Object-oriented Knowledge Representation for Stability Limit of Power Grid

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Abstract: At present, the application of stability limit of transmission interface mainly relies on manual input control platform and data maintenance, and intelligent identification and expression has not been realized yet. This paper proposes an object-oriented artificial intelligence identification and knowledge representation for stability limit of power grid. First, classify and decompose the stability limit. Combining with object-oriented knowledge structure, establish the model of stable quota without monitoring condition and with monitoring condition under normal and maintenance mode. Finally, the method is used to instantiate knowledge expression of various stability limits.

1. Introduction

The stability limit of the power grid section is an important boundary condition for the safe and reliable operation of the power grid. Under different operation modes, the limits of each section of the power grid will change correspondingly.

The main task of power system operation mode major is to ensure the safe and stable operation of the power grid. Every year, according to the annual operation mode and major overhaul operation mode of the power grid analysis calculation and stability quota compilation. The section stability limit of power grid is not only related to the operation mode, but also related to the type of equipment group involved in the section, whether the protection is normal, the direction of the limit and other monitoring conditions of the limit.

At present, the application of section stability quota of power grid mainly depends on manual input and data maintenance, and intelligent identification and representation has not yet been realized, so it is inefficient, slow accident response and difficult to deal with complex accidents. The development of AI technology provides technical support for solving these problems.

Artificial intelligence knowledge representation methods include first-order predicate logic representation, production representation, semantic network representation, frame representation, object-oriented representation and so on. Object-oriented knowledge representation is to describe the data structure of the object as the center of the construction of the system, which is directly corresponding to human knowledge and record the objective. The way things are done conforms to people's general thinking process. It is entirely feasible to apply it to the knowledge representation of power grid stable operation regulations. This article mainly solves the automatic identification of stability regulations, and lays the foundation for the intelligent preparation of accident plans.

2. Basic theory

2.1 Object-oriented knowledge representing methord

Object-oriented is achieved by defining "classes," which describe entity characteristics with a set of data (attributes) that reflect the dynamic and static attributes of an entity and support a set of operations (events or methods) imposed on it. Object-oriented knowledge representation method can also integrate other commonly used knowledge representation methods, such as production, process representation and other methods into the "class" framework.

In object-oriented knowledge representation, concrete objects are composed of classes and instances of classes. The "class" structure is as follows:

Class < class name > [: < parent class name >]
    [< class variables table >]
        Structure < description of static structure of objects >
        Method < definition of object operation >
        Restraint < restrictive conditions >
EndClass

2.2 Classification of stability limit

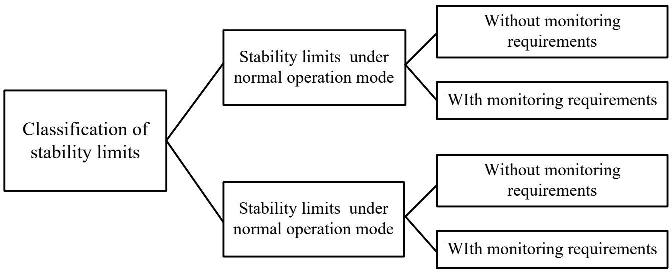

Fig. 1. Classification diagram of power grid stability limits

Stability limits can be divided into two categories: normal mode stability limits and maintenance mode stability limits. Each category can be divided into monitoring conditions and no monitoring conditions, as shown in Figure 1. Details of the monitoring conditions can be seen in 2.1.1.

2.3 Implementation steps

The object oriented knowledge representation method of the power grid stability limit is shown in Figure 2. The specific steps are as follows:

1) Step 1: According to the classification of quotas and the class structure of object-oriented knowledge representation, different types of quotas are decomposed to determine the hierarchical structure.

2) Step 2: According to the hierarchical structure determined in step 1, an object-oriented knowledge representation model for each level of stable quotas (including class variable table, Structure, Method and Restraint) is established.

3) Step 3: Acquire real-time model data of power grid based on smart grid dispatching control system (hereinafter referred to as D5000).

4) Step 4: Combining the object-oriented model of power grid stable operation regulations established in step 2 and the real-time model data acquired in step 3, the instantiation of all kinds of quota knowledge expression in the document of power grid stable operation regulations is realized.

