Research on Transition Stability Control of Smart Grid Substations

Jiawei Xu
Wuzhou Bureau of China Southern Power Grid UHV Transmission Company, Wuzhou 543000, Guangxi, China
DOI: 10.32629/aes.v4i1.1165

Abstract: Research on the optimal control method of smart substation to improve the power grid parameters and reliability. This paper proposes different methods to achieve optimal performance in power systems, with improved parameters being the ability to track the reference signal, to stabilize the system, to reduce steady-state error and to control transient behavior. The focus is on achieving good transient stability when considering the voltage and frequency dynamic parameters. The optimal model of control is to minimize energy consumption under the premise of maintaining controllable parameters, by improving the robustness of the controller, by exploring some optimization techniques to find the optimal control, and aiming by minimizing response time, energy consumption and reliability.
***Keywords*:** smart grid substation, reliability, stability

1. Introduction

The comprehensive smart grid plan at the national level with the road map as the goal is implemented in the five fields composed of smart grid, smart, consumer, smart transportation, and smart new renewable smart power services [1]. The purpose of building a smart grid based on the country is to build a standardized framework, such as reducing the time and cost of system construction, providing a variety of systems, ensuring the interactive environment between domain names and other smart grid interoperability standard framework and load as the basis for building standardization. It is necessary to ensure the interoperability of the smart grid and the composition of the reference model definition and road map of the standardized part [2]. The construction of smart grid at the national level is divided into three stages: the goal is to build a stronghold city of smart grid, and to successfully complete these blueprints, strategies and related contents are published; Cultivate, popularize and promote the standard framework in various fields required by the smart grid industry. The elements of smart grid system and the information and communication interaction between the elements as well as the related standards are proposed. The goal is to develop the standardization development blueprint through the application and status analysis of the standards. The goal of the smart grid is to achieve a smart grid based on the country from 2010 to 2030 [3].

Recently, the government issued a large-scale green new policy, and it is expected that the smart grid, which can save energy and stabilize power supply, will play an important role [4]. Smart grid refers to a new generation of power grid that is grafted with IT technology to optimize energy efficiency. Previously, the standardization of smart grid was mainly to wireless the meters of each household. Even without inspectors, the communication specifications that periodically convey power use information were relevant [5]. Even if the same specifications as the existing Zigbee, NORA and NB-IoT are used, there will be no problem. However, communication needs to reliably and regularly transmit the power measurement data of the smart grid. In order to build a power grid that can exchange information between power suppliers and consumers in real time and maximize energy efficiency, the national development blueprint of smart grid and the basic plan of smart power grid are being formulated [6]. However, most of the main systems of the system are still based on analog hardware. The power system operator takes the upper transmission system of the substation located in the main locations of the country as the object to obtain the power status information, and then controls and manages the power station and transmission network. The reality is that the program bus level of most power equipment, including the bus and power supply of the substation system under the power grid, and the electrical signal information of the distribution system are not considered at all. Just adding the communication monitoring function of one-way monitoring and control mode to the power system does not mean that it has the appearance of smart grid. This paper will propose the necessity of wireless connection in the smart grid environment, the reliability of wireless connection and the method to meet the requirements. The purpose of this paper is to unify the production, transmission and distribution of energy in order to improve the stability of the entire system in the region. There is a huge gap in the development of regional energy networks. The achievements of researchers have promoted technological progress in this field. The second section shows the technical methods to understand the substation, and the third section shows the technical status quo. It shows the control level in intelligent substation and the strategy of optimizing operation, and gives the conclusion and future work.

