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Optimal power system load shedding via heuristic algorithms

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Abstract

Nowadays, the rapid growth in electricity demand and the high costs associated with infrastructure development have forced power transmission systems to operate close to their stability limits. Under such stressed operating conditions, the occurrence of contingencies such as generator outages, transmission line failures, and sudden load disturbances can significantly threaten system security. These events may trigger voltage instability, frequency deviations, or even partial and widespread system collapse if appropriate corrective actions are not taken in a timely manner. Therefore, maintaining power system stability under both normal and disturbed conditions remains a critical challenge for modern power networks. One of the most effective emergency control strategies to prevent system collapse and restore operation to acceptable limits is load shedding. Load shedding involves disconnecting a portion of the system load to rebalance generation and demand, thereby improving voltage and frequency stability. However, indiscriminate load disconnection can impose severe economic and social costs. Consequently, load shedding must be performed in an optimal manner by selecting loads with lower interruption costs while still achieving the desired improvement in system stability. This creates a multi-objective optimization problem in which system stability enhancement and minimization of load disconnection cost must be addressed simultaneously. In this study, an optimal load shedding strategy is developed that balances these two conflicting objectives. In addition to controlled load reduction, the proposed approach considers relieving overloaded transmission lines and improving busbar voltage deviations to further enhance overall network performance. The objective is not only to stabilize the system following disturbances but also to restore it as close as possible to its rated operating conditions with minimal economic impact. To solve the resulting optimization problem, two advanced metaheuristic algorithms are employed: the Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). These algorithms are well suited for complex, nonlinear, and multi-objective power system problems. The proposed load shedding model is tested on the IEEE 30-bus standard power system under various contingency scenarios. Simulation results demonstrate that both algorithms are capable of identifying effective load shedding schemes that improve voltage stability, reduce transmission line overloads, and minimize load interruption costs. The comparison also highlights the effectiveness of evolutionary optimization techniques as practical tools for emergency control and stability enhancement in modern power systems.

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1. Introduction

Voltage and frequency stability is one of the fundamental principles in power systems. The control systems in the network are responsible for regulating and stabilizing the network voltage and frequency at their nominal values. Various errors, load growth, lack of generation, and other factors are serious threats to system security and disrupt voltage and frequency stability. Load shedding is one of the last control measures to maintain the stability of the power system. Therefore, when something happens to the power system, unnecessary loads are separated from the network. The load removed from the power system must be distributed among the network load buses in such a way that goals such as improving system stability indicators and maximizing system stability under current conditions are achieved, and also the lowest load shedding cost is imposed on the operator. The load shedding plan must be able to eliminate all overloads on the network lines and place them within the thermal stability range in terms of performance. The load shedding plan must maintain the voltage of all network buses within the permissible functional range. One of the optimal load shedding methods in power systems is the use of innovative algorithms, which are discussed here. Two algorithms can be mentioned: genetic optimization and PSO.

There are several ways to deal with any type of instability by means of network protection and by using information collected from different points of the network and by having various control tools throughout the network. [1]. Due to the competitive environment created in the restructured electricity networks, electric power and energy has become a commodity that must be offered to the consumer at the cheapest price so that its producer can have a profitable competition in the electricity market. In the private structure of the electricity industry, in addition to the price of electric energy, its quality and capability indicators are also very important. So that some consumers prefer to pay more for the consumption of electrical energy with higher reliability. The philosophy of designing and using network protections is actually to detect and predict controllable emergency situations that may cause the instability of the power network.Some indicators of quality and reliability include suitability The values of the voltage range and frequency of the network as well as the continuity of time of the energy delivered to the consumer. Therefore, the design, operation and protection of the power grid should also be done in order to maintain the continuity of electric energy by considering these criteria. The resulting network must act in a way that responds well to the disturbances and continues to work within the acceptable range or has the minimum possible deviation from the acceptable conditions [2]. The proposed adaptive UVLS method based on PTSI is suitable for plans that are separate and non-integrated in one area. Another load removal method proposed in the articles is based on Ant Algorithm (ACO) [3] his algorithm is based on the concepts of the static limit of voltage stability and its sensitivity value at the collapse point, and voltage stability is modeled as a limitation in the load shedding scheme. The proposed method has been investigated on the IEEE 14-bus system and solved by two heuristic methods, GA genetic algorithm and PSO particle mass, and then the obtained results have been validated with GAMS software using classical mathematical methods. In another article, a comparative article is presented between the proposed method called adaptive load shedding based on PTSI technique and two other methods named constant load reduction with fixed delay FSFD3 and variable load reduction with variable delay VSVD4 to avoid voltage collapse [4]. In this plan, load reduction corresponds to the intensity of disturbance. This intensity is estimated based on the rate of change of frequency. The new method has been tested in the HV network of Khorasan province in Iran. The proposed method shows definite improvement compared to conventional methods. A control and monitoring scheme based on the SCADA system has been presented by Parniani and her colleagues [5]. Today, with the occurrence of total and partial collapses in power systems around the world, the idea of using network protection has been proposed. Network protection, which was initially introduced under the name of special protection plans, is actually the second generation of power system protection [6]. The rate of frequency change is useful in determining the overload when disturbance occurs, and hence, it is used to estimate the amount of load that should be reduced from the network. This plan has overcome the shortcomings of the adaptive UFLS plan. Load shedding voltage relays are set to operate under low voltage conditions. A system affected by a disturbance may maintain its stability but the bus voltage is still low. As the voltage reaches the limit of instability and collapse, even very fast reactive power control schemes and it also has no effect on the system and cannot prevent voltage collapse. This voltage drop can be corrected by using load removal algorithms and plans and reducing the appropriate amount of load from each bus. Emrai and Sadati have described an article about voltage load removal that defined an optimal load removal algorithm [7]. Loads with a lower frequency balance factor are prioritized for removal or reduction, and then loads with a high frequency balance factor are removed. Therefore, loads with a lower balance factor will be prioritized for removal by the load removal plan. Another scheme considers frequency rate variation in the adaptive load shedding algorithm in the paper written by Sidi et al [8]. Many low frequency load shedding schemes mainly set relays to detect frequency changes. As soon as the frequency drops below a certain value, a certain amount of load will be reduced. If the frequency reduction continues, the network load will be reduced again to a certain amount. The amount of load as well as the location of the load to be removed is predicted in advance. Theresa and his colleagues have presented a scheme about frequency load removal [9]. In the first stage of this design, the frequency and range of frequency changes are estimated with an algorithm. In the second step, the range of disturbances will be estimated with the simple generator oscillation equation, and then the load removal values will be calculated based on the range of frequency changes. The main idea in the article proposed by Xiong is to include load frequency balance factors in the load shedding scheme [10].

