Research on Multi-scene and Multi-station Fusion Mode Based on Layered Theory of Energy Internet

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Abstract. Multi-station integration is a new form of business in the development of energy Internet and a brand new practice of power iot. It is an innovative form that strengthens the interaction between charge and storage of source network on both sides of energy supply and demand, and enhances the flexibility of power grid by taking substation, energy storage station, distributed energy station and other resources as the core. However, there is not a set of construction mode that can guide implementation, copy and popularize. Therefore, guided by the existing construction practice of multi-station fusion in China and combined with multi-user scenarios, this paper studies the multi-station fusion mode, proposes a multi-station fusion planning system based on EIST theory, gives the fusion mode under different business scenarios, and synchronously constructs a new ecological business chain with multi-station fusion as the core. It aims to make full use of the innate advantages of substation in energy flow convergence, realize the "integration of energy flow, business flow and data flow", comprehensively support the transformation of digital power grid, and practice the national development strategy of "digital economy" and "digital China".

1. Introduction
Substation is the power transmission hub, is an important place in the power system for voltage conversion, energy concentration and distribution, energy flow control and voltage adjustment, plays a role of link between power plants and users. At the same time, in the context of the development of energy Internet, substation can also serve as an important information node and relay station for energy conversion between users and power grid, which transforms the traditional single source-load mode into a friendly interaction mode of "source-load mode and load-load mode".

"Multi-station integration" is an important content of implementing the national "new infrastructure" development strategy. The so-called multi-station integration means to explore and utilize densely distributed substation resources to construct and operate data center station, energy storage station, distributed energy station, 5G base station, Beidou ground enhancement station, etc., which can support smart grid business internally, assist new infrastructure externally, and promote economic and social development [1-3].

"Multi-station" refers to the infrastructure and system platforms related to information communication and energy environment, including 5G communication base station, Beidou Foundation Reinforcement Station, distributed new energy power station [4-7] and environmental monitoring station, in addition to the traditional three stations [5-8]. "Convergence" means to realize the integration of energy, information communication, government affairs and other fields through the construction of "multiple stations", and realize the coordination of power grid enterprises, communication operators, and relevant government commissions and bureaus as service subjects.
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**Figure 1.** Schematic diagram of multi-site fusion energy flow.

In this paper, 110kV substation will be taken as the main research object. According to the construction scale of substation, user energy characteristics, urban planning land nature and other factors, different fusion scenarios will be set up to carry out multi-station fusion research in multi-scenes, and the "N+N" multi-mode multi-station fusion configuration scheme will be given. It will lay a foundation for the whole network to realize the construction and implementation of the source-network-load interactive system, and help the grid transform to an intelligent, digital, clean and efficient new power system.

2. Analysis of the Current Situation of Multi-Station Integration Construction in China

Since early 2019, the state grid company should explore the use of substation resources construction operating charge for electricity (storage) station and data center mode, namely "multistation fusion" concept, after the mail tunnels industry group was established "multistation fusion" working group, responsible for coordinating the internal unit from technology, construction, operation and business model, investment and financing to carry out in-depth study, With the goal of completing the top-level scheme design of "multi-station integration", selecting and constructing pilot projects and putting them into operation, pooling resources and cooperating. At present, the construction situation and functions of "multi-station integration" demonstration projects carried out by power grid companies of some provinces and cities in China are as follows:

2.1. State Grid Gansu Power Supply Company

On April 23, 2020, its power supply company and China telecom company, gansu province, gansu province lanzhou 110 kv sand flat variable data center formally completed delivery, through to the substation reusable site resources utilization, the redevelopment of the old warehouse 632 square meters, the production of a total of 172 face 7 kw rack, is within its system first outdoor type of large and medium-sized multistation data fusion center.

