Extension of Common Information Model of Load Storage in Regional Energy System Based on IEC61970

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Abstract. The need to reform the energy system is urgent. Choose new energy to supplement traditional energy according to local conditions, to build a comprehensive energy system will become more and more emerging development areas of the rigid demand. However, in the practical application of RIES, due to its high complexity and wide range of involvement, there are information islands between various equipment and systems, which cannot support its high efficiency and timeliness. Therefore, The common information model (CIM) modeling method can break the information interaction barriers between RIES. Taking a new area as an example, the CIM model expansion of photovoltaic generating electricity system, wind power system, EV charging equipment, substation class, thermoelectric conversion equipment and user load is established. The classes and class attributes required for the information interaction of RIES control center in the new area were designed, which laid the foundation for the interaction between different energy systems and the load and storage of the source network.

1. Introduction

With the major strategic thinking of the country’s "four revolutions and one cooperation" and the proposal of the "3060-year Plan" double-carbon goal, China will comprehensively carry out the development of green and low-carbon circular economy. The optimization of energy structure will gradually realize that fossil energy will be gradually replaced by renewable energy, energy system reform will continue to break the ice, and new business type, new models and new practices in the energy field will continue to emerge. Breaking through the traditional single and independent energy supply mode, building an integrated energy system and providing integrated energy services will become a universal choice for urban energy transformation and upgrading. Integrated energy system (IES) means that the energy system in a certain region uses advanced power technology management mode, gas, renewable energy and other energy resources in the region. A new integrated energy system to promote the sustainable development of energy [1]. Regional integrated energy system (RIES) is a common application and implementation scenario of integrated energy. According to the scale level, it can be divided into building-level integrated energy system, park-level integrated energy system, new district-level energy system and so on. At present, in view of the implementation and manoeuvrability of integrated energy system, the related research of building-level and park-level integrated energy system is more common, but with the continuous increase of the number of new areas in China.

For the regional integrated energy system (RIES), the integrated development of the energy system can not be achieved without the support and innovative development of Internet technology and information technology. However, at present, there are many device entities participating in the operation and management of RIES, and there are isolated islands of information among various devices and systems. Common Information Model (CIM) is an important part of IEC61970 series
standards. IEC61970 defines the application program interface standard of energy management system. CIM is an abstract model, which provides a unified representation method for power system objects, and can realize the interaction and integration between different systems.

At present, preliminary progress has been made in the research of physical model and computational model of RIES[1]. In the aspect of distributed new energy system, Summer Thunder [2] established the CIM expansion model of wind power, the photovoltaic power generation system and energy storage system are connected to the design of power grid capacity management system[2], but did not involve the relationship between each equipment. Ding Ming et al. [3] not only expand wind, photovoltaic and energy storage, but also increase the CIM modeling of fuel cell power generation system and improve the distributed energy system model. Tao Shun et al. [4] added the CIM extension of electric vehicles to the original distributed energy system model. In addition, preliminary results have been made in the research on the interaction and impact between systems, especially between different types of energy systems. For example, Liu,X et al. [5] established a coupling relationship between power and thermal networks using the use of cogeneration units, heat pumps and electric boilers, and studied the decomposition and integration of electro-hydro-thermal computing technology. Li,Y et al [6] proposed a low-carbon micro electro-gas-thermal system, which includes renewable energy generation, electric gas generation based on carbon capture (P2G) technology and cogeneration technology, and takes into account the energy exchange between the system and the upstream energy system, as well as the constraints of battery energy storage, natural gas energy storage and heat storage system. Based on the new concept of energy centres, the coupling between different infrastructures is explicitly taken into account[7].

It can be seen that the CIM of each equipment in the energy system has been expanded in detail in the above literature, but there is still a lack of CIM expansion to the regional integrated energy system, especially the coupling and interaction among various energy systems, as well as between source, network, load and storage, which is the basis of high efficiency and intelligence of RIES. Therefore, taking a new area RIES as an example, this paper establishes the CIM model extension of photovoltaic power system, wind power generation system, electric vehicle charging equipment, substation, thermoelectric conversion equipment and user load.