In this method, two basic principles are considered. The first principle is related to voltage stability. In fact, the algorithm first calculates the sensitivity of the voltage stability limit in each bus to the load changes in other buses through sensitivity analysis. The second principle determines the amount of load that must be removed from the target bus. Determining the value of the elimination load after selecting the target bus is done by the Ant algorithm and solving the nonlinear optimization problem by this algorithm. The performance of this method has been investigated under critical loading conditions of IEEE 30-bus system.

2.the proposed load removal pian

In this part, the load removal method for this article is presented for network protection of the power system after the occurrence. Today, with the increasing importance of problems and the speed of finding answers and the lack of answers, classical methods of heuristic search algorithms such as the hereditary algorithm, the colony algorithm of the Morjes, etc. have grown significantly. In this section, we will describe the algorithms used in this article to solve the optimization problem. The algorithms used are the genetic algorithm and the bird community of severe incidents such as outage soft rans mission and production lines. Definition of optimal load removal problem and objective function: The proposed objective function of this thesis has 4 objectives, which include economic and technical objectives of power system performance.

A) Economic purpose

1) Minimizing the amount of load interruption based on the importance factor of each bus: In this part, an importance factor is determined for each bus and the cost of load interruption is defined according to the following relationship:

$$OF_1 = \min : \sum_{i=1}^{N_{Bus}} \alpha_i \left(P_{Di}^{0} - P_{Di}^{p} \right) \quad (١)$$

In the above relationship, the loads with higher importance coefficient have a larger value than the loads with lower importance coefficient. The definition of the importance factor above causes loads with a lower importance factor to be prioritized for load removal. where the active power of the load before and after the output of the transmission line and the load removal of the i-th bus are in the network, respectively

b) Technical objectives

2) Reducing the excess power passing through the transmission lines: this goal is also modeled according to the following relation in the objective function:

$OF_2 = min$:

$$\begin{cases} \sum \left(|S_{trans\,ij}^{p}| - S_{trans\,ij}^{max} \right) & if\ \ S_{trans\,ij}^{p} > S_{trans\,ij}^{max} \\ 0 & if\ \ S_{trans\,ij}^{p} \le S_{trans\,ij}^{max} \end{cases} \quad (٢)$$

in which $S_{trans\,ij}^{p}$ and $S_{trans_{ij}}^{max}$ They are, respectively, the power passing through the line after the load is cut off and the maximum power passing through the line

3) Optimizing total bus voltage deviations: the amount of voltage deviation in the network is calculated according to the following equation:

$$V_{deviation} = \sum_{i=1}^{N_{bus}} \left(\frac{V_{i\ \mathrm{ref}} - V_i}{V_{i\ \mathrm{ref}}} \right)^2 \quad (٣)$$

in which $V_{i\ \mathrm{ref}}$ Initial guess of bus voltage and V_i The bus voltage after load distribution is N_{bus} is the number of tires. Therefore, the third goal, which is a technical goal from the point of view of system studies, will be modeled according to the following relationship in the goal function:

$$OF_3 = min: \sum_{i=1}^{N_{bus}} \left(\frac{V_{i\ ref} - V_i}{V_{i\ ref}}\right)^2 \quad (4)$$

