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Price Based Optimal Scheduling Of Thermal Units In Deregulated Power System Using Intelligent Algorithm

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Abstract: Optimal power generation of thermal units is one of the salient problems in interconnected power system. Economical power production is key operations for minimizing the overall operating cost of the system. Under deregulated environment, optimal generation scheduling is changed in to self scheduling of Generation Companies (GENCOs) to maximize the owners profit and referred as Profit Based Unit Commitment (PBUC) Problem. This paper solves the PBUC problem to maximize the profit of GENCOs by proper scheduling of thermal generators A new nature-inspired human-based optimization algorithm of Corona Virus Herd Immunity Optimizer (CVHIO) is proposed to achieve the maximum profit of GENCOs. The inspiration of CVHIO is originated from the herd immunity concept as a way to tackle corona virus pandemic (COVID-19). The CVHIO is a very powerful optimization algorithm that can be used to tackle many optimization problems across a wide variety of optimization domains. Validity of the projected method tested on IEEE 39 bus system and simulation results are numerically reported. Comparative study is also done to prove the effectiveness of proposed CVHIO approach.

1. INTRODUCTION

The introduction of deregulation and restructuring in Electric power system creates a competitive open market scenario to improve the performance and optimal operation of existing power systems [1]. In the deregulated electricity markets, generation companies (GENCOs) are operated to maximize their own profit apart from minimizing the total production cost. In this process, it is not necessary for GENCOs to meet the system demand and reserve generation. So, the unit commitment performed by these GENCOs has a different objective than that of traditional unit commitment and is referred as profit based unit commitment (PBUC) to emphasize the significance of profit [2, 3].

Many researchers documented various approaches to solve the PBUC problem. .Earlier, classical methods such as Lagrangian relaxation, Mixed-integer programming, Muller method and Tabu- search [4-9] were used to solve the PBUC problem. Also stochastic optimization techniques such as Genetic algorithm, Memetic algorithm, Ant colony optimization, PSO, ABC and hybrid approaches [10-15] were introduced to solve the PBUC problem.

Nowadays, Prabakaran et al. [16] have presented a Hybrid Particle Swarm Optimization (HPSO) algorithm that integrates the features of Evolutionary Programming (EP) and Particle Swarm Optimization (PSO) to solve the PBUC problem. with emission limitations. The EP method has applied to solve the 1-0 part of the PBUC problem and PSO method optimizes the economic load dispatch (ELD) which is a sub-problem of PBUC. Security Constrained Unit Commitment (SCUC) in a power system executes ISO using Mixed Integer Programming (MIP) and Benders Decomposition (BD) approach in thermal generating units by [17]. Here, minimize production cost of generating units and value of the loss of load (VOLL) cost considering load shedding at each bus.

The ABC algorithm with Tabu search (TS) has been proposed [18] to solve the PBUC problem in deregulated electricity market with emission limitations. The multi-objective optimization problem is formulated to maximize the profit and minimize the pollutants into the atmosphere by satisfying all the system constraints. ABC algorithm is applied to solve the 1-0 part of the PBUC problem and lambda iterative method optimizes the economic load dispatch problem. Elephant Herding Optimization (EHO) algorithm [19] to get solution for the PBUC problem under deregulated power marketplace. The effectiveness of projected EHO has been tested on various systems with various market conditions. An Adaptive Predator-Prey Optimization (APPO) has been proposed by [20] to solve multi-objective thermal power dispatch problem considering objectives of operating cost and pollutant emission. The performance of the proposed algorithm is investigated on six power system test problems.

Solves PBUC problem [21] using quantum inspired binary grey wolf optimizer (QI-BGWO) algorithm. The proposed QI-BGWO is modelled to solve UC problem with test systems of different dimensions starting from 10 to 100 units for 24 h scheduling horizon. This method is tested in 20 units, 40 units, 60 units, 80 units and 100 units are generated by duplicating the 10 unit test system. Similarly, the hourly load for the test systems other than 10 unit system is estimated by duplicating/multiplying with appropriate scalar value. A hybrid Lagrange Relaxation (LR)–Differential Evolution (DE) [22] has been applied for solving the PBUC problem The LR method identifies the optimal UC schedule and the DE algorithm is used to update the Lagrange multipliers with economic operation of generators.

The integration of binary successive approach (BSA) and civilized swarm optimization (CSO) has been proposed [23] to solve same problem. This strategy reduces the computational burden while searching the optimal unit status. In this method three test systems have been undertaken. In reference [24] projected a binary coded fireworks algorithm through mimicking spectacular display of glorious fireworks explosion in sky. This algorithm is tested on thermal unit system for different participation scenarios namely with and without reserve market participation. A binary sine–cosine algorithm (BSCA) applied [25] for solving PBUC problem. The SCA based on fluctuating nature of individual candidates/search agents in the search space around the global solution. It uses modified sigmoid transformation function for binary mapping of continuous real-valued search space to binary counterpart.

