https://doi.org/10.33472/AFJBS.6.6.2024.7124-7134

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Optimum Unit Commitment Using Genetic Algorithm Toolbox

Sarika Tade[1], Amol Kalage[2], Ratnamala Biradar[3], Sachin Datey[4], Vijaykumar Kamble[5], Amita Mane[6]

[1,2,3,4]Department of Electrical Engineering, Sinhgad Institute of Technology, Lonavala, (MS), India
[5]Department of Electrical Engineering, AISSMS, Institute of Information Technology, Pune, (MS), India
[6]First Year Engineering Department, Pimpri Chinchwad college of Engineering, Ravet, Pune, (MS), India

Article Info

Volume 6, Issue 6, July 2024

Received: 22 May 2024

Accepted: 20 June 2024

Published: 13 July 2024

doi: 10.33472/AFJBS.6.6.2024.7124-7134

ABSTRACT:

Optimum Unit Commitment (UC) is one of the most challenging tasks to the power system operator as it directly related to the generation cost. This motivates the researchers to formulate the optimization problem to minimize the generation cost by committing the generation units with satisfying total load demand. In this paper UC problem is formulated to minimize the total generation cost. Genetic Algorithm is applied directly using the toolbox available in MATLAB software. The results show that the GA Toolbox has capable to find the solution with lower time compared to program developed using m-file. Also it reduces the efforts and complications in program development. Also, the effectiveness of GA Toolbox is validated by comparing the results the various techniques available in the literature. The obtained results represent the reduction in total operating cost with satisfying all the constraints of the UC problem.

Keywords: GA Toolbox, MATLAB, Optimization, Unit Commitment,

1. Introduction

Unit commitment (UC) is a crucial optimization problem in power systems and electrical grid management. It involves determining the optimal -schedule for activating or deactivating generating units to meet the forecasted electricity demand at the lowest possible cost while satisfying various operational constraints. The primary goal of unit commitment is to find an economically efficient and reliable generation schedule for power plants over a specific time horizon. Unit commitment plays a vital role in the efficient and reliable operation of power systems, contributing to the economic dispatch of electricity generation resources while maintaining system stability. Researchers continuously explore new methods and algorithms to address the complexities and challenges associated with unit commitment in modern power systems. Conventionally, the unit commitment process, also known as generation scheduling, involves solving a mixed-integer optimization problem. This problem aims to determine the optimal times for starting up and shutting down power generators over a specified time period. The goal is to minimize operational costs while ensuring the fulfilment of load demand and compliance with various constraints [1-2]. Initially the UC problem is solved by Priority List Method and Dynamic Programming (DP). The priority list is a simple heuristic approach where generating units are ordered based on their operating costs, and units are committed in ascending order until demand is satisfied and DP represents an optimization technique that breaks down the problem into sub-problems and solves them recursively.
Numerous researchers have dedicated their efforts to develop various optimization strategies for addressing the unit commitment problem. The conventional methods for unit commitment include the traditional methods like priority list method [3-4] and dynamic programming [5-6]. However, it is noteworthy that the classical priority list method tends to yield solutions associated with higher generation costs. The dynamic programming approach faces challenges related to dimensionality, resulting in an escalation of total computation time as the number of generation units increases. Additionally, these methods encounter convergence issues and produces local solutions. Recently, researchers have developed various artificial intelligence-based optimization algorithms inspired by natural phenomena. Numerous numerical techniques, including linear programming (LP) and nonlinear programming (NLP) [10–14], have been explored for solving the Unit Commitment problem. In addition, meta-heuristic approaches such as genetic algorithms (GA) [8-9], adaptive genetic algorithms [10], tabu search [11], ant colony optimization (ACO) [12], artificial bee colony algorithms [13], and particle swarm optimization (PSO) [14–16] have gained popularity. Researchers have also explored various optimization techniques such as the glowworm metaphor algorithm [17], quantum-inspired binary gravitational search algorithm [18], improved gravitational search algorithm [19], and Teaching Learning based optimization algorithm [20] for optimum unit commitment. This paper presents use of Genetic Algorithm toolbox to solve the Unit Commitment Problem effectively.

