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IEEE Guide for Electric-Power–Oriented Knowledge Graph

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IEEE Guide for Electric-Power–Oriented Knowledge Graph

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Standards Activities Board
of the
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Abstract: Guidelines for knowledge graphs (KGs) in electric power fields are provided in this guide. Data and schema requirements, an electric power–oriented KG construction process, KG integration, performance evaluation, and application scenarios are also discussed. Institutions and enterprises that develop KGs in the electric power field follow the general implementation method outlined here. In addition, suppliers may be supported in providing compatible KGs under the unified power knowledge model and interface specifications. With this guide, electric power KGs can be simply and efficiently combined and integrated, forming a more complete and accurate knowledge service ecosystem in the power industry.

Keywords: electric power, EPKG, EPKG ODM, IEEE 2807.3™, knowledge graph, knowledge graph application

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Introduction

This introduction is not part of IEEE Std 2807.3–2022, IEEE Guide for Electric-Power–Oriented Knowledge Graph.

Knowledge graphs (KGs) have been increasingly applied to many scenarios in the electric power industry. However, today significant barriers exist for different electric power enterprises to exchange and integrate knowledge because of a lack of consistent knowledge schema and no unified interface standard.

This guide defines guidelines for KGs in electric power fields and specifies data and schema requirements, an electric-power–oriented KG construction process, KG integration, performance evaluation, and application scenarios.

This guide also helps institutions and enterprises that develop KGs in the electric power field follow a general implementation method. In addition, it may help the suppliers provide compatible KGs under the unified power knowledge model and interface specifications. With this guide, electric power KGs can be simply and efficiently combined and integrated, forming a more complete and accurate knowledge service ecosystem in the power industry.

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IEEE Guide for Electric-Power–Oriented Knowledge Graph

1. Overview

1.1 Scope

This guide defines guidelines for knowledge graphs (KGs) in electric power fields. The guide specifies data and schema requirements, an electric power–oriented KG (EPKG) construction process, KG integration, performance evaluation, and application scenarios.

1.2 Purpose

This guide helps institutions and enterprises that develop KGs in the electric power field follow a general implementation method. In addition, it may help the suppliers provide compatible KGs under the unified power knowledge model and interface specifications. With this guide, EPKGs can be simply and efficiently combined and integrated, forming a more complete and accurate knowledge service ecosystem in the power industry.

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The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

[1]The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.
[2]The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 2807™-2022, IEEE Standard for Framework of Knowledge Graphs.[3, 4]

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. [5]

attribute: The characteristic of an entity, an entity type, or a relation.

electric-power–oriented knowledge element: Knowledge structure used to describe an object or concept that is independent and cannot be divided in electric-power–oriented knowledge graph (EPKG), including entity, relation, attribute, entity type (concept), relation type, rules (reasoning logic), and so on.

electric-power–oriented knowledge graph: A knowledge network that describes the graph structure of core concepts, entity objects, and their relations in the electric power industry.

electric-power–oriented knowledge graph (EPKG) application: A process of querying and computing the required results based on the constructed EPKG; it includes the process of using these results to provide further data processing and scenario-based services.

NOTE—The knowledge computing results from EPKG application are used to provide external knowledge services without changing the content of the existing KG.[6]

electric-power–oriented knowledge graph (EPKG) application system: A system that interacts with the EPKG core engine and uses its output results for further data processing and scenario-based services.

electric-power–oriented knowledge graph (EPKG) construction: A process of acquiring and fusing knowledge from data from various sources, deriving new knowledge through knowledge computing, and storing uniformly identified knowledge of a specific form in a special storage system according to the agreed requirements of knowledge representation and model definition in the electric power industry.

NOTE 1—See IEEE Std 2807-2022[7] for definitions of knowledge representation, knowledge modeling, knowledge acquisition, knowledge fusion, knowledge storage, and knowledge computing.

NOTE 2—The results of knowledge computing in EPKG construction will form new knowledge, which will be integrated into the original KG.

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electric-power–oriented knowledge graph (EPKG) core engine: An engine that stores EPKG and is a set of systems to retrieve, compute, maintain, and manage knowledge.

electric-power–oriented knowledge modeling: An activity that abstracts electric-power–oriented knowledge modeling objects into knowledge elements in the graph.

electric-power–oriented knowledge modeling object: An object that needs to be represented in an electric-power–oriented knowledge graph (EPKG), including information on object, person, event, method, measurement result, time, and location, as well as certain accumulated forms of the information.

electric-power–oriented knowledge ontology definition model: A set of vocabularies and rules that describes entities, relations, and attributes under various subject domains in the electric power industry, as well as defines and constrains their associations.

electric-power–oriented knowledge representation: An activity of representing various types of electric-power–oriented knowledge elements as a complex graphic data structure.

NOTE 1—The main elements of the composite graphic data structure include vertices (nodes) and directed edges, as well as the key value pairs used to describe the vertices and edges.

NOTE 2—Knowledge representation originally refers to the activity of using symbols and methods that machines can recognize and process to describe the knowledge acquired by human beings when they are discovering or understanding the objective world. Within this standard, it specifically refers to the process of representing electric-power–oriented knowledge with an electric-power–oriented knowledge graph (EPKG).

electric-power–oriented knowledge unit: A set of electric-power–oriented knowledge elements organized by certain rules.

entity: Something distinguishable that can exist independently.

NOTE 1—An entity might exist physically or might be an abstract concept or the object of a thinking activity.

NOTE 2—In an EPKG, no strict boundary exists between an entity type and an instance. An instance in one modeling scenario might be an entity type in another scenario. For example, in principle analysis, a device of a certain model can be regarded as an instance of a device type, whereas in inventory checking, a device of a certain model needs to be regarded as an entity type, of which a specific device is an instance.

NOTE 3—Whether an entity is considered an instance or an entity type is determined by the granularity of knowledge modeling.

event: A change in the state that involves one or more actions by one or more characters at a specific time point in a specific geographic area.

NOTE—It can be represented by a combination of an entity and a relation with a time attribute in the electric power industry.

fact: The smallest unit of knowledge that describes the nature of a certain aspect of an object or concept in the electric power industry.

NOTE—It is expressed as "subject-predicate-object (SPO)," including two forms: "entity-relation-entity" and "entity-attribute-value."

knowledge element: Knowledge cell(s) describing a certain object or concept that is independent and inseparable. (*Source:* IEEE Std 2807-2022).

knowledge graph: Assemblies of knowledge elements and their relations described in a structured form.

relation: Something to connect two entities and to characterize the connections between them.

NOTE—A relation type is a restricted definition of a relation. It starts from and ends at an entity type (a concept) representing the definition domain and the range of the relation.

3.2 Acronyms and abbreviations

API	application programming interface
APP	application
CIM	common information model
EMS	energy management system
EPKG	electric-power–oriented knowledge graph
I/O	input/output
KG	knowledge graph
ODM	ontology definition meta-model
RDF	resource description framework
ID	identifier
IT	information technology
SDK	software development kit
SPO	subject-predicate-object
XML	Extensible Markup Language

4. Framework of electric-power–oriented knowledge graph

4.1 Main activities

As shown in Figure 1, the relevant activities of EPKG are divided into the following four groups:

a) Generating EPKGs with relevant construction technologies, encapsulating EPKG core engines, and providing related services by using the relevant data and industrial knowledge of the electric power industry

b) Developing EPKG application systems, integrating EPKG core engines, integrating relevant subsystems to provide complete system functions, and solving scenario-based application problems

c) Using EPKG-related products and services to meet the needs of EPKGs

d) Providing the necessary information infrastructure, data, tools, methods, standards, specifications, and mechanisms, which are independent of the core technologies of KGs but necessary for the construction and application of EPKGs.

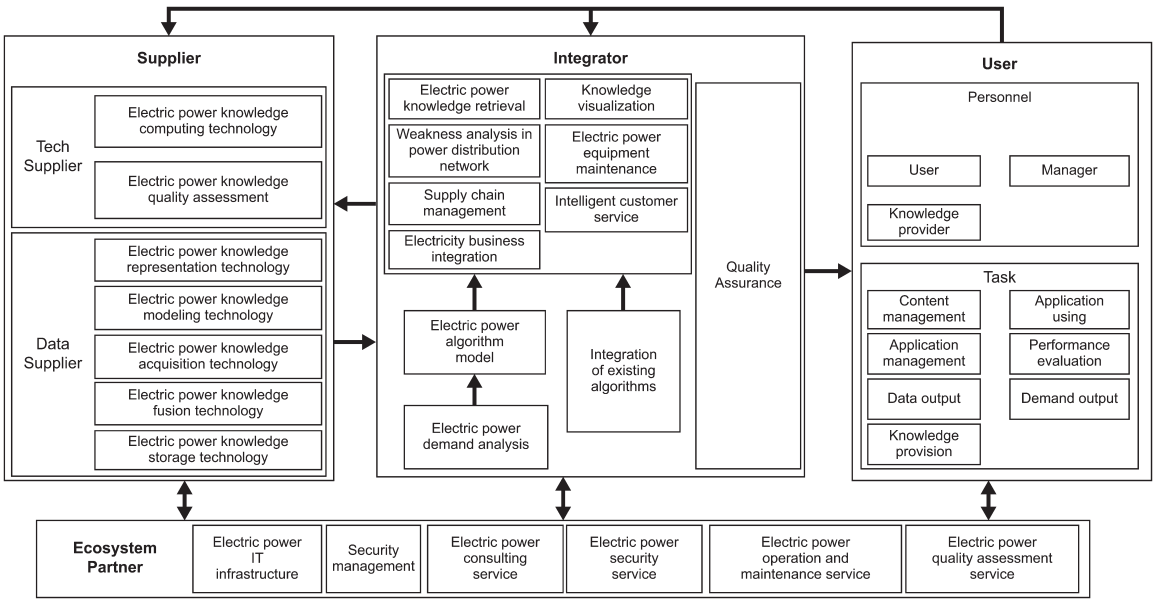


Figure 1—Main activities of electric-power–oriented knowledge graph organizations

4.2 Roles

The main activities of EPKGs involve multiple types of organizations that assume different work contents, and each type of organization contains a series of personnel with different work roles.

NOTE—A participant can assume multiple roles at any given point of time. For a given role, a subrole is a subset of its KG activities.

4.2.1 Types of organizations

As shown in Figure 1, the technical framework of EPKGs includes the following four types of organizations:

a) EPKG suppliers

b) EPKG integrators

c) EPKG users

d) EPKG ecosystem partners

The four types of organizations can further be divided into several subtypes, and their conceptual hierarchy and definitions are listed in Table 1.

Table 1—Subtypes of organizations

Types of organizations		Description
EPKG suppliers		Organizations that generate EPKGs with relevant construction technologies, encapsulate EPKG core engines, and provide related services by using the relevant data of the electric power industry and combining the knowledge and application demands of the electric power sector.
	Knowledge content providers	Organizations that provide structured electric-power–oriented knowledge data that meet the quality requirements.
	KG construction technology providers	Organizations that provide expert services and software tools and complete knowledge modeling, knowledge representation, knowledge extraction, knowledge fusion, knowledge storage, and knowledge computing services.
	KG core engine providers	Organizations that provide knowledge query, knowledge computing, and other EPKG data-based interface services for knowledge applications based on EPKGs. Organizations that have KG tools or systems with basic functions such as knowledge acquisition, retrieval, relational reasoning and visualization, and knowledge operation and maintenance.
EPKG integrators		Organizations that provide KG application system integration services for applications in the electric power industry and assist in ensuring that the integrated system has complete functions, stable operations, and outputs that meet business and data requirements.
	KG application system providers	Organizations that provide online services for solving specific power business application problems based on KGs.
	KG platform providers	Organizations that provide various functional services of KG platforms except knowledge contents.
EPKG users		Organizations that apply products or services based on EPKGs to meet their own needs and improve their sustainable operations.
	EPKG product operators	Users that undertake maintenance tasks such as adding, updating, deleting, backing up, and restoring knowledge, and knowledge quality management tasks, through human–computer interfaces.
	Electric power knowledge users	Users that use products and services provided by EPKGs to help individuals or groups achieve their goals and create value. Through human–computer interfaces of the KG systems, users complete the requirements of the power application scenarios, directly or indirectly give feedback on the application effects of EPKGs, and put forward the business requirements.
	EPKG ecosystem partners	Sets of participants that provide suppliers, integrators, and users with the necessary information infrastructure, data, tools, methods, standards, specifications, and mechanisms, which are independent of the core technologies of KGs but necessary for the construction and application of KGs.

Table continues

Table 1—Subtypes of organizations *(continued)*

Types of organizations		Description
	IT infrastructure suppliers	Organizations that provide the hardware and software infrastructure required for KG construction and application, such as hardware devices, cloud service resources, big data storage computing platforms, intermediate tool plug-ins, and so on.
	Electric power data suppliers	Organizations that introduce electric power industry information and electric power software system data into EPKG applications for the discovery, access, transformation, and presentation of EPKG applications.
	Electric power data governance service suppliers	Organizations that assess, guide, and monitor KG data and their application processes based on the application requirements and specifications of the electric power industry to maintain operational compliance and risk controllability while improving the value of data assets.
	Consulting service suppliers	Organizations that provide the expert knowledge of the electric power industry necessary for KG technology, application, maturity evaluation and determine the applicability, application scope and application degree of KGs, as well as the association relationship between KGs and the information specifications of the electric power industry, to popularize and promote KG technology.
	Security service suppliers	Organizations that carry out the security and privacy protection of knowledge data, and operational security management of KG platforms/systems, external interface and access management, and credibility management of system performance.
	Assessment and certification service suppliers	Organizations that assess the products, services, and activity processes of EPKGs, as well as set the assessment levels according to the relevant criteria.
	Supervisory service suppliers	Organizations that supervise EPKG technology products and services to verify whether the activities comply with industry standards and local laws, thereby reducing violations.

4.2.2 Types of individual roles

EPKG activities involve several different work contents that require personnel with different professional skills.

According to the work contents, the individual roles involved in EPKG activities can be divided into several types listed in Table 2.

Table 2—Individual roles

EPKG role types	Description
Electric power business experts	Personnel who provide the domain knowledge necessary for the construction and application of EPKGs.
Knowledge model architects	Personnel who design EPKG models according to the application requirements and extend models according to the specifications.
Knowledge model maintainers	Personnel who maintain the updates, upgrades, and version management of KGs.
Knowledge quality analysts	Personnel who analyze and monitor the quality of knowledge in KGs, including its volume, integrity, accuracy, reliability, and timeliness.
Natural language processing engineers	Personnel who extract entities and relationships from unstructured data (especially text data) by natural language processing and machine learning (including deep learning).
Machine learning algorithm engineers	Personnel who build machine learning models or rule engines to implement knowledge reasoning methods.
Database administrators	Personnel who track and monitor the running status of various data storage systems, including stability and response performance.
Graph computing engineers	Personnel who use graph computing to reason directly or to process machine learning characteristics or rule elements.
Graph data warehouse architects	Personnel who design and construct graph data warehouses for KGs using a variety of data storage systems, including graph databases, and design, integrate, and schedule links related to knowledge processing to form a complete knowledge production and consumption process.
System architects	Personnel who design KG systems to support knowledge processing, storage, and other services.
System development engineers	Personnel who develop and implement systems related to KGs.
Visual human–computer interaction development engineers	Personnel who develop human–computer interaction interfaces and visualize knowledge content and analysis results through graph structures.
Electric power industry data architects	Personnel who analyze the data structures of electric power software systems, define the mapping relationships between various data and KGs, and design data conversion schemes.
Electric power industry business intelligence analysts	Personnel who explore the application value and modes of KGs in the electric power industry.
Electric power data system application personnel	Personnel who carry out operations based on EPKGs.
KG system product managers	Personnel who design the product functions and interaction modes of system modules related to KGs.
KG exchange administrators	Personnel who maintain the supply–demand relationship of knowledge exchange.
Knowledge auditors	Personnel who supervise the compliance and legality of knowledge production, storage, and consumption.
Knowledge specification designers	Personnel who define the various specifications of EPKGs.

5. Electric-power–oriented knowledge graph model

This standard proposes a set of standardized common electric power knowledge graph ODMs, such as the IEEE EPKG Model, including the following contents:

a) Description and representation methods for entity types, relation types, and attributes of entities or relations of electric-power–oriented knowledge

b) Constraint methods for definition domains and ranges of relations and attributes

c) Naming rules for all kinds of descriptive words

d) IEEE EPKG model extension method

The basic set of IEEE EPKG model in each subject domain is provided in Annex B.

5.1 Electric-power–oriented knowledge graph model framework

The EPKG can be logically divided into two layers: 1) the instance layer (also known as the "data layer" and the "entity layer") and 2) the concept layer (also known as the "schema layer" and the "ontology layer"). The former consists of a series of entities that represent facts and their relations, whereas the latter describes entity types, their hyponymy (inclusion/subordination relations), and the types of relations that may exist among instances of entity types.

In the EPKG, an entity refers to the abstract description of a concrete object, which can be a physical object, an abstract concept, or a thinking activity. For example, a device, a record, or an event can serve as an entity of the EPKG. An entity type is an abstraction of a collection of entities that have common attributes.

The IEEE EPKG model recommends describing various electric-power–oriented knowledge elements with attribute graphs. An attribute graph is a graph data structure consisting of two types of elements: vertices (nodes) and edges. Each element in the graph contains a set of key value pairs that represent attributes. Figure 2 describes the IEEE EPKG model framework:

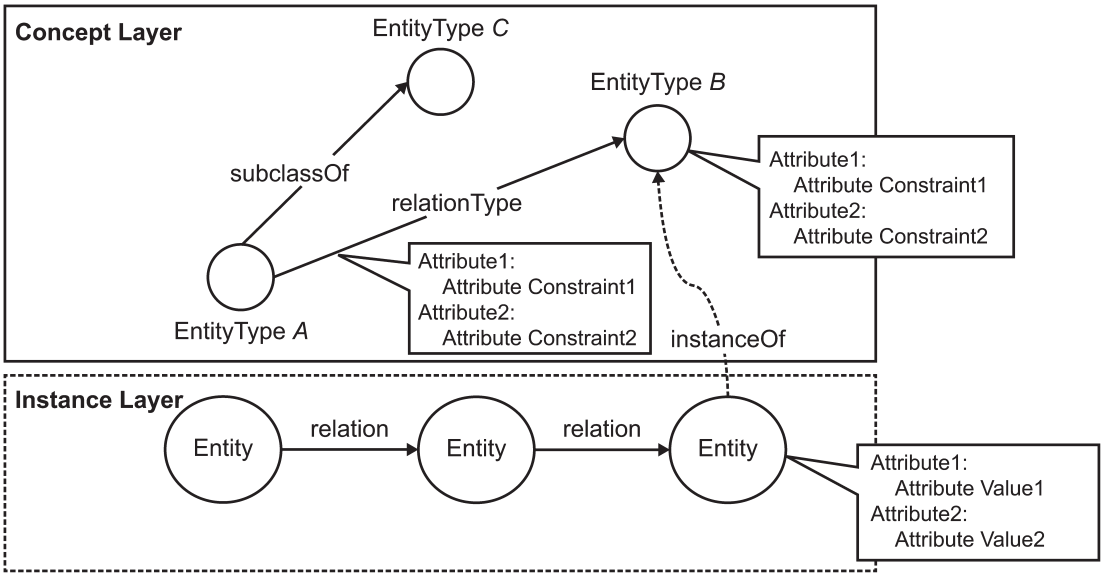


Figure 2—Electric-power–oriented knowledge graph model framework

5.2 Electric-power–oriented knowledge graph concept layer

In the concept layer, each entity type is represented by a node, and the "entity type node" defines the name and range of the public attribute of this type of instance; Each relation type is represented by a directed edge, where the starting point is the definition domain of the relation type, while the ending point is the range of the relation type.

Hyponymy (inclusion/subordination relations) also exists among entity types. In the EPKG, hyponymy is called *subclassOf*, which is also represented by a directed edge pointing from the inferior type to the superior type. Except for the parent "Thing" of all entity types, an entity has and only has one superior type.

The entity types of EPKG form a tree-like structure through hyponymy, with Thing as the root node of the tree. The Thing has five direct subclasses: *Organization*, *Person*, *Place*, *Time*, and *PowerThing*. The *PowerThing* entity type is the parent node of all exclusive electric power entity trees. The primary categories under this type include *PowerItem*, *PowerEvent,* and *PowerRecord*. These categories represent objective things and events in the electric power industry and electric power data records, respectively.

The conceptual hierarchy tree of a part of electric power entity types is as follows:

- Thing
  - PowerThing
    - PowerItem
      - ConnectivityNode
        - Termial
        - Equipment
          - ConductingEquipment
          - ProtectionEquipment
        - EquipmentContainer
          - Substation
          - Bay
          - Plant
          - Line
    - PowerEvent
  - Organization
  - Person
  - Location
  - Time

For the convenience of storage and computation, only binary asymmetric relation types in the EPKG are considered. A binary symmetric relation can be expressed by two reciprocal asymmetric relations. Multivariate relation types can be represented by abstract entity types. Taking the "topological connection" among common *Equipment* types in the EPKG as an example, topological connection involves cases in which multiple entities are connected so an abstract entity type of *ConnectivityNode* is constructed in the EPKG to represent the common connectivity node (Figure 3).

For the same device, connections from terminals at different positions may have completely different electrical characteristics. Therefore, a *Terminal* entity type must be defined. The *Terminal* entities participating in the topological connection *I* belong to one device only.

A *ConnectivityNode* instance can *connectTo* a *Terminal* instance, where the starting point (head entity) is the *ConnectivityNode* instance and the ending point (tail entity) is the *Terminal* instance.

As shown in Figure 3, equipment *i*, *j*, and *k* are all connected to node *x*; *I* and *j* are connected to *x* via terminals *a* and *b*; and *k* has two terminals, which are connected to *x*.

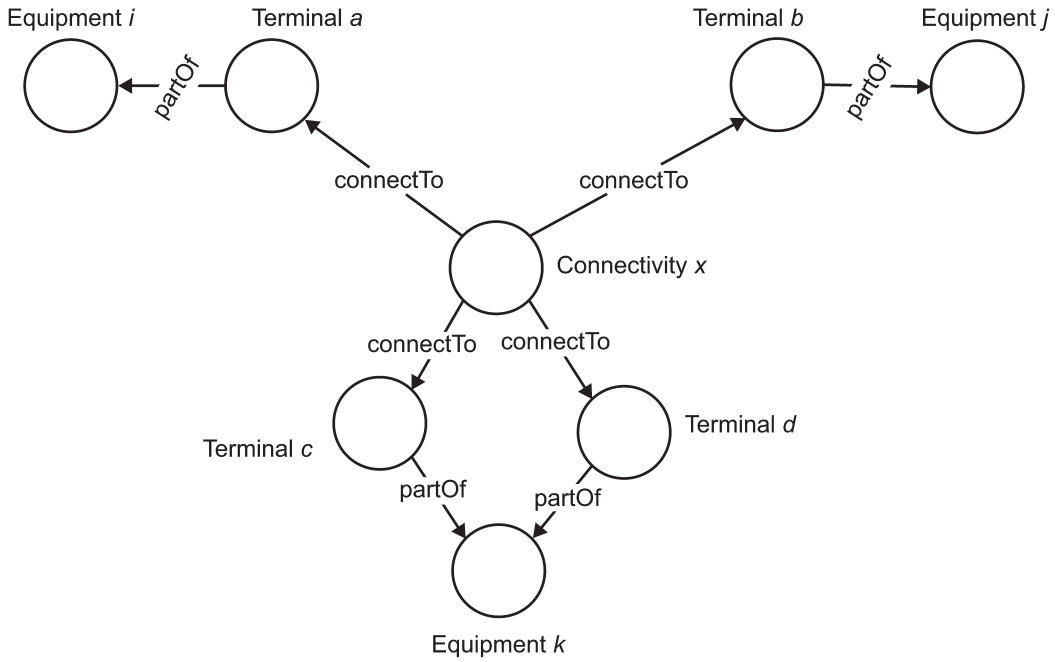


Figure 3—Topological connections among multiple entities

5.3 Electric-power–oriented knowledge graph instance layer

In the instance layer, each entity is represented by a node, and the entity node defines the value corresponding to each attribute.

For the convenience of reasoning, the EPKG prescribes that each entity shall belong to one entity type only. The subordination relation between an entity and its type, called *instanceOf* in EPKG, is also represented by a directed edge pointing from the entity to its type.

Relations among entities are represented by directed edges. A relation shall meet the constraints of the relation type to which it belongs (defined in the concept layer). The types of its head entity and tail entity are the starting type and ending type of its relation type in the concept layer, respectively.

