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Research on state monitoring and regulation of distribution network with high percentage of distributed energy access based on intelligent optimization algorithm

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Abstract The large-scale access of distributed power sources will accelerate the formation of active distribution networks, which will have a greater impact on the safe and stable operation of distribution networks. In this context, this study constructs a state monitoring model for high proportion distributed energy access distribution network. Firstly, the objective optimization function of distribution network state is established, and then the model is solved by combining genetic algorithm and ant colony optimization algorithm. Simulation experiments are carried out with the IEEE 33-node distribution system as an example. The GA-CAO algorithm in this paper accurately portrays the state change characteristics of the distribution network, and its errors in estimating each state of the distribution network are smaller than those of the GA algorithm, with the root-mean-square error and the average absolute error being reduced by 1.07%~2.46% and 0.35%~3.02%, respectively. Experiments show that the method in this paper improves the accuracy of distribution network condition monitoring and has obvious advantages over other distribution network condition monitoring models, and the monitoring results can provide valuable information for distribution network enterprises as well as managers. In addition, the distribution network can be regulated by optimizing load management and scheduling, applying power management system and optimizing the design of distribution network architecture for the access of high proportion of distributed energy sources, which can promote the safe and stable operation of the distribution network.

Index Terms distributed energy, genetic algorithm, ant colony optimization algorithm, condition monitoring model, distribution network

I. Introduction

Based on the consideration of grid economy and security, distributed generation (DG) is usually directly connected to medium and low voltage distribution networks. Currently, China's traditional distribution network is mostly a single power supply radial structure, the current in the system is distributed unidirectionally, and the protection does not need to consider the directionality [1], [2]. After the access of distributed power supply, the distribution network becomes a multi-power system, coupled with the new energy type of distributed power with a certain degree of randomness, so that the distribution network in the normal operating conditions may appear bidirectional indeterminate current problem [3]-[5]. Traditional protection methods are difficult to meet the security and stability requirements of distribution networks under DG access conditions [6]. Therefore, this paper takes the distribution network with high percentage of DG access as the application background to carry out the distribution network condition monitoring and regulation research and charging, which can provide valuable suggestions for guaranteeing the stability of the distribution network.

Since the access to distributed power sources with output uncertainty in distribution networks will have an impact on the original method of monitoring and regulation strategy development, it should be fully considered [7], [8]. On the one hand, it is necessary to maximize the ability to consume distributed power output and reduce the loss of power losses, and on the other hand, it is also necessary to reduce the violation of operational constraints as well as the occurrence of secondary loss of load [9]-[11]. Through the load transfer operation of the distribution network, if the power of distributed power sources decreases, the load transfer scheme that has been obtained may have power imbalance, violate the operational constraints, and be forced to carry out secondary load transfer or even load shedding [12], [13]. If the distributed power output increases, there exists a better load transfer scheme to dissipate more distributed power output and reduce the lost load [14], [15]. Based on the above principles, the problems related to distribution network condition monitoring and regulation can be optimally solved to maintain the stability of the distributed distribution network and reduce the operation cost at the same time.

The study takes voltage magnitude and phase angle as state variables, minimizes the error between measured and estimated values as objective function, takes the upper and lower limits of trend equations and estimated values as constraints, constructs an optimization model for distribution network state monitoring, and adopts a combination of Genetic Algorithm (GA) and Ant Colony Optimization (ACO) algorithms to estimate the state of distribution network, and realizes the distribution network state monitoring model based on multi-intelligent optimization algorithms. The IEEE 33-node distribution system is selected for simulation testing and analysis, and the GA algorithm is used as a comparison method to compare the monitoring results of node voltage magnitude, voltage phase angle, line active power, line reactive power, DG active power and load active power by the two methods, so as to preliminarily judge the accuracy of the proposed method for distribution network state monitoring. The root-mean-square error and average absolute error are then introduced to compare the estimation accuracy to further test the performance of the GA-CAO algorithm of this paper for distribution network state detection. On this basis, the regulation strategy of high percentage distributed energy access to distribution grid is discussed to support the efficient utilization of energy and the safe construction and development of smart grid.

