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Research Article

Optimal Fault-Location in Smart Grids with BFA and TS Algorithms with the Approach of Reducing Losses and Network Costs

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Abstract

The smart grid is actually the result of the integration of the structures of the power system and its communication structures, and this is the key point in the implementation of smart grid projects. This means that the integration of electricity production and distribution reduces the costs of implementing a smart network. In this regard, the preparation of the telecommunication platform is one of the most necessary requirements for moving in the direction of smartening the network. The ability to locate the fault and restore the power supply in time is one of the important indicators of a strong smart grid. Especially when many DGs are connected to the system, the network structure and working mode will change, and the demands on the traditional fault location method will increase. In this article, due to the difficulty of using the traditional fault location method in distribution networks with DG, two smart algorithms, TS and BFA, have been used for fault location in this type of networks. So that the location of dynamic distributed generation sources such as wind turbines is done first, then their effect on providing the load profile in the presence of distribution network faults is discussed. The results of the simulation confirm the correctness and correctness of the performance of the proposed method, so that the case studies conducted can open the way for engineers to evaluate new fault.

Keywords: Fault Location; Optimization; Bacterial Foraging Algorithm (BFA); Micro grid; DG; Tabu Search (TS)

1. Introduction

According to statistics, errors due to distribution networks account for more than 85% of error outcomes. Therefore, error processing technologies for distribution networks are of great importance in improving the reliability of services. Like ground-based systems, error processing technologies for inter-fuzzy short-circuit interruptions and single phase-to-ground errors are similar. But in dysfunctional systems, such as those in China, systems are such that they operate in less than two hours under single-phase fault conditions to ensure the reliability of the services. The single-phase fault situation on the ground should be specified and resolved in the first instance to prevent single-phase short circuit faults. Fuzzy short-circuit interruptions should be resolved quickly and retrieved as much as possible into healthy areas. Increasing the volume of DG in distribution networks, error processing technologies have faced numerous challenges. This chapter reviews the progress made in error processing technologies, and most articles written by the authors that are presented in the next chapters of the book are covered in this section. Distribution network error due to short circuit fault and ground faults with small flow Divided. In the event of an earth fault with a small current, the fault current is small, so it is allowed to flow for 1 to 2 hours. But when the short circuit fault occurs, the error flow is much larger and severely damages the distribution network. Therefore, the ability to locate errors and restore timely power supplies is an important indicator of a strong intelligent network. Especially when many DGs are connected to the system, the network structure and operating mode change and demands are raised from the traditional error-detection method. To date, a set of centralized error detection methods including matrix algorithm (Irshad et al., 2022), Neural Networks, (Singh et al., 2022), Ruff's Theory [exact] (Barzegaran et al., 2012), Petri's Network, Bayesian Algorithm (Shintemirov et al., 2010),etc. Although these algorithms have achieved certain results in the problem of locating an error, their disadvantages generally include a complex model and low locating efficiency, especially when connecting DGs. A hybrid artificial intelligence algorithm (Kim et al., 2022), has been widely used in the electric power industry in recent years. This kind of algorithm is a global optimization algorithm with error tolerance. Reference (Kumar et al., 2022) - (Alanazi et al., 2022), can successfully identify the location of an error in a simple distribution network, but it may make a mistake when the DG is connected to the network. Reference (Ngaopitakkul et al., 2014), with an improved particle swarm optimization algorithm, the reference (Satish et al., 2015), with an improved coordination algorithm, can detect errors in the grid distribution network with DG, but they can't yet set aside the process of constructing a complex switching function. The problem of locating a short circuit short circuit network distribution is a typical NP problem (Reddy et

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al., 2008). In this project, the bacteria foraging optimization algorithm (BFOA) and TS is used to solve this problem. Compared to the genetic algorithm, this algorithm has the benefits of fast search speeds, easy jumps from local optimal response, and so on. The grid matrix and DG matrix are introduced to construct a mathematical model. These two matrices describe the topological relationship between the key and the switch, as well as between the key and the DG. These matrices can easily be gained by the GIS system. Compared to the traditional bionic algorithm, there is no need for the process of constructing a complex switching function, and the model has a more self-adaptive capability. Distribution network failure is divided into short circuit faults and ground error with small flow. In the event of an earth fault with a small current, the fault current is small, so it is allowed to flow for 1 to 2 hours. But when a short circuit error occurs, the error flow is much larger and severely damages the distribution network (Kong et al., 2016). Therefore, the ability to locate errors and restore timely power supplies is an important indicator of a strong intelligent network. Especially when many DGs are connected to the system, the network structure and operating mode change, and demands from the traditional error-locating method increase (Omar et al., 2022).Due to the difficulty of using the traditional detection method in distribution networks with DG, an improved bacterial nutrition algorithm has been used to locate errors in these types of networks. In this method, there is no need to build complex switching functions in the original intelligent bionics. The relationship between the key and the line in the network communication matrix, and the effect of DG's presence on the DG matrix are hidden. The mathematical model has been improved so that it can be easily adapted for multiple DGs and multiple errors (Zadehbagheri et al., 2022).Even when the information is distorted; this method still can tolerate the error. Simulated examples show the ability to run this program.

