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A New Remote Reading Method for Alarm Information Suitable for Power Automation System

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Abstract—In order to achieve efficient integration and optimization of alarm information in the dispatching /distribution integration monitoring mode, it is necessary to solve the problem of remote access of alarm information between independent control and monitoring systems. This paper proposes a remote access method of the alarm information based on load balancing, type filtering, fault takeover, and safe box mechanism. Through this method, the synchronous transmission of data can be reduced, transmission efficiency can be improved, and transmission reliability can be improved, It can still ensure that alarm information is not lost in the event of some node failures. This method can provide technical support for achieving the dispatching /distribution integration monitoring mode.

Keywords- alarm information; remote access; fault takeover; data safe mechanism

1. Introduction

In order to improve the reliability of the power grid and enable it to operate safely, economically, and efficiently, in recent years, in accordance with the requirements of the State Grid Corporation of China's comprehensive promotion of the construction of the large-scale operation system, a construction concept of integrated monitoring and control of the dispatching /distribution system has been proposed. The integrated dispatching /distribution monitoring system mainly monitors and manages the operational data of the dispatching /distribution networks[1]. In the integrated monitoring mode of dispatching /distribution, it is necessary to achieve efficient fusion and optimization of alarm information, and improve the global awareness and synchronous perception ability for the safe operation of the large power grid. It subscribes alarm information from multiple systems as needed according to the focus of monitoring by operators, and then performs unified monitoring [2].

At present, the monitoring systems of dispatch and control centers at all levels are independent of each other, and various abnormal situations within each monitoring system are notified to users through alarms. In the integrated monitoring mode, there

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will inevitably be situations where the superior system needs to check the internal abnormal alarms of the subordinate system[3]. For example, the provincial dispatch and control system in Jiangsu needs to check the alarms of the municipal dispatch and control system in Zhenjiang. This requires remote transmission of alarm information from Zhenjiang to Nanjing. How to ensure the minimum amount of information transmitted and the stability and reliability of transmission will be the key points to ensure the successful remote retrieval of alarm information.

At present, when solving data synchronization and synchronization reliability issues between remote systems, proxy forwarding and error retransmission methods are generally used. However, this method has limitations, that is, the bandwidth of a proxy node is limited by the bandwidth of the server network card, and since alarms are transmitted within the system in the form of multicast, the error retransmission method is not applicable because multicast in the past period no longer exists. The error retransmission method is only applicable to data transfer within files or databases[4-7]. However, power automation systems have very high requirements for real-time and reliability, so there is an urgent need for transmission methods that can increase bandwidth, reduce the amount of transmitted data, and ensure transmission reliability [8-9]. To address the above issues, this article proposes a remote retrieval method for alarm information suitable for power automation systems.

2. Architecture for Cross System Retrieval of Alarm Information

2.1 Power System General Service Protocol

Unlike traditional power system communication protocols that use binary message streams for transmission, the national standard GB/T33602-2017 Power System General Service Protocol (GSP) adopts a service-oriented architecture and multiple service transmission modes[10], This provides a basic guarantee for the on-demand filtering and remote retrieval and transmission of alarm information between various levels of dispatch control systems and between dispatch master stations and sub stations.

Service Oriented Architecture (SOA) is the exchange of information between service consumers and service providers through a series of interface services. The Power System General Service Protocol uses a service-oriented architecture and an object-oriented real-time data transmission mechanism to realize cross domain network services through service agents, which can be used to realize static and dynamic data exchange between power grid dispatching control centers at all levels and between dispatching centers and substations [11].

2.2 Service Agent

Service agents are deployed on designated machine nodes (proxy machines) within the system to support the establishment of cross system (service domain) associations, and can achieve functions such as link management, service request and service response forwarding. According to the settings of the Power System General Service Protocol, in wide area communication mode, the server and client cannot be directly connected and must interact through a service proxy.

