Research on Construction of Smart Grid and Production Operation Management of Power Supply Enterprises

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Abstract. Smart grid construction is an inevitable trend for the development of future power grids. Based on the consideration of grid security risks, the key technologies for smart grid construction include intelligent power distribution and power generation technologies, power generation distribution, and energy storage technologies. After putting into use, it strictly describes the production, operation and management of production, operation and technological transformation, technological progress, and equipment management. It hopes to provide reference for the development of China's smart grid and maintenance of the safe and stable operation of the power system.

1. Introduction
As an ultra-large state-owned enterprise related to national economy and people's livelihood, China's power grid enterprises shoulder major economic responsibilities, social responsibilities, and political responsibilities. They need to continuously accelerate the pace of development to meet the requirements of China's national economic development [1]. How to strengthen the smart grid construction and development and achieve standardization and lean management of operation and management, is an important measure to continuously improve the level of business management and meet the needs of social development [2].

2. Introduction to Key Technologies for Smart Grid Construction

2.1. Smart Grid Development Trends
One of the core driving forces for the development of smart grids is to achieve a safe and stable operation of the system. China’s strong smart grid construction is based on the UHV grid as the backbone grid and the strong grids for the coordinated development of all levels of grids. During the “Twelfth Five-Year Plan” period, it will plan to build “three vertical and three horizontals” UHV AC lines and fifteen the problem of weak DC grids and grids will be solved gradually. Inter-regional grids will support each other through a strong backbone network, which will avoid power outages and slow recovery of power supply due to weak grids [3].

2.2. Distributed Generation Grid Connection Technology
The application of distributed generation technology in the current load-concentrated areas can effectively meet the requirements of users for power supply flexibility and reliability. At the same time, as a clean and efficient power generation technology, the large-scale development will also help achieve the goal of energy conservation and emission reduction. For autonomous regions such as
remote areas (such as Xinjiang's non-electric areas) and other autonomous regions, the use of large power grids to extend their power supply problems is costly. Designing small single off-grid power plants has not yet reached an economically viable stage, through distributed generation technologies. Can effectively solve its power supply problem. Studying the management model, price and cost system of China's distributed energy grid connection and coordinating the interests of related parties are the issues that need to be resolved in the future to promote distributed energy and grid integration [4].

2.3. **Intelligent Power Distribution Technology**
Smart distribution network is a highly automated and intelligent power distribution system, through the distribution of data communication network, advanced sensor measurement technology, advanced protection and control technology, advanced measurement system, flexible distribution technology and fault current limiting technology, etc[5]. The application of power distribution technology provides technical support for grid connection of distributed generation, electric vehicles, etc., to provide users with intelligent power supply, and meets the requirements for reliability and efficiency of power systems. It has strong self-healing, high safety, and electric energy. Good quality features can effectively prevent the entire network from crashing due to equipment failure during a blackout [6].

2.4. **Smart Power Technology**
The first is the technology development and platform construction for the smart grid-based interactive service system. Compared with the traditional grid, the intelligent power supply requires the grid side to grasp the user-side information very timely and fully, and the user side can also get from the grid side. Real-time market prices and grid operation information, the realization of this two-way interaction between power customers and the grid requires advanced technology and mature business operation model support, and also requires more flexible and complex demand-side management strategies; second, smart electricity the idea was introduced into the power system expansion planning work. In the smart power consumption technology, the demand side resource needs to be analyzed, compared and selected as the same resource as the supply side resource, and studies are made to determine which method to use to influence the user's power consumption mode. In order to reduce the overall operating cost of the system or improve the reliability of power supply, intelligent power utilization can be started from the initial stage of power planning. This change has more important implications and practical value for the construction and management of China's smart grid.

2.5. **Power System Energy Storage Technology**
Power system energy storage technology specifically refers to energy storage technologies that can be strategically charged and discharged and provide balanced capacity services for power systems. The development of energy storage technology is conducive to the efficient and comprehensive utilization of large-scale intermittent renewable energy sources, alleviating the pressure on the operation of power grids, enhancing the regulation and control capabilities of the power grids, and meeting the requirements for the reliability of power systems and the balance between power supply and demand.

