Design and Implementation of Visualized and Rule Based Integrated Primary Equipment Overhaul Management System Build on Dcloud

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Abstract. The systems are deployed at all levels of dispatching organizations which are connected by microservices. In this paper we introduced unified equipment model to achieve show overhaul plans on geographic information system map. Balancing and scheduling overhaul plans by build a rule based expert library. Information exchange and workflow pushing achieved by introducing data exchange service and workflow pushing service which registered on service bus provide by Dcloud, with help of the service the information could be shared among all levels of dispatching organizations, the workflow could be ran more smoothly. The system also provides a collaboration planning platform which is used for make the processing of workflow more efficient. This system is a powerful technique support for continuous protection of the safe operation of the power grid.

1. Introduction
For the rapid growth of State grid, the Ultra High Voltage transmission lines grid takes shape. Professional knowledges and experiences are need for dispatching the grid. Thus, higher management level and latest technologies are required. Following are some disadvantages of current primary equipment overhaul system.

The isolated workflow, the workflows ran by dispatching organizations are self-build on different platforms and data forms. Dispatching organizations exchange information by files which carry formed data to share data and push workflow, however, it is not true integrated system, just a conceptional integration. Workflows are still isolate, data are partly exchanged and could be modified after exchanging or encountering transmission problem like data lost or encoding error, that cause data difference between systems.

The out date demonstration of data, the tree-table structure system could not meet the requirement of modern power grid dispatching. User could not get whole view of overhauls and outages only by separated tree nodes.

The human experiences depended system, in current system, scheduling and balancing overhaul plans still depends on man experiences which is less efficient and not always reliable.

The development of information technology is similar to power grid. It is developed from Stand-alone Information Island to wide area internet. State Grid build a platform called Dispatching cloud(Dcloud). The Dcloud provides various microservices and PaaS services. The Dcloud platform also provides equipment’s data from one origin. A whole new overhaul management system could be development on this platform with four features:

1) Light wight and easy to integrate: The new overhaul scheduling system decomposed into several microservices, each part could be run and use alone with the main application and microservices could
be integrated into third party systems to enable the features provided by new overhaul scheduling system.

2) Fast and wide-area data exchange and connected workflow. The new overhaul scheduling system provides fast and direct data transmission and workflow by register functions on service bus.

3) Visualized demonstrating. The new overhaul management system demonstrate data on geographic information system (GIS) map with various colors and sharps to represent overhaul state.

4) Rule based plan balance and auto scheduling. In the new system, a rule responsories will be maintained to achieve the goal of auto rescheduling and balancing.

2. General Toughs

2.1. Distributed Deployment, Connected System
To achieve distributed deployment, connected systems of all-level dispatching organization overhaul scheduling system is based on Dcloud. The new overhaul management system is decomposed into several microservices. Each microservice do its own job. In State Grid there are five levels dispatching departments. Each level deploys its own system, the systems could be connected by integrating data exchanging service and workflow pushing service. These two services are registered on services bus which provided by Dcloud’s PaaS. Via data exchange service, the permitted consumer with secure key could get data directly from database to avoid errors occurred when data transmitted by file or other forms. The data exchange service not only use to exchange data but also use to compare data from each level to ensure the correction of data after exchange. User will get notification if encountering error or data be modified in other system. This feature is used to ensure the completeness of data which are critical for safety of dispatching grid.

The workflows are connected by workflow pushing services. Workflow could be pushed forward or retrieve backward by calling this service directly without waiting time. With workflow pushing services integrated into self-build system of each level. The interacting of all-level workflow could be considered as one workflow. Users work on their own system but pushing all-levels at same time. This feature could avoid latency of pushing workflow via scheduling task and files which carry workflow information.

2.2. Unified Equipment Model
The key problem of integrate five levels organizations’ systems is non-unified power grid primary equipment model and data form. To unify the model and data form, Dcloud provides model-data management module. The power grid primary equipment model could be edited in client, shared in real time, subscribed on-demand, data structure is edited on server side, push globally and update automatically through model data service provided by Dcloud.

