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Intrinsic Safety & Reliability, and Supervision Intelligentization of Equipment in Refinery Enterprises

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Abstract: The frequent occurrence of equipment accidents in the refinery enterprises in China have brought to the great challenges regarding the intrinsic safety and reliability of the equipment. The equipment reliability design/manufacturing, risk management, monitoring, and intelligent control have arisen as urgent engineering requirements. This study elucidates the connotation of intrinsic safety, reliability, and intelligent supervision of equipment. It clarifies the development trends of reliability design/manufacturing, risk management, monitoring, and intelligent control technologies. It also proposes corresponding countermeasures for improving the intrinsic safety and reliability and realizing intelligent supervision of the equipment. These measures are applied for the transformation of the main fan of a catalytic unit. The results show that this type of equipment transformation is conducive to the safe operation of the equipment.
Keywords: intrinsic safety; reliability design; reliability manufacturing; risk management; supervision intelligence

1 Introduction

Safety accidents frequently occurred in China's refining and chemical enterprises from 2005 to 2016, attracting considerable scrutiny from the state. On Nov. 13, 2005, a nitrobenzene rectifying tower blasted at the biphenyl plant of Jilin Petrochemical Co., of CNPC, which led to cross-border water pollution in the Songhua River. On Sep. 8, 2011, in Shanghai Secco Petrochemical Co., Ltd., the valve cover of a flow meter from a bypass gate detached from the valve body of a supercritical ethylene pipeline led to ethylene leakage, which resulted in an explosion and fire. On Nov. 22, 2013, crude oil leakage led to an explosion in the Donghuang Oil Pipeline of the China Petroleum and Chemical Corporation Pipeline Storage and Transportation Branch. On Apr. 21, 2015, the ethylene glycol t-430 tower in the olefin plant of Sinopec Yangzi Petrochemical Co., Ltd. blasted. The constant occurrence of accidents at large refinery units led to tremendous economic losses, apart from the severe social and, at times, global impact on the country [1]. By the end of 2016, China had reached a refining capacity of 7.5×10^8 t/a. Of the total capacity, 42% (3.14×10^8 t/a) was fulfilled by 24 large refineries, each of which had a refining capacity of 1×10^7 t/a. The manufacturing of large-scale, high-speed, automatic, and intelligent refining equipment had become a national strategy [2]. Even though large equipment possess huge economic benefits, once an accident occurs, the production interruption causes substantial economic losses to the enterprises [3]. The resultant safety and

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environmental protection accidents would cause severe social and, at times, global impacts on the country. The intrinsic safety, reliability, and realization of intelligent supervision for the equipment plays a significant role in the safety and reliability of refinery enterprises, ensuring a clean and environmentally friendly operation.

The concept of intrinsic safety and intelligent supervision of equipment has been dramatically expanded in China and abroad. Moreover, multiple studies relevant to the intrinsically safe and reliable operation of equipment and reliability design/manufacturing have been conducted. Xu Zhengquan et al. analyzed the current situation and the problems present regarding the research on intrinsic safety management in China. They put forth guidelines for intrinsic safety management based on the theory of interactive safety management [4]. According to the actual needs of industrial development, Wang Qinfang proposed an enterprise intrinsic safety model. This model comprised of five modules: human, machinery and equipment, working environment, management, and culture [5]. By integrating the idea of intrinsic safety into the PDCA (plan, do, check, action) management mode, Wu Zongzhi et al. put forward a practicable PDCA management mode based on the intrinsic safety culture [6]. By analyzing the hazard factors of the equipment, its control principles, and ways of achieving equipment safety, Bai Jing proposed that the focus of strengthening the safety management of equipment should be on the intrinsic safety of the equipment and the safety management of the process of equipment use [7]. Woo expounded the necessity of the reliability embedded design process and the development of its method and proposed to introduce a new parameter called accelerated life test (ALT) into the reliability method [8]. P Perng et al. conducted research in the area of supervisory intelligence, and proposed two types of smart supervisory controllers with performance reaching or exceeding the limit of linear control, which is superior to fuzzy controllers and neural controllers [9]. Miao et al. studied complex and changeable industrial control systems, summarized the comprehensive application of intelligent industrial control technologies, such as computers, communication, artificial intelligence, and information and decision-making. Consequently, they outlined the development trends of intelligent industrial control [10]. Dai et al. proposed a method for signal selection and reliability evaluation based on the condition information and reliability analysis method [11].