2. Technical methods of power grid substation

2.1 Engineering simulation method of power grid substation

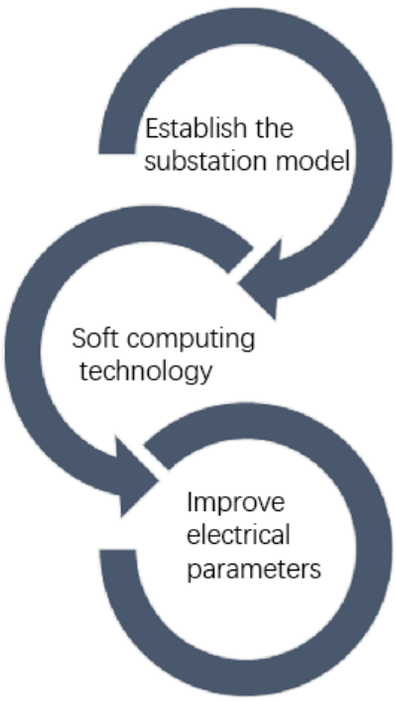

Figure 1. Method of controlling intelligent substation

Based on the scientific information extracted from the advanced technology, consider the documents that solve problems with mathematical modeling and engineering simulation methods. It is very important for smart grid wireless network to maintain synchronization error when the system is connected. To this end, the following ATS (Absolute Time Synchronization) program is proposed. It is assumed that the unit radius of smart grid is 2.5 km [3]. The maximum propagation delay time is 8.3μs, and the round-trip delay is 16.6μs. Therefore, it is necessary to maintain an ATS program with an error of ±0.5μs in the smart grid. Figure 1 explains the method of controlling intelligent substation: firstly, the substation model is established, and the power station model is achieved through software calculation and identification technology. In control engineering, it is very important to determine the controlled equipment. Secondly, some soft computing technologies, such as neural network or fuzzy logic and meta-heuristics, are usually used to identify the system.

2.2 Design and distribution process method of power grid substation

Traditional substations can no longer meet the requirements of modern power grid. When designing the power distribution process, multiple factors need to be considered, including the reliability and quality of the power supply. In addition, the designer must consider such parameters as safety, economy, maintainability, simplicity of operation and function. In addition, the substation needs distributed control, protection system and communication infrastructure. The international standard for substation automation is IEC61850, which contains international general recommendations for the implementation of substation automation and guides the development and trend of substation technology [6]. In order to realize the transformation of substation, a high-performance computing platform composed of intelligent substation must be realized. The intelligent substation software uses the time synchronous measurement and high-speed data acquisition in the substation to realize monitoring, protection, control and communication functions. The intelligent substation realizes the protection and control actions in the substation. The recognition rate of household rated voltage. If the load connected to the power grid uses different current at different times, the phase voltage of the bus connected to each load will also record different values with time, which is higher or lower than the voltage measured in the transformer. However, in order to promote stable voltage to the entire grid family, the phase voltage measured by the bus must be within 10% of the rated voltage. In order to judge this situation, as one of the result indicators, the rated voltage approval rate based on the family time is used. The proportion of the measured load of the whole power grid is lower than the standard range for the specific phase voltage change of the measured load.

2.3 Digital control technology method of power grid substation

The reduction of global nuclear energy development and the consideration of national investment in renewable energy development, taking into account the necessity of systematic research on the development of smart grid for new renewable energy, photovoltaic power generation, wind power generation, energy storage and discrete event system specifications with subordinate factors represent the smart grid through the use of environmental simulation. The control technology must be implemented in the controller, and the best performance can be achieved in the general system by using traditional methods or soft computer technology, such as improving the tracking of reference signals, stabilizing the system, reducing state errors, and controlling transient behavior. New renewable energy is transformed by modeling the actual wind speed and solar energy information in minutes. The relationship between the development of this model and the storage device and the focus of modeling, compared with the information used in the virtual environment, our model splits the power consumption of each subordinate and uses the data of the component. Considering the modeling of AC circuit such as direct load and impedance between loads, it can be said that the respective decisions of load elements are considered more carefully. Compared with the existing research, the scope of this study is limited to low-voltage distribution systems. The use of the factors of discrete event system normative formalism and the use of basic modeling to diversify consumer behavior patterns, rather than the use of market-based simulation, has solved certain limitations in enabling consumers to arbitrarily give economic value to their actions. The power flow calculation algorithm based on AC circuit is applied to the simulation, and the simulation that reflects the reality from the circuit level is developed. It is assumed that the realized intelligent substation controller does not achieve the optimal performance for the following reasons: (a) the identification process is not fully developed, which allows the overall representation in the mathematical model of dynamic system behavior. (b) The optimization technology is not completely carried out by the application controller. Advanced technology is divided into relevance and influence in the world and regions. However, there is a lack of research in this area. Therefore, most of the research comes from other parts of the world. Advanced technologies include other models used to solve problems, as well as some methods in this field and different models used to solve optimization.

