

城市轨道交通信号系统大数据智能运维平台设计方案

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摘 要 [目的]城市轨道交通信号系统的维护管理包括设备监测、生产组织、信息管理等业务,每种业务都包含一个或多个业务系统,各业务系统建设年限不一,且同一线路的不同业务系统在功能上有叠加或重复,因此需建设具备数据集成化及大数据分析功能的信号系统大数据智能运维平台。

[方法]结合信号系统维保业务现状和信号系统数据特点,从实际应用角度出发,采用数据分层方法,构建了信号系统大数据智能运维平台;介绍了该平台整体架构;阐述了数据共享、数据分析、数据应用等3个子平台的设计方案。[结果及结论]信号系统大数据智能运维平台已在郑州地铁线路中心试点应用。该平台实现了:信号集中监测系统、施工管理系统、物资管理系统等业务系统的数据汇聚和数据统一存储;生产计划、检维修记录、检查问题、故障记录、监测报警、电气特性、设备台账等业务数据的关联分析;统一的数据接口规范;多维度数据应用,如关键信号设备质量的量化评分及重点检维修任务质量的量化评分。该平台的应用,可减少信号系统数据冗余,降低信号设备信息维护的复杂性,提高资源利用率,提升维护人员查阅数据的便捷性。

关键词 城市轨道交通;信号系统;大数据;智能运维

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Design of Big Data Intelligent Operation and Maintenance Platform for Urban Rail Transit Signaling System

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Abstract [Objective] The maintenance and management of urban rail transit signaling systems encompass various tasks such as equipment monitoring, production organization, and information management, each task involving one or more business systems. These systems vary in construction ages and often have overlapping or redundant functions on the same railway line. Therefore, there is a need to develop a big data IOM (intelligent operation and maintenance) platform for signaling systems that integrates data and enables analytical functions.

[Method] Based on the current state of signaling system main-

tenance operations and the characteristics of signaling system data, a signaling system big data IOM platform is constructed using a layered data approach to meet practical application needs. The overall architecture of the platform is introduced, the design scheme of its three sub-platforms: data sharing, data analysis, and data application, is expounded. [Result & Conclusion] The signaling system big data IOM platform is piloted on Zhengzhou Metro network, which achieves the aggregation and unified storage of data from various business systems, including the centralized signal monitoring system, construction management system, and material management system. It enables the correlation analysis of business data such as production plans, maintenance records, inspection issues, fault records, monitoring alarms, electrical characteristics, and equipment ledgers. Additionally, the platform regulates standardized data interfaces and multi-dimensional data applications, such as quantitative scoring of key signal equipment quality and key maintenance tasks. The application of this platform reduces data redundancy within the signaling system, simplifies the complexity of maintaining signal equipment information, enhances resource utilization, and improves the convenience for maintenance personnel in data reviewing.

Key words urban rail transit; signaling system; big data; intelligent operation and maintenance

信号集中监测系统、施工管理系统、物资管理系统以及办公管理软件在城市轨道交通中的应用,提高了信号设备维护自动化、信息化水平。由于信号设备具有运营环境时空多尺度、机电软硬件混成等特殊性,信号系统内各业务系统之间缺乏一定的关联性,数据共享、多源数据分类分析、数据可视化的应用程度不高,在日常维护过程中,维护人员往往需要通过查阅不同业务系统的数据进行综合评估。各业务系统使用差异较大以及数据的分类不能统一,给维护人员增加了工作量。

对于信号系统大数据平台,国内已有许多研究成果,但还需进一步优化。在数据集成及交换实时性、一致性方面,信号系统大数据平台可以通过数

据归类和关联,提供实时的数据交换服务,从而大幅提高数据复用性,降低重复投入成本;在数据服务方面,通过独立且分布式部署信号系统大数据平台,可以提供原始数据、关联分析后数据等多种维度数据,降低上层用户的应用难度;在数据应用方面,通过微服务,信号系统大数据平台可以提供软硬件平台一体的应用部署方案,也可以仅为相对独立的应用提供数据服务,兼容 PC(个人计算机)、手机或 PAD(平板电脑)等不同展现方式。

本文采用大数据技术,结合物联网建设思路,以信号系统数据为研究对象,设计了信号系统大数据智能运维平台,该系统已在郑州地铁线路中心进行试用。

1 信号系统数据特点

信号系统内各业务系统产生的数据是相互独立的,主要分为专业设备数据、管理数据和公共数据,不同数据源之间的数据差异较大。相较于其他领域,信号系统大数据具有以下特点:

1) 生成和存储周期不一。数据来源较多,有的数据每秒几十组,但存储时间不到 1 年;有的数据按天、周或月生成,存储周期几年不等;还有的数据由人工产生。

2) 建设年限不一,造成部分数据重叠和不一致。比较典型的是设备履历数据,由于在多个业务系统中没有统一设备编码,不同业务系统之间的设备履历数据无法共享,导致数据一致性和完整性不足。

3) 数据受影响因素较多。信号系统数据容易受环境和人为因素影响,比如天气特性、温度因素、行车密度等,所以一些数据分析方法和评估算法不能适用于所有情况。

信号系统数据往往通过不同形式存储在文件或者程序中,通常还包含不同时期版本,如果管理不当还会造成文件的丢失、冗余或不同步等问题。使用信号系统数据时,维护人员需要查阅不同的业务系统及大量的电子表格。信号系统数据只有得到合理分类、处理和分析,才能为信号系统的安全可靠运行提供有效的保障。

2 信号系统大数据智能运维平台建设目标

综合应用背景、管理现状及信号数据特点,信号系统大数据智能运维平台着重实现以下建设

目标:

1) 提升设备运维管理能力。通过整合设备静态履历、动态监测等信息实现设备生命周期管理,提前发现并预警设备劣化趋势,为检修提供决策。

2) 提升生产组织管理能力。结合设备信息、生产信息和人员作业情况,全方位监控作业过程,推动生产组织管理水平及人员素质的提高。

3) 提升设备隐患和风险管理能力。运用问题库、故障库数据,加强闭环管理,与设备运行质量、生产组织相结合提前发现设备隐患风险。

3 信号系统大数据智能运维平台设计

信号系统大数据智能运维平台包括数据共享、数据分析及数据应用等 3 个子平台,各子平台可以独立运行,也可整合运行。各子平台为上层平台提供数据和应用服务,同时具备较强扩展性。各子平台互相协作能实现合力效果。信号系统大数据智能运维平台整体架构如图 1 所示。

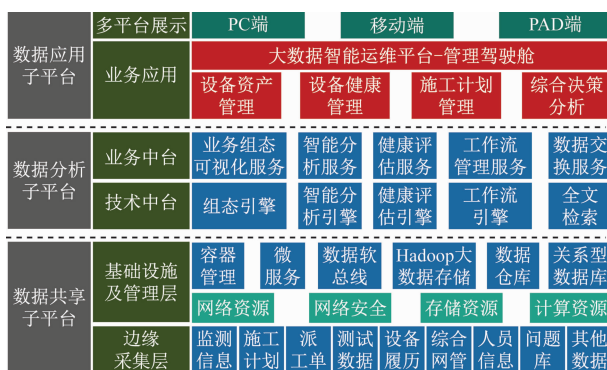


图 1 信号系统大数据智能运维平台架构图

Fig. 1 Architecture diagram of the signaling system big data intelligent operation-maintenance platform

3.1 数据共享子平台

数据共享子平台通过现场采集数据,获取多源数据库数据及电子表格数据。在信号集中监测系统、施工管理系统、物资管理系统等业务系统中,由于命名规则不统一、数据记录不规范、部分信息缺失,数据关联实现困难。针对多源数据库命名规则不统一的问题,数据共享子平台采用关键字符分析并手动建立设备关联关系表,使不同业务系统的数据相关联;对非格式化电子台账数据,首先进行数据格式转换,其次建立对应数据库关系表,统一数据类型,完善数据库设计;对经过预处理与数据融合后的基础数据,建立大数据仓库,规范数据类型,

为上层应用提供基础。

数据库关联关系的确定对数据分析起着关键作用。信号大数据智能运维平台数据包括生产数据、检查问题、故障库、监测报警、电气特性变化、设备台账、检维修表等数据。数据共享子平台通过分析数据库关联关系,建立反映现实和数据之间联系且易于理解、更改和转换的模型。

设计统一的数据共享子平台数据接口规范,并按照规定对基础数据进行处理,为不同类型的数据集提供开放接口,为上层应用提供规范化的数据,从而进一步为数据开发利用提供数据源。

数据共享子平台可为不同角色人员提供相应的使用规范,明确责任分工,使决策管理人员与检维修维护人员共享数据,这减少了人为因素及系统因素带来的数据误差、时间误差,可实现信号系统数据的高效管理与精准维护。

数据共享子平台通过云平台提供微服务及容器管理支持,便于用户进行数据分析及搭建数据应用。结合人员角色设置,该平台可将数据使用权细化到行、列颗粒度,并通过安全授权,为上层平台提供软硬件支撑。

