Research on Energy Consumption Analysis System of Large Buildings Based on Big Data Monitoring

Bin Meng *, Xinyang Ji, Gaoshan Hu
Shenyang Urban Construction University, Shenyang,110167, China
*Corresponding author email: mengbin@syucu.edu.cn

Abstract. Public buildings should install itemized electricity metering devices. The thesis establishes an energy consumption monitoring system and ensures that the energy consumption statistics are true and complete. The characteristics of big data on energy consumption of public buildings are analysed. At the same time, the article expounds the design thinking and implementation strategy of the big data public building energy consumption monitoring system. The building energy management system can monitor the status of energy-consuming equipment, with more detailed and broader classification, and realization of energy consumption decision feedback and optimized control.

Key words: Public buildings; energy consumption monitoring; big data; design and implementation strategies; design patterns.

1. Introduction
With the acceleration of my country's urbanization process, energy conservation in large public buildings is imperative. How to meet the needs of use and comfort, but also scientifically and reasonably save energy and reduce consumption is a problem that the whole society must think about. In the stage of vigorously promoting energy saving and emission reduction, to achieve the fastest and most obvious energy saving effect, not only the use of equipment energy saving means, but also the use of sub-metering to accurately, timely and effectively discover energy use problems, and form and achieve the most effective Energy-saving measures. Energy consumption sub-metering refers to the monitoring of various energy consumption of buildings, such as water, electricity, gas, central heating, and central cooling, so as to obtain the total energy consumption of the building and the total energy consumption of different energy types and different functional systems [1]. Energy consumption. To realize sub-metering, data collection, data transmission, data storage and data analysis must be carried out. Therefore, energy consumption sub-metering is a typical streaming big data system, which has the characteristics of large data volume, fast data generation speed, and complex data structure. In order to construct a unified building energy consumption information database, it is necessary to establish a building energy consumption information model. One is to provide a basis for the design of the unified database structure, and the other is to facilitate the convenient extraction of related data from the unified database and conduct large-scale projects on various topics. data analysis.

This article passed
Use Apache Kafka and Spark Streaming module to build a real-time streaming data processing system to perform energy consumption sub-metering. Different from the traditional architecture, the real-time streaming data processing system captures and processes the data in real time in the process of data flow, and calculates and analyses the data according to business requirements. On the one hand, the captured abnormal information is reported to the front end in time, and the classification the results of sub-item statistical processing are saved to the database for offline analysis and data mining. This article will describe in detail the system architecture and internal structure of the real-time energy consumption sub-metering system, and introduce and analyse the big data technology and system used in the architecture [2]. Finally, the real-time energy consumption sub-metering system will be measured in real time through actual test results. Data processing capabilities are verified and analysed.

2. Static data of building energy consumption monitoring and IFC standards

For big data applications, in order to make full use of the data corresponding to different floors or even different rooms, the corresponding information model was established in the previous work using object-oriented methods. The simplified model is shown in Figure 1, which includes the entities of the building and its electromechanical system. This model is used to reflect the static data of the energy consumption site, energy consumption carrier, energy consumption subject, and energy consumption measurement device corresponding to each energy consumption monitoring data record [3]. The above static data can be divided into different granularities. For example, energy-using sites are divided into 6 levels of granularity, from buildings to rooms and corridors, and the granularity decreases; energy carriers and energy-using subjects are both divided into 4 levels of granularity. These entities of different granularities all have corresponding attributes. For example, the building entities of energy-using sites have attributes such as "building area", "building exterior wall material form", "building exterior wall thickness" and "building exterior wall window-to-wall ratio". The energy-consuming equipment entity of the energy-consuming carrier has attributes such as "equipment brand", "equipment model" and "rated power", and the unit entity of the energy consuming subject has attributes such as "unit nature" and "working time". And these entities and their attribute information are the required static data of building energy consumption monitoring.