II. Intelligent Optimization Algorithm Based Condition Monitoring Method for Distribution Networks

With the continuous promotion of clean energy construction, the proportion of distributed photovoltaic power generation, wind power generation and energy storage access to the distribution network is getting higher and higher, which has changed the original single power radial power supply structure of the traditional distribution system. The access of high proportion of distributed power supply makes the operation mode, current characteristics and short-circuit current of the distribution network have undergone large changes, which brings “new challenges” to the safe and stable operation of the distribution network. Based on this, this paper proposes a state monitoring model for high proportion of distributed energy access to the distribution network, and adopts an intelligent optimization algorithm combining genetic algorithm and ant colony algorithm to estimate the state of the distribution network.

II. A. Basic structure of the distribution network

Currently there are many types of distributed power sources, such as wind power generation, etc. Since distributed power sources are received into the distribution grid system, the voltage stability can be enhanced and the distribution grid losses are reduced substantially. The distribution network system realizes the distribution network state estimation by constantly measuring the data and according to the supplementary power load data, and the typical distribution network structure is shown in Fig. 1.

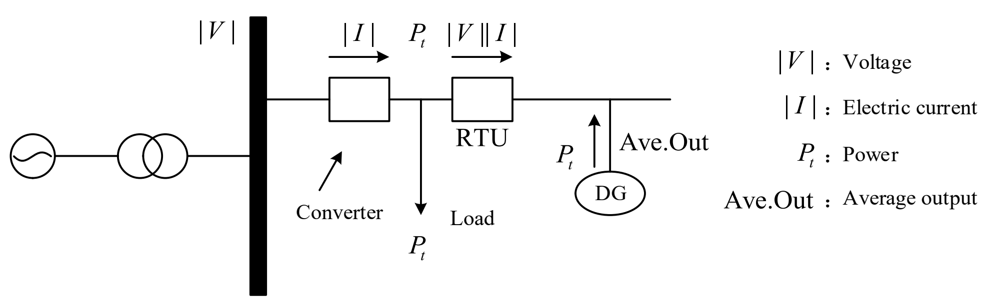

Figure 1: Typical structure of distribution network

Real time measurement data is collected in real time through measurement devices, there are many current measurement data which can be load power, branch power etc. Pseudo-measurement data is mainly the power load data used by the consumers, which plays a vital role in estimating the state of the distribution network. For a distribution network system in a region, the power loads at the entry and exit points can be measured, then the total load in the region is:

$$S_d = s_d - \sum_{j \in \Omega} s_j \tag{1}$$

where s_d and Ω are the loads at the entry and exit points, respectively, and s_j is the load flowing through the switch j.

II. B. Genetic Algorithm and Ant Colony Optimization Algorithm

II. B. 1) Genetic algorithms

Inspired by the natural law of "survival of the fittest, survival of the fittest", the genetic algorithm does not require too much prior knowledge of the solution object, has few constraints, and optimizes and solves the problem by simulating population evolution, has good global search ability, and has hidden parallelism, and has high efficiency in solving complex problems, which is introduced into the state estimation of distribution network in this paper.

In the process of estimating the state of the distribution network, the genetic algorithm should determine the initial population, that is, the possible optimal solution set of the distribution network state, and evaluate the individuals in the initial population, mainly using the adaptation function value to determine. In this paper, the state estimation error of the distribution network is selected as the adaptation function value, and then the population continues to evolve in a better direction by simulating the process of "survival of the fittest, survival of the fittest", that is, searching in the direction of the minimum error of the state estimation of the distribution network, and finally finding the state estimation value of the distribution network with the smallest error through the process of selection, crossing, and mutation.

II. B. 2) Ant colony optimization algorithm

Scholars have proposed an intelligent optimization algorithm--Ant Colony Optimization (ACO) by studying the process of crawling and searching for food by ants. During the process of searching for food, ants will leave a substance called pheromone on the path, and the colony will communicate and exchange information through the pheromone and constantly change the direction of crawling and searching. Finally reach the destination, the working process can be described as:

(1) Initialize the colony according to the problem to be solved, where each ant is placed on a starting point and the paths between the nodes have a certain initial pheromone $\tau_{ij}(0)$.