1. Problem Formulation

1.1. Objective function

The objective function is formulated to minimize the fuel cost for a day. This is having an addition of fuel cost of all generating units for 24 hours. The total cost including fuel cost, start-up cost and shutdown cost is considered to minimize the total generation cost of all thermal units as represented in Eq. (1) and considered as objective function for the UC problem [10].

$$\min Z = \sum_{j=1}^{H}\sum_{i=1}^{N}\left\{C_i PG_{i,j} + SUC_{i,j}.\left[1 - u_{(i,j-1)}\right]\right\} u_{i,j} + SDC_{i,j} \tag{1}$$

Where

Z - The total operating costto be minimize

CiPGi,j - Fuel cost for ith unit at jth hour

SUCi,j - Start-up cost of ith unit at jth hour

SDCi,j - Shut down cost of ith unit at jth hour

ui,j - On/Off status of ith unit at jth hour

H - Total number of hours

N - Total number of thermal units

2.1.1. Fuel cost function

Eq. (1) contains three terms, the first term is fuel cost. This is calculated using Eq. (2) for each generator depending on power generated by it.

$$C_i\left(PG_{i,j}\right) = a_i + b_i.PG_{i,j} + c_i.PG_{i,j}^2 \quad (2)$$

Where

ai, bi, ci - Cost coefficients for the ith generator

PGi,j - Power generated for ith generator at jth hour

2.1.2. Start-up cost

To start the thermal unit, some parameters are required so set initially. The cost required to set these parameters is known as start-up cost. Further this cost is divided into hot start-up cost and cold start-up cost. Eq. (3) represents the start-up cost of generation unit.

$$SUC_i = \begin{cases} HSUC_i t_i^{off} \le t_i^{down} + t_i^{cold} \\ CSUC_i t_i^{off} > t_i^{down} + t_i^{cold} \end{cases} \quad (3)$$

Where

SUCi - start-up cost of thermal unit i,

HSUCi - hot start-up costs for ith thermal unit ($/h)

CSUCi - cold start-up costs for ith thermal unit ($/h)

t_i^{off} - time of Off state for ith thermal unit at jth hour

t_i^{down} - time of downstate for ith thermal unit at jth hour

t_i^{cold} - time for the cooling state of ith thermal unit

2.1.3. Shutdown cost

As value of shut down cost is very small as compared to start-up cost, so this cost is neglected in further calculations.

1.2. Constraints

2.2.1. Power balance constraint

Power balance constraints considering Thermal units, Wind power and PHS can be represented by Eq. (4).

$$PG_{(i,j)} = LD_j \quad (4)$$

2.2.2. Spinning reserve Constraints

Spinning reserve constraints with Thermal Units is represented by Eq. (5).

$$PG_{(i,j)}^{max}.u_{(i,j)} \ge LD_j + Sr_j \quad (5)$$

2.2.3. Thermal power generation limits

The power generated by each Thermal unit should be within its minimum and maximum limits. This can be mathematically represented by Eq. (6).

$$u_{(i,j)}.PG_{(i,j)}^{min} \le PG_{(i,j)} \le PG_{(i,j)}^{max}.u_{(i,j)} \quad (6)$$

2. Genetic Algorithm

Genetic Algorithm (GA) is an optimization algorithm constructed on Darwin's theory of survival of the fittest. GA is inspired through the principles of natural evolution and natural selection.GA permits a population composed of numerous possible solutions to change under specific rules for the maximization of the fitness function. Like other optimization algorithm GA also starts by defining the objective function (fitness function) and optimization variables and ends by testing for convergence like other optimization algorithms. In GA a strings of binary numbers 0 and 1 represents the total design variables. A design vector is denoted using a total length of a string made up of design variables. The strings of all the variables are placed to achieve the design vector. This string (string of total length) is named as a chromosome and a group of chromosomes recognized as population. In binary representation, a set of discrete values are used to represent a continuous design variable. A string of binary digits is used to represent a continuous design variable. A desired accuracy of the continuous variables can be achieved, using more number of bits for representing the value of variable in its binary representation. Some basic operations like mutation, crossover, and reproduction of natural genetics, are executed throughout the process of numerical optimization carried out by GA.

