Article

Feeder Topology Configuration and Application Based on IEC 61850

Haotian Ge, Bingyin Xu *, Xinhui Zhang, Yongjian Bi, Zida Zhao

Smart Grid Research Institute, Shandong University of Technology, Zibo 255049, China; sdutght@163.com
* Correspondence: xuby@ vip.163.com

Abstract: To describe the feeder topology and information exchange between intelligent electronic devices (IEDs) for Internet of Things (IoT), it is necessary to extend IEC 61850 and add a logical model. The feeder model described in IEC 61970 is then extended in IEC 61850 to serve as a container for the equipment along the distribution line. For the physical connections in the electrical equipment, both terminal and connectivity node logical models are added. Taking logical node XCBR as the example, its attributes for the terminals are added to the electrical equipment. The logical node LCNN is then further added in order to describe the connectivity node. By next adding the logical node LTPN to describe the topological node, and FTPA to describe the results of the topology analysis, we can efficiently describe the topology analysis results. Based on these new logical nodes, the exchange of topology information between intelligent terminals no longer relies on configuration files, but only requires logical nodes. Through the above expansion, the topology description and information exchange of medium and low voltage feeders are realized.

Keywords: Feeder topology; IEC 61850; Common Information Model; Power distribution network

1. Introduction

The power utilities implements distribution automation (DA) and Internet of Things (IoT) may bring about many benefits, including providing a fast method to improve reliability, and reducing power outage time [1]. Topology analysis is an important aspect of distribution automation, being the basis for power flow calculations, state estimations, fault locations, and line loss reductions. Most distribution lines are radial [2] and connect the substations to users. However, due to changes in user load, such as load growth, the structure of the distribution line needs to be modified. In addition, due to some faults, it is necessary to close or open the switchgear on the line during the operation; something which will also affect the topology of the distribution line. The topology information configuration and exchange of distribution lines are both important subjects in this field. In recent years, distribution protection and control systems have been of wide concern for the smart distribution grid. The distribution system is highly flexible and adaptable, characteristics that are more suited to the structural characteristics and operational requirements of intelligent distribution networks [3-6]. Thus, the configuration and analysis of the distribution line topology in distributed systems is a topic that is being widely researched currently.

The description of the topological model needs to be standardized in order to facilitate information sharing. The International Electrotechnical Commission (IEC)'s technical commission (TC) 57 has undertaken a lot of work to facilitate the description of the power grid information model, as well as the interconnection of equipment and systems from different manufacturers. IEC TC 57 has established IEC 61970, 61968, 61850, among other standards, and standardized the information model and information exchange model. IEC 61970 and IEC 61968 are used for information sharing between master station systems. IEC 61850 is mainly used for information sharing among field intelligent electronic devices (IED). The new description and information exchange of the feeder topology need to refer to the above three standards.

Distribution feeders are an important concept within the distribution system. A feeder is one of the circuits out of the substation, which includes symmetrical three-phase lines and asymmetrical two-phase and single-phase lines. When viewed logically then, a feeder constitutes a collection, and specifically, a collection of equipment for organizational purposes which is used for grouping distribution resources [7]. Any given feeder is made up of a main feeder, branches or laterals, and sub-laterals. It is usually sectionalized by reclosing certain devices, and protected by fuses [8]. Reference [9] proposed a feeder-oriented method to be used to carry out a topology analysis of the medium-voltage distribution grid. Reference [10] proposed that information models (including the feeder) be used to facilitate information integration between the distribution network production repair platform (DNPRP) and other IT systems. The latest IEC 61970 common information model (CIM) (IEC61970 CIM 17v38) adopts the feeder model. Meanwhile, the description language to be used for the system configuration language (SCL) of IEC 61850 is generally also used for the topology configuration. In references [11-12], the SCL process and line models are used to describe the distribution grid topology. Moreover, Chen uses a logical node to express the topology for both the feeders and for information exchange between IEDs [13]. Cong meanwhile, uses a distribution method to store the feeder topology [14-15]. Reference [16] configures the feeder's adjacent switches based on a user-defined format. In references [17-18], a local topology based on smart terminal unit (STU) storage is proposed, and then, through an STU query on the real-time feeder topology, it realizes the STU itself.