Cuckoo search ahead with GWO has been developed to [26] solve PBUCP in a restructured power market. Under this structure, the issues in profit are improved using objective functions such as maximize profit of GENCOs. Emission constrained PBUC has been formulated as a bi-objective optimization function and solved using Exchange Market (EM) algorithm [27]. Here, two conflictive objectives of profit maximization and reduction of environmental emission has been considered. Three binary grey wolf optimizer (BGWO) has been presented to obtain the solution [28]. The algorithm tested on two test systems, a 3 unit and a 10 unit test system. In addition, two cases of GENCO market participation with and without reserve market participation was also simulated.

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Lagrangian relaxation (LR) combined with secant method-invasive weed optimization (IWO) [29] has been applied to maximize GENCOs profit. It has been tested for various test cases such as 3 units, 10 units and 20 units system. A memetic binary differential evolution [30] algorithm has been proposed to obtain the solution by committing and scheduling the thermal generating units efficiently. The algorithms has been researched on the PBUCP test systems comprising of 10-, 40- and 100-units test system.

In this paper, express the solution of PBUC problem in a commutative electricity market. A new intelligent and natural inspired optimization tool of CVHIO algorithm is proposed to maximize the profit of GENCOs.in the day-ahead energy and markets. Numerical example with IEEE 39 bus test system is conceded to illustrate the performance of proposed CVIHO algorithm.

2. PROBLEM FORMULATION OF PBUC PROBLEM

The objective is to determine the generating unit schedules for maximizing the profit of Generation Companies subject to all prevailing constraints such as load demand, spinning reserve and market prices. The term profit is defined as the difference between revenue obtained from sale of energy with market price and total operating cost of the generating company

The objective function

The PBUC can be mathematically formulated by the following equations.

$$Maximize\ PF = RV - TC \tag{1}$$

$$RV = \sum_{t=1}^{T}\sum_{i=1}^{N} P_{it} SP_t X_{it} \tag{2}$$

$$TC = \sum_{t=1}^{T}\sum_{i=1}^{N} F(P_{it}) X_{it} + ST.X_{it} \tag{3}$$

The total operating cost, over the entire scheduling period is the sum of Fuel cost and start-up/shutdown cost for all the units. Here, the shutdown cost is considered as equal to zero for all units.

The Fuel cost of the scheduled units is given in a quadratic form

$$Min.F_{it}(P_{it}) = a_i + b_i P_{it} + C_i P_{it}^2 \tag{4}$$

Constraints

1. Load demand constraint

$$\sum_{i=1}^{N} P_{it} X_{it} \leq P_{D\,t} \qquad 1 \leq i \leq N \tag{5}$$

2. Generator limits constraint

$$P_i^{\min} \leq P_i \leq P_i^{\max} \qquad 1 \leq i \leq N \tag{6}$$

3. Spinning reserve constraint

$$\sum_{i=1}^{N} R_{it} X_{it} \leq SR \qquad 1 \leq t \leq T \tag{7}$$

4. Minimum up/down time constraints

$$\begin{aligned} &Ton_i \geq Tup_i, \quad i = 1.........N \\ &Toff_i \geq Tdown_i, \quad i = 1.........N \end{aligned} \tag{8}$$

3. SOLUTION METHODOLOGY

3.1 Overview of Corona Virus Herd Immunity Optimizer (CVHIO)

A new nature-inspired human-based optimization algorithm of Corona Virus Herd Immunity Optimizer (CVHIO) is proposed in this research work [31, 32]. The motivation of CVHIO is originated from the herd immunity concept as a way to tackle corona virus pandemic (COVID-19). The speed of spreading corona virus infection depends on how the infected individuals directly contact with other society members. In order to protect other members of society from the disease, social distancing is suggested by health experts. Herd immunity is a state the population reaches when most of the population is immune which results in the prevention of disease transmission. Here, three types of individual cases are utilized for herd immunity: susceptible, infected, and immuned. This is to determine how the newly generated solution updates its genes with social distancing strategies. The structure of Herd immunity and Population hierarchy of CVHIO are represented fig. 1 and fig. 2.