2. Review on Performance of Optimization Methods

The application of intelligent meta-heuristic methods in controlling complex and nonlinear systems has been widely used in various fields of science and technology in the last decade. Sometimes, such problems can have a very complex objective function or model constraints, depending on their actual and practical nature. Such methods are powerful and their effectiveness in solving various types of optimization problems has been proven (Cong et al., 2005). A huge literature is available on non-traditional optimization tools. These methods include, genetic programming (GP) (Javadian et al., 2021),evolution strategies (ES), differential evolution (DE) (Bo, Z. Q et al., 1998), cultural algorithm (CA), evolutionary programming (EP), whale optimization algorithm (WOA) (Abbasi et al., 2015), grasshopper optimization algorithm (GOA) (Abbasi et al., 2021), kidney-inspired Algorithm (KA) (Yadav et al., 2014), salp swarm algorithm (SSA) (Kamarposhti et al., 2021), sine cosine algorithm (SCA), bat algorithm (BA), general relativity search algorithm (GRSA) (Abbasi et al., 2022), farmland fertility algorithm (FFA), artificial bee colony (ABC) (Furse et al., 2006), cuckoo search optimization (CSO), interior search algorithm (ISA), teaching-learning-based optimization (TLBO), harmony search (HS) (Satyanarayana et al., 2019), biogeography-based optimization (BBO) , seeker optimization algorithm (SOA), moth search algorithm (MSA), hybrid pattern search–sine cosine algorithm (HPS-SCA), modified version of multi-objective particle swarm optimiza tion (MOPSO), moth search algorithm (MSA), gray wolf optimization (GWO)) (Castillo et al., 2018), hybrid of genetic algorithm and pattern search (GA–PS), brainstorm optimisation algorithm (BSOA), asexual reproduction optimisation(ARO), and others were developed for multi-machine PSSs design. PSS is one of the convenient and inexpensive method to improve the dynamic stability of power systems. PSS provides a suitable control signal to increase damping and thus increase the transmission power by the lines. CPSS contains several parameters that must be specified during the design phase, and their precise adjustment has a great impact on the performance of power systems (Mengelkamp et al., 2018). CPSS parameters are usually calculated and determined using various methods. However, power system structure and changes in system loading conditions can affect CPSS performance in damping all modes, especially inter-region oscillations. To overcome this problem and have a suitable optimal power system stabilizer, good research has been done in this area in recent years. In these studies, different methods have been proposed to design CPSS parameters, by increasing the PSS performance, it can act well against power system fluctuations and dampen them. In the following, we will discuss the latest optimal methods presented in recent years for PSS design (Balakrishna et al., 2017). In (Hou et al., 2020), an analytical method for finding CPSS parameters such as washout signal and operation is presented. According to the obtained results, it can be concluded that by properly adjusting the CPSS parameters, it can work well in a wide range of system conditions. In (Cheena et al., 2022), focuses on distributed excitation control for multi-machine power systems. The proposed distributed power system stabilizer (DPSS) aims to synchronize all generators after being disturbed rather than to require them to operate at the rated speed. The proposed DPSS is analyzed on a double-machine infinite bus system and shows that the proposed DPSS can enhance the stability of power systems by increasing the synchronizing torque. In (Ishraque et al., 2021), the structure of a robust PSS using a fuzzy type PID controller optimized with a firefly algorithm (FA-PID-FLC) to increase the dynamic stability of the power system is proposed. Optimization by FA overcomes the convergence problem in GA, PSO. FA requires several parameters to adjust and faster results than other computational methods. In [30], the BSOA is a novel promising heuristic optimization algorithm inspired by the brainstorming process in human beings. In this paper, BSOA is employed to find the optimal location and setting of flexible ac transition systems (FACTS) devices. Based on the brainstorming process in human beings, Shi Cheng proposed BSOA for solving optimization problems. In BSOA, individuals are analogous to ideas in brainstorming, clusters are analogous to brainstorming groups and cluster canters are analogous to best ideas of brainstorming groups. BSOA leads to a better voltage profile and lower losses than other optimization methods. In (Ildarabadi et al., 2017) , the dominant pole spectrum Eigen solver algorithm, and integral of square time multiplied square error (ISTSE) criterion as the objective function were used for the optimal design of the power system stabilizer in a two-area standard power system. In (Li et al., 2022), an innovative algorithm called hybrid pattern search–sine cosine algorithm (HPS-SCA) is proposed to determine the lead-lag stabilizer parameters online. In this paper, the fitness is the function of eigenvalue displacement. The optimization algorithm determines the decision variables in such a way as to ensure that the eigenvalues are within the allowable range in different operating conditions. In (Ishraque et al., 2021), the hybrid BFOA-PSO algorithm has been applied to IEEE 14 bus test system under normal, light and heavy load conditions, BSO combines both algorithms BFOA and PSO thus using the advantages of both techniques. The aim is to make use of PSO ability to exchange social information and BFOA ability in finding a new solution by elimination and dispersal. In (Kamarposhti et al., 2021), a MOPSO is proposed for the optimal design of the stabilizer of lead-lag PSSs. In (Yadav et al., 2014), the neural network is used to design the PSS.One of the problems of neural networks application, which is mentioned in this article, the long training time of the network as well as the difficulty of selecting the number of layers and neurons. As a result, in some articles, including (Sharma et al., 2021), fuzzy controller has been used for this purpose. Given that the design of the fuzzy controller does not require complete specification of the model, it is very efficient in practice. In (Sharma et al., 2021), an adaptive fuzzy sliding-mode controller is provided with the help of a proportional-integral (PI) controller for damping power system oscillations. In this study, a neural network based on the wavelet transform function was used. In (Cheena et al., 2022), the bacterial Foraging optimization method has been used to adjust the stability coefficients of the power system. A combined method of bacterial optimization of the particle algorithm has been used. The GOA is also used for this purpose.

3. Research Approach

Distribution network fault is divided into short circuit and ground faults with small current. When an earth fault occurs with a small current, the fault current is small, that's why it is allowed to flow for 1 to 2 hours. But when a short circuit fault occurs, the fault current is much larger and severely damages the distribution network. Therefore, the ability to locate the fault and restore the power supply in time is one of the important indicators of a robust smart grid. Especially when a large number of DGs are connected to the system, the network structure and working mode will change, and the demands on the traditional fault location method will increase.The problem of locating a short-circuit network distribution is a typical NP problem. In this paper, BFA and TS algorithms are used to solve this problem. Compared to other algorithms, these algorithms have the advantages of fast search speed, easy jump from the local optimal answer, etc. Due to the difficulty of using the traditional method of fault location in distribution networks with DG, these two algorithms have been used for fault location in this type of networks.In this method, there is no need to build complex switching functions in the original smart bionic method. The connection between the switch and the line is hidden in the network connection matrix, as well as the effect of the presence of DG in the DG matrix. The mathematical model is improved in such a way that it can be easily adapted for the case of connecting multiple DGs and the occurrence of multiple faults. Even when the information is distorted, this method still can tolerate the error.Simulated examples show the possibility of implementing this program. The nutritional behavior of bacteria consists of three important steps: Chemotaxis (Swing & Swim), Reproduction, Elimination and Dispersal (Cheena et al., 2022).

3.1. The objectives and necessity of research

Implementing the proposed method in a sample microgrid - Optimizing the network voltage situation and automatically fixing the error, along with automatically connecting the DG sources to the system under study. Due to the fact that automation in the recovery of the power of the distribution network in case of fault is one of the things that cannot be ignored in the distribution network and affects its stability. Therefore, it is necessary to reduce operating costs by providing the appropriate optimization algorithm while considering the system limitations. In this article, it is proved that the proposed optimization method provides more acceptable results than the methods presented so far.

4. A Brief Overview of the BFA Optimization Method

The BFA method is an evolutionary optimization technique that is inspired by the exploratory behavior of the bacteria E.coli.Biological aspects of bacterial exploration methods and their movement behavior. In addition to their decision-making mechanisms, they can be found in (Kumar et al., 2022). As an exploratory method, the BFA method is designed to overcome the problems of gradient-free optimization and to deal with complex and non-differentiable objective functions. In the

BFA method, tumbling with a single length is represented in a random direction φ(j), which determines the direction of movement after tumbling. The size of the step taken in the random direction is indicated by the unit length constant C(i,j). Recently, the search and optimal nutrition of bacteria have been used to solve optimization problems. The joint search function of an animal requires communication facilities and in a period of time, it can use the facilities of observing the whole group. (Over some time, this increases the benefits that it can take advantage of the ability to see the whole group). This behavior helps the group catch more extensive prey, or alternatively, members can have better support in terms of catching in the group. The overall function of this bio-inspired algorithm is from the search behavior of the bacteria to find nutrition, which sometimes it has done collectively. The principles of moving bacteria are innovative and toward more food, eventually, the bacteria that get enough food will survive (Reddy et al., 2008). The survival of species in any natural evolutionary process depends on the criterion of their appropriateness, which is itself based on motor behavior and food search. The law of gradual evolution supports species that have the ability to search for better food, the eliminates or deforms those that have the ability to search less. Stronger species genes are propagated in the evolutionary chain in later generations due to their ability to reproduce even better species. Therefore, the correct understanding and modeling of exploration behavior in each of the evolutionary species leads to the possibility of applying it in any nonlinear system optimization algorithm .The control system processes of these bacteria, dictating how foraging should occur, can include chemotaxis, swarming, reproduction, and elimination and dispersal (Cheena et al., 2022).

