Research on Intelligent Construction of Shale Oil Station in Daqing Oilfield

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Abstract. This article takes the Daqing shale oil station as the research object and explores the research direction of intelligentization of shale oil stations. With the continuous development of digital and intelligent technology, oil field production is gradually realizing digital transformation and intelligent upgrade. However, as a new type of station, shale oil production and operation management costs are huge. Therefore, how to use digital and intelligent technology to improve the production efficiency and management level of shale oil stations has become an urgent problem to be solved. This article first analyzes the current production, operation, and management status of the Daqing shale oil station, pointing out the existing problems and challenges. It proposes the direction of intelligent research on the Daqing shale oil station and, for each research direction, it puts forward specific research content and technological routes, which has theoretical and practical significance for promoting the digital transformation and intelligent upgrade of the Daqing shale oil station.

Keywords: Shale oil station; Digital twin; Energy consumption control; Intelligent;

1. Introduction
Daqing Oilfield has learned from the successful experience of digital transformation of outstanding enterprises at home and abroad, and actively and orderly carried out the construction of "Digital Intelligence Daqing Oilfield". Daqing Shale oil block as a ground engineering demonstration area, the initial construction of centralized monitoring, oil and gas production Internet of things construction project, and focus on improving the data collection, automatic regulation, video surveillance and other construction standards. However, how to realize the evolution from digital oil field to smart oil field is still in the research and development stage. Unlike digital oil field, which focuses on data collection and monitoring, smart oil field focuses more on data analysis, understanding and deep mining. This transformation is not only a simple processing of data, but also a transformation from "data" to "knowledge". To assist and guide oil field production decision-making, so as to optimize the traditional process flow, operation mode, personnel management, provide scientific management methods, and realize the leap from static to dynamic, intelligent to wisdom, simple to in-depth, passive to active, so that shale oil blocks can be better managed and operated.

2. The overall idea of intelligent construction of shale oil station
The intelligent development of shale oil fields should take the shale oil business scenario as the starting point of all, closely focus on the production difficulties, pain points and blocking points of shale oil fields, combine the overall needs of Daqing oil and gas field to improve production efficiency, reduce production costs, ensure safe production and improve environmental protection level, and make use of advanced technologies such as the Internet of Things, artificial intelligence, big data and cloud computing. It provides strong technical support for the intelligent development of shale oil blocks. In view of the difficulties of complex geological conditions, high mining costs, high technical difficulty, and high environmental protection pressure in shale oil blocks, as well as the pain points of chaotic data management, multiple safety hazards, difficult equipment maintenance, low production efficiency, and blocked points such as poor information transmission, lack of basis for decision-making, serious waste of resources, and lagging technological innovation, focusing on the production site of shale oil blocks, the following functions are implemented:
1) Digital foundation improvement;
2) Construction of digital twin in stations;
3) Shale oil block production control platform construction;  
4) Shale oil block data construction and management;  
5) Shale oil block data fusion;  
6) Shale oil block energy consumption control;

3. Intelligent exploration of ground engineering

1) Digital foundation improvement:  
a) Reverse plan the data collection content according to the needs of users' business pain points, supplement the on-site automatic collection equipment, realize the full collection of data related to production safety, ensure the integrity of data, meet the needs of different users, and improve the availability of data.  
b) Strengthen the monitoring and maintenance of the oil well, collect the running status of the oil well for real-time monitoring.  
c) Strengthen the construction of video surveillance, add AI intelligent video surveillance, scientifically plan the location and number of monitoring points, and ensure the full coverage of key areas such as personnel entrances and exits, important channels, and key equipment; Secondly, the height and Angle of the monitoring point should be reasonably selected to avoid blind areas and repeated coverage. In addition, factors such as light and occlusions should be considered to ensure that the picture is clearly visible.  
d) Add multi-form joint inspection equipment, and select intelligent equipment such as rail-mounted or wheeled robots and drones according to different scenarios. For example, rail-mounted robots can be selected for inspection in narrow or complex terrain areas; In the wide field area road or seriously blocked places, wheeled robots or drones can be selected for inspection. For the key parts of the plant area, tank area, pipeline and other sites, the joint inspection equipment is used to set inspection tasks. Based on the operating status and leakage events, the detection technology such as optical AI, infrared thermal imaging, intelligent iot perception is used to automatically inspect and generate hidden danger alarms, and gradually realize machine inspection and virtual inspection instead of human inspection to reduce inspection safety risks.  
2) Construction of digital twin in stations  
The shale oil block adopts the forward and reverse modeling method to build the digital twin model of the station and yard. Some of the stations have built the digital twin of the station and yard through the forward digital delivery of related engineering information at various stages of design, procurement and construction, forming the information management mode of the whole life cycle of the station and yard. The three-dimensional modeling of other stations and yards has adopted the reverse ground three-dimensional laser scanning technology. The space structure and equipment information of the existing station and yard are obtained by high-precision 3D scanning. Then, the information is integrated into the station and yard digital twin model to form a complete station and yard digital twin.

3) Shale oil block production control platform construction  
With the help of digital twins, the ground production management and control platform is constructed, and the intelligent management of the station and yard is realized by setting 6 modules, including station and yard visualization, intelligent monitoring and analysis, intelligent auxiliary inspection, intelligent diagnosis and emergency response, intelligent operation and maintenance, and station and yard integrity management.