![Figure 1. Static data model of building energy consumption monitoring](image-url)
3. Establishment of building energy consumption information model

The building energy consumption information model includes the overall model of building energy consumption information and the granularity model of related entities. According to the above-mentioned requirements, all models are established and expressed using object-oriented methods. In this paper, EXPRESS-G is used to express the models. The entities in the model represent the types of objects, for example, the power system entity represents the power system type. When used to express data, types are used to generate instances [4]. Among them, the energy use period represents the time of energy consumption, which is composed of the start time and the end time; the energy consumption data measured by the metering device can be a power metering device, a water metering device, a gas metering device, etc. The other three entities, namely the main body of energy, the carrier of energy and the place of energy can all have different granularity. The granularity models established based on the above requirements are shown in Figure 2.

![Figure 2. Granularity model of energy consumption carrier](image)

In view of the fact that the IFC standard cannot fully express the required static data of building energy consumption monitoring, it is necessary to extend the IFC standard so that the relevant data in the BIM model can be imported into the IFC file. There are three main extension methods: First, increase the IFC entity type. This method is an extension of the IFC standard model. This method involves the complex process of standard formulation and is generally used when the IFC version is updated. Second, use Ifc Proxy or Ifc Building Element Proxy is extended, this method is easy to implement by instantiating the entity and combining the attribute set to express the undefined entity; third, adding the attribute set, through user-defined attribute set, this method is relatively easy to implement. In this study, the second method will be adopted to extend the entities that cannot be directly expressed in the IFC standard; the third method will be used to extend the attributes that cannot be expressed in the IFC standard [5]. For example, this research focuses on the extended attribute set of office buildings. The name of the attribute set is office building extended information, which is applicable to the entity Ifc Building, and the application value type is any value of the entity attribute Predefined Type. Table 1 shows the 5 included in the attribute set. Definition of each attribute.
Table 1. Attribute definitions in the special extended attribute set of office buildings

| Attribute name          | Attribute type            | Attribute value type     | Description |
|------------------------|---------------------------|--------------------------|-------------|
| Office form            | Ifc Property Enumerated   | PEnum_Work Type: Centralized office, independent office | no          |
| Architectural nature   | Ifc Property Enumerated   | PEnum_Building Use For: rent, own use, sale | no          |
| Number of energy-      | Ifc Property Single       | Ifc Integer              | no          |
| consuming units        | Value                     |                          |             |
| Main office type       | Ifc Property Enumerated   | PEnum_Work Business: Finance, IT, Media, General, Mixed | no          |
| Normal use period      | Ifc Property Single       | Ifc Label                | no          |
|                        | Value                     |                          |             |

4. Architecture design of building energy consumption cloud platform

4.1. Overall design

According to the “Technical Guidelines for the Construction of Energy Monitoring Systems for Office Buildings and Large-scale Public Buildings of the State” issued by the Ministry of Housing and Urban-Rural Development in 2008 (hereinafter referred to as the “Guidelines”), the standard building energy consumption monitoring system should include data transfer stations, Energy consumption data collector and metering device [6]. Among them, the data transfer station collects and caches the energy consumption data of the monitored building in its management area, and completely forwards it to the upper-level data centre. However, in applications such as building energy efficiency diagnosis and energy efficiency evaluation, temporary energy consumption monitoring systems are often built to obtain energy consumption data of the space, systems, and equipment in the building. During the construction of a temporary building energy consumption monitoring system, the wiring of communication cables is difficult and costly. In addition, due to factors such as walls and beams in the building space, short-distance communication systems often have unstable signals and low communication quality. Phenomenon. To this end, this paper proposes a building energy consumption data collection node, so that the collected building energy consumption data can be directly transmitted to the building energy consumption cloud platform, and the pre-processing, fusion and analysis of the building energy consumption data are realized on the cloud platform to provide pre-processing data support for energy saving diagnosis and energy efficiency evaluation. Therefore, this paper proposes an improved building energy consumption monitoring system architecture. The system architecture is shown in Figure 3. In the monitored building, the building energy consumption data collection node (DAU) obtains real-time data from the metering device, and directly uploads the building energy consumption data to the building energy consumption cloud platform through the 4G network. Based on this scheme, general building energy consumption data collectors and local data servers are no longer installed in the monitored buildings [7]. The data storage, data pre-processing and data analysis functions of the building energy consumption data collector will be directly moved to the building energy consumption cloud platform.
4.2. Functional design