4.1. Chemotaxis

Characteristic of the bacterial movement in search of food can be defined in two ways: swimming or tumbling, which is called the combination of these two movements Chemotaxis. Depending upon the direction of rotation of the flagella in a bacterium, it either moves in a predefined direction (swimming) or changes its direction (tumbling). Mathematically, the rotation of any bacteria can be denoted by the unit length of a random motion φ(j) multiplied by the step length of that bacteria C(i). In swimming mode, this random length is predetermined.

4.2. *Swarming*

To model cell-to-cell signaling via an attractant and a repellent that operate upon swarming bacteria, the function $Jcc(\theta)$, i = 1,2 .,S, is represented by Equation 1:

$$Jcc\big(\theta, P(j,k,l)\big) = \sum_{i=1}^{s}\left[-datt \exp\left(-\omega att. \sum_{m=1}^{p}(\theta m - \theta^{i} m^{1})^{2}\right)\right] + \sum_{i=1}^{s}\left[hrep\colon \exp\left(-\, \omega rep\colon . \sum_{m=1}^{p}(\theta m - \theta^{i} m^{1})^{2}\right)\right] \quad (1)$$

Where, j and k are the index for the chemotactic step and the index for the reproduction step, respectively.

4.3. Reproduction

The least healthy bacteria die and the remaining healthiest bacteria each split into two bacteria, which are placed in the same location, replacing the same number of unhealthy bacteria. This makes the population of bacteria constant.

4.4. Elimination and dispersal

It is possible that, in the local environment, the live population of bacteria changes either gradually (e.g. via consumption of nutrients) or suddenly due to some other influences. For each elimination-dispersal occurrence each bacterium is dispersed with a probability of ρe.d. In the proposed smart bacteria foraging algorithm (SBFA) it is assumed that bacterial foraging takes place in a homogeneous medium, so the probability is performed only for unhealthy bacteria. This gives a faster and a faster convergence than BFA (Zadehbagheri et al., 2023).

5. Implementation of BFA

Suppose that we want to find the minimum of J (θ),θ ∈ ℜp

5.1 Initialization

a) Number of parameters (p) to be optimized;
b) Number of bacteria (S) to be used for searching the total region;
c) Swimming length Ns after tumbling of bacteria will be undertaken in a chemotactic loop;
d) The number of iterations to be undertaken in a chemotactic loop Nc > Ns ;
e) Nr: the maximum number of reproduction s to be undertaken;
f) Ned: the maximum number of elimination and dispersal events to be imposed over the bacteria;
g) ρe.d : the probability that the elimination and dispersal will continue;

h) The location of each bacterium P(i, j, k) which is specified by P (i , j , k) { θ i (j , k , l) i= 1,2,..., S };
i) The value of essential chemotactic step size " C (i) " for i =1,2,… , S is assumed to be constant in our case for all of the bacteria to simplify the design strategy;
j) To represent a tumble, a random direction unit length between (0,1) say ϕ (j) is generated. This will define the direction of movement after a tumble by using β(i) . The value of ϕ (j) is represented by Equation.

$$\Delta(\mathrm{i}) = \beta(\mathrm{i}) \frac{\Delta(\mathrm{i})}{\sqrt{\Delta t(\mathrm{i}) \Delta(\mathrm{i})}} \quad (2)$$

Where, β (i) : {β m (i) | m = 1,2 ,..., p} is 1 or -1 and Δ (i) ∈ R^{p} , { Δ m (i) | m 1,2 ,..., p} is a random number on (0,1]. Alsoβ (i) at first is chosen randomly and then changes with attention to the cost function smartly (Zadehbagheri et al., 2023).

5.2 The Iterative algorithm for optimization

This section models the bacterial population chemotaxis, swarming, reproduction, elimination and dispersal (initially *j=k=l=0* and θ *i* are chosen randomly).

Step 0) Initialization of variables Δ (*i*) , β 0 (*i*) and θ^i randomly. For *i* = 1,2,..., *S* , calculate the cost function value for each bacterium using initial variables *(j=k=l=0)*, as follows. . Compute the value of the cost function *J* (*i* , *j* , *k* , *l*) that: *Jsw* (*i*, *j* , *k* , *l*) =*J* (*i*, *j* , *k* , *l*)+ *Jcc* (θ^i (*j* , *k* , *l*), *P*(*j* , *k* , *l*))

Step 1) Elimination-dispersal loop *l* = *l* + 1.

Step 2) Reproduction loop *k* = *k* + 1.

Step 3) Chemotaxis loop *j* = *j* + 1

a) For *i* =1,2,..., *S* calculate the cost function value for each bacterium *i* as follows. Compute the value of cost function *J* (*i* , *j* , *k* , *l*) let;

b) For *i* = 1,2 ,..., *S* , take the tumbling/swimming decision.**. Tumble:** Generate a random vector Δ(*i*) with each element. . **Move:** let θ^i (j+1, *k* , *l*)=Γ= θ^i (j, *k* , *l*)+C(i)β(i)$\frac{\Delta(i)}{\sqrt{\Delta^t(i)\Delta(i)}}$ .The fixed step size in the direction of tumble for bacterium is considered. **. Swim:** 1) Let *N* = 0 ; (counter for swim length); 2) While *N* < *Ns* (have not climbed down too long). **c)** Go to the next bacterium *i* = *i* + 1 if *i* ≠ S(i.e., go to b) to process the next bacterium.

Step 4) If *j* < *Nc* , go to Step 3). In this case, continue chemotaxis since the life of the bacteria is not over.

Step5) If *l* > *Ned* , The algorithm stops.

Step 6) Reproduction. For the given *k* and *l* , and for each *i* = 1,2 ,..., *S* , let $J^i health$ = min{ *J SW* (*i* , *j* , *k* , *l*)}, *j*∈ {1,... *Nc* } be the health of the bacterium (a measure of how much nutrients were received over its lifetime and how successful it was at avoiding noxious substances). Sort bacteria in order of ascending cost *Jhealth* (higher cost means lower health).

Step 7) If *k* < *Nr* , go to 2. In this case, we have not reached the number of specified reproduction steps, so we start the next generation in the chemotactic loop.

Step 8) Elimination dispersal: after sorting bacterium in order of ascending cost Jhealth (higher cost means lower health), for *i* = *Se.d* , *Se.d* +1,..., *S* , (*Se.d* = *n.S*,{*n* <1}) with probability ρ *e.d* , eliminate and disperse each bacterium (this keeps the number of bacteria in the population constant) to a random location on the optimization domain. After that, go to 1. The flowchart of this algorithm in shown in Figure 1. (Zadehbagheri et al., 2023).