The representation requirement for the circumstance that an entity belongs to more than one entity type is met in EPKG through an "equivalent agent" node. "Different" entities that have an equivalent (*equalTo*) relation with the same equivalent agent node are synonymous entities that refer to the same facts. As shown in Figure 4, entity nodes *a* and *b* belong to entity type A and B, respectively. Both entities *a* and *b* are pointed to by equivalent agent node *x*, indicating that *a* and *b* are descriptions of the same object.

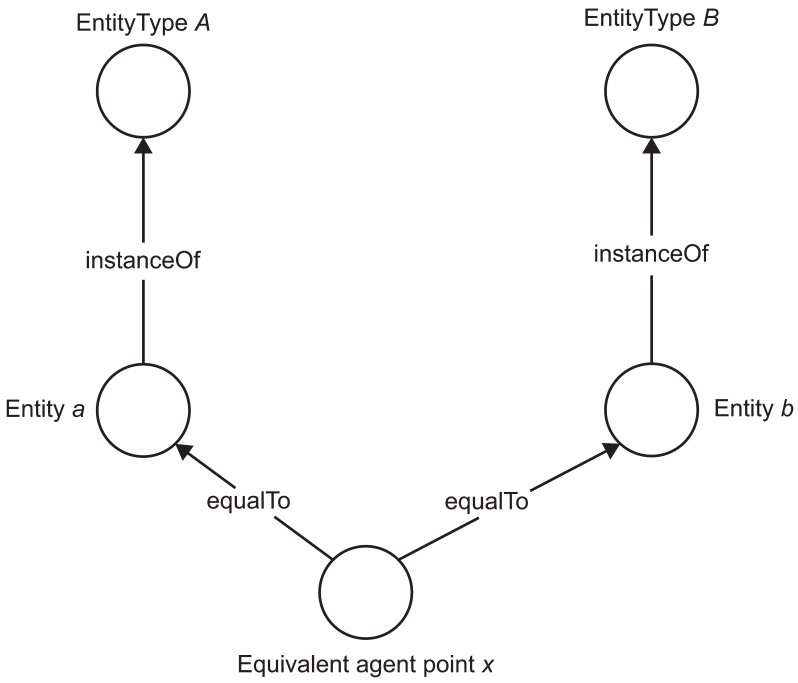


Figure 4—Agent node

5.4 Naming rules for electric power ontology definition meta-models

Entity type names: Adopt the method of upper camel case, such as *PowerItem*.

Relation names: Adopt the method of lower camel case, such as *connectTo* and *instanceOf*.

Attribute names: Adopt the method of lower camel case, such as *name* and *id*.

5.5 Entity type definition

It declares the type name, parent entity type, and exclusive attributes of each entity type, as well as explains its meaning and other supplementary information.

For example, the equipment entity type is described in Table 3.

Table 3—Example of the equipment entity type

Entity type name	*Equipment*			
Meaning	A component of an electric power system or electronic or mechanical physical equipment			
Parent entity type (parent class)	*PowerItem*			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	Attribute name	Attribute value type	Attribute range	Description
	normallyInService	Boolean		Whether the equipment is in normal operation
NOTE—See Annex C for more entity types.				

5.6 Relation type definition

It declares the type name, relation attributes, and relation constraints (the definition domain declared by the entity type of the starting point and the range declared by the entity type of the ending point) of each relation type, as well as explains its meaning and other supplementary information.

For example, the connection relation is described in Table 4.

Table 4—Example of the *connectTo* relation

Relation type name	*connectTo*		
Meaning	The parts of a power system that are physical devices, electronic or mechanical		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	ConnectivityNode	*Terminal*	
Relation attributes	[None]		
NOTE—See Annex C for more entity types.			

5.7 Electric-power–oriented knowledge graph subject domain

In the EPKG model, the modeling object domains are divided into several subject domains, such as the electric power supplies domain, power grid domain, power generation domain, market domain, and security domain.

The electric power supplies domain includes the abstraction of the objects involved in the warehousing and allocation of electric power supplies and their relations. The power grid domain includes the abstraction of the objects involved in the process of transmission, transformation, and their relations. The power generation domain includes the abstraction of the objects involved in the process of power generation and their relations. The market domain includes the abstraction of the objects involved in the process of electricity sales, consumption, and their relations. The security domain includes the abstraction of the objects involved in the process of hidden danger investigation and their relations.

5.8 Principles for extension of electric-power–oriented knowledge graph ontology definition meta-models

The extension of EPKGs shall follow the principle of downward compatibility; that is, the extended ODM shall be compatible with the ODM before extension.

Extensions shall be arranged in one of the following ways:

— Adding attributes to an entity type that does not have subclasses

— Adding attributes to a relation type

— Adding attributes to entity types that have subclasses, with all descendant types of that type inheriting the newly added attributes

— Adding a new entity type, which is a subclass of an existing type and inherits the attribute definition from the parent class

— Adding new relations to connect existing entity types

6. Electric-power–oriented knowledge graph construction technology

6.1 Overview

EPKG construction is the process of acquiring and fusing knowledge from data from various sources, deriving new knowledge through knowledge computing, and storing uniformly identified knowledge of a specific form in a special storage system according to the agreed requirements of knowledge representation and model definition in the electric power industry.

The key technologies of EPKG construction include electric-power–oriented knowledge modeling, electric-power–oriented knowledge acquisition, electric-power-oriented knowledge storage, electric-power–oriented knowledge fusion, electric-power–oriented knowledge computing, and so on.

6.2 Electric-power–oriented knowledge modeling

Electric-power–oriented knowledge modeling refers to the processes of unified definition and EPKG ODM formation of all business concepts and logical rules involved in the production, operation, and management of the electric power industry with entities, attributes, and their relations, including concepts (entity types) definitions, relation definitions, attribute definitions, and so on.

The main inputs of general knowledge modeling activities mainly include application requirements, application scenarios, industry knowledge, expert knowledge, and quality indicators; the main outputs include concepts (entity types), attributes, and relations among concepts.

In terms of electric-power–oriented knowledge modeling, the first step is to specify the knowledge scope, namely, the “subject domain,” according to the application requirements, scenarios, and databases; and the next step is to determine the concepts and relations based on the subject domain.

To improve the compatibility of output results from different EPKG suppliers, a common basic EPKG ODM (such as the IEEE EPKG model defined in this standard) should be used, and the basic EPKG ODM should be extended with nominative methods according to the specific application requirements.

The specific modeling process is as follows:

a) One or more subject domains shall be selected from the basic EPKG model according to the application requirements.

b) Concepts and relations should be screened in the selected subject domain according to the application requirements to form the basic ontology structure.

c) The concepts, relations, and attributes defined in the basic model (including attribute names, constraints of attribute values, and so on) cannot be modified or deleted.

d) The basic ontology structure can be expanded according to the requirements and the principles specified in 5.8. It may maintain the naming conventions of newly added concepts, relations, and attributes to keep consistency with those of the basic ODM.

6.3 Electric-power–oriented knowledge acquisition

6.3.1 Main works

Electric-power–oriented knowledge acquisition refers to the process of extracting structured knowledge from electric power business data from various sources according to defined models.

Electric power business data refers to the basic data, industry data, and other data necessary for KG construction, including structured, semistructured, and unstructured data from different sources.

The data required by EPKG mainly come from the electric power energy management system and electric power industry data, as follows:

a) Energy management system (EMS): The data in standardized electric power EMS are structured data that strictly comply with specific data models (e.g., IEC CIM [B1][8]). To keep the compatibility between EPKG products and services and standardized electric power EMS, the IEEE EPKG model should be consistent with the data model in EMS.

b) Electric power industry data: The electric power industry data include electric power equipment operation manuals, operation and maintenance business processes, relevant academic papers, and common knowledge, including unstructured data such as texts, audios, and videos, as well as semistructured data such as XML files.

6.3.2 Main activities

The main activities of electric-power–oriented knowledge may include, but are not limited to, the following:

a) Structured data extraction: For structured data of the database type, it may define the mapping rules and carry out structural transformation to transform a two-dimensional table structure into graph data construction.

b) Semistructured data extraction:

   1) Design of XML wrappers: For semistructured data such as XML files, it may design wrappers for knowledge unit acquisition.

   2) Generation of wrappers: It can learn how to generate wrappers automatically.

c) Unstructured data extraction: Design of text extraction algorithm: For unstructured data, knowledge units may be acquired through dictionary matching, machine learning, and so on.

6.4 Electric-power–oriented knowledge storage

As shown in Figure 5, the tasks of electric-power–oriented knowledge storage activities should include, but are not limited to, the following:

a) Database selection and database design:

[8]The numbers in brackets correspond to those of the bibliography in Annex A.

1) It may select the database according to the requirements of knowledge storage and application combined with the resource configuration conditions, and design the knowledge storage structure based on the selected database.

2) Electric-power–oriented knowledge data may be stored by multiple storage methods, including the relational database, RDF database, graph database, and document retrieval engine.

b) Storage I/O interface definition:

1) It may implement graph structure access abstraction through a unified I/O interface.

2) It may query knowledge units stored in the database through I/O interfaces.

3) It may maintain knowledge units, including adding, deleting, or modifying knowledge units stored in the database, as well as may update knowledge units through I/O interfaces.

c) Storage management:

1) It can acquire metadata information.

2) It can provide data storage activity logs.

3) It may establish a data security mechanism to enhance data storage security.

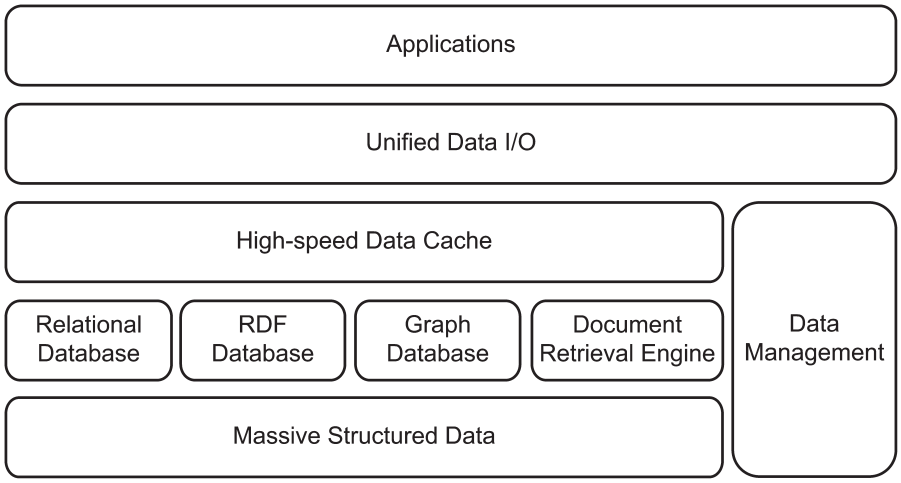


Figure 5—Electric-power–oriented knowledge storage architecture

6.5 Electric-power–oriented knowledge fusion

The tasks of electric-power–oriented knowledge fusion activities should include, but are not limited to, the following:

a) Ontology alignment:

1) Entity type alignment: To align equivalent entity types in different ODMs and merge them.

2) Relation alignment: To align equivalent relations in different ODMs and merge them.

3) Attribute alignment: To align equivalent attributes in different ODMs and merge them into one attribute.

b) Entity linking: To identify entity names in the text and map them to corresponding entities.

c) Entity alignment: To identify equivalent entities in knowledge units, including entity unification, entity disambiguation, attribute value alignment and fusion, and so on.

d) Knowledge consistency verification: To verify the consistency of knowledge units after fusion.

NOTE—For details of the relevant activities, see the definitions in IEEE Std 2807-2022.

In electric-power–oriented knowledge fusion, in terms of the selection of multiple values, it may design an automatic method to sort each value and select the optimal result.

6.6 Electric-power–oriented knowledge computing

The tasks of electric-power–oriented knowledge computing activities should include, but are not limited to, the following:

a) Definition of computing requirements:

   1) It may define the business problems to be solved and the computing goals to be achieved through knowledge computing.

   2) It may analyze knowledge models, rules, and constraints that depend on knowledge computing.

b) Design of knowledge computing algorithm: It may design the relevant data structures and algorithm models for knowledge computing according to the business objectives, computing objectives, and characteristics of existing EPKGs.

c) Execution of knowledge computing process:

   1) It may execute knowledge computing according to the designed algorithm model and specific infrastructure.

   2) It can provide search computing for graph structures and their characteristics through statistical analysis.

   3) It can provide implicit knowledge excavation computing for graph structures and their characteristics through reasoning computing.

d) Evaluation of knowledge computing performance: It may evaluate the quality of the knowledge computing results and overall performance of the process according to knowledge computing quality indicators.

e) Supplement of knowledge: It can supplement the missing knowledge of KGs such as missing entities, relations, and attributes.

f) Provision of knowledge computing services: It can provide knowledge computing services for downstream tasks through API or SDK, such as graph basic information statistics, graph search, classification of triples, and link prediction.

NOTE—For details of the relevant activities, see the definitions in IEEE Std 2807-2022.

7. Electric-power–oriented knowledge graph application

7.1 Overview

The applications of EPKGs can be divided into technology-oriented applications and scenario-oriented applications. The technology-oriented application reflects the capabilities of EPKG supporting advanced technical function, such as visual analysis and semantic comprehension, whereas the scenario-oriented

application describes EPKG's support for the electric power industry scenario, such as the grid domain and power generation domain.

7.2 Technology-oriented applications of electric-power–oriented knowledge graphs

According to the applied technology functions, technology-oriented applications of EPKGs can be divided into visual analysis, semantic comprehension, intelligent retrieval, state inference, path tracing, and so on.

7.2.1 Visual analysis of electric power information based on electric-power–oriented knowledge graphs

7.2.1.1 Definition

Electric power information is presented intuitively in graph structures through graph drawing. A clearly structured graph can present information more intuitively, efficiently, and completely compared with text.

The application architecture is shown in Figure 6.

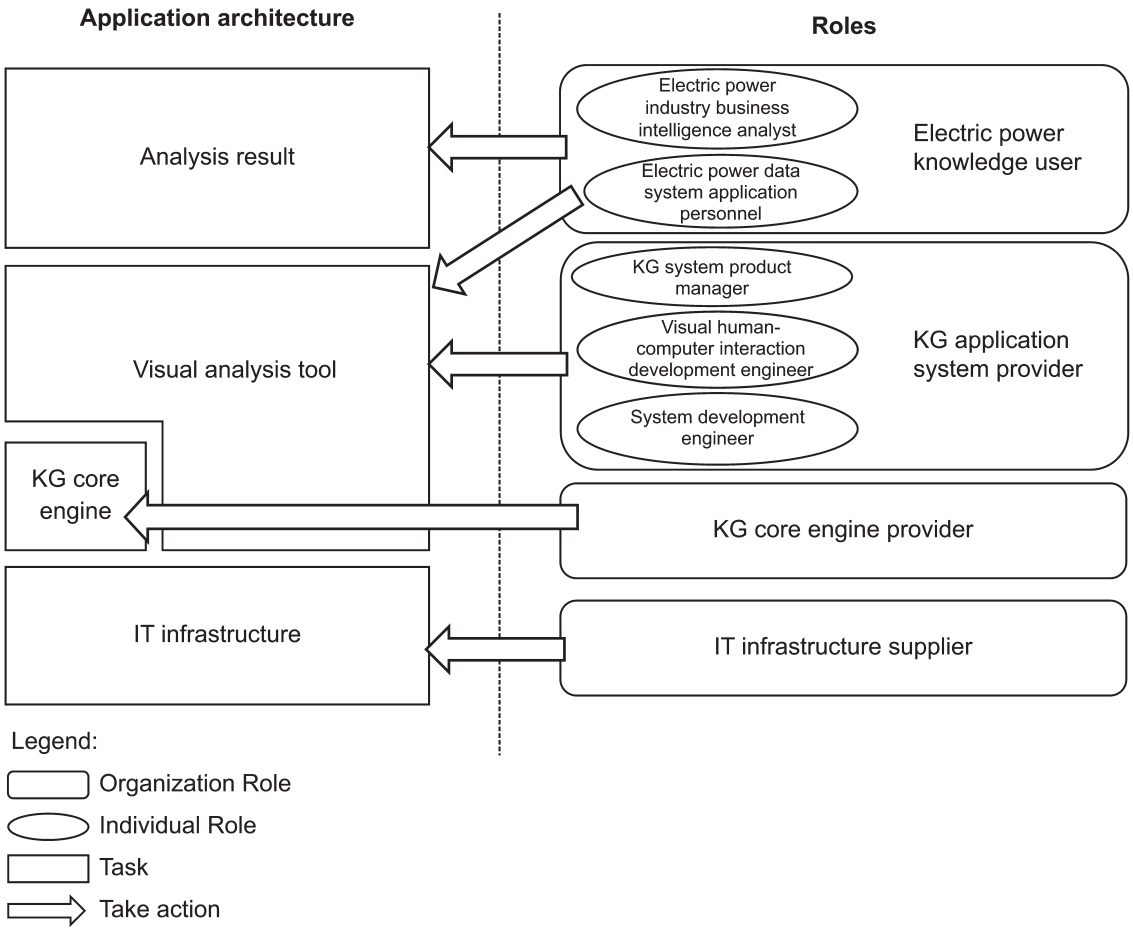


Figure 6—Participant roles of visual analysis of electric power information based on electric-power–oriented knowledge graphs

7.2.1.2 Participant roles

7.2.1.2.1 Organizational roles

Organization roles should include, but are not limited to, the following:

a) Main participants, who are as follows:
    1) EPKG application system developer
    2) Electric power knowledge user
b) Cooperators, who are as follows:
    1) KG core engine provider
    2) IT infrastructure supplier

7.2.1.2.2 Individual roles

Individual roles should include, but are not limited to, the following:

a) KG application system developers, who are as follows:
    1) System development engineer
    2) Visual human–computer interaction development engineer
    3) KG product manager
b) Electric power knowledge users, who are as follows:
    1) Electric power industry business intelligence analyst
    2) Electric power data system application personnel

7.2.1.3 Input and output

For KG system developers, the inputs of visual analysis should include, but are not limited to, the following:

a) KG basic services
b) IT infrastructure and user requirements

The outputs of visual analysis should include, but are not limited to, the following:

c) Visual analysis tools
d) Online services

For electric power knowledge users, the inputs of visual analysis should include, but are not limited to, the following:

e) Visual analysis tools
f) KG schemas to be analyzed

The outputs of visual analysis should include, but are not limited to, the following:

g) Analytic results

h) Business decision

7.2.1.4 Tasks

The tasks of visual analysis of electric power information based on EPKG may include the following:

a) Requirement analysis, identifying the requirements for graph forms to be displayed, which are as follows:

   1) Scale of nodes and edges: It may present a large number of nodes (with thousands of nodes and edges displayed in the same frame for knowledge drilling).

   2) Pattern of nodes: It may support customized entity presentation modes such as node shape, node color, and display icon.

   3) Pattern of edges: It may support customized edge presentation modes such as color, thickness, and bending of edges.

   4) Interactive requirements (folding, expanding, etc.): It may support interactive knowledge exploration, enabling users to continuously drill through knowledge data interactively.

   5) Display of information richness: It may be displayed in linkage with other graphs (such as maps, statistical graphs, and function curve graphs).

b) Development and implementation, visual technical solutions selected and implemented:

   1) Browser/server architecture solutions may be used.

   2) It may support visual exploration and analysis through browsers on multiple devices (PCs and mobile devices).

   3) It may have a high rendering speed of graph representation (second-level response).

   4) Container deployment schemes can be used to facilitate system expansion.

c) Interactive exploration, KG visual tools used to analyze electric power information:

   1) The number of results returned should be limited.

   2) A suitable layout mode is chosen to switch the layout of the KG data as required.

   3) According to different business requirements, statistics of different dimensions of data and measurement methods can be dynamically defined, statistical results can be quickly formed, and statistical reports can be generated to assist in decision-making.

   4) The found focal node can be moved to the center of the view and scaled to the appropriate size for display.

7.2.1.5 General quality description characteristics

The quality of this application should be assessed by the following characteristics:

a) Interactive user-friendliness: Whether various users can conveniently and easily use the system

b) Response time: The time for the system to react (respond) after a user sends a request or instruction

c) Functional comprehensiveness: The basic functions of the system and the extent to which such functions are extended

7.2.2 Semantic comprehension of electric power based on knowledge graphs

7.2.2.1 Definition

Linking the entity reference words in a given text to the corresponding entities in the KG and associating the words that represent action or state types to the relations or attributes of the entities. This is the basis for machines to comprehend natural language.

The application architecture is shown in Figure 7.

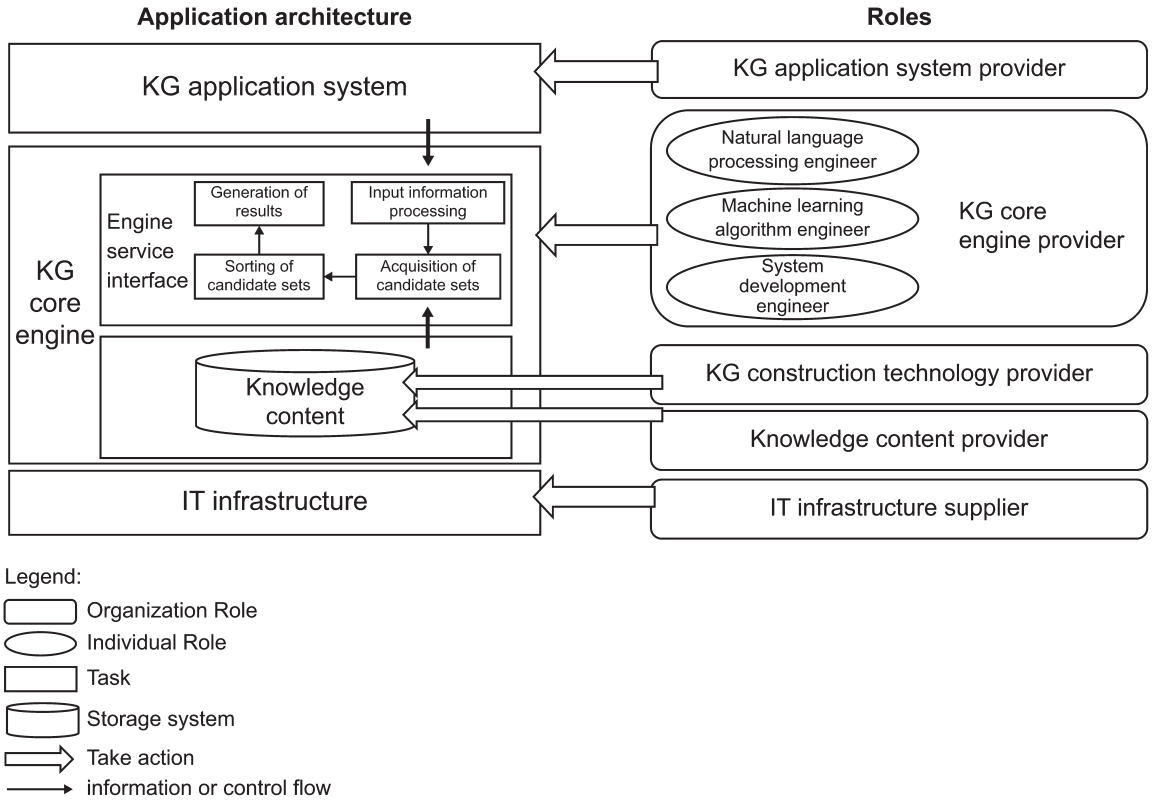


Figure 7—Participant roles of visual analysis of electric power information based on electric-power–oriented knowledge graphs

7.2.2.2 Participant roles

7.2.2.2.1 Organizational roles

Organization roles should include, but are not limited to, the following:

a) Main participant, who is as follows: KG core engine provider

b) Cooperators, who are as follows:

1) KG application system provider

2) KG construction technology provider

3) Knowledge content provider

4) IT infrastructure supplier

7.2.2.2.2 Individual roles

Individual roles should include, but are not limited to, the following:

— Natural language processing engineers
— Machine learning algorithm engineers
— System development engineers

7.2.2.3 Input and output

The inputs of semantic comprehension of electric power should include, but are not limited to, the following:

a) EPKGs that have been constructed
b) Character strings to be comprehended
c) Context of character strings (optional)

The outputs of semantic comprehension of electric power are the association results (namely, one or more associated entities), which should include, but are not limited to, the following:

d) IDs of associated entities (mandatory, possibly null)
e) The most fine-grained entity types that can be associated
f) Primary attributes of associated entities (optional)
g) Confidence coefficient of associated entities (optional)

7.2.2.4 Tasks

The main tasks of the semantic comprehension of electric power based on EPKG include the following:

a) Input information processing:
    1) It can parse the context, obtain the font strings that represent entity references, and learn knowledge elements such as relation types and attributes from the input text.
    2) It can parse user input information and obtain relevant knowledge elements such as subject domains, entities, relations and attributes.
    3) It can supplement restricted information according to environment information (time, geographic location, input system, historical retrieval, and so on) when users are inputting.
    4) It can extend and rewrite the input to expand the scope of association.
    5) It can extend the input across languages.
b) Acquisition of associated candidate sets:
    1) Simple and efficient methods satisfying the performance requirements of semantic comprehension should be adopted to screen candidate entity sets from KGs.
    2) Professional electric power knowledge should be used to limit the retrieval range and improve the query speed.
    3) It should be matched on the levels of concept and instance.
    4) The association of electric power entities of exact types shall be congruent.

c) Sorting of candidate sets, which are as follows:

   1) Subgraph information should be used to replace single-point information sorting.

