Data model of multiple new energy equipment for energy internet application

Z W Peng¹, B J Wen¹, H Y Xie¹, J W Huang¹, L H Wei¹, Z H Xiao¹, J Jiang¹, T F Zhang², Y He², G Zhao² and J Hu²,³

¹Guangdong Power Grid Co., Ltd., Guangzhou, Guangdong, 510620, China
²State Key Lab of Power Systems, Energy Internet Research Institute, Tsinghua University, Beijing, 100084, China

E-mail: hjun@tsinghua.edu.cn

Abstract. In order to meet the application demand of the "Internet Plus" smart energy demonstration project in Zhuhai, following the IEC61970/61968 CIM and the ECIM specification of China Southern Power Grid, an extension of CIM for multiple new energy equipment is carried based on the power grid resource CIM model and the physical model of GIS platform, where the DC model, the urban multi energy pipe network model, the energy production model, the energy storage model, customer energy source and load model are added to build a comprehensive multiple energy equipment data model from the perspective of the grid, city, park and user. The data model supports the integration of internal data and external data of integrated energy, and satisfies the integration and sharing of information among different systems of energy internet.

1. Introduction

With the development of energy internet, many Energy Internet application projects have been launched around the world [1]. Multi-energy complementary, comprehensive energy utilization has become the current research hotspot and the future trend of energy industry development [2], which is also an important measure to implement the concept of low-carbon energy conservation, green environmental protection. China has promulgated relevant policies such as the "Internet Plus" initiative [3,4] and "The Belt and Road Initiative" [5], and actively promoted the construction of Energy Internet demonstration projects [6] to establish the new energy and future energy systems [7].

Under this background, "City-Park" two level "Internet Plus" smart energy demonstration project in Zhuhai is initiated as one of the first batch approved national demonstration projects. The demonstration project coordinates at the "City-Park" two level to carry out the four themes of "multi-energy integrated operation", "flexible access to supply and demand", "information coordination interaction", "new market mode". It will realize the multi-energy flow cooperative energy management, flexible access of new energy and energy storage [3], active response on demand side, flexible multi-energy transaction, Energy Internet data sharing and energy consumption oriented construction in the demonstration area. Then it will support the energy consumption revolution with the "Internet Plus" smart energy model with extensive demonstration significance, eventually improve energy efficiency, promote energy conservation and emission reduction, reduce energy consumption costs, and innovate energy consumption patterns.

In the process of constructing the new energy and future energy systems, the information and
communication technology is essential for the implementation of Energy Internet project [2]. The demonstration project needs to manage multi-energy equipment involving electricity, cold, gas, heat, water and so on, to realize the collection and access of more than 10 kinds of energy information such as cold, heat, gas, charge, light and storage, and more than 1 million measuring points in the physical layer of the city. It needs high comprehensive energy data service capability, to ensure the security of energy transaction data and to support the development of advanced applications of intelligent energy in the application layer.

From the point of view of energy utilization model centered on electricity energy, Energy Internet can be regarded as smart grid 2.0. The existing power grid has basically solved the problem of information islands on the basis of IEC61970/61968 international standard [8,9]. However, once the scope is extended to other energy fields outside the power grid, due to the different management subjects, the information models are not unified, information integration and fusion problem become very serious [6]. Despite extensions of CIM for distributed generation system [10-13], DC system [14], feeder [15], relay protection for dispatcher training simulator [16], power system multi-area state estimation [17] and have been developed in many literatures [18], it is still far from enough to cover the multi-energy fields and lack of modeling details, which makes it difficult to be used in practical operation. Therefore, in order to solve the problem of information integration and fusion of multi-energy systems, this paper extends the CIM model of multi-energy equipment. This paper is organized as follows: Section 2 introduces comprehensive energy CIM model, and section 3 presents CIM extension. Then, the application of comprehensive energy CIM model in Zhuhai smart energy project is explicated in section 4. At last, section 5 states the conclusion of this paper.

2. Comprehensive energy CIM model

Comprehensive energy CIM model is based on the IEC61970/61968 international standard CIM and the ECIM specification of the China Southern Power Grid [19], expanded on the basis of the power grid CIM model and the physical model of GIS platform where the DC model, the urban multi-energy pipe network model, the energy production model and the energy storage model are added to build a comprehensive multiple energy equipment data model from the perspective of the grid, city, park and user. The structure of multiple energy equipment model is shown in figure 1.

![Figure 1. The structure of multiple energy equipment model.](image)

The power grid resource model mainly comes from the Wires package of IEC 61970/IEC 61968 CIM, which is stored in CIM V15 format. It covers the objects and topological relationships of power grid resources from substations, distribution lines, distribution stations, various switches, overhead wires and cables, poles and towers to EnergyConsumer, and establishes the relationship between EnergyConsumer and the marketing through the metering point. CIM extension of DC equipment,
energy production, energy storage equipment, urban multi-energy network equipment and power user load are described in detail in figure 1.

