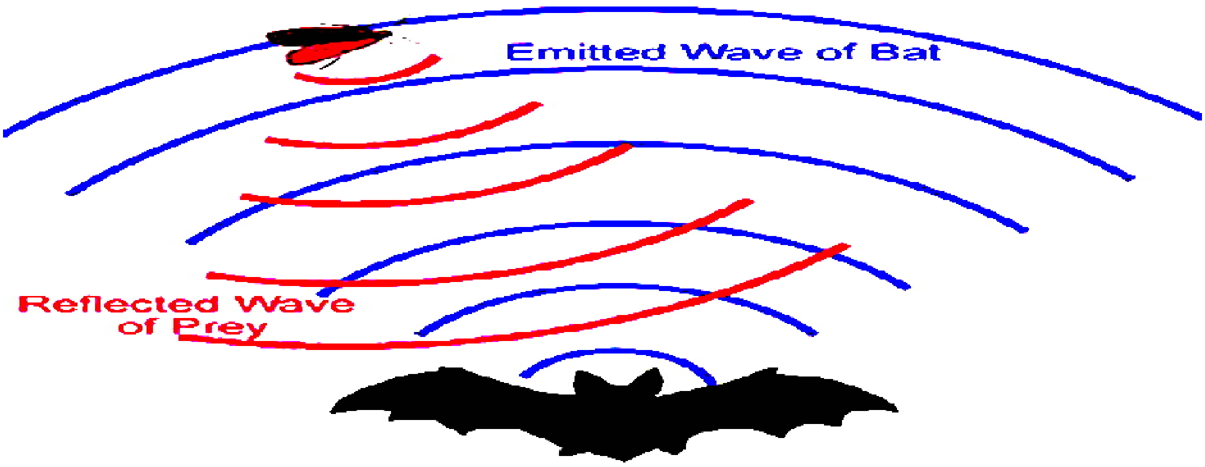


Fig.1.Ecolocation behaviour of bats

**INITIALIZATION OF BAT POPULATION**

Population initialization of bats randomly in between the lower and the upper boundary can be achieved by the equation.

$$x_{ij} = x_{\min j} + \text{rand}(0,1) * (x_{\max j} - x_{\min j}) \quad (5)$$

where i = 1, 2,…n, j=1, 2,….d, $x_{minj}$ and $x_{maxj}$ are lower and upper boundaries for dimension j respectively.

**UPDATE PROCESS OF FREQUENCY, VELOCITY AND SOLUTION**

The step size of the solution is controlled with the frequency factor in BA. This frequency factor is generated randomly in between the minimum and maximum frequency [fmin, fmax]. Velocity of a solution is proportional to frequency and new solution depends on its new velocity and it is represented as.

$$f_i = f_{\min} + (f_{\max} - f_{\min})\beta \quad (6)$$

$$v_i^t = v_i^{t-1} + (x_i^t - x^*)f_i \quad (7)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (8)$$

Where β ϵ[0, 1] indicates randomly generated number, $x^*$represents current global best solutions. For local search part of algorithm (exploitation) one solution is selected among the selected best solutions and random walk is applied.

$$x_{new} = x_{old} + \varepsilon A^t \quad (9)$$

Where $A^t$, is average loudness of all bats, ε∈ [0, 1] is random number and represents direction and intensity of random-walk.

**UPDATE PROCESS OF LOUDNESS AND PULSE EMISSION RATE**

As iteration increases, the loudness and pulse emission must be updated because when the bat gets closer to its prey then their loudness As usually decreases and pulse emission rate also increases, the updating equation for loudness and pulse emission is given by

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$$A_i^{t+1} = \alpha A_i^t \quad (10)$$

$$r_i^{t+1} = r_i^0\left[1 - e^{(-\gamma t)}\right] \quad (11)$$

where α and γ are constants. $ri^0$ and $A_i$ are factors which consist of random values and $Ai^0$ can typically be [1, 2], while $ri^0$ can typically be [0,1].

**PSEUDO CODE OF BAT ALGORITHM**

1).Objective function: f(x), $x=(x_1....x_d)^t$
2).Initialize bat population $x_i$and velocity $v_i$ i=1, 2...n
3).Define pulse frequency $f_i$ at $x_i$
4).Initialize pulse rate $r_i$ and loudness $A_i$
5).While (t < maximum number of iterations)
6).Generate new solutions by adjusting frequency, and updating velocities and location/solutions.
7).If (rand > $r_i$)
8).Select a solution among the best solutions
9) Generate a local solution around the selected best solution
10) End if
11) If(rand < Ai and f(xi) < f(x*))
12) Accept new solutions
13) Increase $r_i$, reduce Ai
14) End if
15) Ranks the bats and find current best x*
16) End while
17) Display results.