Built the project put into operation, it is its power in gansu "5 g + grid innovation application" to carry out actively explore an important step, for local new infrastructure development in gansu province has provided a reference, promotion of ideas, for new infrastructure build cross-industry enterprise cooperation pattern model, realize the complementary advantages and win-win cooperation between enterprises, It is of great significance to support local economic and social development.
2.2. State Grid Hefei Power Supply Company
On April 28, 2020, the two data centers of Zhonghai Open and close Office and Yulong Road Substation of State Grid Hefei Power Supply Company in Binhu New District were officially put into operation. By not changing the original overall layout, solar photovoltaic panels were installed in the roof space of the station to build an 88 kW PHOTOVOLTAIC power station. 16 sets of DC quick charging piles and 8 sets of AC charging piles are equipped to meet the needs of vehicles in the economic and economic zone of Hefei. At the same time, the original xinlu ev charging station and newly allocated batteries will be comprehensively utilized to build an energy storage station with a capacity of 5.14 MW.

Station is not only the anhui electric power first "multistation fusion" project, but also domestic advanced green renewable "micro grid" demonstration project. photovoltaic power plant green electricity supply of electric vehicle charging station, data center and communication station, excess electricity deposited in the on-site energy storage station, the formation of "light ChuChong micro network system integration. At the same time, it is a response to the implementation of the national "new infrastructure" strategy, which will play an important role in promoting the construction of smart city in Hefei.

2.3. State Grid Shanghai Power Supply Company
On April 15, 2019, the 35-kilovolt Yinjiabang Substation "multi-station integration" demonstration project was officially started in Zhangjiang Science City, Pudong, Shanghai. It is based on the traditional substation, equipped with 3.78 MW / 7.65 MW/energy storage system and a data center with 24 server cabinets. At the same time, a 5G tower and six communication screens are reserved to form the multi-station integration mode of "substation + energy storage station + data center".

The energy storage station can effectively cut peak load and fill valley of the power grid, so that the maximum load rate of the main transformer of Yin Jia Bang substation can be reduced to about 70% from the current heavy load state, which greatly improves the power supply capacity of the regional power grid. Data center can store and utilize a large amount of equipment status information to support the development of comprehensive energy service. In the later stage, it will be equipped with super foundations such as 5G base stations to provide effective resources and means for the construction of digital power grids and the expansion of comprehensive energy services.

To sum up, local construction features are the transformation and upgrading of traditional substation or switch station and other old station site resources, using their idle space, based on the construction and operation mode of "unified planning, unified design, characteristic construction", and their business types and ways are different. However, a multi-station integration construction scheme has not been constructed to facilitate the replication and promotion of construction across the province and the country.

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3. Multi-Station Integrated Energy Interconnection Planning System Based on the Layered Theory of Energy Internet

3.1. The Concept of Complex Adaptation Theory
Complex adaptive system (CAS), the core of which is adaptation produces complexity, complexity is the condition of intelligence. Its basic characteristics include agent, aggregation, nonlinearity, factor flow, diversity, feature identification, internal model and building blocks. The first five are common
characteristics of complex adaptive systems, which will play a role in adaptation and evolution. The last three are the mechanisms by which individuals interact with their environment.

Complexity is generated, not given; The internal cause of complexity is that the system or things adapt to the environment for survival and development, and complexity emerges in the adaptation. So adaptability creates complexity. In order to adapt to the continuous development of the urban order, the energy system must constantly adapt to the new form, and study the new ideas to solve the energy problem under the new situation.

3.2. Layered Theory of Energy Internet
Energy Internet Stratification Theory (EIST) is based on the theory of complex adaptation, combining with each project to gradually summarize experience and expand the types of projects, forming the core idea of paying attention to terminal Energy users and progressive evolution layer by layer. Combined with system theory, information theory and cybernetics, the multi-station integrated energy interconnection planning system is built, giving full consideration to the increasing proportion of distributed energy and the inevitable trend of the development of the Internet of things. The core part of the theoretical system is to build a planning framework suitable for energy Internet, which is divided into three layers of energy cell, function unit, operation unit and an energy supply and demand center, referred to as the "Trinity Principle". Based on the characteristics and development trend of multi-station integration construction, the specific hierarchical definition is proposed:

Energy cell layer: the area formed by the boundary of 10kV line/power supply area on/off, which contains all power equipment, sensing equipment, network equipment, intelligent terminal and corresponding energy users, etc.