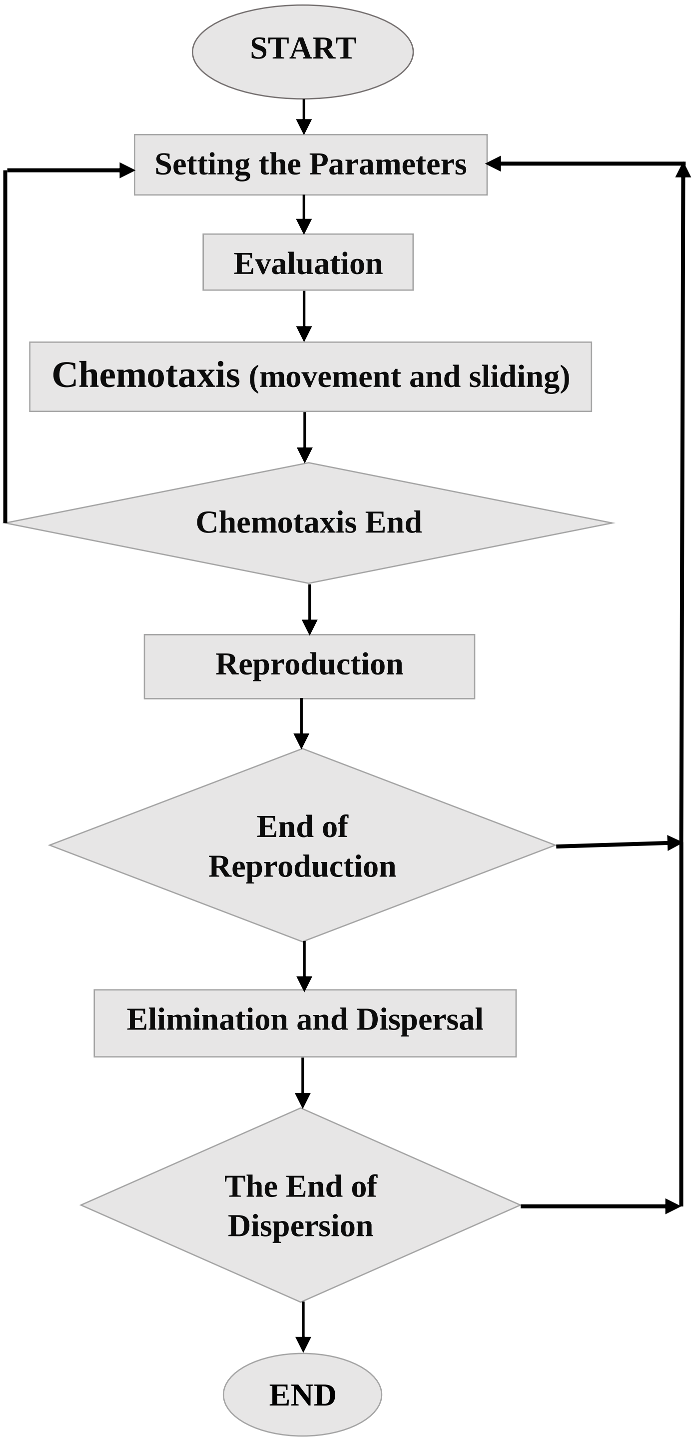

Fig.1. Flowchart of BFO algorithm

6. Tabu Search Algorithms (TS)

Tabu search algorithm (TS) is a memory search strategy that was first proposed by Glover in 1986 .This algorithm works almost like local search algorithms, with the difference that it uses a concept called Tabu list to avoid rounds and sequences in the answers and falling into the trap of local optimal answers. Shifting from the current solution to the feasible neighbor solution is done when it is not in the Tabu list. Otherwise, another neighbor's answer, which is placed in the next rank in the evaluating the neighbor's answers, is selected and shifted to it. Whenever the neighborhood structure is symmetrical, there is a risk of falling into the circle. The flowchart of the Tabu search algorithm is as follows. The Tabu list has fixed or variable dimensions that keeps the Tabu places and its main use is to avoid converging to local optimal solutions (Alanazi et al., 2022). In other words, using the Tabu list, it will be forbidden to shift to recently searched answers, and only those parts of the answer set that have not been examined before will be considered. To reach the optimal solution in an optimization problem, the Tabu search algorithm starts shifting from an initial solution. In each iteration of the algorithm, a neighborhood is defined for the current solution. Then, the algorithm selects the best neighbor solution among the neighbors of the current solution. To reach the optimal answer in an optimization problem, the Tabu search algorithm starts moving from an initial answer. In each iteration of the algorithm, a neighborhood is defined for the current answer. Then, the algorithm selects the best neighbor solution among the neighbors of the current solution. If this answer is not in the Tabu List (TL), the algorithm moves to the neighboring answer, otherwise, the algorithm will check a criterion called the breathing criterion. Based on the breathing criterion, if the neighbor's answer is better than the best answer found so far, the algorithm will move to it, even if that answer is in the Tabu list. After the algorithm moves to the neighboring answer, the Tabu list is updated, meaning that the previous move by that the side moved to the neighboring answer is placed in the Tabu list to prevent the algorithm from returning to that answer and creating a cycle (Cheena et al., 2022). In fact, the Tabu list is a tool in the Tabu search algorithm that prevents the algorithm from reaching the local optimum. After placing the previous move in the Tabu list, a number of moves that were previously placed in the Tabu list will be removed from the list. The length of time that moves are banned is determined by a parameter called the Tabu Tenure (TT). Moving from the current answer to the neighbor answer continues until the termination condition is met. Different termination conditions can be considered for the algorithm. For example, limiting the number of moves to a neighbor's answer can be a termination condition. The flowchart of this algorithm in shown in Figure 2.