(2) Each ant $k(k=1,2,3,\cdots,m)$ analyzes the pheromone on the path and decides which node to move to next. Let $S_{tabu.k}$ denote the set of nodes that ant k currently crawls through, then the transfer probability of the ant moving from node i to node j is:

$$p_{ij}^k=\begin{cases}\dfrac{\left[\tau_{ij}(t)\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum\limits_{s\in S_{\text{allowed},k}}\left[\tau_{is}(t)\right]^{\alpha}\left[\eta_{is}\right]^{\beta}} & j\in S_{\text{allowed},k}\\ 0 & \end{cases} \tag{2}$$

where $S_{allowed\cdot k}=\{C-S_{tabu\cdot k}\}$ is the set of nodes to which ant k can move next, α is the information heuristic factor, β is the expectation heuristic factor, and $\tau_{ij}(t)$ is the moment at t. intensity of the pheromone on path (i,j), and η_{ij} is the heuristic function.

(3) In order to avoid too much residual pheromone leading to flooding the heuristic information, when the ants complete all the node search, the residual information is realized to update the operation, and the amount of information at the $t+n$ moment is adjusted in the following way:

$$\tau_{ij}(t+n)=(1-\rho)\tau_{ij}(t)+\Delta\tau_{ij}(t) \tag{3}$$

$$\Delta\tau_{ij}(t)=\sum_{k=1}^{m}\Delta\tau_{ij}^k(t) \tag{4}$$

where: ρ is the pheromone volatilization coefficient, $\Delta\tau_{ij}(t)$ is the pheromone increment of this time, and $\Delta\tau_{ij}^k(t)$ is the amount of information of the k th ant on the path (i,j), and the specific calculation of the metric is as follows:

$$\Delta\tau_{ij}^{k}(t)=\begin{cases}Q/L_k & \text{If the KTH ant passes through path } (i,j) \text{ in this cycle}\\ 0 & \text{Otherwise}\end{cases} \tag{5}$$

where: Q is the pheromone intensity, L_k is the total length of the path searched by the k th ant.

(4) If the termination condition is satisfied, find the optimal solution of the problem based on the shortest path, otherwise go to step (2) to continue the search.

II. C. Distribution network condition monitoring

II. C. 1) Objective optimization function

The state estimation optimization model of distribution network is established by taking voltage magnitude and phase angle as state variables, and minimizing the errors of measured and estimated values as objective functions, respectively.

$$\min J(x)=\sum_{i=1}^{m}w_i(z_i-h(x))^2 \tag{6}$$

$$x=\left[U_i,\delta_i\right]^T \tag{7}$$

$$z_i=\left[U_i^{'},P_{ij}^{'},Q_{ij}^{'},P_i^{'},Q_i^{'}\right]^T \tag{8}$$

where: x is the state variable to be solved, including node voltage magnitude and node voltage phase angle. U_i denotes the voltage magnitude, kV, of the i th node. δ_i denotes the voltage phase angle, rad, of the i th node. w_i is the weight factor of the i th quantity variable. z_i denotes the quantity measurements at the i th node, including node voltage magnitude quantity measurements, branch circuit active and reactive power quantity measurements, and node active and reactive power quantity measurements. $U_i^{'}$ denotes the node voltage magnitude quantity measurement of the i th node, kV. $P_{ij}^{'}$ and $Q_{ij}^{'}$ denote the active and reactive power quantity measurements between node i and node j, kW, respectively. $P_i^{'}$ and $Q_i^{'}$ denote the active power quantity measurement and reactive power quantity measurement of the i th, kW, respectively.

II. C. 2) Constraints

The distribution network current equations are as follows:

(1) Nodal power equation:

$$P_i=U_i\sum_{j=1}^{j=n}U_j(G_{ij}\cos\delta_{ij}+B_{ij}\sin\delta_{ij}) \tag{9}$$

$$Q_i=U_i\sum_{j=1}^{j=n}U_j(G_{ij}\sin\delta_{ij}-B_{ij}\cos\delta_{ij}) \tag{10}$$

where: P_i is the active power at node i, kW. Q_i is the reactive power at node i, kW. U_i is the voltage magnitude at node i, kV. U_j is the voltage magnitude at node j, kV. δ_{ij} is the phase angle at node i, kV. δ_i is the difference, rad, between the node i phase angle δ_j. G_{ij} is the real part of the element Y_{ij} in the conductivity matrix and B_{ij} is the imaginary part of the element Y_{ij} in the conductivity matrix.