Functional unit layer: it is composed of multiple energy cells (10kV line/switch) and formed by the boundary of substation power supply area, that is, a multi-station fusion substation. Including distributed energy station, energy storage station, big data center and other types of energy facilities, can be divided according to the power supply unit area in grid.

Operation unit layer: it is composed of multiple functional units (substations) and formed by the boundary of the management scope of municipal power company. Intelligent energy dispatching, intelligent operation and maintenance service cloud platform of municipal grid is built to realize intelligent energy dispatching, intelligent operation and maintenance and intelligent early warning within the region. It can be divided according to the grid area of power supply grid. At the same time, it can flexibly split and merge functional units according to the changes of different energy mechanisms, so as to meet the demand of optimal power supply in the region.

Energy supply (Demand) center (provincial power grid Company, Internet of Things as "cloud" level): it is an area bounded by the management scope of provincial power company. It is the comprehensive management of supply and demand from lower-level energy to higher-level energy. By building a smart energy management platform, it can complete the intelligent scheduling and energy transaction of energy supply and demand balance.

3.3. Multi-Station Fusion Planning System Based On EIST Theory
Based on the theory of complex adaptation and stratification, according to the trinity principle, a multi-station fusion planning system based on EIST theory is proposed. Urban multi-station fusion planning will highlight the hub and fusion characteristics of substation, define a functional unit by a single substation, and define different subordinate energy facilities as an energy cell. Considering the underlying energy demand and supply capacity, and considering the reliability and economy of energy transmission, the energy cells are divided into self-supporting functional units, externally supplied functional units and mixed functional units. Specific definitions are as follows:

Self-contained functional unit: refers to an independent building or area, which uses its own energy production to meet energy use needs and does not participate in energy trading and energy dispatching. Usually, photovoltaic, wind power and energy storage systems can be configured in the
region to jointly solve the problems of cold, heat and electricity supply in the form of electric energy substitution.

External supply functional unit: refers to the unit with small energy load demand and poor economic efficiency of independent construction of energy equipment, relying on the nearby large energy station to meet the regional cold, heat and electricity load demand in the form of external energy supply, and participating in energy trading and energy dispatching.

Hybrid functional unit: refers to the functional unit with large area and load. Its energy supply capacity can not only meet its own energy supply demand, but also supply energy for surrounding functional units. It can also purchase energy from other cells for regional supply based on energy price, which is a comprehensive functional unit. At the same time, participate in energy dispatching, adjust the overall peak load of the region and optimize the load curve. Generally, a variety of energy sources such as cold and heat combined power supply, new energy, energy storage, heat storage and cold storage can be considered in the region to meet the energy needs of multiple functional units in the form of integrated energy allocation and supply.

Multiple substation function units can be formed into energy networks with different sizes and functions according to different operation units and modes. A large amount of operation and transaction data can be quickly calculated by using low-delay characteristics of 5G network through underlying data storage and edge computing. Finally, the event results will be returned to the municipal energy management platform, unified operation and scheduling, multi-business operation, forming a multi-station integrated business system for digital power grid. The system can effectively realize the flexible interaction between the side source, the network and the load of the substation, and the diversity of energy sources also makes it possible for the power grid company to provide better energy services to the user side. The schematic diagram of multi-station integration service planning system for digital power grid is as follows:

Figure 2. Schematic diagram of multi-station integrated service planning system for digital power grid.
4. Research on Fusion Mode of Multi-Station Fusion in Multi-Scene

Facing the future development of digital power grid, intelligent substation has become an irreversible trend. Therefore, substation network and information construction can provide information support for power grid scheduling optimization, operation management, energy transaction, comprehensive energy innovation business, etc., and provide guarantee for information interaction between power network and multi-energy system. The digital construction of substation needs data center station and 5G base station as important support.