2. CIM Expansion of Each System

2.1 Photovoltaic Power Generation System
Photovoltaic power generation systems directly convert solar energy into electrical energy without a thermal process, which will become one of the important development directions of sustainable energy in the future[7]. Photovoltaic power generation systems are divided into distributed rooftop photovoltaic and centralized power stations. The distributed rooftop photovoltaic system makes full use of the building space, absorbs nearby, and has low loss, which can reduce the user's dependence on the grid power supply and alleviate the impact of user load changes on the power grid; the centralized photovoltaic power station has a large capacity and is directly connected to high-voltage power transmission. The system supplies long-distance loads, and its advantages are stable output and easier power grid frequency adjustment. In RIES, two forms of photovoltaic systems exist in the region. Therefore, the characteristics of the photovoltaic system itself, the calculation and interaction of the power flow between different photovoltaic systems and the grid need to be considered in the process of creating a photovoltaic system CIM.

Extend the Solar Generating Unit class to describe photovoltaic generator sets, inherited from the Generating Unit class, and can be used for optimal dispatch of photovoltaic power generation systems. The photovoltaic cell unit is the most basic unit of the photovoltaic power generation system, which converts solar energy into electricity. Expand the Photovoltaic Cell class in the Core package to describe photovoltaic cells. Two or more photovoltaic cells form a photovoltaic array. The photovoltaic array is described by extending the Photovoltaic Array class. The Photovoltaic Array class and the Solar Generating Unit class are in an aggregation relationship.
The working performance of photovoltaic cells is greatly affected by the external environment. In order to monitor the operation of the photovoltaic power generation system[8], the Photovoltaic Generation Curve class is extended to describe the photovoltaic power generation characteristic curve.

For the optimal scheduling of regional integrated energy system, the role of photovoltaic system is essential. The expansion of photovoltaic scheduling class can guide the optimal scheduling of integrated energy system[8]. The Photovoltaic OP Schedule class inherits from the Regular Interval Schedule class of the Core package.

![CIM class diagram of photovoltaic power generation system](image)

**Figure 1.** CIM class diagram of photovoltaic power generation system

| Attribute     | Meaning                        |
|---------------|--------------------------------|
| area          | PV array area                  |
| Rated Power   | Array rated output power       |
| Max Power     | Array maximum output power     |

### 2.2 Wind Power Generation System

The wind power model in the existing CIM describes the physical characteristics, electrical characteristics, operating characteristics, and control characteristics of the wind power system in more detail, and summarizes the basic extensions of the wind power system. However, there is still a lack of offshore wind power models, which affects data sharing and exchange between the offshore wind power system and the grid management system. Therefore, the need to fully expand the description of offshore wind power systems in accordance with certain rules on the basis of the existing CIM model is one of the key issues in making full use of abundant offshore wind power resources.

Compared with the external environment and resource conditions, offshore wind turbines are completely different from onshore wind turbines.

In order to facilitate the management and dispatch of offshore wind power generation, it is necessary to record marine weather forecasts and historical offshore wind information. Derive historical curve class Wind History Curve from Curve class to record historical data of wind resources. Derive the marine weather environment prediction class Marine Weather Environment Forecast from the Regular Interval Schedule class in the Core package to store the comprehensive marine environmental forecast information and comprehensively predict the offshore wind power environment. The wind speed prediction module in the power distribution management application can use the wind history data provided by the Wind History Curve model and the weather environment forecast provided by the Marine Weather Environment Forecast model to predict wind power output, and establish the wind speed forecast Wind Forecast to store the wind speed forecast information.

The Wind Generation Op Schedule class is designed to describe the operation plan of the wind power unit. This class is usually obtained by means of the unit combination module in the advanced application. Extended wind power generation failure evaluation category Failure Effects Evaluation belongs to the category of wind power generation operation planning, which conducts real-time evaluation of the operation of offshore wind turbine equipment and detects faults in time.
2.3 Charging Equipment for Electric Vehicles
Vigorously developing electric vehicles and charging piles is the basis for building a green transportation system and an effective way to save energy and reduce emissions. Electric vehicles can increase the penetration rate and effectively alleviate the fluctuations of the grid and renewable energy [7]. In addition, as a sensing terminal for the Internet of Things, the charging pile combines vehicle, communication technology, and digital technology. Based on the charging scene, it forms a data link for charging time, mileage, payment methods, remote appointments, and life services. Therefore, electric vehicle charging piles play a vital role in the public information model. Refer to the Substation class and extend the EV Charging Station class to describe the electric vehicle charging station, inherited from the Power System Resource class. A large number of electric vehicles charging at the same time will also have a certain impact on the grid, so the EV Charging Schedule class is extended, and the Regular Interval Schedule class inherited from the Core package is extended to describe the electric vehicle charging plan, so that the electric vehicle charging equipment can also participate in the regional integrated energy scheduling.