(2) Branch power equation:

$$P_{ij}=U_i^2g-U_iU_jg\cos\delta_{ij}-U_iU_jb\sin\delta_{ij} \tag{11}$$

$$Q_{ij}=-U_i^2(b+y_c)-U_iU_jg\sin\delta_{ij}+U_iU_jb\cos\delta_{ij} \tag{12}$$

where: P_{ij} is the branch ij active power, kW. Q_{ij} is the branch ij reactive power, kW. U_i is the node i voltage magnitude, kV. U_j is the node j voltage magnitude, kV. g is the conductance on the branch ij, S. b is the conductance on branch ij, S. y_c is the line-to-ground conductance, S.

(3) State variable upper and lower bound constraints:

$$x_{i\min} \le x_i \le x_{i\max} \tag{13}$$

II. C. 3) Distribution network condition monitoring steps

(1) Collect the measured data of the distribution network and preprocess them to remove some abnormal or useless data.

(2) Establish the objective optimization function for state estimation of distribution network according to Eq. (6) and Eq. (7).

(3) Initialize the population of the genetic algorithm and set the values of parameters such as crossover and variance.

(4) Determine the fitness value of each individual according to the error between the distribution network state estimation result and the real measurement, and find the optimal individual and save it.

(5) Select some of the better individuals directly to the new population, and perform crossover and mutation operations on some of the individuals, and keep the better individuals to form a new population.

(6) If the maximum evolution number is reached, output the optimal individuals to get the estimated value of the distribution network state.

(7) Initialize the population of the ant colony optimization algorithm, as well as the relevant parameters.

(8) Initialize the initialized pheromone on each path according to the estimated value of the distribution network state of the genetic algorithm.

(9) Based on the initialized pheromone, each type of ant carries out the transfer to the next node.

(10) Each ant updates the pheromone concentration on its own crawling path.

(11) Update the pheromone on the whole path.

(12) If the end point is found, get the distribution network state estimate based on the optimal path.

(13) Determine the weights of the genetic algorithm and the ant colony optimization algorithm, and fuse their distribution grid state estimates to obtain the final value of the distribution grid state estimate.

III. Simulation test results and analysis

III. A. Simulation system and parameters

In this paper, an IEEE 33-node distribution system is simulated to verify the effectiveness of the proposed state estimation method, with a bus voltage reference value of 12.66 kV and a three-phase power reference value of 10 MW. Wind power is accessed at node 9 and node 30, and photovoltaic (PV) power is accessed at node 15 and node 23. The simulated distribution system connected to wind and photovoltaic power generation is shown in Fig. 2, where PV denotes photovoltaic module and WT denotes wind turbine.

In the distribution system, the size of the wind power generation capacity are 500kW, and the parameters of the wind turbine are adopted as the relevant parameters of the model V52-850. Let the wind farm in the ρ = 1.23kg/m3, blade wind area A = 2645m², v = 15m/s, C_p = 0.122, the initial slip is -0.0045. photovoltaic arrays using TDB125×125-72-P model of photovoltaic cells, the node 15 and 23 of capacity size Both are 400kW, and the simulated operating conditions of the PV modules are G =1000W/m² and T =298 K. The power factors at the wind and PV grid-connected points are 0.85 and 0.75, respectively.

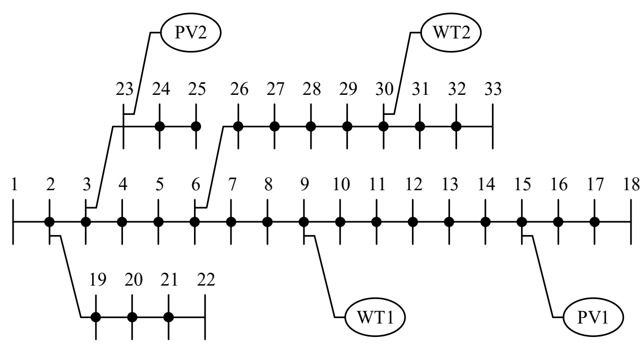

Figure 2: A simulation distribution system with multiple distributed power supply