The process of information exchange between different systems through proxy machines (service proxies) is shown in Figure 1. Remote service invocation is achieved between the client of system A and the server of system B through a proxy machine (service proxy). Proxy machines (service proxies) can establish connections between them through TCP or UDP. The proxy machine (service proxy) needs to identify and manage service connections through Association IDs. During the service association establishment stage, association IDs for local and remote connections are generated, and the mapping relationship between the two is recorded in the association corresponding table. In subsequent actual communication, based on this mapping relationship, alarm information can be quickly forwarded.

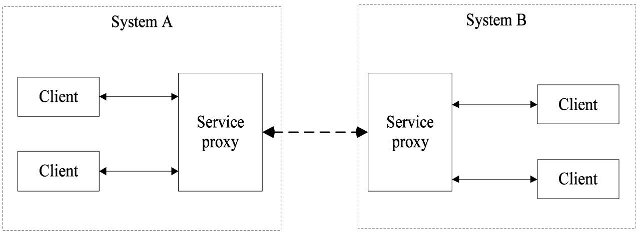


Figure 1. Schematic diagram of interaction between systems based on service agents

As shown in Figure 1, both power grid dispatch and control systems have deployed proxy machines (service agents), and different systems are interconnected through proxy machines (service agents). According to the design of the Power System General Service Protocol, the proxy machine (service proxy) can achieve link management, forwarding of service requests and service responses. Therefore, for the proxy machine (service proxy) deployed in the lower level power grid dispatch and control system, it can not only forward alarm subscription requests, alarm subscription responses, and alarm events of the local system, Additionally, it is possible to forward alarm retrieval requests issued by the higher-level power grid dispatch and control system agent (service agent).

3. New Remote Reading Method for Alarm Information

In order to minimize the synchronization of alarm information between systems and increase the synchronization bandwidth, and to ensure that alarm information is not lost even when some nodes or communication links fail, the author proposes a remote access method for alarm information suitable for power automation systems. This method has the characteristics of high transmission bandwidth, high transmission efficiency, load balancing, and high reliability. It takes the reliability of information synchronization as the main purpose, and the small amount of synchronized data as the secondary purpose. It can be applied in distributed network environments to achieve remote synchronization of alarm information. This method adopts load balancing, type filtering, fault takeover, and safe mechanism to increase transmission bandwidth, reduce the amount of data synchronously transmitted, improve transmission reliability, and ensure that alarm information is not lost in the event of some node failures. This method is implemented by a computer program and can run on various operating systems such as UNIX, Linux, and Windows, without relying on third-party software. It has good portability.

The characteristics of this method can be summarized as follows:

(1) Load balancing transmission of alarm information: Alarm information is transmitted across nodes using messages within a system. Load balancing message communication is achieved between systems through multiple network connection paths between proxy nodes, thereby achieving cross system transmission of alarm information.

(2) Filtering of alarm information: When the system needs to access the alarm information of a remote system, the agent node of the system sends the alarm types that need to be accessed to the agent node of the remote system. After receiving the alarm information retrieval request, the agent node of the remote system stores such alarm information in the Distributed memory storage system, so that each agent node can obtain it in time. The proxy node only sends alarm information that matches these types to the remote system, while other types of alarms are discarded to ensure the minimum amount of data transmitted remotely.

(3) The overall control mechanism for alarm information transmission: Within a system, alarm information is transmitted in the form of multicast from point to multipoint. A master control node is set in the system to evenly allocate the alarm type information sent by the system to each agent node, and store such control information in Distributed memory. The agent node obtains the alarm type that the local machine is responsible for from the Distributed memory storage, and sends the alarm information that the local machine is responsible for sending to the agent node of the remote system through TCP or UDP after receiving the multicast of the alarm information.

(4) Fault handling of alarm information transmission: When a proxy node in the system fails, the alarm information it is responsible for transmitting will be evenly distributed among other proxy nodes on the local side through the control of the master control node. Although other proxy nodes will transmit newly allocated alarm information, the peer proxy receiving nodes of this part of alarm information remain unchanged to ensure sufficient bandwidth utilization and load balancing.