The most important thing for electric vehicle charging equipment is the charging pile, which extends the Charging Pile class to describe the charging pile and forms an aggregation relationship with the EV Charging Station class. The Charging Controller class is designed to describe the power regulator used to control the voltage and current in the charging pile [8]. In order to monitor the working condition of the charging pile. The extended Characteristic Curve class is associated with the Charging Controller class and is used to describe the charging characteristic curve of the charging pile. The Electric Vehicle class is designed to describe electric vehicles, which are associated with charging piles and connect electric vehicles with their charging equipment. Perform real-time assessment of the equipment operation of offshore wind turbines and discover faults in time.
Figure 3. CIM class diagram of Electric vehicle equipment

Table 3. Charging pile class attributes

| Attribute         | Meaning                                      |
|-------------------|----------------------------------------------|
| Pile Type         | Charging pile type                          |
| Position          | Geographical location of charging pile       |
| Rated Temp        | Rated working temperature                    |
| Rated Power       | rated power                                  |
| Input Voltage     | Rated input voltage                          |
| Output Voltage    | Rated output voltage                         |

2.4 Transformer Substation

The purpose of the substation is not to generate or use electricity, but to transform or modify the characteristics of electrical energy [8]. The natural gas station category is similar to the substation category of the power system, which is used to describe the natural gas station. Its purpose is to adjust the pressure level of natural gas and change the phase state of natural gas. The extended pressure level Gas Pres Level class describes the pressure in the natural gas system. In the same analogy to the power system substation class, the Oil Station class is established to describe the oil station. The purpose of the oil station is to adjust the pressure level of the oil and change the phase state of the oil. The extended pressure level Oil Pres Level class describes the pressure in the oil system.

Figure 4. CIM class diagram of substation
Table 4. Natural gas station class attributes

| Attribute     | Meaning                                |
|---------------|----------------------------------------|
| State Of Matter | Phase state of natural gas             |
| position      | Geographical location of natural gas station |
| Input Pres    | Natural gas input pressure             |
| Output Pres   | Natural gas output pressure            |

2.5 Thermoelectric Conversion Equipment

2.5.1 Electric Boiler Unit.
The boiler is an important energy conversion device in the integrated energy system, which is divided into natural gas boilers, electrode boilers etc. [9]. The fuel used by the natural gas boiler is natural gas, which has a high calorific value, and is equipped with a high-performance burner, which can make the combustion fully burned; Electrode boilers can be heated by electric heating tubes from cold to hot, basically no emissions, so the efficiency is extremely high. The electric boiler can convert the renewable energy, it is difficult to improve the consumption rate of renewable energy.

Extend the Electric Boiler class to describe the boiler unit. The extended class EB Efficiency Curve refers to the efficiency curve of electric boilers.

Table 5. The boiler units class attributes

| Attribute     | Meaning                                |
|---------------|----------------------------------------|
| Capacity Of Boiler | Boiler capacity                      |
| pressure      | preset pressure                        |
| Efficiency    | Boiler efficiency                      |
| Rated Steam Temperature | Rated steam temperature            |

Table 6. Heat pump units class attributes

| Attribute         | Meaning                        | Attribute       | Meaning                           |
|-------------------|--------------------------------|-----------------|-----------------------------------|
| Heating Capacity  | Heating capacity               | Cold Water Resistance | Cold water resistance              |
| Heating Consumption| Heating power consumption     |                 |                                    |
| COP               | Performance parameter(COP)    |                 |                                    |
| Hot Water Flow    | Hot water flow                 | Maximum Operating Power | Maximum operating power            |
| Hot Water Resistance| Hot water resistance        | Maximum Operating Current | Maximum operating current          |
| Cold Water Flow   | Cold water flow                | Cold Water Inlet/Outlet Temperature | Cold water inlet/outlet temperature |
|                   |                                |                 |                                    |
Heat pump is a high-efficiency energy-saving device that uses low-grade heat energy to convert low-grade heat into high-grade heat [9]. Greater heating can be obtained by consuming a small amount of circulating net power [10].