4) Minimizing system losses:

$$OF_4 = \sum_{I=1}^{b} R_1 I_1^2 = \quad (5)$$
$$= \sum_{I=1}^{b} [V_i^2 + V_j^2 2V_i V_j \cos(\delta_i - \delta_j)] Y_{ij} \cos\varphi_{ij}$$

in which b The number of system lines, Rl line resistance, I1 current passing through the line,

Vi the size of the bus voltage, δ_i Bass voltage angle, Yij The size of the admittance matrix and

φ_{ij} are its angles. Limitations: The mentioned optimization problem has limitations that are discussed below.1) limitation of equality and balance between active and reactive power production and consumption as well as losses of active and reactive power of the network:

$$\sum_{i=1}^{N_{Bus}} \left(P_{Gi}^p - P_{Di}^p\right) - P_L^p = 0 \quad (٦)$$
$$\sum_{i=1}^{N_{Bus}} \left(Q_{Gi}^p - Q_{Di}^p\right) - Q_L^p = 0 \quad (٧)$$

That in these relationships, $Q_L^p, P_L^p, Q_{Di}^p, P_{Di}^p, Q_{Gi}^p, P_{Gi}^p$ ، Active and reactive power are production, consumption and losses after the possible event of transmission line outage and load interruption, respectively

2) The voltage of all the busses in steady state after removing the load should be within the operating range

$$V_i^{min} \le V_i^p \le V_i^{max} \quad i = 1و2و\dots و n \quad (8)$$

In the above relationship V_i^{min}, V_i^{max} respectively the maximum and minimum permissible value of the bus voltage i and n is the total number of system buses V_i^p Also, it is the voltage of the i-th bus after removing the load in the system

3) Limitation of the production capacity of power plants:

$$P_{Gi}^{min} \le P_{Gi}^p \le P_{Gi}^{max} \quad (٩)$$
$$Q_{Gi}^{\min} \le Q_{Gi}^p \le Q_{Gi}^{\max} \quad (١٠)$$

which include the minimum and maximum limits of production and production power after load shedding.

4) Limitation of decision variables: every optimization problem needs to form an initial population of decision variables. In this chromosomal problem, which is taken into account for the formation of the initial population, it includes the production power of generators and bus loads. The range considered for the load in each tire is as follows:

$$P_{Di}^{\min} \le P_{Di}^p \le P_{Di}^0$$
$$P_{Di}^{\min} = 0.5 \times P_{Di}^0 \quad (١١)$$

In this regard P_{Di}^0 Tire load before load removal plan implementation, P_{Di}^p Tire load after removing the load and, $P_{Di}^{\min}$ The permissible range of the load can be cut by the load removal plan, which in the considered problem, 50% of the load in each tire can be removed. In addition, load removal in the system will be done at a constant power factor, which reduces network variables and simplifies calculations.

$$\frac{\Delta P_{Di}}{P_{Di}^0} = \frac{\Delta Q_{Di}}{Q_{Di}^0} \quad (١٢)$$

The range considered for the production of each generator is as follows:

$$P_{Gi}^{min} \le P_{Gi}^p \le P_{Gi}^{max}$$
$$P_{Gi}^{min} = 1.2 * P_{Gi}^0 \quad (١٣)$$
$$P_{Gi}^{min} = 0.8 * P_{Gi}^0$$

that P_{Gi}^{0} and P_{Gi}^{p} They are according to the production of the power plants before and after the accident and load cut.

3.The proposed method

Solving the multi-objective optimization problem using meta-heuristic algorithms

Consider the following function, which is a bounded multi-objective function:

$$Min\ \left(f_1(x), f_2(x), \ldots, f_M(x)\right)$$
$$Subject\ to: \begin{cases} h_k = b \\ x^{(L)} \le x \le x^{(U)} \end{cases} \qquad (١٤)$$

where the first adverb is the equality adverb and the second adverb is the variable range $x^{(U)}$ and

$x^{(L)}$ They are the upper and lower limits of the x variable, respectively. In order to obtain the optimal answer of this problem, we turn it into an unconstrained optimization problem:

$$Min\ \left(w_1 f_1(x), w_2 f_2(x), \ldots, w_M f_M(x)\right) + \lambda(b - h_k) + \lambda_x \sum_{N_X^{lim}}^{\Sigma} (\Delta x)^2 \qquad (15)$$

in which ω_1 ،ω_2....and ω_M The weight coefficients of the multiple objectives of the problem are arbitrarily determined according to the importance of each of the objectives of the problem

and λ_x and λ There are penalty coefficients, which are considered large fixed numbers to meet the constraints of the problem.

$$\Delta x = \begin{cases} X - x^{(u)} & if \quad x > x^{(u)} \\ X^{(l)} - x & if \quad x < x^{(L)} \end{cases} \qquad (16)$$

By placing equation (15) in the merit function of the used algorithms, the optimal answer is obtained. In order to solve the problem, according to the materials presented in this section, genetic algorithms and bird community have been used. search algorithm, which is known as the PSO algorithm.