3.2 数据分析子平台

数据分析子平台是基于城市轨道交通信号系统数据特点定制的技术中台和业务中台。技术中台基于解耦复用策略,提供业务解耦的核心组件引擎,可提升同质化业务的开发效率;业务中台基于技术中台组件,构建面向业务的服务化解决方案,支撑业务需求实现。

数据分析子平台可以实现基础数据检索功能,为管理人员及现场人员提供全文检索、设备分类检索、区域分类检索、统一展示,实现大数据的基础数据交换。数据分析子平台也为不同业务系统提供实时的数据交换服务,交换的数据可以是原始数据或分析后的结果。数据的可视化程度反映了数据共享的效果。针对来源不同但业务相同的数据,按不同设备分类进行统计,并展示数据的概要信息及详细信息。针对模拟数据,采用电气特性变化趋势图方式实现数据展示,并可以查看详细数据。

业务中台还可以提供前端业务组态可视化、智能分析、健康评估及工作流等服务,以满足应用层不同展示需求。

3.3 数据应用子平台

数据应用子平台是为用户提供大数据展示并

辅助决策的窗口,支持多应用厂商及应用管理。通过业务分析及挖掘,根据信号系统需要,可将数据应用子平台划分为设备资产管理、设备健康管理、施工计划管理及综合决策分析等功能模块,实现以下典型功能:

1) 设备及检维修质量评价。通过层次分析法与模糊综合评价法相结合的算法建立评价模型。分析影响设备质量的关键因素(包括监测报警、电气特性、检查问题、故障记录、器材更换频次、设备上道时间、环境因素等),构建设备质量评价模型;分析检维修质量的关键信息(包括生产数据、关键作业项完成情况、监测报警、电气特性变化、检查问题、日常检维修等),建立作业质量评价模型。根据设备质量评价模型,建立道岔转辙机、轨道电路、信号机、区间移频、电源屏和电缆绝缘等健康评价标准,并根据指数估算法、环比分析法确定影响因子,计算设备的健康度,检测设备的健康状态,及早发现问题,避免发生设备故障。

2) 运维综合报告生成。设备质量评价与检维修质量评价结果应该呈正相关性,即:设备质量越高,检维修质量越好;设备质量低时,检维修质量也相应较低。分析设备质量与检维修质量的关联关系,计算两者的关联系数,根据评价标准生成相关维度的详细评价结果,最终形成运维综合报告。

4 信号系统大数据智能运维平台应用

信号系统大数据智能运维平台已在郑州地铁线路中心开始试用。试用结果表明,该平台初步达到了数据融合共享和辅助生产决策的效果,提升了维护人员查阅数据的便捷性,提高了设备信息维护水平。该平台尚有待于在信号设备维护精细化、智能化等方面进行实践应用。

信号系统大数据智能运维平台构建了线路侧数据共享、数据分析、数据应用等3个子平台,实现的功能主要包括:

1) 数据集成。对信号集中监测系统、施工管理系统、物资管理系统等业务系统,通过系统接口实现多源数据汇聚,将预处理后原始数据统一存储到大数据仓库,并规范了数据类型。

2) 数据关联分析。对生产计划、检维修记录、检查问题、故障记录、监测报警、电气特性、设备台账等数据建立关联关系模型,实现了多种业务数据的关联分析。

3) 数据共享。设计了统一的数据接口规范,并按照该规范进行基础数据处理,为不同类型的数据集提供开放接口,按照人员角色设置权限。

4) 设备质量评价。可分析影响设备质量的关键因素,构建设备质量评价模型,实现了对关键信号设备(道岔转辙机、信号机、轨道电路)质量的量化评分。

5) 作业质量评价。可分析检维修质量的关键信息,建立作业质量评价模型,实现了重点检维修任务质量的量化评分。

5 结语

本文分析了城市轨道交通信号系统在数据管理方面的现状和问题,通过现场采集数据,设计并建设了信号系统大数据智能运维平台,在试点线路完成了该平台阶段性建设,实现了数据集成、关联分析、数据共享、设备及检维修质量评价等功能。信号系统大数据智能运维平台的应用,解决了信号设备维护管理中查找复杂关联数据时效率低下的问题,降低了数据的冗余,提高了资源的利用,为信号设备维护人员的日常维护管理工作带来便捷,为进一步探索信号系统的大数据价值、持续进行业务

和管理的创新创造了有利条件。

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Commentary

Difficulty of Digital Transformation lies in Transformation

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In the current context of the booming development of digital technology, the digital transformation of urban rail transit enterprises has become the key to improving management capabilities and achieving sustainable development. The digital transformation process not only faces technical challenges, but also involves management revolutions.