## IV. IMPROVED BAT ALGORITHM (IBA)

Bat Algorithm is an efficient algorithm at exploitation but has some insufficiency at exploration, thus it can easily get trapped in local minimum on most of the multimodal test functions. In order to overcome this problem of standard BA, some modifications are made in the update process of frequency to improve exploration and exploitation capability of BA .

Normally, in bat algorithm the frequency is randomly generated in between the minimum and maximum value, this frequency will have same effect to all dimensions of solution. In order to adopt the effect of change in dimensions on solutions a dynamic frequency varying concept is assigned in this improved bat algorithm.

$$diff_j = \sqrt{(x_{ij} - x_j^*)^2} \quad (12)$$

$$range = \max(diff) - \min(diff) \quad (13)$$

$$f_j = f_{min} + \frac{\sqrt{(\min(diff) - (diff_j))^2}}{range} * (f_{max} - f_{min}) \quad (14)$$

The distances between $i_{th}$ solution and global best solution are calculated first then the frequency updating are assigned according to Eq. (14), so the frequency variation is depend on difference in distances as per the Eq. (12).By varying the Frequency the step size of the solutions also varied. Thus, dimensions which are closer to global optimum point do not steer for irrelevant regions. Instead, they locally search around global optimum point. Velocity formulation Eq. (15) must be updated as follows.

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$$v_{ij}^{t} = v_{ij}^{t-1} + (x_{ij}^{t} - x_{ij}^{*})f_j \quad (15)$$

**Pseudo Code for Improved Bat Algorithm**

1).Initialize the population of n bats randomly and evaluate the objective function for all bats.
2).Initialize temporary best solution among the solutions.
3).Define frequency as per the Eq. (12-14).
4).Define loudness $A_i$ and the initial velocities $v_i$ (i= 1, 2, . . . , N); Set pulse rate $r_i$.
5).While (t < maximum number of iterations)
6).Evaluate objective function for generating new solutions by varying the frequency and update velocity Eq.( 12-15).
7).If (rand > $r_i$)
8).Select a solution among the best solutions.
9).Generate a local solution around the selected best solution.
10).End if
11).If (rand < $A_i$ and $f(x_i) < f(x^*)$)
12).Accept new solutions
13).Increase $r_i$, reduce $A_i$
14).End if
15).Ranks the bats and find current best x*
16).End while
17).Display results.

## V. RESULT

In this case Improved Bat algorithm is employed to solve the economic dispatch of forty unit system with demand 10500MW consist of valve-point effect. the simulation results and the converge of the cost function is shown in Fig-2 for 100 iterations. the random value of frequency change of IBA is shown in Fig-4.

Table-1. Simulation results for forty unit system.

| Unit | Power Output | Unit | Power Output | Unit | Power Output | Unit | Power Output |
|---|---|---|---|---|---|---|---|
| P1 (MW) | 113.726 | P11(MW) | 169.0811 | P21 (MW) | 523.5416 | P31(MW | 189.72 |
| P2(MW) | 113.7486 | P12 (MW) | 94.25 | P22 (MW) | 523.5353 | P32(MW | 189.78 |
| P3(MW) | 97.6741 | P13 (MW) | 215.0163 | P23(MW) | 523.5297 | P33(MW | 189.71 |
| P4(MW) | 179.9827 | P14 (MW) | 386.5352 | P24(MW) | 523.5494 | P34(MW | 199.7498 |
| P5(MW) | 89.9011 | P15 (MW) | 304.7687 | P25(MW) | 523.5365 | P35(MW | 165.3897 |
| P6 (MW) | 105.6544 | P16(MW) | 394.5311 | P26(MW) | 523.5436 | P36(MW | 172.2775 |
| P7(MW) | 260.0002 | P17 (MW) | 489.5307 | P27 (MW) | 10.24 | P37(MW | 109.79 |
| P8(MW) | 288.7034 | P18 (MW) | 489.5332 | P28 (MW) | 10.2501 | P38(MW | 109.75 |
| P9 (Mw | 284.896 | P19 (MW) | 511.5345 | P29 (MW) | 10.26 | P39(MW | 93.3462 |
| P10 (MW) | 205.062 | P20 (MW) | 511.5549 | P30 (MW) | 89.2639 | P40(MW | 511.5496 |
| **TOTAL OUTPUT(MW)** | | | | 10500MW | | | |
| **COST ($/hr)** | | | | **121401.1112** | | | |