The protection plan has been implemented as a proposed method in the environment of the article, which after receiving the numbers of productions and lines removed, determines the amount and optimal location of the load removal due to the removal of the

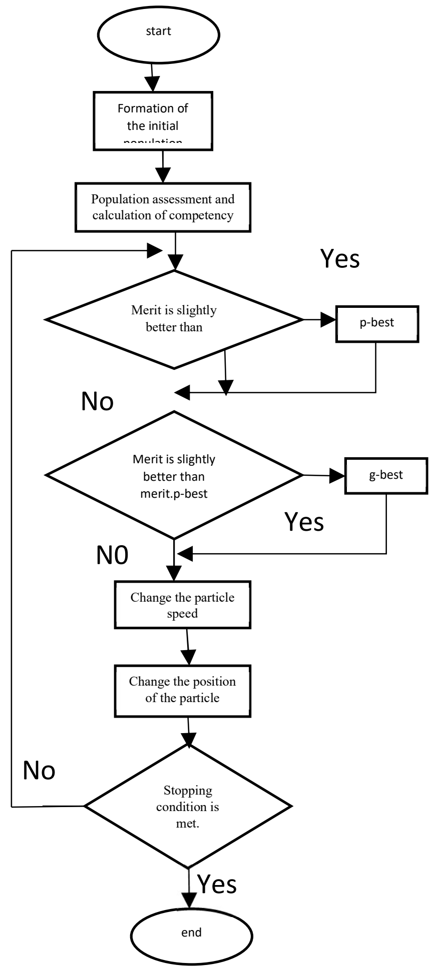

Figure-1 Flowchart algoritm

transmission and production line to remove the load. In this software package, genetic algorithms and PSO are used to obtain optimal load shedding.

Implementation of load shedding in sample networks

The process of implementing the algorithm to solve the problem is as follows (Figure 1):

At first, the load distribution is taken from the system and the performance values of the objective function are calculated (for use in normalizing the performance of the objective function).

The initial population is formed based on the maximum and minimum values of the variables given in the previous chapter.

The merit of the population is calculated based on the following objective function:

$$Object = K_1 \frac{O_1}{\sum_{i=1}^{N_{bus}} a_i\, p_{Di}^0} + K_2 \frac{O_2}{\begin{cases} \sum\left(\left|Strans_{ij}^0\right| - Strans_{ij}^{max}\right) & if\ Strans_{ij}^0 > Strans_{ij}^{max} \\ 0 & if\ Strans_{ij}^0 \leq Strans_{ij}^{max} \end{cases}} + K_3 \frac{O_3}{\sum_{i=1}^{N_{bus}} \left(\frac{V_{i\ ref} - V_i}{V_{i\ ref}}\right)^2} + K_4 \frac{O_2}{P_{loss}} + \lambda_P \Delta P + \lambda_Q \Delta Q + \lambda_V \Delta V \quad (17)$$

in $which\, K_1 = 0.3، K_2 = 0.2، K_3 = 0.3\ and\ K_4 = 0.2$ The weight coefficients of the desired objectives of the unloading problem.

$\lambda_p، \lambda_Q\ and\ \lambda_v$The penalty coefficients are related to the constraints of the objective function, which are considered 10.

Determining the best member of the crowd. Applying algorithm operators and forming a new population to participate in the next iteration of the algorithm loop Checking the loop exit condition Print the results. In order to implement the load shedding scheme proposed in this article, the IEEE 30-bus network is used.

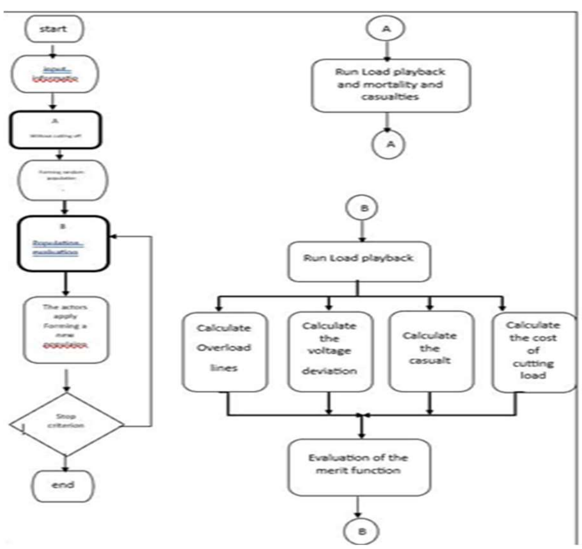

Figure2- Flowchart of the implementation of the proposed

4. Results

The network of 30 buses includes 6 generators, 21 consumers and 41 transmission lines. The single-line diagram of the standard network is shown in Figure 3.