The power grid primary equipment model includes uniquely identify, device name, etc. The source of power grid primary equipment model data is client side, dispatching organizations create and edit device object and data according to device administer relationship. The platform-level data synchronization tool could perceive incremental change of data and synchronize to Dcloud. The server side will push changed data to subscriber by subscribe rule of object to make model same at all levels of dispatching organizations.

The data structure contents metadata and data dictionary. The data structure only create and edit on server side of model data structure. Further update will be published through message bus, the client side will subscribe automatically and update local data structure at all levels of dispatching organizations. This make database, data table and attribute meaning all the same.

2.3. Visualized Plan Demonstrating
In modern days, tree-table view is outdated. The tree-table only display plan in separated state. User could not get whole vision of all plans. To get whole vision of plans helps user have a blue print of Power Grid. User will know which equipment is overhauling or which one is running. This feature could help improve the dispatching safety of Power Grid. In this system, geographic information system (GIS) map provide by Dcloud is introduced to Display the overhaul data. The data could be
painted and located by Latitude and longitude with state such as preparing, overhauling represent different colors and sharps. By glancing on the map user could get status of plans of different states and types to determine what to do next or is plans need to rescheduling.

To rescheduling plan, the overhaul scheduling system also provide a visualized view to modify date, user do not need to open specified plan. The plans could reschedule by drag bar on a Gantt view. The date could be modified easily by dragging and saving.

2.4. Rule Based Plan Balance and Auto Scheduling
The growth of State Grid is very fast, the complexity is higher. To balancing and scheduling plans still depends on dispatcher’s knowledge and experiences. The overhaul scheduling system provided a expert library which could maintenance by user. The expert library stores rules such as Overlapping power outage, device outage window. With stored rules, notification could be giving out while the scheduling period is not in device outage window. Plans could be balanced and optimized with suggestion to rescheduling. This feature helps optimize the plans to decrease overlapping power outage.

3. Key Technologies

3.1. Services on Bus
The global data exchange service and workflow push service relay on message bus and service bus. Each service has two parts, service and API. Service run on data provider’s server. Services registered on Dubbo server bus provided by Dcloud. Consumers integrate the API into their system to call for data and push workflow. Consider some systems are not spring boot project, the service also provides RESTful API for convenience. Consumers with secure key could call the API to get data or push workflow they need directly and immediately.

The global data exchange service also could pass information via message bus. The message bus calls WebSocket to broadcast changes to everyone who stay on the pages.

3.2. The Expert Library
The expert library stores the rules of devices outage and devices outage window. Before submit the overhaul plans. The system would run algorithm with the rules and window to determine whether the device could be overhaul or not. The algorithm runs set times to get the optimized result and gives out suggestion.

3.3. Geographic Information System (GIS) Map
To demonstrate overhaul plans on GIS map. Latitude and longitude of devices are needed. Geographic information could be easily getting from Dcloud primary equipment model. By geographic information and map module we could put a new layer on the map to point out and paint special figure of the equipment or the station contains the specified equipment.

4. Implementation of Visualized and Rule Based Integrated Primary Equipment Overhaul Management System

4.1. Architecture

4.1.1. Overall architecture. Main idea of visualized and rule based integrated primary equipment overhaul management system is the system decomposes into several independent microservices. On business logic microservices connected by unified primary equipment model which provided by Dcloud. On technique side, microservices connected by message bus and service bus. The unified primary equipment model could used as identifier to identify the plans lower level submitted or higher level approved do exactly same work. The unified model could also use to locate equipment on map or do balancing or scheduling by consider all-level plan.
The message bus and service bus are used to broadcast message and register service to exchange data and push workflow. The message service push message to message bus, message bus push message to WebSocket then broadcast to everywhere. The service bus let services register on it. The service bus provides two ways, inner service bus and wide service bus. Which one to register on depends on the server environment, only difference is a proxy is needs for outside service to call inner service bus’s API. Overall architecture shown as Figure 1.