The key elements of digitalization are data and algorithms. Data is the foundation of digitalization, while algorithms are the key to mining data value and realizing intelligent decision-making. From a technical perspective, data acquisition can rely on sensors, information systems, AI recognition and other means; algorithm generation can be achieved through mechanism analysis, machine learning and other methods. The purpose of digital transformation is to use digital technology to improve service quality, increase operational efficiency, and reduce operating costs. To achieve this goal, it is necessary to adjust management organizations, optimize management processes, and break down professional barriers under the background of digital technology support, which is the gist of management revolution and transformation. In the field of urban rail transit, the requirements for digital technology are not the highest compared to other fields. The real difficulties often appear at the management level of transformation, which are mainly reflected in the following aspects.

First, there are difficulties in managing the authenticity of data. The authenticity of data requires accuracy, timeliness, and completeness. Due to human factor influence, some key sensitive data may be biased across different organizations and levels,

which will cause trouble for decision-making. Therefore, it is necessary to enhance the authenticity of the data by means of establishing an effective reward-punishment system, and introducing data verification technology etc. . The timeliness and completeness of data are crucial for decision-making, and manual filling is often difficult to meet the requirements. When the data granularity is more detailed and the quality requirements are higher, the amount of information that users need to fill in is greater. The manual reporting method will lead to a worse user experience and make system promotion and application difficult. Therefore, when designing the system, it is necessary to focus on measuring the most cost-effective and feasible data collection accuracy and scope from the perspective of demand, avoid inefficient reporting work, and give priority to the use of sensors, data middle platform and other technologies to reduce manual operations, so as to achieve data accuracy while enhancing user experience.

Second, there is a lack of relevant management systems for data sharing. Cross-disciplinary, cross-organizational and cross-stage data sharing is an important part of the digital transformation for urban rail transit enterprises to realize their value orientation. There are inter-disciplinary data needs in power supply, communication signal, vehicle, track work and other disciplines. More efficient data flow is also needed between operations and facility equipment maintenance. There is also a large demand for data in the handover from design to construction and from construction to operation. However, the existing organizational culture and institutional design often lack incentives or mandatory provisions for data sharing, and thus often leads to a mentality of unwillingness to share, fear of trouble, afraid of taking responsibility and fear of their own shortcomings being seen by others. The existence of such a mentality makes data sharing much more difficult. On the other hand, some people dare not share data due to concerns about information security, which also restricts data sharing and circulation. Therefore, it is necessary to create a culture of positive sharing, establish a responsibility system for data sharing and flow, add constraints on data sharing in business contracts, and strengthen information security management.

Third, in management process revolution, basic management lacks motivation, and middle management has little confidence. Digital transformation must be accompanied by management process revolution. Values of transformation that only changes the form without changing the process is bound to be low. However, basic management often lacks internal motivation to change management processes, and middle management lacks confidence in execution too. Traditional job setups and processes have been gradually formed over many years of practice, and the matching management systems and staffing arrangements are very solid. Therefore, process revolution may create resistance among employees who are worried that the changes will affect their positions and interests. This requires management to pay attention to communication and coordination with employees in the process of promoting management process revolution to minimize employee resistance and ensure the smooth progress of revolution. For middle management, changing the process means breaking the established mature model. Potential liability risks need to be prevented by formulating new processes that match the digital technology background. This is a great test for middle management on their understanding of the nature of the business that they are managing. As the saying goes, "Capable person is fearless". We should enhance the confidence in revolution through continuous learning of the business.

Despite the difficulties mentioned above, the goals of digital transformation are always clear: to ensure security, enhance efficiency, improve quality and reduce costs. In order to achieve these goals, three strategies are recommended. First, top-level design should serve strategic goals; second, project planning should be closely aligned with production management needs; and third, implementation should start from the easy part. During the implementation process, we should start with specific business process improvements, establish a clear responsibility system for supporting, change employees' work habits, strengthen the business capabilities of middle management, and cultivate a positive data sharing culture, so as to promote the revolution of the entire organizational process and achieve the goals of digital transformation.

In summary, digital transformation is the product of digital technology development to a certain stage. It is both a technological innovation and a management renovation. Only by deeply understanding and effectively responding to the management challenges faced during the transformation process can urban rail transit enterprises achieve steady and long-term development.

(Translated by JIANG Na)