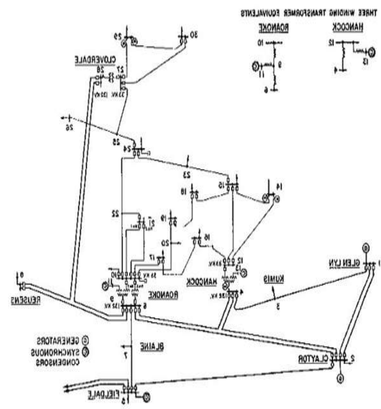

Figure 3- Network diagram of 30 IEEE buses

Table 1- Loads on the buses after the implementation of the genetic algorithm with the same importance coefficients

Bass number	1	2	3	4	5	6	7	8	9	10
bass power	0	18/7	2	3/8	47/1	0/0	11/4	20/1	0/0	4/5
Bass number	11	12	13	14	15	16	17	18	19	20
bass power	0/0	11/2	0/0	5/5	4/1	2/1	4/5	2	5/1	1/1
Bass number	21	22	23	24	25	26	27	28	29	30
bass power	8/75	0/0	1/6	4/35	0/0	1/75	0/0	0/0	1/9	5/3

After implementing the proposed method written based on the presented multi-objective function, the results are obtained as follows. In the first step, we set the importance factor of all the buses to cut the load equal to one.

Cost of load shedding: 4/283

Voltage deviation: (p.u) 0.053811

Total excess power passing through the line (MVA): 3.539

Casualties (MW): 79/695

After the accident, because the load has not yet been cut and the importance factor of all buses is the same, the cost of cutting the load is 283.3. By implementing the genetic algorithm, the loads on the buses with the same importance coefficients will be as in Table1.

The results related to the implementation of the objective function after the implementation of the genetic algorithm in the case of the same coefficients are as follows:

Cost of disconnection: 110/8

Voltage deviation: (p.u) 0.066134

Total excess power passing through the line (MVA): 45/489

Casualties (MW): 16/642

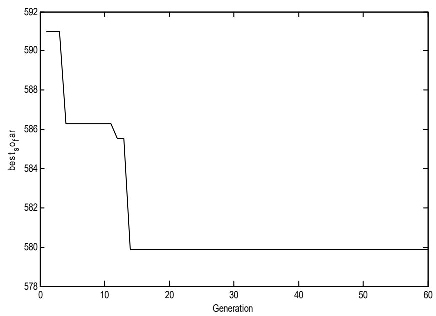

Figure 4 -Convergence diagram of the genetic algorithm in the case of the same importance coefficients

Table 2- Load distribution results after cutting lines 1-2 and 2-5 in the genetic algorithm with the same importance coefficients

Bass number	The size of the bus voltage (p.u.)	Bass voltage angle (deg)	Active production (MW)	Reactive production (MVar)	active load (MW)	Reactive load (MVar)	Linepower distribution results			
							Line number	start	termination	Line throughput (MVA)
1	1/06	0/0	149/24	3/08	0/0	0/0	2	1	3	149/28
2	1/043	-18/092	40/0	27/06	12/059	7/0576	3	2	4	14/389
3	1/0203	-14/675	0/0	0/0	1/4346	0/7173	4	3	4	142/04
4	1/0148	-17/804	0/0	0/0	6/3816	1/3435	6	2	6	26/33
5	1/01	-27/439	0/0	32/0	50/875	10/261	7	4	6	104/17
6	1/0162	-20/295	0/0	0/0	0/0	0/0	8	5	7	55/361
7	1/0093	-23/528	0/0	0/0	13/428	6/4196	9	6	7	67/971
8	1/01	-20/68	0/0	4/45	19/252	19/252	10	6	8	21/254
9	1/061	-21/961	0/0	0/0	0/0	0/0	11	6	9	18/77
10	1/0618	-22/823	0/0	0/0	3/8015	1/3109	12	6	10	9/1203
11	1/082	-21/961	0/0	10/9	0/0	0/0	13	9	11	10/719
12	1/0676	-21/889	0/0	0/0	7/1054	4/7581	14	9	10	15/421
13	1/071	-21/889	0/0	2/5	0/0	0/0	15	4	12	33/902
14	1/0582	-22/542	0/0	0/0	4/3545	1/1238	16	12	13	2/5732
15	1/0555	-22/665	0/0	0/0	4/7893	1/4602	17	12	14	5/774
16	1/0602	-22/469	0/0	0/0	2/826	1/4534	18	12	15	13/726
17	1/0585	-22/823	0/0	0/0	4/7893	3/0843	19	12	16	6/3408
18	1/0495	-23/183	0/0	0/0	2/3069	0/64883	20	14	15	1/2481
19	1/0481	-23/358	0/0	0/0	6/6862	2/393	21	16	17	3/4338
20	1/0512	-23/256	0/0	0/0	1/1871	0/37771	22	15	18	4/8857
21	1/0552	-23/08	0/0	0/0	8/9382	5/7204	23	18	19	2/53
22	1/0554	-23/085	0/0	0/0	0/0	0/0	24	19	20	4/8844
23	1/049	-23/115	0/0	0/0	2/0	1/424	25	10	20	6/1768
24	1/0476	-23/42	0/0	0/0	3/3925	3/3827	26	10	17	3/8742
25	1/0371	-23/595	0/0	0/0	0/0	0/0	27	10	21	10/42
26	1/0244	-23/89	0/0	0/0	1/578	1/6941	28	10	22	5/1312
27	1/0369	-23/529	0/0	0/0	0/0	0/0	29	21	22	0/69499
28	1/0155	-20/764	0/0	0/0	0/0	0/0	30	15	23	4/9447
29	1/018	-24/686	0/0	0/0	1/3191	0/86965	31	22	24	4/9323
30	1/0071	-25/515	0/0	0/0	4/253	1/8378	32	23	24	2/0051

The results of Table 2 show the ability of the presented method to cut the load. Also, Figure 3 shows a good convergence towards the optimal response, the results show the improvement of the bus voltage and also the reduction of the power passing through the lines.