3. Technical status of smart grid substation

3.1 Control electrical application of smart grid substation

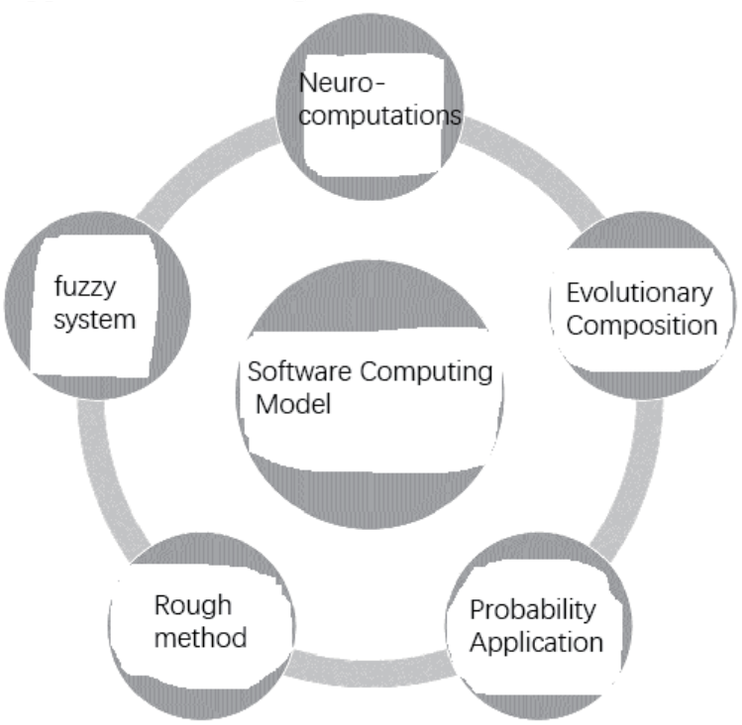

Figure 2. Software calculation model for control electrical application

Software calculation model for controlling electrical application, including fuzzy system, neural calculation, evolutionary composition, probabilistic application and rough method (Figure 2). There are several heuristic methods, among which

the adaptive neuro-fuzzy inference system method is a special neural network structure, which improves the basic structure of the neural network and can include new patterns through learning. A software framework for nonlinear optimization and optimal control problems. The program solves constraint problems through differential equations. The use of field programmable gate array to evaluate the strategy of new coordination methods in intelligent substations and the experimental implementation of hardware in the loop are helpful to demonstrate the actual performance of any practical application. Determine the optimal virtual inertia and frequency control parameters to maintain the stability of the microgrid main system. Among the new renewable energy sources, solar power generation and wind power generation have the highest power generation rate. Therefore, the new renewable energy sources and distributed power sources that constitute the smart grid are generally used to model solar generators and wind turbines. In particular, solar generators are the most suitable for household power generation in the new renewable energy, and one of the main new concepts that constitute the smart grid is to produce substantive energy for consumers. Therefore, the way to reflect the reality of smart grid in solar energy and wind turbines has been studied. The utilization of DC power and power grid as AC current mode for the development of solar generators has not been fully reflected. In addition, this paper also divided the control types, including primary control and secondary control. The first control is responsible for keeping the electrical parameters within an acceptable range, and the second control is responsible for economic and reliable power grid operation. Centralized control realizes online optimization routines, while decentralized control coordinates the actions of grid connection system and microgrid.