III. B. Results and analysis

Measurement errors are prevalent in the real state estimation of distribution systems. In order to compare the state monitoring model of distribution network considering high percentage of distributed energy access (GA-ACO) proposed in this paper with the GA model, a normal random error of (0, 0.001) is added to the real-time measurements. The state estimation based on the state monitoring model proposed in this paper, the results obtained for voltage magnitude and voltage phase angle are shown in Fig. 3 and Fig. 4, respectively. Among them, the voltage magnitude is the standardized value. Compared with the GA model, the estimated value of the GA-ACO model proposed in this paper is closer to the true value of the system, especially the nodes with a high proportion of distributed energy access that have a large impact on the voltage magnitude, which are greatly improved after using the state estimation model proposed in this paper, such as node 3, node 7, node 11, node 27, and node 31, where the deviation of the voltage magnitude is reduced by more than 0.1%. Comparing the average errors of the two state estimation models, the errors of voltage magnitude and phase angle for state monitoring using the GA algorithm are 4.62% and 2.96%, respectively, and the errors of voltage magnitude and phase angle for the model proposed in this paper are 3.15% and 2.43%, respectively.

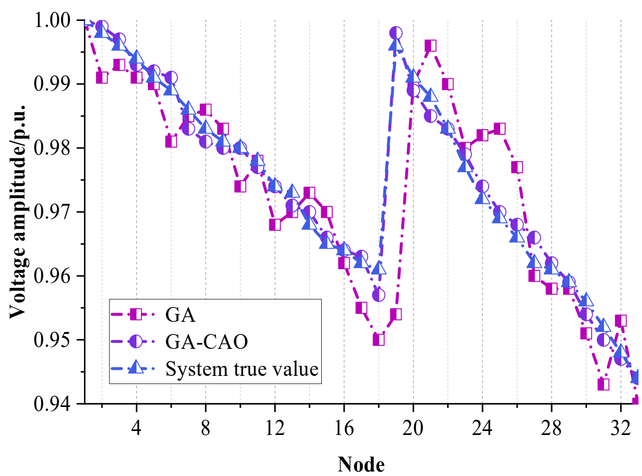

Figure 3: State estimation results of voltage amplitude

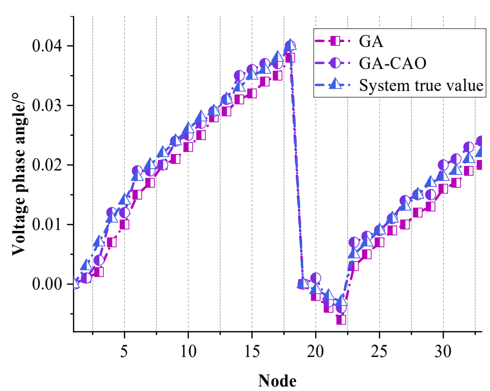

Figure 4: State estimation results of voltage phase angle

The state monitoring results of branch circuit active power and the state monitoring results of branch circuit reactive power are shown in Fig. 5 and Fig. 6. In this paper, the branch reactive power monitoring results and the branch active power state monitoring results based on genetic algorithm and ant colony optimization algorithm are closer to the real value of the system, while the results under GA algorithm, the branch reactive power and active power state estimation results are susceptible to large fluctuations in the influence of the distributed energy (DG) access, and the results of the state estimation deviate from each other.