By implementing the genetic algorithm in the case of buses with different importance coefficients, the loads on the buses will be as shown in Table 3. In this case, we set the importance coefficient of basses 23, 24, 26, 29 and 30 to 3, and we consider the importance coefficient of the rest equal to one in different importance coefficient.

Table 3 -Loads on the buses after the implementation of the genetic algorithm

Bass mum ber	1	2	3	4	5	6	7	8	9	1 0
bass pow er	0	1 4	/9 1	/8 5	/2 60	/0 0	/7 13	/4 17	/0 0	/6 3
Bass mum ber	1 1	1 2	1 3	1 4	15	1 6	17	18	1 9	2 0
bass pow er	/0 0	/4 8	/0 0	5	12 4/	/8 1	/9 5	/7 2	/2 6	/2 1
Bass mum ber	2 1	2 2	2 3	2 4	25	2 6	27	28	2 9	3 0
bass pow er	/9 8	/0 0	/6 2	/6 4	/0 0	/2 2	/0 0	/0 0	/3 1	/4 6

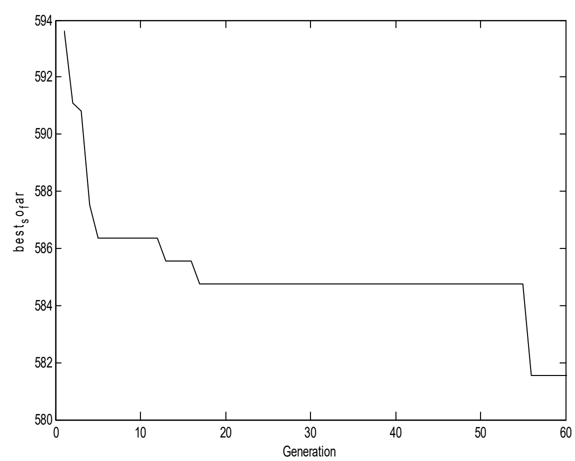

Figure 5- Convergence diagram of genetic algorithm with different importance coefficients

Figure ٥ shows the convergence diagram of the genetic algorithm in the case of different importance coefficients, which represents a good convergence towards the optimal answer. By implementing the particle assembly algorithm in the case of buses with the same importance coefficients, the loads on the buses will be as shown in Table 5.

Table 4. Loads on the buses after the implementation of the algorithm of particle assembly with the same coefficients

Bass number	۱	۲	۳	۴	۵	۶	۷	۸	۹	۱۰
bass power	۰	۱۸/۷	2	۳/۸	۴۷/۱	۰/۰	۱۱/۴	۲۰/۱	۰/۰	۴/۵
Bass number	۱۱	۱۲	۱۳	۱۴	۱۵	۱۶	۱۷	۱۸	۱۹	۲۰
bass power	۰/۰	۱۱/۲	۰/۰	۵/۵	۴/۱	۲/۱	۴/۵	۲	۵/۱	۱/۱
Bass number	۲۱	۲۲	۲۳	۲۴	۲۵	۲۶	۲۷	۲۸	۲۹	۳۰
bass power	۸/۷۵	۰/۰	۱/۶	۴/۳۵	۰/۰	۱/۷۵	۰/۰	۰/۰	۱/۹	۵/۳

Table 5- Results of load distribution after disconnection of lines 1-2 and 5-2 of Parangan community algorithm with the same coefficients