(5) The data safe mechanism for alarm information transmission: When a proxy node on the sending side fails, there will be a certain time delay before discovering the node failure, which is the time interval for heartbeat judgment. The alarm information multicast during this period cannot be reproduced. Therefore, a backup node is set up for each proxy node in the system, which is called a shadow node. In addition to sending its own responsible alarm data, the shadow node also temporarily stores its corresponding main node's alarm multicast data in memory. The temporary data will include all multicast data within the time interval determined by the heartbeat. When the main node fails, the shadow node sends the temporary data to the corresponding proxy node at the remote end of the main node to ensure that the data is not lost.

4. Implementation of Remote Reading Method for Alarm Information

This section focuses on the implementation process of remote retrieval methods for alarm information.

4.1 Load Balancing of Alarm Information

The schematic diagram of load balancing transmission of alarm information in this method is shown in Figure 2.

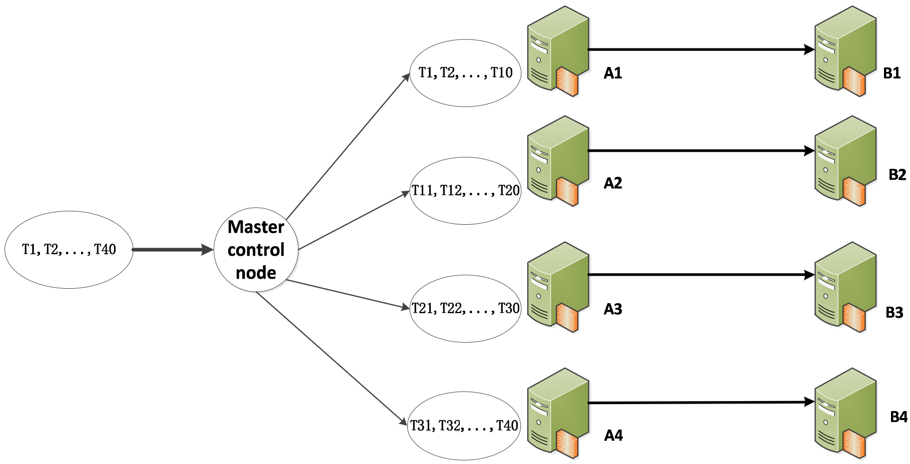


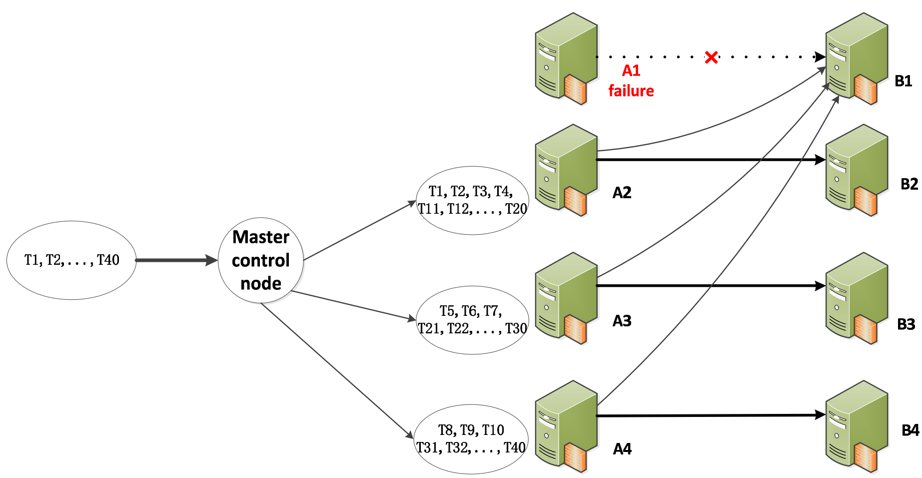
Figure 2. Schematic diagram of load balancing transmission of alarm information.

First, the superior system that accesses the alarm information issues the alarm type concerned. When the type information reaches the subordinate system, it will be stored in the distributed shared memory storage system, such as Zookeeper. Then, the master control node in the lower level system evenly distributes all types of information to each agent node, and these sending agent nodes and receiving agent nodes in the upper level system will pair up for transmission one by one. If the number of proxy nodes in two systems is inconsistent, the smaller number shall prevail.

