Research on Key Technologies of Power System Automation in Smart Grid

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Abstract. The paper summarizes the construction mode of distribution network automation system, and sorts out the operating characteristics of centralized intelligent mode and distributed intelligent mode. In view of the construction and operation of China's distribution network automation system, point out common problems in system construction, operation and management in most regions. At the same time, the paper proposes the optimization of distribution network automation technology based on the gravity search algorithm, and improves the algorithm. Finally, the improved gravity search algorithm is applied to the IEEE 6-node power system. The calculation results show that the active power loss and voltage obtained by the algorithm are compared with the original state, the level has been greatly improved, which greatly improves the automation efficiency of the power system. In this paper, the gravity search algorithm is used to calculate the optimization of power system automation technology, and the algorithm is improved, which overcomes the shortcoming of easy convergence to the local optimum.

1. Introduction
The distribution network directly faces users and is the last mile of the grid. Whether the topological structure of the distribution network is reasonable is the physical basis for the realization of basic functions, and the matching communication system is the supporting platform for the basic and advanced applications of the distribution automation system. The distribution automation system covers not only the primary equipment, lines, but also the technical fields of secondary equipment such as protection and automation. Intelligent distribution network is an advanced stage of distribution automation, and it is the ultimate goal and the highest form of distribution automation. China's distribution automation mainly adopts a variety of methods such as introduction, digestion, absorption, and improvement to implement and promote. Initially, from the introduction of Japan's distribution network automation equipment, continuous digestion and absorption, and gradually started the construction of the distribution network automation system [1]. The implementation of power distribution automation system has been carried out in some cities by adopting the mode of piloting, summarizing, and upgrading to popularization and application in phases and batches. So far, the acceptance of the practical functions of power distribution automation in many cities has been completed. Its technical path is: from the research of key distribution automation technologies to pilot and demonstration projects, and then to popularization and application, a large amount of engineering experience and effective data have been obtained. Its development has also experienced the continuous
deepening of feeder automation, simple distribution automation to complex distribution automation applications.

2. Analysis of the relationship between intelligent distribution network and power system automation

2.1. Smart Distribution Network (SDG) Technology
SDG is a power distribution system that integrates traditional and cutting-edge power distribution engineering technology, advanced sensing and measurement and control technology, modern computer and communication technology, which is safer, more reliable, high-quality, and efficient, and supports a large number of distributed power sources (DER) access, and provide users with services that interact with the distribution network such as timing of electricity use [2].

The main technical contents of SDG are: 1) Distribution data acquisition and monitoring (SCADA) technology. 2) Substation Automation (SA). 3) Feeder Automation (FA), refers to the fault location, isolation and automatic power restoration technology of the medium-voltage power grid. 4) Advanced Measurement System (AMI) is a system that uses smart meters to collect and analyse user electricity consumption data. AMI is a new development of traditional automatic meter reading (AMR) technology. 5) Distribution management automation, including equipment management, maintenance management, power outage management, planning and design management, etc. 6) Customer Information System (CIS), also known as electricity management system, computer management of users and electricity consumption information. 7) Online monitoring technology for power distribution equipment. 8) DER grid-connected technology, including DER's "plug and play", optimized scheduling, and microgrid (MG) in 3 parts. MG refers to the power distribution subsystem connected to DER, which can operate independently from the main network. 9) Flexible AC power distribution technology (distribution FACTS for short) is an extension of FACTS technology in the distribution network, also known as customized power technology. 10) Fault current limiting technology refers to the use of power electronics, high-temperature superconductivity and other technologies to limit short-circuit current.

2.2. Distribution Network Automation (DA) Technology
DA refers to the use of modern computers, communication and information technology to integrate the real-time operation of the distribution network, grid structure, equipment, users, and geographic graphics to form a complete automation system to realize the automation and information of the monitoring and management of the distribution network. Its main role is to improve the quality of power supply, user service quality and the efficiency of distribution network management. The main technical content of DA includes: 1) Distribution network operation automation (DOA), including three aspects of distribution SCADA, SA, and FA. 2) Power distribution management automation functions, including equipment management, maintenance management, power outage management, planning and design management and other functions. 3) User automation, including two parts: automatic meter reading and customer information management.

