Semantic Modeling Method of Highly Elastic Power Grid Based on OWL

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Abstract. As an important supporting technology for the development of power grid, highly elastic power grid is the intelligent development of power grid, which can effectively improve the information level of power system. However, due to the massive terminal data, various communication modes and independent application platforms, it is very difficult to extract a unified and effective data expression format from complex equipment, which hinders the power system to achieve intelligent services. In this paper, the ontology description language OWL is used for semantic extension, and the understanding gap between heterogeneous identifiers is eliminated by adding device semantics. Through the establishment of equipment information, service overview and quality of service ontology model, the interconnection between heterogeneous identities of highly elastic power grid terminals can be realized, which can conveniently carry out intelligent control of transmission/transformer/distribution equipment.

Keywords: Highly elastic power grid · Ontology · OWL · Semantic model

1 Introduction

With the rapid development of IoT technology, its application is more and more extensive. The combination of IoT and smart grid has attracted more and more attention. With the long-term goal of building an energy Internet with Chinese characteristics, State Grid strives to promote the integration of power IoT, edge computing and AI [1]. And through the design of a new type of highly elastic power grid, promote the opening and sharing of intelligent power grid system. The number of power equipment may reach millions in the future. The power network will face a series of challenges, such as information communication, remote control, monitoring and so on. However, because the terminals are independent of each other, it is difficult to achieve standardized access and representation of terminals, which hinders the realization of intelligent service in the power system [2].

In view of the current problems of heterogeneity and multi-source of terminal devices, semantic technology is gradually coming to the public eye. Semantic technology is often

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used for semantic annotation of web documents, realizes barrier-free communication between people and machines. However, the research on the combination of power grid and semantic Web is still in its infancy. And the existing identification methods only have a single IP addressing, which is not compatible with the service content, spatial constraints, QoS, and other attributes of equipment, and can't meet the diversified and professional requirements of service requesters.

In this paper, a semantic model is designed to realize the integration of equipment identity and existing power business, and to realize the multimodal addressing of power equipment. The user can customize the data identity according to device properties. In order to realize the semantic model of power grid more comprehensively, this paper establishes a unified device description format by collecting, encapsulating, analyzing and extracting semantic information from underlying terminal data. The interoperability of heterogeneous devices is realized.

2 Related Work

A large number of heterogeneous devices makes power IoT form an information island in the vertical direction, which makes it difficult for information exchange and transmission. The establishment of semantic model enables terminal devices to interconnect horizontally, achieve semantic coordination, and enable devices to understand and communicate with each other. At the same time, it can easily manage a variety of heterogeneous devices and obtain the semantic of smart devices in time.

Therefore, in order to solve this problem, there is an urgent need to design a unified and extensible semantic model to meet the characteristics of heterogeneous devices, so as to facilitate information communication and interaction.

Reference [3] proposes SGIP architecture to address the data and communication interoperability requirements of smart grids, and demonstrates the use of the common semantic model. Reference [4] designs a data flow-centric semantic model DS-ontology for the IoT, which establishes semantic specifications and can realize semantic-based service discovery. In reference [5], a semantic ontology for sensor network is designed, and the theme, space, and time of entity are modeled by extending the model. Although there have been numerous studies, most studies do not fully describe the functional and non-functional properties of device, and do not consider the scalability needs of the model. At the same time, there are few researches on the semantic model for the highly elastic power grid.

Reference [6] introduces a QoS measurement model by analyzing the non-functional characteristics of services The model can be used to further determine appropriate service according to QoS when the registry returns multiple devices with the same function. Although the model takes into account the importance of QoS in device description, it lacks the user's individual requirements for QoS.

Semantic technology is the key technology to solve the integration and interoperation of cross-domain and cross-platform device data. Semantic services encapsulate the functions implemented by the underlying devices into services, and then combine with the attributes of device resources to make device have semantic. It can provide the required service set to the upper application layer for system to realize interconnection

[7]. In order to realize the semantic description of the underlying device, this paper uses OWL semantic service language to describe it. However, the OWL cannot specifically express the attributes of power grid, such as electricity volume, power generation, power generation status. Although the model can express information and attributes of device, it can't obtain the dynamic status of device in real-time. Therefore, this paper further extends OWL-S to meet the needs of highly elastic power grid, and introduces in detail the scalable semantic model and its characteristics.