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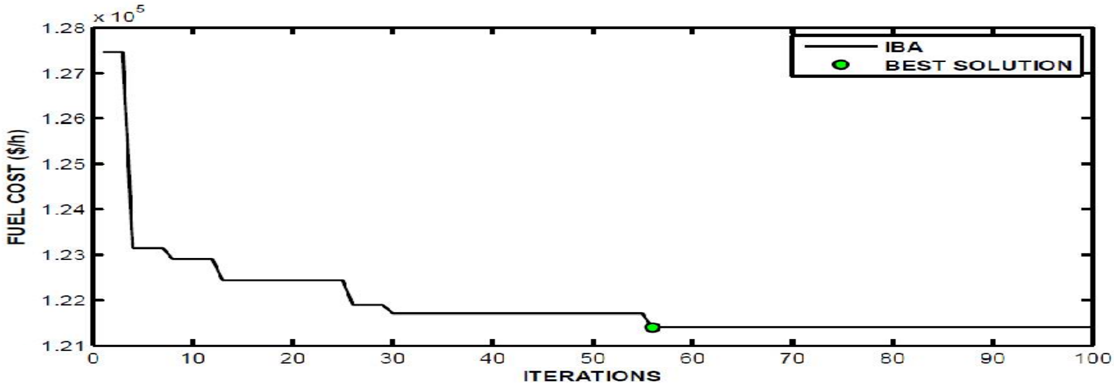


Fig.2.Convergence Characteristics of IBA.

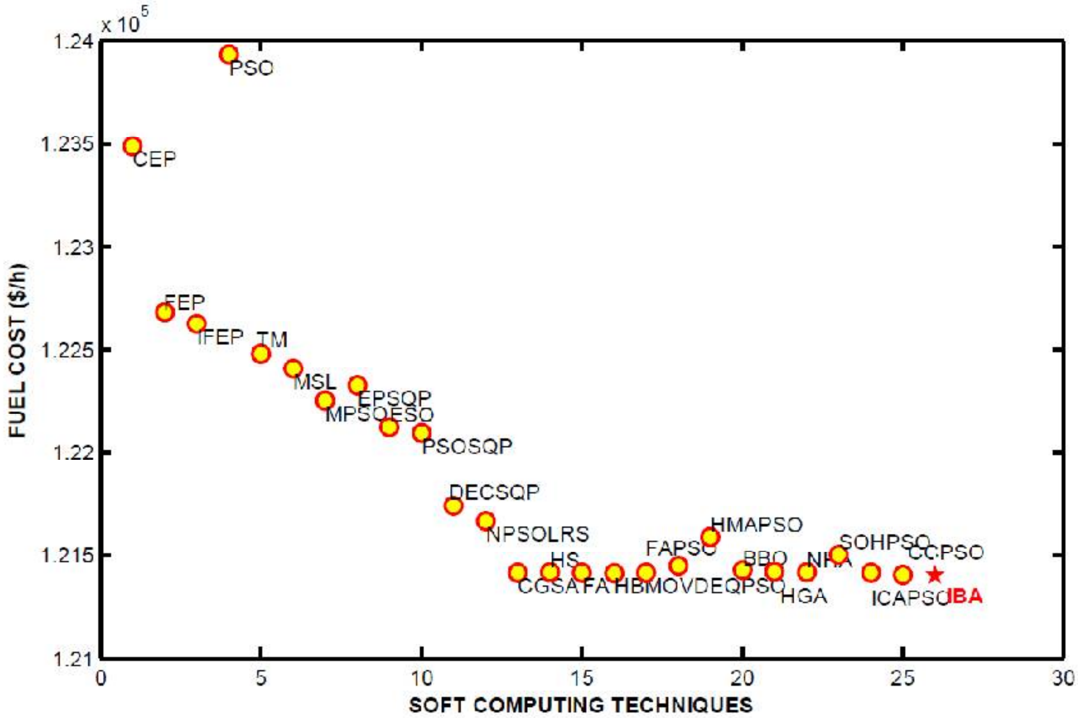


Fig.3.Result Comparison of IBA with Other Techniques.