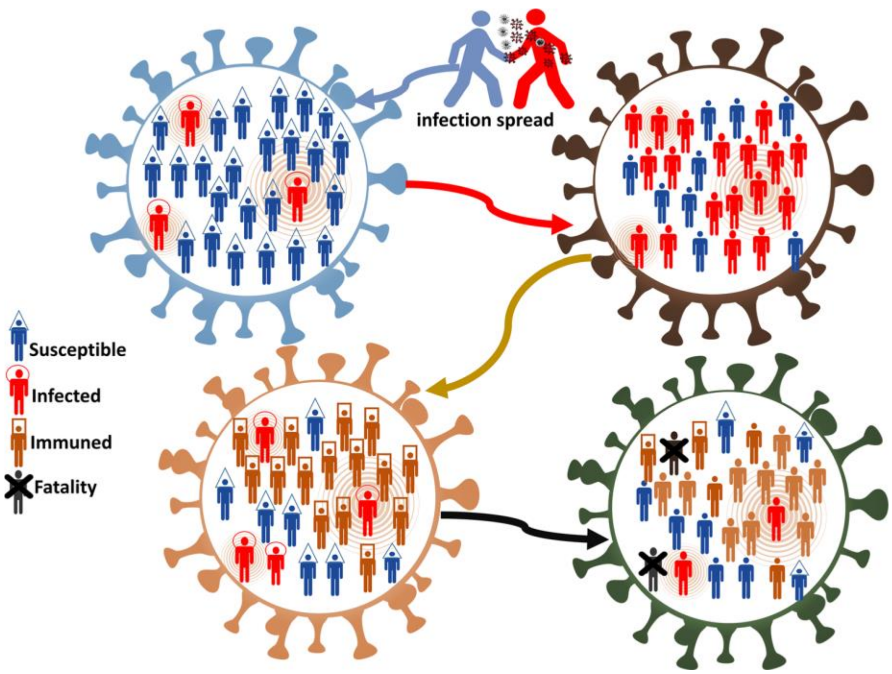

Fig. 1 Herd immunity of CVHIO

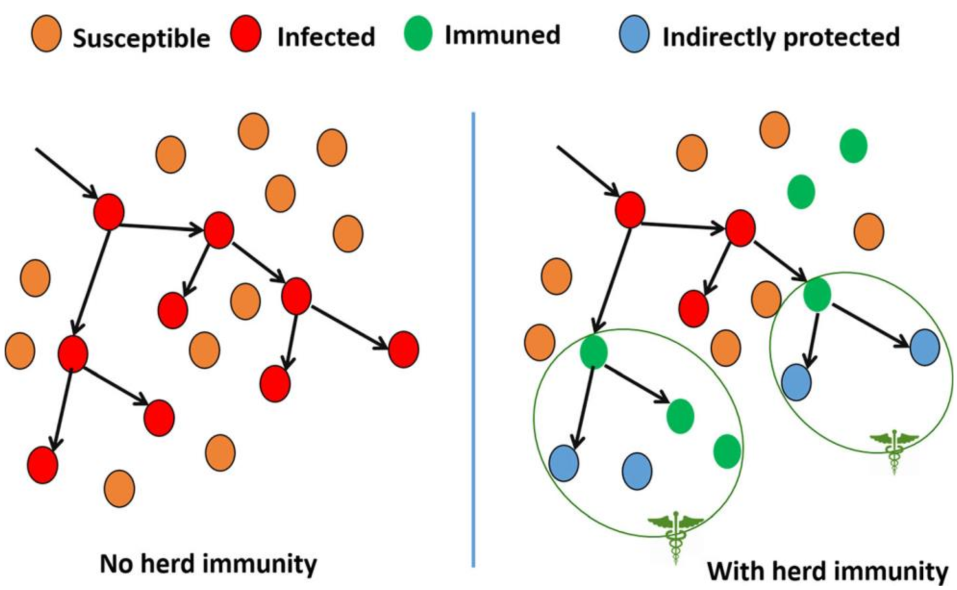

Fig. 2 Population hierarchy of CVHIO

3.2 Implementation of CVHIO for PBUC optimization problem

These concepts are modeled in terms of optimization concepts for the solution of engineering optimization problems. From the overview, CHIO is a very powerful optimization algorithm that can be used to solve the PBUC optimization problem under deregulated environment. The implementation flowchart of CVHIO algorithm is illustrated in fig. 3 The algorithm has six main steps discussed as follows:

a. Initialization

Initialize parameters of CHIO and optimization problem. In this step, the optimization problem is formulated in the context of objective function as follows:

$$\min_{x} f(x) \quad x \in [lb, ub] \tag{9}$$

b. Generate herd immunity population

Initially, CHIO randomly (or heuristically) generates a set of cases (individuals) as many as HIS. The generated cases are stored as two-dimensional matrix of size n×HIS in herd immunity population (HIP) as follows:

$$HIP = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_n^1 \\ x_1^2 & x_2^2 & \cdots & x_n^2 \\ \vdots & \vdots & \cdots & \vdots \\ x_1^{HIS} & x_2^{HIS} & \cdots & x_n^{HIS} \end{bmatrix} \tag{10}$$

c. Corona virus herd immunity evolution

This is the main improvement loop of CHIO. The gene (x_i^j) of case x^j is either remain the same or affected by social distancing using three rules according to the percentage of the BR_r as follows:

$$x_i^j(t+1) \leftarrow \begin{cases} x_i^j(t) & r \geq BR_r \\ C(x_i^j(t)) & r < \frac{1}{3} \times BR_r. \quad \text{//infected case} \\ N(x_i^j(t)) & r < \frac{2}{3} \times BR_r. \quad \text{//susceptible case} \\ R(x_i^j(t)) & r < BR_r. \quad \text{//immuned case} \end{cases} \tag{11}$$

where r generates a random number between 0 and 1.The three rules can be discussed as follows:

Infected case: Within the range of $r \in \left[0, \frac{1}{3} BR_r\right)$, the new gene value of $x_i^j(t+1)$ is affected by some social distancing which is achieved by the difference between current gene and a gene taken from an infected case $\mathbf{x}^m$ such as

$$x_i^j(t+1) = C\left(x_i^j(t)\right) \tag{12}$$

where

$$C\left(x_i^j(t)\right) = \mid x_i^j(t) + r \times \left(x_i^j(t) - x_i^c(t)\right) \tag{13}$$

Note that the value $x_i^c(t)$ is randomly chosen from any infected case x^c based on the status vector (S) such that $C = \{i \mid S_i = 1\}$

Susceptible case: Within the range of $r \in \left[\frac{1}{3} BR_r, \frac{2}{3} BR_r\right)$, the new gene value of $x_i^j(t+1)$ is affected by some social distancing which is achieved by the difference between the current gene and a gene taken from a susceptible case $\mathbf{x}^m$ such as

$$x_i^j(t+1) = N\left(x_i^j(t)\right) \tag{14}$$

where

$$N\left(x_i^j(t)\right) = x_i^j(t) + r \times \left(x_i^j(t) - x_i^m(t)\right) \tag{15}$$

Note that the value $x_i^m(t)$ is randomly spread from any susceptible case $\mathbf{x}^m$ based on the status vector (S) such that $m = \{i \mid S_i = 0\}$.

Immuned case: Within the range of $r \in \left[\frac{2}{3} BR_r BR_r\right)$ the new gene value of $x_i^j(t+1)$ is affected by some social distancing which is achieved by the difference between the current gene and a gene taken from an

immuned case $\mathbf{x}^v$ such as

$$x_i^j(t+1) = R\left(x_i^j(t)\right) \tag{16}$$

where

$$R\left(x_i^j(t)\right)=x_i^j(t)+r\times\left(x_i^j(t)-x_i^m(t)\right) \tag{17}$$

Note that the value $x_i^v(t)$ is spread from the best immuned case $\mathbf{x}^v$ based on the status vector (S) such that

$$f\left(x^v=\arg\min_{j\sim\{k|S_k=2\}} f\left(x^j\right)\right)$$

d. Update herd immunity population

The immunity rate $f\left(x^j(t+1)\right)$ of each generated case $x^j(t+1)$ is calculated and the current case $x^j(t)$ is replaced by the generated case $x^j(t+1)$, if better, such as $f\left(x^j(t+1)\right)<f\left(x^j(t)\right)$. The age vector A_j is also increased by one if S_j=1.

The status vector (S_j) is updated for each case x^j based on the herd immune threshold which utilizes the following equation:

$$S_j\leftarrow\begin{cases}1 & f\left(x^j(t+1)\right)<\dfrac{f(x)^j(t+1)}{\Delta f(x)}\wedge S_j=0\wedge is\_corona\left(x^j(t+1)\right)\\ 2 & f\left(x^j(t+1)\right)>\dfrac{f(x)^j(t+1)}{\Delta f(x)}\wedge S_j=1\end{cases} \tag{10}$$

e. Fatality cases

In case the immunity rate $\left(f\left(x^j(t+1)\right)\right)$ of the current infected case (S_j == 1) could not improve for a certain number of iterations as specified by the parameter Max_Age (i.e., A_j ≥Max_Age), then this case is considered died. After that, it is regenerated from scratch using $x^j(t+1)=lb_i+\left(ub_i-lb_i\right)\times U(0,1),\ \forall i=1,2,\ldots\ldots,n$. Furthermore, A_j and S_j are set to zero. This can be useful to diversify the current population and thus escaping local optima.

f. Stop criterion

CHIO repeats Step 3 to step 6 until the termination criterion which normally depends if the maximum number of iteration is reached. In this case, the total number of susceptible and immuned cases dominate the population. The infected cases are also disappeared.