   2) The sorting model can be continuously improved through iterative learning based on massive click logs by users.

d) Generation of association results:

   1) The association results of entity instance and entity category identification should be included.

   2) The association result of entity instance can be null.

   3) In the case that the association result of entity instance is null:

      i) The result of entity category identification shall not be null and should be the most fine-grained distinguishable types.

      ii) The relation between category granularity and category accuracy should be balanced.

   4) Accurate matching results and recommended results should be distinguished.

7.2.2.5 General quality description characteristics

The quality of this application should be assessed by the following characteristics:

a) Correctness: The ratio of times of correct comprehension to total times of comprehension is included in all semantic comprehension result experiments.

b) Response time: The time from requesting semantic comprehension to returning the comprehension result. The response speed of electric power entity resolution should be measured in seconds.

7.2.3 Intelligent retrieval based on knowledge graphs

7.2.3.1 Definition

Obtaining retrieval results based on EPKGs and semantic comprehension through complex reasoning.

Traditional retrieval is based on character matching, which has a low recall rate when different words are synonymous, and low accuracy when the same word has different meanings.

NOTE—Application forms such as intelligent recommendation and intelligent question and answer can be regarded as special intelligent retrieval.

The application architecture is shown in Figure 8.

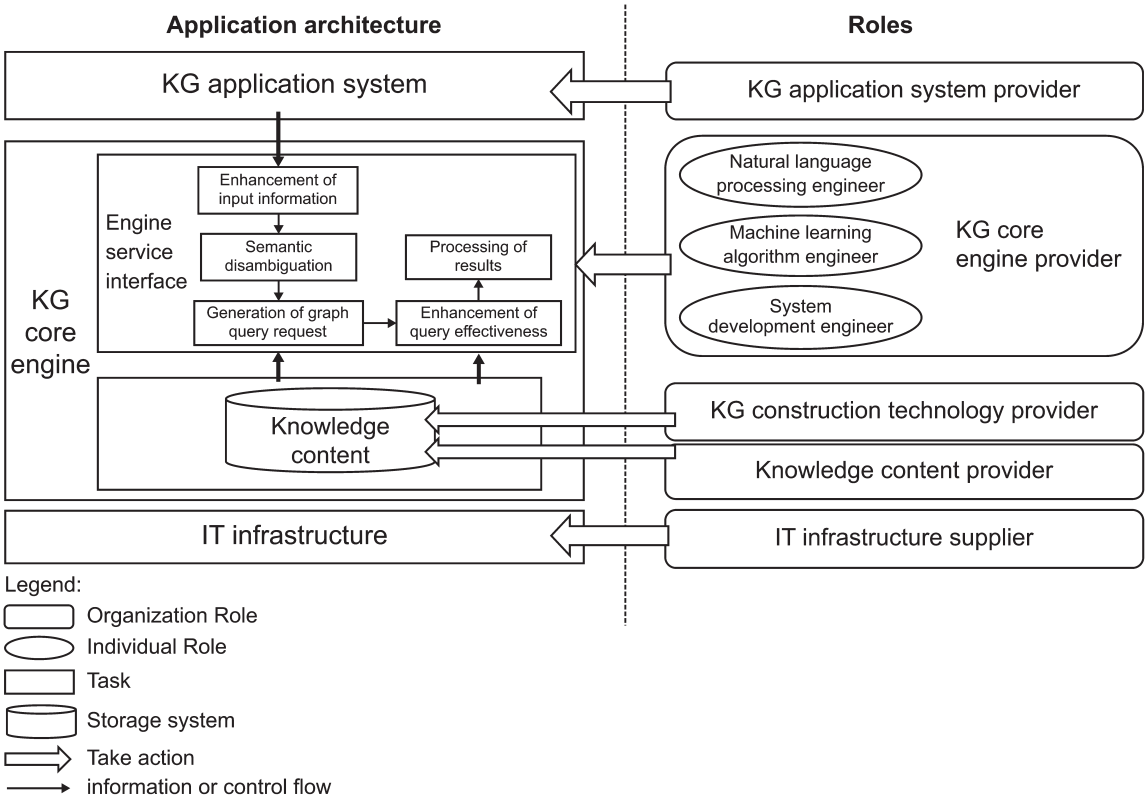


Figure 8—Participant roles of intelligent retrieval based on electric-power-oriented knowledge graphs

7.2.3.2 Participant roles

7.2.3.2.1 Organizational roles

Organization roles should include, but are not limited to, the following:

a) Main participants: KG core engine provider

b) Cooperators:

1) KG application system provider

2) KG construction technology provider

3) Knowledge content provider

4) IT infrastructure supplier

7.2.3.2.2 Individual roles

Individual roles should include, but are not limited to, the following:

— Natural language processing engineer

— Machine learning algorithm engineer

— System development engineer

7.2.3.3 Input and output

The inputs of intelligent retrieval of electric power should include, but are not limited to, the following:

a) EPKGs that have been constructed

b) Questions to be retrieved

c) Problems supplemented by users

The outputs of intelligent retrieval of electric power should include, but are not limited to, the following:

d) Final retrieval results

e) Extended association information for retrieval results (optional)

f) Questions that induce users to supplement information (optional)

7.2.3.4 Tasks

Intelligent retrieval is closely related to semantic comprehension. On the one hand, semantic comprehension is the basis of intelligent retrieval; on the other hand, intelligent retrieval and semantic comprehension have very similar processes.

The main tasks of the intelligent retrieval of electric power based on EPKG include the following:

a) Enhancement of inputs information:

   1) It can supplement electric power industry knowledge retrieval and inputs processes, including supporting functions such as prefixion, fuzzy processing, semantics, pinyin, and error correction.

   2) It can induce users to input more information through interactive question and answer.

b) Semantic disambiguation of the inputs based on semantic comprehension.

c) Generation of graph query request:

   1) The inputs may be rewritten as a graph-oriented query request.

   2) The user inputs can be associated with a preset query template via a classification algorithm.

   3) A graph algorithm may be used to quickly find the query results.

d) Enhancement of query effectiveness:

   1) It can define the characteristics of data in different domains; support various definitions of characteristics, including the complete matching, inclusion type, scope type, and semantic type; and support characteristics matching strategies with high-, middle-, and low-level semantics.

   2) In the absence of direct retrieval results, reasoning can be carried out through knowledge computing.

e) Processing of query results:

   1) If the result is not unique, the result entities may be sorted before returning.

   2) Multiple query results may be reasonably classified and aggregated to the topics according to the contents.

   3) Associative expansion is carried out for each query result to present relevant information.

7.2.3.5 General quality description characteristics

The quality of this application should be assessed by the following characteristics:

a) Accuracy: To measure relevance among query results and target knowledge

b) Response time: The time for the system to react (respond) after a user sends a request or instruction

c) User-friendliness of result presentation: Whether various users can intuitively and clearly understand the retrieval results

d) User-friendliness of interactive question and answer: Whether various users can conveniently and easily use the system

7.2.4 State inference based on knowledge graphs

7.2.4.1 Definition

Inferring the state of some parts of the KG through neighborhood information. The components of the KG include some vertices (nodes), edges, or subgraphs composed of several nodes and edges. “State” herein refers to categories, labels, attribute values, and so on

The application architecture is shown in Figure 9.

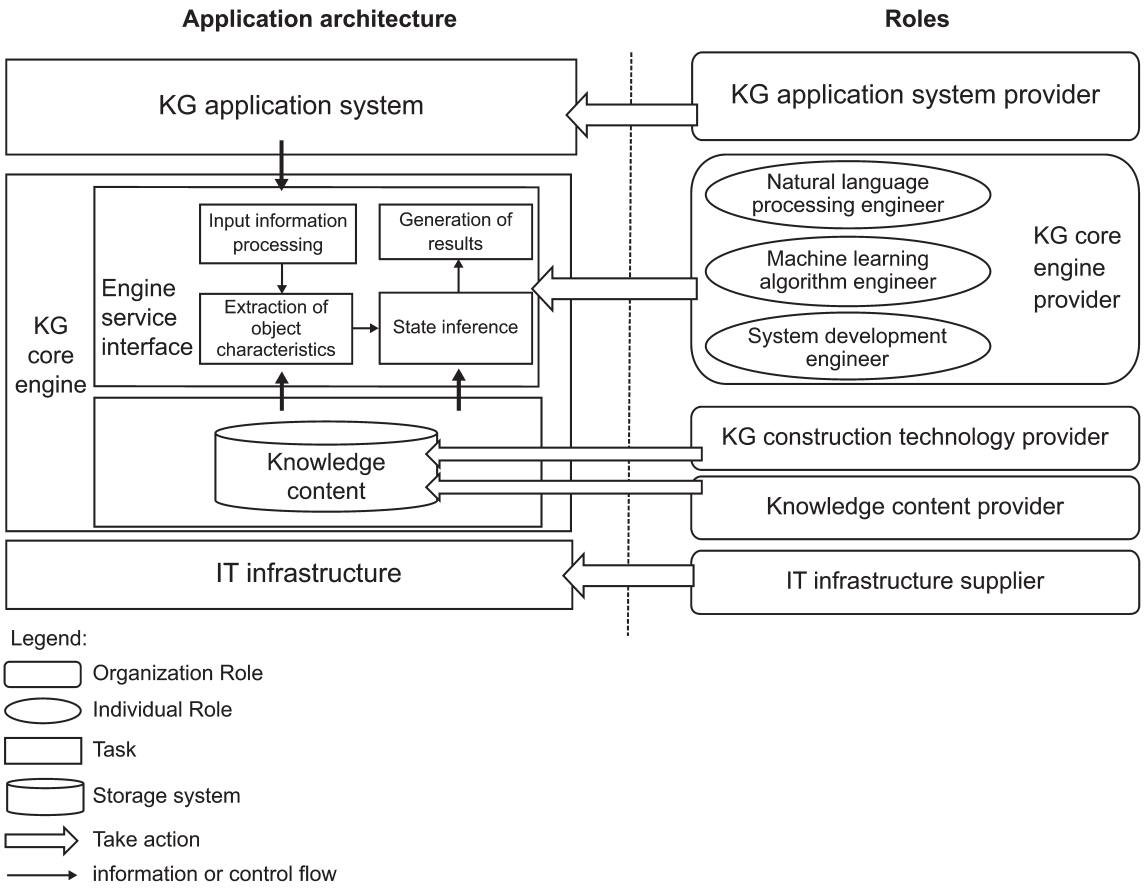


Figure 9—Participant roles of intelligent retrieval based on electric-power–oriented knowledge graphs

7.2.4.2 Participant roles

7.2.4.2.1 Organizational roles

Organization roles should include, but are not limited to, the following:

a) Main participants: KG core engine provider
b) Cooperators:
    1) KG application system provider
    2) KG construction technology provider
    3) Knowledge content provider
    4) IT infrastructure supplier

7.2.4.2.2 Individual roles

Individual roles should include, but are not limited to, the following:

— Natural language processing engineer
— Machine learning algorithm engineer
— System development engineer

7.2.4.3 Input and output

The inputs of state judgment activities of EPKG should include, but are not limited to, the following:

a) EPKGs that have been constructed
b) Knowledge objects to be investigated: Vertices (nodes), edges or subgraphs composed of several nodes and edges
c) Types of states to be inferred: Categories, labels, attribute values, and so on

The outputs of state judgment activities of EPKG should include, but are not limited to, the following:

d) Inferred results
e) Confidence coefficient of inferred results (optional)

7.2.4.4 Tasks

The main tasks of the state inference based on EPKG include the following:

a) Defining objects of investigation:
    1) Explicit objects directly designated
    2) Implicit objects indirectly associated
b) Extraction of object characteristics KG components, which are as follows:
    1) Graph characteristics: Graph characteristics of nodes (such as out-degree and in-degree) and graph characteristics of the neighborhood

2) Knowledge characteristics: Node attributes, node types, edge attributes, edge types, and neighborhood node attributes

3) Vector characteristics: An embedded representation of the nodes and edges contained in the components

c) State inference:

1) Decision methods include statistical learning, conditional rules, computing formulas, and so on

2) Multiple iterations can be performed to gradually change the state value until it converges to a stable value

7.2.4.5 General quality description characteristics

The quality of this application should be assessed by the following characteristics:

a) Accuracy: Ratio of times of accurate inference results to times of queries in the process of state inference

b) Coverage rate: Proportion of KG content for quantification in the electric-power–oriented knowledge sector

7.2.5 Path tracing based on knowledge graphs

7.2.5.1 Definition

Tracing back to the target node from several start nodes according to the connections among nodes and obtaining results according to the state values of the target node or by tracing the characteristics of the path.

The application architecture is shown in Figure 10.

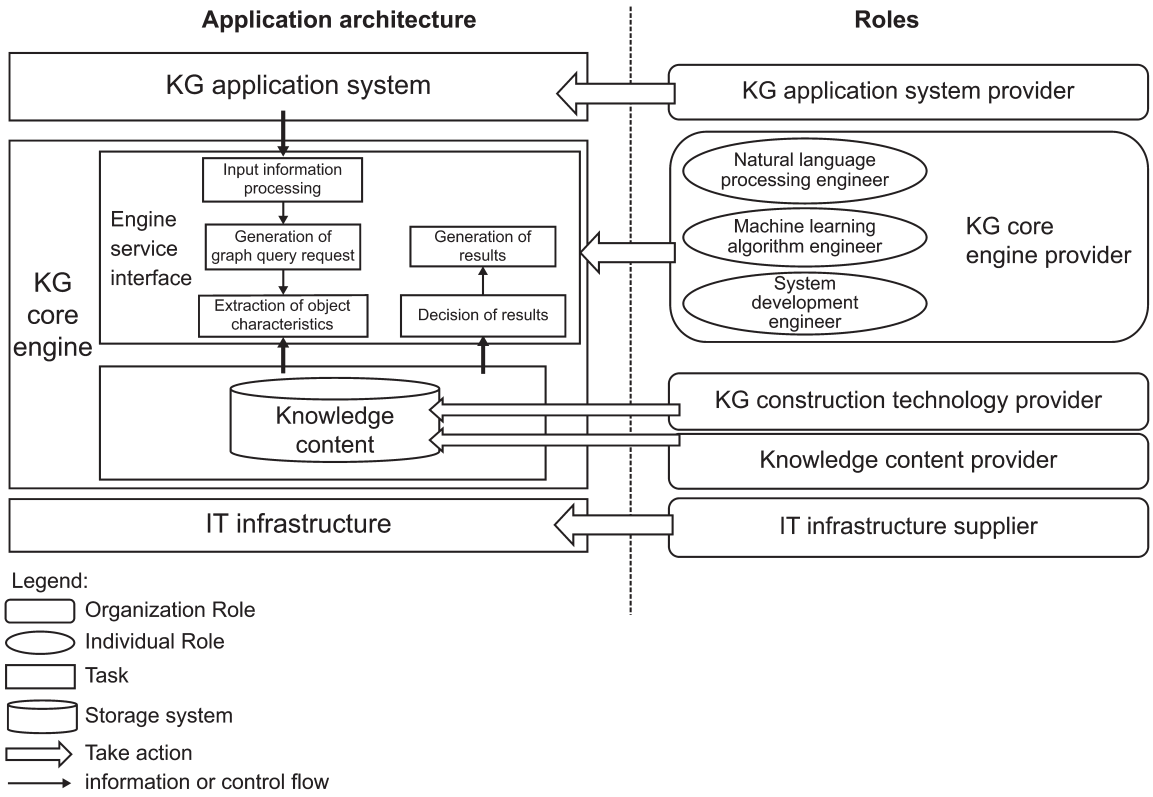


Figure 10—Participant roles of path tracing based on electric-power–oriented knowledge graph

7.2.5.2 Participant roles

7.2.5.2.1 Organizational roles

Organization roles should include, but are not limited to, the following:

a) Main participants: KG core engine provider

b) Cooperators:

1) KG application system provider

2) KG construction technology provider

3) Knowledge content provider

4) IT infrastructure supplier

7.2.5.2.2 Individual roles

Individual roles should include, but are not limited to, the following:

— Natural language processing engineer

— Machine learning algorithm engineer

— System development engineer

7.2.5.3 Input and output

The inputs of path-tracing activities of EPKG should include, but are not limited to, the following:

a) Requirements for start node
b) Restrictions on path tracing

The outputs of path-tracing activities of EPKG should include, but are not limited to, the following:

c) Queried path or endpoint
d) Decision results based on path or endpoint

7.2.5.4 Tasks

The main tasks of path tracing based on EPKG include the following:

a) Specifying start nodes, which are as follows:
    1) Explicit start nodes directly designated
    2) Implicit start nodes associated in certain ways
b) Searching path based on restrictions, which are as follows:
    1) Restrictions on endpoint types
    2) Restrictions on endpoint instances
    3) Restrictions on path lengths (not more than the specified hop count)
    4) Restrictions on path modes (e.g., with or without loops)
    5) Restrictions on edge types
c) Getting search results according to the requirements, which are as follows:
    1) Number of paths (one, many, or all)
    2) Path lengths (longest, shortest, and so on)
    3) Number of endpoints (one, many, or all)
d) Extracting features from results, which are as follows:
    1) Graph features: Number of paths, path lengths, graph characteristics of nodes (such as out-degree and in-degree), and so on
    2) Knowledge features: Node attributes, node types, edge attributes, edge types, and so on
    3) Vector features: An embedded representation of nodes and edges in the search results
e) Inferring results with specific methods, which are as follows:
    1) Statistical learning
    2) Conditional rules
    3) Computing formulas

7.2.5.5 General quality description characteristics

The quality of this application should be assessed by the following characteristics:

a) Path coverage: Ratio of the count of path searched to the count of all path meeting requirements

b) Accuracy: To measure consistency between the inferred results and the facts

c) Response time: The time for the system to react (respond) after a user sends a request or instruction

7.3 Scenario-oriented applications of electric-power–oriented knowledge graphs

Based on scenario objectives, scenario-oriented applications can be divided into power grid equipment management (power grid domain), power generation management (power generation domain), physical asset warehouse management (asset domain), electric power market analysis (market domain), electric power marketing management business (customer domain), and power grid security control (security domain).

7.3.1 Application of power grid domain

7.3.1.1 Inputs

The inputs for application of the power grid domain should include, but are not limited to, the following:

a) Equipment operation monitoring information

b) Equipment connection information

c) Equipment management and maintenance information

d) Electric power information system related to the above information

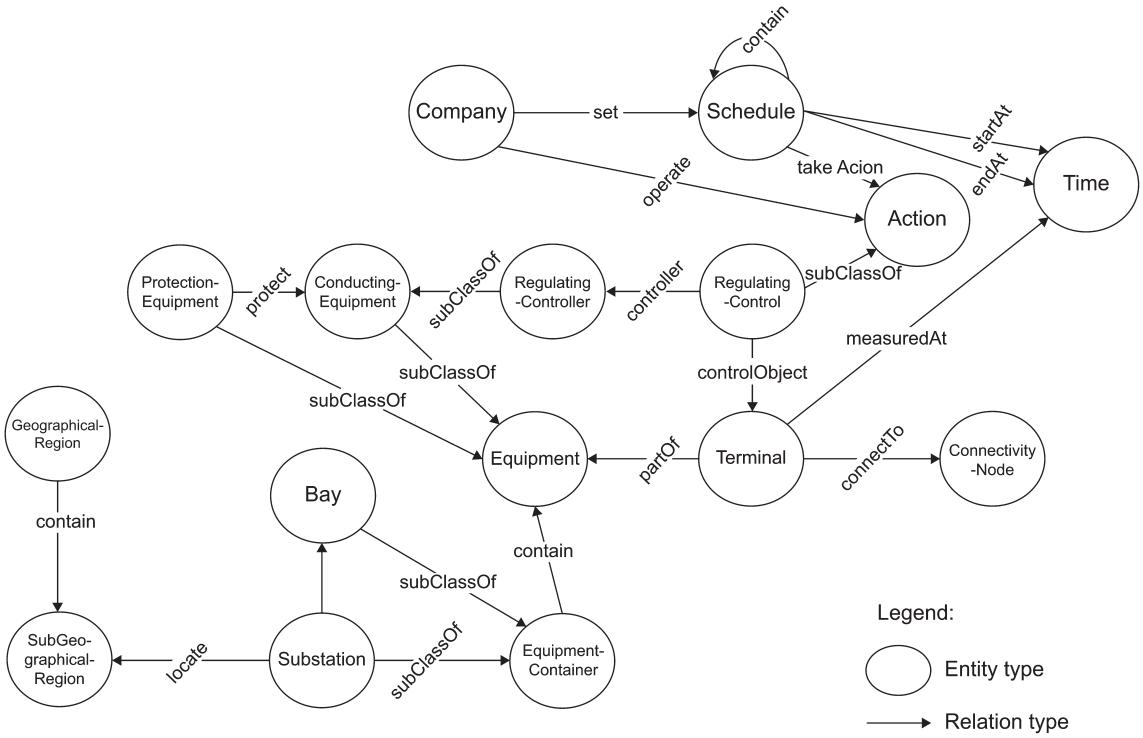
7.3.1.2 Core elements of ontology model

The core entity types of the EPKG model in the power grid domain should include, but are not limited to, the items listed in Table 5.

Table 5—Core elements of ontology model in the power grid domain

Level I category	Level II category	Level III category	Level IV category
PowerThing	PowerItem	EquipmentContainer	Substation
			Bay
		Equipment	ConductingEquipment
			ProtectionEquipment
		ConnectivityNode	
		Terminal	
	PowerEvent	Action	
		Schedule	
Person	Worker		
Location	GeographicalRegion		
	SubGeographicalRegion		
Organization	Company		
Time			
NOTE 1—See Annex C for detailed entity type definitions, similarly hereinafter. NOTE 2—The schema used can be extended based on the recommended core entity type. See Clause 5 for the expansion method.			

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 11.



NOTE—See Annex C for detailed relation type definitions.

Figure 11—Relation types among entity types in the power gird domain

7.3.1.3 Application scenarios

Application scenarios of the power grid domain may include, but are not limited to, the following:

a) Decisions on the dispatching schedule may be made based on the power grid KG.

b) Mobile load analysis may be conducted and decisions on the electric power demand response may be made based on the power grid KG.

c) Integrated energy management may be carried out and the optimal position in the power distribution network may be determined to install renewable energy based on the power grid KG.

d) The power distribution network equipment ledger may be managed based on the power grid KG to implement the multiangle and multidimensional fast query of power grid equipment.

e) The defects of power grid equipment may be analyzed based on the power grid KG. Faults and defect events of specified equipment may be filtered and classified considering such conditions as equipment type, voltage level, and operating environment, and the potential relation between the root cause of the problem and the phenomenon may be explored, thereby facilitating users to quickly analyze equipment defects and locate the root of the problem.

f) The quality of the power grid equipment may be traced based on the power grid KG. The real causes of equipment faults/defects and key components that cause equipment faults/defects may be analyzed according to the external environment of the equipment when the faults/defects occur, operating load of power grid, faulty components of equipment, fault phenomena, fault causes, fault qualitative identification, and fault nature, to identify equipment/component suppliers and put forward suggestions for equipment quality improvement.