According to the characteristics of the medium and low voltage distribution grid, combined with the information models IEC 61970 and IEC 61850, we propose a topology configuration method based on the feeder model. To facilitate the exchange of topology information between the IEDs, the logical nodes from both the connectivity and topological nodes are added. The subsequent sections of the paper are ordered as follows: Section 2 discusses the physical structure of the feeder; Section 3 presents the feeder's logical model; in Sections 4 and 5, logical nodes are added to the connectivity and topology models in order to facilitate information sharing between the IEDs. Finally, Section 6 presents the summary of the study and provides an insight for future work.

2. Physical Structure of the Feeders

2.1. Feeder Model

There are obvious differences between the transmission lines and distribution lines. The transmission line is generally connected to two substations, with the material and size of the line being the same. Additionally, there is no switchgear in the middle of the line, as per seen in Figure 1 (a). Generally, when analyzing the transmission line, it is considered to be a section of the conductor, but the distribution line is different, with the distribution line including a switch, load, and distributed generation. Within the distribution grid, the term "feeder" is more commonly used than the term "line." Therefore, in this paper, the distribution lines will be referred to as feeders. A feeder, as specified in the IEC 61970 Part 301 CIM [19], is a static collection of conducting equipment which originates at the main distribution center and supplies one or more secondary distribution centers, one or more branch-circuit distribution centers, or any combination of these two types of equipment. The feeder is divided into several sections, as shown in Figure 1 (b), but the key part is the feeder section. Besides this, a feeder may also have switch devices, MV/LV distribution transformers, capacitors, and line voltage regulators, among other components. In addition, the transmission line is three-phase symmetrical, that is to say, it has the same voltage, load and line impedance. It thus further resembles a single-phase circuit rather than a three-phase circuit. Though the distribution feeder has both single-phase and two-phase loads, many distribution loads are three-phase asymmetric and work in three phases. Therefore, we also need to carry out an asymmetric analysis approach on the distribution feeders.

According to the function and voltage level, feeders can be divided into medium-voltage feeders and low-voltage feeders. A medium-voltage feeder is also known as a primary feeder, and is usually 600V to 35kV, while in China it is mainly 10kV and 35kV. The primary feeder obtains electric energy from the substation and distributes it to the user. When close to each end user, a distribution transformer steps down the current to a low-voltage secondary feeder (380Y/220 V in China).

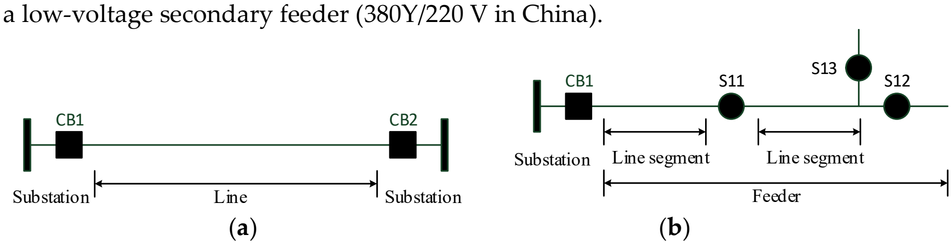

Figure 1. Power line: (a) Transmission line; (b) Distribution feeder.

2.2. Primary Feeder

A typical medium-voltage feeder is three-phase with symmetrical loading, and as per standard three-phase circuits with symmetrical loading, the neutral wire carries almost no current. The neutral wire is therefore sometimes left out. Three-phase four-wire systems and three-phase three-wire systems are both common configurations for primary feeders, but the most common distribution primaries in North America are four-wire multi-grounded systems: three-phase conductors plus a multi-grounded neutral. In Europe and China meanwhile, the three-phase three-wire systems are the most popular. In China, the neutral point of the medium-voltage distribution system has not been effectively grounded, and so a three-phase three-wire system is adopted. Utilities in China often design the primary feeder for 400 A but often allow an emergency rating of 600 A. Distribution circuits meanwhile come in many different configurations and circuit lengths.

A feeder is one of the circuits from the substation. The breaker or recloser in the substation is usually the feeder's starting point, while the end point is the load, distributed generation, and tie switch (normally open switch), which are associated with another feeder, switching station, etc., as shown in Figure 1 (b). The feeder is divided into several sections through section switches (as shown in S11, S12). The feeder is regarded as a collection of equipment, though this does not consider the tower, foundation, stay wire, cross arm, etc., but only considers the conductor, distribution transformer, circuit breaker, disconnector, fuse, reactive power compensation device, etc.