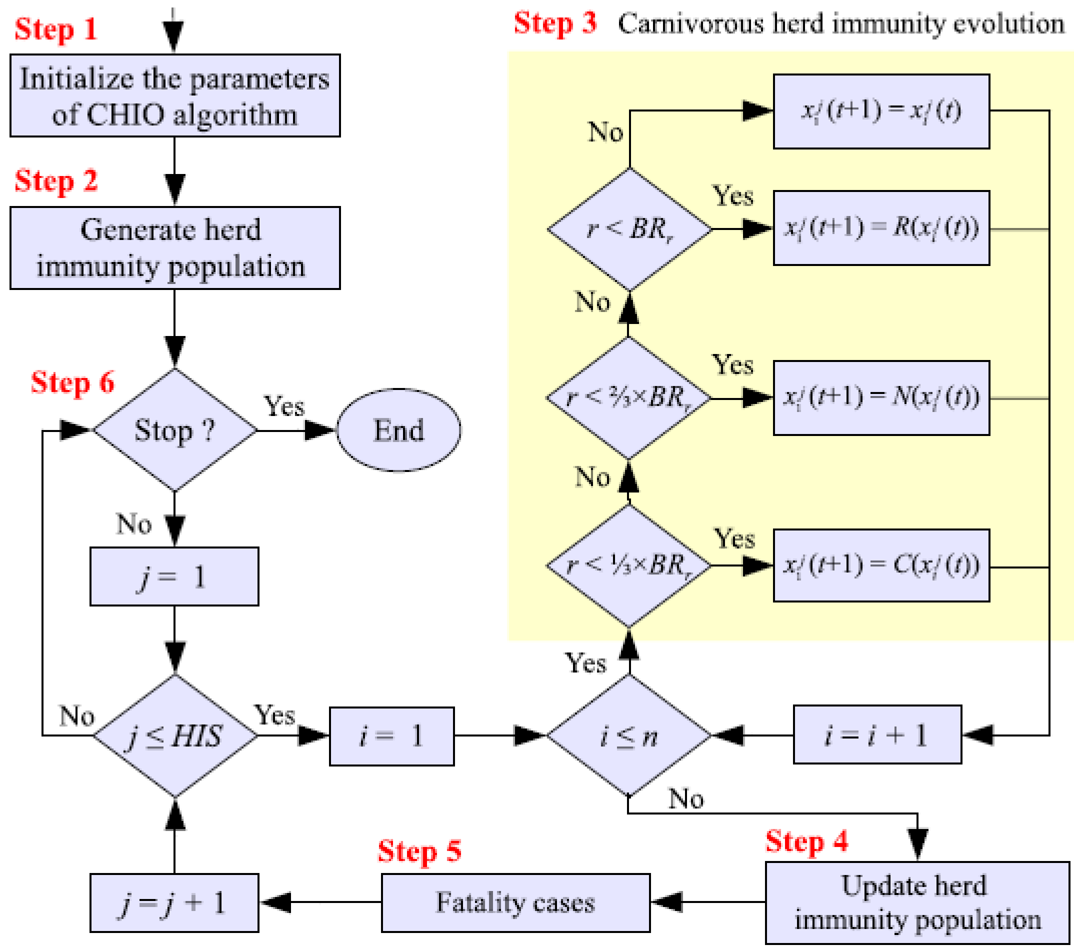

Fig. 3 Flow diagram of proposed CVHIO algorithm

4. SIMULATION AND RESULTS COMPARISON

The effectiveness of proposed CVHIO algorithm are analyzed and solve the PBUC problem. Simulation is carried out using IEEE 39 bus test system. This test system adapted from [13] consisting of ten generating units with twenty four hour scheduling periods and the fuel cost of each generators is estimated into quadratic form. The generator data, forecasted market price and demand are also considered from the same reference. The Single line diagram of IEEE-39 Bus System is shown in fig. 4.

