Design of Intelligent Operation and Maintenance Architecture for Grid Dispatching and Control System

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Abstract: As the scale of the grid expanding, the operation and maintenance of power grid dispatching and control system becomes more complex, the traditional passive operation mode of grid dispatching and control system is difficult to meet the challenges. In order to improve the quality and efficiency of operation and maintenance, the design of intelligent operation and maintenance architecture for grid dispatching and control system is proposed. In this paper, with the boost of the information technology level in the power grid, disaster-tolerant and load balancing technology of operation and maintenance are studied in detail as well. The new architecture can effectively improve the efficiency of operation and maintenance, and ensure the system operation safety and stability.

Introduction

The current power grid dispatching and control system still adopts the traditional method of operation and maintenance, which is only focused on hardware issues and application key performance indicators. It is low efficiency in taking the corresponding remedial measure, weakness in monitoring and management based on partial information. With the scale expansion of the grid and the increasing of equipment amount, the new requirements and challenges are raised that how to ensure the safe and stable operation and maintenance, and make performance optimization on the grid dispatching and control system.

Therefore, it is urgent to construct a new integrated intelligent operation and maintenance system, and implement the intelligent monitoring on the operation and maintenance of grid dispatching and control system, accurately detect the changing trend, comprehensively analyze the operation and maintenance data, and improve the capability of on-line diagnosis and fault detection.


In this paper, an integrated intelligent operation and maintenance framework consisting of metrics acquisition and data collection, data caching and storage, monitoring alarm and integrated data display is presented. Disaster-tolerant and load balancing technologies are studied in detail to support intelligent operation and maintenance. Through the proposed architecture, we can monitor the entire system operating conditions in real time, and make health assessment on the host, cluster, storage and application effectively, accurately and timely.
Framework

The intelligent operation and maintenance architecture of grid dispatching and control system is designed based on data flow. The data, multiple level metrics, is collected from OS, middleware and applications. Collected data is cached and stored in RRD-based database, then the data will be presented and monitored as well. Corresponding warnings will be generated on screen and send the notifications to the registered stakeholders by email or by short message. Fig. 1 gives the details as below, and it can be figured out the data flow across the operation and maintenance of the grid dispatching and control system.

Data Collection

In grid dispatching and control system, we focus on 3 level metrics: OS level metrics, such as CPU usage, memory usage and storage usage, etc. which indicates whether OS system is working correctly or not; middleware level metrics, which monitors the middleware such as Kafka, HBase, Redis, Message Bus and Service Bus, etc.; and application level metrics on application process, request number, etc.

In our operation and maintenance architecture, we use open source tools, for example, Collectd[7], Stated and Carbon in Graphite[8] to get metrics and data collection for operation and maintenance.

Collectd is a daemon which collects system and application performance metrics periodically and provides mechanisms to store the values in a variety of ways, for example in RRD files. It is lightweight open source tool and is widely used in system matrix collection work. Collectd gathers
metrics from various sources, e.g. the operating system, applications and logfiles, stores the information or makes it available over the network. Those statistics can be used to monitor systems, find performance bottlenecks, and predict future system load.

Stated is a Nodejs daemon program, it is also simple and lightweight. It is UDP protocol based and can be combined with Graphite image rendering applications. Stated has a concept of a time period that defaults to 10 seconds, which means that Stated sends the collected data (processed) every 10 seconds to the backend. It would send the counter cumulative value within 10 seconds to the back end, so do the number of times, the maximum value, the minimum value, the average value of metrics to the backend in that cycle time.

Carbon is one of the three components within Graphite application. It is the daemon which is responsible for receiving metrics over the network and processing them as well.

We also retrieve some operation and maintenance indicator data from application log itself, and can make application health assessment based on it.

**Data Caching and Storage**

Usually we can get bunch of metrics data from time to time, if we send it back to RRD database directly when we receive it, it will definitely increase the disk I/O operation and introduce the I/O traffic. To avoid the traffic and make the work efficiently, we cache the data by using Carbon-cache tool. The client application publishes the metrics by sending the data point to the carbon process. The application establishes a TCP connection on the port that the carbon process listens on, and then sends the data point information in plain text format. The TCP connection may remain open and reused as many times as necessary. The carbon process listens for incoming data but does not return any response to the client so far. Instead, Carbon-cache accepts metrics over various protocols and writes them to disk as efficiently as possible. This requires caching metric values in RAM as they are received, and flush them to disk on an interval using the underlying whisper library.

In the monitoring system, there are two kinds of storage methods for monitoring data: fine granularity storage and rough granularity storage. Fine granularity storage holds all data pushed up by data acquisition points, the advantage is data integrity, the disadvantage is that the cost of storage, query and data drawing is too expensive; rough granularity storage compresses and archives historical data, saves storage space and improves query and drawing efficiency.