This article is based on the progress and current status of research on the intrinsic safety, reliability, and intelligent supervision of the refining and chemical equipment. Furthermore, it strives to reveal their connotation and characteristics. By sorting out the development trend of the essential safety and reliability of the refining and chemical equipment and intelligent supervision, the challenges faced by the refining and chemical enterprises could be elucidated and overcome. Countermeasures and suggestions for the intrinsic safety and reliability of the equipment and the intelligent supervision are proposed herein. These measures could find potential application in the relevant cases of domestic engineering.

2 Connotation and characteristics of intrinsic safety & reliability and supervision intelligentization of refining equipment

2.1 The connotation of intrinsic safety & reliability and supervision intelligentization of refining equipment

Research on foreign intrinsic safety theory focuses on the theory of system reliability, with more emphasis on the technical factors. The research focus gradually shifts from safety evaluation to problem-solution design, thereby improving overall system security [12]. Intrinsic safety refers to the use of organizational structure design, technology, management, norms, and culture under the premise of ensuring the reliability of people, things, and the environment. It rationalizes the interactions and relationships among the basic, normative, and culture of the operating system. Moreover, it prevents the system from being influenced by the inconsistencies caused by adverse, invalid, and type II effective interactions. It ensures the realization of system safety, reliable equipment, comprehensive management, and a culture of safety deeply rooted in people’s psyche, thus ensuring long-term prevention [4]. Intrinsic safety runs through all the stages of the entire life cycle of equipment, such as design, manufacturing, operation, and maintenance. In the design stage, intrinsic safety technology is used, with sufficient safety factors; mechanization and automation are implemented with safety devices (fixed, interlocked, controlled, tripped, etc.). The manufacturing stage implements processing, assembly, and testing standards to ensure the reliability of the parts in service. The design of the control system used in the operation phase should consider the modes of various operations, with functions, such as fault display, automatic monitoring, and manual intervention. In the maintenance phase, technologies such as Internet of Things, fault diagnosis, and risk-based maintenance management are used to achieve accurate maintenance, ensuring that the equipment is always in a reliable and available state.

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The connotation of the equipment's intrinsic safety and reliability and intelligent supervision can be defined as follows: considering the reliability design and manufacturing of equipment as the foundation; taking risk management measures as the core means by incorporating monitoring, control intelligence, and information as supporting technologies to realize real-time state awareness; state identification and prediction; external environmental disturbances or self-failure adaptive adjustment control, and autonomous maintenance decision-making. It ensures that the equipment is operating reliably and safely, and the human, machine, and environment are in a harmonious state. The reliability design/manufacturing, risk management, as well as intelligence monitoring and informatization are the three key elements for ensuring the intrinsic safety and reliability of the equipment.

2.2 Characteristics of intrinsic safety & reliability and supervision intelligentization of refining equipment

2.2.1 Considering reliability design/manufacturing as a fundamental measure

Reliability can be defined as the ability of a device to perform a specified function within a specified time. The reliability design includes three aspects—quality, cost, and reliability. The optimization process considers the overall reliability of the product as a performance constraint, which would result in a balanced design that is coordinated with reasonable safety [13]. The reliability design/manufacturing refers to technical activities performed in terms of equipment design and manufacturing. The intent behind this is to eliminate potential defects and weaknesses and to prevent the occurrence of failures. It enables the attainment of the specified inherent reliability requirements in the light of equipment intrinsic safety. Approximately 90% of the operational reliability of the equipment is determined by reliability design/manufacturing. A reliable design/manufacturing can ensure the intrinsic safety of the equipment, prevent or reduce injuries and deaths, and reduce equipment failures. Therefore, it aids in increasing the equipment utilization and achieving safe production. Moreover, choosing products with reliable design/manufacturing guarantee during the design and selection of equipment is crucial.