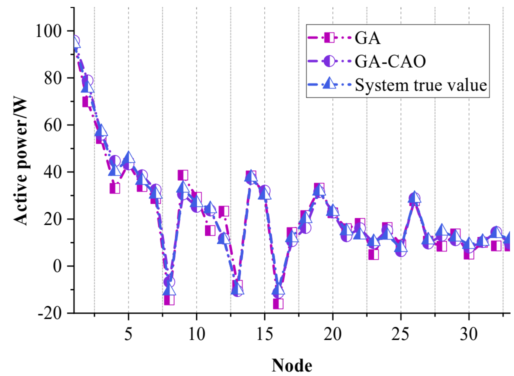

Figure 5: The status monitoring result of the active power of the branch

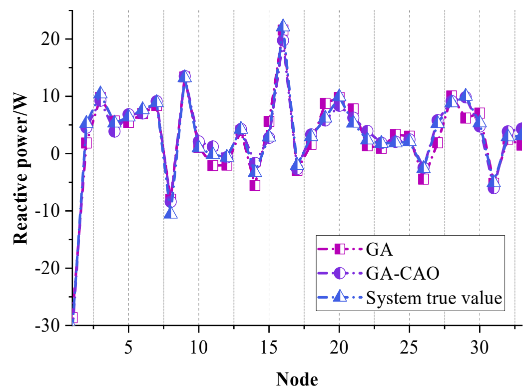

Figure 6: The status monitoring result of the reactive power of the branch

The comparison of DG active power at each node is shown in Fig. 7, and the comparison of load active power at each node is shown in Fig. 8.Comparison of the state estimation results of DG active power at each node under GA-CAO and GA shows that the state estimation results under GA-CAO are clearly seen to be more in line with the measured values at nodes 1, 5, and 8. Comparison of the load active power state monitoring results at each node under GA-CAO and GA clearly shows that the state monitoring results under GA-CAO are more in line with the measured values. Detailed analysis of the comparison is shown in Table 1.The computation time of the GA algorithm is slightly longer, 30.106s, while the speed of the GA-CAO algorithm in this paper for solving the state monitoring parameters of the distribution network is significantly improved, with an average computation time of 22.569s.

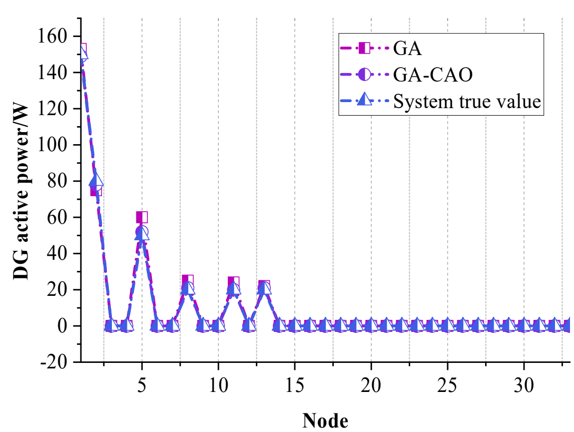

Figure 7: The comparison of the active power of each DG node

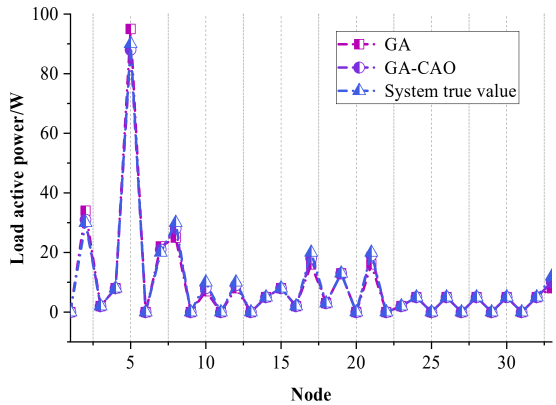

Figure 8: The comparison of the load active power of each node

Table 1: The effect of calculating the results of the target function

Method	GA	GA-CAO
First simulation	0.000165	0.000112
Second simulation	0.000183	0.00095
Third simulation	0.000176	0.000114
Mean time/s	30.106	22.569

In order to examine the efficiency of the proposed multi-intelligent optimization algorithm applied to the condition monitoring error processing of a high percentage of distributed energy distribution network, the root mean square error and the average absolute error, respectively, are defined:

$$R_{MSE}=\sqrt{\frac{1}{p}\sum_{q=1}^{p}(X_E-X_A)^2} \tag{14}$$

$$M_{AE}=\frac{1}{p}\sum_{q=1}^{v}|X_E-X_A| \tag{15}$$

where X_E is the estimate, X_A is the measure, q is the summation variable, p is the number of groups, and v is the number of estimates or measures.