2.2. Secondary Feeder

Low-voltage distribution feeders are also called secondary feeders. From the distribution transformer, the secondary feeders connect to the end user at the service entrance. This area is composed of different types of power cables, transformer units and other equipment, with all equipment specifications and construction complying with current national standards. The voltage level of low-voltage distribution feeders in China is usually 380Y/220 V, while the connection modes are mainly radial, trunk and ring. Moreover, the voltage of phase-to-phase is 380 V, and phase-to-neutral voltage is 220 V. In most cases, only one distribution transformer will supply the power to the customers, while the loads are usually at the end of the distribution network. The radius of the power supply in the city center usually measures less than 150 meters.

The circuit going from the distribution transformer to the end user can be divided into two parts: mainline and lateral. The mainline is formed up of a common trunk line running from the distribution transformer to the customers' buildings. The mainline is usually composed of overhead lines and underground cables with modestly large conductors, with those conductors normally used being 120mm^2, 150mm^2, and 185mm^2 aluminum conductors. The wires used for low-voltage overhead lines are generally three-phase four-wire systems insulated with cross-linked polyethylene (XLPE), and these are then installed on outdoor poles. The distance between two conductors for overhead lines should not be less than 1000 m. Underground cables meanwhile, are generally buried in underground cable trenches. Their low-voltage cables are generally made of three-phase and four-wire, and cross-linked polyethylene insulated power cables can be selected. One or more laterals will branch off from the mainline to the end users. These laterals may be single-phase, two-phase, or three-phase, and are normally fused to separate them from the mainline if they are faulty. Low-voltage cross-linked polyethylene copper-core insulated conductors are used for household connections. The conductor's cross-section shall be selected according to the continuous current carrying capacity and voltage loss, which is generally 10mm^2, 20mm^2, etc.

3. Abstract Model of the Feeder

3.1. Feeder Supervisory Control and Automation

As a basic component of the smart distribution grid and distribution automation, feeder automation (FA) realizes fault detection, location, isolation of distribution feeders and restoration of power supply in those sections deemed safe. Distributed feeder automation (DFA) meanwhile, is an automation mode that is independent from the master station. The communication network and the distribution terminals on the feeder communicate with each other to collect any fault information regarding the adjacent switches. Then, following a comprehensive comparison, the relevant fault section is judged. The switches at both ends of the section are first tripped to complete the fault isolation action. Then, the safe section's power supply is restored by closing the tie switch. Finally, the processing results are reported to the main distribution station's system. Distributed control is an especially suitable system for the distribution grid: The feeder is generally bounded by the medium-voltage bus in the substation; the number of control nodes will not be excessive; and the structure and algorithm design of the control system is relatively simple. In distributed control systems, it is necessary to configure the distribution lines model within the control range, and exchange topology information in real time according to changes in the section switch.

In recent years, the development of power utilities has made great strides in the monitoring and management of low-voltage power grids. The application of automatic meter readings and line loss management systems has improved the level of low-voltage power grid monitoring, improved power quality for end users, and reduced the loss of low-voltage feeders. To realize these functions however, a large number of distributed monitoring terminals must be installed, and the low-voltage feeder topology's configuration and information exchange is required.

3.2. Feeder Information Model

The feeder model, as specified in the IEC 61970 Part 301 CIM, is a static collection of conducting equipment that originates at a main distribution center and supplies one or more secondary distribution centers [7], one or more branch-circuit distribution centers, or any combination of these two types of equipment. A feeder's equipment can contain a substation or bay, as shown in Figure 2 [7]. In the distribution grid however, all conducting equipment is considered a member of either a substation or a feeder. All substation equipment is housed. A feeder is generally outside a physical enclosure and consists of a collection or connected set of AC line segments, switches, transformers (which may or may not be considered a substation) [19-20], etc. Additionally, it can usually be sectionalized by closing certain devices and is protected by fuses.

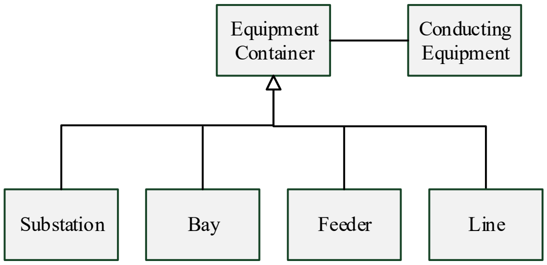

Figure 2. Feeder model.