3. Genetic Algorithm Toolbox

In recent years, MATLAB software is most widely used to solve the complex mathematical operations. This software contains certain toolboxes which will make easy the task of operators. As toolboxes are available in the MATLAB, it is quite easy to do the calculations. One of the toolbox available in the MATLAB software is optimization toolbox. This optimization toolbox is specially designed to obtain the optimum solution of objective function using traditional numerical methods as well as modern heuristic optimization techniques. Genetic algorithm is a tool available in the optimization toolbox and its application to solve the UC problem is presented below. For implementation of algorithm to a unit commitment problem it is necessary to model an objective function along with equality as well as non-equality constraint functions. These functions are coded in MATLAB 'm file' and executed. This will produce the information about objective function and constraint function to the toolbox. Some additional data like number of design variables and their upper and lower limits is also required. Then the optimization is carried out till it satisfies the stopping criteria. Once stopping criteria is satisfied the global optimum solution will displayed. This process is explained below using the case study of 3-Unit system.

3.1. Case Study – I

To illustrate the application of GA toolbox to optimum UC problem a 3-unit system presented in [17] is considered. The 3-unit system data like minimum/maximum limits and generation parameters are presented in Table 1. The objective function is modelled using the system data as per Eq. 3.1 and Eq. 3.2.This objective function to minimize the total fuel cost is expressed by Eq. 3.7

min z = 0.0022*P12+10*P1+500+0.00252*P22+8*P2+300+0.0052*P32+6*P3+100 (7)

where,

P1, P2 and P3 are the power generated by unit 1, 2 and 3 respectively.

Table 1. Three - unit system data [25]

Units	G1	G2	G3
Pmax(MW)	600	400	200
Pmin(MW)	100	100	50
A($/h)	500	300	100
B($/MWh)	10	8	6
C($)	0.002	0.0025	0.005

Start-up cost($)	450	400	300

The objective function presented in Eq. (4) is having equality and inequality constraints. Equality constraints are used to represents the upper and lower limit of generator units and inequality constraint represents the balance between the total load demand and total generation of all the units running in parallel.

These constraints are represented by Eq. (4), Eq. (5) and Eq. (6) respectively.

$100<P1<600$

$100<P2<400$

$50<P3<200$ (8)

$PD= P1 + P2 + P3$ (9)

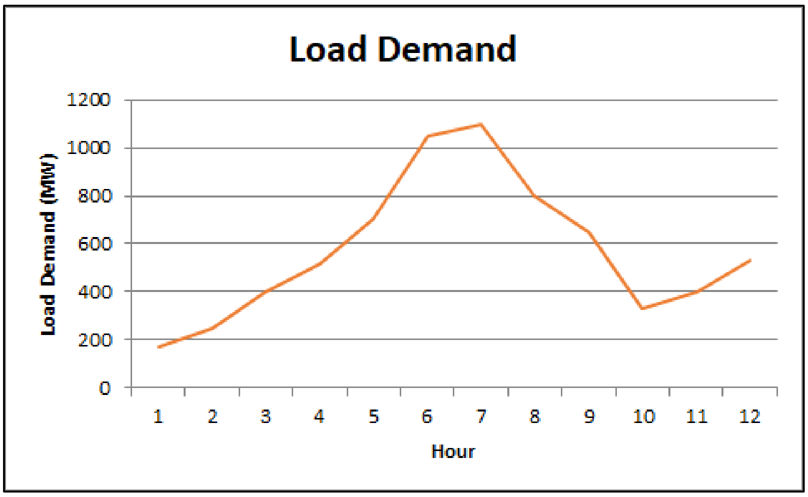
The objective function presented in Eq. (1) and the constraint function modeled as per in Eq. (4), Eq. (5) and Eq.(6) are coded in MATLAB 'm' file and represented using Fig. 1 and Fig. 2 respectively. These functions are executed in command window to call the data in GA toolbox. Some additional information like number of design variables, upper and lower bounds on generator units are provided. Fig. 3 represents the GA toolbox with the input data. The optimization using GA toolbox is carried out for the various load demand as per the Fig.3.5.This figure represents the load demand for 12 hours which will be supplied by 3-unit system. The obtained results are tabulated in Table 3.2. This table gives the load shared by each unit and the generation cost of each unit.

```
Unit_Commitment_hourly.m   myfun.m   nonlconctr.m
function f=myfun(x)
f=(0.002*x(1)^2+10.0*x(1)+500+0.0025*x(2)^2...
+8*x(2)+300+0.005*x(3)^2+6*x(3)+100);
```

