Research on an invasive and low-frequency power consumption data acquisition method

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Abstract: Aiming at the large-scale, compatibility and reliability problems faced by the data acquisition engineering for power consumption in the industrial field, for reducing the complexity and cost of the data acquisition engineering, and improving the quality, maintainability, scalability and manageability of the data acquisition, an engineering-oriented, intrusive, low-frequency data acquisition scheme for power consumption is proposed. The scheme leverages multi-agent networking technology to solve the large-scale problem, utilizes the communication driver of the dynamic loading adapter mode to tackle the compatibility trouble. Furthermore, the local storage, breakpoint retransmission, flow control, automatic recovery, automatic connection, and time synchronization are combined to solve the reliability issue. Engineering tests show that the proposed scheme possesses the significant backward compatibility characteristics, which can effectively reduce the complexity and cost of data acquisition engineering for power consumption, and significantly improve the quality, maintainability, scalability and manageability of data acquisition.

1. Introduction

Facing the compatibility problem of energy consumption data collection of power-consuming equipment in the industrial field [1-2], this paper proposes an intrusive, low-frequency power consumption data collection method, which aims to solve the problem of large-scale, compatibility and reliability in the context of energy consumption. Consumption data collection problems, provide the industrial field with excellent performance, good scalability, strong maintainability, complexity and low cost energy consumption data collection method [3], and the effectiveness of this method has been well verified in engineering practice.

2. Methodology framework

The intrusive, low-frequency power consumption data collection method proposed in this article consists of a data collection module, a collection network, a transmission network, and a data collection agent constitute [4-5], used to solve the problems of large-scale, compatibility and reliability faced in the process.
of power consumption data acquisition. This method uses the data collection area to organize energy-consuming equipment. The number of power-consuming equipment (N) included in DCA is limited by the collection period (T) and sensor data collection time (△t). DCA is energy consumption data collection, the smallest identification granularity.

This method uses multi-Agent networking technology to solve the large-scale problem of data collection, dynamically loads the communication driver constructed in the adapter mode into the DCA to solve the compatibility problem of data collection, through the DCA's local storage, resumable transmission, automatic functions such as recovery, automatic connection, flow control and time synchronization solve the reliability problem of data collection. The logical structure of the power consumption data management system of this method is shown in Figure 1.

![Figure 1 Schematic diagram of logical structure of electric energy consumption data management system](image)

### 2.1 Networking mode of data collection network
Building DCN based on multi-agent networking technology is an effective way to meet the needs of large-scale data collection. According to the different tasks undertaken in the networking process, DCA is divided into DCA Client and DCA Server. The DCA Client is connected to the smart meter and the DCM communication interface through the southbound interface of the communication driver, uses the TCP/IP protocol to connect to the DTN, and uses the token bucket algorithm for flow control. The DCA Server uses its local time as a unified clock, and uses UDP detection packets to detect the status of each DCA Client and complete time synchronization.

In a power consumption data acquisition system, a DCA Server and multiple DCA Clients are set up, and the data acquisition network topology is shown in Figure 3. The scale of the data collection point (N) is only limited by the input cost, which is calculated according to formula 1.

\[ N = \sum_{i=1}^{k} N_i \]

Where k is the number of DCA Clients in the system, and Ni (i=1,2,...k) is the number of data collection interfaces provided by each DCA Client. This value is limited by the time granularity required for data collection and analysis and the collection cycle. Generally, due to the time granularity of data collection and the serial port server port limitation, Ni \( \leq 32 \). The value of k is only limited by the engineering cost.

### 2.2 Driver for Adapter Mode
This paper proposes a method of building and loading communication protocol drivers based on the adapter mode to solve the compatibility problem of energy consumption data collection. The communication protocol driver based on adapter mode has two data interfaces: one is the standard data interface between the driver and DCA kernel, namely north interface; The second is the proprietary data connection between the driver and the communication interface of intelligent instrument, power consumption equipment and data acquisition module, namely the South interface. The northbound interface shields the communication protocol rules and simplifies and standardizes the DCA data collection process; the southbound interface realizes the syntax, semantics and timing of the
communication protocol, and realizes the data collection of the specific communication interface. The conversion of heterogeneous data between the northbound interface and the southbound interface is implemented by the internal logic of the driver, so as to solve the compatibility problem of data collection caused by the difference of communication protocols.

3. Engineering example

According to the method proposed in this paper, the construction task of a coal production and processing enterprise's electric energy consumption monitoring and analysis system is taken as an example for analysis. The system includes data collection, aggregation, processing and analysis functions. Energy consumption data collection needs include two branch plants and a coal mine, with a total of 59 collection points. The distribution of data collection points is shown in Figure 2.

