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Key technologies and system development for regional integrated energy system

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Abstract

To combat energy shortage, RIES has become an important research direction in the international energy field. In order to improve energy efficiency and the large-scale consumption of renewable energy, this paper presents the key technologies of RIES, which consists of the coupling relationship, the applicability of control equipment for multi-energy systems and the principle of fault handling. Furthermore, a control system for RIES is designed and discussed in software architecture and data processing. The simulation and practical results indicate that it can effectively deal with the unexpected situation of RIES.

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Keywords: Regional multi-energy system; Energy coupling; Coordinated control; Regional integrated control system

1. Introduction

With the rapid growth of energy demand, comprehensive utilization of energy is an effective way to improve its efficiency. And comprehensive utilization of energy main performance is the integrated multi-energy system(IMS). At present, IMS has been studied on a certain scale. A development plan for IMS is proposed by the US Department of Energy (DOE) in 2001. K Peng (2017) [1] introduced the operation control, energy storage technology, electricity market mechanism and so on in the ELECTRA Demonstration Project. E-Energy project promotes regional participation in building ICT-based efficient energy systems to achieve the goal of replacing or reducing the using of nuclear energy in the future. In Asian region, Japan is the first country to carry out IEMS research. And Japan has established the Japan's Approaches to Smart Community (JSCA). Ziqing Jiang and H. Ran (2017) [2] pointed that

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the energy utilization efficiency and power supply reliability is improved in Comprehensive Energy Management System Development and Demonstration Project of Conghua Industrial Park.

In conclusion, there are few studies on system development for RIMS. In this paper, the key technologies for RIES are introduced in terms of coupling relationship, the applicability of control equipment for multi-energy systems and the principle of fault handling. IEMS for RIES is developed based on the vertically encrypted hardware communication architecture and multi-tie software architecture. And based on the industrial park data, IEMS is applied to RIMS to deal with the energy management problems.

2. Key technologies for RIES

Hongjie Jia (2015) [3] pointed that compared with the traditional energy system, RIES integrates various types of resources, which has the characteristics of high reliability of energy supply and high efficiency of energy utilization. And the key technologies of RIES can be elaborated in three ways.

(1) Coupling of Multi-Energy Sources

RIES combines electricity, heating, gas and so forth in the process of energy production and consumption. The structure of a basic RIES is presented in Fig. 1. There are interactions between different energy systems in the RIES. Chapman (2016) [4] and Li Z (2015) [5] pointed out the interaction of CHP, Chen Xinyu (2015) [6] and Weijia Liu (2016) [7] studied the coupling between power system and natural gas system, Herrando and Maria (2014) [8] introduced the combination of energy storage technology and photovoltaic system. Electricity, heating, cooling, gas and so on can be directly utilized by users. And these also can be utilized indirectly by cogeneration units, refrigerant compressor units and so on.

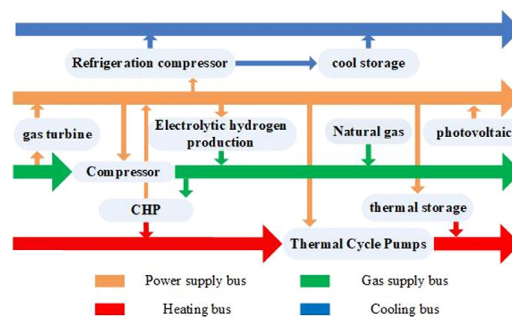


Fig. 1. Structure of Integrated Energy System.

(2) Applicability of Control Equipment to Multi-Energy Systems

Owing to abundant renewable energy and various load components, RIES is difficult to control and its structure is complex. Traditional control equipment can only coordinate the single energy system, and cannot be applied to the RIES with multi-energy systems. Therefore, it is necessary to develop RIES integrated control system, which can exchange necessary information through distributed control and reduce the dependence of control system on communication network. The control system should realize supervisory control and data acquisition (SCADA).

(3) Fault Handling of RIES

Jianyang Y. U (2016) [9] pointed that the fault can be located and isolated by analyzing the fault current. And Dong X (2012) [10] suggested that self-recovery and regulation system can ensure the reliability of power supply. The RIES consists of several sub-energy systems which are coupling with each other, and the time scale and response speed of each sub-energy system are different. So when a fault occurs in RIES, the impact of the fault will be expanded because of the interaction of coupled energy systems. And that will increase the difficulty of fault handling.