3 OWL-S Service Description

OWL-S is a service ontology language based on OWL, which has formed a set of Web semantic annotation system through research and development. This system is used to describe Web services, enabling multi-source heterogeneous services to interact and invoke, and promote service discovery. Figure 1 shows the OWL-S service ontology model. The model consists of three parts: ServiceProfile, ServiceModel and ServiceGrouding.

ServiceProfile provides a description of the service, and explains the function and basic information of the service through the description of service. It includes the input, output, prerequisites and results of the service, which is very important for the discovery of service. ServiceModel provides the specific process when the service works, and describes the communication method of service. ServiceGrouding describes how services are accessed [8]. The creation of OWL-S lays the foundation for the semantic description of devices.

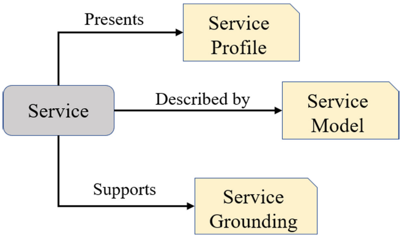

Fig. 1. The OWL-S service ontology model

4 Semantic Model of Highly Elastic Power Grid

In order to accurately describe the semantic model of Highly elastic power grid, it is necessary to define an appropriate OWL-S extension. This extension can meet the basic information and service status representation needs of power terminals. The extended semantic model corresponds to the access interface, which is used to search for available request services on the one hand, and realize the interoperability of terminals on the other hand.

This paper extends it on the basis of the original model. They are the external extension of 'service' of OWL-S and the internal extension of its subclass 'ServiceProfile' [9]. The internal extension is designed to add a description of device. External extensions make up for the lack of QoS. It provides a shared and personalized service ontology framework for service providers and selectors.

4.1 Expansion of ServiceProfile

In this paper, ontology description refers to the semantic modeling of highly elastic power grid through OWL-S. By giving semantic information to enhance the value of data, the semantic system can dynamically perceive and share devices. This paper combines OWL-S with power scenarios to create an ontology model containing physical device information and event services, to achieve a common understanding of terminal devices under different application systems.

The service reflects the corresponding functions of terminals equipment, and realizes the mutual invocation and interaction. As the power network infrastructure, equipment is the basis of service discovery. However, as the standard of information processing, the existing OWL-S language lacks the description information of terminal, which increases the difficulty of service discovery. Therefore, aiming at the extension of ServiceProfile, the device-related information is modeled as the DeviceInfo ontology. The relational hasDeviceInfo binds the DeviceInfo ontology to make it associated become the operation object of profile. At the same time, based on retaining the original process ontology and service overview ontology, the service overview ontology is optimized. The expanded profile includes three models, namely Service-Process ontology, Service-Overview ontology, and DeviceInfo ontology, as shown in Fig. 2.

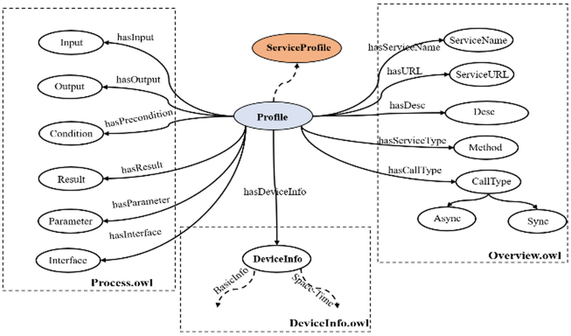

Fig. 2. Profile extension model

1) **Service-Process Ontology Model**

Process.owl is essentially the specification of internal operation flow of highly elastic power grid service, and it is the concrete way to realize service. It contains the necessary attributes in the process of service execution.