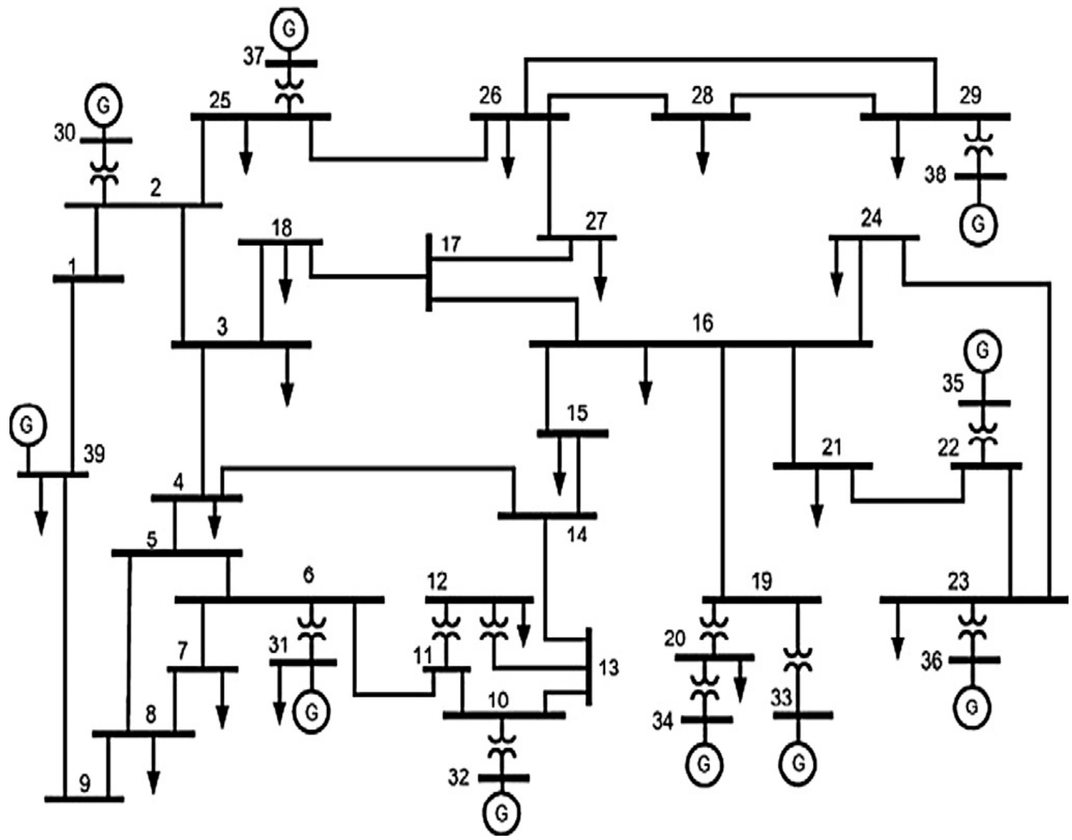

Fig. 4. Single line diagram of IEEE-39 Bus System

The proposed CVHIO methodology is experienced to demonstrate its superior performance on ten units twenty four hour system using MATLAB software 11.0. Simulation was carried out to obtain the profit of GENCOs holding a cumulative installed power of about 1662 MW.

Table 1 Unit Status of Conventional UC and PBUC (Proposed) for Ten unit 24 hour system

H (h)	Unit Commitment										Profit based Unit Commitment (Proposed)									
	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**	**U1**	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
1	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
2	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
3	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
4	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
5	ON	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
6	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
7	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
8	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
9	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
10	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
11	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF

12	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
13	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
14	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
15	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
16	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
17	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
18	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
19	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
20	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
21	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
22	ON	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
23	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
24	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

H (h)	PD (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	P7 (MW)	P8 (MW)	P9 (MW)	P10 (MW)	Power Gen (MW)
1	700	454.8439	245.1561	0	0	0	0	0	0	0	0	700
2	750	296.2006	453.7994	0	0	0	0	0	0	0	0	750
3	850	405.3151	444.6848	0	0	0	0	0	0	0	0	849.9999
4	950	455.0000	455.0000	0	0	0	0	0	0	0	0	910
5	1000	455.0000	455.0000	0	0	0	0	0	0	0	0	910
6	1100	455.0000	455.0000	0	130.0000	0	0	0	0	0	0	1040
7	1150	454.9835	454.9953	0	130.0000	0	0	0	0	0	0	1039.979
8	1200	455.0000	455.0000	0	130.0000	0	0	0	0	0	0	1040
9	1300	454.9981	454.9894	129.9932	129.9998	130.0194	0	0	0	0	0	1300
10	1400	454.7905	454.6826	129.9882	129.4702	157.7756	73.2928	0	0	0	0	1400
11	1450	455.0000	455.0000	130.0000	130.0000	162.0000	79.9883	0	0	0	0	1411.988
12	1500	455.0000	455.0000	130.0000	130.0000	162.0000	79.9883	0	0	0	0	1411.988
13	1400	455.0000	455.0000	130.0000	130.0000	162.0000	71.58248	0	0	0	0	1403.582
14	1300	455.0000	455.0000	122.6409	130.0000	116.1076	0	0	0	0	0	1278.749
15	1200	455.0000	455.0000	130.0000	130.0000	0	0	0	0	0	0	1170
16	1050	455.0000	454.9937	0	129.9973	0	0	0	0	0	0	1039.991
17	1000	454.9957	416.1059	0	128.8983	0	0	0	0	0	0	999.9999
18	1100	455.0000	454.9912	0	130.0000	0	0	0	0	0	0	1039.991
19	1200	455.0000	455.0000	0	129.9914	0	0	0	0	0	0	1039.991
20	1400	455.0000	455.0000	0	130.0000	0	0	0	0	0	0	1040
21	1300	455.0000	454.9912	0	130.0000	0	0	0	0	0	0	1039.991
22	1100	455.0000	454.9912	0	130.0000	0	0	0	0	0	0	1039.991
23	900	450.226	449.7658	0	0	0	0	0	0	0	0	899.9918