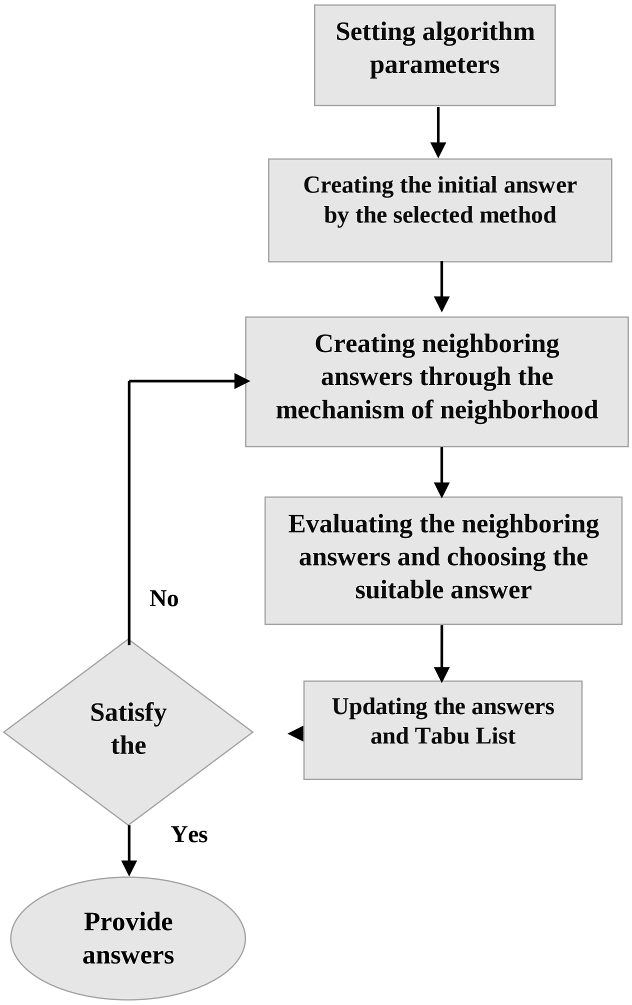

Fig. 2. Flowchart of TS algorithm

Many meta-heuristic algorithms have been created to achieve at least one good (not necessarily the best) solution to a problem. Many of these methods use a local search (LS) mechanism. LS can be considered as an iterative search procedure that starts from a possible solution and continues it until reaching a local optimum by making partial transitional corrections (Kong et al., 2016). Keeping in mind that in the usual case this local optimum is nothing more than an average answer. In LS, the quality of the obtained answer usually depends to a large extent on the richness of defined transitions, and this is the basic issue in LS-based approaches. The basic principle in TS is to allow non-improving transitions to continue the search in LS when a local optimum is encountered. Of course, in this method, we use a memory called TL to avoid bypassing and reaching answers that have been obtained before. This memory records recent answers or recent transfers. In fact, a simple TS can be considered a combination of a short-term memory with LS.

7. Optimal Placement of DGs

The problem of locating DGs in the power system, similar to all optimization problems, is to select the best member from a set of achievable members (according to the limitations and constraints of the problem) according to that the desired objective function is minimized. Therefore, this problem can be shown as follows (Omar et al., 2022):

$$\begin{aligned} &\min\ f(x,y) \\ &s.t\quad h(x,y)=0 \\ &\quad g(x,y)\geq 0 \\ &\quad \underline{x}\leq x\leq \overline{x} \\ &\quad y_i\in D_{y_i}, i=1,2,...,n_y \end{aligned} \quad (3)$$

7.1. The objective function

As mentioned before, the objective function in the problem of optimizing the placement of DGs can be a combination of different functions. Often, the amount of active power loss (Ohmic) of the power system and the voltage stability criterion or a combination of them (multipurpose objective function) are considered as goals.

7.1.1 Minimization of active power losses

One of the important objective functions in the problem of optimal placement of DGs is to minimize the amount of active power losses, which is expressed as follows:

$$Minimize \quad P_{Loss}=\sum_{k\in N_E} g_k\left(V_i^2+V_j^2-2V_iV_j\cos\theta_{ij}\right) \quad (4)$$

In the above relationship, N_E is the number of branches of the system (number of lines), g_k is the conductance of line k between the i-th and j-th lines, Vi and Vj are the voltages of the i-th and j-th buses and θ_{ij} the phase difference between the i-th and j-th buses.

7.1.2 Increasing voltage stability

Voltage stability is the ability of the power system to continuously maintain the desired voltage on each bus in the normal state of the system. A power system may experience voltage disturbances at times of instability. We consider Equ. 5 as the voltage stability index (SI). The larger the positive number of the voltage stability index, the more stable the system will be.

$$SI=V_S^4-4V_S^2\left(RP_L+XQ_L\right)-4\left(XP_L-RQ_L\right)^2 \quad (5)$$

8. Optimal Placement of Faults

In traditional methods, most faults are located without using any measurements. Location is easily obtained through physical landmarks, field methods, and brute force methods: Recovery through switching- Recovery through the recloser function- Indication by fuse and fault detection function - Downed wires, customer calls, maps. Error-processing methods based on centralized intelligent methods are actually the core technologies in distribution automation systems based on centralized smart methods, which have always been a hot topic for research and many advances have been made. An integrated matrix-based algorithm for fault segment identification and isolation in distribution systems is presented in (Ngaopitakkul et al., 2014), which was also modified in (Cong et al., 2005). But matrix-based methods require both computational time and a lot of space for large-scale distribution networks. A directed graph-based fault location method is proposed in (Yadav et al., 2014), which is matrix-free. In (Kamarposhti et al., 2021), a large-scale distribution network is divided into several small-scale connected systems, which includes a series of connected feeders, and the fault can be propagated in this network according to the connections of the system. Therefore, the computational space and time can be significantly reduced despite the large distribution network. In (Furse et al., 2006), an algorithm based on a hierarchical model is proposed to identify the fault section in distribution networks. The fault location method based on pattern recognition is also described in (Cheena et al., 2022). A multipurpose recovery method of the distribution network using the empirical method as well as the correct mixed programming method is proposed .

8.1. DMS based fault location

Reference (Satyanarayana et al., 2019), has presented a fault location method that was developed as part of the development of the distribution management system (DMS). The main idea of DMS is used in this project to develop a new information system based on the integration of network information system and distribution automation. From a fault location perspective, this basic idea means that only existing equipment and data should be used instead of developing a method that requires detailed network modeling and specific equipment at the network level. This basis is very important from a practical point of view because this method can be used without high investments. The principle of distance-based fault localization is very simple: find the similarity between measured and calculated fault currents. The database of the network information system contains the data required for the analysis of the fault current of the distribution network, which is obtained in the offline engineering analysis. This network modeling and fault current calculations are also part of DMS and together with real-time topology information, provide a basis for fault location. The measured fault current can be obtained for microprocessor-based relays, which are very common today. even a relay with such capability if it is installed on the entrance side of the station; It will be efficient. As a result, this algorithm calculates one or more faulted line segments based on distance. DMS provides an excellent environment for further processing, since the result of distance-based fault localization is not an explicit result. Information on possible fault identifiers and even weather and terrain conditions can also be considered. The research done in (Castillo et al., 2018), proposes an experimental protection scheme based on the phase jump measured in the current waveform during fault conditions. In each node, the phase jump is recorded and used to detect changes in any direction of the flow. The change in current direction is determined by the difference between the phase angle of the fault and pre-fault currents. The requirements of the communication channel and the cost of the communication equipment can be reduced by considering the phase angle comparison of the positive sequence component related to the line current. This issue leads to an increase in the sensitivity and security of the relay or a combination of positive and negative sequence components. However, these methods cannot determine the defective phase . In addition to protection plans, self-repairing plans have also been examined in distribution networks. The research done in (Mengelkamp et al., 2018), introduced a process of negotiation between message exchange in multi-agent systems so that the situation with system error is detected and separated from the system and then restored and repaired. The research done in (Mengelkamp et al., 2018), proposed a Fast location, Fast Isolation and Fast repair (FLISR) algorithm that can reduce the network outage time on the client side. The main weakness in this field is that they centralize these methods and depend on a large amount of data for communication capabilities and power exchange in the direction of network repair. Based on this, the distribution protection method is presented to locate and determine the type of fault in the distribution lines, which shows the weakness of intensive communication needs by reviewing other articles. The main idea in this research is that the phase angle of the currents of each of these three phases in the two terminals of each section of the network is measured using phasor measurement units (PMU) and is connected with the sector agent (SA), which is placed in the middle of the section. Then the SAs calculate the phase angle difference and send the trip signal to the circuit breakers, which are connected to the two ends of the distribution line in abnormal operation. The advantages of the proposed method are:

- Dependence on current measurement leads to cost reduction by eliminating the use of voltage converters.
- Minimizing communication delays to isolate the fault section, as this method depends on data transmission between the two ends of the distribution line and an SA is placed in the middle of the line.
- Stable phase comparison methods using numerical relays and time-synchronous meters that have communicated with the relays. (Coordination should be implemented only on SAs instead of two relays on each side of each section).
- Smart microgrid protection devices are not expected to trip phases during unbalanced short circuit. Therefore, some networks as well as relay manufacturers have started to use one-pole or two-pole trips in distribution systems (Balakrishna et al., 2017). This design can detect the reliability of the faulty phase and improve the relaying speed without compromising the network security to a significant extent, it can also increase the stability and power transmission capabilities of a distribution system after an earth fault.