3. Development of RIES control system

3.1. Overall functional architecture and implementation of REMS

(1) IEMS Hardware Architecture and Implementation

The communication scheme adopts special optical fiber channel for power grid, and realizes security protection by deploying longitudinal encryption device. The overall hardware architecture of the integrated control system is shown in Fig. 2(a).

(2) IEMS Software Architecture and Implementation

In order to ensure the advancement, extendibility and security of the software, its architecture can be divided into five parts. The specific system software design architecture is shown in Fig. 2(b).

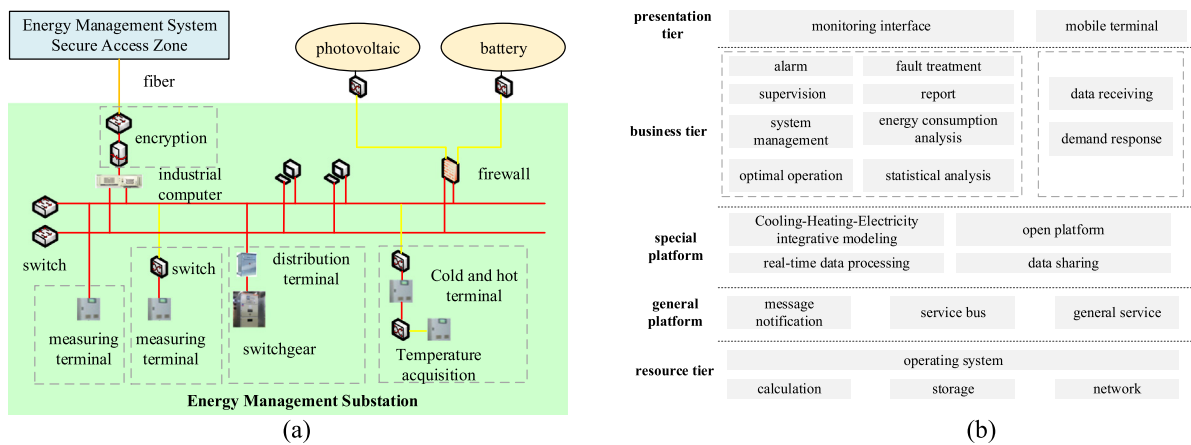


Fig. 2. (a) Overall Design and Implementation of IEMS; (b) IEMS Software Architecture.

(3) IEMS Data Interaction

The sub-station energy management system (SEMS) can collect the information of cooling, heating and electricity load terminals, distributed photovoltaic, energy storage and other equipment in real time. The system data interaction architecture diagram is shown in Fig. 3(a).

3.2. Architecture and implementation of user energy management sub-station

(1) Integrated Cooling–Heating–Electricity Modeling

In thermal grid and electric grid, SEMS can achieve unified object management and model validation. And all the models, energy storage and so on are based on the integration of the diagram library maintenance interface.

(2) Real-time Data Processing for Multi-Energy Flow

SEMS can collect, dispose and store the information in real time that belongs to different resources. In addition to the common power system protocol, the data acquisition protocol also includes the common communication protocol of MODBUS and other cooling–heating systems. The data processing types cover analog quantity, state quantity, electrical measurement and calculation quantity.

(3) Open Integrated Data Sharing

SEMS can provide comprehensive display and release which is about enterprise energy monitoring, adjustable resources, day-ahead and day-ahead plans, energy using analysis and other data. And the data consists of enterprise energy using indicators, energy saving indicators, economic indicators, user integrated energy optimization strategy and optimized operation data.

3.3. Implementation of IEMS function

Based on the research of several hardware platforms, enterprise user integrated control system is established, and various research functions are realized. The logic diagram of the integrated control system is shown in Fig. 3(b).