Objective function for 3 – unit system

```
Unit_Commitment_hourly.m   myfun.m
function [c,ceq]=nonlconctr(x)
c=[100-x(1);
    x(1)-600;
    100-x(2);
    x(2)-400;
    50-x(3);
    x(3)-200;];
ceq=[];
```

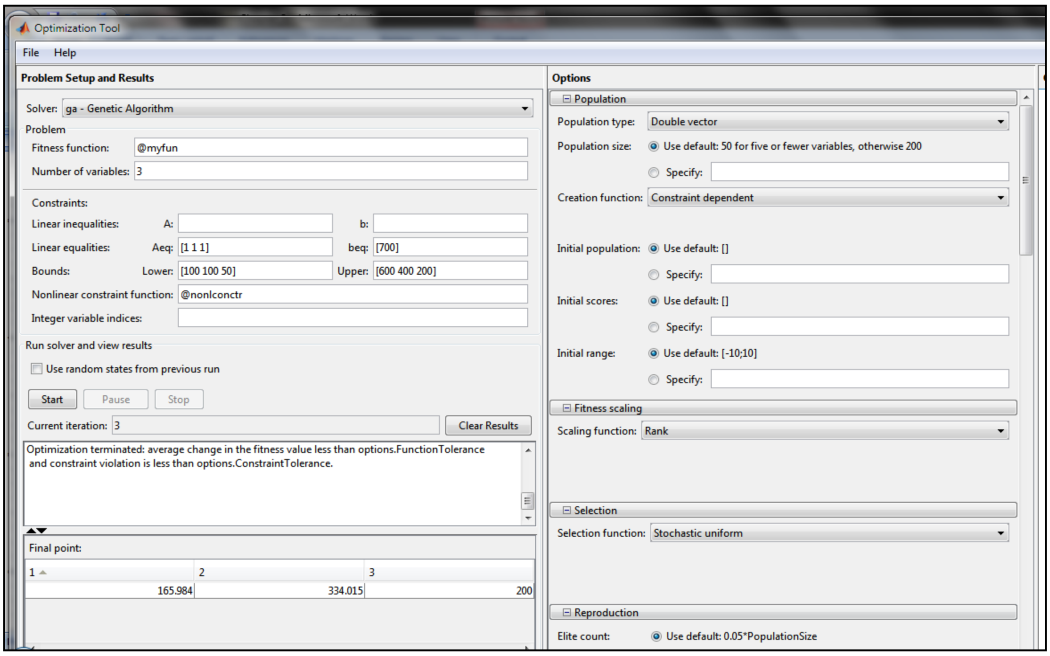
Fig. 1. Constraint function for 3 – unit system



Load demand curve for 3 unit system [17]

Table 2. Results obtained using GA toolbox [3 unit system]

Hr	LD (MW)	G1 (MW)	G2 (MW)	G3 (MW)	C1 ($)	C2($)	C3($)	Total Cost
1	300	100	100	99	1525	1120	649	3294
2	350	100	100	50	1525	1120	711	3356
3	400	100	102	197.9	1525	1137	796	3458
4	520	100	243	176	1525	2362	755	4642
5	700	166	334	200	2229	3195	800	6224
6	1050	450	399	200	5506	3810	800	10117
7	1100	500	400	200	6125	3820	800	10745
8	800	200	400	200	2600	3820	800	7220
9	650	100	349	200	1525	3336	800	5661
10	330	100	100	129	1525	1120	683	3328
11	400	100	100	200	1525	1120	800	3445
12	530	112	217	199	1651	2130	334	4116
Total Cost ($)								65605