2.2.2 Considering risk management as the core measure for life cycle management

Risk management entails the use of means, such as risk identification, risk analysis, quantitative risk calculation, and reliability management to ensure the normal and safe operation of the equipment [14]. After conducting risk assessments, such as reliability-centric maintenance (RCM), risk-based inspection (RBI), and safety integrity level (SIL) for electrodynamics and static equipment, key factors that affect the reliable operation of equipment can be identified, fault eradication measures can be taken, and risk reduction measures or one-time change tasks can be developed. The intrinsic safety and reliability can then be improved based on the above measures. The risk management technology is implemented during all stages of the equipment's life cycle, including equipment design, construction, installation, operation, maintenance, and retirement.

2.2.3 Considering intelligent monitoring and control as technical support

"Monitoring and early warning as well as diagnosis and prediction" have directed the development of equipment monitoring and diagnosis. Based on industrial interconnection technology, mobile interconnection, condition monitoring, diagnosis, and information-based cloud platform, people and machines can be connected through data. RCM can then be achieved, which can in turn improve the human work efficiency and ensure safe operation of the equipment.

2.2.4 Considering comprehensive perception, status identification and prediction, and autonomous maintenance decisions as a realization approach

Based on the RCM assessment of refining equipment, fault detectability analysis for high-risk fault modes can be conducted; further, fault characteristic sensitive parameters can be determined, ensuring that machines installed with various sensors exhibit fault perception capabilities. By configuring the machine with a "brain" for signal processing analysis using an equipment health evaluation model, an energy efficiency evaluation model, a reliability evaluation, and corresponding evaluation performance standards, we ensure that it has the ability to identify and predict its operating status. By connecting the machine to the network, the state identification and prediction information can be used to implement an early fault warning. By utilizing a maintenance decision knowledge base, maintenance decision-making content can be self-determined.

2.2.5 Considering self-adaptive adjustment control for external environment disturbance or self-fault, as technical support

Under the guidance of system theory, we should break the traditional professional barriers, learn from and transplant modern medical “autonomous conditioning” treatment principles, integrate technologies, such as condition monitoring and diagnosis, artificial intelligence, active and adaptive control together, and conduct research on adaptive regulation to achieve accident prevention and self-healing. This could incorporate the function of fault self-healing into the equipment of the refining and chemical enterprises, which can substantially reduce the failures, accidents, and the production loss.

2.2.6 Taking fault eradication tasks in an effective manner

Equipment maintenance can only maintain rather than improve the inherent reliability of the equipment. The autonomous maintenance support decision determines the best timing and content of maintenance and avoids “under-repair” or “over-repair.” The fault eradication task is an important content of autonomous maintenance support decision making. A few of the effective manners to improve the inherent reliability of equipment are aiming at high-risk fault modes, conducting fault root cause analysis, and formulating fault eradication measures [15].

3 Development trend of intrinsic safety, reliability, and intelligent supervision of equipment

3.1 Development of equipment design and manufacturing towards intelligence

3.1.1 Reliability design/manufacturing as fundamental measures

In the digital integration environment, the design and simulation of reliability and performance integration should be conducted for structure/mechanism, equipment, and system-level complex products. The reliability of multi-field coupling and multi-mechanism must be studied. The methods include quantitative analysis, life prediction, and solution optimization. The reliability research includes seven functional modules, such as multidisciplinary tool integration, test design, response surface coupling, reliability analysis, system reliability analysis, reliability optimization, and durability analysis.

3.1.2 Intelligent mechanical equipment as the development trend

The current society uses several intelligent technologies, including various production control systems, logistics systems, and manufacturing systems. The process equipment’s self-awareness, automatic identification, automatic prediction, adaptive adjustment of external disturbances, and self-healing of faults all have typical intelligent characteristics. The automatic control facilities, such as anti-surge control, steeples air volume adjustment control, interlock protection, and overload protection of fluid machinery, form the basis of intelligent control.