7.3.2 Application of power generation domain

7.3.2.1 Inputs

The inputs for application of the power generation domain should include, but are not limited to, the following:

a) Monitoring information on the operation of power generation equipment
b) Drive information on power generation equipment
c) Equipment management and maintenance information
d) Electric power information system related to the above information

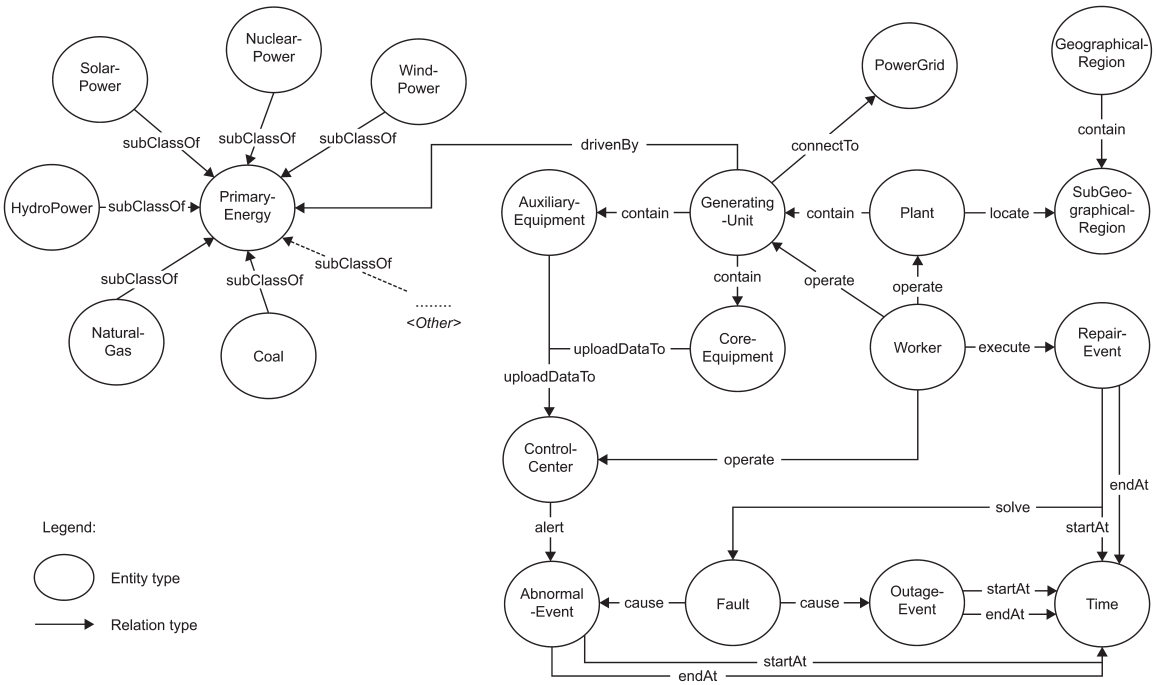
7.3.2.2 Core elements of ontology model

The core entity types of the EPKG model in the power generation domain should include, but are not limited to, the items listed in Table 6.

Table 6—Core elements of ontology model in the power generation domain

Level I category	Level II category	Level III category	Level IV category
PowerTing	PowerItem	GeneratingUnit	CoreEquipment
			AuxiliaryEquipment
		PrimaryEnergy	Coal
			NaturalGas
			HydroPower
			WindPower
			SolarPower
			NuclearPower
	PowerEvent	OutageEvent	
		AbnormalEvent	
		RepairEvent	
		FaultEvent	
Personnel	Worker		
Location	GeographicalRegion		
	SubGeographicalRegion		
Organization	ControlCenter		

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 12.



NOTE—See Annex C for detailed relation type definitions.

Figure 12—Relation types among entity types in the power generation domain

7.3.2.3 Application scenarios

Application scenarios of the power generation domain may include, but are not limited to, the following:

a) The power generation equipment may be analyzed, and the health condition of the equipment may be determined based on the power generation KG.

b) The equipment correlation analysis may be conducted, the influence scope of equipment failure may be determined, and the cause of equipment failure may be traced based on the power generation KG.

c) Generation load forecasting may be made based on the power generation KG to provide accurate data support for power grid dispatching.

d) Maintenance plans may be made and maintenance operations for the equipment may be provided based on the power generation KG.

e) A knowledge base in the field of power generation with lifelong learning characteristics may be built based on the power generation KG.

f) Data analysis support for optimizing power production process may be provided based on the power generation KG.

7.3.3 Application of power market domain

7.3.3.1 Inputs

The inputs for application of the market domain should include, but are not limited to, the following:

a) Customer contracts and bill data

b) Electric power supplier management system data

c) Electric power customer relation management system data

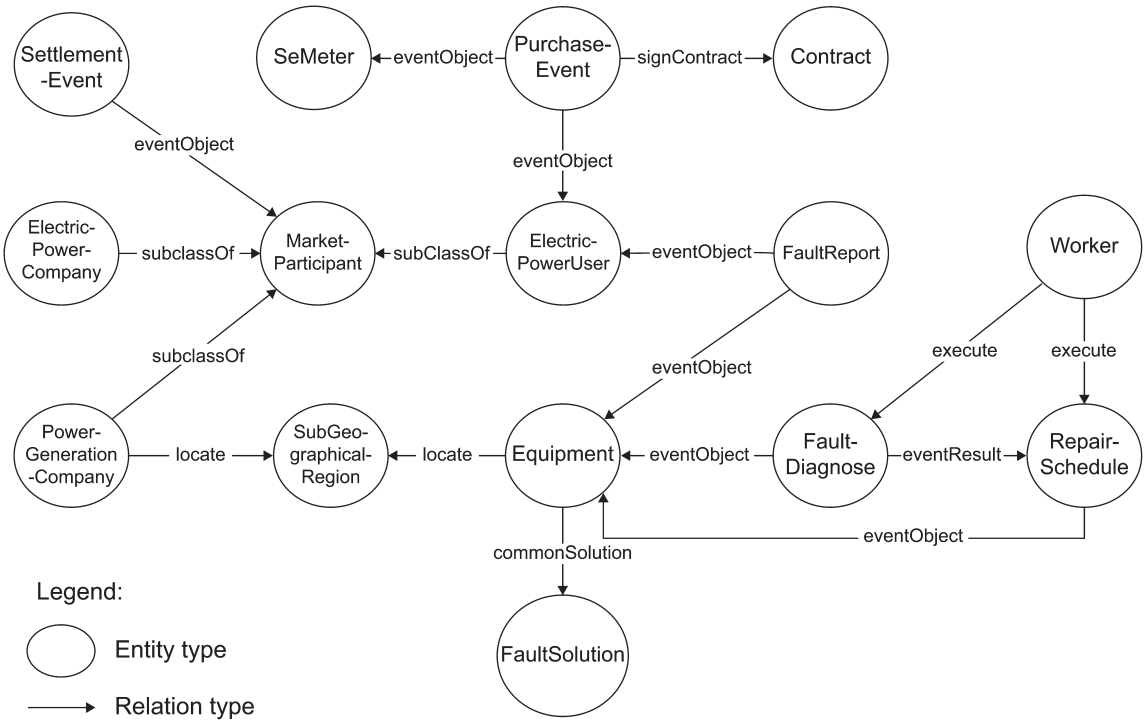
7.3.3.2 Core elements of ontology model

The core entity types of the EPKG model in the power market domain should include, but are not limited to, the items listed in Table 7.

Table 7—Core elements of ontology model in the power market domain

Level I category	Level II category	Level III category
PowerThing	PowerItem	Equipment
		SeMeter
		Contract
		FaultSolution
		RepairSchedule
		SettlementEvent
		PurchaseEvnet
		FaultReport
		FaultDiagnose
Person	Worker	
Location	SubGeographicalRegion	
Organization	MarketParticipant	ElectricPowerCompany
		PowerGenerationCompany
		ElectricPowerUser

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 13.



NOTE—See Annex C for detailed relation type definitions.

Figure 13—Relation types among entity types in the power market domain

7.3.3.3 Application scenarios

Application scenarios of the market domain may include, but are not limited to, the following:

a) Electric-power–oriented knowledge based on KGs may be popularized among users to reduce life and property loss caused by incorrect use or improper operation.

b) A customer service assistant system may be built based on KGs to improve customer service efficiency.

c) User demands may be understood based on KGs to improve the timeliness and security of power transmission.

d) Maintenance manpower may be allocated based on KGs to improve the efficiency of customer responses.

7.3.4 Application of supply chain domain

7.3.4.1 Inputs

The inputs for application of the supply chain domain should include, but are not limited to, the following:

a) Integration of suppliers' basic qualification and capability information

b) The state grid's modern supply chain information:

   1) Procurement by invitation to bid
   2) Contract signing
   3) Material production
   4) Material allocation and delivery
   5) Warehousing and distribution
   6) Transportation monitoring
   7) Equipment installation and commissioning
   8) Equipment operation
   9) Equipment decommissioning and scrap

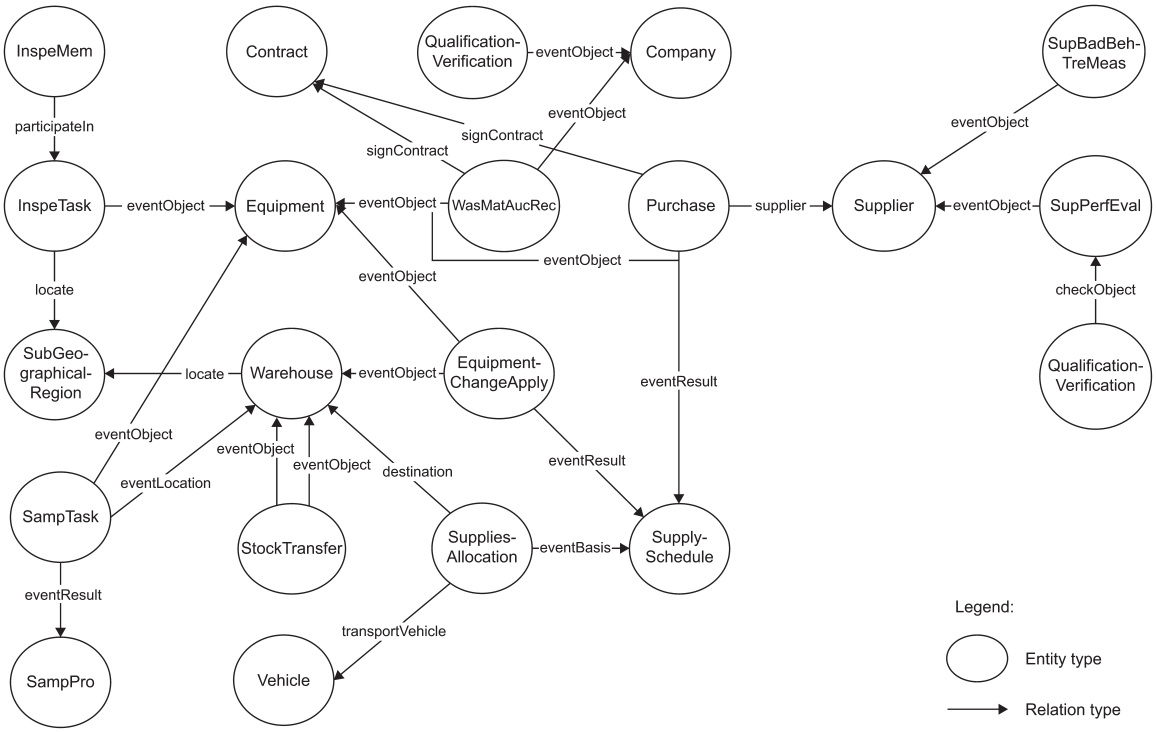
7.3.4.2 Core elements of ontology model

The core entity types of the EPKG model in the supply chain domain should include, but are not limited to, the items listed in Table 8.

Table 8—Core elements of ontology model in the supply chain domain

Level I category	Level II category	Level III category
PowerThing	PowerItem	Equipment
		Warehouse
		Vehicle
	PowerEvent	Fault
		SampPro
		Contract
		InspeTask
		SampTask
		StockTransfer
		SuppliesAllocation
		QualificationVerification
		WasMatAucRec
		Purchase
		SupBadBehTreMeas
		SupplySchedule
Personnel	InspeMem	
Organization	Company	
	Factory	Supplier

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 14.



NOTE—See Annex C for detailed relation type definitions.

Figure 14—Relation types among entity types in the supply chain domain

7.3.4.3 Application scenarios

Application scenarios of the supply chain domain may include, but are not limited to, the following:

a) Suppliers should be individually profiled, classified, and graded:
   1) Supplier classification and grading models are built via label portrait technology and big data analysis technology based on panoramic information of the electric power supply chain.
   2) The grades of supplies provided by suppliers are evaluated according to supply categories.
   3) Suppliers are graded based on the total scores converted from the scores of supplies by grading.

b) Supplier relations may be associated, and risks may be monitored:
   1) The multidimensional data of suppliers are gathered (operating status, operating risks, personnel change risks, legal risks, public opinion risks, and other risks).
   2) Abnormal information related to suppliers is integrated.
   3) Centralized display, tracking and monitoring, and early warning are carried out.
   4) The industry chain is dynamically matched, and the upstream and downstream of the industry are analyzed based on the industry chain KG to analyze the upstream and downstream risks of target suppliers.

c) The accurate recommendation of suppliers may be carried out:
   1) Suppliers make accurate recommendations based on individual supplier portraits in combination with bidding requirements (materials, qualifications, performance, and so on).
   2) Sorting occurs according to the matching degree of suppliers.

d) Intelligent warehouse management may be carried out:
   1) Warehouse resource utilization analysis is conducted based on the safety inventory, usage conditions of shelf space, and information on in-transit supplies, and proposing specific opinions to improve warehouse utilization.
   2) An expert system for the optimization of supply chain logistics transportation is built that considers inventory information, in-transit supplies, logistics information and the dynamic optimization of logistics transportation, improving the efficiency of supplies transportation and distribution, assisting in ensuring production needs, and reducing transportation costs.

7.3.5 Application of security domain

7.3.5.1 Inputs

The inputs for application of the security domain should include, but are not limited to, the following:

a) Equipment parameters and indicators
b) Equipment operation and monitoring data
c) Safety accident investigation report

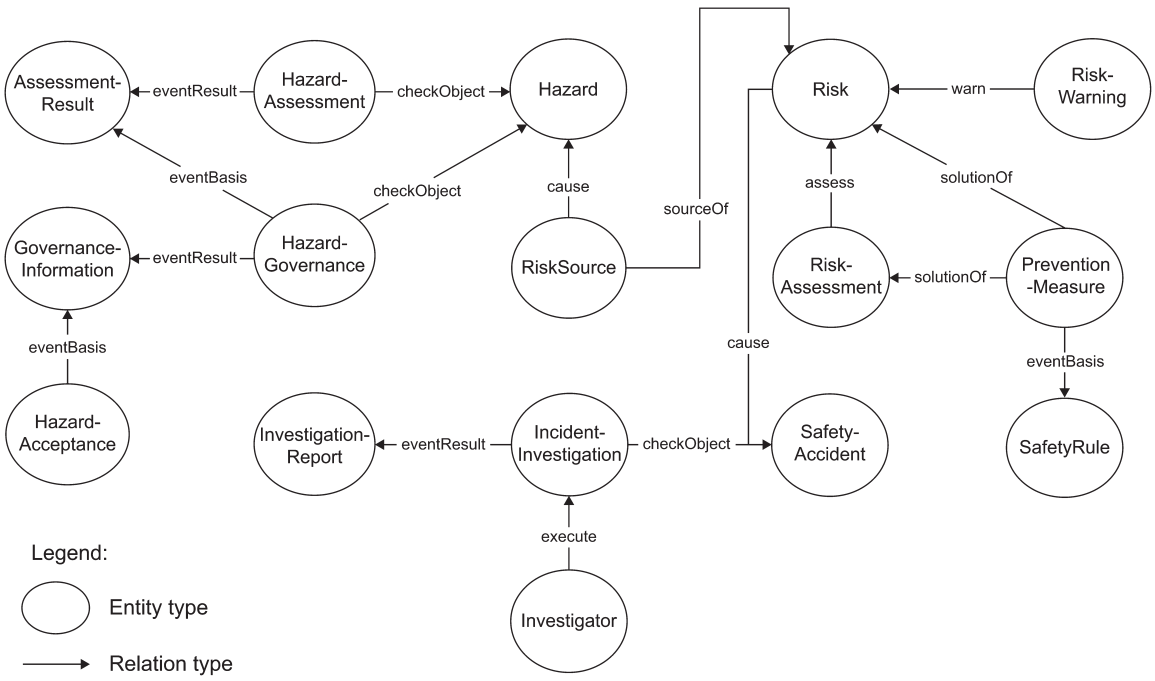
7.3.5.2 Core elements of ontology model

The core entity types of the EPKG model in the security domain should include, but are not limited to, the items listed in Table 9.

Table 9—Core elements of ontology model in the security domain

Level I category	Level II category	Level III category
PowerThing	PowerRecord	AssessmentResult
		InvestigationReport
		Hazard
		RiskSource
		Risk
		SafetyRule
		PreventionMeasure
		GovernanceInformation
	PowerEvent	HazardAssessment
		HazardGovernance
		HazardAcceptance
		RiskAssessment
		IncidentInvestigation
		SafetyAccident
		RiskWarning
Person	Investigator	

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 15.



NOTE—See Annex C for detailed relation type definitions.

Figure 15—Relation types among entity types in the security domain

7.3.5.3 Application scenarios

Application scenarios of the security domain may include, but are not limited to, the following:

a) Risk warning may be carried out based on the security domain KG.

b) Risk assessment may be carried out based on the security domain KG.

c) Hidden dangers may be managed based on the security domain KG.

d) Accident causes may be located, and security responsibility may be traced based on the security domain KG.

e) Potential source of risk and loophole may be found based on the security domain KG.

7.3.6 Application of distributed energy domain

7.3.6.1 Inputs

The inputs for application of the distributed energy domain should include, but are not limited to, the following:

a) Virtual power plant management system

b) Power consumption schedule

c) Power supply schedule

d) Electric power information system related to the above information

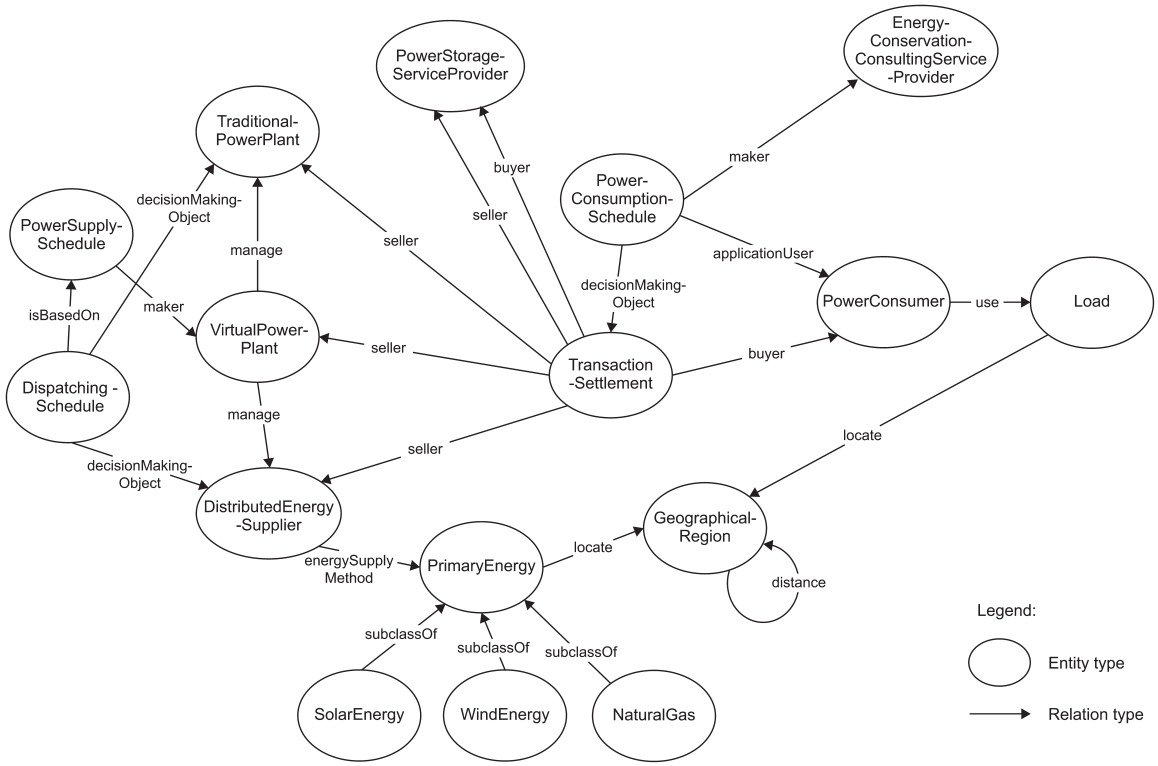
7.3.6.2 Core elements of ontology model

The core entity types of the EPKG model in the distributed energy domain should include, but are not limited to, the items listed in Table 10.

Table 10—Core elements of ontology model in the distributed energy domain

Level I category	Level II category	Level III category	Level IV category
PowerTing	PowerItem	Load	
		PrimaryEnergy	WindEnergy
			SolarEnergy
			NaturalGas
	PowerEvent	TransactionSettlement	
		DispatchingSchedule	
		PowerSupplySchedule	
		PowerConsumptionSchedule	
Location	GeographicalRegion		
Organization	TraditionalPowerPlant		
	VirtualPowerPlant		
	DistributedEnergySupplier		
	EnergyConservationConsultingServiceProvider		
	PowerConsumer		

The relation types among these entity types should include, but are not limited to, the edges shown in Figure 16.



NOTE—See Annex C for detailed relation type definitions.

Figure 16—Relation types among entity types in the distributed energy domain

7.3.6.3 Application scenarios

Application scenarios of the distributed energy domain may include, but are not limited to, the following:

a) A virtual power plant scheduling plan may be made based on the distributed energy management KG: In order to optimize the economic benefits on the premise of maintaining the stability of the power supply, virtual power plants may formulate power supply plans and design scheduling schemes based on distributed energy suppliers and the traditional power plants that they manage, forms of primary energy used by distributed energy suppliers, and the stability of the energy supply.

b) Power consumption plans may be made based on the distributed energy management KG: Energy conservation consulting service providers formulate optimal power consumption plans for users according to power supply organizations (including traditional power plants, virtual power plants, and distributed energy suppliers), power demand (load) of users, and distance relation between power supply organizations and the regions where users use the load; users conduct transaction settlement based on the optimal power consumption plan to optimize the cost on the premise of maintaining the power demand.

c) Energy storage plans may be made based on the distributed energy management KG: Energy storage service providers adjust their roles (buyer or seller) in the transaction settlement process based on changes in the supply-and-demand relation and optimize the inputs–outputs ratio while maintaining the balance between supply and demand, and reducing energy waste.

8. Requirements for electric-power–oriented knowledge graph system

8.1 Composition of electric-power–oriented knowledge graph system

A complete EPKG system can include the following subsystems:

a) KG basic service subsystem (required)

b) Knowledge construction subsystem (optional)

c) Knowledge application subsystem (optional)

d) Knowledge exchange subsystem (optional)

e) Platform support subsystem (optional)

8.2 Electric-power–oriented knowledge graph basic service subsystem

8.2.1 Definition

An EPKG basic service subsystem contains knowledge data and provides a system interface or human–computer interface for maintaining and managing knowledge data.

8.2.2 Module

a) The knowledge storage module shall be included to provide a medium for storing electric-power–oriented knowledge.

b) The knowledge retrieval module shall be included to provide an interface for querying electric-power–oriented knowledge.

c) The knowledge import module should be included to provide an interface for accessing electric-power–oriented knowledge.

d) The knowledge management module may be included to provide functions such as electric-power–oriented knowledge model management and metadata management.

8.2.3 Knowledge storage module

The main functions of the knowledge storage module include, but are not limited to, the following:

a) It shall contain a core knowledge base for storing standardized and direct knowledge data for external services.

b) It should control knowledge access and expose different knowledge data to different users.

c) It should support a variety of data types, including Char, Numeric Type (Integer and Float), Enumerated Type, and Boolean.

d) It should support a variety of character sets, including unicode, UTF-8, GBK, and so on.

e) It may contain a variety of storage media and storage formats, including relational database, graph database, object storage, and so on.

f) It may support large-scale knowledge data storage and accommodate hundreds of millions of nodes and edges.

g) It can carry out knowledge storage model management, allowing users to plan storage layers and achieving the orderly management of original data, structured knowledge data, fused knowledge data, and intermediate data not included in the core knowledge base.

h) It can support distributed storage, including graph partition, distributed transaction, online capacity expansion, and so on.

8.2.4 Knowledge retrieval module

The main functions of the knowledge retrieval module include, but are not limited to, the following:

a) It should provide a graph-oriented data model abstraction method and operate graph structure data through the interface.

b) It should support the query of electric-power–oriented knowledge unit information, such as query, addition, deletion, and modification of details on points and edges.

c) It may provide metadata query to understand the stored knowledge model, knowledge scale, updated information, and so on.

d) It may support the interaction between a variety of APIs and applications, such as ODBC, JDBC, RPC, RESTful, and so on.

e) It may support graph database descriptive query languages such as Cypher, Gremlin, SPARQL, and so on.

f) It may support interfaces that invoke the database through library functions in programming languages such as Python, Java, C++, and so on.

g) It can support basic graph algorithms, including PageRank, WCC (Weakly Connected Components), community discovery, and so on.

h) It can support knowledge display and user interaction through the graphic interface.

i) It can support high-concurrency queries.

j) Under the condition of distributed storage, it may support load balancing.

