Knowledge Modeling of power grid regulation based on reasoning map

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Abstract—To contribute to the intelligence and knowledge of power grid regulation and control operations, this paper presents a method of power grid regulation knowledge modeling based on ELG (Event Logic Graph), which includes an event word extraction based on a predicate-argument model, an event chain extraction and fusion based on event similarity theory, an event generalization based on a soft-pattern algorithm, and an event relationship recognition based on rule pattern matching method and joint constraints. Finally, this paper uses events as nodes and event relationships as directed edges to construct an affair graph stipulated by the power grid regulation and control regulations. The ELG is also called the new generation knowledge graph. But the knowledge graph can only describe the existence of entities and the upper and lower associations between entities. ELG can explain the inheritance, causality between entities and the logic of affair evolution, and the probability of transition between legacy and causality. Therefore, knowledge modeling based on ELG has intelligent advantages. Also, compared with ontology-based knowledge modeling methods, the method proposed in this paper can realize the dynamic representation of control operation knowledge, can express the logic of behavior and logic of operation, and also has higher retrieval accuracy.

1. Introduction
With the deepening of intelligent power grid regulation, the problem of regulation knowledge modeling is prominent, for example, ① the regulation rules are not knowledgeable enough, and the traditional knowledge management mode \cite{1} leads to frequent access to all kinds of relevant texts, which is easy to be omitted and inefficient. ② Regulation big data has not been fully utilized, so it is necessary to mine valuable regulation operation rules to guide grid regulation work more safely and efficiently. ③ The existing knowledge base of regulation and control operation is based on expert systems \cite{2}. The knowledge acquisition and maintenance are manually edited, and the expansibility is poor.

Knowledge modeling \cite{3} includes knowledge representation, storage, and retrieval, in which knowledge representation is the basis. At present, there are many knowledge representation methods \cite{4}, such as ontology knowledge representation \cite{5}, first-order predicate logic representation \cite{6}, production representation \cite{7}, semantic network representation \cite{8}, framework representation \cite{9}. The construction of power grid dispatching knowledge base based on Ontology \cite{10}, using OWL language to describe the meaning of professional terms and the relationship between terms, can generate retrieval index, analyze and provide retrieval for structured and unstructured data, which is helpful to improve the operation efficiency of the power grid. However, power grid regulation is a dynamic process, and the relationship between entity concepts described by ontology is...
a static process. Ontology representation cannot express emotional knowledge and my analytical knowledge. Event logic graph (ELG), as a new generation of the knowledge graph, can not only describe the existence of entities and the relationship between entities but also describe the succession, causality, and the evolutionary logic of reasoning between entities. It can make up for the deficiency of dynamic knowledge representation between knowledge graph and native representation.

Therefore, this paper proposes a knowledge modeling method of power grid regulation based on ELG. By extracting the dynamic events and event relations from the text of power dispatching procedures and constructing ELG with events as nodes and event relations as edges, the diligent representation of the power grid dispatching process is realized, and the logic and reasoning are expressed through the sequence and causal relationship between events. Because this reasoning is only based on causality and consequent relationship, it reduces the number of rules and improves reason efficiency.

2. Knowledge modeling based on ELG

Knowledge modeling based on event graphs includes event extraction, event generalization, and event relation recognition. The modeling process is shown in Figure 1:

Event extraction includes event word extraction and event chain fusion. Firstly, it is necessary to segment and divide the control text, then mark the sentence segmentation and dependency syntax analysis [11-12]. If the subject-predicate relationship and object relation point to the same predicate verb, the word is extracted as the event. Finally, based on event similarity calculation [13], it is judged whether the event slot is included in the event chain of a scenario.

Event generalization [14] is a class of events, which refers to the relationship between a course of events and a specific event. Event generalization can control the event nodes in the readable level manually and avoid the generation of logical chaos. This paper uses a soft pattern algorithm [15] to filter events and generalize patterns.

Event relationship identification is to identify the logical relationship between events [16]. This paper proposes an event relationship recognition method based on rule pattern matching and joint constraint conditions [17-21], which can effectively improve the logical correctness of event relationship recognition and the relationship between event pair and other events.

Figure 1. ELG modeling process
3. ELG Application of Regulatory Knowledge Model

3.1. Visualization of Control Knowledge
The visualization of the power grid regulation knowledge module can help the staff quickly and clearly understand the whole process of power grid regulation operation, which has important reference significance for regulating and guiding decision-making. In this paper, the event slot and event relationship are extracted from the power grid dispatching regulations, and the tabular data is formed. Using gephi tool, the tabular data is visualized. Taking the event as the node and the relationship between events as the edge, the local overview diagram is obtained, as shown in Figure 2.

