Smart Transformation Technology for Digitizing T Oilfield

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Abstract: In response to the current situation of T Oilfield being remote, with high total labor demand, dispersed well distribution, and low automation levels, this paper systematically summarizes the digital technologies and application effects in the construction of S operation area. By integrating process optimization, streamlining management levels, and incorporating video and communication technologies, a low-cost digital construction model for T Oilfield is established. During the "14th Five-Year Plan" period, with the goal of reducing construction investment and streamlining management levels, the low-cost digital construction model is applied to adjust the organizational structure of T Oilfield, reduce total labor demand, and achieve cost-effective, digitally lean management.

Keywords: Unmanned operation, Centralized monitoring, Optimization, Operation and maintenance.

1. Overview

The approach to the digitization construction of T Oilfield involves leveraging mature station control construction technology and integrating it into a centralized monitoring model. In the design process of constructing the ST Joint Station, an unmanned design is adopted for each production unit, with minimal personnel in the comprehensive control room implementing monitoring. In this capacity expansion construction, newly built oil-water wells and oil collection and distribution stations are digitally constructed according to the standards of digital construction. The newly constructed ST Joint Station is designed with a centralized monitoring and unmanned operation mode, and the collected data is wirelessly transmitted to the newly built production management center. The centralized control room in the ST Joint Station conducts centralized monitoring. Video surveillance is installed at platform well sites, and the video signals are transmitted wirelessly.

2. Design Concept

To meet production needs, ensure safe and reliable operation, and enhance production management, a PLC control system is employed for centralized monitoring and control of process parameters. The operating station serves as the human-machine interface, utilizing on-site instruments for automated detection and control of the production process. All parameters are fed into the control system for display, alarms, interlocking, recording, and printing. Signals from individual instruments within the station are connected to remote I/O cabinets at the operator's station. Control unit signals are then accessed by the central control room through the station's internal network.

2.1 Establishing the Central Control Room

In this project, a central control room is established in the comprehensive control room, mainly comprising the control room and equipment cabinet room. The central control station is constructed according to the standards for important facilities and electronic computer rooms throughout the entire station. The operation stations and centralized display stations are set up based on the number of acquired I/O points.

2.2 Optimize Internal Processes at the Station

The heating process adopts a phase-change vacuum heating furnace, with the water treatment process for heating water and the pumping method retained. The heating equipment is installed outdoors. The technical advantage of the phase-change heating furnace is that there is no risk of expansion, explosion, or scaling, making it safe and reliable. The equipment is compact, equipped with its own control device, making it convenient for control. It operates without the need for constant supervision, providing more convenient management.

2.3 Remote Control

Equipment, whether self-contained or third-party control devices, should have open communication protocols, including but not limited to: RS485: MODBUS RTU or PROFIBUS DP; MODBUS TCP/IP or DNP3. The specific project's design technical documents should specify the communication method, protocol standards,

and version adopted. Third-party control equipment suppliers should provide a data interface condition table, etc., for the PLC to obtain data in a read-only manner.
When variable frequency drives (VFDs) are used for rotating process equipment, the following signals need to be transmitted to the PLC through hardwiring or communication: frequency control, frequency, equipment power frequency/VFD operation status, VFD operation status, VFD fault alarms, and VFD start. If the original equipment does not have this functionality, cooperation with the manufacturer is required to install it on the original equipment.

2.4 Installation of Video Security System

To establish safety and security for personnel and equipment, the station is equipped with video surveillance and alarms, with a focus on preventing intrusion and monitoring for any signs of leakage.
The entire station is equipped with a network-based video surveillance system, with a total of ** sets of surveillance front-end installations. The dual three joint station's video monitoring images are connected to the comprehensive control room via optical fiber. A new industrial network switch is installed in the room to manage and call up video monitoring images within the jurisdiction, and to store video monitoring images in real-time. In the control room, * sets of new LCD monitors are installed, displaying well and interstitial video images, site video images, video monitoring management images, and perimeter intrusion alarm images. The backend equipment of the perimeter intrusion alarm system is installed in the comprehensive control room's equipment cabinet room and is linked with the industrial television monitoring system. Management personnel can confirm on-site situations based on the monitoring images. The central control uses PLC + remote I/O, and the * production units within the station operate unmanned. Since 2020, the station's production operation has been centrally monitored, and it is currently running smoothly.

