Application and Implementation of General Service Protocol in Transparent Access Framework

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Abstract. In order to break through the bottleneck of grid data use, support the cross-business data access requirements, and adapt to the future "physical distribution and logical unification" architecture, this paper starts with the current requirements for wide area data transparent access, analyzes from three aspects of architecture, data, and business. The service framework for transparent access to wide area data is constructed by applying the general service protocol of the power system in the existing smart grid general standard system. This frame is applied to scheduling system and forms the overall construction scheme of a transparent access framework. Besides this, it determines the unified definition of the business service model and service interface in combination with the general business access requirements. At the same time, the implementation process of distributed business data stream processing technology and wide area service proxy interaction method is also proposed in the article, and a method of transparently accessing service-oriented and existing application functions in the transition phase is proposed. It provides technical support and implementation basis for building a transparent access framework for wide area data.

1. Introduction

The rapid development and technological progress of IT and Internet technologies have promoted breakthrough technological changes in many industries. In the field of power grid dispatching control, around the dispatching data network, multi-level control centers, substation station control layers, bay layers and other network nodes form an ecological environment similar to the wide area Internet within the security zone. At the same time, due to the rapid development of the power grid, higher requirements have been imposed on data collection, transmission, and analysis [1]. Therefore, in consideration of security conditions, it is entirely possible to combine advanced IT and Internet technologies with the objective laws of the power system and apply them to enhance the global application function of the control system.

At present, with the rapid progress of data interaction technology, the data interaction between the control-centers and substations has evolved from the simple "four remotes" to a mode of integrating multiple data types represented by remote browsing and alarm direct transmission. At the same time, the data interaction between the control centers has also developed from a simple data forwarding to a complex data exchange mode represented by remote access. However, because the essential method of data interaction is still a narrow-band communication-oriented protocol transmission method, it is
incapable of facing the comprehensive requirements of mass information processing and the speed of future decision-making. In view of this, it is urgent to study the access method of wide area information from the perspective of the entire network, and use Internet technology to build a service-oriented transparent data access model to gradually replace the current data access model of the protocol, and improve the real-time nature of data acquisition and Convenience.

2. Transparent access requirements of wide area data

2.1. Architecture requirements

The data interaction mode of the existing protocol cannot meet the requirements of future "physical distribution, logical uniformity" scheduling architecture [2]. After several years of research, the industry has reached a consensus on a new model for integrated dispatching of large power grids in the future, which is characterized by "physical distribution and logical unity", that is, localization of collection, monitoring, and control execution, and regionalization of grid model management. The goal of decision-making is to integrate the entire network. Therefore, from a logical point of view, the entire network can be considered as a system, and there are many data interaction requirements between the constituent nodes.

The current data interaction mechanism causes the source-side data resources of the substation to be directly accessed only by the regulatory center under its jurisdiction, which limits the data flow across the entire grid and affects the accuracy and timeliness of cross-region application calculation analysis. For example, in the calculation and analysis of long-distance transmission and receiving ends across regions, due to the inconsistency of the source of the basic data, the data at both ends may not be at the same time, resulting in inconsistent analysis results at both ends. In the future, the integrated dispatch of large power grids needs to ensure the fluidity and consistency of data resources in a wider area, and it must use a service-oriented data interaction model [3-4] to reduce.

2.2. Data requirements for master and sub station

Except for the "Four Remotes", most of the data in the substation are in the station. It is difficult to provide sufficient data to support the operation analysis and accident analysis of complex large power grids. The traditional power grid data is forwarded by protocol step by step. Both the master station and the substation end need to be library-to-point. As a result, the content transmitted is limited to "four remote" data, which has caused a bottleneck in the use of data between upstream substations and downstream control centers.

At the same time, as smart substations use more new technologies and new equipment, a large amount of new data is generated, and due to the constraints of the protocol, these data are all stranded in the station. At the same time, due to the centralization of the dispatching and monitoring services of the master station, the master station needs more data support from the substation, which further exacerbates the situation where the substation data cannot be sent out and cannot be used, it also leads to the inability to provide sufficient data for operators to analyze in the event of a complex power grid accident, which directly affects the processing efficiency.