9. Fault location based on the coordination of reclosing process and disconnection of DGs

After the fault occurs, the tripping of a given circuit breaker by the corresponding relay protection device leads to the tripping of the feeder. DGs connected to the feeder are cut off by anti-islanding protection within two seconds. Based on this feature, the fault location methodology is coordinated with the reclusig process; The main actions are as follows: For circuit breakers, the reclose delay time is changed to 3-4 seconds. In the event of a fault, a specific circuit breaker is tripped with a self-closing delay start timer. Two seconds after the fault, all DGs connected to the faulted feeder are disconnected by the anti-mains protection. 3-4 seconds after the fault, the tripped circuit breaker closes again. If the fault was temporary, service is restored and DGs are quickly connected to the network. If it is permanent, the fault phenomenon is the same as when the feeder is without DG and the short-circuit current flows only from the main power source.

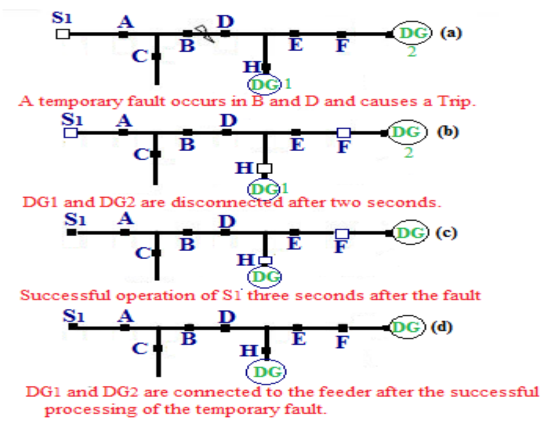

Fig. 3..An example of the fault location based on the coordination of the method of retrieving and interrupting DGs

In Figure 3, S1 is the main power supply node, A, B, C, D, E are the branch switches, F and H are the output breakers of DGs; DG1 is a large capacity photovoltaic power source, and DG2 is a large capacity micro gas turbine. After 2 seconds, F and H open, causing the DGs to disconnect from the circuit (Figure 3(b)). One second later, S1 closes as shown in Figure 3(c). In a short time, F and H are connected and DG is connected to the feeder(Figure 3(d)). The distribution network is restored to its normal state.

10. System Modeling

8.1. Parameter coding

In fault location mode based on the FTU, the FTU monitors the key status of the received error information. There are two rules here: the FTU key is seen as a node; the area between the nodes is seen as an independent line. Typically, the positive direction is the direction in which power flows only to the main power supply. Therefore, the node in the network has three modes: **-1**, **0**, and **+1**. These modes, respectively, represent the direct current, the normal current and the inverse current flow from the node. For the standalone line, it is also coded **0** and **1, 0** represents the normal line, and **1** represents the error line.

10.1. Network connectivity matrix

The network communication matrix describes the topological relationships between the key and the key (Kong et al., 2016), it is defined as (6).

$$A_{ij} = \begin{cases} 1 \; i = j \\ 1 \; j \neq i \\ 0 \quad \text{else} \end{cases} \tag{6}$$

In (6), $A_{ij} = 1$ $(i = j)$, that is, the node ***i*** is visible. Each row vector represents the relationship between node i and all the downstream node nodes ***i***. This means that if the node ***j*** is located at the bottom of node ***i***, then $Aij = 1$, otherwise $Aij = 0$. Figure 4 illustrates a simple distribution network with ***DG***. In this figure, ***A*** power supply, ***CB*** circuit breaker, ***S*** separator key, ***DG*** power supply, Node number subtitle. The id number of each line represents the top node of the hand (Kong et al., 2016).

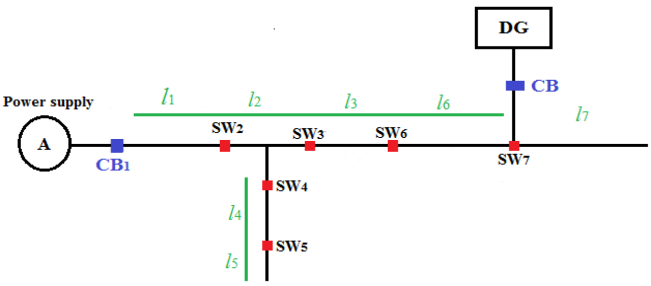

Fig.4.Simple Distribution Network with DG

The network connection matrix of Figure 3 is like .

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ & 1 & 1 & 1 & 1 & 1 & 1 \\ & & 1 & 0 & 0 & 1 & 1 \\ & & & 1 & 1 & 0 & 0 \\ & & & & 1 & 0 & 0 \\ & & & & & 1 & 1 \\ & & & & & & 1 \end{bmatrix} \tag{7}$$

Matrix ***A*** is a matrix of 7×7. Since all nodes can be viewed by the *FTU*, therefore, $Aii == 1$ $(i = 1\text{-}7)$. Since node ***2*** to ***7*** is located at the bottom of node ***1***, so $A1j = 1$ $(j = 2\text{-}7)$; only node ***5*** is lower than node ***4***, so ***A45 = 1*** and other elements of this line are ***zero***. Compared to the network description matrix mentioned in (Hou et al., 2020), the network communication matrix shows not only the relationship between node ***i*** and first down node ***i*** but also the relationship between node ***i*** and all downstream ***i*** nodes. This matrix contains more information and has a stronger global visibility (Li, Z.et al., 2022).

10.2. Distributed generation matrix

In a radial distribution network, the node's condition depends only on the lines located at the bottom of the node. If this error node occurs on each downline, this node will alert you. But when the DG is connected to the network, by loading the load in both directions, the status of some nodes can be affected by the lines above it. The DG matrix is used to describe this situation.

$$A_{DG} = \begin{bmatrix} A_{DG1} & A_{DG2} & \dots & A_{DGn} \end{bmatrix}^T$$
$$A_{DGi} = K_i \overline{A}_i \, (i = 1 - n) \tag{8}$$

In (8), A_{DGi} is the row vector of the A_{DG}. In (8), $\overline{\boldsymbol{A}}$ is the inverse of ***A***, in that the Boolean value is ***1*** to ***0*** and the Boolean value is ***0*** to ***1***. Matrix ***K*** is of the order $n \times 1$ and represents the location of the node ***i*** and *DG*, if a *DG* is located at the bottom of the ***i*** node, then $Ki = 1$ $(i = 1\text{-}n)$, otherwise $Ki = 0$. ***ADG*** is the result of the transformation of matrix ***A*** elemental. The elements of the row ***i*** in matrix ***K*** are multiplied, respectively, in the elements of the row ***i*** and matrix $\overline{\boldsymbol{A}}$. One important and limiting reason for the traditional error-finding method is the "Connect and Run" feature of DG. When each DG is connected or disconnected from the system, the switching function in the traditional algorithm must be changed. In this project, this change is brought about by the *DG* in matrix. We modulate the ***K*** matrix only when DG is connected to or from the system and we can express this change. Therefore, this algorithm is adaptable. In Fig. 3, the *DG* matrix is shown in (9) (Kong et al., 2016).