Process.owl describes the call information when the terminal executes the command. The Input represents the instruction information required by the service to produce the desired output. The Output represents the result of the information transformation after service execution, that is, the feedback requirements after the operation is completed. The Condition refers to the prerequisites for the successful execution of a service. The Result indicates the effect after the execution is completed, and the change of the power grid system caused by it. The Interface refers to the interface specification required by the service request, which describes the communication and access method between the device and power grid.

2) **Service-Overview Ontology Model**

The Overview.owl describes the basic information of the service. The power terminal can know the types of services invoked through the overview ontology, and accurately locate the required services. In this ontology, the Desc represents a short description of service, describing its functions, features, requirements, and other information that the service provider wants to include. It is dynamic.

The CallType describes the way to call the service. When asynchronous (Async) calls the service, the service can be executed concurrently, and the requester can get the result of the service execution directly. When the service is called by synchronous (Sync), the current state of service may be in executing state, and requester needs to wait for a reply from the device. The waiting delay is introduced in the Sync mode, and if the device does not reply within the waiting delay, it will be judged as a timeout and re-request a new service. The Sync method is used for the services of meter tripping, meter alarm, meter power protection and cancellation, and the proxy operation and safe transmission of the collection terminal in the highly elastic power grid. The meter time calibration service adopts the Async method.

3) **DeviceInfo Ontology Model**

Due to the complexity and diversity of power equipment, it is difficult to achieve the interoperability of power applications through a unified and effective expression format. Therefore, by analyzing the characteristics and requirements of the power grid, we design the BasicInfo and Space-Time ontology model. This paper mainly focuses on TTU, watt-hour meters, temperature and humidity sensors, and other equipment.

- BasicInfo Ontology Model

  BasicInfo ontology is used to describe the device's details throughout its life cycle. By uniformly naming the information with the same attributes, it shows the semantics that device should have from many aspects.

  In this ontology, the eOID is the identification of power grid, and it is the unique identification of equipment. The DeviceModel refers to the type of equipment, which is achieved by classifying and identifying a variety of devices. DynaProperty represents the dynamic attribute of device, which can be used to describe the real-time status by the device during operation, or personalized information. It is the real-time data collected or calculated by the monitoring system during the operation of equipment, such as the electricity value of watt-hour meter, the CurrentSpeedr of photovoltaic equipment, the data of temperature and humidity detection device, etc. (Fig. 3).

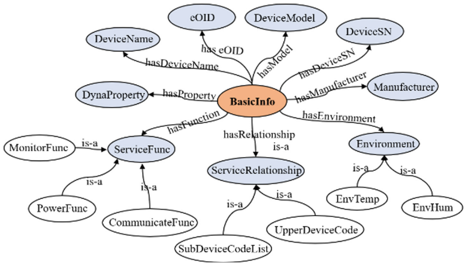

Fig. 3. BasicInfo ontology model

The ServiceRelationship refers to the superior-subordinate relationship of terminal. The relationship consists of two types: the identification list of the parent device and the child device that represents the device. The ServiceFunc is an important essential for calling the device. There are many types of equipment, which are generally divided into monitoring function, communication function, power supply function and so on.

- Space-Time ontology model

  The Space-time ontology reflects the environmental information of device in the physical world, and contains two sub-ontologies: Time ontology and Space ontology. In the highly elastic power grid, the coordination of time and space plays an important role in data, and power grid equipment may have different characteristics in different times and locations (Fig. 4).

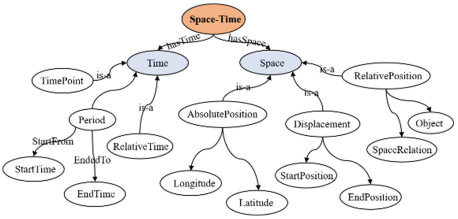

Fig. 4. Space-time ontology model

The Space ontology represents the location information of terminal equipment in space, and the AbsolutePosition is determined by longitude and latitude. It is difficult to express the Space semantic of terminal device only by longitude-latitude, so the RelativePosition are introduced to express the Space relationship. It is determined by two attributes, the SpaceRelation and the Object, and is expressed as the device's location information relative to the operation object. The SpaceRelation can be adjacent, the same, far away, etc. The Displacement reflects the position change of equipment in the spatial range.