24	800	346.2582	453.7526	0	0	0	0	0	0	0	0	800.0108

Table 2 Power generation of IEEE39 bus test system by proposed method

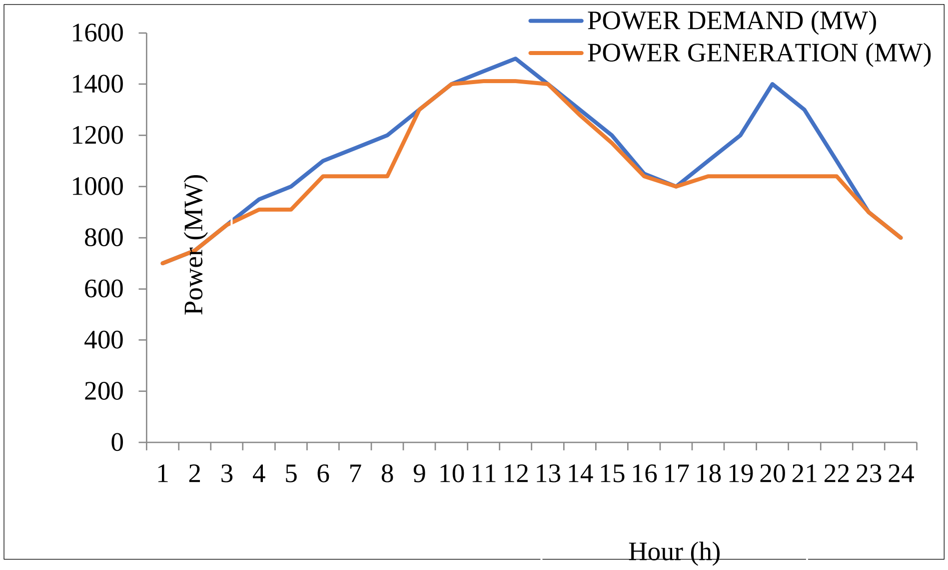

Fig. 5 Power generation and power demand of the 10 unit 24 hour test system

Table 3 Simulation Results of IEEE39 bus test system by proposed method

H (h)	Power Demand (MW)	Power Generation (MW)	Fuel cost ($)	Start up cost ($)	Revenue ($)	Profit ($)
1	700	700	13683	0	15505	1822
2	750	750	14554	0	16500	1946
3	850	849.9999	16302	0	19635	3333
4	950	910	17353.2228	0	21521.5	3258.777
5	1000	910	17353.2903	0	20247.5	3804.71
6	1100	1040	20213.8818	1120	23868	2534.118
7	1150	1039.979	20213.8839	0	23399.53	4561.116
8	1200	1040	20213.8818	0	23036	5702.118
9	1300	1300	26184	2900	29640	1656
10	1400	1400	28768	340	41090	11892
11	1450	1411.988	29047.841	0	42571.44	13524.16
12	1500	1411.988	29047.841	0	44689.42	15642.16
13	1400	1400.582	28768.2821	0	34454.32	5671.718
14	1300	1278.749	26210.8653	0	31329.35	5639.135
15	1200	1170	23106	0	26325	3219
16	1050	1039.991	20213.8818	0	23191.8	3201.118

17	1000	999.9999	19513	0	22250	2737
18	1100	1039.991	20213.8818	0	22931.8	2718.118
19	1200	1039.991	20213.8861	0	23087.8	2874.114
20	1400	1040	20213.9588	0	23556	3342.041
21	1300	1039.991	20213.8818	0	24023.79	3810.118
22	1100	1039.991	20213.8818	0	23867.79	3654.118
23	900	899.9918	17177.9396	0	20474.81	3297.06
24	800	800.0108	15442.7154	0	18040.24	2597.285
Total ($)			**504437**	**4360**	**615236.10**	**106439.10**

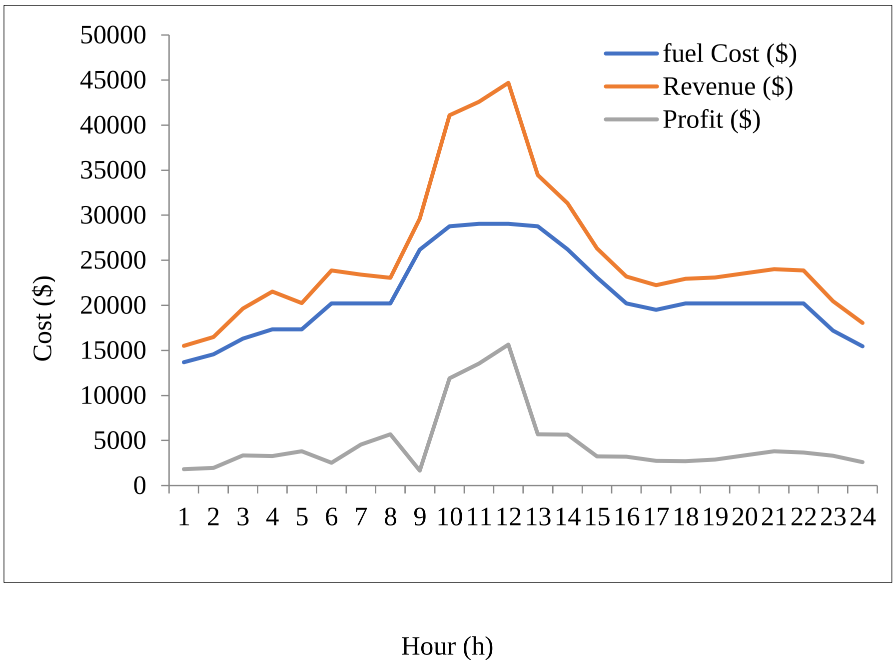

Fig. 6 Fuel cost, Revenue and Profit of IEEE39 bus test system

The control parameters of proposed approach is represented as Herd Immunity Size (HIS) is 40, Basic Reproduction Rate (BRr) is 0.05 and maximum age of the infected cases (Max Age) is 300. The approach is having more ability to achieving the best solutions.