The data acquisition node system that this text puts forward has more abundant data acquisition interface, namely support RS-485/M-bus/Mod-bus bus interface at the same time. However, the proposed node system design plan does not have data processing functions, nor does it have a dedicated building energy consumption data storage space [8]. The collected building energy consumption data is directly uploaded to the cloud platform without local storage and processing; at the same time, it is different from the "Guidelines" is: the node system has no wireless communication interface, and only communicates with the cloud platform through the 4G network.

4.3. Circuit structure

The circuit design of the data acquisition node system proposed in this paper is shown in Figure 4, which mainly includes a microprocessor, data acquisition interface and 4G communication module. Among them, the microprocessor uses the IAP15W4K chip, the data acquisition interface supports RS-485, M-bus and Mod-bus bus interfaces, and the 4G communication module is WH-LTE-7S4. This node system collects the data of building energy consumption metering equipment through RS-485/M-bus/Mod-bus bus, and realizes the transmission of building energy consumption data to the cloud platform with the help of 4G network.
5. Conclusion
Realizing the leapfrog development of public building energy consumption monitoring system with big data is the task of the new generation of public building energy management system. The building energy consumption monitoring platform can only obtain energy consumption and resource data, which can be used for macro analysis and cannot directly save energy; while the building energy management system can not only collect energy consumption data, but also monitor the status of energy consuming equipment, with more detailed and broader classifications. Energy consumption decision feedback and optimal control. The powerful automatic control of the energy consumption monitoring platform can help save 30% of energy, while 8% is lost due to the lack of reasonable monitoring and maintenance measures. Therefore, technical energy saving and efficiency enhancement must be coupled with solutions for energy saving and efficiency improvement in order to continue to save energy.

Acknowledgments
Supported by the Research and Development Fund of Shenyang Urban Construction University (Grant No. XKJ202101).

References
[1] Mocanu, E., Mocanu, D. C., Nguyen, P. H., Liotta, A., Webber, M. E., Gibescu, M., & Slootweg, J. G. On-line building energy optimization using deep reinforcement learning. IEEE transactions on smart grid, 10(4) (2018) 3698-3708.
[2] Rodríguez-Mier, P., Mucientes, M., & Bugarín, A. Feature selection and evolutionary rule learning for Big Data in smart building energy management. Cognitive Computation, 11(3) (2019) 418-433.
[3] Al-Ali, A. R., Zualkernan, I. A., Rashid, M., Gupta, R., & Alikarar, M. A smart home energy management system using IoT and big data analytics approach. IEEE Transactions on Consumer Electronics, 63(4) (2017) 426-434.
[4] Cai, W. G., Wu, Y., Zhong, Y., & Ren, H. China building energy consumption: situation, challenges and corresponding measures. Energy policy, 37(6) (2009) 2054-2059.
[5] Zheng, D., Yu, L., & Wang, L. Research on Large-Scale Building Energy Efficiency Retrofit Based on Energy Consumption Investigation and Energy-Saving Potential Analysis. Journal of Energy Engineering, 145(6) (2019) 04019024-04019033.
[6] Zhao, H. X., & Magoulès, F. A review on the prediction of building energy consumption. Renewable and Sustainable Energy Reviews, 16(6) (2012) 3586-3592.
[7] Moreno, M. V., Dufour, L., Skarmeta, A. F., Jara, A. J., Genoud, D., Ladevie, B., & Bezian, J. J. Big data: the key to energy efficiency in smart buildings. Soft Computing, 20(5) (2016) 1749-1762.
[8] Liu, Z., Wu, D., Liu, Y., Han, Z., Lun, L., Gao, J., ... & Cao, G. Accuracy analyses and model comparison of machine learning adopted in building energy consumption prediction. Energy Exploration & Exploitation, 37(4) (2019) 1426-1451.