3. Unmanned Transformation of Oil Collection and Water Distribution Unit

1) Process instruments adopt wireless communication, while flow instruments use a bus system, making construction simple and valve groups aesthetically pleasing.
2) The control unit uses RTU, leveraging its high integration, small size, easy layout, and support for wireless communication.
3) Data transmission is carried out wirelessly, requiring less investment, facilitating networking, avoiding the difficulties of wired network installation, and addressing the issue of high investment.
This technological approach is implemented in the construction of new valve groups, using a mesh network approach, which has proven effective. It has successfully achieved the unmanned management of ** oil collection and water distribution valve groups and * oil transfer stations. Subsequently, it has been widely promoted in areas such as T.

4. Pumping Unit and Water Injection Well Transformation

Exploring the technological direction of digitizing oil-water wells, the shift to outdoor work environments necessitates comprehensive consideration of instrument explosion-proofing, low-temperature resistance, and data transmission modes. After technical investigations and comparisons, the following approaches are adopted:
1) Pumping wells have an integrated wireless condition acquisition unit for load, displacement, and stroke collection at the wellhead, as well as a wellhead pressure detection unit and current and voltage detection devices.
2) Single-tube single-well injection wells are equipped with a high-pressure flow detection and control device, along with inlet and outlet pressure detection, flow measurement, and regulation. Power can be sourced from the nearby pumping unit platform transformer. In cases where nearby power sources are unavailable, solar power generation devices can be installed.
3) The wellsite's integrated control device, considering comprehensive investment and maintenance needs, uses DTU technology for wireless radio parameter analysis controllers (single well, main well) and intelligent wireless radio parameter analysis control modules (for secondary wells). It employs more compact and intelligent data acquisition technology.
4) Considering the decentralized nature of T Oilfield well sites and the scarcity of mobile base stations in the area, wireless transmission adopts the method of establishing self-built wireless base stations.
After preliminary research and in accordance with relevant national regulations, available technology solutions for meeting the requirements of transmitting video bandwidth over a wide area include self-built LTE, wireless bridges, leasing operator 4G networks, WIAFA technology, and ADSS fiber optic cables.
In compliance with network security regulations, the use of public network 4G for transmitting production data must go through a demilitarized zone (DMZ) for isolation before connecting to the office network. Due to the long transmission path from the data collection equipment to the monitoring terminal, there is a high failure rate, and the number of DMZ points is limited, making expansion difficult. The construction cost of ADSS fiber optic cables is approximately 35,000 RMB/km, and it is costly to deploy them for all wells and sites outside the station. Wireless bridges and WF technology require a line of sight with no obstructions for transmission between two points.

5. Construction of the Technical Application for the Production Management Center

Utilizing IoT (Internet of Things) technology, a system is established to centrally manage and control production data and equipment status information from oil and gas field well areas, measurement stations, oil transfer stations, and joint stations at the production command center and production control center of the oil and gas

production plant. The system comprises data collection and monitoring subsystems, data transmission subsystems, and production management subsystems, collectively forming a large-scale SCADA (Supervisory Control and Data Acquisition) system. It constitutes an information management system that incorporates real-time monitoring of production data, production analysis, safety warnings, operational scheduling, and data management, all built using data processing and data analysis technologies.