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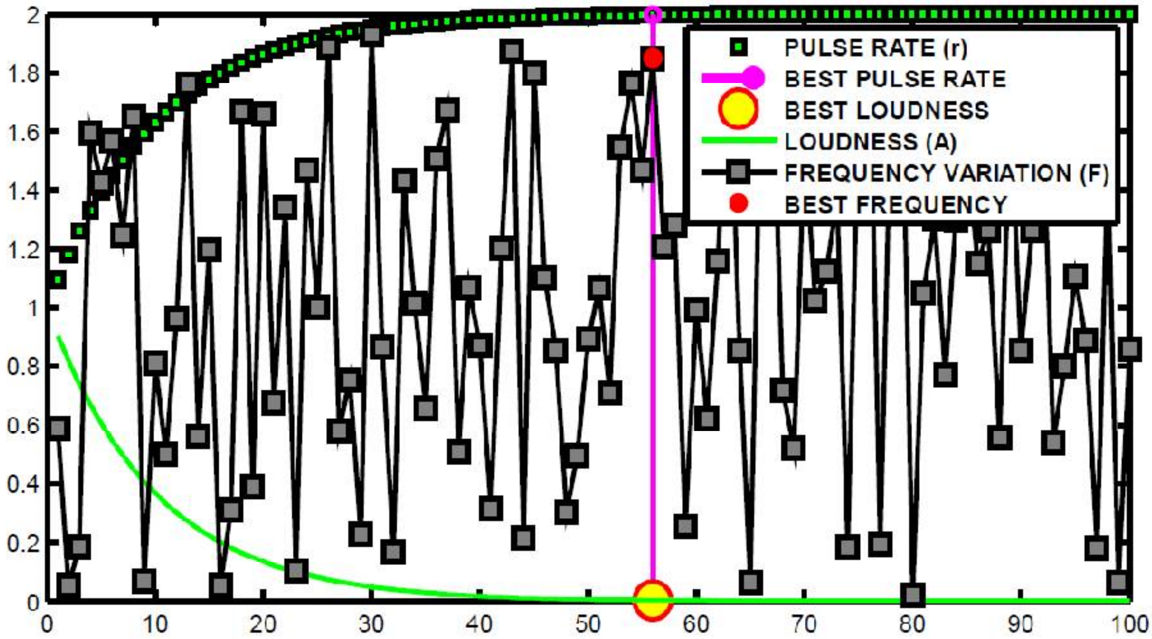


Fig.4.Parameter variation of IBA.

Table-2. Result Comparison of IBA with Other Techniques.

| S.NO | METHODS | FUEL COSTS ($/H) |
|---|---|---|
| 1 | CEP - Classical Evolutionary Programming [9] | 123488.29 |
| 2 | FEP - Fast Evolutionary Programming [9] | 122679.71 |
| 3 | IFEP - Improved Fast Evolutionary Programming [9] | 122624.35 |
| 4 | PSO - Particle Swarm Optimization [9] | 123930.45 |
| 5 | TM - Taguchi Method [9] | 122477.78 |
| 6 | MSL - Maclaurin Series-Based Lagrangian [9] | 122406.10 |
| 7 | MPSO - Modified Particle Swarm Optimisation [9] | 122252.27 |
| 8 | EPSQP - Evolutionary Programming Sequential Quadratic Programming. [9] | 122323.97 |
| 9 | ESO-Evolutionary Strategy Optimisation. [9] | 122122.16 |
| 10 | PSOSQP - Sequential Quadratic Programming [9] | 122094.67 |
| 11 | DECSQP- Decombination With Sequential Quadratic Programming [9] | 121741.98 |
| 12 | NPSOLRS - New PSO With Local Random Search [9] | 121664.43 |
| 13 | CGSA- Clustered Gravitational Search Algorithm [9] | 121414.90 |
| 14 | HS- Harmony Search [10] | 121415.4560 |
| 15 | FA - Firefly Algorithm[10] | 121415.0522 |
| 16 | HBMO - Honey Bee Mating Optimization[10] | 121412.5704 |
| 17 | FAPSOVDE- Variable DE With Fuzzy Adaptive PSO [11] | 121413.3 |
| 18 | QPSO - Quantum Inspired PSO [11] | 121448.21 |
| 19 | HMAPSO - Multi Agent Based Hybrid PSO [11] | 121586.9 |
| 20 | BBO - Bio Geography Based Optimization [11] | 121426.953 |
| 21 | HGA - Hybrid Genetic Algorithm [11] | 121418.27 |
| 22 | NHA - New Heuristic Algorithm [11] | 121416.937 |
| 23 | SOHPSO - Self-Organizing Hierarchical PSO[12] | 121501.14 |
| 24 | ICAPSO -Improved Coordinated Aggregation-Based PSO [12] | 121413.2 |
| 25 | CCPSO -PSO With Both Chaotic sequence and Crossover [13] | 121403.5362 |
| **26** | **IBA-Improved Bat Algorithm** | **121401.1112** |

## VI. CONCLUSION

In this paper, Improved Bat algorithm is applied to economic load dispatch problems with forty unit system as a test case. The results obtained by this method are compared with other soft computing techniques. The comparison shows that Improved Bat algorithm performs better and got good convergence characteristics. The Bat algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that Improved Bat algorithm is a promising technique for solving complicated problems in power system.

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