3. **Standard cost multi-objective optimization model for smart grid production operations**
With the deepening of power market reforms, the government has increasingly stringent requirements on the standardization and transparency of power grid enterprise cost management. The implementation of standard cost management will establish a more scientific and standardized cost management mechanism for power grid companies, which will help power grid companies actively adapt to government and industry supervision. China's electricity demand has been greatly affected. The growth of power generation has greatly weakened the pulling effect of power grid companies' profits. The profitability of power grid companies is limited, and power grid companies are required to benefit from management. The harmonization of cost standards and the implementation of standard cost management will help power grid companies deepen detailed budget management, scientifically
guide budgeting, increase the level of scientific and lean management of cost management, and promote the implementation of cost-saving, cost-reducing, and efficiency-relief measures by grid companies.

3.1. Objective Function

3.1.1. Minimize Smart Grid Operating Costs. For smart grid operating costs, the total cost of operations includes distributed energy generation costs, startup and shutdown costs for generating units, and other costs for smart grid and utility grid exchange of electricity. The goal of the cost function is to pursue the lowest total operating cost of the smart grid while meeting the load requirements of the load center at a given moment. The following formula can be used:

$$\min f_1(X) = \sum_{t=1}^{T} \text{cost}_t$$

$$= \sum_{t=1}^{T} \left\{ \sum_{i=1}^{N} \left[ u_i(t) \left( P_{\text{Gi}}(t) + B_{\text{Gi}}(t) + S_{\text{Gi}}(t) - u_i(t) + P_{\text{Grid}}(t) B_{\text{Grid}}(t) \right) \right] \right\}$$

Where $B_{\text{Gi}}(t)$ denotes the bid price of the distributed power generating unit at time $t$, $S_{\text{Gi}}$ denotes the start-up cost of the distributed generator for the itch station, and $P_{\text{Grid}}(t)$ $B_{\text{Grid}}(t)$ are respectively the time when the smart grid purchases electricity from the utility grid or transmits power and energy to the utility grid. The price of electricity exchanged between the grid and the utility grid, where $X$ is the state vector of each device.

3.1.2. Minimization of Pollutant Emissions. For the smart grid operation of pollutant emissions, the goal is to minimize the total pollutant discharge in the entire smart grid operation. Pollutant emissions include SO$_2$, SC$_2$, and NO$_x$. The mathematical expression of this objective function is

$$\min f_2(X) = \sum_{t=1}^{T} \text{Emission}_t$$

$$= \sum_{t=1}^{T} \left\{ \sum_{i=1}^{N} \left[ u_i(t) \left( P_{\text{Gi}}(t) + E_{\text{Gi}}(t) + P_{\text{Grid}}(t) B_{\text{Grid}}(t) \right) \right] \right\}$$

Where $E_{\text{Gi}}(t)$, $E_{\text{Gj}}(t)$, and $E_{\text{Grid}}(t)$ are the number of pollutants emitted per kilowatt-hour of electricity generated by the power generation unit, storage unit (electric vehicle), and utility grid at $t \left( \text{kg} \cdot \text{MV} \cdot \text{h}^{-1} \right)$.

3.2. Constraints

In order to ensure the safe and stable operation of the smart grid, related constraints such as load balance in the power supply area, active power limitation of each distributed power supply unit, and charge and discharge constraints of the storage unit (electric vehicle group) must also be considered. Since the power grid where the smart grid is located is generally a low-voltage distribution network, the loss of electric energy is large, and special consideration must be given to the power balance. The network loss of the system can be calculated by the load flow. However, the focus of this study is not to consider the loss of the load, which can be analyzed by using the valuation.

All distributed generation units, as well as the electrical energy obtained from the utility grid, satisfy the smart grid's commitment to the regional power supply load.
\[
\sum_{i=1}^{N} P_i(t) + P_{\text{grid}}(t) = P_L(t)
\]  

(3)

In the formula, \(P_L(t)\) is the regional power supply load that the smart grid bears at \(t\).