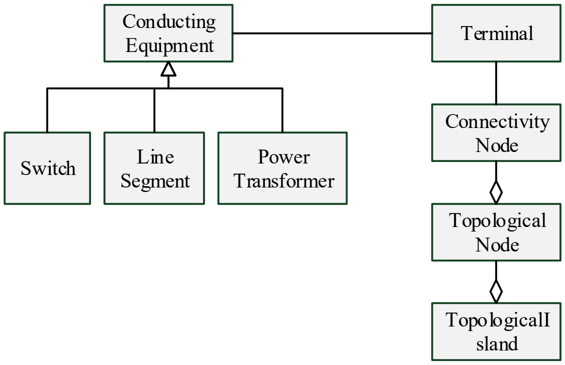

Figure 3. Topology model.

3.3. Topology Model

The topology of the feeder refers to the connection relationship between the outgoing break, sectional switch, and the line segments of the feeder. Figure 3 shows the topology class diagram which models connectivity between different types of conducting equipment. IEC 61970 is divided into connectivity and topology models. The connectivity model is the physical definition of how the equipment is all connected together, and it is associated with the terminal and connectivity node classes, as shown in Figure 4 (a). The connectivity model is a relatively static model, only related to the planning and design of the distribution grid and having nothing to do with the operation mode. The topology model on the other hand, is the logical definition of how equipment is connected via closed switches using the topological node and topological island classes, as shown in Figure 4 (b). The topology model is considered a dynamic model that can be modified through changes of switch position and operation mode. In addition, the topology model is not identical when used for different applications. For example, during fault location and isolation, we are only concerned with the topology of a single feeder, but when the power supply is restored, it is necessary to consider the topology of all those feeders connected to the fault section. Therefore, the topology model is also related to its specific application, and we thus call this application topology.

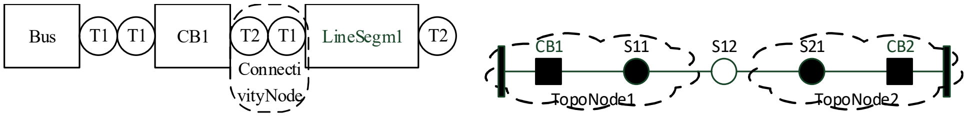

Figure 4. Feeder topology model: (a) Connectivity model; (b) Topology model

4. Connectivity Model and Configuration

4.1. Connectivity Model

The feeder connectivity model describes the connection relationship between the distribution grid equipment along the feeder. To model connectivity, the terminal and connectivity node classes are all used. As defined in the CIM of IEC 61970, each conducting equipment has one, two or more terminals, and each terminal belongs to one conducting equipment, and may be connected to a connectivity node, as shown in Figure 4 (a). A connectivity node is a point where the conducting equipment's terminals are all connected together with zero impedance. Distribution equipment can be divided into two categories: component equipment and station equipment. Component equipment consists of specific primary and secondary equipment, such as circuit breakers, load switches, disconnectors, current transformers, voltage transformers, etc. Station equipment meanwhile, refers to the collection of a group of equipment that is used to complete the functions of the feeder line segmentation, power distribution, collection, etc., including the ring main unit, switching station, power distribution room, etc. To simplify the topology of the feeder then, is the purpose of setting up substation equipment. The topology of the internal station equipment needs to be described in detail, while for external station equipment, only a few terminals are mentioned. For example, the ring main unit is considered station equipment. For this piece of equipment, the detailed connection relationship of several switches needs to be described for the internal aspect, while for the external aspect, as it is a component of the feeder, only two terminals are required.

4.2. SCL Description for Connectivity Model

According to IEC 61850-6 [21] and IEC 61850-90-6 [22], SCL can be used to both describe and configure the connectivity model. Each IED needs only to configure the relevant connection relationship. The SCL defined in IEC 61850-6 meanwhile, can describe the connection relationship of the equipment along the feeder. In order to describe the feeder and its equipment, the feeder model shown in Figure 2 is used. A feeder, like a substation, is an equipment container. However, the equipment in the substation belongs to the Substation class, and the equipment along the feeder belongs to the Feeder class.

The phase attribute must be in the connection model. In distribution networks, especially in low-voltage ones, single-phase lines and two-phase lines are very common. The connection node may be single-phase connection (A, B, C), two-phase connection (AB, BC, AC), or three-phase connection (ABC). Furthermore, it is necessary to extend the terminal in IEC 61850-6 to include the phases attribute. With the terminal phases attribute, the phase information of each conducting equipment can be expressed for multi-phase distribution networks. The data type of phase is "Phase Enum," and the data value may be "A," "B," "C," "N," "all," "none," "AB," "BC," or "CA," while the default value is "all." In this way, it can remain compatible with the original version.