Implementation of genetic algorithm using MATLAB Toolbox

Table 3. Cost of each generator unit for different load demand

Load Demand	Coefficients and power generated by Unit 1				Coefficients and power generated by Unit 2				Coefficients and power generated by Unit 3				c1 ($)	c2 ($)	c3 ($)	Total Cost ($)
	a1	b1	c1	PG	a2	b2	c2	PG	a3	b3	C3	PG				
300	0.0025	10	500	104	0.002	8	300	108	0.005	6	100	88	1567	1187	639	3393
350	0.0025	10	500	102	0.002	8	300	104	0.005	6	100	144	1546	1154	704	3403
400	0.0025	10	500	105	0.002	8	300	107	0.005	6	100	188	1578	1179	777	3533
520	0.0025	10	500	104	0.002	8	300	232	0.005	6	100	184	1567	2264	769	4600
700	0.0025	10	500	170	0.002	8	300	332	0.005	6	100	198	2272	3176	796	6245
1050	0.0025	10	500	553	0.002	8	300	398	0.005	6	100	199	6795	3801	798	11393
1100	0.0025	10	500	503	0.002	8	300	397	0.005	6	100	200	6163	3791	800	10754
800	0.0025	10	500	203	0.002	8	300	398	0.005	6	100	199	2633	3801	798	7232
650	0.0025	10	500	107	0.002	8	300	344	0.005	6	100	199	1599	3289	798	5685
330	0.0025	10	500	101	0.002	8	300	107	0.005	6	100	122	1536	1179	674	3389
400	0.0025	10	500	101	0.002	8	300	105	0.005	6	100	194	1536	1162	788	3486
530	0.0025	10	500	117	0.002	8	300	218	0.005	6	100	195	1704	2139	326	4169

Total Generation Cost	6728 2

3.2. Case Study – II

To illustrate the application of GA toolbox to optimum UC problem a 10-unit system presented in [17] is considered. The 10-unit system data like minimum/maximum limits and generation parameters are presented in Table 4. The objective function is modeled using the system data and results are obtained for different load demand using GA toolbox and presented in Table 5.

Table 4. 10 unit system Data

Unit	P_G^{max} (MW)	P_G^{min} (MW)	a ($)	b ($/MWh)	C ($/MWh$^{2)}$)	RU (MW)	RD (MW)	HSC ($)	CSC ($)
1	455	150	1000	16.19	0.00048	152.5	152.5	4500	9000
2	455	150	970	17.26	0.00031	152.5	152.5	5000	10,000
3	130	20	700	16.60	0.00200	55.0	55.0	550	1100
4	130	20	680	16.60	0.00211	55.0	55.0	560	1120
5	162	25	450	19.70	0.00398	68.5	68.5	900	1800
6	80	20	370	22.26	0.00712	30.0	30.0	170	340
7	85	25	480	27.74	0.00079	30.0	30.0	260	520
8	55	10	660	25.92	0.00413	22.5	22.5	30	60
9	55	10	665	27.27	0.00222	22.5	22.5	30	60
10	55	10	670	27.79	0.00173	22.5	22.5	30	60