![Figure 2](image_url)

Figure 2: Schematic diagram of a coal production and processing enterprise

Among them, 18 collection points have deployed smart meters, 13 have deployed DCM collection points, and the other 28 have no communication interface. The above-mentioned deployed data collection points all use Modbus as the communication protocol, but the equipment belongs to four different manufacturers. And the communication protocols are slightly different. See the above communication protocols belonging to different manufacturers are marked as Modbus (A), Modbus (B), Modbus (C) and Modbus (D). See Table 1 for details.

| Collection area     | Low voltage distribution box | High voltage distribution box | communication interface | communication protocol |
|---------------------|------------------------------|-------------------------------|--------------------------|------------------------|
| Coking plant        | 201 low voltage power room   | 13                            | /                        | /                      |
|                     | 202 low voltage power room   |                               |                          | /                      |
|                     | High voltage distribution    | /                             | 8                        | Acquisition module     |
|                     | room                         |                               |                          | Modbus (A)             |
|                     | 1 Low voltage distribution   | 3                             | /                        | intelligent instrument |
|                     | room                         |                               |                          | Modbus (A)             |
|                     | Preparation workshop power  | 2                             | /                        | /                      |
|                     | room                         |                               |                          | /                      |
|                     | 2 Low voltage distribution   | 5                             | /                        | /                      |
|                     | room                         |                               |                          | /                      |
|                     | 4 Low voltage distribution   | 2                             | /                        | intelligent instrument |
|                     | room                         |                               |                          | Modbus (C)             |
| Coal washing plant  |                              |                               |                          |                        |
|                     | High voltage distribution    | /                             | 2                        | Acquisition module     |
|                     | room                         |                               |                          | Modbus (B)             |
|                     | 35kV distribution room        | /                             | 3                        | Acquisition module     |
|                     | 10kV distribution room        | /                             | 8                        | /                      |

The DCM of Shandong Lichuang brand is selected as the data acquisition module of 28 data acquisition points without communication interface. The communication protocol adopted by this DCM is Modbus (E). Combined with Table 1, the specific DCM and protocol deployment in the project are shown in Table 2.
Table 2: List of data collection point distribution, quantity, collection method and collection time

| Collection area | Distribution and quantity of collection points | Acquisition time (ms) |
|-----------------|-----------------------------------------------|------------------------|
|                 | low pressure | High pressure | communication interface | communication protocol |                  |
| Coking plant    | 201 low voltage power distribution room        | 13 /                  | Acquisition module      | Modbus (E)         | 90              |
|                 | 202 low voltage power distribution room        | 13 /                  | Smart meter             | Modbus (A)         | 50              |
| Coal washing    | High voltage distribution room                 | / 8                   | Acquisition module      | Modbus (B)         | 100             |
| plant           | 1 Low voltage distribution room                | 3 /                   | Smart meter             | Modbus (A)         | 50              |
| Coal mine       | Preparation workshop                           | 2 /                   | Acquisition module      | Modbus (E)         | 90              |
|                 | power distribution room                        |                       |                        |                    |                  |
|                 | 2 Low voltage distribution room                | 5 /                   | Acquisition module      | Modbus (E)         | 90              |
|                 | 4 Low voltage distribution room                | 2 /                   | Smart meter             | Modbus (C)         | 80              |
|                 | High voltage distribution room                 | / 2                   | Acquisition module      | Modbus (B)         | 100             |
|                 | 35kV distribution room                         | / 3                   | Acquisition module      | Modbus (D)         | 80              |
|                 | 10kV distribution room                         | / 8                   | Acquisition module      | Modbus (E)         | 90              |

In summary, the number of data collection points for this project is N=59, the polling I/O mode is adopted, the link is statically divided, and the communication protocol is 5 kinds. The interval is 5 minutes), each DCA supports data collection points N ≤ 30, and each DCA loads 5 communication drivers. The actual deployment of DCA is shown in Table 3, and the topology of the system is shown in Figure 3.

Table 3 Summary of DCA deployment

| Serial number | Location          | DCA Quantity | Number of protocol drivers loaded |
|---------------|-------------------|--------------|-----------------------------------|
| 1             | Coking plant      | 2            | 5                                 |
| 2             | Coal washing plant| 1            | 5                                 |
| 3             | Coal mine         | 1            | 5                                 |
Figure 3 topology diagram of power consumption monitoring and analysis system of a coal production and processing enterprise

After the system is deployed, it works well, the reliability, scalability and maintainability meet the needs of users, and the function, performance and cost of power consumption data acquisition are within the expected range. At the same time, through the set scenario test and system log analysis, the breakpoint continuation, automatic connection, automatic recovery and time synchronization of DCA can work normally, and the integrity, timeliness and accuracy of data reach the preset goals.

4. Conclusion
The method proposed in this paper solves the large-scale, compatibility and reliability problems faced by energy consumption data collection in the industrial field, which can effectively reduce the complexity and cost of the project, and improve the maintainability, scalability and manageability of the system. It has the characteristics of backward compatibility, especially in the energy consumption data collection of a large number of non-intelligent power-consuming devices, the advantages are very obvious. However, in some complex production environments or scenarios where OPC protocol is widely used and the acquisition scale is not large (such as: highly integrated production workshop or high-end power-consuming equipment with built-in OPC client.), this method has some limitations in performance. Compared with non-invasive data collection methods, this method has no advantages in complexity and cost. Therefore, non-invasive collection methods should be the mainstream method of energy consumption data collection in the future. Nevertheless, the accuracy of data collection due to non-intrusive methods cannot meet the current actual needs, especially in the industrial field. Therefore, for a long time, intrusive power consumption data collection methods are still the main method of power consumption data collection in the industrial field, and the complexity, cost, construction period, and data quality of energy consumption data collection projects still need to be paid attention to. Important factor.

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