3.1.3 Intelligent manufacturing as the way for achieving intrinsically safe, reliable, and intelligent equipment

Intelligent manufacturing refers to information-based manufacturing under the ubiquitous perception conditions during the course of the product’s life cycle. Based on advanced technologies, such as modern sensing technology, network technology, automation technology, and anthropomorphic intelligence technology, the design process, manufacturing process, and manufacturing equipment can be made intelligent via intelligent perception, human-computer interaction, decision-making, and execution technology. Here, information technology, intelligent technology, and equipment manufacturing technology are deeply integrated. Utilizing technologies, such as networked manufacturing and digital manufacturing, integrated artificial intelligence, and robotics, the interaction between human, machine, and things can be realized along with deep integration. The equipment can be made intelligent at all stages, including design, process, test simulation, production process, guarantee, and management [16,17].

3.2 Risk management technology as an important support parameter for equipment integrity management

3.2.1 Equipment integrity management as the development trend for equipment management

The equipment management mode has been developed from breakdown maintenance (BM), time-based maintenance (TBM), condition-based maintenance (CBM), and risk-based maintenance (RBM) to asset integrity management (AIM). Integrity management runs throughout the life cycle of equipment design, manufacturing,

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installation, operation, maintenance, scrap, and other stages; this is the mainstream development trend of equipment management mode in refining and other enterprises.

3.2.2 Risk management is the core measure of integrity management

In the design stage, quantitative risk assessment (QRA), hazard and operability analysis (HAZOP), reliability and availability analysis (RAM), SIL, and other risk assessment tools are applied to identify the risk factors and adopt one-time change measures to ensure that the equipment are intrinsically safe and reliable during the design phase.

In the operation and maintenance phases, failure tree analysis (FTA) and root cause analysis (RCA) are employed to identify potential factors that can cause equipment defects. The risk-based inspection (RBI) is used for pressure equipment and piping to conduct risk analysis and formulate inspection plans. The RCM and RAM technologies are applied to the dynamic equipment to conduct reliability analysis and formulate inspection and maintenance strategies. The electrical instrument uses SIL technology to perform safety integrity-level analysis and formulate corresponding management strategies. In terms of operation, the integrity operating window (IOW) is used to set the operating boundary of equipment failure, to prevent and intervene in accidents caused by the deterioration of equipment status, and to ensure the safe operation of equipment.

3.2.3 Risk management promotes the traditional equipment management model from the institutional level to the technical level

Traditional equipment management relies on institutional norms, which clarifies how people manage equipment. From a technical perspective, risk management proposes the management guidelines for the equipment to ensure a safe and reliable operation of the equipment, while reducing the cost of maintenance resources and increasing the operating cycle of the device.

3.3 Development of Equipment monitoring towards network and intelligence

3.3.1 Intelligent monitoring and early warning

Conventional monitoring alarms are prone to false alarms, missed alarms, and repeated crossing alarms. The development trend of intelligent monitoring and early warning aims to replace the threshold alarm method and set intelligent alarm lines according to factors such as equipment operating conditions and service life. The alarms are classified, and in addition, the location, danger level, release, and delay of the alarm are all informed.

3.3.2 Intelligent monitoring and diagnosis

Multi-parameter and large-capacity replacement of single-parameter monitoring, stable operation monitoring toward non-smooth operation monitoring, and technologies, such as information integration, fusion, decomposition, and purification (instead of single-parameter threshold comparison) form the basis of research on the development of intelligent monitoring diagnosis. The development trend of intelligent monitoring and diagnosis is to realize automatic fault diagnosis, automatic fault prediction, and remaining useful life prediction.