3.2 Online monitoring system of smart grid substation

At present, the monitoring point data of substations in the province are uploaded to the monitoring center of the provincial company for further analysis and processing. Some have established a two-level monitoring center structure of prefectural and municipal bureaus and provincial companies, and finally gathered to provincial companies. With the evolution and development of substation automation system technology, the measurement and control devices are displayed in different technical forms at different stages, from remote control terminal units to independent measurement and control units. In the future, energy production and supply decisions have never considered the inclusion of new elements, and the objective function can now be combined with other forms. This is a new kind of decision-making that does not exist in society so far, which means that it must be implemented. If there is a simulation model that can well reflect the real world, it will be of great help to decision-making and mastering the impact. The current research focuses on the diversification of resources, taking the basic demand and supply decisions of energy in the future, and generally taking economic efficiency as the goal. Relevant researchers have fully reflected the logic of the market, and how any decision affects the methods that can be easily mastered by the whole power grid can be considered as provided, but generally specific consumption patterns and household modeling. Using the external power supply mode is the minimum goal, which can only produce a sense of distance from reality. This is difficult to reflect in the decisions of individual consumption sources and decentralized power supply because the purpose function is regarded as the whole grid; there are various modes of production, supply and consumption, and there are limitations in terms of the declining analytical power of liquidity.

3.3 Actual implementation of smart grid substation

The smart substation includes the actual implementation of protection and control in the smart grid or microgrid centralized substation, which depends on the implementation location. The intelligent substation has developed an algorithm to solve the problem of designing robust control, so as to enhance the optimal transient performance of the substation, take into account the electrical variables, and have the best energy management. The algorithm should adopt a distributed and extensive design method, declare its limitations and future opportunities, and allow dynamic control of the system by considering different fault types, even if it does not include related problems, such as fault identification and isolation. The intelligent substation characterizes the optimal control of the system through the identified model, including the comparative analysis of the conditions for the system to enhance the transient performance of electrical variables. Because the new equipment and concept of smart grid is different from the existing energy grid, it is very important to model various equipment and elements in smart grid simulation. Multi-factor modeling research can refer to the household star power consumption and production mode of the most basic unit of smart grid, and the level of household appliances such as refrigerators and air conditioners. Considering the relationship between equipment and family factors, family factors and urban factors, it is possible to design dynamic energy behavior model based on smart cities. The diversity and hierarchical modeling of equipment and elements are worthy of reference, but it is limited that the action modes of various equipment and elements are not modeled in a variety of ways. Through consumer-based decentralized demand management and behavior modeling to clearly grasp and analyze consumer needs. This is the result of optimizing the power utilization efficiency and applying it to the simulation framework, reducing the actual power loss at a meaningful level. However, it is necessary to model the consumer's action

mode realistically. Relevant research is also based on the premise of managing and controlling the consumer's demand from the perspective of the whole power grid. Therefore, it is limited to apply to the smart grid.

3.4 Influence of control elements of smart grid substation

Among the multiple elements of smart grid, PMU can measure the magnitude of voltage and current, phase, frequency change rate and other power-related information in real time. Use satellite signal (GPS) to visually synchronize the measurement time in units of 1μs [4]. The PDC is set at the Regional Control Center (RCC) to collect power data from the PMUs of power plants and substations across the country and send it to the Central Control Center (GCC). GCC receives power data from multiple PDCs and conducts data processing and events to enable the administrator to take appropriate measures. Figure 1 shows the PMU data transfer path. GCC's Digital Shared Memory will distribute and store the data collected from multiple PDCs. DFS (Distributed FileSystem) will store and manage the PMU data as the file basis. The event server is responsible for the collection and management of PMU data and events. HCI (Human Computer Interface) is responsible for providing the real-time monitoring results of PMU data. The algorithm server is responsible for real-time driving and event occurrence according to the algorithm based on PMU data. The communication between PMU and PDC is connected by line, and the absolute synchronization time error between PMUs is required to be within ± 0.5μs [5]. The PMU device transmits the measured data to the PDC at most 60 times per minute, and installs the GPS module to meet the time error requirements of throttling band between PMUs. However, the PMU device must be installed in each substation and is a permanent equipment, so it must work indoors. In addition, if you want to use GPS indoors, you need to set up another GPS antenna, so there are restrictions on setting and moving. In addition, when the substation with PMU is located in mountainous and remote areas where the cable network connection is not easy, the cost of installing optical cables is quite high. It is judged that there will be a lot of demand, especially in overseas areas with large area and low population density. In addition, the existing wired communication of PMU equipment needs to be replaced by wireless, but the security and reliability of data involved are very important, so it is not suitable to use wireless communication with unlicensed bandwidth such as Zigbee, NoRa and WiFi [6]. Therefore, it is necessary to introduce cellular communication that can not only achieve ± 0.5μs absolute synchronization time error, but also ensure data reliability. Through the absolute time synchronization technology proposed in this paper, the above absolute synchronization time error can be achieved, and it can also replace GPS, greatly saving new installation and maintenance costs.