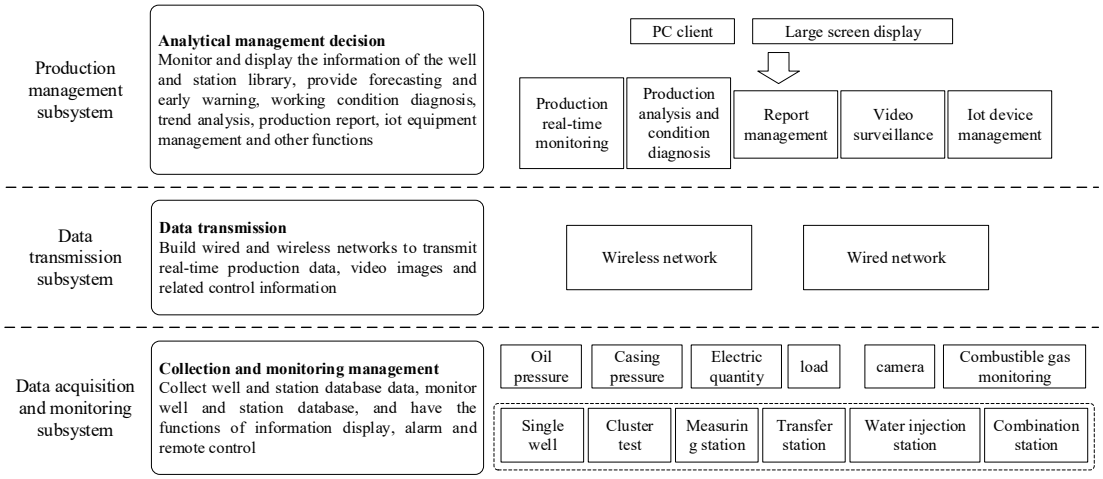

Fig.1 Overall system framework

In the construction of this system, the following main technologies are applied:

(1) Application of Database Technology:

The relational databases of the oil and gas field company's production management subsystem should be built using the databases specified by the headquarters. The dynagraph relational database in the operational area should also be constructed using the databases specified by the headquarters. The database should consider technical reliability, openness, and scalability. The real-time database should support multiple servers and server clusters, as well as multiple CPUs. It should also support a distributed structure and distributed data collection and processing.

The real-time database should adopt a modular structure, making it easy to add new application modules to the real-time database software. Hardware devices should be designed, deployed, and upgraded based on the data volume and user access at each deployment point.

(2) Application of Network Technology:

As the construction of the production IoT progresses, distinct from the internet, the IoT has strict requirements for professionalism and security. Considering the undulating terrain, complex topography, and the area being a flood-prone zone along the river between the ST Joint Station and the production management center, this project uses point-to-point long-distance bridge equipment to achieve data upload.

The straight-line distance between the ST Joint Station and the production management center in the operational area is approximately ** km. The data transmission is achieved through point-to-point wireless communication using 45m communication towers at the Oilfield production management command center and 35m communication towers (constructed simultaneously) to ensure line-of-sight wireless transmission.

(1) Data Transmission:

The production management center receives production and office network data transmitted by the wireless communication system, which is then laid directly through buried optical cables to the equipment cabinet room at the Oilfield production management center. One set of Layer * industrial switches is installed, with two sets of Layer * industrial switches underneath. One is used for transmitting production data, and the other is used for transmitting video data.

(2) Isolation of Production Network and Office Network:

The isolation of the production network and office network uses firewalls and unidirectional isolation gateways, allowing only one-way transmission of production network data to the office network to ensure the security of the production network.

6. Analysis of Application Effects

After applying this construction model, three transformations are achieved: (1) a shift from manual operations to fully automated processing, (2) a transition from intermittent data points to continuous information flow, and (3) a shift from experience management to refined management.

6.1 Application Effects in Implemented Regions

Through the construction in the region, a two-tier digital monitoring architecture has been established, consisting of the work area and operational area. An integrated operational area-level production management center has been created, incorporating regional production anomaly alarms, statistical summaries, and decision-making commands. In the region, data collection for * joint station, * oil transfer stations, and ** measurement stations has transitioned from manual to automatic, with reports generated automatically. The management mode has

shifted from manual periodic inspections to inter-station video inspections, optimizing frontline production staffing by nearly ** people. This has successfully achieved the established goals of centralized monitoring for joint stations and oil transfer stations, as well as unmanned operation for measurement stations and water distribution stations.

6.2 Predicted Application Effects After Promotion

Based on the digital production management model and considering geographical proximity, adjustments and mergers of mining-level production units are made. The entire plant is divided into * production blocks, with each block having one regional production management center, centered around large-scale station areas. Following the transformation, it is expected to dissolve 4 mining-level production units, reducing the total frontline production staff from 2*** people to 1*** people, a decrease of 1*** employees, representing a reduction of 47.5%. This is estimated to result in an annual savings of 158 million yuan in labor resources costs.

Fig.2 Overall Intelligent and unmanned monitoring methods

7. Conclusion

Currently, frontline operational staff is aging, and the availability of labor is becoming increasingly tight. The challenging situation demands the optimization and innovation of traditional management methods. Innovation in management is inseparable from the innovation and use of new technologies. It requires a continuous absorption of advanced design concepts and innovative application of technology. In future designs, the introduction of advanced technology will replace manual daily inspections and operations. Simultaneously, the reduction in operational staff requires higher equipment maintenance demands and greater needs. Therefore, it is imperative to establish a comprehensive maintenance system, intensify efforts in cultivating digital professionals, and effectively ensure the smooth operation of unmanned guarding systems on-site.

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