The heat pump extension class Heat Pump inherits from the Equipment class and is used for heating of the integrated energy system. Its external factors will affect its performance indicators under working conditions, such as inlet/outlet temperature, evaporation temperature, condensation temperature etc., which are mainly reflected by the characteristic curve of performance parameter COP value. The extended class COP Curve heat pump performance parameter COP curve, inherited from the Curve class, has a one-to-many aggregation relationship with Heat Pump. Since the heat pump can not only be used for cooling and cooling, but also for heating and heating, there is a performance curve for all heating conditions and a performance curve for all cooling conditions. The extended class Heat Pump Heating Curve describes the performance curve of heat pump heating under full working conditions. It is inherited from the Curve class and has the same aggregation relationship as Heat Pump.

Extend the enumerated type of class Heat Pump in the domain package, and add the following attributes to the original device class.

2.6 User Load of Substation Category

The integrated energy system is an important physical carrier to realize the multi-energy complementary characteristics of the energy Internet [11], and most of the existing CIM model research focuses on small-scale micro-grids. The user-level regional integrated energy system has a large scale, large load fluctuations, and uncertainty. Therefore, higher requirements for accurate and reliable CIM models are put forward.

2.6.1 Thermal Load. The heat load of the urban central heating system is mainly for heating, hot water supply and production process heat load. Extended Heat Load Type is used to describe the type of heat load. Space Heating Load heating heat load, Hot Water Heating Load hot water supply heat load, Process Heating Load production process heat load [11].

In order to predict Heat Load demand, it is also necessary to obtain historical heat load information and environmental weather forecasts. The Heat Load Forecast class is used to describe the predicted heat load. The Weather Forecast class and Heat Load Forecast class are also inherited from the Regular Interval Schedule class in the Core package.

3. Overall Modeling Scheme of Regional Integrated Energy System

There are six key areas in a certain area, namely the modern service industry open area, the international innovation collaboration community, the urban commercial life center, the international cultural and creative port, the heavy equipment industrial park, and the special comprehensive bonded area.

In this paper, the extended CIM modeling of the regional integrated energy system is carried out.
Figure 7 is the overall CIM class diagram of the regional integrated energy system. Due to the diverse types of energy, the sources of electrical energy are also diverse. Derived from the Generating Unit class, the Solar Generating Unit class describes photovoltaic generator sets, the Wind Generating Unit class describes wind generator sets, and the Thermal Generating Unit class describes thermal generator sets. These three power generation methods together form the power source of regional integrated energy. Different from the park-level integrated energy system, it needs peak shaving units to meet regional energy demand due to its large area and heavy loads. The Peak Shaving Unit class is extended to describe the peak shaving units. The Peak Shaving Unit class inherits from the Thermal Generating Unit class. Extend the Photovoltaic Generation Curve and Wind Generation Curve classes to describe photovoltaic generators and wind generators. The above two categories are inherited from the Curve class. With the development of electric vehicles, the issue of electric vehicle charging has attracted more and more attention [11]. A large number of electric vehicles are connected to the grid, which poses new challenges to the dispatching ability of the grid. This article uses the extended EV Charging Station class to describe the electric vehicle charging station, the extended Charging Pile class describes the charging pile, an indispensable device for electric vehicle charging, and the extended EV Charging Schedule class describes the electric vehicle charging plan, which helps electric vehicles participate in the scheduling of the integrated energy system. Since the current supply and demand of energy cannot reach the equilibrium state, the energy storage system is indispensable. This article divides the energy storage of the regional integrated energy system into electric hydrogen, thermal energy storage units and energy storage units.

Figure 7. Overall CIM class diagram of the regional integrated energy system

Figure 8. A regional energy system

4. Application of CIM Model of Regional Integrated Energy System

The energy system of a new area is illustrated in Figure 8. The regional integrated energy system includes wind power generation, photovoltaic electricity generation, gas yield electricity, natural gas load, thermal load, heat storage, gas storage, gas station, substation and other parts.