3. CIM extension

3.1. CIM extension of DC equipment
CIM extension of DC equipment [11] in Wires package is shown in figure 2. Those red-highlighted ones are new classes (new attributes added in some classes), the black-and-white ones are existing classes, which are defined in CIM standard [8,9]. This note also applies to subsequent figures. Those new or updated classes are DC Line Segment, DC Breaker, Rectifier Inverter, DC Busbar, DC Chopper, ACDC Converter, DC Disconnector, DC Ground, DC Series Device, DC Shunt, Per Length DC Line Parameter, Vs Converter and Cs Converter.

![Figure 2. DC equipment model.](image)

DC Breaker is the key equipment for safe and efficient operation of DC microgrid. A new class of DC Breaker is added. It inherits from the Breaker class and the inherent attributes of type Name, rated Current, rated Voltage and break time are added. At the same time, the enumeration class DC Breaker Type is expanded in the Wire package, which may be Solidstate Breaker, Hybrid Breaker, Vacum Breaker and so on.

3.2. CIM extension of energy production
Wind Turbine and Electric Steam Supply model is shown in figure 3. New classes in this model include Wind Turbine, Electric Steam Supply, Wind Turbine Leaf Speed Rate Curve, Wind Turbine Utilization-Factor Curve and Wind Turbine Utilization Factor Curve.

CIM extension of energy production in Generation package for CIM v15 is shown in figures 4 and 5. The new classes of Windplant, Photovoltaic Plant, ACUnit, Absorption AC Unit, Direct Fired Absorption ACUnit, Electric ACUnit, Heat Pump AC Unit. The relationship between HeatPumpACUnit and Absorption ACUnit is established through Heat Recover Boiler. The energy
conversion relationship of gas turbine or internal combustion gas waste heat refrigeration is expressed. Absorption AC Unit Heat Cooling Curve is used to describe the conversion relationship between the input hot water heat and the output cold water cooling capacity of lithium bromide absorption refrigeration units. Direct Fired Absorption AC Gas Cooling Curve is used to describe the conversion relationship between gas consumption and output cold water cooling capacity of direct-fired lithium bromide absorption refrigeration units. Electric AC Cooling Curve is used to describe the relationship between the energy consumption and output cold water cooling capacity of electric refrigeration units. Heat Pump Temperature Electric Cooling Curve is used to describe the relationship between the temperature of the hot and cold end of the heat pump unit, the energy consumption and the output cooling capacity.

Figure 3. Wind turbine and electric steam supply model.

Figure 4. Air conditioning and heat pump model.

Figure 5. Photovoltaic Plant and Wind Plant model.

The models of PV are designed. Photovoltaic Plant representing the PV power generation station, which aggregating one or more Photovoltaic Generating Units derived from Generating Unit. Photovoltaic Array will be Photovoltaic Generating Unit when it works. Photovoltaic Array are
composed of several Photovoltaic Cells in parallel, and shunt Cell Numbers represents the number of Photovoltaic Cells. The photovoltaic component is represented by Photovoltaic Cell, in which the serial number attribute serial Cell Numbers denotes a single photovoltaic cell (value is 1) or a series photovoltaic cell (value is greater than 1).

The output power of photovoltaic plant is predicated by solar irradiation forecast. Class Solar Irradiation Forecast Curve Curve describes the prediction of solar illumination intensity, is associated with Photovoltaic Plant. Photovoltaic CellIV Curve describes the volt-ampere curves of photovoltaic cells. There are several groups of curves at different temperatures, which have a one-to-many relationship with Photovoltaic Cell.

Wind Plant is added, with an aggregation relation with Wind Generating Unit, one or more Wind Generating Units is aggregated.

3.3. Distributed energy storage model
The model extensions of distributed energy storage are shown in figure 6. The basic energy storage unit Energy Storage Unit is included in this model, from which Electric Storage Unit, Cold Storage Unit and Heat Storage Unit is derived. Battery Storage Unit and Super Capacitor Unit are derived from Electric Storage Unit, and one or more Batteries are aggregated. Battery batteries are associated with Battery Discharging Curve and Battery Charging Curve. Ice Storage Unit, Water Cold Storage Unit and Phase Change Cold Storage Unit are derived from Cold Storage Unit to represent different storage media. Heat Storage Unit derives Water Heat Storage Unit and Brick Heat Storage Unit.

3.4. Urban multi-energy pipe network equipment model
Urban multi-energy pipe network equipment model is presented in figure 7. New classes involving multi-energy pipe, heat exchangers, gas stations and other multi-energy station resources are added in a created Energy Equipment CIM package. The equipment model of urban multi-energy network includes gas, hot water (steam), cold water and other multi-energy pipe, heat exchanger station, gasstation and other multi-energy building resources. Fluid Equipment is derived from Equipment as the basic class of fluid equipment. The fluid types of gas, hot water (cold water), steam and other fluid media are distinguished by Fluid Type. Valve, Joints, Pipe, Heat Exchanger, Water Boiler, Heat Radiator, Heat Consumer are further derived from the base class of Fluid Equipment.