4) Shale oil block data construction and management  
According to the "six unified" data ecological construction ideas adopted by Daqing Oilfield, that is, unified development of data standards, unified combing of data sources, unified sharing of business data, unified rules of data governance, unified management of data channels, and unified provision of data services, data management of shale oil block development and production, ground engineering, engineering technology, operation management, safety and environmental protection and other data will be carried out into the lake. The tool software of data lake is used to build knowledge graph, transform unstructured data, and realize unified data collection, management and service of the block, providing a solid foundation for the construction of intelligent application of related business.

5) Shale oil block data fusion  
In order to realize data fusion in Daqing oilfield regional lakes, it is necessary to integrate various databases at the model level to form a unified data model of data lakes. This is because different database types and multiple databases have the problem of multi-source heterogeneity, which leads to data dispersion and difficult management and maintenance. Through data fusion, centralized data management can be realized and data utilization efficiency can be improved.

6) Shale oil block energy consumption control  
Provide artificial intelligence model building, data mining, technical analysis and other capabilities through various analysis and optimization of energy consumption control. Based on the consumption of electricity, gas and water, it can realize the functions of energy consumption overview, monitoring and alarm, dynamic evaluation, energy consumption optimization and comprehensive analysis, carry out real-time evaluation and optimization of energy consumption, and realize the comprehensive perception of energy control, deep interconnection, collaborative sharing and intelligent application and the final realization of energy visualization, optimization and intelligence and maximum energy efficiency.

4. System stability analysis

In the study of impedance analysis, the stability of the subsystem needs to be ensured, assuming that the wind farm and the wind side MMC system are in a stable state when operating independently. In the interconnected operation of the system, the stability of wind power flexibility depends on the stability of the transfer function \( G(s) \). Similarly, when the characteristic curve of the ratio of \( \frac{Z_{\text{mc}}(s) + z_L(s)}{Z_{\text{wf}}(s)} \) meets the Nyquist
criterion, the interconnected system can reach a stable state.
Based on the above derivation, the stability analysis method of impedance analysis for interconnected systems is roughly as follows:
(1) Each subsystem runs stably under ideal conditions.
(2) Impedance ratio \( \frac{z_{mwc}(s) + z_L(s)}{Z_{wf}(s)} \) conforms to the Nyquist stability criterion. That is, if \( G(s) \) does not include the right half-plane pole, then the Nyquist curve of the equivalent impedance ratio of the interconnected system does not surround the point \((-1, j0)\), and the interconnected system reaches stability.

Nyquist Figure 1 and Figure 2 of equivalent impedance of wind farm and field-side MMC respectively.
As can be seen from Figure 1, the Nyquist plot has no encircling point \((-1, j0)\) counterclockwise. According to Nyquist criterion, the wind farm system is stable.

According to the above analysis, both the wind farm and the MMC system at the wind farm side are stable, and the interconnection system is used. Figure 3 shows the Nyquist diagram.

As can be seen from Figure 3, the Nyquist diagram of the MMC interconnection system at the wind farm and the wind farm side does not have an enveloping point \((-1, j0)\), so the interconnection system as a whole is stable.
Then, the influence of the output power of different wind fields on the stability of the interconnected system is discussed, and the Nyquist stability criterion is used to judge the interconnected system. First of all, for the interconnection system stability under different wind farm output power, as shown in Figure 4, Figure (a) is a wind farm consisting of 10 doubly-fed asynchronous wind motors with a total capacity of 15MW, each with a 400m interval, one unit connected to each outlet and 10 outlets, and Figure (b) is a wind farm composed of double-fed asynchronous wind motors with a total capacity of 45MW with a distance of 400m and 3 units connected to each outlet line and 10 outlets. As can be seen from the figure, when the output power of the wind farm is 15MW, the interconnected system curve does not surround the point \((-1, j0)\), indicating that the system is stable, and the calculated phase Angle margin is 22.1°. When the output power of the wind farm is 45MW, the passing point of the interconnected system curve \((-1, j0)\) indicates that the system is unstable, and the calculated phase Angle margin is 9.04°.

In order to verify the running stability of the wind-power flexible straightening system discussed above, a time domain model is established on Simulink software for simulation analysis. Figure 4.5 shows the voltage, current and spectrum analysis at PCC point of the interconnected system under 15MW output power. It can be seen from the figure that the overall system is stable. Due to the low
phase margin, the system will contain certain harmonic components and low-frequency fluctuations \[61\], but the overall stability of the output current and voltage has not been affected.

5. Summary

At the heart of a smart oilfield is data analysis and understanding. Through the collection, sorting and analysis of a large amount of data, we can have a deep understanding of the operation status of the oilfield, take specific application scenarios as a breakthrough, fully integrate with business personnel, sort out business requirements, iteratively improve, quickly extract the correlation and law, bring more rapid and accurate solutions for each business link of the oilfield, and find potential problems and opportunities. This in-depth understanding of the data allows us to better predict the future development trend of the oil field and make more scientific and rational decisions.

Secondly, by deeply mining the data, the "data" is transformed into "knowledge". This knowledge can not only help us optimize traditional processes and improve production efficiency, but also provide us with scientific management methods that enable us to better manage and operate our oil fields.

References


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