$$A_{DG} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad (9)$$

If matrix ***A*** describes the relationship between node ***I*** and its downstream nodes, then the ***ADG*** matrix describes the relationship between the nodes affected by the *DG* and its upstream nodes. For example, when the *DG* is connected, the power in node ***2*** flows in both directions, and node ***1*** is located at the upstream node of node ***2***, so *A21 = 1*. The nodes **5** and **4** are in the sub-line, in which they can still flow in one direction and its status is not influenced by *DG*, so the elements of row ***5*** and ***4*** are zero (Fu et al., 2018).

$$f_{min} = sum|sgn\ CA^T - sgn\ CA_{DG}^T - B| + \mathrm{wsumC} \quad (10)$$

In (10), $\boldsymbol{A^T}$ is a transposition of ***A. B*** is an error information matrix reported by the *FTU*. ***C*** is a misplaced answer for the error section. In addition, ***C*** is the location of each bacterium in the bacterial nutrition algorithm. $sgn\ CA^T$ - $sgn\ CA^T_{DG}$ is a matrix of order $\boldsymbol{1 \times n}$ that shows the theoretical information of the error, in which ***C*** is a conditional line matrix that is error-prone. So we can see that the first polynomial represents the difference between the theoretical error information from matrix ***C*** and the practical error information of *matrix* ***B***. The smaller the difference, the *better* ***C***. To avoid misjudgment, an additional item ***ω*** sum ***C*** has also been introduced. ***ω*** is the weight coefficient located in the interval (0,1). ***A*** special theoretical analysis is presented in (Fu et al., 2018) (Li, Z.et al., 2022).

11. Simulation Results

As shown in Figure 5, the distributed distribution network is simulated with DG. A is the main power supply. DG represents three dispersive power supplies. There are 33 nodes in total. The ID numbers of each node and line are shown in Fig. 5. According to the method presented in this project, this issue was programmed by MATLAB. The parameters are as follows: the population S = 12, the number of chemotaxis operators Nc = 7, the maximum number of steps for moving the chemotaxis operators Na = 5, the number of reproduction s operators Nre = 5, the number of migration operators Ned = 1, the probability of migrating Pe = 0.3.

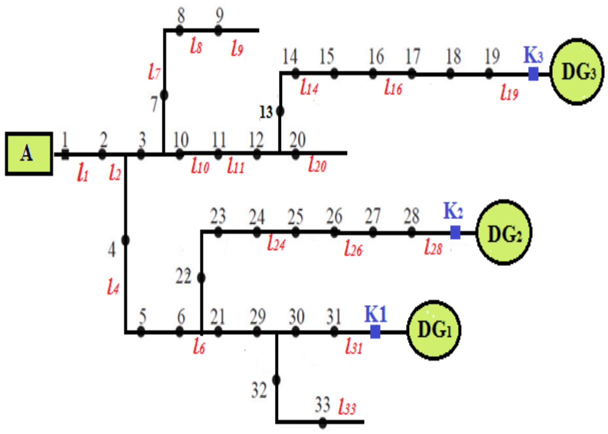

Fig.5. Compound Distribution Network with DG

To validate this method, a single error and multiple errors are simulated in compound distribution networks. Assuming the operation of all three *DGs*, matrix ***K*** can be determined as follows:

$$K = [111111000111111111101111111111100] \qquad (11)$$

Given the occurrence of a single error in ***l16*** and multiple errors in ***l16***, ***l22*** and ***l30***, the simulation results are presented in Table 1. In table 1, ***e12*** means the error in line ***16, B*** represents the error information matrix sent by the *FTU* when an error occurs. The optimal answer is the *BFA* result, we can see that the ***16th*** element is equal to one, so the line **16** error algorithms is detected and the result of the diagnosis is correct. ***L16, L22***, and ***L30*** mean an error in lines ***16, 22***, and ***30***. Because the element ***16, 22, 30*** in the optimal answer is ***1***, the errors in lines ***16, 22*** and ***30*** are detected and the result of the diagnosis is correct. Since the FTU is mainly installed outdoors, error messages may be distorted or lost due to the natural environment or electromagnetic interference. This situation is simulated to examine the error tolerance of the proposed algorithm. The simulation results are shown in Table 2.

Table 1
Simulation Results of Single Fault and Multiple Faults

Fault Point	**B**	**Optimal Point Solution**	**Diagnosis Result**
***E*16**	[101-1-1-1000111-1-1-1 -1-1-1-10-1-1-0-1-1-1-0 -1-1-1-100]	[110010000001 0001110000000 00001100]	*l*16 **fault**
***E*16 *E*22 *E*30**	[101111000111-1-1-0-1-1-1-10111111011-1-101]	[001100000001 0100000000011 00100001]	*l*16 *l*22 *l*30 **fault**

Table 2
Simulation Results with Distorted Information

Fault Point	**B**	**Optimal Point Solution**	**Diagnosis Result**
***E*16**	[101-1-1-1000111-1-1-1 -1-1-1-10-1-1-0-1-1-1-0 -1-1-1-100]	[11000000000100 000000000000000 0100]	*l*16 error S12 Wrong warning
***E*16 *E*22 *E*30**	[111111000111-1-1-1-1-1-1-10111111111-1-111]	[001100111001 0100000000011 10100101]	*l*16 *l*22 *l*30 error S8 S12 Wrong warning

From Table 2, we can see that if the error occurs in the same line in Table 1, the algorithm can still correct the error when distorting the error information. For example, when node information is changed from **12** to ***1*** or the data for nodes ***6*** and ***15*** is ***zero***, the optimal answer is always the same as in Table 1. This means that if the node information is distorted, the algorithm has a good error tolerance.

11.1. DG performance fault

To check the error of DGs, it is assumed that the wind speed changes in such a way that the torque of the DG connected to bus 14 increases by one unit at the moment t=2s. In this case, the bus voltage diagram and the current of the main feeders can be expressed according to figures 6 and 7.