The new area has sufficient power grid access. The existing 800KV converter station with a rated
transmission capacity of 6.4 million kilowatts is the landing point of the 800KV UHV DC transmission project. There is also a 500KV Far East substation as the main station of the new area. The current reserves of LNG (liquefied natural gas) receiving stations are 495,000 cubic meters. The sufficient LNG supply gives the new area a very large natural gas supply advantage. There are two gas-fired power plants in the area, which are combined heat and power units and peak-shaving units. A total of 72 fuel (gas) stations have been built within the scope, with a site density of about 8 per 100 square kilometers; of which, there are 3 special fueling stations for expressways and 3 fueling and gas (LNG). The land area has a large number of tidal flats, farmland, shorelines and green areas. Based on the overall advantages of wind resources, it has the potential for large-scale development. At present, 8 wind farms have been put into operation, including 4 land-based wind farms and 4 offshore wind farms. The average total solar radiation in the area is 4565MJ/(m².a), and the annual power generation is about 1.05MWh/kWp. It belongs to the third and fourth categories of the country. The air in the new area is clean, the wind is strong, and the impact of dust and backplane temperature is small. The power generation efficiency is better.

The extended CIM model in this paper covers all the types of energy systems in this area[10], as illustrated in Table 7.

Table 7. Class of energy system in a region

| Regional System | Name                          |
|-----------------|-------------------------------|
| Source side     | Photovoltaic power generation |
| Wind power      | Solar Generating Unit         |
| Wind power      | Wind Generating Unit          |
| Gas power generation | Thermal Generating Unit   |
| Network side    | Gas station                   |
| Transformer substation | Natural Gas Station |
| Lotus side      | Thermal load                  |
| Natural gas load | Natural Gas Load              |
| Storage side    | Thermal energy storage        |
| gas storage     | Thermal Storage Unit          |
|                 | Natural Storage Unit          |

5. Conclusion

Based on the IEC61970 series of standards, this paper analyzes the composition and characteristics of the RIES, and because the regional integrated energy system has the problem of mismatch of optimal scheduling information, the information model of the system is extended. The information models of photovoltaic power generation systems, wind power generation systems, electric vehicle charging equipment, thermal power conversion equipment, and user loads have been improved to meet the needs of information models and information interaction for the regional integrated energy optimal dispatch systems.

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7. References

[1] Zeng Ming 2018 Construction of comprehensive energy system [J].(China Electric Power Enterprise Management) (10):57-59.
[2] Xia Tianlei 2015 Wang Lingjing, Jiang Quanyuan.IEC 61970 standard based modeling scheme of wind power.Photovoltaic Power, Energy Storage[J]. (Automation of Electric Power Systems),39(19):9-14.
[3] Ding Ming, Zhang Zhengkai, Bi Rui 2008 CIM extension for distributed generation systems [J]. (Automation of Electric Power Systems) (20):83-87+96.
[4] Tao Shun, Zheng Jiawei, Chen Meng, et al 2016 Extension of common information Model for active distribution networks[J]. (Modern Electric Power) 33(06):74-80.
[5] Xuezhi Liu, Nick Jenkins, Jianzhong Wu, Audrius Bagdanavicius 2014 Combined Analysis of Electricity and Heat Networks[J]. (Energy Procedia) 61:
[6] Li Y., Zou Y., Tan Y., et al 2017 Optimal Stochastic Operation of Integrated Low-Carbon Electric Power, Natural Gas and Heat Delivery System[J]. (IEEE Transactions on Sustainable Energy) 1-1.
[7] Guo Jianfu, Zhao Song, Han Xiaojuan 2020. Research on electric vehicle virtual energy storage based on redundancy configuration to participate in power grid peak regulation [J]. (Thermal Power Generation) 49(08):162-168.
[8] Energy Management System Application Program Interface(EMS-API) Part 301: Common Information Model (CIM) Fundamentals: DL/T 890.301—2016 [S]. Beijing: China Electric Power Press, 2016.
[9] Ding Tao, Mou Chenlu, He Yuankang, et al 2020 Current situation and Typical Case analysis of Clean heating policy in Northwest China(2): Typical case and economic Analysis[J]. (Proceedings of the CSEE) 40(16):5126-5136.
[10] Gao Yaokui, Zeng Deliang, Ping Boyu, et al 2020 Calculation of safe area of absorption heat pump heating unit[J]. (Thermal Power Generation) 49(02):58-64.
[11] Ai Qian, Hao Ran 2018 Key technologies and challenges of multi-energy complementary and integrated optimization of energy systems[J]. (Automation of Electric Power Systems) 42(04):2-10+46.