2.3. Requirements of business

Grid data is transmitted separately by profession, forming a chimney effect, and lacking cross-business data horizontal support means. Although the current power grid communication network has a star-shaped radial structure, due to the division of the responsibility areas of different power grid services, the power grid data transmission presents a chimney effect. From the front-end collection to the application system, it is used and managed by a single business. For example, guarantee, SCADA, condition monitoring, WAMS, and metering services all have independent channels. Data is restricted to use in a specific range, and applications and platforms are too coupled, which makes system
maintenance difficult. When the requirements of the master station change, it is difficult to quickly upgrade the existing architecture, and it can only adapt to new services by expanding the protocol.

With the construction of China's smart grid UHV AC / DC hybrid system, global dynamic security analysis, real-time state awareness, and centralized monitoring in complex power grid environments are increasingly pressing for large-scale data requirements. In this environment, no matter from the perspective of grid operation or equipment monitoring, higher requirements are imposed on data collection, transmission, and analysis.

Therefore, a cross-business open plant and station service is formed, and station-side resource services are built to improve the availability of data resources. The station control layer and even the interval layer of the substation will gradually provide open and transparent data access capabilities as a service, making arbitrary services available. The client can easily remotely access the content of the plant and station without permission, and does not depend on the platform, location and data format of the service provider. At the same time, the substation has the ability to customize and publish the service, forming a station-side data resource Warehouse, thereby changing the publishing model that has only been able to publish predefined data through traditional communication specifications for a long time, and improving the ability of substations to support grid services.

3. Overall construction plan of transparent access framework

3.1. Agent-based service agreement framework

In order to meet the interaction needs between the intelligent substation and the dispatching master station, in the power grid data service framework based on the General Service Agreement (GSP) of the power system, both the plant station and the master station can serve as service nodes in the grid. The principle of "access required" realizes the efficiency, immediacy and accuracy of data interaction between the main plants and stations [5].

From the perspective of the protocol, the general service protocol of the power system can not only support the construction of a service-oriented communication architecture, but also be compatible with existing common communication protocols. The general service protocol establishes a real-time data transmission mechanism based on object-oriented technology and combines dynamic information of the power system coding technology [6] adds data units that support class description information, which can be used to dynamically define and identify data during data interaction. The protocol specifies the architecture, interaction mode, service primitives, and communication protocols of common services, which can be used to implement Static and dynamic service data exchange between power grid dispatching and control centers at all levels and various types of power plants and substations.

![Figure 1. Proxy-based Service Protocol Framework](image)

As shown in Figure 1, the basic interaction framework of the general service agreement considers the use of an agent-based service model, through the interaction between the service provider's local service agent and the remote service agent. On the one hand, the service requester and service provider are considered. The problem of not being directly connected enhances the ability to extend and expand the service. On the other hand, it can also securely control access requests through a proxy method, which enhances communication security.
3.2. **Transparent access framework applied to scheduling system**

Transparent access refers to any network node. On the basis of security and controllability, it can flexibly understand the information of the grid control system and substation system according to needs. Its main characteristics are as follows: it breaks the limit of point-to-point interaction, as long as any authorized node on the network both can be used; based on service-oriented design ideas, flexible data set customization methods are provided to achieve on-demand access to grid control system and substation system information.

Combining the deployment characteristics of the existing schedule system and the substation system, a service agent can be deployed on the front gateway of the existing sub-station, and the service of the sub-station is registered in the dispatch control center [7]. In terms of services, the local monitoring nodes in each place can obtain the service information of the sub-node data node that is responsible for monitoring through the service management client. In terms of data, the on-site monitoring node can directly obtain the substation data for monitoring and form the analysis result. The local monitoring data service node provides data services to the outside; the centralized control center can obtain data from the local monitoring node or directly from the sub-station node according to business needs. The overall architecture is shown in Figure 2.

![Figure 2. Transparent Access Architecture](image)

Substation nodes, local monitoring nodes, and dispatch control centers can all become a service node in the network, and they can provide two types of data acquisition mechanisms: request-response and subscription-publishing, thereby achieving on-demand acquisition of data at different levels. This service-based interactive architecture can also achieve sub-region-oriented access services for substations by registering / publishing substation services to achieve plug-and-play effects.