Table 2: The R_{MSE} and M_{AE} result of two methods estimating each state value

Parameter		R_{MSE}/%	M_{AE}/%
Voltage amplitude	GA	4.62	2.96
	GA-CAO	3.15	2.43
Voltage phase angle	GA-CAO	4.57	3.52
	GA-CAO	3.18	2.61
Active power of the branch	GA-CAO	4.72	4.13
	GA-CAO	3.65	3.25
Reactive power of the branch	GA-CAO	3.72	3.43
	GA-CAO	2.51	2.06
DG active power	GA-CAO	5.99	5.76
	GA-CAO	3.53	2.74
Load active power	GA-CAO	3.68	2.54
	GA-CAO	2.47	2.19

Based on the data obtained from Fig. 3 to Fig. 8, the results of comparison of root mean square error and mean absolute error of node voltage magnitude, voltage phase angle, line active power, line reactive power, DG active power and load active power are then analyzed in GA-CAO algorithm and GA algorithm respectively. The results of R_{MSE} and M_{AE} for each state value estimated by both methods are shown in Table 2. When using the GA-CAO algorithm for state estimation of the distribution network with a high proportion of distributed energy sources, the errors in the estimation results of the GA-CAO algorithm in this paper are smaller than those of the GA algorithm, whether calculating the active power of the DG or the estimated value of the active power of the loads; the R_{MSE} values of the GA-CAO algorithm in this paper are reduced by 1.07%~2.46% and the M_{AE} values are reduced by 0.35% compared with the GA algorithm ~3.02%. Therefore, the GA-CAO algorithm calculates the state estimation value with less error, and its monitoring performance of the distribution network is better, and at the same time, it can be proved that the improvement of the algorithm effectively improves the accuracy of the state monitoring of the distribution network with high percentage of distributed energy.

IV. Regulation strategies for distributed energy access to the distribution network

A high proportion of distributed energy access will have a multifaceted impact on the distribution grid, including changes in the grid structure, the impact on power quality, and possible problems in terms of operational security and stability. For this reason, the regulation measures for distributed energy access to the distribution network are discussed. The regulation strategy for distributed energy access to the distribution network is shown in Figure 9, which is mainly divided into three levels: optimizing load management and scheduling, applying power management system, and optimizing the design of distribution network architecture.

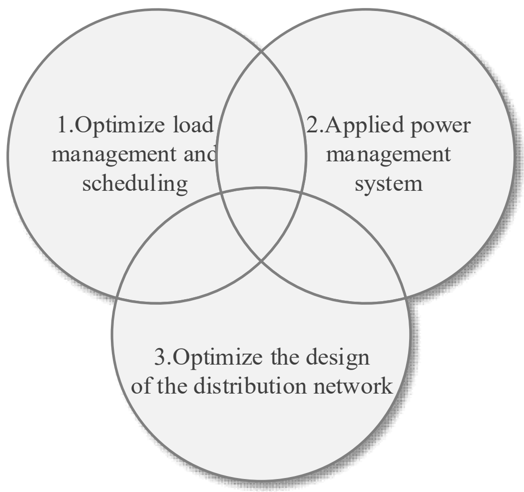

Figure 9: The adjustment strategy of distributed energy accessing distribution network

IV. A. Optimize load management and dispatch

In the process of distributed power supply access to the distribution network, load management and scheduling optimization is a crucial link. Reasonable load management can effectively avoid “traffic jams” in the power supply and ensure that every household and enterprise can use electricity smoothly. Collecting load data with the help of smart meters and distribution network condition monitoring systems can help to gain a deeper understanding of the demand for electricity at different times of the day. According to statistics, about 30% of power loss is caused by load imbalance. Hence, it is imperative to adopt load forecasting techniques. Machine learning algorithms are used to predict the power demand in the coming hours, and the output of distributed power sources is rationally dispatched based on the prediction.

Scheduling optimization is also critical, and optimization algorithms such as genetic algorithms or particle swarm optimization algorithms can be used to develop optimal power generation plans. These algorithms can minimize power generation costs and reduce power losses while meeting load demand. For example, when solar power generation is sufficient, solar power generation is prioritized, and at night or on cloudy days, it is switched to wind power or other traditional energy sources. This not only improves the utilization rate of renewable energy, but also reduces greenhouse gas emissions.