Bass number	The size of the bus voltage (p.u.)	Bass voltage angle (deg)	Active production (MW)	Reactive production (MVar)	active load (MW)	Reactive load (MVar)	Line power distribution results			
							Line number	start	termination	Line throughput (MVA)
1	1/06	0/0	141/72	1/9975	0/0	0/0	2	1	3	141/74
2	1/043	-17/383	40/0	31/058	18/709	10/949	3	2	4	13/998
3	1/0221	-13/915	0/0	0/0	2/0775	1/0388	4	3	4	134/46
4	1/0165	-16/865	0/0	0/0	3/8	0/8	6	2	6	22/414
5	1/01	-25/666	0/0	27/871	47/1	9/5	7	4	6	97/154
6	1/0177	-19/18	0/0	0/0	0/0	0/0	8	5	7	50/556
7	1/0111	-22/098	0/0	0/0	11/4	5/45	9	6	7	61/6
8	1/01	-19/539	0/0	0/60813	20/114	20/114	10	6	8	23/03
9	1/0625	-20/758	0/0	0/0	0/0	0/0	11	6	9	18/163
10	1/0641	-21/575	0/0	0/0	4/5456	1/5675	12	6	10	8/743
11	1/082	-20/758	0/0	10/147	0/0	0/0	13	9	11	9/964
12	1/0669	-20/908	0/0	0/0	11/2	7/5	14	9	10	14/71
13	1/071	-20/908	0/0	3/135	0/0	0/0	15	4	12	33/975
14	1/0571	-21/537	0/0	0/0	5/5844	1/4411	16	12	13	3/1232
15	1/0575	-21/536	0/0	0/0	4/1	1/25	17	12	14	5/7167
16	1/0617	-21/343	0/0	0/0	2/1438	1/1025	18	12	15	10/946
17	1/0607	-21/606	0/0	0/0	4/5	2/9	19	12	16	4/6676
18	1/0531	-21/928	0/0	0/0	2/0303	0/57103	20	14	15	0/11501
19	1/0525	-22/043	0/0	0/0	5/1691	1/85	21	16	17	2/5181
20	1/055	-21/955	0/0	0/0	1/1	0/35	22	15	18	3/6569
21	1/0581	-21/791	0/0	0/0	8/75	5/6	23	18	19	1/6209
22	1/0584	-21/786	0/0	0/0	0/0	0/0	24	19	20	4/1534
23	1/0537	-21/797	0/0	0/0	1/6	0/8	25	10	20	5/3397
24	1/0529	-21/979	0/0	0/0	4/35	3/35	26	10	17	4/0031
25	1/047	-21/745	0/0	0/0	0/0	0/0	27	10	21	9/2716
26	1/0385	-21/941	0/0	0/0	1/75	1/15	28	10	22	4/4125
27	1/0475	-21/481	0/0	0/0	0/0	0/0	29	21	22	1/1967
28	1/0182	-19/559	0/0	0/0	0/0	0/0	30	15	23	2/8471
29	1/036	-22/159	0/0	0/0	1/9625	0/73593	31	22	24	3/245
30	1/0314	-22/528	0/0	0/0	5/3	0/95	32	23	24	1/2097
							33	24	25	2/0214

The results related to the implementation of the objective function after the implementation of the bird community algorithm in the same and different mode are as follows:

Cost of disconnection: 11/116

Voltage deviation: (p.u) 0.074782

Total excess power passing through the line (MVA): 23/35
Casualties (MW): 14/44

The results obtained in this part show that the particle assembly algorithm subtracts more loads from the end buses than the genetic algorithm and the remaining load on the initial buses is more than before. Meanwhile, the total overload on the lines and losses of the entire system shows a significant reduction, and the network is in a good state in terms of voltage, while the cost of disconnection shows a slight increase. All this shows the high ability of the particle community algorithm to reach the optimal answer (Figure 6).

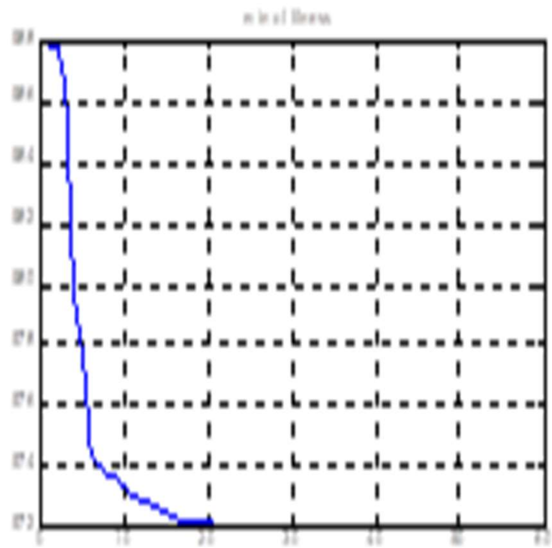

Figure 6- Convergence diagram of the particle community algorithm

By implementing the particle assembly algorithm in the case of buses with different importance coefficients, the loads on the buses will be as shown in Table 7. In this case, we set the importance factor of basses 23, 24, 26, 29 and 30 to 3 and consider the importance factor of the rest equal to one.

The results related to the implementation of the objective function after the implementation of the bird community algorithm in different modes are as follows:

Cost of load shedding: 9/152
Voltage deviation: (p.u) 0.087053

Total excess power passing through the line (MVA): 126/71
Casualties (MW): 16/754

According to the results obtained in this section, the amount of reduced load on the basses with a higher importance factor has been reduced compared to the previous state. But the cost of load shedding, the total extra power passing through the lines and losses have increased compared to the previous situation, which seem reasonable (Figure 7).