3.3. **Service model and unified definition in transparent access**

The data interaction service in transparent access should support two modes of request-response service and subscription-publish service. Among them:

1. Request-response services are applicable to the scenario of a single service request, and the interaction process is shown in Figure 3. The service interaction process includes four phases: service request, service instruction, service confirmation, and service response. Most services in practical applications are requesting responsive services, such as: remote screen browsing services, plant site model acquisition services, query of historical data and alarms, etc.
(2) Subscription publishing service. It is applicable to the scenario of submitting service registration once and returning service results multiple times. The interaction process is shown in Figure 4. Typical applications such as remote subscription, telemetry, and remote signaling of substation alarm events Send etc.

![Figure 3. Request Response Service Flow](image)

**Figure 3. Request Response Service Flow**

![Figure 4. Subscription Publishing Service Process](image)

**Figure 4. Subscription Publishing Service Process**

On this basis, the general service protocol also uniformly defines the service method of data resources, provides an access interface for data acquisition, and the service description follows the definition requirements of the simple service interface specification of the power system [8]. It is the conventional measurement data, model (graphic) data, historical data, alarms data and so on. [9-10].

Table 1 lists the services related to data access in the typical application scenario of the grid dispatch control in the general service protocol.

| Service primitive | Service primitive Chinese name | Typical application scenarios |
|-------------------|--------------------------------|------------------------------|
| GetDataSet        | Read data set                  | Model access, transmission and on-line monitoring data access |
| SetDataSet        | Setting up the data set         | Model access, transmission and on-line monitoring data access |
| SetDataSetValues  | Data value of the sent data set | Telemetering and telecommunicating data upload, remote browsing, online |
Table 2 lists the services related to file access in typical application scenarios of grid dispatch control.

| Service primitive | Service primitive Chinese name | Typical application scenarios |
|-------------------|-------------------------------|------------------------------|
| ListModels        | Get list of models            | Model access, transmission and on-line monitoring data access |
| GetModel          | Get the model                 | Model access, transmission and on-line monitoring data access |
| ListDisplays      | Get screen list               | Plant graphics import master |
| GetFile           | Read file                     | Plant station graphics import master station, relay protection device information access |
| BrowseDisplay     | Subscription screen           | Remote browsing              |

Table 3 lists the services related to alarm access in typical application scenarios of power grid dispatch control.

| Service primitive | Service primitive Chinese name | Typical application scenarios |
|-------------------|-------------------------------|------------------------------|
| SubscribeEvent    | Subscribe to events           | Alarm direct transmission, relay protection device information access |
| SendEvent         | Event push                   | Alarm direct transmission, relay protection device information access |
| QueryEvent        | Query event                  | Historical data and alerts   |
| Report            | Send report                  | Relay protection device information access |

4. Analysis and application of key technologies

4.1. Distributed business data stream processing technology
Among the conventional wide area business data service requirements, the requirements for distributed business data streams are the most extensive. Therefore, the general service protocol also adopts independent settings for such needs to improve the efficiency of transmission and use.

4.1.1. Object-oriented data information description method
The data batch processing mode and stream processing mode are two different mass data processing modes. The batch processing mode focuses on the throughput of data processing, while the stream processing mode focuses on the timeliness of data processing, and the overall delay requirements for the data processing process are very high. Distributed stream processing technology is a distributed, high-throughput, low-latency, and fault-tolerant real-time computing technology for streaming data. Power grid distributed services can use data stream processing models.
In the general service protocol, distributed business data stream processing uses stream data units (UT = 2) to transmit multi-frame streaming data, such as large files or images. The stream data encoding structure of standard units is shown in Figure 5. In ASDU Standard header, the unit identification UI occupies 1 octet, where the unit type is UT = 2, and no encoding type is used; the sub-service SS (Sub-Service) is an extension of the service code SC, and its encoding and meaning are provided by the service. The relative sequence number SEQ occupies 2 octets, and the value ranges from 0 to 65535. It automatically returns to 0 when it reaches the maximum value of 65535. In the transmitted message, it indicates the relative message sequence number of the packet in the buffer. The relative message sequence number in the reception confirmation message.