4.1.2. Infrastructure. Infrastructure is hardware and software that support whole system run properly. Infrastructure includes computing node, storage node, network device and operating system. So far, the cloud computing technology is more popular in large system integrate area. The advantage of cloud architecture is virtualization, and it could achieve fast deployment of application. When some node failed, new virtual machine could be created in time to migrate application. These features improve the safety and reliability environment. Relay on virtualized resources, resources could be extended dynamically. When preparing plans in same time, the server side of overhaul management system deal with large number of tasks, while computing nodes could increase dynamically, the efficiency of system could be improved. When finish balancing and scheduling plans or low-load time, system will release resources for other applications.

4.1.3. Software platform architecture. Software platform composed by basic software, general tools and public services. Software platform is used to support upper level dispatch plan preparing application. Basic software include database, middleware which are used to store data and publish web application. General tool contains message bus and service bus which are used for message broadcasting, subscribe and service register and publish. Public service provides stable universal interface for upper lever application. Public service contains model service, workflow service and log service. Public service play role of public resource of different application and function, public service achieve abstract and management of general functions which are related to business cluster, decrease repeated development and deployment, improve operational efficiency, reduce management costs. Software platform architecture shown in Figure 2.

4.2. Data Exchanging and Workflow Pushing
True integrated system has many benefits. Systems connected by microservices not isolated parts but all parts working, communicating, interacting together. The two part of service, provider and consumer, register on upper level dispatching organization and lower level. Lower level organization call APIs provided by upper level to submit application. The message transmit in the lightweight data-interchange format text (JSON). The upper level organization’s service receives application data in JSON then analyses and stored in database directly. The upper level could call workflow pushing
service to push workflow forward or retrieve backward. Of course, the workflow pushing service provide by upper level could be called by lower-level if needed. When the upper level approve or disapprove the application, a comment should return to lower level, at this time provider became consumer. The upper level call APIs registered by lower level to return comments and pushing workflow.

The advantages of systems connected by microservices are light wight and no latency. The new features are easy to integrate, do not need to reconstruct the system structure, just simply call a new API or a RESTful API. The data commit into database directly and push workflow immediately.

4.3. Visualized Demonstrating

4.3.1. The modern power grid is complex. Every day, even hundred plans is submitting or working on at same time. Dispatchers hard to have whole view of entire power grid only by tree-table view. Geographic information system (GIS) map is a better way to demonstrated plans. For example, we could paint an acline by finding its start and end stations. In primary equipment model the station has latitude and longitude. With this geographic information start and end position could be located on map. We put a new layer on map, then put figures of specified figure of different type of stations and draw a line between two points. The line could be colored according to the state of overhaul plan. The benefit of unified model could be shown here. The equipment data related to plan could be used to retrieve data from other services provided by Dcloud. That extension information could be put on the map to help dispatcher to have whole view of power grid and figure out relationship between overhaul plans, even overhaul plans with operation tickets.

4.4. Rule Based Balancing and Scheduling

Each year, annual overhaul plan should be scheduled. The annual overhaul plan is a blue print of year. Monthly plan, weekly plan and a day ahead plan are based on annual plans. To schedule annual plans must consider various conditions like outage window, decrease outage times, benefit to economic, etc. The power grid is complex, it is not easy for dispatcher to have all conditions considered to balancing and scheduling overhaul plans.

An expert library with balancing and scheduling algorithm introduced to do balancing and scheduling. The library records all conditions and rules must be considered. The outage plan could be ensuring in the outage window while editing. After editing, running rounds could be set to balancing and rescheduling automatically. When rounds finished a Gantt view of plans will give out with
rescheduling suggestion. With unified model all-levels’ plans could be compute together. After computing, dispatcher could reschedule plan by dragging and move Gantt bars. Computation procedure shown in figure 3.

![Figure 3.](image)

5. Conclusion
With data exchange service and workflow pushing service. Systems could be connected and truly integrated. Message service help user know changes of the data. Workflow pushing by workflow pushing service registered on service bus, smooth information delivery will improve the convenience of collaborated work plan preparing, no latency workflow will shorten the period of approval. Visualized plan demonstration helps dispatch have whole view of power grid. Rule based balancing and scheduling module helps make optimized combination of overhaul plans. With these advantages efficiency of dispatch plan preparing will be improved and give strong support to make power grid safe.

6. References
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