3.5 Control technology optimization of smart grid substation

In order to find the optimal solution of the control problem, there are specific optimization applications in the control technology, which can focus on searching the optimal energy management of the controlled system. Due to the activation of new institutions such as power exchanges, and the popularization of the concept of "production consumers" that can simultaneously play the role of energy production and consumption, the future energy supply sources will be diversified. Not only that, the continuous development and promotion of new technologies such as electric vehicles also have great mobility due to users' use of electricity. With the diversification of energy supply and utilization, there is no guarantee that the central centralized energy supply is stable and efficient. Its main goal is to maximize energy efficiency. If technological barriers are overcome, this renewable energy can meet the global electricity demand, especially in rural areas. Similar studies to optimize the optimal power exchange can be carried out, especially with other power generation, such as wind power or hydropower. In addition, this limitation is solved through the two-way action model of energy demanders and suppliers, and the mechanism of electricity market is analyzed. Therefore, most of the simulation models for energy supply and demand considerations and those based on the market are realistic, and it is difficult to determine the value of price and factor compensation. It also has the limitation of not considering distributed power supply, which is a great limitation for smart grid research, because the generation of new renewable energy is the main reason for smart grid research.

4. Conclusion

The most cited relevant research in the fields of power system, power electronics, renewable power generation, smart grid, heuristic methods and intelligent control systems. Intelligent substation is a planned control scheme, which controls the whole system in layers. This study is based on the position of policy makers on the stability and efficiency of the entire power grid when the increase of new renewable energy and distributed power sources in the future is faced with various unpredictable situations due to the diversification of energy sources and consumption, considering the goal of decision-making to help develop simulators. Specifically, the situation of the transformer passing through the distribution system stage is modeled to reflect the impedance between lines or the power data used by each furniture according to time.

References

[1] Ahmad W, Hasan O, Tahar S. Formal reliability and failure analysis of ethernet based communication networks in a smart grid substation[J]. *Formal Aspects of Computing*, 2020, 32: 71-111.

[2] Singh N K, Mahajan V. Detection of cyber cascade failure in smart grid substation using advance grey wolf optimization[J]. *Journal of Interdisciplinary Mathematics*, 2020, 23(1): 69-79.

[3] Reda H T, Ray B, Peidaee P, et al. Vulnerability and impact analysis of the IEC 61850 GOOSE protocol in the smart grid[J]. *Sensors*, 2021, 21(4): 1554.

[4] Xu Dongwei. Intelligent substation integrated monitoring system based on artificial intelligence technology [J]. *Electrotechnical*, 2022, (12): 62-65.

[5] Li Yonghua. Research on key technologies of intelligent substation relay protection online monitoring system [J]. *Electronic Components and Information Technology*, 2022, 6(06): 105-107+112.

[6] Shen Xin, Xiong Jun, Tan Taiyang, Zhang Jianwei, Yu Hengjie. Optimal implementation of measurement emergency processing based on smart key management system of power grid [J]. *Information and Computer* (theoretical version), 2022, 34(11): 236-239.