3.2.1. Active power constraints of each unit. In order to ensure stable operation of the smart grid, the active power output of each unit must be within the specified range.

\[
P_{\text{grid-min}} (t) \leq P_i(t) \leq P_{\text{grid-max}} (t)
\]

(4)

3.3. Niche Multi-Objective Particle Swarm Optimization Algorithm

3.3.1. Introduction to the Algorithm. The particle swarm optimization algorithm is often used to solve the optimization problem because it has the advantages of easy implementation, high precision and fast convergence. However, in the multi-objective optimization model of the smart grid operation constructed above, there are mutual constraints between the two objective functions, and the basic particle swarm algorithm cannot meet its solution needs. In order to effectively solve the model proposed in this paper, a niche sharing mechanism was added to modify the basic particle swarm optimization algorithm to form a multi-objective optimization model for solving cost-effective, sewage-discharging smart grid operation. The Niche-Multi-Objective Particle Swarm Optimization algorithm was used to achieve smart grid energy distribution. And management. Different from the basic particle swarm algorithm, this algorithm adopts the niche sharing mechanism for the selection of the best individuals in the external archives and adds the chaotic variation mechanism to solve the problem of convergence to the local final and improves the operating efficiency of the algorithm so as to quickly obtain Smart grid operation decision plan.

3.4. Simulation Analysis

The smart grid test system studied in this paper consists of a smart generator set, a set of low-temperature fuel cells, a set of photovoltaic power generation equipment, and a set of wind turbines. The minimum and maximum power limits of each distributed generator set in the smart grid are shown in Table 1. The bid price and pollution emissions of the distributed generator set are shown in Table 2. The daily load status of the smart grid power supply area is shown in Table 3. Wind power generation and photovoltaic power generation Output predictions. Based on the above settings, a multi-objective model of smart grid operation is constructed according to the above, and a niche multi-objective particle swarm optimization algorithm is used to simulate and analyze smart grid operation and management under the scenarios of smart grid and public grid interconnection.

| No. | Generator type                  | Minimum output power/kW | Maximum output power/kW |
|-----|--------------------------------|-------------------------|-------------------------|
| 1   | MT                             | 6                       | 30                      |
| 2   | PAFC                           | 3                       | 30                      |
| 3   | PV                             | 0                       | 25                      |
| 4   | WT                             | 0                       | 15                      |
| 5   | Bat                            | -30                     | 30                      |
| 6   | Exchangeable with large power grids | -30                     | 30                      |

Table 1. Data of micro grid distributed installed power generation capacity
The corresponding program was programmed to simulate the two targets using the basic particle swarm optimization algorithm for single-objective and niching multi-objective particle swarm optimization algorithms. The final results are shown in Table 3. According to the simulation results shown in Table 3, if a single target is used for smart grid operation and management, the goal can only be optimized, and the corresponding increase in other goals is needed as the cost. Smart grid operation and management with multi-objective situations can realize comprehensive consideration of cost and emission multi-objective.

### Table 3. Optimization results by PSO

| No. | Simulation objective function                  | cost  | emission |
|-----|------------------------------------------------|-------|----------|
| 1   | Simulate cost as an objective function         | 753.867 | 815.38   |
| 2   | Simulate emissions as an objective function    | 912.632 | 684.325  |

### 4. Conclusion

As a supplement to the large-scale power grid, the smart grid effectively extends the power supply scope of the power grid and increases the reliability of power supply and the diversity of power points. The development and extension of smart grids can promote the large-scale access of distributed power sources and renewable energy sources, enabling the transition from traditional grids to smart grids. However, how to manage these distributed power sources scientifically and reasonably when the smart grids are functioning properly in order to ensure that the smart grid can meet the power quality requirements of the load at different times and obtain the best economic benefits, it is one of the key issues in the study of smart grid operation and management.

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