8.2.5 Knowledge import module

The main functions of the knowledge import module include, but are not limited to, the following:

a) It should support the functions of batch data import and incremental data import.

b) It should support the batch/incremental update of data, including the addition, deletion, and modification of vertices (nodes) and edges, as well as their attributes.

c) It should support the import of a variety of data formats such as CSV, JSON, RDF, and so on.

d) It may support the function of manual addition to add and edit entity and relation instances through the interface.

e) It can support the export of knowledge data with the standard format.

8.2.6 Knowledge management module

The main functions of the knowledge management module include, but are not limited to, the following:

a) It shall support the knowledge ODM function and define entity types, relationship types, and corresponding attributes, including:

1) "Definition of entity type"—The design of entity types and their attributes in the graph schema. It should support the functions of adding, deleting, and viewing the entity types and entity attributes of the graph.

2) "Definition of relationship type"—The design of relationship types and their attributes in the graph schema. It should support the function of adding, deleting, and viewing graph relationship types and relationship attributes.

b) It should support ontology fusion and the ontology connection and alignment of multisource heterogeneous graphs.

c) It should support the updating of data structure or data contents caused by changes in the knowledge model.

d) It may support the function of "Schema Viewing" for the view of the designed graph schema.

8.3 Electric-power–oriented knowledge graph construction subsystem

8.3.1 Definition

The EPKG construction subsystem provides computing methods, computing resources, and scheduling services for KG construction.

8.3.2 Module

The main modules of the KG construction subsystem should include, but are not limited to, the following:

a) It should contain a knowledge construction algorithm management module to manage algorithm components.

b) It should include a knowledge construction task management module to manage task scheduling.

c) It may include a knowledge construction task development module to support users to customize task execution contents.

d) It can include a knowledge construction algorithm development module to support the development of various knowledge construction algorithms

8.3.3 Knowledge construction algorithm management module

Knowledge construction algorithm components should include, but are not limited to, the following:

a) Knowledge extraction: Transforms structured or unstructured data into knowledge statements in the form of subject-predicate-object (SPO) triple according to the specified schema.

b) Knowledge fusion: Provides the functions of entity alignment, entity linking, and attribute value disambiguation.

c) Knowledge computing: Provides the functions of knowledge statistics and reasoning.

d) Knowledge maintenance: Provides the functions of knowledge adding, deleting, and updating.

e) Data I/O: Provides data read-out and write-in functions.

The main functions of the knowledge construction algorithm management module should include, but are not limited to, the following:

a) It should support the display and selection of knowledge construction algorithm components.

b) It should support the addition, configuration, and deletion of algorithm components.

c) It should assist in ensuring that each category of algorithm components has fixed input and output formats.

d) It may support the version maintenance of algorithm components.

e) It may support algorithm management through the visual interface.

8.3.4 Knowledge construction task management module

A knowledge construction task is composed of a variety of knowledge construction algorithms and data I/O components, forming a complete knowledge processing process.

The main functions of the knowledge construction task management module should include, but are not limited to, the following:

a) It should support the function of task scheduling and execute knowledge construction tasks according to the schedule.

b) It should support the function of task query to query the task-by-task ID and status and view the task execution status.

c) It should support the functions of task start and stop to manually start and stop the knowledge construction task.

d) It should support the function of task scheduling plan setting.

e) It may support the function of task validity setting to enable or disable the knowledge construction task.

f) It may support task management through the visual interface.

8.3.5 Knowledge construction task development module

The main functions of the knowledge construction task development module should include, but are not limited to, the following:

a) It should support the functions of creating new tasks and editing existing tasks.

b) It should support the function of adding algorithm components to tasks.

c) It should support the function of component arrangement to set the execution sequence of each algorithm component.

d) It may support the functions of condition judgment and dynamic adjustment according to the execution sequence of algorithm components and the intermediate results.

e) It may support the functions of task template management and preset task templates to facilitate rapid development.

f) It may support task development with visual methods and flexibly build tasks in the form of dragging and dropping.

8.3.6 Knowledge construction algorithm component development module

The main functions of the knowledge construction algorithm component development module should include, but are not limited to, the following:

a) It should support algorithm model replacement by assigning new model files to algorithm components.

b) It should support algorithm model version management.

c) It may support algorithm model training and use new sample data training knowledge to construct algorithms.

d) It may support training sample set management to view, import, label, and delete sample sets.

e) It may support the uploading of supporting component framework files that contain the container for the algorithm models.

f) It can support the function of electric power industry dictionary management and the configuration of the business vocabulary and synonym table.

8.4 Electric-power–oriented knowledge graph application subsystem

8.4.1 Definition

The EPKG application subsystem can deploy and manage various EPKG APPs in a container-based way.

Each EPKG APP can declare its compatible schema forms, including the base domains of the IEEE EKPG model, as well as extended entity and relation types.

Each EPKG APP can provide a container mirror image, including the runtime environment resources required by the APP.

8.4.2 Module

The main modules of the KG application subsystem should include, but are not limited to, the following:

a) It should support the EPKG APP deployment module.

b) It may support the EPKG APP management module.

8.4.3 Application deployment module

The main functions of the EPKG APP deployment module should include, but are not limited to, the following:

a) It may support the addition of new APPs and specify mirror image files for new APPs.

b) It may support APP running resource management and set the hardware resources required by the APP and number of running instances.

c) It can support the version upgrade of APPs and carry out the hot upgrade of APPs.

8.4.4 Application management module

The main functions of the EPKG APP management module should include, but are not limited to, the following:

a) It may support APP querying and detail viewing, including descriptions of schema compatibility, and so on.

b) It may support the start and stop of APPs.

c) It can support the modification of APP details.

d) It can support the time scheduling of APPs.

Annex A

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] IEC 61970-301:2011, Energy management system application program interface (EMS-API)—Part 301: Common information model (CIM) base.[9]

[B2] IEC 61970-501:2007, Energy management system application program interface (EMS-API)—Part 501: CIM RDF Schema.

[B3] ISO 8601:2004, Data elements and interchange formats—Information interchange—Representation of dates and times.[10]

[9]IEC publications are available from the International Electrotechnical Commission (https://www.iec.ch) and the American National Standards Institute (https://www.ansi.org/).
[10]ISO publications are available from the International Organization for Standardization (https://www.iso.org/) and the American National Standards Institute (https://www.ansi.org/).

Annex B

(informative)

IEEE EPKG model

B.1 Model version

B.1.1 Version declaration

Version Number: IEEE-EPKG01v01

NOTE—The version number is IEEE-EPKGXXvYY. XX and YY are double digits. XX indicates the larger version number, and YY indicates the smaller version number.

Update date: 2022–07–20

NOTE—The date is in the format: YYYY-MM-DD.

B.1.2 Version change description

This is the first version of the IEEE EKPG model.

NOTE—The version based on which this version of the model is updated.

B.2 Subject domain

B.2.1 Common domain

In general KG, *Thing* is the parent type of all entities. There are four direct subclasses of *Thing: Organization*, *Person*, *Location,* and *Time*. In addition, a new entity type *PowerThing* is defined in EPKG, which is the parent type of all exclusive electric power entity types. The primary categories under this type include *PowerItem and PowerEvent,* representing physical things and logical events in the electric power industry, as follows:

a) PowerThing
    1) PowerItem
    2) PowerEvent
b) Organization
c) Person
d) Location
e) Time

B.2.1.1 PowerThing

Entity type name	***PowerThing***			
Meaning	**Basic type of electric power entities in EKPG**			
Parent entity type (parent class)	***Thing***			
Description	***PowerThing* is a general term for objects in the power industry.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	id	String		Object ID
	name	String		Object name

B.2.1.1.1 PowerItem

Entity type name	***PowerItem***
Meaning	Physical electric power entities in EKPG
Parent entity type (parent class)	*PowerThing*
Description	*PowerItem* refers to the items objectively existing in the electric power industry.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.1.1.2 PowerEvent

Entity type name	***PowerEvent***
Meaning	Power event
Parent entity type (parent class)	*PowerThing*
Description	*PowerEvent* refers to the events occurring in the electric power industry.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.1.2 Organization

Entity type name	***Organization***			
Meaning	**Organizations involved in electric power industry**			
Parent entity type (parent class)	***Thing***			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	orgType	String		Type of organization

B.2.1.3 Person

Entity type name	***Person***			
Meaning	**Participate roles involved in electric power industry**			
Parent entity type (parent class)	***Thing***			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	position	String		Work position of a person

B.2.1.4 Location

Entity type name	***Location***			
Meaning	**Geographical location**			
Parent entity type (parent class)	***Thing***			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	address	String		Address
	x	Numeric		Longitude, or other coordinates.
	y	Numeric		Latitude, or other coordinates.
	coordType	String		Coordinate type

B.2.1.5 Time

Entity type name	***Time***			
Meaning	**Time**			
Parent entity type (parent class)	***Thing***			
Description	**Date and time as “yyyy-MM-dd HH:mm:ss”.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	value	String		String representation of datetime.

B.2.2 Power grid domain

Power grid domain entity types and relation types schema are shown in Figure B.1.

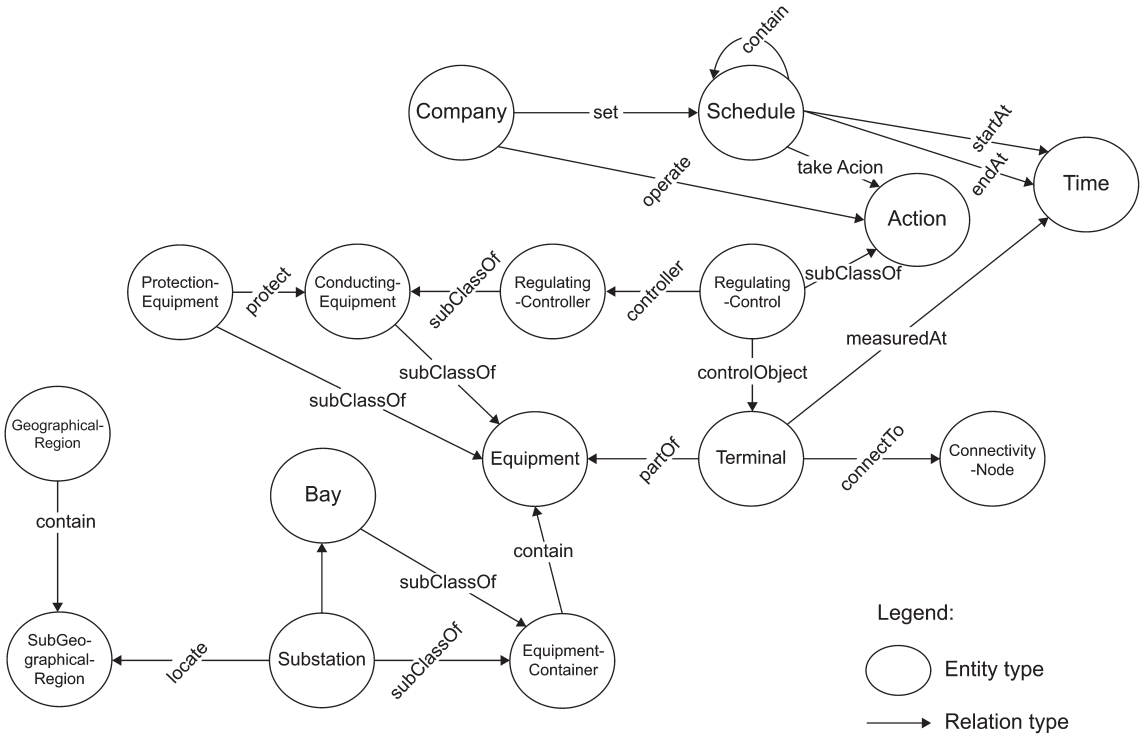


Figure B.1—Power grid domain entity types and relation types schema

B.2.2.1 PowerThing

B.2.2.1.1 PowerItem

B.2.2.1.1.1 Bay

Entity type name	***Bay***			
Meaning	**Bay**			
Parent entity type (parent class)	***EquipmentContainer***			
Description	**A collection of electric power system resources (within a given transformer substation) that contains conducting equipment, protective relays, measurement, and remote measurement and control. Usually, intervals represent physical groupings of modular equipment.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	bayEnergyMeasFlag	Boolean		It indicates kWh/kvarh measurement exists/ does not exist
	bayPowerMeasFlag	Boolean		It indicates MW/Mvar measurement exists/ does not exist
	busLinkMode	String		Bus connection mode
	operationStatus	String		Running state

B.2.2.1.1.2 ConductingEquipment

Entity type name	***ConductingEquipment***			
Meaning	**Conductive equipment**			
Parent entity type (parent class)	***Equipment***			
Description	**As a part of the electric power system, it is designed to carry current or be associated with conductive connections. *ConductingEquipment* is contained in an *EquipmentContainer*, which may be a *Substation* or a *Bay* in a *Substation*.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	phases	String		It describes the phase corresponding to conducting equipment

B.2.2.1.1.3 ConnectivityNode

Entity type name	***ConnectivityNode***
Meaning	Connectivity node
Parent entity type (parent class)	*PowerItem*
Description	A connection node refers to the point at which the terminals of conducting equipment are connected with zero impedance.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.1.4 Equipment

Entity type name	***Equipment***			
Meaning	**Equipment**			
Parent entity type (parent class)	***PowerItem***			
Description	**A component of an electric power system, which is electronic or mechanical physical equipment.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	normallyInService	Boolean		Whether the equipment is in normal operation

B.2.2.1.1.5 EquipmentContainer

Entity type name	***EquipmentContainer***
Meaning	Equipment container
Parent entity type (parent class)	PowerItem
Description	A modeling structure that provides a root class for all equipment classes.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.1.6 ProtectionEquipment

Entity type name	***ProtectionEquipment***			
Meaning	**Protection equipment**			
Parent entity type (parent class)	***Equipment***			
Description	**An electrical device designed to respond to input conditions in a prescribed manner and to cause contact operation or similar abrupt change in associated electric control circuits after specified conditions are met, or simply to display the detected condition.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	relayDelayTime	Time		The time delay from detection of abnormal conditions to relay operation
	highLimit	Numeric		The maximum allowable value
	lowLimit	Numeric		The minimum allowable value
	powerDirectionFlag	Boolean		Direction same as positive active power flow value

B.2.2.1.1.7 RegulatingController

Entity type name	***RegulatingController***
Meaning	A type of ConductingEquipment that can regulate measurements and execute the regulation schedule
Parent entity type (parent class)	*ConductingEquipment*
Description	Specifies a set of equipment that works together to control a power system quantity such as voltage or flow.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.1.8 Substation

Entity type name	***Substation***			
Meaning	**Transformer substation**			
Parent entity type (parent class)	***EquipmentContainer***			
Description	**The place where voltage and current are transformed, and where electric energy is received and distributed in the power system**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	accessNetwork	String		Access to the power grid
	putIntoOperationDate	Time		Date of operation
	transformCapacity	Numeric		Substation capacity
	isFaultSystem	Boolean		Whether to access the fault information of a remote transmission system
	retirementDate	Time		Date of expiry
	isAVC	Boolean		Whether to access AVC
	substationProperty	String		Property of substation
	isFocus	Boolean		Whether to conduct centralized monitoring
	operationStatus	String		Running state

B.2.2.1.1.9 Terminal

Entity type name	***Terminal***
Meaning	Terminal
Parent entity type (parent class)	*PowerItem*
Description	An electrical connection point with conducting equipment. Terminals are connected at physical connection points called “connectivity nodes.”
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.2 PowerEvent

B.2.2.1.2.1 Action

Entity type name	***Action***
Meaning	Action
Parent entity type (parent class)	*PowerEvent*
Description	An action performed during a power event.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.2.2 Schedule

Entity type name	*Schedule*
Meaning	A preestablished pattern over time for a set of actions
Parent entity type (parent class)	*PowerEvent*
Description	Recording information on power event schedule.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.1.2.3 RegulatingControl

Entity type name	***RegulatingControl***			
Meaning	**An action to control a power system quantity such as voltage or flow**			
Parent entity type (parent class)	***PowerEvent***			
Description	**A collection of electric power system resources (within a given transformer substation) that contains conducting equipment, protective relays, measurement, and remote measurement and control. Usually, intervals represent physical groupings of modular equipment.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	targetValue	Numeric		Target value of the control action
	controlMode	Enumeration	*VOLTAGE, FLOW, ACTIVE_POWER, REACTIVE_POWER*	

B.2.2.2 Organization

B.2.2.2.1 Company

Entity type name	*Company*
Meaning	Company
Parent entity type (parent class)	*Organization*
Description	A company is a legal entity that owns and operates power system resources and is a party to the exchange and transmission contract.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.3 Person

B.2.2.3.1 Worker

Entity type name	***Worker***
Meaning	Worker
Parent entity type (parent class)	*Person*
Description	Electricity worker.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.4 Location

B.2.2.4.1 GeographicalRegion

Entity type name	***GeographicalRegion***
Meaning	Geographical region
Parent entity type (parent class)	*Location*
Description	A geographical region of power system network models.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.4.2 SubGeographicalRegion

Entity type name	***SubGeographicalRegion***
Meaning	SubGeographicalRegion
Parent entity type (parent class)	*Location*
Description	A subset of geographicalRegion of power system network models.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.2.5 Relation type definition

B.2.2.5.1 connectTo

Relation type name	***connectTo***		
Meaning	**The parts of a power system that are electronic or mechanical physical devices**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Terminal	**ConnectivityNode**	**Terminals are connected at a node with zero impedance. The measurement of a node applies to all of its terminals.**
Relation attributes	[None]		

B.2.2.5.2 contain

Relation type name	***Contain***		
Meaning	**Contain**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	EquipmentContainer	Equipment	Equipment contained in the equipment container
	Substation	Bay	A collection of power system resources contained in the transformer substation
	EquipmentContainer	Equipment	Equipment contained in the equipment container
	GeographicalRegion	SubGeo-graphicalRegion	SubGeographicalRegions are contained in the geographical region
	Schedule	Schedule	Schedules may contain some subschedules
Relation attributes	[None]		

B.2.2.5.3 controlObject

Relation type name	***controlObject***		
Meaning	**Measurement of equipment's terminal at a specified time**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RegulatingControl	**Terminal**	**Regulating control action controls terminals**
Relation attributes	**[None]**		

B.2.2.5.4 controller

Relation type name	***Controller***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RegulationControl	**RegulationController**	**RegulatingController executes the regulating control**
Relation attributes	**[None]**		

B.2.2.5.5 endAt

Relation type name	***endAt***		
Meaning	**The end time of events**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Schedule	**Time**	**End time of schedules**
Relation attributes	**[None]**		

B.2.2.5.6 locate

Relation type name	***Locate***		
Meaning	**Is located in**		
Description	**It describes the region where entities are located.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Substation	**SubGeographical Region**	**The region where the substation is located**
Relation attributes	[None]		

B.2.2.5.7 measureAt

Relation type name	***measureAt***			
Meaning	**Measurement of an equipment's terminal at a specified time**			
Description				
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**	
	Terminal	**Time**		
Relation attributes	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	measureType	Enumeration	*VOLTAGE, FLOW, TEMPRATURE*	
	value	Numeric		With standard unit

B.2.2.5.8 operate

Relation type name	*Operate*		
Meaning	Operate		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Company	Action	A company may take some actions
Relation attributes	[None]		

B.2.2.5.9 protect

Relation type name	*Protect*		
Meaning	Protect		
Description	It describes the relation between equipment and protection equipment.		
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Protection Equipment	Conducting Equipment	It describes protection equipment that protects or monitors conducting equipment
Relation attributes	[None]		

B.2.2.5.10 partOf

Relation type name	*part of*		
Meaning	Part of		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Terminal	Equipment	Terminals contained in the conducting equipment
Relation attributes	[None]		

B.2.2.5.11 startAt

Relation type name	*startAt*		
Meaning	The start time of events		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Schedule	Time	Start time of schedules
Relation attributes	[None]		

B.2.2.5.12 set

Relation type name	*set*		
Meaning	**Organizations set some events**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Company	**Schedule**	**Companies set some schedules**
Relation attributes	**[None]**		

B.2.2.5.13 subClassOf

Relation type name	***subClassOf***		
Meaning	**Subclass of**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	An entity concept of nonleaf nodes in the conceptual hierarchy tree	**An entity concept of nonleaf nodes in the conceptual hierarchy tree**	
Relation attributes	[None]		

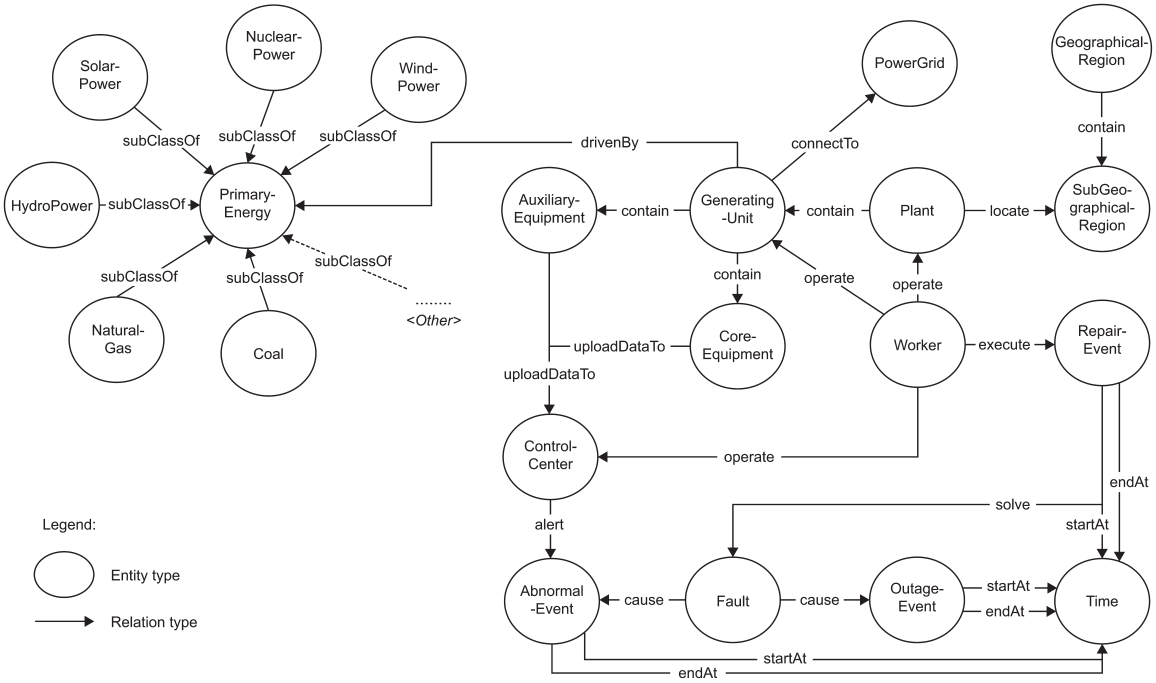


Figure B.2—Power generation domain entities and relationship schema

B.2.2.5.14 takeAction

Relation type name	***tabkeAction***		
Meaning	**Actions taken in the event**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Schedule	**Action**	**Schedules take the action**
Relation attributes	[None]		

B.2.3 Power generation domain

Power generation domain entities and relationship schema are shown in Figure B.2.

B.2.3.1 PowerThing

B.2.3.1.1 PowerItem

B.2.3.1.1.1 AuxiliaryEquipment

Entity type name	***AuxiliaryEquipment***
Meaning	Auxiliary equipment
Parent entity type (parent class)	*Equipment*
Description	Auxiliary equipment in the generator set
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.2 CoreEquipment

Entity type name	***CoreEquipment***
Meaning	Core equipment
Parent entity type (parent class)	*Equipment*
Description	Core equipment in the generator set
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.3 Coal

Entity type name	***Coal***
Meaning	Coal

Entity type name	*Coal*
Parent entity type (parent class)	*PrimaryEnergy*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.4 Equipment

See definition in B.2.2.1.1.4.

B.2.3.1.1.5 EquipmentContainer

See definition in B.2.2.1.1.5.