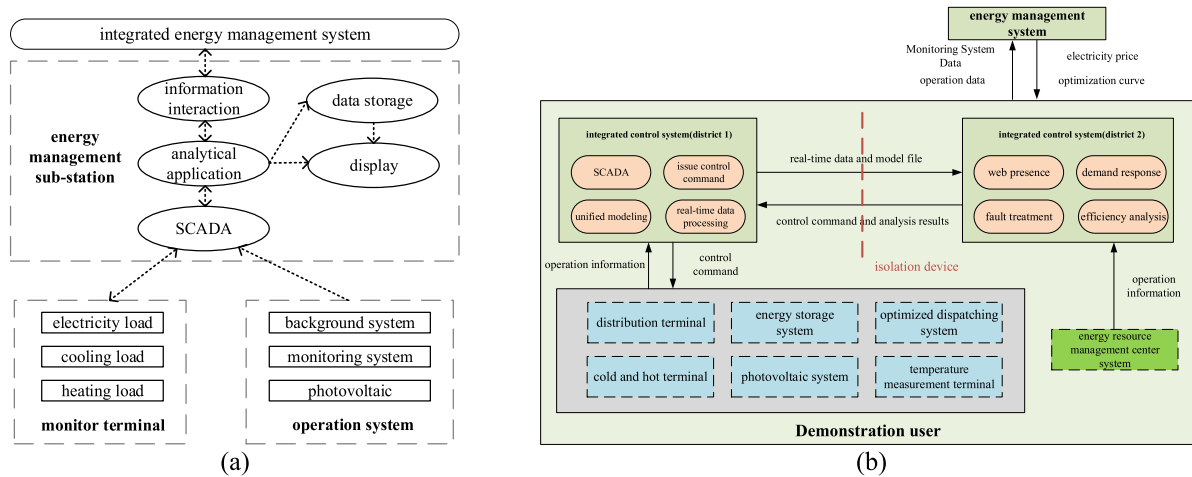


Fig. 3. (a) System Data Interaction Architecture Diagram; (b) Logic Diagram of Integrated Control System.

4. System development

In this paper, case studies are conducted in an actual multi-energy system demonstration project of an industrial park in China. The simplified energy system structure diagram is shown in Fig. 4. The monitoring interface of IEMS is shown in Fig. 5, and control results are shown in Figs. 6 and 7.

In order to identify the reliability, IEMS is tested in two working situations. And the results are in Figs. 6 and 7.

User 1 need to increase load by 300 kW at 15:00–17:00 and 20:00–22:00, and the rest time remains the same. Through the calculation and analysis by the IEMS, the optimal scheduling strategy is shown in Fig. 6. According to the optimal result, when the energy consumption of user 1 load increases, because of the limitation of the battery capacity, the electricity purchase by users increases in the period of high electricity price.

After 12:00, User 2 airborne refrigerator output reduced by 60% suddenly. Through the calculation and analysis by the IEMS, the optimal scheduling strategy is shown in Fig. 7. According to the optimal result, when the system has a fault, the related energy storage equipment will increase output.

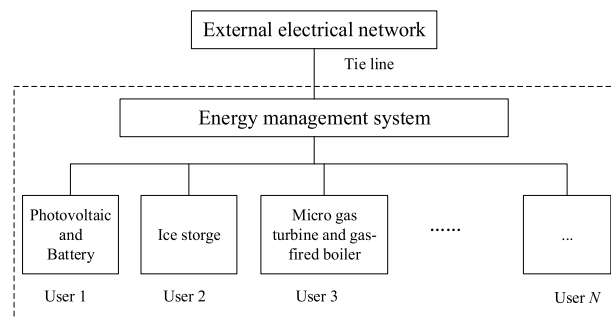
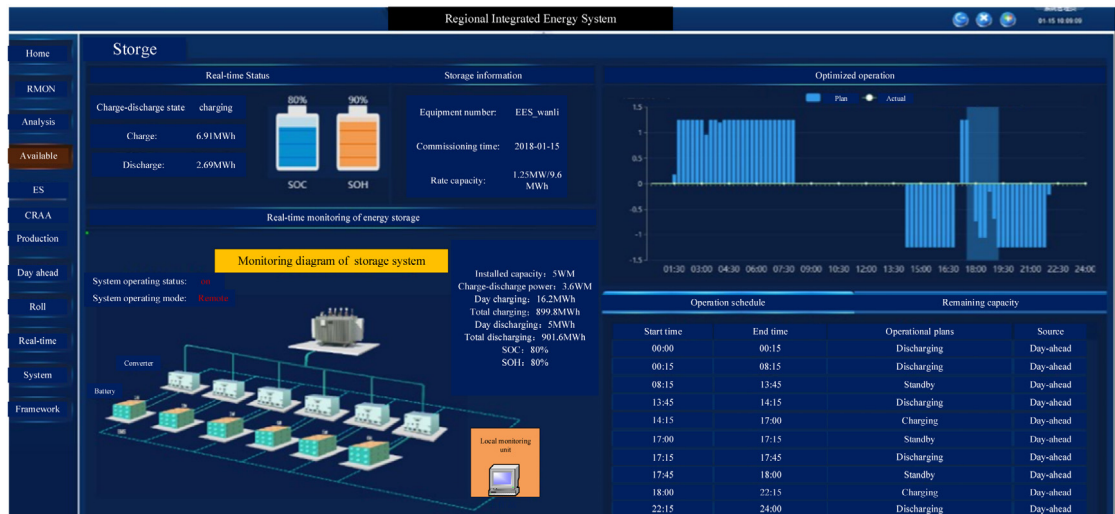


Fig. 4. Schematic Diagram of the Park.