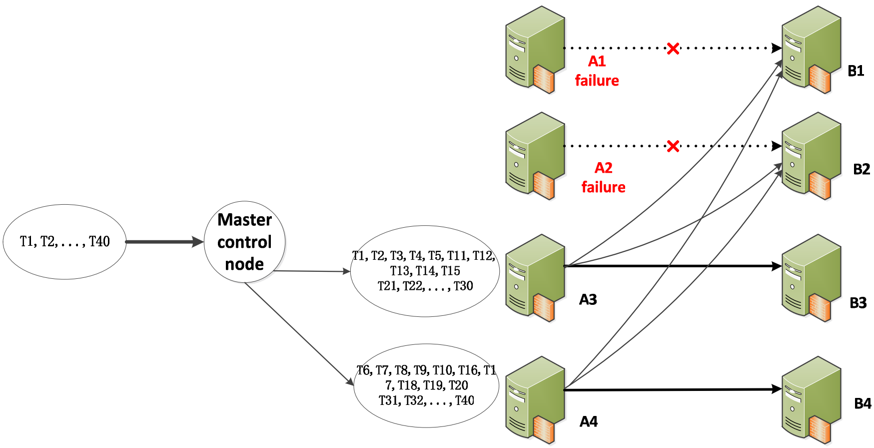
4.2 The Process of Fault Takeover

The fault takeover process of this method is divided into sending agent node fault takeover and receiving agent node fault takeover.

The schematic diagram of sending agent node fault takeover is shown in Figure 3.



(a) Single sending agent node failure.



（b） Multiple sending agent node failure.

Figure 3. Schematic diagram of sending agent node fault takeover.

Among the four pairs of proxy nodes shown in Figure 3 (a), the sending node A1 failed, and its responsible transmission type T1-T10 was evenly allocated to the other three nodes for transmission. But the receiving node for these types of alarm information is still B1. In Figure 3 (b), if the sending node A1 fails and A2 also fails, the transmission type T1-T20 they are responsible for is evenly distributed to the remaining two normal nodes for transmission, while the receiving nodes of these types of alarm information remain unchanged.

The schematic diagram of receiving agent node fault takeover is shown in Figure 4.

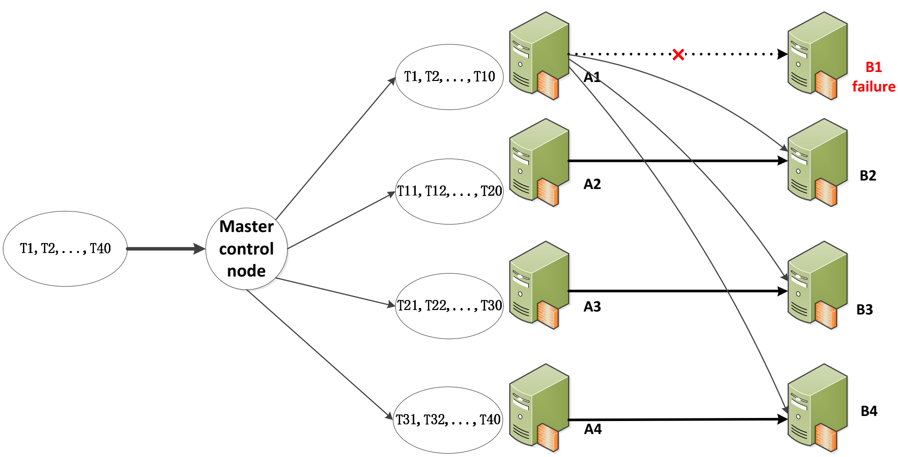


Figure 4. Schematic diagram of receiving agent node failure.

When the receiving node B1 of the superior system fails, node A1 will attempt to establish a link with other proxy nodes of the opposite system. If the link is successfully established, node A1 will send alarm information to nodes B2, B3, and B4 in a load balanced manner. The process of rebuilding the chain does not require the participation of the master control node.