RRD storage is based on file, relatively easy and simple for the operation and maintenance. RRD is a circular database that provides a perfect solution for rough granularity storage, especially suitable for storing time series data. The size of the RRD file is fixed and it has a pointer to the latest data location, which is updated as the data is written. The whole circle has no starting point and end point, the pointer keeps moving with new data, and when the RRD file is full, the pointer continues to write to the beginning of the data, and the previous data is overwritten and lost as well.

We use the Graphite built-in RRD database-Whisper, which has a flexible configuration. We have a lot of recent data acquisitions intensively, such as every 10 seconds/times; for the data in early period of time, Whisper compresses the data such as 30 minutes/times, or 1 hour/times. In this way, the current monitoring object can be processed in time, and the historical data is also compressed for storage.

**Data Presentation and Warning**

Using the chart tool to convert a variety of monitor data collected from the system in a graphical way, can make the invisible operational data into intuitive visual graphics, show the operation condition and the analysis result of the basic resources, and let technical and non-technical personnel directly understand and take actions as required.

Grafana is an out of box visualization tool. It has the characteristics of fully functional measurement dashboard and graphics editor, plentiful and flexible graphical options that can mix multiple styles. It contains a unique Graphite target parser to simplify the editing of metrics and
functions. Grafana uses Flot technology to complete the fast rendering for client. Therefore, even if Grafana runs for a long time, it can be in good condition. So that users can create complex charts with smart axis formats.

Previously, monitoring and alarm configuration relies on the experience of the operational engineer, continuous iterative modification, or even manual troubleshooting. With the development of technology, the standardization and automation of operational monitoring can be implemented by defining monitoring standards and deploying automatical monitoring. The ultimate goal is to solve the problem thoroughly with an intelligent approach.

When the system data fluctuate, it is necessary to judge whether it is in abnormal condition or not, and then start the alarm after confirming the anomaly. There are two main methods to detect the anomaly: automatic constant threshold setting and dynamic threshold setting. Constant threshold setting method: for ordinary data, operations staff set constant threshold on the server, and alarm starts automatically when the server application indicator exceeds the threshold or fluctuates abnormally; Dynamic threshold setting Method: dynamic time window is adopted to generate the thresholds dynamically based on previous timeframe, and it is usually used for solving the abnormal judgment of periodic data. If the data shows the character of strong periodicity, it is suggested to use the dynamic threshold setting method; otherwise, the constant threshold setting method is recommended for the left cases.

Key Technology

![Diagram](image)

Figure 3. Two-layer disaster-tolerant and HTTP reverse proxy load balancing

The data is the most important in the operation and maintenance monitoring system, and the data loss can possibly happen during the operations due to network traffic. To avoid data loss, we use dual data-write strategy. It sends the same data into two copies and transfer them to two data storage nodes simultaneously and respectively. The two storage nodes are backed up to each other. Carbon Relay collects the same metrics and uploads to the upper level Carbon Relay to implement multi-layer dual-write operation.

The server itself also has the possibility of work failure and out of service, we use KeepAlived tool for disaster-tolerant. KeepAlived takes role to detect the status of the web server, if the master web server crashes, or work failure, KeepAlived will remove the failed master web server from the system, slave web server can instantly hand over the work of the master web server. When the master web server is restarted and back to work properly, KeepAlived keeps monitoring that master web server and is aware of its status update, then KeepAlived automatically join this master web server back to
the server cluster for normal usage. All this kind of work are done by KeepAlived without any need of human interaction. As a result, it keeps the high availability of the system.

Meanwhile multi-user simultaneous access may cause network congestion or the server cannot respond in a timely manner, we use Nginx for HTTP reverse proxy load balancing. Nginx is a lightweight web server/reverse proxy server and can be run in a variety of operating systems as well. It is characterized by less memory and strong concurrent ability. Nginx makes full use of asynchronous logic and reduces context scheduling overhead, it is more powerful on concurrent services. Nginx is modular design, has a rich module library and third-party module library and flexible configuration for usage. So we use Nginx to achieve load balancing on operation and maintenance of grid dispatching and control system.

With the deployment of two-layer disaster-tolerant and HTTP reverse proxy load balancing, we can keep monitoring and work on operations and maintenance for grid dispatching and control system in 24x7 properly.

Summary
With the vigorous development of China's smart grid, the number of the servers in the grid dispatching and control system is increasing rapidly, so the pressure of operation and maintenance keeps growing. When facing with vast amounts of operation and maintenance data, quickly locating the business level of problem, achieving precise alarm, and solving the problem in time become the general requirement of operation and maintenance.

In this paper, the problems and deficiencies of the current control system are analyzed. Combined with the current operational technology, an integrated intelligent operation and maintenance architecture is proposed. It can effectively improve the automation and intelligent level of the operation and maintenance of the grid dispatching and control system, and implement active operation and maintenance to ensure the safety, stability and high efficiency of the system.

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References
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