(a)



(b)

Fig. 5. (a) Software interface Diagram of Optimal Multi-Energy Management; (b) Multi-Energy Monitoring and Power Capacity after Demand Response.

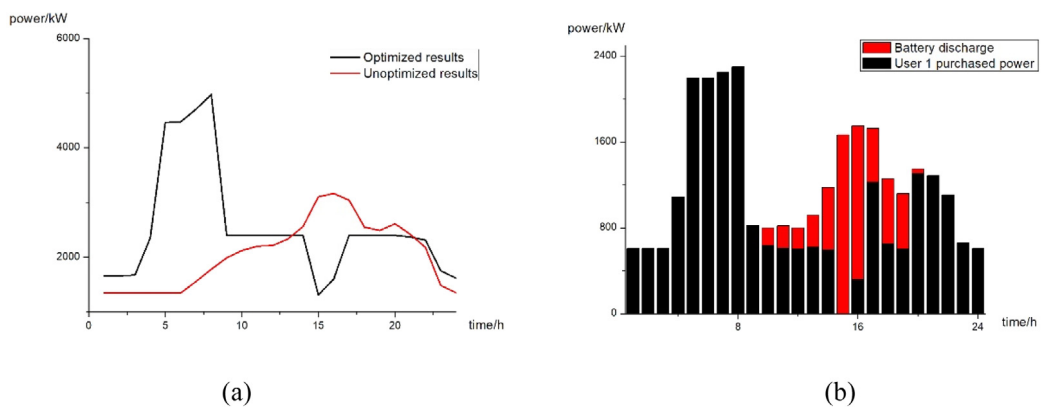


Fig. 6. (a) The Tie Line Power for User Energy Consumption Increased; (b) Power Supply Distribution.

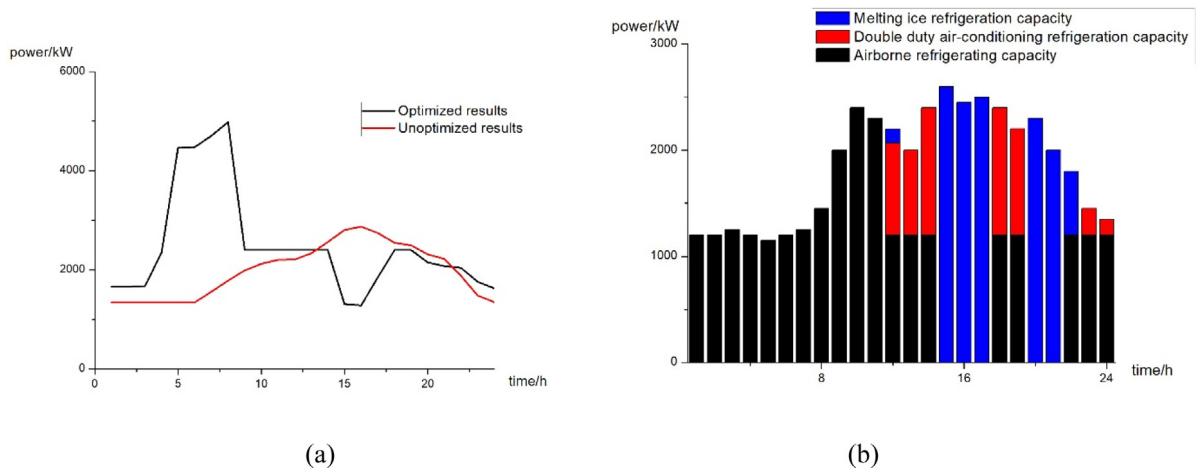


Fig. 7. (a) The Tie Line Power for Customer Energy Equipment Failure; (b) the Units Power Distribution.

5. Conclusions

With the development of multi-energy systems, RIMS has proven to be a new form of comprehensive utilization of energy. In this paper, the key technologies for RIMS are discussed in the coupling relationship, the applicability of control equipment for multi-energy systems and the principle of fault handling. And the IMES is designed in terms of soft architecture and data processing. Two cases are analyzed to verify and validate the feasibility of IEMS. When the load or the equipment changes in RIMS, IEMS will adjust each energy source according to the actual situation. In the future, in order to improve IEMS, the load forecast and uncertainty of renewable energy resource will be studied.

Acknowledgments

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