Taking the S11 load switch in Figure 1 (b) as an example, the description is as follows:

```
<ConductingEquipment name=" S11" type="LBS">
    <Terminal connectivityNode="E1/F01/L2" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName ="L2"/>
    <Terminal connectivityNode="E1/F01/L3" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName="L3"/>
</ConductingEquipment>
```

In Figure 1 (b), S13 is a single-phase switch.

```
<ConductingEquipment name=" S13" type="LBS">
    <Terminal connectivityNode="E1/F01/L4" voltageLevelName="E2" feederName="F01" phases=”A” cNodeName ="L4"/>
```

```
    <Terminal connectivityNode="E1/F01/L5" voltageLevelName="E2" feederName="F01" phases=”A” cNodeName="L5"/>
</ConductingEquipment>
```

The following example describes the feeder in Figure 1 (b).

```
<Feeder name="F1">
  <ConductingEquipment name=" LN1" type="LIN">
    <Terminal connectivityNode="E1/F01/L1" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName ="L1"/>
    <Terminal connectivityNode="E1/F01/L2" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName="L2"/>
  </ConductingEquipment>
  <ConductingEquipment name=" S11" type="LBS">
    <Terminal connectivityNode="E1/F01/L2" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName ="L2"/>
    <Terminal connectivityNode="E1/F01/L3" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName="L3"/>
  </ConductingEquipment>
  <ConductingEquipment name=" LN2" type="LIN">
    <Terminal connectivityNode="E1/F01/L3" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName ="L3"/>
    <Terminal connectivityNode="E1/F01/L4" voltageLevelName="E1" feederName="F01" phases=”all” cNodeName="L4"/>
  </ConductingEquipment>
  <ConductingEquipment name=" S13" type="LBS">
    <Terminal connectivityNode="E1/F01/L4" voltageLevelName="E1" feederName="F01" phases=”A” cNodeName ="L4"/>
    <Terminal connectivityNode="E1/F01/L5" voltageLevelName="E1" feederName="F01" phases=”A” cNodeName="L5"/>
  </ConductingEquipment>
  <ConductingEquipment name=" S12" type="LBS">
    <Terminal connectivityNode="E1/F01/L4" voltageLevelName="E1" feederName="F01" phases=” all” cNodeName ="L4"/>
    <Terminal connectivityNode="E1/F01/L6" voltageLevelName="E1" feederName="F01" phases=” all” cNodeName="L6"/>
  </ConductingEquipment>
  < ConnectivityNode name="L1" pathName="E1/F01/L1" />
  < ConnectivityNode name="L2" pathName="E1/F01/L2" />
  < ConnectivityNode name="L3" pathName="E1/F01/L3" />
  < ConnectivityNode name="L4" pathName="E1/F01/L4" />
  < ConnectivityNode name="L5" pathName="E1/F01/L5" />
</ Feeder >
```

4.3. Logical Nodes for Connectivity Model

The logical node is the smallest part of the function that exchanges data. It is therefore more convenient to use logical nodes for information exchange between IEDs. Moreover, the logical node can also be expanded according to functional requirements. In distributed feeder automation, intelligent terminals need to be able to exchange the connection information of distribution lines. For this information section however, no necessary logical node exists to support the information exchange. Therefore, it is necessary to extend the logical nodes. The extension requirements of logical nodes mainly include: (1) terminal information needs to be added for electrical equipment; (2) connectivity node information description needs to be added.

4.3.1. Terminal

For conductive equipment, the description of terminal information should be added, including information on the circuit breaker (XCBR), circuit switch (XSWI), overhead line

(ZLIN), cable (ZCAB), transformer (YPTR), as well as other logical nodes. Taking the circuit breaker logical node XCBR as an example:

XCBR (Circuit breaker)			
Data object name	**Common data class**	**Explanation**	**M/O**
Logical node data in IEC 61950-7-4:2010			
Settings			
NumTerm	INT32	Number of terminals	O
Terminals	ARRAY[0…NumTerm] of VISIBLE STRING255	Equipment terminals	O

Similarly, other logical nodes, including SXWI, ZLIN, ZCAB, and YPTR, should add the description of their terminals as XCBR.