The real-time information of equipment is time-effective. The Period reflects the start and end time of terminal equipment information collection [10], such as the fault period indicated by the low voltage fault indicator in the power line. The system can quickly locate the associated devices through space-time information at a certain time.

4.2 QoS Ontology Based on Service

QoS is an index for users to measure service satisfaction, which belongs to the non-functional attribute of service. The traditional semantic selection algorithm cannot fully express users' preferences, and only choose from many devices with the same functions according to users' needs. The efficiency of service selection is inefficient and unreliable, and users cannot further select satisfactory services from different angles, which affects the results of service discovery. Therefore, QoS, which is used to describe the non-functional characteristics of services, plays a key role.

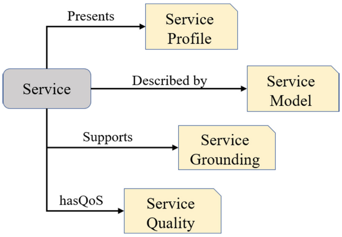

Fig. 5. Extended service ontology model

Because QoS is an important attribute of describing services, and we need to describe the ServiceProfile of OWL-S during service execution dynamically, we add the QoS ontology based on the service model, as shown in Fig. 5. The invocation of the ServiceProfile ontology is completed by creating parameters in QoS ontology. The extended QoS ontology can not only describe quality of service in the field of highly elastic power grid, but also meet the personalized needs of requesters. At the same time, the model established in this paper can express the comprehensive QoS capability of a service to the requestor, which is convenient to realize service filtering quickly (Fig. 6).

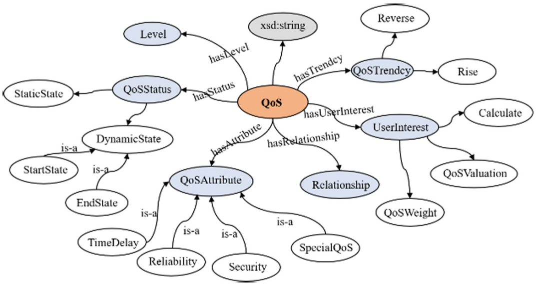

Fig. 6. QoS ontology model

The Level defines different QoS levels, and the user determines whether to perform the service according to the level of QoS. The QoSAttribute defines a variety of QoS Attributes in power field, and extensible Attributes of QoS that requesters and providers can customize. The QoS properties commonly used in the power field are given below:

TimeDelay: It indicates the time required from service presentation to service execution, which is an important index in power system. For example, the TTU is used to collect and control the information of the distribution transformer, and it can transmit the collected information to the master station or other intelligent devices in real-time.

Reliability: It used to describe the probability that a service can be executed successfully. For example, when the watt-hour meter communicates with the power equipment, the equipment is prone to failure, which will weaken the reliability. And suppose the wind turbine or photovoltaic equipment is affected by the natural environment (such as storm or rainfall). In that case, its use effect will be affected, so the reliability will be reduced.

The QoS Attribute also has a combined Attribute type, such as security determined by device stability and transport encryption. The SpecialQoS can make personalized attributes according to the specific service area of the user.

The QoSTrendey indicates the changing trend of QoS attributes in a certain period. The changing trend of attributes can be comprehensively obtained from the state of attributes. The QoSStatus indicates the real-time state of QoS. The change of equipment can bring about the dynamic change of QoS.

The UserInterest has three attributes: QoSWeight, QoSValuation and Calculate. The advance assignment of service provider determines the weight of each QoS. However, the importance of each QoS is different for different requesters. QoSWeight is a context-sensitive attribute. So the QoSValuation attribute allows the requester to assign weights to several QoSs of interest. Finally, the comprehensive measure of QoS weight is realized according to the calculation method defined by the user or provider, and the total value of the service is obtained.

5 Conclusion

In order to design a standard and extensible semantic description model that machines can understand, this paper establishes an OWL-based semantic model of highly elastic power grid. The semantic model can show the real-time state, function, relationship and other attributes of terminal device. It can provide accurate power data for users and enterprises, eliminate cross-equipment and cross-domain technical barriers, and solve the interoperability problem of the power grid.

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