3.3.3 Networked monitoring and diagnosis

Real-time online monitoring replaces regular monitoring and roving monitoring; distributed and networked monitoring replaces centralized monitoring, which forms the development trend of monitoring diagnosis. The new generation of information and communication technologies represented by Internet of Things, cloud computing, and big data plays an active role in innovation and rapid development. It is setting a new round of scientific and technological revolution and industrial transformation worldwide and has become an important force to promote economic and social development. The Internet of Things can connect all ordinary objects that perform independent functions with the Internet for information exchange and communication to achieve intelligent identification, positioning, tracking, monitoring and management. Globally, the Internet of Things, big data processing, and public platform services are still in the ascent. The terminal manufacturing and application services related to the Internet of Things are still growing.

It is also a trend for the intelligent supervision of refining and chemical equipment to rely on big data without relying on mechanism research. With the help of technologies, such as Internet of Things, cloud computing, big data, we can make full use of the big data of refining and chemical enterprises for data mining. Further, we can use methods such as statistics, online analysis, machine learning, and pattern recognition to carry out processes, such as data classification and estimation, rule association, clustering, and visual description application. Therefore, functions such as equipment fault identification, early warning and diagnosis, and online evaluation of equipment health, can be achieved. Some Internet companies have begun the use of artificial intelligence technology to support refining and chemical enterprises to explore intelligent production. A variety of network technologies are comprehensively used to ensure data exchange between equipment and between equipment and manufacturing cloud data centers; moreover, they provide a smart data foundation for monitoring by ensuring intelligent factories.

4 Macroscopic research on intrinsic safety, reliability, and intelligent supervision of China's refining equipment

4.1 Problem on intrinsic safety, reliability, and intelligent supervision for refining enterprises' equipment

The laws and regulations on equipment reliability design/manufacturing, risk management, and intelligent monitoring are not complete. The investigation of major and serious accidents of equipment is usually for the purpose of accountability, and the root cause often cannot be traced.

The equipment reliability design/manufacturing, risk management, and intelligent monitoring standard evaluation system is lacking or incomplete. There is no certification system for the qualifications of employees in risk management and supervision, and the technical level of employees needs to be improved.

The bidding system for procurement of low-cost equipment cannot guarantee the improvement in design/manufacturing quality, and it is difficult to promote the construction of safety facilities required for ensuring intrinsic safety, reliability, and intelligent supervision of equipment.

The technology of equipment design/manufacturing monitoring control is not intelligent and is relatively backward. The product design of design institutes and manufacturing plants is relatively conservative. At the "source," there is a lack of functional design of equipment fault detectability, adaptive control, and self-healing.

In the equipment operation and maintenance management phase, a manager with limited knowledge believes that the monitoring and control of intelligent facilities functions are like "painting the lily." On the other hand, the degree of intelligence of equipment monitoring and control does not reach the user's expected function. Both phenomena exist simultaneously.

The traditional idea of equipment management mode is deeply rooted, and advanced and mature management modes such as RBI, RCM, SIL, and HAZOP are difficult to undertake.

The equipment decision management relies on experience and leadership and lacks the awareness and ability to make scientific decisions using equipment operation data, monitoring and diagnosis data, and maintenance and repair data.

The low degree of intrinsic safety, reliability, and intelligence of the equipment makes it difficult to operate the equipment at an optimal control limit. It is common to sacrifice operating efficiency for safety.

4.2 Countermeasures and suggestions on intrinsic safety, reliability, and intelligent supervision for refining enterprises' equipment

At the national level, we must start to establish laws and regulations related to the design and manufacturing of refining and chemical equipment that are intrinsically safe and reliable. If the root cause of a major equipment accident is a design/manufacturing defect, the relevant unit and personnel should be held accountable.

It is necessary to formulate industry standards or specifications in the design/manufacturing of refining and chemical equipment, risk management, and intelligent supervision, and establish a regular review and update mechanism. Based on the best available technology, it is necessary to increase the participation of enterprises in the standard-setting process. It is necessary to implement a certificate qualification system for employees and improve the authority of risk assessment, monitoring, and diagnosis conclusions.

Based on the inherent needs of the equipment's intrinsic safety, reliability, and intelligent supervision, the procurement management system for equipment and its components must be improved. The equipment operating efficiency, trouble-free operating cycle, average repair time of failure, annual maintenance cost, accident safety impact, and environmental impact should be used as important evaluation indicators to determine the equipment's intrinsic safety and reliability performance.

