A gas well inspection automation system based on IoT perception technology

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Abstract. This article analyzes the problems faced by the daily safety inspection and emergency repair of gas shaft operation. Corresponding countermeasures are put forward for each problem faced. These countermeasures are combined into a gas well inspection automation system using mature IoT perception and communication technologies. This system realizes all-round management and control of gas operation site safety. It is of great significance to the intelligent construction of the gas industry.

1. Introduction

The gas pipeline networks are very large in scale at home and abroad, and there are many gas wells among pipeline networks. In recent years, with the construction of urbanization pipeline networks and the comprehensive rollout of coal to gas in rural areas, the gas pipeline network has maintained a rapid growth of about 10% per year. However, in the case of large-scale application of gas pipelines, accidents such as explosions caused by gas pipeline leaks often occur, which seriously endangers public safety, and the safety of gas pipeline networks is particularly important [1]. Gas well inspections are one of the main tasks of gas companies. At present, the main inspection methods of gas companies are manual downholes and manual data recording. There are three problems in the daily inspection of gas wells. First, accidents in limited space operations are frequent, and the government is increasingly strict in managing limited space operations [2]. Second, the frequency of gate inspections is high, and the labor intensity of employees is high [3]. Third, limited space operations are complicated, inefficient, and require a lot of equipment. Therefore, a gas well inspection automation system is urgently needed to replace the manual downhole inspection and solve the main problems faced by the inspection work.

2. System composition

The gas gate inspection system proposed in the text can replace the daily gate inspections manually. The system composition is shown in Figure 1.
The gas gate well inspection automation system consists of an uphole part and a downhole part. The uphole part includes a PC-side software platform, a mobile-side APP software, an in-ground control unit, a communication module, and a power supply device. The downhole part includes an automatic lifting device, a manipulator, a counterweight device, a stereo imaging unit, a gas detection unit, and a rapid processing unit. Patrol unit is carried downhole by automatic lifting device. The system can perform inspection operations automatically or manually. Inspectors on the well can check the inspection status and query the inspection results through the mobile APP. Command center staff can grasp the real-time working status of all inspection devices in the system through the PC-side platform. The front-end device is designed to be explosion-proof as a whole to ensure the safety of site inspection.

3. Machinery
The main body of the system is a mechanical automatic lifting device that can adapt to different sizes of sluice wells, suitable for sluice wells with a caliber of 0-3 meters and a depth of 0-4 meters. The width of the bracket can be adjusted manually, and it has the functions of electric lifting, hovering at any height, and automatic stop before bottoming[4]. The main body of the device is made of aluminum, which can ensure the strength and lower the cost. The weight can be controlled within 20 kg, which has high practicality. The schematic diagram of the automatic lifting device is shown in Figs. 2.

A robot and a counterweight device are installed on the bottom tray of the automatic lifting device. It’s used to realize the lateral movement of the downhole detection device. The end of the manipulator is equipped with a stereo imaging unit, a gas detection unit, a rapid processing unit, and a connection line. The connection line supplies power to each unit, sends control signals, and returns detection information. The counterweight device is on the other side of the manipulator, which can monitor the real-time moment of the manipulator, automatically calculate and move to a position that can maintain balance.
4. Automatic inspection device
The system's automatic patrol device consists of multiple electronic control devices, including front-end hardware and background software. The PC-side software is deployed on the back-end server, and the
command center staff can view the working status and work records of all front-end inspection devices in the jurisdiction through the software. The software can not only receive the inspection information uploaded by the control unit on the well, but also store the information to realize the traceability of the inspection logs of the gate well, and grasp the abnormal conditions at the first time, so that the deployment of personnel and other resources can be performed quickly, providing detailed and accurate information for quick disposition.

The APP software on the mobile phone is used by on-site inspectors, and the inspection progress and inspection results are grasped through the APP. The APP software communicates with the uphole control unit and can view the current status and historical status. The inspection information is displayed in the form of charts, pictures and videos. It realizes the functions of user interactive control, real-time display of multi-dimensional images in the well, video image analysis, and monitoring results display.

The uphole control unit is the center of the front-end inspection device, which can control the device's one-button lift, 360-degree rotation and manipulator extension, start and stop of the gas detection unit and stereo imaging unit, remote operation of the fast processing unit, and control the real-time feedback of the downhole inspection information. It transmits all information to mobile phone APP and background server, and realizes integrated control functions such as sensor data processing and inspection record storage and statistics.

The communication module includes uplink communication and downlink communication of the control unit on the well. Uplink communication with background server uses 4G communication method. Uplink communication with mobile APP uses 802.11n protocol. The communication with the underground detection device adopts USB3.0 wired data transmission mode. Under the premise of low cost, it meets the requirements for the bandwidth and stability of the data transmission link for control instructions, return data and real-time display of the picture in the well [5].

The stereo imaging unit includes two miniature explosion-proof cameras and lighting devices for multi-degree-of-freedom, multi-spectrum, and multi-imaging module adaptive collaborative imaging to achieve multi-dimensional high-quality imaging under complex background conditions in the well and meet real-time video interaction in multiple scenes and image processing analysis requirements. After the two-camera stereo imaging information is returned, it can calculate the depth of field distance of the picture in the background, eliminate dead angles, achieve downhole holographic imaging, and archive it on the server [6].

The gas detection unit is based on laser detection technology, and uses different frequency bands of lasers to pass through different gases to generate corresponding energy attenuation characteristics to achieve the inverse calculation of gas concentration, which can monitor the concentration of methane and hydrogen sulfide [7]. It realizes comprehensive perception of multi-source heterogeneous gas data in limited space. If the gas concentration is detected to exceed the standard, the point of the highest methane concentration can be found by the movement of the robot arm to determine the location of the leak.

The rapid processing unit consists of two parts, one is a marking device, which can accurately mark the leak position with paint, and the other is a valve closing device, which can rotate the valve to open and close the valve.

5. Conclusion
This article is based on the solution to the problems faced in the daily inspection of gas gate shafts, and has many advantages. This system can completely replace the manual downhole inspection, and the operator can complete the routine gate inspection and simple leak treatment on the well, effectively solving the safety issue of personnel downhole. This system makes the inspection work shift from a single on-site inspection to the command center's real-time control of the scene. The system can mark the suspected leak point with the fast processing unit on the manipulator under the well, so that after the valve is closed, the operator can quickly determine the location of the leak point for repair. This system has the function of remotely controlling the valve opening and closing, closing the valve before the personnel goes down for repairs, and the processing is more timely and the operation is safer. The system
has the functions of real-time uploading of inspection data and background recording, which is convenient for the gas company to evaluate the work effectiveness of inspectors, and it can also effectively reduce the workload of inspectors. The system can save manpower and improve work efficiency. At present, manual inspections require at least 3 people, 2 people in the well and 1 person in the well. The system can be operated by 1-2 people.

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