Load management and scheduling optimization after distributed power supply access to the distribution network is a complex issue that integrates technology and collaboration, and requires the cooperation of many parties. The use of intelligent management modes supplemented by flexible scheduling ideas can realize an efficient response to power demand fluctuations and help improve the stability of power supply at the customer side.

IV. B. Application of electrical energy management systems

A sound dispatching instruction response mechanism should be established to ensure that professional and technical personnel strictly obey the instructions of grid dispatching, especially in the operation of grid-connection and delisting, which should be discussed with the grid dispatching and obtain a positive answer before carrying out the relevant operation.

In the process of power station maintenance, it is necessary to carefully check whether there are "island" power points within the maintenance scope to avoid potential threats to maintenance personnel. Effective anti-"island" measures should be formulated and implemented, and anti-"island" protection devices should be laid to ensure that the "island" power supply is cut off in time. Strengthen the training of maintenance personnel, improve their skills, strengthen the training of maintenance personnel, improve their skill level, so that they have the ability to efficiently implement technical specifications, and ensure the safe and reliable operation of the power station. An energy management system (EMS) can collect energy data from different sources, such as solar, wind, and conventional power generation. By integrating this data, EMS is able to accurately predict future power demand and the power generation capacity of renewable energy. EMS can inform the supply and demand of electricity in a certain period of time in advance to ensure the stable operation of the power grid. EMS can also optimize power dispatch through intelligent algorithms, such as using machine learning algorithms to analyze historical data to find out how power demand is changing, so as to formulate the best power generation plan. The EMS's demand response management function can drive a shift in electricity consumption behavior through interaction with users, adjusting power consumption choices based on electricity price fluctuations and power supply and demand.

IV. C. Optimize the design of distribution network architecture

The design of a new distribution network architecture needs to take into account the access to multiple distributed power sources. These power sources come from a wide range of sources and have different output characteristics. For example, solar power is more efficient during the day, while wind power is significantly affected by weather. Based on this, it is necessary to introduce microgrid technology in the design of the distribution network. Different distributed power sources and loads are connected and managed through an intelligent control system. This microgrid design is able to flexibly dispatch power in a localized area and achieve self-balancing, which greatly improves the reliability of power supply.

The new distribution network also needs to improve its automation and intelligence level. With the introduction of smart sensors and automation equipment, the grid operating status can be monitored in real time, and can quickly respond to all kinds of emergencies. Intelligent sensors can monitor the voltage and current of each access point, and transmit the data to the central control system in real time.

In conclusion, in the optimization process of distributed power access to the distribution grid, the new distribution grid architecture design is crucial. Through flexible microgrid design, intelligent automation system, power quality monitoring and reliable communication network construction, it can better adapt to the future changes in power demand and ensure the safe, stable and efficient operation of the power grid.

V. Conclusion

It is difficult for a single intelligent algorithm to fully reflect the stochastic and time-varying nature of the distribution network state. In this paper, we combine genetic algorithm and ant colony optimization algorithm to design a multi-intelligent optimization algorithm based distribution network state monitoring method to estimate the state of the distribution network with a high proportion of distributed energy access, and simulation tests are carried out by using an IEEE 33-node distribution system, and to explore the regulation strategy of the distribution network for the access of distributed energy.

In the simulation test results, the node voltage magnitude, voltage phase angle, line active power, line reactive power, DG active power and load active power monitored by the GA-CAO algorithm in this paper are closer to the real value of the system, and its root mean square error and average absolute error are reduced by 1.07%~2.46% and 0.35%~3.02% than that of the GA algorithm, which proves that the proposed method has a higher accuracy. This proves that the method proposed in this paper has higher accuracy.

The high proportion of distributed energy access to the distribution network puts forward higher requirements, should be optimized from the optimization of load management and scheduling, the application of power management systems and optimize the design of the distribution network architecture, distribution network optimization, improve the stability and reliability of the distribution network, so as to promote the development of the overall electric power network in the direction of more efficient and sustainable.

The distribution network monitoring method proposed in this paper integrates the advantages of genetic algorithm and ant colony algorithm, accurately reflects the state change characteristics of the distribution network, and obtains a higher state estimation accuracy of the distribution network than the comparative algorithms, which provides a new research tool for the researchers of the distribution network.

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