2.3. Comparison of SDG and DA
Comparing SDG and DA, we can see that there are close connections and extensive commonalities between them. DA is the application of modern computer, communication and information technology in the distribution network, and these new technologies are also the main technical means of SDG. The technical content of DA is completely contained in the SDG, and it is the main content of the SDG, which plays a pivotal role. The hardware of the distribution automation system is mainly composed of the background master station, the distribution terminal and the communication platform; the application software is supported by the distribution automation application software platform system [3]. Its system structure and its positioning in the system are shown in Figure 1.
Improvement of automation technology based on gravity search algorithm

3.1. Gravity search algorithm

The gravitational search algorithm is an algorithm proposed by imitating the action of gravity in physics. In the law of gravity, particles attract each other due to the action of gravity. Suppose there are n particles in a D-dimensional space, and the spatial position of each particle is represented as a vector $X_i = (x_{i1}, x_{i2}, ..., x_{in})$. The position of each particle represents a possible solution of the problem to be optimized, and its flying trajectory in space represents the search process. Select the objective function of the problem to be optimized, and substitute $x_i$ into the objective function for calculation, then the size of the objective function $f$ can be obtained. In each iteration process, there will be an optimal value $f_{best}(t)$ and a worst value $f_{worst}(t)$. The mass of each particle can be calculated according to the following formula:

$$Q_i(t) = \frac{f_i(t) - f_{worst}(t)}{f_{best}(t) - f_{worst}(t)}$$  \hspace{1cm} (1)

$$M_i(t) = \frac{Q_i(t)}{\sum_{j=1}^{n} Q_j(t)}$$  \hspace{1cm} (2)

Among them, $M_i(t)$ represents the mass of the i particle in the t iteration process. According to the mass of each particle and the distance between the particles, the gravitational force between the particles
can be calculated. The resultant force of the gravitational force of each particle in a certain direction is

calculated by the following formula:

\[ F_i(t) = \sum_{j \neq i} \text{rand}(t) G(t) \frac{M_j(t)M_i(t)}{R_{ij}(t)^2 + \varepsilon^2} (x_j(t) - x_i(t)) \]  (3)

According to Newton’s second law, the formula for calculating the acceleration of a particle in this
direction is as follows:

\[ a_i(t) = \frac{F_i(t)}{M_i(t)} = \sum_{j \neq i} \text{rand}(t) G(t) \frac{M_j(t)}{R_{ij}(t)^2 + \varepsilon^2} (x_j(t) - x_i(t)) \]  (4)

The direction of acceleration of a particle under the gravity of other particles is shown in Figure 2.

![Figure 2](image)

**Figure 2.** The direction of acceleration of a particle under the action of other particles

Update the particle's velocity according to its acceleration:

\[ v_i^d(t + 1) = \text{rand}(t) \times v_i^d(t) + a_i^d(t) \]  (5)

Then update the position of the particles:

\[ x_i^d(t + 1) = x_i^d(t) + v_i^d(t + 1) \]  (6)

The moving speed and position of the particles need to be limited within a certain range. The range
of particle velocity is \([v_{i_{\min}}^d, v_{i_{\max}}^d]\), and the range of particle position is \([x_{i_{\min}}^d, x_{i_{\max}}^d]\).

### 3.2. Algorithm improvement

According to the formulas (5) and (6) of the gravity search algorithm, it can be seen that in each iteration
process, each particle will update the speed and position. However, in each iteration process, it cannot
be guaranteed that the value of the objective function of the updated position of each particle will be
better than the value of the objective function before the iteration. Therefore, the algorithm needs to be
improved.

The improved gravitational search algorithm is to calculate the objective function of the updated
position after completing the position update of the particle: if the objective function is better than the
objective function before the update, the position and velocity of the particle will be updated; If the objective function is better than the updated objective function, the position and velocity of the particle are retained and no update is performed [4]. Through selective iterative update, it can be ensured that the particles will not update to the position that deviates from the optimal objective function during the iteration process, and the number of iterations is also shortened.

3.3. Treatment of discrete variables
In the actual power system, the node voltage can change continuously, so the automation optimization problem contains both continuous variables and discrete integer control variables. In this paper, the discrete variables are processed by the method of mapping coding and rounding.