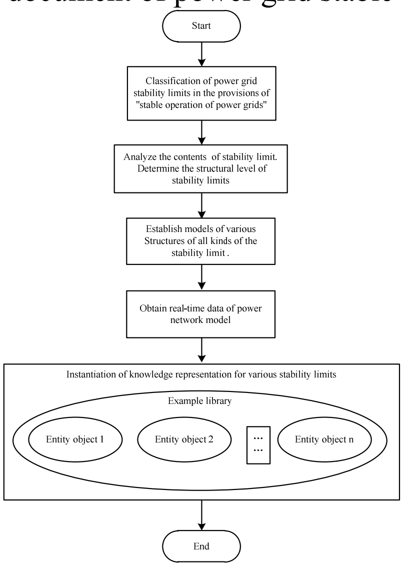

Fig. 2. Step diagram of object-oriented knowledge representation method for stability limits

3. Object oriented knowledge representation models for EACH stability limits

3.1 Stability limits without monitoring conditions under normal operation mode

Limit00 is the most basic stability limit in the regulation of stable operation. The structure of the Limit00 is defined as follows:

Class < Limit00 >
[<The number of equipment, *n* >]
Structure
< Operation mode >
< Equipment type >
< Name of equipment, *YJ*[*n*][2]>
< Name of power supply end >
< Monitoring unit >
< Stability limit value, *XE* >
Method
< To obtain the real-time active power of each equipment, P_Σ>
< To sum the real-time active power of all equipment, P_Σ>
< To compare the values of *XE* and P_Σ>
EndClass

YJ[n][2] in the structure represents a two-dimensional array, where YJ[n][1] represents the Chinese name of each element, and YJ[n][2] represents the key ID number of each element in D5000.

3.2 Stability limits with monitoring conditions under normal operation mode

Limit01, a stability limit class with normal monitoring conditions, adds "Restraint" to represent the monitoring conditions by inheriting Limit00 class. After research, the monitoring conditions can be divided into five categories: related quota constraints, plant-station security constraints, DC power and security constraints, power supply startup constraints and related equipment operation constraints, which are expressed by Restraint 1-Restraint 5 respectively.

The structure of the Limit01 is defined as follows:

Class < Limit01 > [: < Limit00 >]
Restraint
Class Restraint1/2/3/4/5 EndClass
EndClass

A stability limit with monitoring requirements may include one or more different or the same type of monitoring requirements. The expression of Restraint1~ Restraint5 is as follows:

1) Monitoring condition class about correlation limit constraint:

Class < Restraint1 >
[< Number of monitored equipment, *k*>]
Structure
<Name of each monitored equipment, *JK*[*k*][2]>
< Scope requirements for the sum of active power of the monitored equipment, [$P_{JK\Sigma\min}$, $P_{JK\Sigma\max}$]>
Method
< To sum the real-time active power of every monitored equipment, P_Σ>
<To judge whether P_Σ is in the range of [$P_{JK\Sigma\min}$, $P_{JK\Sigma\max}$] >
EndClass

2) Monitoring condition class about power plant and substation safety control function constraint:

Class < Restraint2 >
[< Number of monitored power plants, *k*>]
Structure
< Name of monitored substation >
< The availability of safety control function of the monitored substation >

< Name of each monitored power plant, *DC*[k][2]>
< Number of generators that can be cut in the plant (*DC*[*i*][1], *DC*[i][2]) ,$1\le i\le k$, [KQ_{imin} , KQ_{imax}] >
Method
< To obtain the number of generators that can be cut in each power plant, KQ_i >
<To judge whether KQ_i is in the range of [KQ_{imin} , KQ_{imax}] >
EndClass

3) Monitoring condition class about DC power and safety control function constraint:

Class < Restraint3 >
[< Number of monitored power plants, *k*>]
Structure
< Name of monitored DC line >
< Power range requirements for monitored DC, [P_{ZLmin}, P_{ZLmax}] >
< The availability of safety control function of monitored DC >
< Power requirements for quick control of DC controlled safety control, [$P_{ZLSJmin}$, $P_{ZLSJmax}$]>
Method
< To obtain the power monitored DC line, P_{ZL} >
< To obtain the power for quick contro, P_{ZLSJ}>
<To judge whether P_{ZL} is in the range of [P_{ZLmin}, P_{ZLmax}] >
<To judge whether P_{ZLSJ} is in the range of [$P_{ZLSJmin}$, $P_{ZLSJmax}$] >
EndClass