![Figure 5. Stream Data Unit Architecture of Standard Unit](image)

4.1.2. Stream data transmission method

The streaming data is transmitted as follows:

1) The data sender organizes and sends the data packet according to the stream data slice length and the confirmation window size negotiated during the association, and assigns a transmission sequence number (seq or sq) to each frame of data. The transmission sequence number increases continuously. Return to 0;

2) After the data sender sends several frames of data packets equal to the confirmation window, the waiting data receiver should return the confirmation message;

3) The data receiver shall send a reception confirmation message after receiving several frames of data packets equal to the confirmation window, and its sequence number SEQ (or SQ) indicates that the SEQ (or SQ) message has been correctly received;

4) After receiving the confirmation message from the receiver, the data sender releases the sending buffer and continues sending until the confirmation window is filled, or all data is sent.

When using streaming data transmission, the length of the information slice to be transmitted and the size of the confirmation window can be reasonably set according to the actual transmission requirements. Specifically, it can be negotiated in the associated services of the communicating parties. If no negotiation setting is made, the default slice length is 1024 octets, and the window size is 8. In order to improve data transmission efficiency and reduce network data packetization, it is recommended that the size of the apdu containing the stream packet plus 12 bytes of the proxy header does not exceed the current network transmission maximum Transmission unit (MTU) value.

In this way, when the communicating parties are performing more complex data exchanges, such as file transfer, when it is difficult to use a class-expressed service, they can use the stream data unit for data exchange.

When using a streaming data transmission service, the encoding method of the streaming data is agreed through the sub-service (ss) parameter of the streaming data unit. The encoding and decoding of the streaming data should be implemented according to the s description of the service parameter.

The process of streaming data exchange service is as follows:

1) In the Request process of the service, the IN parameters are individually coded, and the data is encoded according to the parameter encoding method, and then merged in order to form the data stream requesting the service;

2) The Indication process of the service is decoded according to the reverse of the Request;

3) In the Response process of the service, the OU parameters are one by one, and after the data is encoded according to the parameter encoding method, the service response data stream is formed by simply merging in sequence;
4) The Confirm-Process in the service is decoded according to the reverse of the Response.

4.2. Association ID-based wide area service proxy interaction method
In the entire service architecture, the interaction process between service consumers, service agents, and service providers includes association (Associate), service transmission, active release (Release) or suspension (Abort), communication error handling, and the association function among them is the basis of transmission control during service link establishment, identity security authentication, and subsequent service data communication.

4.2.1. Establishment of service association
Association refers to the end-to-end connection between a service consumer (client) and a service provider (server), and is divided into local service association and remote service association through a proxy according to the scope of service access. The association process includes the establishment of the underlying socket (Socket) level connection, as well as the security authentication process after the connection is established.

The establishment of the association is carried out implicitly during each service interaction, that is, the association is established at each service session, and the association should be released at the end of the session according to the service access situation. The client notifies the server, and the server releases the association. For the established connection, the server should create a timer for each established association. If the client's service request has not been received for a long time, it is deemed that the session has ended and the related resources are released. If the client needs to maintain the association for a long time, it should periodically send a Test request. If the client detects an abnormal communication or the server refuses to release the association, it should use the Abort service to terminate the association.

The process of long connection association is shown in Figure 6, and the process of short connection association is shown in Figure 7.

**Figure 6. Constant link Associate Process**

| Serving consumers | Client communication library | Service providers |
|------------------|-----------------------------|-------------------|
| 1. Show Associate | Return to AssociateID |  |
| 2. Return to AssociateID | Request service SC based on AssociateID |  |
| 3. Request service SC based on AssociateID | Return SC service response information |  |
| 4. Return SC service response information |  |  |
| 5. Send Test service request periodically | Return Test Service Response Information |  |
| 6. Return Test Service Response Information |  |  |
| 7. Display Release based on AssociateID |  |  |
| 8. Return Release response information |  |  |
Long connection association is usually used for service communication or subscription/publishing service mode between agents, and short connection association is often applied to request/corresponding service mode.