Taking the switch S11 in Figure 1 (b) as an example, the attribute values of the logical node XCBR are as shown in Table 1:

Table 1. Logical node and its value.

Logical Node	Attribute	Value
XCBR	NumTerm	2
	Terminals	connectivityNode="E1/F01/L1" voltageLevelName = "E1" feederName="F01" phases="all" connectivityNode="E1/F01/L2" voltageLevelName = "E1" feederName="F01" phases="all"
LCNN	NamPlt	L1
	PathName	E1/F01/L1

4.3.2. Connectivity Node

Connectivity nodes are the points where conducting equipment terminals are connected together with zero impedance. The connectivity node in a substation is generally only limited to one bay. For feeder automation meanwhile, the connectivity node can be in the feeder. Its name attribute identifies the instance of the connectivity node instance within the bay; its path name is an absolute reference within the SCL file. For instance, if the connectivity node L1 is within feeder F1 of voltage level E1, then the pathname is "E1/F1/L1."

LCNN (Connectivity Node)			
Data object name	**Common data class**	**Explanation**	**M/O**
Logical node data in IEC 61950-7-4:2010			
Settings			
NamPlt	LPL	Name plate of the logical node	O
PathName	VISIBLE STRING255	Terminals connections to different connectivity nodes	O

When taking the leftmost connectivity node in Figure 1 (b) as an example, its data attributes are as shown in Table 1.

5. Topology Model and Application

5.1. Topology Model

Topology is the logical definition of how equipment is connected via closed switches, and is independent of other electrical characteristics, such as impedance. To model topology, both the topological node and topological island classes in IEC 61970 are needed. A topological node, consisting of a group of connectivity nodes that are connected by the closed switches in the current network state, will change with the switch state. A Topological Island is an electrically connected subset of the network, which can change as the current network state changes. Only energized topological nodes form part of the Topological Island, meaning that a topological island is able to form a power supply area. A topological island will be located adjacently to another topological island through a tie switch. If a topological island has several tie switches that are all connected with other topological islands, there will be several power supply recovery paths.

5.2. Logical Node for Topology

For an IED, the topology analysis consists in synthesizing a topological node from the connectivity node connected through the closed switch. The number of the connectivity nodes contained in each topological node needs to be transferred when exchanging topology information between adjacent IEDs. To calculate the topology of the whole feeder, the master IED is also needed. The master IED starts the whole feeder topology analysis and obtains the topology information through a successive polling of the adjacent IEDs.

For the exchange of topology information, the new logical nodes **LTPN** and **FTPA** must be added. The logical node LTPN starts the topology analysis and reports the topology results. When a switch position changes, the topology analysis (FTPA.Str=1) is started, and **FTPA.Str** indicates the topology analysis state. The topology analysis results in the logical node, LTPN. Connectivity nodes at both terminals are then combined into one topological node through the closed switch, and the connectivity nodes at both terminals of the line segment are then merged into one topological node.

LTPN (Topological node)			
Data object name	**Common data class**	**Explanation**	**M/O**
Logical node data in IEC 61950-7-4:2010			
Settings			
NamPlt	LPL	Name of the topological node	O
PathName	VISIBLE STRING255	A full object reference	O
Status information			
NumCnNode	INT32	Number of terminals	O
CnNodes	ARRAY[0…NumTerm] of VISIBLE STRING255	Connectivity nodes	O

FTPA (Topology analysis)			
Data object name	**Common data class**	**Explanation**	**M/O**
Logical node data in IEC 61950-7-4:2010			
Control			
Str	SPC	Topology analysis start	

Status information			
NumTpNode	INT32	Number of topological nodes	O
TpNodes	ARRAY[0…NumTerm] of VISIBLE STRING255	topological nodes	O

As shown in Figure 3 (b), when the S12 switch is in its open state, two LTPN logical nodes are formed in the figure. The LTPN and FTPA logical nodes are as shown in Table 2.

Table 2. Logical nodes LTPN and FTPA.