Therefore, when considering the integration scheme design of multiple energy stations in multiple scenarios, the basic configuration mode of "substation + data center station + 5G base station" will be adopted. On this basis, different business application scenarios will be set according to different user types and load characteristics in the region. The "3+N" substation fusion mode is proposed to meet the requirements of cold, heat, electricity and user-side services.
According to GB50059-2011 code for Design of 35kV ~ 110kV Substations, 110kV substations generally determine the capacity and number of main transformers according to the power supply conditions, load properties and power capacity of surrounding areas. In addition, in order to facilitate fault or maintenance, they can flexibly switch operation and reduce the scope of power failure and power failure loss. Generally, two or more main transformers are configured to achieve the principle of reliable power supply, convenient maintenance and economic operation. According to the actual construction of 110kV substation, considering the characteristics of substation and the diverse business conditions on the user side within the power supply range, a multi-scene mode and multi-station fusion configuration scheme for digital power grid is proposed. The detailed design is shown in the following table:

**Table 1. Design of multi scene and multi station fusion mode.**

| Design of multi-station fusion mode based on user side service | Type | Scene classification | Multi-station fusion mode design |
|-------------------------------------------------------------|------|----------------------|----------------------------------|
| Service scenario 1: The main power supply area is industrial | Service scenario 2: The main power supply areas are commercial and office areas | The fusion mode of "3+ energy storage station + distributed photovoltaic power station" is adopted | The integration mode of "3+ energy storage station + distributed photovoltaic power station + charging pile charging station + cold storage station/combined cold, heat and electricity power supply station + Beidou base station" is adopted |
| Service scenario 3: The main power supply area is residential | Business Scenario 4: The main power supply area is a mixture of industrial, commercial, residential, and public facilities | The integration mode of "3+ energy storage station + distributed photovoltaic power station + charging pile charging station + heat storage station + cold storage station/combined cold, heat and electricity power supply station + Beidou base station" is adopted |
| Fusion mode utilization of resources, New energy storage station, photovoltaic, charging pile charging station, data center, cold storage station, cold storage station/cold storage station/combined cold, heat and electricity power supply station + Beidou base station" is adopted |

**Diagram of "N" station**

*Figure 4. 3+N station schematic diagram.*
Transform substation: improve power supply reliability and equipment utilization rate
New energy storage, photovoltaic, data center, DC microgrid, etc

Conventional substations: incremental resource utilization and optimization
New energy storage, photovoltaic, charging pile charging station, data center, cold storage station, heat storage station, 5G base station, Beidou base station, DC microgrid, etc

In addition, in order to reflect the social attributes of power enterprises, some substations will have the function of popular science, and the appearance of the substation will be designed to facilitate the public to understand the operation of the power system. Therefore, this kind of multi-station integration mode design will be on top of the basic design, and should also add science station, landscape station, etc.

5. Conclusion
As an emerging business in the field of energy, multi-station fusion has been applied in Shanghai, Nanjing, Tianjin, Chongqing, Xiamen and other places. However, the current substation fusion model, business application scenarios, construction and operation modes are not mature enough to form large-scale popularization and promotion. Therefore, this paper analyzes the construction characteristics and differences of multi-station fusion in various provinces and cities in China, summarizes the commonalities, studies the fusion combination mode of multi-station fusion in multiple scenarios, and innovatively proposes the "3+N" combination mode based on different user-side business types and the combination design mode based on different types of substation. The research results will serve as the practical support criteria for the substation centered regional energy Internet innovation business model, and the theoretical planning system and multi-scene fusion mode will be applied to guide the construction of multi-station fusion system in different scenarios. This model can be built into a new model of multi-station fusion construction that can be replicated and promoted in the whole country, and help the industrialization development of multi-station fusion business. At the same time, it strengthens the digital infrastructure construction of power grid through multi-station fusion technology, strengthens the basic computing and operation capacity of digital power grid, and pushes forward the construction target of digital power grid, source network load interaction system and new power system.

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