B.2.3.1.1.6 GeneratingUnit

Entity type name	***GeneratingUnit***			
Meaning	**Generator set**			
Parent entity type (parent class)	***Equipment***			
Description	**A single motor or a group of synchronous motors that convert mechanical energy and other energy sources into ac electrical energy.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	putIntoOperationDate	Time		Date of operation
	retirementDate	Time		Retirement date
	ratedVoltage	Numeric		Rated voltage of the terminal
	ratedPowerFactor	Numeric		Rated power factor
	activePowerUpperLimit	Numeric		Active power upper limit
	activePowerLowerLimit	Numeric		Active power lower limit
	reactivePowerUpperLimit	Numeric		Retirement date
	generatingType	String		Generator set type
	reactivePowerLowerLimit	Numeric		Reactive power lower limit
	powerType	String		Power type
	generatorModel	String		Generator model
	ratedU	Numeric		Rated voltage
	ratedCurrent	Numeric		Rated current
	ratedActivePower	Numeric		Rated active power
	ratedCapacity	Numeric		Rated capacity
	ratedSpeed	Numeric		Rated speed
	manufacturer	String		Manufacturer

B.2.3.1.1.7 HydroPower

Entity type name	***HydroPower***
Meaning	HydroPower
Parent entity type (parent class)	*PrimaryEnergy*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.8 NaturalGas

Entity type name	***NaturalGas***			
Meaning	**Natural gas**			
Parent entity type (parent class)	***PrimaryEnergy***			
Description	**Natural gas is a mixture of hydrocarbon and nonhydrocarbon gases naturally contained in the stratum.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	calorific	Numeric		Calorific value of gas

B.2.3.1.1.9 NuclearPower

Entity type name	***NuclearPower***
Meaning	Nuclear power
Parent entity type (parent class)	*PrimaryEnergy*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.10 Plant

Entity type name	***Plant***
Meaning	A Plant is a collection of equipment for generation
Parent entity type (parent class)	*EquipmentContainer*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.1.1.11 PowerGrid

Entity type name	*PowerGrid*			
Meaning	**Power grid**			
Parent entity type (parent class)	*EquipmentContainer*			
Description	**Power grid is a whole consisting of all kinds of voltage substations and transmission and distribution lines. Its tasks are to transmit and distribute electric energy and to change voltage.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	operateDate	Time		Time of operation
	expiryDate	Time		Time of expiry
	level	String		Power grid level

B.2.3.1.1.12 PrimaryEnergy

Entity type name	*PrimaryEnergy*			
Meaning	**Primary energy**			
Parent entity type (parent class)	*PowerItem*			
Description	**Primary energy refers to the natural energy existing in original forms without processing and conversion, also known as "natural energy," such as coal, oil, natural gas, hydroenergy, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	energyType	String		Energy type
	cost	Numeric		Cost

B.2.3.1.1.13 SolarPower

Entity type name	*SolarPower*			
Meaning	**Solar power**			
Parent entity type (parent class)	*PrimaryEnergy*			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	sunshineTime	Numeric		Average sunshine time per day
	radiation	Numeric		Average radiation per year

B.2.3.1.1.14 WindPower

Entity type name	*WindPower*			
Meaning	Wind power			
Parent entity type (parent class)	*PrimaryEnergy*			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	AveSpeed	Numeric		Average wind
	duration	Numeric		Duration of effective wind

B.2.3.1.2 PowerEvent

B.2.3.1.2.1 AbnormalEvent

Entity type name	*AbnormalEvent*			
Meaning	Abnormal event			
Parent entity type (parent class)	*PowerEvent*			
Description	Recording information on anomaly events.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	abnormalDesc	String		Abnormal event description

B.2.3.1.2.2 FaultEvent

Entity type name	*FaultEvent*			
Meaning	Fault event			
Parent entity type (parent class)	*PowerEvent*			
Description	Recording information on fault events.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	faultDesc	String		Fault phenomenon description
	faultType	String		Fault type

B.2.3.1.2.3 OutageEvent

Entity type name	***OutageEvent***			
Meaning	**Outage event**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Recording information on outage events.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	outageDesc	String		Outage phenomenon description

B.2.3.1.2.4 RepairEvent

Entity type name	**RepairEvent**			
Meaning	**Repair event**			
Parent entity type (parent class)	**PowerEvent**			
Description	**Recording information on repair events of devices.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	deviceType	String		Fault device type
	faultDesc	String		Fault description
	solution	String		Solution
	repairFlag	Boolean		Whether to repair

B.2.3.2 Organization

B.2.3.2.1 ControlCenter

Entity type name	***ControlCenter***
Meaning	Control center
Parent entity type (parent class)	*Organization*
Description	A control center collects all data from equipment and monitors their states.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.3.3 Person

B.2.3.3.1 Worker

Entity type name	***Worker***			
Meaning	**Worker**			
Parent entity type (parent class)	***Person***			
Description	**Worker of the plant.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	workerID	String		Worker ID

B.2.3.4 Location

B.2.3.4.1 GeographicalRegion

See definition in B.2.2.4.1.

B.2.3.4.2 SubGeographicalRegion

See definition in B.2.2.4.2.

B.2.3.5 Time

See definition in B.2.2.5.

B.2.3.6 Relation type definition

B.2.3.6.1 contain

Relation type name	***Contain***		
Meaning	**Contain**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Plant	GeneratingUnit	
	GeneratingUnit	AuxiliaryEquipment	
	GeneratingUnit	CoreEquipment	
	GeographicalRegion	SubGeographicalRegion	
Relation attributes	[None]		

B.2.3.6.2 subClassOf

Relation type name	*subClassOf*		
Meaning	Subclass of		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	An entity concept of nonleaf nodes in the conceptual hierarchy tree	An entity concept of nonleaf nodes in the conceptual hierarchy tree	
Relation attributes	[None]		

B.2.3.6.3 drivenBy

Relation type name	*drivenBy*		
Meaning	Driven by		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	GeneratingUnit	PrimaryEnergy	The generator set is driven by energy
Relation attributes	[None]		

B.2.3.6.4 operate

Relation type name	*operate*		
Meaning	Operate		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Worker	Plant	Workers run power plants
	Worker	GeneratingUnit	Workers run generation unit
Relation attributes	[None]		

B.2.3.6.5 execute

Relation type name	*Execute*		
Meaning	Executing events		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	Worker	RepairEvent	Executing repair event
Relation attributes	[None]		

B.2.3.6.6 cause

Relation type name	***Cause***		
Meaning	**Cause trouble**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	FaultEvent	AbnormalEvent	Fault can cause abnormal event
	FaultEvent	OutageEvent	Fault can cause outage event
Relation attributes	[None]		

B.2.3.6.7 connectTo

Relation type name	***connectTo***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	GeneratingUnit	**PowerGrid**	
Relation attributes	[None]		

B.2.3.6.8 uploadDataTo

Relation type name	***uploadDataTo***		
Meaning	**Upload data to control center**		
Description	**The equipment uploads data to the information systems of the control center.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	CoreEquipment	ControlCenter	
	AuxiliaryEquipment	ControlCenter	
Relation attributes	[None]		

B.2.3.6.9 alert

Relation type name	***Alert***		
Meaning	**Alert abnormal event**		
Description	**The control center alerts an abnormal event.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	ControlCenter	**AbnormalEvent**	
Relation attributes	[None]		

B.2.3.6.10 solve

Relation type name	***Solve***		
Meaning	**Solve fault**		
Description	**The repair event solves faults.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RepairEvent	**FalutEvent**	
Relation attributes	[None]		

B.2.3.6.11 locate

Relation type name	***locate***		
Meaning	**Is located in**		
Description	**It describes the region where entities are located.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Plant	**SubGeographicalRegion**	**The region where the plant is located**
Relation attributes	[None]		

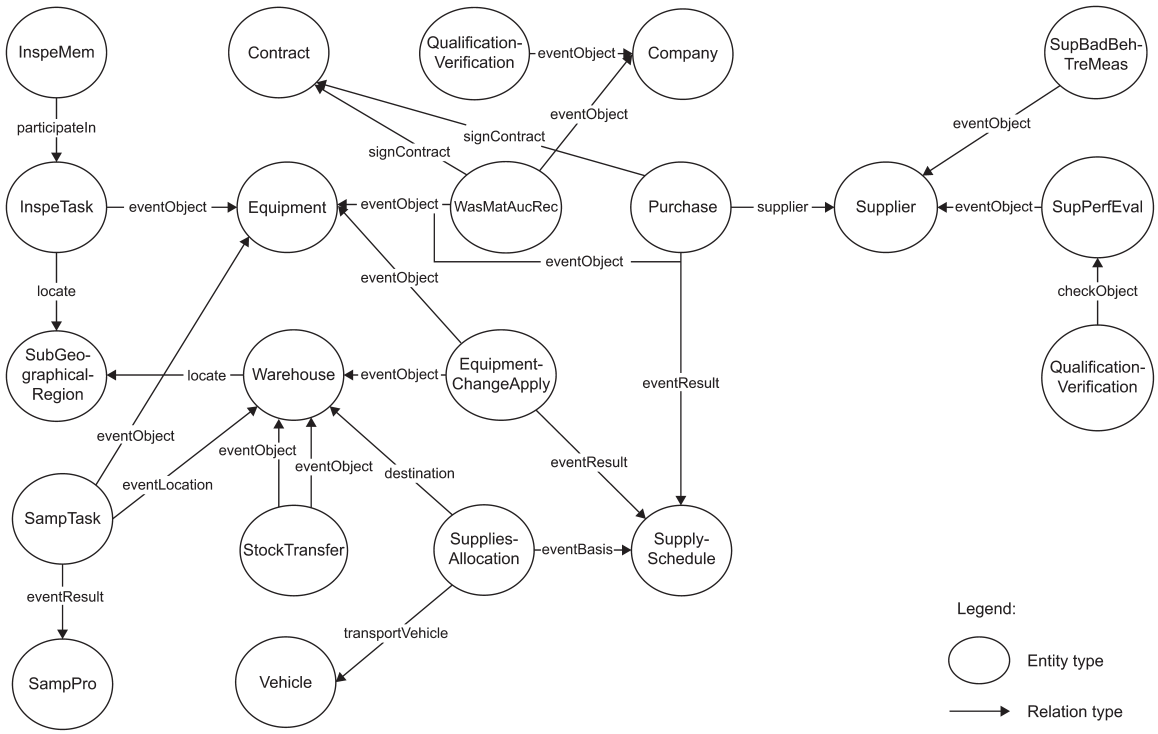


Figure B.3—Supplies domain entity types and relation types schema

B.2.3.6.12 endAt

Relation type name	***endAt***		
Meaning	**The end time of events**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	AbnormalEvent	Time	End time of abnormal events
	OutageEvent	Time	End time of outage events
	RepairEvent	Time	End time of repair events
Relation attributes	**[None]**		

B.2.3.6.13 startAt

Relation type name	*startAt*		
Meaning	**The start time of events**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	AbnormalEvent	Time	Start time of abnormal events
	OutageEvent	Time	Start time of outage events
	RepairEvent	Time	Start time of repair events
Relation attributes	**[None]**		

B.2.4 Supply chain domain

Supply chain domain entity types and relation types schema are shown in Figure B.3.

B.2.4.1 PowerThing

B.2.4.1.1 PowerItem

B.2.4.1.1.1 MatBasicInf

Entity type name	*MatBasicInf*			
Meaning	**Material**			
Parent entity type (parent class)	*PowerItem*			
Description	**All kinds of basic information on materials needed for the project implementation, production operation and maintenance, and daily office work of companies within the scope of the state grid, including material code, material description, unit of measurement, material group, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	materialDesc	String		Material description
	materialGroup	String		Material group
	materialCode	String		Material code
	materialType	String		Material type
	maintenanceType	String		Maintenance type

B.2.4.1.1.2 WasteMaterial

Entity type name	***WasteMaterial***			
Meaning	**Waste material**			
Parent entity type (parent class)	***PowerItem***			
Description	**Recording basic information of waste materials of the unit, such as material description, unit, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	materialDesc	String		Material description
	materialGroup	String		Material group
	wasteMaterialsCoding	String		Waste material code
	materialGroupDesc	String		Material group description

B.2.4.1.1.3 RecQualnfo

Entity type name	*RecQuaInfo*			
Meaning	**Recycler qualification information**			
Parent entity type (parent class)	***PowerItem***			
Description	**Recording basic information of waste materials of the unit, such as material description, unit, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	authRepName	String		Authorized representative name
	bankAcct	String		Bank account no.
	bankId	String		Bank ID
	busiOrgId	String		Business origin ID
	contact	String		Contact
	contactMobile	String		Contact mobile
	eMail	String		Email
	fax	String		Fax
	firstAudPassTime	Time		Time of passing the first audit
	idType	String		ID type
	legalRepIdNo	String		Legal representative ID no.
	legalRepMobile	String		Legal representative mobile
	legalRepName	String		Legal representative name
	postAddr	String		Post address
	recycAchId	String		Recycler qualification information ID
	recycAchStatus	String		Recycler qualification status
	recycId	String		Recycler ID
	recycLev	String		Recycler level
	achInvalidTime	Time		Expiration time of qualification
	achProvId	String		Qualification province ID
	achReqYear	String		Qualification request year

B.2.4.1.1.4 RecycleCom

Entity type name	***RecycleCom***			
Meaning	**Recycler**			
Parent entity type (parent class)	***PowerItem***			
Description	**Recording basic information of waste materials of the unit, such as material description, unit, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	agreeFlag	Boolean		Agreement flag
	areaId	String		Area ID
	busiAchDes	String		Main business scope
	busiLicCode	String		Business license registration number
	coWeb	String		Company website
	email	String		Email
	eSign	String		E-signature
	fax	String		Fax
	legalRep	String		Legal representative
	licType	String		License type
	mailAddr	String		Mail address
	regAreaId	String		Registration area ID
	regContact	String		Registered contact
	regOrgCode	String		Organization code
	regTime	Time		Registration time
	socialCode	String		Unified social credit code
	taxCode	String		Tax code

B.2.4.1.1.5 Vehicle

Entity type name	***Vehicle***			
Meaning	**Distribution vehicles**			
Parent entity type (parent class)	***PowerItem***			
Description	**Describing the basic information on material distribution vehicles and their transport capacity.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	carrier	String		Carrier
	fixedTel	String		Carrier's fixed telephone
	cellPhone	String		Carrier's cell phone
	causeOfReturn	String		Cause of return
	approvalDate	Time		Date of approval
	submissionDate	Time		Date of submission
	licensePlate	String		License plate
	vehicleModel	String		Vehicle model

B.2.4.1.1.6 WareHouse

Entity type name	***WareHouse***			
Meaning	**Warehouse information**			
Parent entity type (parent class)	***PowerItem***			
Description	**Recording information on the warehouse storing materials, including the no., address, and area of the warehouse.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	warehouseVersion	String		Warehouse version Number
	stockPlaceCode	String		Stock place code
	warrhouseLevel	String		Warehouse level
	address	String		Warehouse address
	comptetionDate	Time		Warehouse completion Date
	stockPlaceName	String		Stock place name
	owner	String		Owner of warehouse Assets
	status	String		Warehouse state
	administrativeDept	String		Administrative department
	informatDesc WarehouseRenovat	String		Warehouse renovation information description

B.2.4.1.1.7 Equipment

See definition in B.2.2.1.1.4.

B.2.4.1.2 PowerEvent

B.2.4.1.2.1 Contract

Entity type name	***Contract***			
Meaning	**Purchasing contract**			
Parent entity type (parent class)	***PowerEvent***			
Description	**It describes the basic information on the contract business. After the bid-winning result is issued, the contract operator will generate the draft contract according to the bid-winning result, maintain the information on the contracting parties, draft the contract, and review the relevant business. Suppliers can confirm or reject the draft contract, which will take effect after review.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	conId	String		Contract ID
	conItemCode	String		Contract item code
	conLawCode	String		Contract law code
	conName	String		Contract name
	conSuppMatId	String		Contract purchase supply order ID
	conTransTime	Time		Contract transfer time
	conType	String		Contract type
	conValidDate	Time		Effective date of contract
	demandOrgCode	String		Demand organization code
	demandOrgId	String		Demand organization ID
	demandOrgName	String		Demand organization name
	depositMat	String		Whether it is deposit material
	taxAmt	Numeric		Tax-included amount
	taxRate	Numeric		Tax rate
	taxStringPrice	Numeric		Tax-included unit price
	taxTotPrice	Numeric		Tax-included total price
	amt	Numeric		Quantity
	cfmDlvTime	Time		Confirmed delivery time
	suppId	String		Supplier ID

B.2.4.1.2.2 EquipmentChangeApply

Entity type name	***EquipmentChangeApply***			
Meaning	**Equipment change application form**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Recording the initial application for equipment change.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	applicationTime	Time		Date of application
	changeContent	String		Content of change (String)
	groupOpinion	String		Group leader's opinion (String)
	applicationStatus	String		Status of application form
	specialResponsibility Opinion	String		Special responsibility opinion (String)
	applicationType	String		Application type
	leaderOpinion	String		Leader's opinion (String)
	deviceChangeReason	String		Device change reason (String)

B.2.4.1.2.3 Fault

Entity type name	***Fault***			
Meaning	**Fault**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Describing information on fault.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	faultDesc	String		Fault description
	faultUnit	String		Fault unit
	faultType	String		Fault type
	faultTime	String		Fault time
	location	String		Fault location

B.2.4.1.2.4 InspeTask

Entity type name	***InspeTask***			
Meaning	**Routing inspection task**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Routing inspection tasks are used to track and monitor the whole inspection process and record the progress and status of tasks.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	bQmTcTaskMatId	String		ID of the relationship between the routing inspection task and material type
	matMaxId	String		Maximum material category ID
	matMedId	String		Medium material category ID
	matMinId	String		Minimum material category ID
	mgmtQty	Numeric		Quantity in process
	pbmEquQty	Numeric		The number of faulty devices
	prjSplId	Numeric		Specific project responsibility
	qmGrpQty	Numeric		The number of monitoring groups
	qmMatMaxCatId	String		Maximum material category ID of quality monitoring
	qmTcGroupId	String		Routing inspection group ID
	qmTcTaskId	String		Routing inspection task ID
	taskDlvTime	Time		Routing inspection task delivery time
	taskEndTime	Time		Routing inspection task end time
	taskName	String		Task name
	taskStatus	String		Routing inspection task status

B.2.4.1.2.5 WasMatAucRec

Entity type name	***WasMatAucRec***			
Meaning	**Scrap supplies bidding events**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Bidding records will record the bidding information of recyclers, and the monitoring person can view the bidding process in real time.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	attbidRoundId	String		Bidding round ID
	attbidStatus	String		Bidding status
	beginTime	Time		Begin time
	pkgStringPrice	Numeric		Subpackage quotation unit price
	pkgTotPrice	Numeric		Subpackage quotation total price
	priceTime	Time		Time of quotation
	recycId	String		Recycler ID
	susReason	String		Reason for Suspension
	susTime	Time		Time of suspension
	updTime	Time		Time of modification
	wmAttbidId	String		Bidding record ID
	wmBidPkgId	String		Biding subpackage ID

B.2.4.1.2.6 QualificationVerification

Entity type name	***QualificationVerification***			
Meaning	**Qualification audit event of recycler**			
Parent entity type (parent class)	***PowerEvent***			
Description	**The audit record information formed during the qualification audit of recyclers.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	audNote	String		Audit opinion
	audStatus	String		Audit status
	orgId	String		Organization ID
	recycAchAudId	String		Qualification audit ID of recycler

B.2.4.1.2.7 Purchase

Entity type name	***Purchase***			
Meaning	**Purchase**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Recording material purchase information.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	materialVouNum	String		Material voucher number
	priceUnit	String		The price unit used in the purchase order
	postingDate	Time		The posting date in the Voucher
	item	String		Items in the material Voucher
	moveType	String		Movement type (inventory management)
	amount	Numeric		Amount in standard Currency
	voucherCode	String		Purchase voucher No.
	itemCode	String		Item No. of the purchase voucher
	deliveryDoneFlag	String		Delivery completion flag
	voucherYear	Numeric		Material voucher year
	quantity	Numeric		Quantity

B.2.4.1.2.8 StockTransfer

Entity type name	***StockTransfer***			
Meaning	**Stock transfer**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Stock transfer is mainly used to describe the transfer of materials in the warehouse between warehouses, between factories and between company codes, and the generated information on the stock transfer voucher.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	bankTransferaMount	Numeric		Bank transfer amount
	materialCoding	String		Material code
	materialDocument	String		Material voucher
	moveIntoCompany	String		Move into a company
	moveIntoFactory	String		Move into a factory
	moveOutOfStock	String		Move out of stock
	moveOutOfTheCompany	String		Move out of the Company
	moveOutOfTheFactory	String		Move out of the factory
	moveToThePlaceOfStock	String		Move into the place of Stock
	stringtityOfLibrary	String		The number of bank Transfer
	moveType	String		Movement type

B.2.4.1.2.9 SuppliesAllocation

Entity type name	***SuppliesAllocation***			
Meaning	**Material transfer event**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Allocation is the specific implementation information of a certain material transfer, including the attributes and number of supplied materials.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	deliveryTime	Time		Delivery time
	transferOrderNum	String		Transfer order no.
	entryName	String		Project name
	ERPtransferOrderNum	String		Transfer order number
	feedbackAdvice	String		Feedback advice
	inputOrgCode	String		Input organization code
	allocationLines	Numeric		Amount of allocation lines
	itemPrice	Numeric		Item price
	materialName	String		Material name
	materialCode	String		Material code
	measurementUnit	String		Unit of measurement
	inputOrgName	String		Name of the input organization
	outputOrgName	String		Name of the output organization
	outputOrgCode	String		Output organization code
	delivertyPlace	String		Place of delivery

B.2.4.1.2.10 SupPerfEval

Entity type name	***SupPerfEval***			
Meaning	**Supplier performance evaluation**			
Parent entity type (parent class)	***PowerEvent***			
Description	**It refers to the form of supplier evaluation, mainly including the name of evaluation form, status of evaluation form, supplier code, supplier name, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	suppId	String		Supplier ID
	suppKpiEvaRptId	String		Supplier performance evaluation ID
	evaOrgId	String		Evaluation organization ID
	evaOrgName	String		Evaluation organization name
	evaRateRslt	Numeric		Weighted evaluation score
	evaRslt	Numeric		Evaluation score
	evaTmplName	String		Evaluation template name
	matDes	String		Material description
	matOrgFlag	Numeric		Material range evaluation unit flag
	mdmCode	String		Supplier code
	orgName	String		Supplier name

B.2.4.1.2.11 SupBadBehTreMeas

Entity type name	***SupBadBehTreMeas***			
Meaning	**Punishment measures for supplier's bad behaviors**			
Parent entity type (parent class)	***PowerEvent***			
Description	**It refers to the punishment measures for the supplier's bad behaviors, including the name, type, duration, and status of punishment measures.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	dealBeginTime	Time		Deal begin time
	dealDur	String		Deal duration type
	dealEndTime	Time		Deal end time
	dealNote	String		Deal note
	extraDealNote	String		Extraordinary deal note
	mtdStatus	String		Status of punishment measures
	suppBbhDealMtdId	String		ID of punishment measure for supplier's bad behavior
	suppBbhDealType	String		Type pf punishment measure
	suppBbhOrgTypeId	String		Application scope type of bad behaviors
	suppId	String		Supplier ID

B.2.4.1.2.12 SampTask

Entity type name	*SampTask*			
Meaning	Quality sampling inspection task			
Parent entity type (parent class)	*PowerEvent*			
Description	It refers to tasks to be created in the process of sampling inspection, including task no., task name, task status, sample base, start and end time of sampling inspection task, review flag, times of reviews, and so on.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	conSpId	String		Contract supply plan ID
	qmChkOrgId	String		Inspection organization ID
	qmScTaskId	String		Sampling inspection task ID
	rdOrg	String		Inspection information recording organization
	reviewCnt	Numeric		Times of reviews
	reviewFlag	String		Review flag
	sampleOrgId	String		Sampling organization ID
	sampleQty	Numeric		Sample base
	scTaskBeginTime	Time		Start time of sampling inspection task
	scTaskCode	String		Sampling inspection task no.
	scTaskEndTime	Time		End time of sampling inspection task
	scTaskType	String		Sampling inspection task type
	taskName	String		Task name
	taskStatus	String		Sampling inspection task status

B.2.4.1.2.13 SupplySchedule

Entity type name	*SupplySchedule*			
Meaning	Material supply schedule			
Parent entity type (parent class)	*PowerEvent*			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	materialQuantity	Numeric		Quantity
	materialDesc	String		Material description
	supplyPlace	String		Supply place
	supplyTime	Time		Supply time
	materialCode	String		Material code

B.2.4.1.3 PowerRecord

B.2.4.1.3.1 SampPro

Entity type name	***SampPro***			
Meaning	**Sampling inspection problem**			
Parent entity type (parent class)	***PowerRecord***			
Description	**It refers to sampling problems in the process of sampling inspection, mainly including problem no., problem analysis, problem type, problem details, problem severity, rectification measures, problem status, rectification, and acceptance.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	pbmAna	String		Problem analysis
	pbmLev	String		Severity of sampling inspection problem
	pbmNote	String		Problem note
	pbmSn	String		Problem no.
	pbmStatus	String		Sampling inspection problem status
	pbmType	String		Sampling inspection problem type
	qmScSamplePbmId	String		Sampling inspection problem ID
	repairQty	Numeric		Quantity of repairs

B.2.4.2 Organization

B.2.4.2.1 Company

Entity type name	***Company***			
Meaning	**Company**			
Parent entity type (parent class)	***Organization***			
Description	**A company is a legal entity that owns and operates power system resources and is a party to the exchange and transmission contract.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	companyType	String		Company type

B.2.4.2.2 Factory

Entity type name	***Factory***
Meaning	Manufacturer

Entity type name	***Factory***
Parent entity type (parent class)	*Organization*
Description	Manufacturer or producer
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.4.2.3 Supplier

Entity type name	***Supplier***			
Meaning	**Supplier**			
Parent entity type (parent class)	***Factory***			
Description	**Suppliers of materials and services eligible for bidding within the scope of the state grid, with detailed records of supplier qualifications, basic data, and so on.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	address	String		Address
	bankCode	String		Bank code
	bankAccountNum	String		Bank account number
	bankAcctRequire	String		Reference requirements for bank accounts
	companyCode	String		Company code
	businessLicence	String		Business license
	taxRegistrationCer	String		Tax registration certificate
	uniSocialCreCode	String		Unified social credit code

B.2.4.3 Person

B.2.4.3.1 InspeMem

Entity type name	***InspeMem***			
Meaning	**Routing inspection member**			
Parent entity type (parent class)	***Person***			
Description	**Describing the basic information on material distribution vehicles and their transport capacity.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	eduLevId	String		Education level
	evabidFlag	String		Bid evaluation expert or not?
	leaderFlag	String		Team leader or not?
	majorBeginTime	Time		Major begin time
	majorEqu	String		Professional equipment
	orgName	String		Organization name
	provId	String		Province ID
	qmTcGroupId	String		Routing inspection group ID
	qmTcMemId	String		Routing inspection member ID
	userAcctId	String		User account ID
	userId	String		User ID

B.2.4.4 Location

B.2.4.4.1 GeographicalRegion

See definition in B.2.2.4.1.