Table 5. Result obtained for 10 unit system with TLBO Algorithm

Hr	Total Demand	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	Cost($)
1	700	275.4	166.3	65.6	65.2	31.8	26.1	29.3	13.7	12.9	14.9	19353
2	750	320.2	219.1	63.0	26.0	34.6	25.7	26.2	14.8	12.2	10.1	20150
3	850	357.2	257.8	32.2	82.7	28.0	25.9	31.2	12.4	12.7	10.1	21825
4	950	407.4	220.9	100.4	94.2	32.7	29.5	27.6	14.6	12.6	11.3	23522
5	1000	436.7	302.1	44.7	93.2	28.4	23.0	34.1	14.5	13.6	10.6	24422
6	1100	389.6	349.9	117.1	105.1	40.2	25.5	27.5	21.9	13.5	10.0	26181
7	1150	416.6	375.2	101.5	113.7	40.8	34.0	29.5	13.0	15.5	10.1	27043
8	1200	428.4	412.4	107.0	122.4	32.0	36.5	29.7	11.0	10.8	10.3	27839
9	1300	436.8	454.7	93.6	106.9	99.8	41.4	33.5	11.6	11.8	10.5	29867
10	1400	446.1	447.3	128.7	110.8	135.5	44.4	33.0	18.5	21.7	14.1	31895
11	1450	448.8	447.8	124.0	127.3	140.8	67.1	31.3	16.8	24.8	22.1	33001
12	1500	449.3	444.4	125.4	122.1	156.2	67.1	50.4	30.0	30.2	25.1	34315

13	1400	432.4	446.5	108.7	125.3	148.1	60.6	31.4	18.4	19.2	10.3	31973
14	1300	423.6	441.5	125.4	107.2	102.9	25.1	29.1	17.7	15.0	12.9	29843
15	1200	410.0	446.4	115.6	75.1	50.7	25.6	29.8	18.2	16.1	13.4	28023
16	1050	441.0	276.1	70.8	124.4	32.0	39.5	30.7	14.0	11.7	10.0	25274
17	1000	414.3	289.2	77.0	94.6	31.8	25.9	28.1	13.5	13.7	12.8	24396
18	1100	411.9	331.8	96.6	121.4	32.8	33.3	28.3	17.2	11.7	15.7	26202
19	1200	450.3	404.5	110.9	90.4	36.5	32.8	33.9	17.0	12.0	11.7	27941
20	1400	453.1	444.7	127.8	120.2	95.1	67.7	27.7	20.1	30.4	13.1	31923
21	1170	432.7	345.0	121.2	121.3	51.9	26.3	36.0	11.0	14.5	10.7	27411
22	1100	419.4	350.6	94.5	100.2	38.0	26.3	31.3	14.9	13.3	11.9	26165
23	900	341.9	252.3	86.1	89.2	37.9	27.0	27.5	12.1	12.1	14.6	22713
24	800	320.0	192.3	59.5	87.5	43.2	28.7	28.4	13.5	15.5	11.4	21047
	Total Generation Cost											642324

2. Conclusion

This paper presents the application of Genetic Algorithm Toolbox for optimum Unit Commitment problem. The objective function and constraint functions are defined using m-file. The is carried out for minimization of total operating cost of Thermal units. The optimum solution is obtained using MATLAB TOOLBOX for 3 - unit test system and 10 - unit test system. The results obtained satisfy the equality as well as non-equality constraints. Overall, the results demonstrates that MATLAB TOOLBOX gives optimum solution to Unit Commitment problem, and also offers reliable and accurate results for power system operators seeking to minimize generation costs while meeting the demand requirements.

3. References

1. K. Hussain, "Solution method for unit commitment limitations and utility constraints," in IEEE Computer Applications in Power, vol. 4, no. 1, pp. 16-20, Jan. 1991.
2. Chao-An Li, A. J. Svoboda, Chung-Li Tseng, R. B. Johnson and E. Hsu, "Hydro unit commitment in hydro-thermal optimization," in IEEE Transactions on Power Systems, vol. 12, no. 2, pp. 764-769, May 1997.
3. Sarjiya, S. P. Hadi, P. H. Putra and Tumiran, "Security Constrained Unit Commitment Using Genetic Algorithm Based on Priority List Method with Fuel Constraint Consideration," 2019 7th International Istanbul Smart Grids and Cities Congress and Fair (ICSG), Istanbul, Turkey, 2019, pp. 174-178.
4. W. L. Peterson, S. R. Brammer and S. O. Elder, "A new method for unit ramp rate processing in Lagrangian relaxation unit commitment," Proceedings of SOUTHEASTCON '94,Miami, FL, USA, 1994, pp. 222-224.
5. S. V. Tade, V. N. Ghate, S. Q. Mulla and M. N. Kalgunde, "Application of Dynamic

Programming Algorithm for Thermal Unit Commitment with Wind Power," 2018 IEEE Global Conference on Wireless Computing and Networking (GCWCN), Lonavala, India, 2018, pp. 182-186.