Derived from Equipment Container, Energy Station expresses that energy supply stations, heat exchangers, gasstations and other energy production, transmission and consumption station-type equipment. Energy Station and Energy Cabinet PSR inherited from Equipment Container.
3.5. Customer energy source and load model
On the basis of Energy Source, Customer Energy Source is derived to represent customer's power source a in a general way, includes BESS Plant and Photovoltaic Plant representing customer's energy storage system and customer's photovoltaic station respectively. On the basis of Energy Consumer, Customer Energy Consumer is derived to represent customer's energy consumers and describe low-voltage load equipment in a unified way.

New classes of electrical equipment inherited from Conducting Equipment include: Motor Load representing the motor load for industrial production; Electric Vehicle representing the charging car, Charging Spot, Light Load, Air Conditioning, Heating Load, Cooking Load, Elevator Load, Ventilation Load, Washing Load and Computer Load Charging Port is a charging interface inherited from Equipment, with the aggregation relation with Charging Spot and the association relation with Electric Vehicle. DAC System Terminal represents distributed air conditioning system terminal, with the aggregation relation with Air Conditioning. EV Classified represents the classification information of electric vehicles, inherits from Electric Vehicle. Customer Consumer Info represents the user energy information and inherits from Identified Object. Customer energy source and load model is shown in figure 8.

![Customer energy source and load model diagram](image)

**Figure 8.** Customer energy source and load model.

4. Case study
For Zhuhai smart energy demonstration project, according to the smart energy advanced application needs, data collection involves water, electricity, gas, cold, heat, photovoltaic, storage and other forms of energy data source system. Because different applications have different demands for data and different requirements for data timeliness, platforms need to be connected to various data sources both intra and extra the power grid. Those data sources includes but not limited to CSG "6+1" system, dispatching, meteorology, photovoltaic, water supply, heating supply, gas supply, non-intrusive system data, cooling, Guangdong Easy Charging, etc.

To supporting the information integration and fusion, comprehensive energy information model (equipment parameters, topology and graphics) is needed, mainly covering:

- Microgrid model, distribution network, Tangjiawan flexible DC (1), 10 kV voltage photovoltaic station (8), 0.4 kV voltage photovoltaic station (431), storages (2), charging (410), distributed photovoltaic component models (inverters, photovoltaic cells, shunt boxes);
- The model of urban energy pipeline network, including the heating and cooling pipeline network of Hengqin Energy Company and the pipeline network of Hengqin Gas Company;
- Energy production and energy user model, including internal energy production model of
Hengqin 3 # cold station (triple supply, electric refrigeration, gas boiler, etc.), 17 cooling users, and internal energy production and consumption (power, heating and ventilation, etc.) of enterprises (Changlong Group).

With the CIM extension of multiple-energy equipment above mentioned, Zhuhai smart energy big data cloud platform realized the unified description and management of multi-energy equipment.

It is worth mentioning that the CIM extension of multiple energy equipment is logical model, which can be used as a reference for the physical implementation of application system. In realization process, it can be mapped to database for data store [20], used in XML RDF (Resource Description Framework) file [21] for configuration, or used in XML XSD message to meet the requirements of information exchange [22].

Adopting the CIM extension of multiple energy equipment is beneficial to standards based energy system integration with low costs. According to the project team estimate, the use of the model reduces the cost by 10% and speeds up the development progress by 20%, it has good economic significance.

5. Conclusions
Taking the integrated energy system of industrial parks as the research object, this paper establishes multiple energy equipment data model covering the city-park-user perspective for energy Internet applications, provides a consistent management scheme for multi-energy data, and promotes the standardization of energy Internet data model. The model strongly supports the construction of the information layer of the demonstration project, realizes the unified operation and management of multi-energy equipment.

In the next three years, smart energy construction projects in 19 cities planned to be completed in Guangdong power grid. Zhuhai smart energy project provides a low-cost and efficient demonstration, promotes the development of comprehensive energy utilization, and the technical scheme has good popularization value, its achievements including multi-energy equipment model will be used in the following projects.

This paper presents our latest achievements in information model when we build the smart energy platform in terms of new energy and future energy system.

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Appendices

| Table A. Nomenclature. |
|------------------------|
| **CIM** | Common Information Model |
| **ECIM** | Enterprise Common Information Model |
| **CSG** | China Southern Power Grid |
| **GIS** | Geographic Information System |
| **AC** | Air conditioning |
| -Plant | A factory where power is produced, the prefix is the type of power generation |
| -Unit | A single thing or group that is complete by itself but can also form part of something larger, the prefix is the type of energy |
| **DC** | Direct current |
| **DAC** | Distributed air conditioning |
| **EV** | Electric Vehicle |
| **PV** | Photovoltaic |
| **BESS** | Battery energy storage system |
| -Curve | A curve is a smooth, gradually bending line, the prefix is the meaning of curve representation |
| -Load | Electrical power that is being supplied at a particular time, the prefix is the load type |

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