B.2.4.4.2 SubGeographicalRegion

See definition in B.2.2.4.2.

B.2.4.5 Time

See definition in B.2.1.5.

B.2.4.6 Relation type definition

B.2.4.6.1 subClassOf

Relation type name	***subClassOf***		
Meaning	**Subclass of**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	An entity concept of nonleaf nodes in the conceptual hierarchy tree	**An entity concept of nonleaf nodes in the conceptual hierarchy tree**	
Relation attributes	[None]		

B.2.4.6.2 eventResult

Relation type name	***eventResult***		
Meaning	**Event result**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	SampTask	SampPro	Sampling inspection result
	Purchase	SupplySchedule	Material purchase, generation, and supply plan
Relation attributes	[None]		

B.2.4.6.3 participateIn

Relation type name	***participateIn***		
Meaning	**Event participant**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	InspeMem	**InspeTask**	**Routing person participates in inspection tasks**
Relation attributes	[None]		

B.2.4.6.4 signContract

Relation type name	*signContract*		
Meaning	**Contract signed in transaction event**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	WasMatAucRec	Contract	Sales contract of waste materials
	Purchase	Contract	Material purchase contract
Relation attributes	[None]		

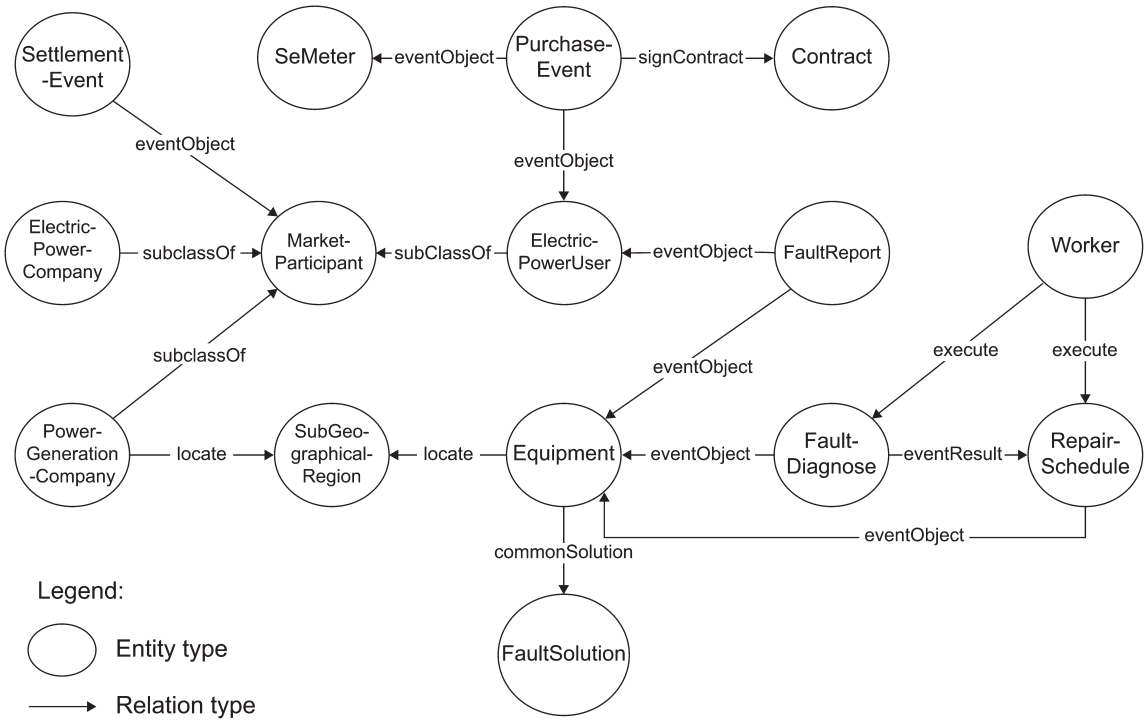


Figure B.4—Market domain entities and relationship schema

B.2.4.6.5 checkObject

Relation type name	***checkObject***		
Meaning	**Information on objects in audit event**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	QualificationVerfication	Company	Information on qualification verification of company
	QualificationVerfication	Supplier	Verification of suppliers' qualifications
	SampTask	Equipment	Sampling inspection object
Relation attributes	[None]		

B.2.4.6.6 eventLocation

Relation type name	***eventLocation***		
Meaning	**Event location**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	SampTask	WareHouse	Place of quality sampling inspection warehouse
	InspeTask	SubGeographicalRegion	Place of routing inspection
Relation attributes	[None]		

B.2.4.6.7 eventObject

Relation type name	***eventObject***		
Meaning	**Event object**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	QualificationVerifacation	Company	Qualification verification object
	QualificationVerifacation	Supplier	Qualification verification object
	SupBadBehTreMeas	Supplier	Object of penalty measures
	WasMatAucRec	Equipment	Waste recovery equipment
	Purchase	Equipment	Purchase equipment
Relation attributes	[None]		

B.2.4.6.8 eventBasis

Relation type name	*eventBasis*		
Meaning	Event basis		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	SuppliesAllocation	SupplySchedule	Material allocation based on the allocation plan
Relation attributes	[None]		

B.2.4.6.9 locate

Relation type name	*Locate*		
Meaning	is located in		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	WareHouse	SubGeographicalRegion	Location of warehouse
Relation attributes	[None]		

B.2.5 Market domain

Market domain entities and relationship schema are shown in Figure B.4.

B.2.5.1 PowerThing

B.2.5.1.1 PowerItem

B.2.5.1.1.1 Equipment

See definition in B.2.2.1.1.4.

B.2.5.1.1.2 SeMeter

Entity type name	***SeMeter***			
Meaning	**Market measurement point**			
Parent entity type (parent class)	***PowerItem***			
Description	**Basic information on measurement points related to power generation in power plants and on-grid power.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	meterCode	String		Measurement point code
	meterRatio	Numeric		Measurement point ratio
	startTime	Time		Start time of measurement point
	endTime	Time		End time of measurement point
	updateTime	Time		Record update time
	caliberType	String		Caliber type
	meterCode	String		Measurement point code
	meterRatio	Numeric		Measurement point ratio
	startTime	Time		Start time of measurement point
	endTime	Time		End time of measurement point
	tableNumber	String		Table number

B.2.5.1.2 PowerEvent

B.2.5.1.2.1 PurchaseEvent

Entity type name	***PurchaseEvent***			
Meaning	**Electricity purchase transaction incident**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Transaction and settlement of direct transactions of large users.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	year	Numeric		Year of data generation
	month	Numeric		Month of data generation
	marketId	String		Service scenario
	transactionNo	String		Transaction no.
	transactionName	String		Transaction name
	transactionType	String		Transaction type
	startTime	Time		Begin time
	endTime	Time		End time
	transactionEnergy	Numeric		Transaction energy
	dealNo	Numeric		The number of deals
	generationEnterpriseNo	Numeric		The number of power generation enterprises
	powerUsersNo	Numeric		The number of power users
	onLineChange	Numeric		Change in the on-grid price compared with the approved price
	usersChange	Numeric		Change in price on the user side compared with the tariff
	lastMonthSeEnergy	Numeric		Actual settled energy quantity by last month
	currentMonthSeEnergy	Numeric		Energy quantity settled in the current month

B.2.5.1.2.2 SettlmentEvent

Entity type name	*SettlementEvent*			
Meaning	Settlement event by the electric power company			
Parent entity type (parent class)	*PowerEvent*			
Description	Describing information on the final settlement results of the electric power company.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	settlementUnitId	String		Settlement unit ID
	recParticipantId	String		Recipient market participant ID
	payerParticipantId	String		Payer market participant ID
	contractId	String		Contract ID
	setComponentTypeId	String		Settlement component type ID
	totalEnergy	Numeric		Total energy
	totEnePrice	Numeric		Total energy price
	totEneFee	Numeric		Total energy fee
	traDeSetUnitId	String		Settlement unit ID of the counterparty
	traDeSetUnitType	String		Settlement unit name of the counterparty

B.2.5.1.2.3 FaultReport

Entity type name	*FaultReport*			
Meaning	Fault report event			
Parent entity type (parent class)	*PowerEvent*			
Description	Describing information on fault report.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	faultDesc	String		Fault description
	faultUnit	String		Fault unit
	faultType	String		Fault type
	faultTime	String		Fault time
	location	SubGeographicalRegion		Fault location
	reportor	String		Reporter

B.2.5.1.2.4 FaultDiagnose

Entity type name	***FaultDiagnose***			
Meaning	**Fault diagnosis event**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Describing information on fault diagnosis.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	faultDesc	String		Fault description
	faultUnit	String		Fault unit
	faultType	String		Fault type
	faultReason	String		Diagnosis of fault reason
	operator	String		Operator

B.2.5.1.2.5 RepairSchedule

Entity type name	***RepairSchedule***
Meaning	Repair schedule
Parent entity type (parent class)	*Schedule*
Description	Describe information in repair schedule.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]

B.2.5.1.2.6 Schedule

See definition in B.2.2.1.2.2.

B.2.5.1.2.7 Contract

Entity type name	***Contract***			
Meaning	**Contract**			
Parent entity type (parent class)	***PowerEvent***			
Description	**The most basic information contained in the contract.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	contractTypeId	String		Contract type ID
	paperContractCode	String		Paper contract code
	paperContractName	String		Paper contract name
	signState	String		State of signing
	signedDate	Time		Date of signing
	contractFilingTime	Time		Time of contract filing
	contractCycle	String		Contract cycle
	purchaser	String		Electricity purchaser
	seller	String		Electricity seller
	contractQuantity	Numeric		Contract quantity
	quantityType	String		Quantity type
	contractStartDate	Time		Contract start date
	contractEndDate	Time		Contract end date
	isOpen	Boolean		Open contract or not
	lossUnderTaker	String		Line loss holder
	execType	String		Contract execution type
	sequenceId	String		Contract sequence ID
	contractPrice	Numeric		Contract price
	purchaserPrice	Numeric		Purchase price

B.2.5.1.2.8 FaultSolution

Entity type name	***FaultSolution***			
Meaning	**Troubleshooting measures**			
Parent entity type (parent class)	***PowerEvent***			
Description	**Recording troubleshooting measures.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	solutionType	String		Solution type
	solutionDesc	String		Solution description
	faultType	String		Fault type corresponding to the solution

B.2.5.2 Organization

B.2.5.2.1 MarketParticipant

Entity type name	***MarketParticipant***			
Meaning	**Market participant**			
Parent entity type (parent class)	***Organization***			
Description	**Basic information on market entities participating in electric power market businesses.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	marketId	String		Service scenario
	oldName	String		Former name
	managerId	String		Business scope
	participantType	String		Market participant type
	participantCode	String		Registration code
	status	String		Status
	startEffectiveDate	Time		Listing date
	delistingDate	Time		Delisting date

B.2.5.2.2 PowerGenerationCompany

Entity type name	***PowerGenerationCompany***			
Meaning	**Power generation group**			
Parent entity type (parent class)	***MarketParticipant***			
Description	**It is mainly used to describe information on the national power generation group used by the electric power market.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	correspondingAddress	String		Correspondence address
	Corporation	String		Legal representative
	linkman	String		Frequent contact
	contactPrio	String		Telephone
	telephone	String		Cell phone
	faxNumber	String		Fax number
	Email	String		Email
	website	String		Website
	marketId	String		Service scenario
	groupId	String		Power generation group ID
	gengroupName	String		Power generation group name
	aliasName	String		Alias
	groupCode	String		Power generation group ID code
	startEffectiveDate	Time		Effective time
	endeffectiveTime	Time		Time of expiry

B.2.5.2.3 ElectricPowerCompany

Entity type name	***ElectricPowerCompany***			
Meaning	**Electric power company**			
Parent entity type (parent class)	***MarketParticipant***			
Description	**The electric power company negotiates the price with the power generation company and eventually sells electric power to customers.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	saleComType	String		Type of electric power company
	Corporation	String		Legal representative
	linkman	String		Frequent contact
	contactPrio	String		Telephone
	telephone	String		Cell phone
	faxNumber	String		Fax number
	email	String		Email
	webSite	String		Website

B.2.5.2.4 ElectricPowerUser

Entity type name	***ElectricPowerUser***
Meaning	Electric power user
Parent entity type (parent class)	*MarketParticipant*
Description	Customers involved in electric power purchase transactions.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]

B.2.5.3 Person

B.2.5.3.1 Worker

Entity type name	***Worker***			
Meaning	**Worker**			
Parent entity type (parent class)	***Person***			
Description	**Maintenance persons are responsible for repairing electrical equipment with faults.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	gender	String		Gender
	age	Numeric		Age
	phone	String		Phone

B.2.5.4 Location

B.2.5.4.1 GeographicalRegion

See definition in B.2.2.4.1.

B.2.5.4.2 SubGeographicalRegion

See definition in B.2.2.4.2

B.2.5.5 Time

See definition in B.2.2.5.

B.2.5.6 Relation type definition

B.2.5.6.1 subClassOf

Relation type name	***subClassOf***		
Meaning	**Subclass of**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	An entity concept of nonleaf nodes in the conceptual hierarchy tree	**An entity concept of nonleaf nodes in the conceptual hierarchy tree**	
Relation attributes	[None]		

B.2.5.6.2 signContract

Relation type name	***signContract***		
Meaning	**Contract signed in transaction event**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	PurchaseEvent	**Contract**	**Contract on electricity purchase transaction**
Relation attributes	[None]		

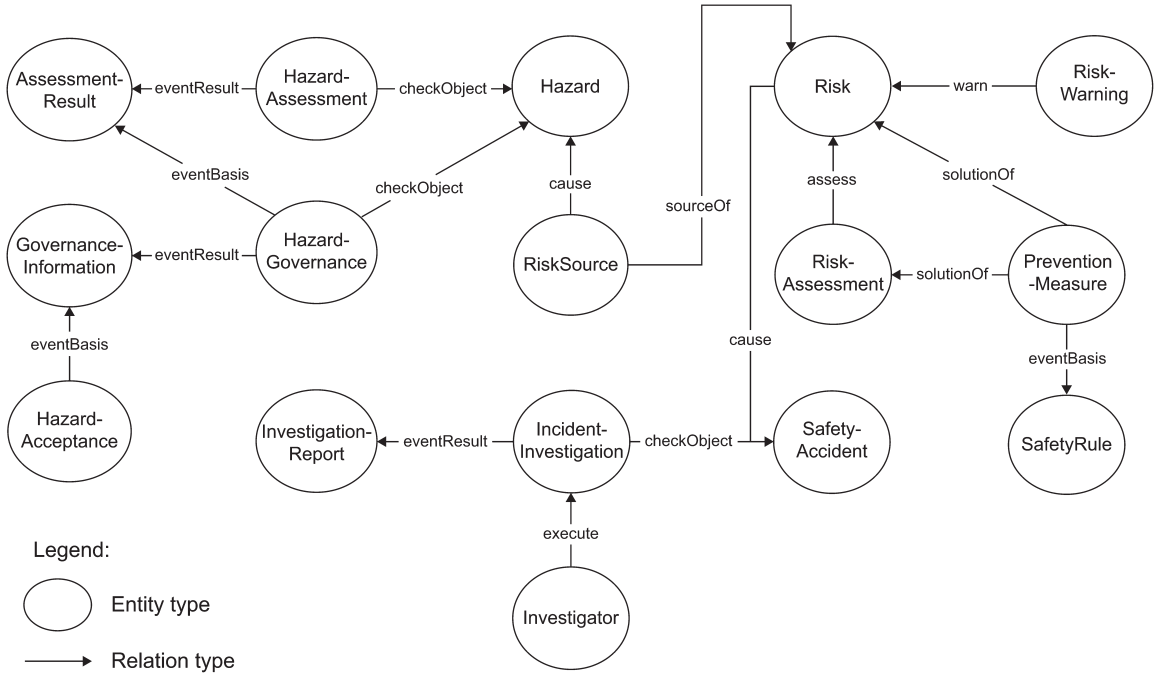


Figure B.5—Security domain entities and relationship schema

B.2.5.6.3 diagnose

Relation type name	*diagnose*		
Meaning	Fault equipment is diagnosed in the faultDiagnose event.		
Description			
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	FaultDiagnose	Equipment	Diagnose fault equipment
Relation attributes	[None]		

B.2.5.6.4 reportEquipment

Relation type name	*reportEquipment*		
Meaning	Report equipment that is to be maintained		
Description	Faulty equipment reported in an event reported by a customer.		
Relation constraints	Entity type of starting point	Entity type of ending point	Description
	FaultReport	Equipment	Equipment reported
Relation attributes	[None]		

B.2.5.6.5 eventObject

Relation type name	***eventObject***		
Meaning	**Event object**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	FaultDiagnose	Equipment	Diagnosis object of a fault diagnosis event
	PurchaseEvent	ElectricPowerUser	Electric power purchase user of an electric power purchase event
Relation attributes	[None]		

B.2.5.6.6 eventResult

Relation type name	***eventResult***		
Meaning	**Event result**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	FaultDiagnose	RepaireSchedule	Diagnosis result of a fault diagnosis event
	PurchaseEvent	Contract	Power purchase contract on a power purchase event
Relation attributes	[None]		

B.2.5.6.7 commonSolution

Relation type name	***commonSolution***		
Meaning	**Common solution**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Equipment	**FaultSolution**	**Common solution to equipment fault**
Relation attributes	[None]		

B.2.5.6.8 execute

Relation type name	*Execute*		
Meaning	**Execute**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	Worker	RepairSchedule	
	Worker	FaultDiagnose	
Relation attributes	[None]		

B.2.6 Security domain

Security domain entities and relationship schema are shown in Figure B.5.

B.2.6.1 PowerThing

B.2.6.1.1 PowerEvent

B.2.6.1.1.1 RiskAssessment

Entity type name	*RiskAssessment*			
Meaning	**Risk assessment**			
Parent entity type (parent class)	*PowerEvent*			
Description	**It is mainly used to record risk information during the assessment phase.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	preAssessmentLevel	String		Preassessment level
	preAssessor	String		Preassessor
	preAssessorDate	Time		Preassessment date
	preAssessmentLeader	String		Preassessment leader
	preLeaderSignDate	Time		Date of signing by the preassessment leader
	preAssessorSigningDate	Time		Date of signing by the preassessor
	assessmentLevel	String		Assessment level
	majorHiddenDangerLevel	String		Major hidden danger level
	assessor	String		Assessor
	assessorSigningDate	Time		Date of signing by the Assessor
	assessmentLeader	String		Assessment leader
	leaderSignDate	Time		Date of signing by the assessment leader

B.2.6.1.1.2 HazardAssessment

Entity type name	***HazardAssessment***			
Meaning	**Hazard assessment**			
Parent entity type (parent class)	***PowerEvent***			
Description	**It is mainly used to record hazard information during the assessment phase.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	preAssessmentLevel	String		Preassessment level
	preAssessor	String		Preassessor
	preAssessorDate	Time		Preassessment date
	preAssessmentLeader	String		Preassessment leader
	preLeaderSignDate	Time		Date of signing by the preassessment leader
	preAssessorSigningDate	Time		Date of signing by the preassessor
	assessmentLevel	String		Assessment level
	majorHiddenDangerLevel	String		Major hidden danger level
	assessor	String		Assessor
	assessorSigningDate	Time		Date of signing by the assessor
	assessmentLeader	String		Assessment leader
	leaderSignDate	Time		Date of signing by the assessment leader

B.2.6.1.1.3 HazardGovernance

Entity type name	*HazardGovernance*			
Meaning	Hazard governance			
Parent entity type (parent class)	*PowerEvent*			
Description	It is mainly used to record hazard information during the governance phase.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	managingInvestmentFunds	String		Funds invested in the governance
	governUnit	String		Governance unit
	governMan	String		Governance officer
	startDate	Time		Start date
	endDate	Time		End date
	controlMeasures	String		Prevention and control measures
	whetherGovernanceObjectives	String		Whether the governance objectives and tasks are defined
	whetherManagementFunds	String		Whether management funds and supplies are in place
	whetherGovernanceTime	String		Whether the governance time requirements are defined
	whetherAdministrativeStaff	String		Whether person of governance organization is decided
	whetherSafetyMeasures	String		Whether safety measures and emergency plans are madee
	completeGovernFunds	String		Accumulated governance funds (RMB 10 thousand)
	governCompletion	String		Completion of governance (rectification) (recording the last governance)
	planGovernFunds	String		Planned investment in governance funds (RMB 10 thousand)
	whetherPlanProject	String		Whether it is a planned project
	projectNumber	String		Project no.
	whetherfinishOnTime	String		Whether it is completed on time
	hazardCode	String		Hazard code
	whetherRectificated	String		Whether the rectification is complete
	rectificationCompletionTime	Time		Rectification completion time

B.2.6.1.1.4 HazardAcceptance

Entity type name	*HazardAcceptance*			
Meaning	Hazard acceptance			
Parent entity type (parent class)	*PowerEvent*			
Description	It is mainly used to record information on hazard acceptance.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	whetherRemoved	String		Whether hazards are eliminated
	acceptanceOrganizationUnit	String		Acceptance organization unit
	acceptMan	String		Acceptance officer
	acceptDate	Time		Date of signing by the acceptance officer
	acceptOpinion	String		Acceptance opinion
	acceptanceConclusion	String		Acceptance conclusion
	acceptLeader	String		Acceptance leader
	leaderSignDate	Time		Date of signing by the acceptance leader

B.2.6.1.1.5 RiskWarning

Entity type name	*RiskWarning*			
Meaning	Risk warning			
Parent entity type (parent class)	*PowerEvent*			
Description	It is used for early warning of risks generated in the process of power grid production, mainly including warning content, warning no., warning level, risk analysis, warning period, elimination time, and so on.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	warnClass	String		Risk category
	warnNum	String		Warming no.
	workDivide	String		Risk analysis
	warnbeginTime	Time		Warning begin time
	warnendTime	Time		Warning end time

B.2.6.1.1.6 IncidentInvestigation

Entity type name	*IncidentInvestigation*			
Meaning	Incident investigation			
Parent entity type (parent class)	*PowerEvent*			
Description	Recording information on safety accident investigation.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	investigationTime	Time		Investigation time
	investigationPlace	String		Place of investigation

B.2.6.1.1.7 SafetyAccident

Entity type name	*SafetyAccident*			
Meaning	Safety accident			
Parent entity type (parent class)	*PowerEvent*			
Description	A series of relevant regulations and methods formulated to guide human safety behaviors.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	type	String		Type
	eventDescription	String		Event description
	TimeOfOccurrence	Time		Time of occurrence
	locationOccur	String		Location of occurrence
	eventLevel	String		Event level
	eventUnit	String		Event unit
	accidentNumber	String		Accident number