6. A. A. Ismail and A. N. Hussain, "Unit Commitment Problem Solution Using Binary PSO Algorithm," 2019 2nd International Conference on Engineering Technology and its Applications (IICETA), Al-Najef, Iraq, 2019, pp. 43-48.
7. S. Marrouchi and S. Chebbi, "Combined use of Particle Swarm Optimization and genetic algorithm methods to solve the Unit Commitment problem," 2014 15th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Hammamet, Tunisia, 2014, pp. 600-604.
8. S. Marrouchi, M. Ben Hessine and S. Chebbi, "Combined Use of an Improved PSO and GA to Solve the Unit Commitment Problem," 2018 15th International Multi-Conference on Systems, Signals & Devices (SSD), Yasmine Hammamet, Tunisia, 2018, pp. 1264-1270.
9. A. Rudolf and R. Bayrleithner, "A genetic algorithm for solving the unit commitment problem of a hydro-thermal power system," in IEEE Transactions on Power Systems, vol. 14, no. 4, pp. 1460-1468, Nov. 1999.
10. Wenping Chang and Xianjue Luo, "A Solution to the Unit Commitment Using Hybrid Genetic Algorithm," TENCON 2008 - 2008 IEEE Region 10 Conference, Hyderabad, India, 2008, pp. 1-6, doi: 10.1109/TENCON.2008.4766718.
11. K. Chandrasekaran and S. P. Simon, "Unit commitment in composite generation and transmission systems using Genetic Algorithm," 2009 World Congress on Nature & Biologically Inspired Computing (NaBIC), Coimbatore, India, 2009, pp. 1115-1120.
12. Sarjiya, A. B. Mulyawan and A. Sudiarso, "Optimal solution of reliability constrained unit commitment using hybrid genetic algorithm-priority list method," 2014 6th International Conference on Information Technology and Electrical Engineering (ICITEE), Yogyakarta, Indonesia, 2014, pp. 1-6.
13. P. K. Singhal, R. Naresh, V. Sharma and N. G. Kumar, "Solution of unit commitment problem using enhanced genetic algorithm," 2014 Eighteenth National Power Systems Conference (NPSC), Guwahati, India, 2014, pp. 1-6.
14. K. Abookazemi and M. W. Mustafa, "Unit Commitment optimization using improved Genetic Algorithm," 2009 IEEE Bucharest PowerTech, Bucharest, Romania, 2009, pp. 1-6.
15. R. Ma, Y. Huang and M. Li, "Unit Commitment Optimal Research Based on the Improved Genetic Algorithm," 2011 Fourth International Conference on Intelligent Computation Technology and Automation, Shenzhen, China, 2011, pp. 291-294.
16. H. S. Madraswala, "Modified genetic algorithm solution to unit commitment problem," 2017 International Conference on Nascent Technologies in Engineering (ICNTE), Vashi, India, 2017, pp. 1-6.
17. M. B. Kokare and S. V. Tade, "Application of Artificial Bee Colony Method for Unit Commitment," 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), Pune, India, 2018, pp. 1-6, doi: 10.1109/ICCUBEA.2018.8697562.
18. S. U. Pathade and A. A. Kalage, "Optimum Coordination of Directional Overcurrent Relay using Genetic Algorithm Technique," 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore, India, 2017, pp. 278-283.
19. M. K. Manikshetti and A. A. Kalage, "Optimum Unit Commitment using Teaching Learning based Optimization Algorithm," 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore,

India, 2017, pp. 267-272.
20. A. S. Vikhe and A. A. Kalage, "Power System Optimisation using Ant Lion Optimisation Technique," 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2019, pp. 355-361.