Table 6. Loads on the buses after the implementation of the algorithm of particles with different coefficients

Bass number	1	2	3	4	5	6	7	8	9	10
bass power	0	12	1/4	6/3	50/8	0/0	13/4	19/2	0/0	3/8
Bass number	11	12	13	14	15	16	17	18	19	20
bass power	0/0	7/1	0/0	4/3	4/7	2/8	4/7	2/3	6/6	1/1
Bass number	21	22	23	24	25	26	27	28	29	30
bass power	8/9382	0/0	2/8481	4/3925	0/0	2/578	0/0	0/0	2/3191	10/253

Table 7- Results of load distribution after cutting lines 1-2 and 5-2 of the particle assembly algorithm with different coefficients

Bass number	The size of the bus voltage (pu)	Bass voltage angle (deg)	Active production (MW)	Reactive production (MVar)	active load (MW)	Reactive load (MVar)	Line power distribution results			
							Line number	start	termination	Line throughput (MVA)
1	1/06	0/0	124/76	-1/5961	0/0	0/0	2	1	3	160/55
2	1/043	-15/084	40/0	22/597	18/644	10/912	3	2	4	16/36
3	1/0289	-12/214	0/0	0/0	1/5008	0/7504	4	3	4	151/7
4	1/0234	-14/794	0/0	0/0	3/8	0/8	6	2	6	28/13
5	1/01	-23/193	0/0	24/152	47/1	9/5	7	4	6	114/01
6	1/0246	-16/904	0/0	0/0	0/0	0/0	8	5	7	65/975
7	1/0153	-19/735	0/0	0/0	11/4	5/45	9	6	7	79/822
8	1/02	-17/198	0/0	2/6906	15/0	15/0	10	6	8	19/308
9	1/067	-18/253	0/0	0/0	0/0	0/0	11	6	9	19/269
10	1/0695	-18/952	0/0	0/0	2/9	1/0	12	6	10	10/7807
11	1/082	-18/253	0/0	7/8164	0/0	0/0	13	9	11	11/881
12	1/0738	-18/059	0/0	0/0	5/6	3/75	14	9	10	15/827
13	1/071	-18/059	0/0	-2/1703	0/0	0/0	15	4	12	34/3
14	1/067	-18/568	0/0	0/0	3/1	0/8	16	12	13	3/3
15	1/0645	-18/698	0/0	0/0	4/1	1/25	17	12	14	6/3
16	1/0683	-18/569	0/0	0/0	1/75	0/9	18	12	15	13/1
17	1/0665	-18/936	0/0	0/0	5/9648	2/9	19	12	16	6/2
18	1/0601	-19/132	0/0	0/0	1/8575	0/52242	20	14	15	0/8
19	1/0592	-19/285	0/0	0/0	4/75	1/7	21	16	17	4/2
20	1/0614	-19/23	0/0	0/0	1/1	0/35	22	15	18	4/1
21	1/0633	-19/179	0/0	0/0	8/75	5/6	23	18	19	3/2
22	1/0635	-19/177	0/0	0/0	0/0	0/0	24	19	20	4/3
23	1/0596	-19/075	0/0	0/0	1/9	0/8	25	10	20	5/5
24	1/0572	-19/416	0/0	0/0	4/98	3/35	26	10	17	4/1
25	1/0476	-19/468	0/0	0/0	0/0	0/0	27	10	21	8/9
26	1/0305	-19/863	0/0	0/0	2/5	2/3	28	10	22	5/1
27	1/501	-19/263	0/0	0/0	0/0	0/0	29	21	22	2/1
28	1/0252	-17/266	0/0	0/0	0/0	0/0	30	15	23	4/5
29	1/0376	-19/993	0/0	0/0	2/1	0/9	31	22	24	3/5
30	1/0334	-20/337	0/0	0/0	6/4	0/95	32	23	24	1/87

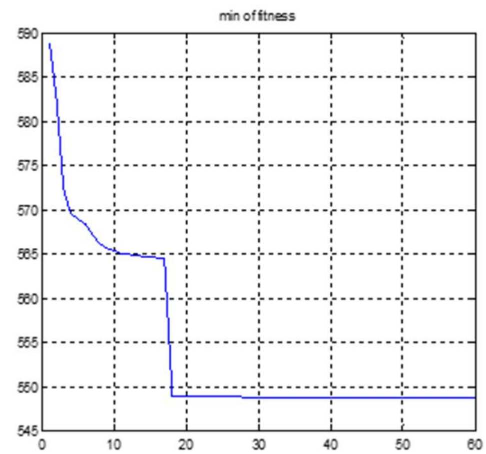

Figure 7- Convergence diagram of particle assembly algorithm

5- Conclusion

The proposed load shedding method is implemented on IEEE 30-bus network. For this purpose, a suitable proposed method has been written in the MATLAB environment, which, having system information including the active and reactive power consumption of the buses, the production power of the generators and the structure of the power network, determines the optimal amount and place of load removal in such a way that all the restrictions are met. As much as possible, less important loads are separated from the system. The results obtained from the written proposed method show the ability of the presented method to be used in the appropriate solution of the problem of load shedding. The results obtained from the particle assembly algorithm are more suitable than the results of the genetic algorithm. The studies conducted on sample networks show that using the method proposed in this article removes less important loads from the system and reduces the outage cost. In order to further investigate the problem of load removal, steady state analysis or transient state analysis can be used. In this artical, the load removal technique was investigated using steady state analysis and static analysis, and a suitable proposed method was prepared for this purpose. But to complete the discussion, it is appropriate to add transient stability analysis software and consider generator controllers and especially motor loads modeling, the answer obtained from the static analysis evaluated the removal of the load in the transient mode, and if the response of the transient mode was not suitable, another design was selected.

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