B.2.6.1.2 PowerRecord

B.2.6.1.2.1 AssessmentResult

Entity Type Name	*AssessmentResult*			
Meaning	Event assessment result			
Parent entity type (parent class)	*PowerRecord*			
Description	It is mainly used to describe the result information obtained by event assessment.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	assessmentCode	String		Assessment code
	assessmentTime	Time		Assessment time
	conclusion	String		Assessment conclusion

B.2.6.1.2.2 InvestigationReport

Entity Type Name	***InvestigationReport***			
Meaning	**Incident investigation report**			
Parent entity type (parent class)	***PowerRecord***			
Description	**It is mainly used to describe the report information generated by the investigation after the event.**			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	accidentCode	String		Accident number
	superiorUnit	String		Superior unit
	accidentCorp	String		Accident unit
	affiliation	String		Affiliation relationship
	accidentClass	String		Accident category
	deathCount	String		Death toll
	seriouslyCount	String		The number of seriously injured people
	slightCount	String		The number of slight injuries
	accidentVest	String		Accident attribution
	directLoss	String		Direct loss

B.2.6.1.2.3 RiskSource

Entity type name	***RiskSource***
Meaning	RiskSource
Parent entity type (parent class)	*PowerRecord*
Description	It is the cause, state, or behavior, or a combination thereof, which may cause personal injury and (or) harm to health. One category includes energy or harmful substances that constitute the category I source of risk. The other category includes unsafe behavior of human, or the unsafe state of objects and the defects of supervision, namely, unsafe state, unsafe behavior in the definition of hazard.
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.6.1.2.4 Hazard

Entity type name	*Hazard*			
Meaning	Hazard			
Parent entity type (parent class)	*PowerRecord*			
Description	It is mainly used to record hazard information.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	Attribute name	Attribute value type	Attribute range	Description
	hazardTitle	String		Hazard title
	hazardCode	String		Hazard code
	hazardUnit	String		Hazard unit
	specialtyAssort	String		Specialty assortment
	specialtyDetailAssort	String		Detailed assortment of specialties
	discoveryPeople	String		Discoverer
	discoveryPeopleUnit	String		Discoverer's unit
	discoveryDate	Time		Discovery date
	hazardContent	String		Hazard content
	induceAftermate	String		Possible consequences
	attachFunctDept	String		Functional department
	whetherRecord	String		Whether the unplanned filing is completed
	causeClassification	String		Cause classification

B.2.6.1.2.5 PreventionMeasure

Entity type name	*PreventionMeasure*			
Meaning	Prevention measure			
Parent entity type (parent class)	*PowerRecord*			
Description	Protective and control measures for known risks.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	Attribute name	Attribute value type	Attribute range	Description
	measureType	String		Measure type
	content	String		The main content of prevention and control measures
	applicableScene	String		Application scenarios of prevention and control measures

B.2.6.1.2.6 Risk

Entity type name	*Risk*			
Meaning	Risk			
Parent entity type (parent class)	*PowerRecord*			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	riskContent	String		Risk content

B.2.6.1.2.7 SafetyRule

Entity type name	*SafetyRule*			
Meaning	Safety rules			
Parent entity type (parent class)	*PowerRecord*			
Description	A series of relevant regulations and methods formulated to guide human safety behaviors.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	ruleContent	String		Rule content

B.2.6.1.2.8 GovernanceInformation

Entity type name	*GovernanceInformation*			
Meaning	Governance information			
Parent entity type (parent class)	*PowerRecord*			
Description	It is mainly used to record hazard information during the governance phase.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	governUnit	String		Governance unit
	governMan	String		Governance officer
	startDate	Time		Start date
	endDate	Time		End date
	controlMeasures	String		Prevention and control measures
	governCompletion	String		Completion of governance (rectification) (recording the last governance)
	projectNumber	String		Project no.
	whetherfinishOnTime	String		Whether it is completed on time
	hazardCode	String		Hazard code
	whetherRectificated	String		Whether the rectification is complete

B.2.6.2 Person

B.2.6.2.1 IncidentInvestigator

Entity type name	*IncidentInvestigator*			
Meaning	Incident investigator			
Parent entity type (parent class)	*Person*			
Description	Person who conducts investigations and analyses on security incidents.			
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	nvestigatorName	String		Investigator name
	investigationTime	String		Investigation time
	surveyUnit	String		Investigation unit

B.2.6.3 Relation type definition

B.2.6.3.1 subClassOf

Relation type name	*subClassOf*		
Meaning	subclass of		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	An entity concept of nonleaf nodes in the conceptual hierarchy tree	**An entity concept of nonleaf nodes in the conceptual hierarchy tree**	
Relation attributes	[None]		

B.2.6.3.2 eventResult

Relation type name	*eventResult*		
Meaning	Event result		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	HazardAssessment	AssessmentResult	Event assessment result
	HazardGovernance	GovernanceInformation	Hazard governance result
	IncidentInvestigation	InvestigationReport	Investigation result
Relation attributes	[None]		

B.2.6.3.3 eventBasis

Relation Type Name	**eventBasis**		
Meaning	**Event basis**		
Description			
Relation Constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	HazardGovernance	AssessmentResult	Basis for hazard governance
	HazardAcceptance	GovernanceInformation	Basis for hazard acceptance
	PreventionMeasure	SafetyRule	Basis for prevention and control measures
Relation Attributes	[None]		

B.2.6.3.4 execute

Relation type name	***Execute***		
Meaning	**Event is executed by someone**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	IncidentInvestigator	**IncidentInvestigation**	**An investigator involved in an incident investigation**
Relation attributes	[None]		

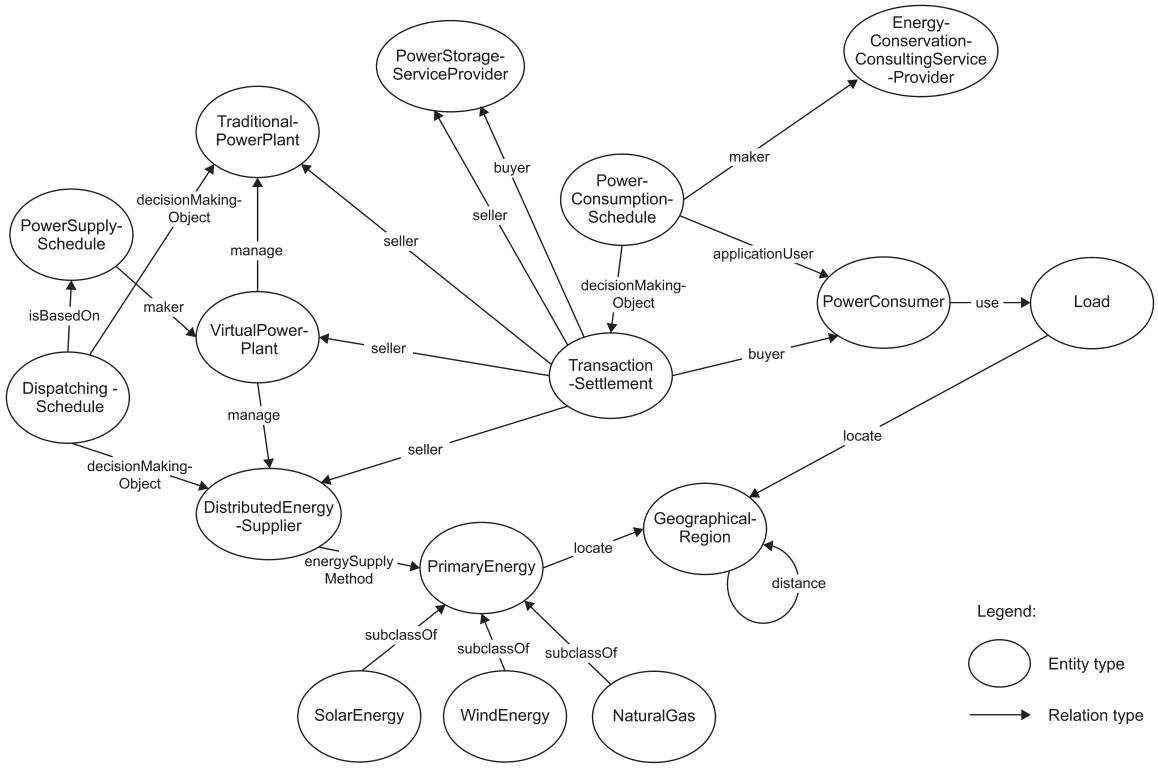


Figure B.6—Distributed energy domain entities and relationship schema

B.2.6.3.5 checkObject

Relation type name	***checkObject***		
Meaning	**Event object**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	HazardAssessment	Hazard	Hazard assessment object
	RiskAssessment	Risk	Risk assessment object
	IncidentInvestigation	SafetyAccident	Safety accident under investigation
Relation attributes	[None]		

B.2.6.3.6 sourceOf

Relation type name	***sourceOf***		
Meaning	**Source of**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RiskSource	**Risk**	**Risk comes from sources of risks**
Relation attributes	[None]		

B.2.6.3.7 solutionOf

Relation type name	***solutionOf***		
Meaning	**Solution of**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	PreventionMeasure	**Risk**	**Risk prevention and control measures**
Relation attributes	[None]		

B.2.6.3.8 cause

Relation type name	***Cause***		
Meaning	**Cause trouble**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RiskSource	Hazard	
	Risk	SafetyAccident	
Relation attributes	[None]		

B.2.6.3.9 warn

Relation type name	*Warn*		
Meaning	**Early warning of risks generated**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RiskWarning	**Risk**	
Relation attributes	[None]		

B.2.6.3.10 assess

Relation type name	*Assess*		
Meaning	**Assess event**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	RiskAssessment	**Risk**	**Assess risk**
Relation attributes	[None]		

B.2.7 Distributed energy domain

Distributed energy domain entities and relationship schema are shown in Figure B.6.

B.2.7.1 PowerThing

B.2.7.1.1 PowerItem

B.2.7.1.1.1 Load

Entity type name	*Load*			
Meaning	**Load**			
Parent entity type (parent class)	***PowerItem***			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	loadType	String		Type of load
	ratedPow	Numeric		Rated power
	maxPow	Numeric		Maximum power
	minPow	Numeric		Minimal power

B.2.7.1.1.2 NaturalGas

See definition in B.2.3.1.1.8.

B.2.7.1.1.3 PrimaryEnergy

See definition in B.2.3.1.1.12.

B.2.7.1.1.4 SolarPower

See definition in B.2.3.1.1.13.

B.2.7.1.1.5 WindPower

See definition in B.2.3.1.1.14.

B.2.7.1.2 PowerEvent

B.2.7.1.2.1 DispatchingSchedule

Entity type name	***DispatchingSchedule***
Meaning	A schedule plan for dispatching.
Parent entity type (parent class)	*Schedule*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.1.2.2 PowerSupplySchedule

Entity type name	***PowerSupplySchedule***
Meaning	
Parent entity type (parent class)	*Schedule*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.1.2.3 PowerConsumptionSchedule

Entity type name	***PowerConsumptionSchedule***
Meaning	
Parent entity type (parent class)	*Schedule*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.1.2.4 TransactionSettlement

Entity type name	***TransactionSettlement***			
Meaning				
Parent entity type (parent class)	***PowerEvent***			
Description				
Exclusive attributes (attributes inherited from a parent class are not defined here)	**Attribute name**	**Attribute value type**	**Attribute range**	**Description**
	amount	numeric		Amount of money

B.2.7.2 Organization

B.2.7.2.1 DistributedEnergySupplier

Entity type name	***DistributedEnergySupplier***
Meaning	DistributedEnergySupplier
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.2.2 EnergyConservationConsultingServiceProvider

Entity type name	***EnergyConservationConsultingServiceProvider***
Meaning	
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.2.3 PowerConsumer

Entity type name	***PowerConsumer***
Meaning	
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.2.4 PowerStorageServiceProvider

Entity type name	***PowerStorageServiceProvider***
Meaning	
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.2.5 TraditionalPowerPlant

Entity type name	***TraditionalPowerPlant***
Meaning	TraditionalPowerPlant
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.2.6 VirtualPowerPlant

Entity type name	***VirtualPowerPlant***
Meaning	VirtualPowerPlant
Parent entity type (parent class)	*Organization*
Description	
Exclusive attributes (attributes inherited from a parent class are not defined here)	[None]: inherited from the parent entity type

B.2.7.3 Location

B.2.7.3.1 GeographicalRegion

See definition in B.2.2.4.1.

B.2.7.3.2 SubGeographicalRegion

See definition in B.2.2.4.2.

B.2.7.4 Relation type definition

B.2.7.4.1 applicationUser

Relation type name	***applicationUser***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	PowerConsumptionSchedule	**PowerConsumer**	
Relation attributes	[None]		

B.2.7.4.2 buyer

Relation type name	***buyer***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	TransactionSettlement	PowerStorageServiceProvider	
	TransactionSettlement	PowerConsumer	
Relation attributes	[None]		

B.2.7.4.3 decisionMakingObject

Relation type name	***decisionMakingObject***		
Meaning	**decisionMakingObject**		
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	DispatchingSchedule	TraditionalPowerPlant	
	DispatchingSchedule	DistributedEnergySupplier	
	PowerConsumptionSched	TransactionSettlement	
Relation attributes	[None]		

B.2.7.4.4 distance

Relation type name	***distance***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	SubGeographicalRegion	**SubGeographicalRegion**	
Relation attributes	[None]		

B.2.7.4.5 energySupplyMethod

Relation type name	***energySupplyMethod***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	DistributedEnergySupplier	**PrimaryEnergy**	
Relation attributes	[None]		

B.2.7.4.6 isBasedOn

Relation type name	***isBasedOn***		
Meaning			
Description			
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	DispatchingSchedule	**PowerSupplySchedule**	
Relation attributes	[None]		

B.2.7.4.7 locate

Relation type name	***locate***		
Meaning	**Is located in**		
Description	**It describes the region where entities are located.**		
Relation constraints	**Entity type of starting point**	**Entity type of ending point**	**Description**
	PrimaryEnergy	SubGeographicalRegion	
	Load	SubGeographicalRegion	
Relation attributes	[None]		

Annex C

(informative)

EPKG application examples

C.1 Power distribution operation command system

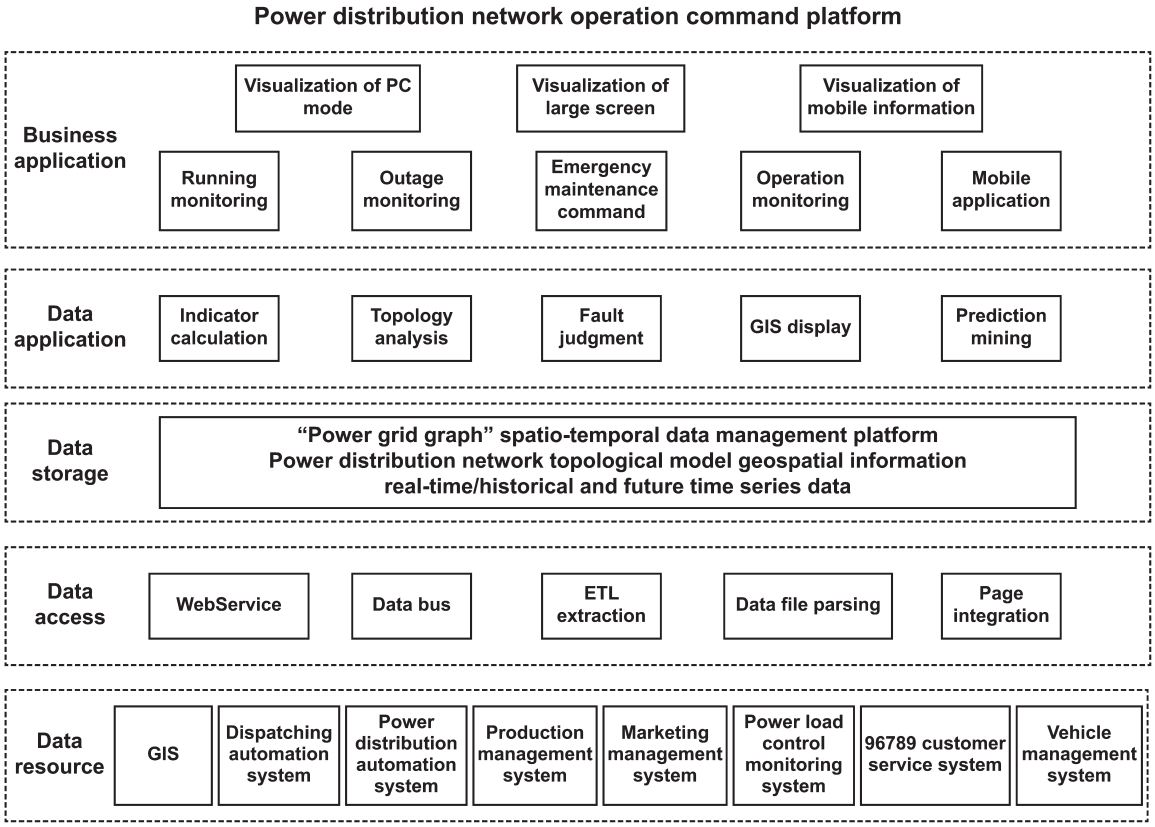


Figure C.1—Power distribution network operation command platform

C.1.1 Input and output

Input

a) Global Information System, dispatching automation system, power distribution automation system, production management system, marketing management system, power load control monitoring system, 96789 customer service system, and vehicle management system

b) Power distribution network corpus data and knowledge processing algorithm

Output

c) Power distribution operation KG

d) Power distribution operation methods based on KGs, such as fault analysis and decision-making, business service management, index calculation, topology analysis, and so on

C.1.2 Entity types and relationship types

The power distribution operation command system includes entities and relationships in the power grid domain and market domain.

Entity types: Bay, ConductingEquipment, Contract, ConnectivityNode, EquipmentContainer, Equipment, FaultDiagnose, GeographicalRegion, MarketParticipant, ProtectionEquipment, PurchaseEvent, Schedule, SubGeographicalRegion, Substation, Terminal, and so on

Relationship types: connectTo,contain, diagnose, locate,execute,occur, operate, protect, startAt, endAt, measureAt, and so on

C.1.3 Main activities

a) Collating the information management system used in services, and the business scenarios involved in the system

b) Organizing entities, relationships, and attributes based on the collation results

c) Extracting power distribution operation knowledge and constructing the power distribution operation KG based on natural language processing technology

C.1.4 Application value

a) Eliminating independence among systems and improving the cross-utilization of information among businesses

b) Improving the efficacy of automatic equipment and troubleshooting efficiency.

C.2 Integrated energy service system

C.2.1 Input and output

Input

a) “Power distribution network graph” spatiotemporal data management system

b) Graph storage technology and graph computing algorithm technology

Output

c) Integrated energy management KG

d) Integrated energy management methods based on KGs (data quality analysis, mobile load analysis, and electricity behavior analysis)

e) Distribution transformer load/distributed photovoltaic power generation forecasting methods (meteorological factor analysis, distribution transformer load forecast, and photovoltaic power generation forecast)

f) Precision marketing methods (load characteristic analysis, customer segmentation, and precision marketing strategy)

g) Power distribution network asset management methods (equipment ledger, equipment defect analysis, and equipment quality tracing)

h) Optimal control methods based on virtual power stations (market quotation, resource optimization, and profit distribution)

C.2.2 Entity types and relationship types

The integrated energy service system includes the entities and relationships in the power grid domain, market domain, and supply chain domain.

Entity types: Bay, ConductingEquipment, Contract, ConnectivityNode, EquipmentContainer, Equipment, FaultDiagnose, GeographicalRegion, MarketParticipant, ProtectionEquipment, PurchaseEvent, Schedule, Worker, SubGeographicalRegion, Substation, Terminal, and so on

Relationship types: connectTo,contain, diagnose, locate,execute,occur, operate, protect, startAt, endAt, measureAt, and so on

C.2.3 Main activities

a) Collating all controllable resources within the business scope of electric power companies

b) Extracting the entities, relationships, and attributes reflected by these resources to form graph schema

c) Collecting data from data sources and extracting knowledge for knowledge processing and fusion to construct a unified energy management KG

C.2.4 Application value

a) Assisting power distribution companies in undertaking the responsibility for the overall monitoring, management, and optimal control of all controllable resources in the region

b) Carrying out the comprehensive analysis of power grid data, such as data quality analysis, power consumption behavior analysis, and so on

C.3 Customer service support system

C.3.1 Input and output

Input

a) “Power distribution network graph” spatiotemporal data management system

b) Graph storage technology, graph computing algorithm technology, and algorithm recommendation technology

c) Electric power corpus knowledge, electric power business knowledge, and electric power equipment fault phenomena and handling methods

Output

d) Electric power integrated business KG

e) Intelligent question–answering robot based on the electric power integrated business KG

C.3.2 Entity types and relationship types

The customer service assistant system includes the entities and relationships in the power grid domain and market domain.

Entity types: Contract, EquipmentContainer, Equipment, FaultDiagnose, GeographicalRegion, MarketParticipant, ProtectionEquipment, PurchaseEvent, Schedule, Semeter, Terminal, and so on

Relationship types: diagnose, reportEquipment, execute, signContract, and so on

C.3.3 Main activities

a) Collating businesses in the electric power market domain, as well as objects and attributes involved in the businesses

b) Extracting entities, relationships, and attributes from businesses to construct KGs

c) Designing an intelligent question–answering system according to conventional user interaction modes and constructed power grid market KGs

C.3.4 Application value

a) Providing electric power users with information query, business acceptance, repair, and complaint services

b) Supporting the self-service processing of common services and troubleshooting, as well as special services

c) Improving the user experience and service processing efficiency

C.4 Electric power equipment warehouse management system

C.4.1 Input and output

Input:

a) Electric power equipment data management system, electric power warehouse management system, and supplier management system

b) Electric power equipment fault phenomena and handling methods

Output:

c) Electric power equipment management KG

d) Equipment warehouse dispatch management methods based on KGs

C.4.2 Entity types and relationship types

The electric power equipment warehouse management system includes the entity and relationship types in the power grid domain and supply chain domain.

Entity types: Bay, ConductingEquipment, Contract, ConnectivityNode, EquipmentContainer, Equipment, FaultDiagnose, GeographicalRegion, MarketParticipant, ProtectionEquipment, PurchaseEvent, Schedule, Worker, SubGeographicalRegion, Substation, Terminal, and so on

Relationship types: connectTo, contain, diagnose, locate, execute, occur, operate, protect, startAt, endAt, measureAt, and so on

C.4.3 Main activities

a) Collating all relevant spare parts, faults, and phenomena before faults

b) Organizing all entities, relationships, and attributes based on the business collation results

c) Constructing standardized and unified spare parts, aging fault entities, and various relationships with natural language processing related technologies based on electric power business knowledge

d) Storing the entities, relationships, and attributes of the extraction stage in the graph database to construct the equipment management KG

C.4.4 Application value

a) Optimizing the warehouse dispatch schedule

b) Improving the management efficiency of supplies and spare parts

c) Achieving the reasonable purchase and recovery of electric power supplies

d) Assisting in maintaining the healthy and stable operation of electric power equipment, and the continuous and stable supply of electric power

C.5 Power generation production management system

C.5.1 Input and output

Input:

a) Expert knowledge base, ERP system, and routing inspection system

b) Electric power equipment fault phenomena and handling methods

c) Knowledge extraction algorithm, knowledge fusion algorithm, and knowledge tracing algorithm

Output:

d) Whole-process power generation equipment KG

e) Fault diagnosis and analysis methods of power generation equipment based on KGs

C.5.2 Entity types and relationship types

The power generation production management system includes the entity and relationship types in the power generation domain and supply chain domain.

Entity types: Coal, Equipment, GeneratingUnit,HydroPower, NaturalGas, PrimaryEnergy, Plant, SolarPower, and so on

Relationship types: cause, connectTo, contain, drivenBy, execute, operate, solve, uploadDataTo, and so on

C.5.3 Main activities

a) Collating the power generation equipment and production process to construct the electric power equipment graph

b) Collating equipment and its fault phenomena and maintenance strategies to construct the fault KG

c) Integrating the electric power equipment KG and equipment fault KG to construct the whole-process electric power equipment fault diagnosis KG

C.5.4 Application value

a) Integrating the data of various power generation equipment and information management systems in the power generation process to eliminate isolated information islands

b) Solving miscellaneous professional problems, high equipment coupling, and fault tracing difficulties

c) Improving the equipment management and control level on the power generation side and enhancing the decision-making capability in equipment operation and maintenance

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