4) Monitoring condition class about power supply start-up mode constrains:

Class < Restraint4 >
[< Number of monitored power plants, *k*>]
Structure
< Name of monitored substation >
< Name of each monitored power plant >
< Range requirements for start-up generator of each monitored power plant, [KJ_{imin} , KJ_{imax}] >
< Power supply start-up mode of hydropower >
Method
< To obtain the number of start-up generators in each power plant , KJ_i >
<To judge whether KJ_i is in the range of [KJ_{imin} , KJ_{imax}] >
< To judge whether the Hydropower generation capacity is large or not >
EndClass

5) Monitoring condition class about related equipment operation mode type:

Class < Restraint5 >
[< Number of related equipment, k>]
Structure
< Name of related equipment >
< Requirements for operation state of related equipment >
Method
< To obtain the operation state of each related equipment >
<To judge whether the operation state of each related equipment meet the requirement >
EndClass

3.3 Stability limits without monitoring conditions under maintenance operation mode

Stability limits without monitoring conditions under maintenance operation mode expressed as Limit10, inheriting the Limit00 class, add the name of maintenance equipment and the way of adjustment.

The structure of the Limit10 is defined as follows:

Class <Limit10> [:<Limit00>]

Structure
<Name of maintenance equipment >
< Is there a way to adjust the operation? >[a]
If YES
Then <Class Adjustment Mode … EndClass>
EndClass

Attention: a. When one equipment is overhauled, other equipment may be adjusted.

The “Adjustment Mode” in the above structure indicates the adjustment of other equipment except maintenance equipment. Its definitions are as follows:

Class < Adjustment Mode >
[<Number of actions that need to be adjusted., k>]
Structure
< Adjustment action 1>
……
< Adjustment action k>
EndClass

Relevant adjustment actions may be: a two-line closing loop operation, a substation to separate or parallel operation of the positive and negative buses, a substation to adjust the connection of two lines, accompany the main transformer or unit, two substations combined supply area operation.

3.4 Stability limits with monitoring conditions under maintenance operation mode

Stability limits without monitoring conditions under maintenance operation mode expressed as Limit11, inheriting the Limit10 class, add relevant restraints.

The structure of the Limit11 is defined as follows:

Class <Limit11> [:<Limit10>]
Restraint
Class Restraint1/2/3/4/5 EndClass
EndClass

4. Example

4.1 Example 1

Taking Jianglian I and II double-line normal mode as an example, as shown in Table 1, the monitoring conditions of the stability limit include the related limit constraint and power plant and substation safety control function constraint.

TABLE I. Stability Limit of Jianglian Double Line Under Normal Operation Mode

Name of Equipment	Jianglian line I, Jianglian line II
Name of power supply end	Liandu
Operation mode	Nomal
Stability limit	1 million KW [a]
Monitoring conditions and instructions	1) Zhejiang Liandu high voltage safety control system Liandu station cutting generator function is available. 2) only one generator set that can be removed in Datang Ningde power plant, and the number of generator sets in Kemen power plant ≥1. 3) Jiangdan 5456 line and Longjiang 5462 line double line tidal current (the direction sent by Shuanglong substation) is less than 2 million KW [a]
Monitoring unit	East China power grid dispatching organization; Zhejiang power grid dispatching organization

a. The nunbers is virtual.

The object oriented knowledge representation of the stability limit is as follows:

Class < Limit01 >

[<The number of equipment, *n*=2 >]
Structure
< Operation mode: normal >
< Equipment type: power line >
< Name of equipment, *YJ*[2][2]={(Jianglian line I, 5188561); (Jianglian line II, 5188562)}>
< Name of power supply end: Liandu >
< Monitoring unit: East China power grid dispatching organization; Zhejiang power grid dispatching organization >
< Stability limit value: *XE*=1 million kilowatts >
Method
< To obtain the real-time active power of Jianglian line I and Jianglian line II>
< To sum the real-time active power of Jianglian line I and Jianglian line II, P_{Σ}(Jianglian line I, Jianglian line II)>
< To compare the values of *XE* and P_{Σ}(Jianglian line I, Jianglian line II)>
Restraint
Class < Restraint1 >
[< Number of monitored equipment, *k*=2>]
Structure
<Name of each monitored equipment, *JK*[2][2]= {(Jiangdan line, 5235456); (Longjiang line, 5235462)}>
< Scope requirements for the sum of active power of the monitored equipment, [$P_{JK\Sigma min}$, $P_{JK\Sigma max}$]=[0, 2 million KW]>
Method
< To obtain the real-time active power of Jiangdan line and Longjiang line>
< To sum the real-time active power of Jiangdan line and Longjiang line, P_{Σ}(Jiangdan line, Longjiang line)>
<To judge whether P_{Σ}(Jiangdan line, Longjiang line) is in the range of [0, 2 million KW] >
EndClass
Class < Restraint2 >
[< Number of monitored power plants, *k*=2>]
Structure
< Name of monitored substation: Zhe-Fu UHV security control system Liandu station >
< The availability of safety control function of the monitored substation : available>
< Name of each monitored power plant, *DC*[2][2]= {(Datang Ningde power plant, 3415865), (Kemen power plant, 3415857)}>
< Number of generators that can be cut in the plant (Datang Ningde power plant, 3415865): [1,1] >
< Number of generators that can be cut in the plant (Kemen power plant, 3415865): [1,4] > [a]
Method
< To obtain the number of generators that can be cut in each power plant, KQ_1, KQ_2>
<To judge whether KQ_1 is in the range of [1,1] >
<To judge whether KQ_2 is in the range of [1,4] >
EndClass
EndClass

Attention: a. The installed capacity of the Kemen power plant is 4, so the largest number of the generator that can be cut is 4.

4.2 Example 2

Take the stability limit of the remaining two main transformers in Lanting No.1 transformer maintenance mode as an example, as shown in Table 2, which includes “Adjustment Mode” class.

TABLE II. Under maintenance mode of No. 1 main transformer in Lanting substation, stability limit of the rest two main transformers

Name of Equipment	Lanting No. 2 transformer Lanting No. 3 transformer
Name of power supply end	Lanting
Operation mode	maintenance
Stability limit	2 million KW [a]
Monitoring conditions and instructions	1) Operation mode adjustment action 1: Jinghu - San Kong channel changed to ring operation. 2) Operation mode adjustment action 2: The operation mode of Shunjiang and Guyue sub districts keep normal conditions. 3) Operation mode adjustment action 3: The generator running on the Tang Shao power plant (Shun Jiang side) is not more than 1
Monitoring unit	East China power grid dispatching organization; Zhejiang power grid dispatching organization; Shaoxing power grid dispatching organization

b. The nunbers is virtual.

The object oriented knowledge representation of the stability limit is as follows:

Class < Limit10 >

[<The number of equipment, n=2 >]

Structure

< Operation mode: maintenance >

< Name of maintenance equipment: Lanting No.1 transformer >

< Equipment type: power line >

< Name of equipment, YJ[2][2]={(Lanting No.2 transformer, 5284572) ; (Lanting No.3 transformer, 5284573)}>

< Name of power supply end: Lanting >

< Is there a way to adjust the operation? : YES>

Class < Adjustment Mode >

[<Number of actions that need to be adjusted., k>]

Structure

< Adjustment action 1: Jinghu - San Kong channel changed to ring operation >

< Adjustment action 2: Operation mode adjustment action 2: The operation mode of Shunjiang and Guyue sub districts keep normal conditions >

< Adjustment action 3: The generator running on the Tang Shao power plant (Shun Jiang side) is not more than 1>

EndClass

< Monitoring unit: East China power grid dispatching organization; Zhejiang power grid dispatching organization; Shaoxing power grid dispatching organization >

< Stability limit value: XE=2 million kilowatts >

Method

< To obtain the real-time active power of Lanting No.2 transformer and Lanting No.3 transformer >

< To sum the real-time active power of Lanting No.2 transformer and Lanting No.3 transformer, P_{Σ}(Lanting No.2 transformer, Lanting No.3 transformer)>

< To compare the values of XE and P_{Σ}(Lanting No.2 transformer, Lanting No.3 transformer)>

EndClass

5. Conclusion

Aiming at the shortcomings of manual input and data maintenance of stability limit in current power grid stability regulations, this paper provides a method of knowledge representation of four kinds of quota in power grid stability regulations by using object-oriented "class" structure. This method lays a foundation for intelligent identification and modeling, and can also be used in the future. In the category structure, the scope and depth of the types are broadened, and the application of the category structure in the preparation of accident plans is guaranteed.

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