In terms of equipment design/manufacturing, it is necessary to conduct fault detectability design and industrial interconnection design tests and improve the equipment's fault perception ability, state identification and prediction ability, and industrial interconnection ability. It is also necessary to improve the level of equipment intrinsic safety design through processes such as digitalization, automation, modeling, intelligence, and

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information. Moreover, it is necessary to realize the integration of safety production management and control in the entire processes involved in refining and chemical enterprises and facilitate the identification and prediction of equipment operation status, adaptive planning control, dynamic compensation and repair capabilities, and intelligent maintenance decision-making capabilities (Fig. 1).

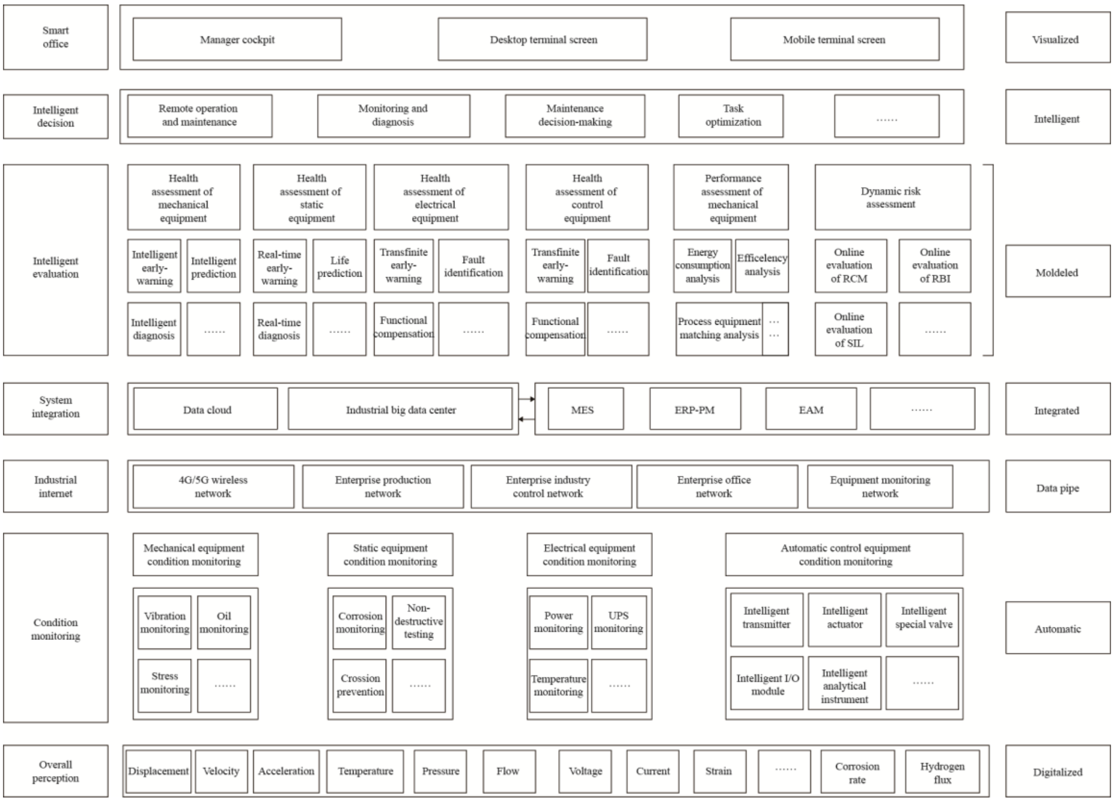

Fig. 1. Equipment intrinsic safety, reliability, and intelligent supervision design framework.

Besides the aforementioned aspects, it is necessary to establish and improve the equipment integrity management system to realize the full life cycle management of equipment design, manufacturing, installation, operation, maintenance, and scrap.