In Figure 2, the arrow direction points from the event with the first time sequence to the event with the next time sequence, which can intuitively show the whole process of scheduling operation when the device is abnormal.

![Figure 2: ELG Partial Overview](image)

3.2. Intelligent Assistant Decision Making
The workflow of ELG based regulatory knowledge model is "knowledge base + keyword retrieval + online result analysis." For example, when the control personnel retrieves the relevant process of the abnormal situation through keyword search, the knowledge engine can match the relevant events of the scene according to the keywords information, call the relevant events from the knowledge base, and analyze the timing chain and causal chain associated with the event online. If the matching scope is too large, it can increase the keywords and narrow the retrieval scope. Finally, the specific process is displayed through the intelligent assistant decision engine. If the results cannot be retrieved, the historical data is mined, and the original knowledge base is expanded through the ELG modeling process such as event extraction and event relationship recognition, and then the retrieval is carried out.

4. Application Case Analysis

4.1. Event Extraction and Generalization
This paper selects part of the text corpus of power grid dispatching regulations, for example, analysis. The content of the text is as follows: "when the equipment under the jurisdiction of provincial dispatching permission and local dispatching is abnormal, the local dispatching supervisor shall report the situation to the local dispatching dispatcher at the first time, and then the local dispatching
dispatcher shall immediately report the brief situation to the provincial dispatching dispatcher and then report the fault reason of the equipment, the restoration of power transmission and the impact on regional load and unit output to the provincial dispatching dispatcher.". First, the segmentation annotation is carried out, and the result is shown in Figure 3.

![Figure 3. Segmentation annotation results](image)

Next, the dependency syntax of the text content needs to be analyzed, as shown in Figure 4:

![Figure 4. Partially dependent syntactic analysis diagram](image)

From the above text, four-event slots can be extracted, namely, "abnormal equipment under provincial dispatching permission and jurisdiction of local dispatching", "report to local dispatching controller", "report the brief situation of local dispatching dispatcher (to provincial dispatching controller)", and "report equipment failure reason, power recovery and regional load The influence of unit output (to provincial dispatching dispatcher). " Four event slots form an initial event chain C. Then, the event similarity calculation and event chain fusion are carried out. For example, the similarity between the event slot "provincial dispatching and power grid dispatching plan" and the existing event chain C is 0.15, which does not reach the threshold of 0.7. Therefore, a new event chain is needed to be built for this event slot.

Then, the event generalization is carried out according to the soft-pattern algorithm. For example, comparing the event slot "local dispatching dispatcher reports to provincial dispatching dispatcher" with the event slot "local dispatching dispatcher reports brief information to provincial dispatching dispatcher" extracted from the above example, "report" and "report" are both non named entities, but they are synonyms, cost = 5; The entity types of "situation" and "brief situation" are the same, cost = 5; The sum of matching costs does not reach the set threshold, so the generated soft pattern is reliable and can be generalized for the two event slots, that is, it can be represented by any one of the two event slots.

4.2. Event relation recognition

According to the method described in Section 2.4, the extracted event slots are identified. Firstly, the rule pattern matching is carried out. The results show that "the provincial dispatching permission and the equipment under the jurisdiction of the local dispatching are abnormal" and "the local dispatching supervisor reports the situation to the local dispatching dispatcher" are synchronic, and "the local dispatching supervisor reports the situation to the local dispatching dispatcher" and "the local dispatching dispatcher reports the brief situation to the provincial dispatching dispatcher" constitute the sequential relationship, "Local dispatching dispatcher reports brief information to provincial
dispatching dispatcher" and "report equipment fault reason, power transmission recovery and impact on regional load and unit output to provincial dispatching dispatcher" constitute sequence relationship. According to the definition of transitivity in the joint constraint conditions, the three-event slots have a sequence relationship: "the local dispatching supervisor reports the situation to the local dispatching dispatcher", "the local dispatching dispatcher reports the brief situation to the provincial dispatching dispatcher" and "reports the equipment fault reason, power transmission recovery and the impact on regional load and unit output to the provincial dispatching dispatcher".