4.3 Data Safe Mechanism

Each node has set up a number of data safes to temporarily store alarm data for other nodes. The number of safes depends on how many other proxy nodes cache data for each proxy node. The schematic diagram of the data safe mechanism is shown in Figure 5.

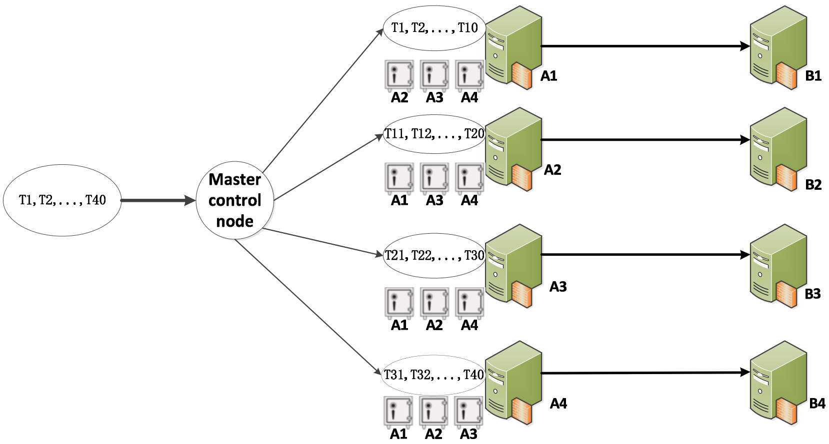


Figure 5. Schematic diagram of data safe mechanism.

Assuming there are a total of n proxy nodes in the system, there can be at most n-1 other nodes caching data for a certain proxy node. At this point, each node has n-1 data safes, meaning that each node caches data for other n-1 nodes. Assuming a node in the system does not receive a heartbeat within 3 seconds (heartbeat is sent once per second), it is determined that the node is faulty. The data cached in the safe is the alarm information that should be forwarded by the safe node within 3 seconds, and continues to replace the old information with new information. After node A3 in the figure malfunctions, the master control node selects node A1 to send the data in the safe to the opposite node B3. If multiple sending nodes fail, the master control node selects several nodes to send safe data, and the principle of selection is not to send it centrally by a single node, which can avoid significant delays.

Through the above steps, this method can achieve the following technical effects: 1. Load balancing transmission by multiple pairs of proxy nodes can increase transmission bandwidth; 2. Pre publishing remote access alarm types and filtering transmitted alarms can reduce the amount of information transmitted; 3. When a proxy node fails, its traffic is evenly distributed among other proxy nodes, ensuring high reliability; 4. Adopting a safe deposit box mechanism ensures that data is not lost during the period from node failure to its discovery, thus achieving zero data loss; 5. In the case of any proxy node failure, as long as there are still normal proxy nodes, the system can operate normally, which greatly improves the robustness of the system; 6. All functions are fully implemented by computer programs and can run on operating systems such as UNIX, Linux, and Windows without the need for any built-in software, thus having good portability.

In summary, this method is a remote retrieval method for alarm information with high transmission bandwidth, high transmission efficiency, load balancing, high reliability, zero data loss, high robustness, and good portability.

Driven by the construction requirements of the State Grid Corporation of China's large-scale operation system, it is necessary to upgrade and transform the existing independent systems to achieve integrated monitoring of the dispatching /distribution systems. The remote retrieval method for alarm information proposed in this article can effectively solve the requirement of on-demand subscription of alarm information between different dispatch and monitoring centers, and can fully utilize effective resources to implement it while ensuring the safe operation of the original system.

5. Conclusion

In order to minimize the synchronization of alarm information between systems and achieve a larger synchronization bandwidth, and to ensure that alarm information is not lost even when some nodes or communication links fail, this paper proposes a remote retrieval method for alarm information suitable for power automation systems. This method takes the reliability of information synchronization as the main purpose, and the small amount of synchronized data as the secondary purpose. It adopts strategies such as load balancing, type filtering, fault takeover, and safe mechanism. This method can increase transmission bandwidth, reduce synchronous transmission of data, improve transmission reliability, and ensure that alarm information is not lost in the event of partial node failures.

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