4.2.2. Transmission of safety certification information
The general service agreement specifies that the interface parameters of the associated service include the security authentication parameter "authPara". Before making service connections and requests, the service consumer should provide the identity authentication information required for association in advance and put it in the security authentication parameters. After obtaining the security authentication parameters, the service provider or service provider agent can authenticate the visitor's user identity and operation authority through a unified security authentication center or a designated authentication technology.

The authentication information provided from the service architecture level is an effective supplement to the existing end-to-end encrypted authentication method. It can be more fine-grained from the connection application and access request of each service to control and help improve the prevention of messages. The ability to tamper with and repeatedly submit messages, such as cyber attacks.

4.2.3. WAN service agent interaction process
Service proxy interaction is used to support the establishment of associations across service domains, to implement link management, service request and service response forwarding. The service proxy can add a proxy frame header containing an associate ID (AssociateID) before the protocol data unit. The association ID includes both global and local. The global AssociateID remains unique within the end-to-end range, and the local AssociateID remains unique in the segmented connection. The wide area service proxy interaction process is shown in Figure 8.
Figure 8. Constant link Associate Process

Client C sends a service request to the local service agent X, and establishes an association with service agent X. At this time, service agent X generates a local association identifier AsID1, and service agent X queries or preconfigures through the service domain management to connect to service provider Y. At this time, after the service agent Y passes the verification, the inter-agent association identifier AsID2 is generated, and the association is established with the server S, and the server S generates the association identifier AsID3. At this time, the links from the client C to the server S are all established.

Service agent X, after obtaining AsID2, encapsulates the service request message of client C into a proxy message, adds the proxy frame header, and sends it to service proxy Y. Service proxy Y removes the proxy frame header after parsing the message and sends the service request message to the server S; after the server S finishes processing, a service response message is generated and returned to the service agent Y. The service agent Y is encapsulated as a proxy message according to AsID2 and returned to the service agent X. The service agent X removes the proxy frame after the header is returned to the client C. At this point, the service request/response process between the agents is completed.

Although the process of using proxy forwarding adds to the data interaction process, it has significant advantages for current cross-region service expansion, access control, and flow control.

4.3. Correlation methods of object-oriented data access and existing protocol functions

Existing application functions may still use the DL/T 860.72 protocol, the DL/T 634.5104 protocol, the GB/T 18700.1 protocol, or the DL/T 476 protocol. The real-time transparent access technology based on the general service protocol uses object-oriented data access. Therefore, the service object number can be used to associate the object-oriented data access method with existing application functions. The data frame structure is shown in Figure 9.

![Diagram](image-url)
Compatibility mode provided in the general service protocol. In the control code of the protocol, the PI field of the applicable protocol is set to the value of the protocol type of the data packet that needs to be compatible (1 ~ 6, 7 ~ 15 are reserved), on this basis, the original data message is encapsulated according to the protocol service number mapping provided in the appendix A to D of the agreement (corresponding to the range of PI values 1 to 4 respectively). In order to reduce the development and modification workload of the original application functions. This method is used during the project transition phase, and the project transition should be completed gradually in the future to provide complete transparent access.

5. Conclusion
This paper uses the general service protocol of the power system to build a unified transparent access service for each node, which solves the problems of poor scalability and low transmission capacity of existing communication protocols. It uses general data resource service, interactive processes and data acquisition methods to provide real-time transparent access to data resources is improved, and the access and acquisition of regulated data is improved to achieve the purpose of data demanders to request on demand. At the same time, the reliability of transparent access to business data is guaranteed from the physical level of the dispatch data network through the application of Internet technology. At present, the scheme of this article has been initially applied to the demonstration verification unit, and the use effect is good, which effectively enhances the control center's access to substation data, enriches the type of application analysis data, and improves the accuracy of application analysis results.

With the development of scheduling control requirements and changes in the architecture of the control system, in the subsequent promotion and application process, further research will be continued in the following areas:
Firstly, the service architecture and unified interface of transparent access are continuously supplemented and improved to meet the growing and changing access needs;
Secondly, strengthen research on transparent access authentication and permissions to ensure the security and stability of service access and data transmission;
Thirdly, the application method of the service-based transparent access technology in the online collection and transmission of the operating status of the new generation control system is studied to support the cross-regional integrated operation and maintenance requirements.

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