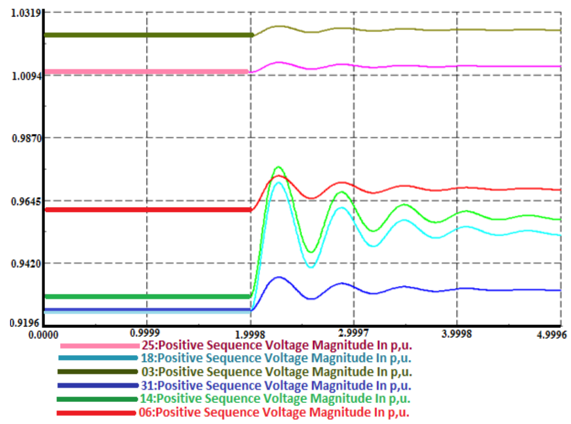

Fig.6. voltage diagram of some buses after applying the mechanical fault

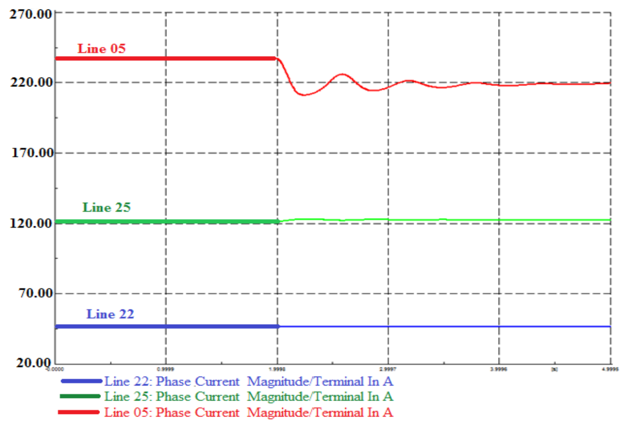

Fig.7. Current diagram of some feeders after applying the mechanical fault

At this stage, it is assumed that at the moment t=2s, the switches at both ends of line No. 5 have an error and unintentionally open phases B and C. In this situation, the current passing through the feeder is greatly reduced and causes a lot of voltage drop in the network. Figure 8 the diagram show the important feeder voltages of the circuit.

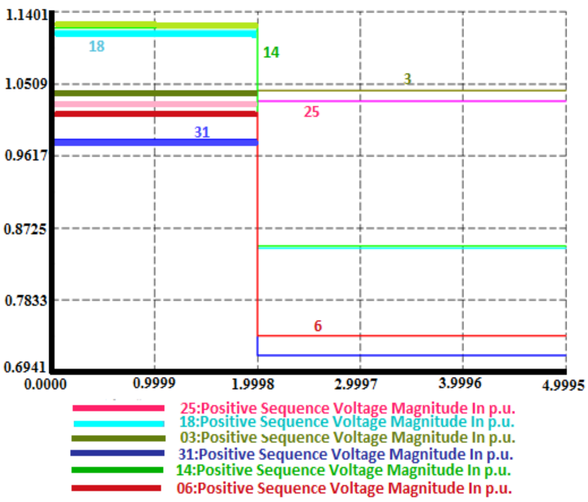

Fig. 8. The voltage diagram of some buses after the operation of the switches

It also carries out a search for a multiplicity of searches, many searches are conducted in parallel and independently, and there is no direct exchange of information between bacteria. In addition, at the reproduction stage, half the bacteria are eliminated, but the other half is equally involved in generating subsequent responses. For this reason, half of the bacteria affect the production of subsequent solutions, and therefore more accurate answers are obtained.

Suggestions

Improving network protection conditions according to adaptive protection in the context of automation- Comparison of distributed and non - distributed automation in the distribution network - Using new software and algorithms to improve the obtained answers - Extracting the small signal model and checking the power modes flowing on the lines - The use of multi-area micro-grids to connect to each other and increase the inertia of the entire network. In this case, micro-grids are separated from each other with network security considerations.

12. Conclusion

This study shows a dispersal output system and disposable output power. A developed control strategy that manages power flows into energy and network storage. A controller is systematically designed for a wind transform system based on the developed dynamic model. The system performance is evaluated in various operational modes based on the simulation of the digital time domain in the MATLAB software environment. Network support during the high volatility created by network disturbances is connected to the technical and load characteristics of the generator and features The network dynamics depends. The TS and BFO algorithm is an easy solution for implementation and the ability to handle complex optimization problems. Here, this algorithm is used to find the location and size of the DG installation in the radial distribution system to obtain minimum system losses. Operational limitations include load voltage limits, distribution thermal constraints, system power balance, and power generation constraints. The existence of DG in the grid illustrates the nonlinear complex nature of nature and can be solved using optimization techniques. The bacterial optimization algorithm (BFOA) is one of the best methods for solving any complex nonlinear optimization problem. Adjustable motion steps of this algorithm performed using C(i) make the algorithm in high-dimensional spaces Better performance.

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Appendix

Matrix A

A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
11	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
12	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Continuation of matrix A

A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continuation of matrix A

A	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1
2	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1
3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1
5	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1
6	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continuation of matrix A

A	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
18	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0
22	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0
23	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0
24	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
25	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
26	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
30	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Matrix Adg

Adg	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	1	1	1	0	0	1	1	0	0	0	0	1	0
3	1	1	1	1	1	1	0	0	1	1	0	0	1	1	0	0
4	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0
5	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0
6	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	1	0	1	1	0	1	1	0	0	1	1	1	0	0
11	1	0	1	1	1	0	0	1	0	0	0	0	0	0	1	0
12	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
13	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0
14	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0
15	0	1	1	1	0	0	0	0	0	0	0	1	0	1	1	0
16	1	0	0	0	0	1	1	0	1	0	0	1	1	1	1	0
17	1	1	0	0	1	1	1	1	0	1	0	1	0	0	0	0

Continuation of Matrix Adg

Adg	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	1	1	1	1	0	0	1	1	0	0	1	0	0	1
3	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0
4	0	1	1	0	1	1	0	1	1	0	0	0	0	0	1	0	1
5	0	0	0	0	1	1	0	1	0	1	1	0	0	0	1	0	1
6	0	1	1	1	1	0	1	1	0	1	1	0	1	0	0	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
11	1	1	1	1	0	0	1	1	0	1	1	0	0	1	0	0	1
12	1	0	0	1	0	1	1	1	0	1	0	0	1	0	1	0	1
13	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	0
14	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0
15	0	1	1	0	0	0	0	1	1	1	1	0	1	1	0	1	1
16	0	0	0	1	0	1	0	0	0	0	1	0	1	1	1	1	1
17	1	1	0	1	1	1	0	1	1	0	0	0	0	0	1	0	1

Continuation of Matrix Adg

Adg	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
18	1	0	0	1	1	0	0	0	1	0	0	0	1	0	1	1	1
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	1	0	1	0	0	0	1	1	0	1	0	1	1	1
22	0	0	1	1	1	0	1	1	0	0	0	0	1	0	1	1	1
23	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0	1
24	1	1	0	0	1	1	0	1	0	0	1	0	1	1	1	0	1
25	0	0	0	1	1	1	0	0	0	1	1	0	1	0	1	1	0
26	0	1	1	0	1	0	0	0	1	1	0	0	0	1	1	0	0
27	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	1	1	0	0	1	0	1	1	0	1	1
30	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continuation of Matrix Adg

A	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
18	0	0	1	1	1	1	1	0	1	1	0	0	0	1	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0
22	1	1	1	0	0	1	1	0	1	0	0	1	0	1	0	0
23	0	0	0	0	0	1	0	0	1	0	0	1	0	1	1	0
24	0	1	1	0	0	1	0	1	1	1	0	0	1	0	0	0
25	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0
26	0	1	1	1	0	1	0	1	0	1	0	0	0	1	1	0
27	0	0	1	1	1	0	0	1	1	1	0	0	1	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0
30	0	1	1	0	1	1	1	0	1	0	0	0	0	1	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0