Table 1 depicts scheduling of committed units, under traditional UC approach which ensures the equilibrium nature of Generation and Demand. The Table 1 also provides information for the PBUC in which inequality demand constraint is explained. From this table, it is observed that the GENCO decides to shut OFF Units 7 to 10 in all the commitment period and to sell power below the forecasted level in some periods.

Table 4 Comparison of total profits of proposed method with the existing methods

Method	Total Profit ($/24h)	Profit difference with proposed Method ($/24h)	CPU Time (Sec)
Traditional UC	75093	31346.10	---
TS-RP	101086	5353.1	---
TS-TRP	103261	3176.10	---
Muller Method	103296	3143.10	---
ACO	103890	2549.10	---
PSO	104356	2083.10	---
NACO	105549	890.10	---
PABC	105878	561.10	83.87
MPPD–ABC	106301	138.10	55.46
CVHIO (Proposed Method)	**106439.10**	**---**	**53.59**

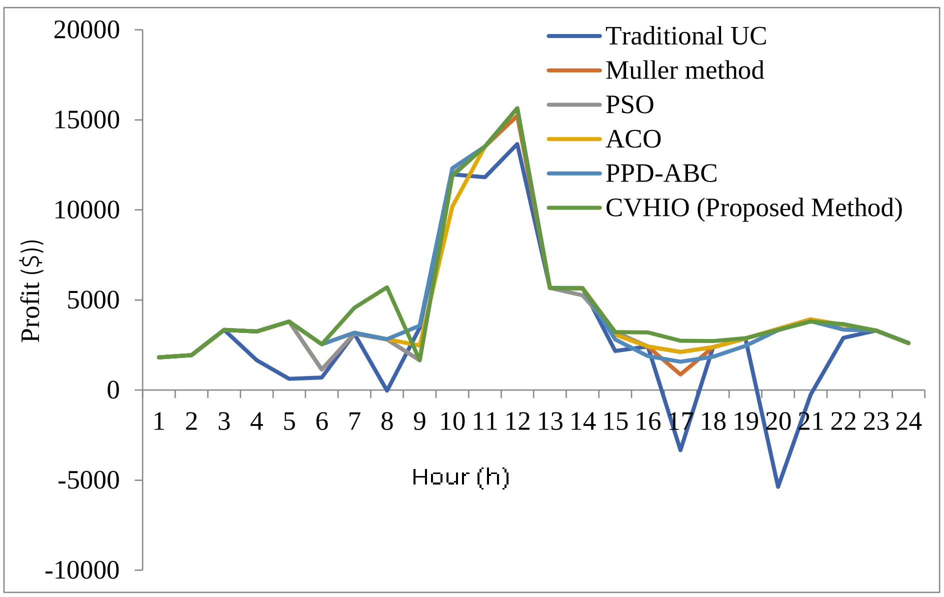

Fig. 7 Comparison of profits of proposed method with other methods

The power generation of each generators and total power generation of committed units are numerically reported in Table 2. The graphical representation of power generation and load demand of referred test system is illustrated in fig.5. Table 3 describes the simulation results of the proposed test system. It includes generated output power, fuel cost, start-up cost, revenue, and profit of GENCOs for entire 24 hour. The total profit and computational time is $ 106439.10 and 53.59 sec. Revenue, Total cost and Profit of the GENCOs is reported for each hour of the day-ahead electricity market. The graphical representation of fuel cost, revenue and profit for 24 hour is reported in fig. 6.

The result of the proposed method is compared with that of existing methods such a traditional UC, TS-RP, TS-IRP, Muller method, ACO, PSO NACO, PABC and MPPD–ABC are displayed in Table 4 and graphically displayed in fig.7. From the results, it is clear that the proposed method provides maximum profits and is compared with those published in the recent literatures.

5. CONCLUSION

This paper solves the Profit Based Unit Commitment (PBUC) problem is described under deregulated environment. A new and natural inspired optimization algorithm of CVHIO is proposed to solve the PBUC problem. The CVHIO is effectively determines the most economical scheduling plan for GENCO by considering both power demand and market price. To demonstrate the efficiency and applicability of this algorithm it has been tested on IEEE 39- bus test system (ten units 24 hour and fifty units 24 hour) optimized results are displayed. Results are obtained for the optimal unit commitment schedule and MW values for real power, hourly profit and also the total profit of the GENCO. The simulation result has been compared with other soft computing and hybrid methods This results show that the proposed algorithm provides maximum profit with less computational time compared to existing methods.

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