It is also necessary to implement risk assessment tools such as RBI, RCM, and SIL at all stages of the equipment's life cycle. This measure must be made a national or industry technical specification. All refining and chemical enterprises should formulate corresponding management rules and regulations and accept and allow the supervision of government organizations during the implementation process.

Through the utilization of technologies such as big data, cloud computing, and artificial intelligence, we must achieve breakthroughs and develop key technologies, such as automatic device fault diagnosis, automatic prediction, and intelligent early warning systems, and build an intelligent operation and maintenance decision information platform for equipment integrity management to achieve data-driven intelligent operation and maintenance of equipment decision (Fig. 2).

It is necessary to master such key technologies for monitoring the health and energy efficiency of refinery equipment and establish an intelligent control system for compressor units. It is also necessary to utilize an expert system to centrally monitor and control refining and chemical equipment and employ intelligent algorithms to optimize load distribution, such that each compressor unit runs at the optimal working conditions, to maximize the operating benefits. Moreover, anti-surge optimization control and fault self-healing control technology should be adopted for large units to improve their operating efficiencies while ensuring that the involved equipment operates safely and reliably.

5 Engineering application case

The engineering case implementation is conducted using the intrinsic safety and reliability supervision intelligence technology [18]. The primary fan of the catalytic unit of a subsidiary of the Sinopec Group had experienced several failures in relation to jamming, system alarms, and incorrect interlocking during the eight years of its work life. From Feb. to Apr. 2011, the system was shut down owing to two stationary blades of the main fan drifting by 22°. According to incomplete statistics, domestic-related units demonstrate 3–5 system shutdowns each year due to the locking or running position of the main fan stationary blade adjustable mechanism, and the average loss incurred owing to each system shutdown is approximately 30.24 million Yuan. The intrinsic safety and reliability supervision intelligence technology are applied for the transformation of the main fan to reduce the losses caused by system shutdowns and to ensure the safe operation of the equipment.