Logica Node	Attribute	Value
LTPN	NamPlt	TPN1
	PathName	E1/TPN1
	NumCnNode	5
	CnNodes	B1 L1 L2 L3 L4
LTPN	NamPlt	TPN2
	PathName	E1/TPN2
	NumCnNode	5
	CnNodes	B2 L8 L7 L6 L5
FTPA	NumTpNode	
	TpNodes	TPN1 TPN2

5.3. Topology Analysis of IED

For an IED, only a little equipment needs to be monitored, and the method used for the topology analysis is relatively simple. The depth-first method can be used to generate topological nodes, with the following steps taken:

1) The topology analysis starts, FTPA.Str=1, with an IED start, or a switch state change.
2) All the topological nodes should be cleared. The unprocessed flag of the topological node is set to 1.
3) The depth-first method is used to traverse all the connectivity nodes.
If the connectivity node's unprocessed flag is 1, a new topological node is enabled and the connectivity node information is filled into it. The connectivity nodes connected by closed switch or line segments are combined into one topological node.
4) Finally, the generated topology nodes array information should be put into FTPA. This marks the completion of the topology analysis.

5.4. Topology Analysis for Feeder

In order to carry out the topology analysis of the whole feeder, or for multiple feeders, cooperation between several IEDs is needed. References [18, 21] provide a successive polling method for the feeder topology analysis. The following steps are taken:

1) The master IED sends the network topology query command to its adjacent IEDs.
2) The IED receiving the query command replies with the information of the monitored switches and forwards the query command to its next level neighbor IEDs.
Repeat this step until the end of the feeder.
3) The master IED obtains the feeder's real-time topology according to all the returned topology information.

The exchanged information in this method includes connectivity and topology information. The connectivity information is exchanged with the terminal information of the device in Section 4.3, while the topology analysis results can be exchanged through the topological node information discussed in Section 5.2.

5.5 Case Analysis

Based on the IEEE 13 node test feeder, the section switches and IEDs are arranged on the feeder as shown in Figure 5.

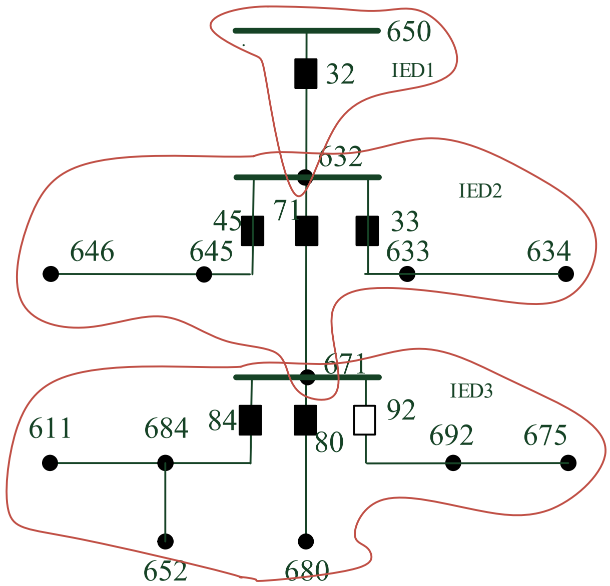

Figure 5 IEEE 13 node feeder and IEDs

As shown in Figure 5, three IEDs are placed on the IEEE 13 node feeder, with each IED configured with a local topology. When analyzing the feeder topology, the three IEDs first analyze the local topology according to the algorithm in 5.3, then IED1 is used as the main control IED, and the feeder topology is analyzed according to the algorithm in 5.4. The information exchange between IED1, IED2 and IED3 is carried out according to the logical nodes in sections 4.3 and 5.2.

Firstly, a local topology analysis is carried out on both IED2 and IED3. IED1 is relatively simple, as following a local topology analysis, one topology node is formed. For IED2, the switches 45, 71 and 33 in are all closed, and so form one topology node. In IED3 meanwhile, switch 92 is open, which forms two topology nodes.

Next, IED1 initiates a level-by-level query, IED1→IED2→IED3, and after this level by level query, it must be merged with the topology node. The wiring diagram shown in Figure 4 finally forms two topology nodes.

So far, the topology analysis is completed and correct.

6. Conclusions

Topology contains important information regarding medium-voltage and low-voltage distribution automation. In order to realize the configuration and exchange of this topology information, both the configuration language and logical nodes in IEC 61850 can be used. As an equipment set, the Feeder class defined in IEC 61970 needs to be extended and applied in IEC 61850, while the equipment connection information is described by the SCL of IEC 61850. The exchange between terminal devices can pass on the relevant terminal information and add a description of the connection node's logical LCNN node. Finally, for the resulting topology analysis information exchange, it is necessary to add the topology analysis and topology logical node (FTPA), and the logical topological node (LTPN) in order to achieve an efficient information exchange.

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