For example, for a transformer with a variable ratio between \([T_{i \min}, T_{i \max}]\), an adjustment step of \(T_{\text{step}}\), and a total of \(l\) level taps, assuming that it corresponds to the \(i\) dimensional control variable \(x_i\), the value range of \(x_i\) is equal to the number of taps, that is, \(1 \leq x_i \leq l\). The particles are initialized in this range, and after the speed and position are updated, according to formula (7), transform \(x_i\) into the corresponding variable ratio value and substitute it into the objective function for calculation (\([\ ]\) means rounding):

\[
T_i = T_{i \min} + \lfloor x_i - 1 \rfloor \times T_{\text{step}}
\]  

3.4. Improve GSA algorithm flow
The process of improving the GSA algorithm is as follows: (1) Reading in the initial data, random initialization of the spatial position and initial velocity of each particle; (2) Calculating the fitness function of each particle; (3) Updating the best value, the most Bad value and particle mass; (4) Calculate the resultant force in all directions, calculate the acceleration and velocity of the particle; (5) Update the position of the particle; (6) Return to the second step, know the number of cycles required; (7) The loop ends and the result is output.

4. Algorithm verification
In this paper, the basic GSA algorithm and the improved GSA algorithm are used to write programs in MATLAB language, and the IEEE 6-node system is optimized for automation technology, and the results are compared with the initial results. In the initial state of the system, the network loss is 11.62MW, the node 3 voltage is the lowest, and the unit value is 0.8552. Figure 3 shows the convergence process diagram of the basic GSA algorithm and the improved GSA algorithm.

![Figure 3. Comparison of automatic and non-automatic convergence process](image-url)
Table 1 lists the comparison between the results obtained by using the basic GSA and the improved GSA algorithm and the initial state of the system.

| Node voltage | Initial | Basic GSA | Improve GSA |
|--------------|---------|-----------|-------------|
| 1            | 1.05    | 1.1       | 1.1         |
| 2            | 1.1     | 1.15      | 1.15        |
| 3            | 0.8552  | 1.0207    | 0.9996      |
| 4            | 0.9525  | 0.9871    | 0.9911      |
| 5            | 0.9096  | 1.0104    | 1.0332      |
| 6            | 0.9332  | 0.9638    | 0.9637      |
| System automation level | 0.1162 | 0.0928 | 0.0894 |

5. Discussion
Distribution automation is the primary form of the intelligent distribution network and the foundation of the intelligent distribution network. The distribution automation system first realizes the monitoring function of the distribution network operating conditions, and can realize the functions of "one remote", "two remote" or "three remote" if conditions are available. Intelligent distribution network is the future of distribution automation development [5]. The intelligent distribution network gradually realizes its advanced application functions on the basis of satisfying the general functions of distribution automation. Intelligent distribution network is the development and extension of distribution automation. Distribution automation is the foundation of intelligent distribution network. Distribution automation is the basic function and basic application of intelligent distribution network. Intelligent distribution network pays more attention to the foundation of distribution automation. Advanced applications on the Internet. The two information application systems of intelligent distribution network and distribution network automation are both built on a complete distribution network framework and various forms of communication platforms, which are the integration of information flow and power flow [6]. The intelligent distribution network relies on a complete collection, communication, information platform, etc., to achieve continuous monitoring of self-state, give accurate judgments on the operation status of the power grid, and form decisions through intelligent analysis, automatically conduct comprehensive control, and realize fault location and removal. Quickly restore the power supply, perform fault analysis, shorten the troubleshooting time, and make the grid operation state tend to be optimal.

Smart grid is most likely to be implemented in the distribution network system, that is, smart distribution network is a necessary condition for the realization of active distribution network in the future [7]. Realize large-scale access to renewable energy and clean low-carbon energy, increase the degree of substitution of electric energy for fossil energy, promote the development of low-carbon economy and energy saving and emission reduction; promote demand-side management, save energy and reduce consumption, improve energy efficiency, and promote energy and electricity Efficient use of assets; realize the sharing of information between the power grid, power source and users, and support the interaction between the power grid and users.

6. Conclusion
This paper summarizes and analyses the current situation of distribution automation construction and its existing problems, combined with the new business needs of the distribution network dispatching organization, and proposes a technical plan for the distribution network dispatching control system under a large operation system. The construction of distribution automation is a long-term and arduous task, and the technologies discussed in this article still need to be further improved and perfected.

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