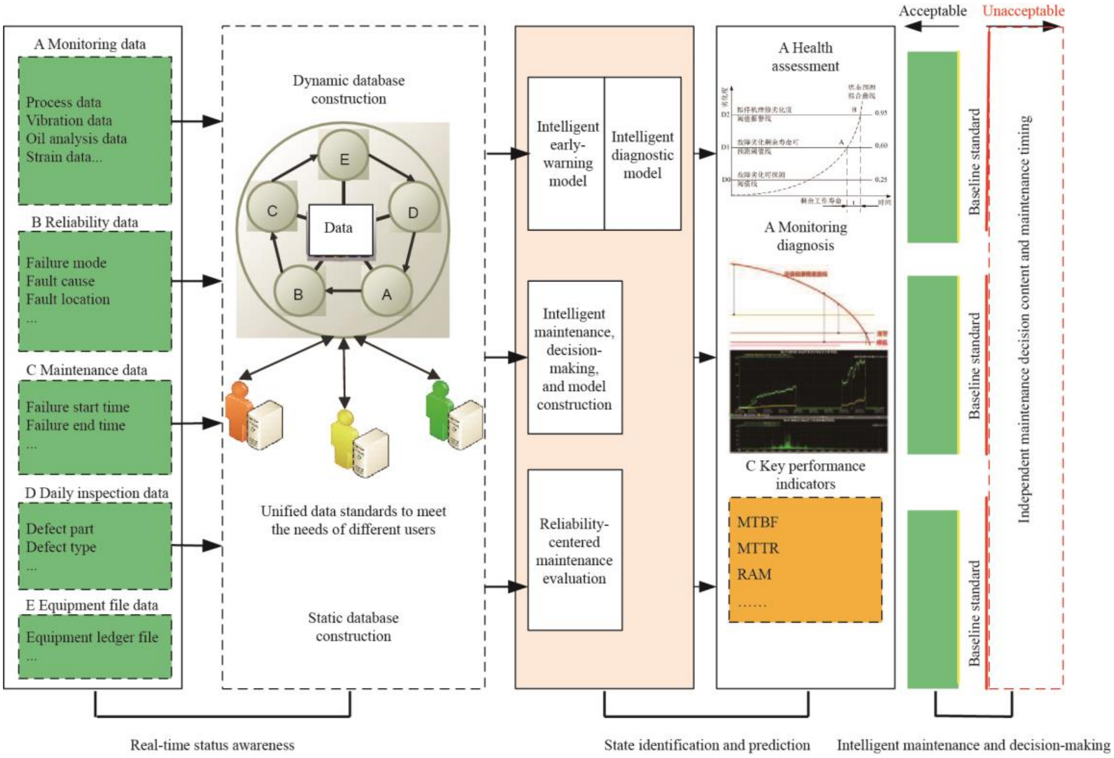

Fig. 2. Schematic for data-driven equipment intelligent maintenance decision framework.

5.1 Determination of objects of intrinsic safety & reliability and supervision intelligentization

The statistical analysis of the reliability and maintenance data shows that the conventional electro-hydraulic control system of the main fan demonstrates a probability of failure on demand (PFD) of 2.5207, while the advanced level control system PFD of the same period is only 0.1. The component for ensuring the main fan's intrinsic safety, reliability, and supervision is determined to be the conventional electro-hydraulic control system of the main fan static leaf adjustable actuator.

5.2 Key factors affecting reliability and personalized redesign

The primary factor affecting the reliability of the main fan operation is the special valve of the conventional electro-hydraulic control system of the adjustable actuator of the main fan that demonstrates the phenomenon of "blocking, jamming, and drifting," and low intelligence. On the basis of the principle of reliability design and fault bionic self-healing, an intelligent electro-hydraulic control system exhibiting self-diagnosis and self-healing characteristics is developed. A multi-target electro-hydraulic control system based on functional compensation is proposed for the fault self-healing regulation. On the basis of the distributed control system/safety instrument system (DCS/SIS) platform, the electro-hydraulic control fault self-healing control system for the stationary blade adjustable actuator of the main fan is developed. Fundamental improvements have been achieved in terms of fault detectability and adaptive regulation of the stationary blade adjustable actuator structure.

5.3 Transformation effect of intrinsically safe and reliable intelligent supervision

In terms of technology, the electro-hydraulic control achieves state awareness, fault detection, static leaf adjustable actuator valve position locking, or running position self-healing regulation.

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In terms of economics, the development cost of the intelligent electro-hydraulic control system with self-healing control function is 1.2 million Yuan, and the expected returns are 30.24 million Yuan based on reduction of one system shutdown each year. The input–output ratio is only 0.039 68.

In terms of service, the PFD of the intelligent electro-hydraulic is only 0.005 864. Online non-stop maintenance has been realized for the system, and the mean time to repair (MTTR) does not exceed 2 h. The design service life can be as long as 3×10^5 hours.

In terms of resources, the intelligent electro-hydraulic control operating power consumption is 0.47 kW, which is better than the best value achieved at the domestic level (12 kW), and the average power consumption and steam consumption per unit of crude oil are reduced by 0.5%.

In terms of environmental protection, the operational reliability of the main fan has been significantly improved, and the total gas and liquid emissions caused by system shutdowns have been reduced by more than an order of magnitude.

6 Conclusions

This article revealed the connotation and characteristics of equipment intrinsic safety and reliability and intelligent supervision. The reliability design/manufacturing, risk management, and monitoring intelligence and informatization are the three key elements for ensuring the intrinsic safety and reliability of equipment.

This article clarified the development trend of the equipment's intrinsic safety, reliability, and intelligent supervision and showed that the development of equipment design and manufacturing tends towards intelligence. The risk management technology can prove to be important for supporting equipment integrity management, and development of equipment monitoring can tend towards intelligence.

This research clarified the challenges faced with regard to intrinsic safety and reliability as well as supervision intelligentization of China's refining and chemical equipment, and it has herein put forward countermeasures and suggestions for addressing these issues.

In the future, technologies such as comprehensive sensing of equipment, early failure early warning, real-time evaluation of operating status, and intelligent maintenance decision systems will guide the development trends for equipment intrinsic safety and reliability as well as supervision intelligentization.

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