4.3. ELG visualization
In this paper, Gephi software (java1.8.0_231) is used for ELG construction. According to the event node and event relationship extracted from the scheduling rules, the data table of the event node is listed and visualized. The ELG showing the node content and the directed edge is obtained. The direction of the directed edge is from the source to the target. The data table is shown in Figure 5:

| source                                      | target                                      |
|---------------------------------------------|---------------------------------------------|
| Scheduling relationship                     | (Provincial company) issue dispatching business instructions |
| (Provincial company) Issue dispatching business instructions | (Provincial dispatch) Command the whole grid operation and accident handling |
| (Provincial dispatch) Command the whole grid operation and accident handling | On-site execution by provincial dispatch monitors, local dispatchers and plant and station duty personnel |
| East China sub-distribution permits provincial level transfer jurisdiction equipment | East China Distribution License |
| East China Distribution License             | Provincial adjustment operation management |
| Provincial adjustment operation management  | Plant and station site operation execution  |
| Scheduling relationship                     | Provincial transfer license equipment management |
| Provincial transfer license equipment management | Provincial dispatcher agreed |
| Provincial dispatcher agreed                 | Local dispatcher execution                  |

Figure 5. Event node data table

After the directed edge is set, the degree of each node is calculated, and the degree is expressed by the depth of the node color and the size of the area. The larger the degree is, the larger the node area and the darker the color is. Some contents of the ELG are shown in Figure 6:

Figure 6. Dispatch regulations stipulate ELG

4.4. Query and intelligent assistant decision
After the ELG is completed, the dispatcher can query the event through the knowledge base engine. For example, when you need to query the processing flow of "abnormal equipment under provincial dispatching permission and local dispatching jurisdiction", enter the keywords "provincial dispatching permission" and "local dispatching jurisdiction" to get the event chain "abnormal equipment under provincial dispatching permission and local dispatching jurisdiction → (local dispatching supervisor..."
The operator on the duty of the plant and station shall report to the local dispatching dispatcher → (the local dispatching dispatcher shall report the brief situation to the provincial dispatching dispatcher). If too many results are found, the retrieval scope can be reduced by the size of the node degree. For example, the above event query can be narrowed down by retrieving the "scheduling relationship" and then retrieved again. If the results can not be found after multiple searches, it is necessary to expand the knowledge base for secondary matching.

In addition, when the operation steps of a specific regulation are not clear, it is only necessary to retrieve through the relevant event slot rather than the whole operation process. For example, if you need to find the operation of "brief report to provincial dispatching," you can query the event slot with sequence relationship of "report to the local dispatching supervisor and station duty personnel." This can significantly improve retrieval efficiency and reduce the difficulty of retrieval.

4.5 Result evaluation
In this paper, the accuracy P, recall rate R, and F values are used to evaluate the query results. The index is defined as follows:

Accuracy rate P (also known as precision rate):

\[ P = \frac{TP}{TP + FP} \]

Recall rate (probability of being inquired):

\[ R = \frac{TP}{TP + FN} \]

F value is the harmony of accuracy and recall:

\[ F = \frac{2 \times R \times P}{R + P} \]

Among them, TP is the number that the recognition results are consistent with the actual situation; FN refers to the quantity that should be identified but not identified; FP denotes the number that should not be identified but is identified. The results of relationship recognition are shown in Table 1:

| Relationship recognition results | TP  | FP  | FN  | total |
|--------------------------------|-----|-----|-----|-------|
| causal relationship            | 56  | 5   | 7   | 68    |
| Consequent relationship        | 168 | 12  | 14  | 194   |
| total                          | 224 | 17  | 21  | 262   |

Based on the above statistical results, the accuracy P, recall R, and F of the query results are 0.929, 0.914, and 0.921, respectively. It shows that the ELG modeling method has high accuracy and recall.

5. Conclusion
In this paper, a knowledge modeling method of power grid regulation based on a logic map is proposed. The reasoning map is also called the new generation knowledge map because the knowledge map can only describe the existence of entities and the relationship between them. The reasoning map not only has the above ability but also can explain the succession and causality between entities, the logic of their reason evolution, and the transition probability between them. Therefore, the knowledge modeling method of power grid regulation based on the logic map has some intelligent advantages.

This method realizes the sharing and reuse of regulatory knowledge. It can query regulatory expertise according to the scheduling scenarios and scheduling requirements input by regulators, which helps to reduce the work intensity of regulators.

This method makes up for the defect that other knowledge modeling methods cannot express dynamic knowledge. By adding joint constraints to improve the rule pattern matching method, the association between events is strengthened, the logical contradiction between events is effectively eliminated, and the accuracy of event relationship recognition is improved. By showing the consequent and causal relationship of the control events, the control personnel can grasp the cause,
evolution trend, and the result of the events and give the corresponding control operation tips to realize the intelligent auxiliary decision-making power grid control. The next step is to carry out the relevant application research combined with the actual operation scenario, enrich and improve the power grid regulation knowledge base.

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