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Research and application of an online safety monitoring system for hydrogen production based on Arduino

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Abstract. Leakage of flammable gases will bring great losses to life and property. For this reason, this article in the Arduino development platform application based on the use of MQ-8 (MQ-8 Fire Scout, Fire Scout UAV) hydrogen sensor for the construction of hardware circuits, and on this basis, the use of Arduino language on the MQ-8 hydrogen sensor for hydrogen production safety situation of real-time monitoring. Thus realising the sound and light alarm for the hydrogen leakage safety event occurred in the high altitude meteorological detection operation place of the meteorological station, so as to remind the main body of hydrogen production and the corresponding users to do the emergency plan in time. While ensuring the safety of hydrogen production, it further improves the safety of high-altitude meteorological monitoring work of meteorological stations.

1 Introduction

In the context of the accelerating development process of the modernisation of high-altitude meteorological detection at meteorological stations in China, the degree of automation and digitisation of different detection operations, such as high-altitude meteorological data monitoring, data acquisition and data integration, has made great progress, and the effectiveness of the high-altitude meteorological detection operations has also been improved. At the same time, this has also prompted the high-altitude meteorological detection data not only in the observation accuracy, observation quality has been greatly improved, but also in the space and time of data monitoring has been further developed and strengthened, for climate forecasting, weather forecasting and artificial weather influence and other operations to provide a powerful data and information to support the smooth implementation of the business. In China's current high-altitude meteorological observation operations, as a key component of meteorological observation, the safe production of hydrogen monitoring and application is crucial [1]. However, due to the existing hydrogen safety monitoring equipment in China's meteorological stations are

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mostly installed and fixed in the hydrogen filling room and production room and other related business places, can not be moved, narrow monitoring range, resulting in the production and use of hydrogen in the process of the existence of a greater safety risk. Hydrogen's reactivity is higher than that of conventional hydrocarbons, and is highly susceptible to detonation-explosion, resulting in more serious consequences, while the conditions for detonation are not easy to form. The lower explosive limit of hydrogen is in the range of 13%-18.3% (by volume), while the upper explosive limit of detonation is 59%, and at less than 13% or more than 59% hydrogen will not explode even in the presence of an ignition source [2]. In comparison, the lower limit of detonation for natural gas and petrol gas is 6.3% and 1.1% respectively. Therefore, the risk of explosion can be effectively reduced by timely monitoring of leakage (As shown in Fig. 1) and effective ventilation. Therefore, the development of a low-cost, easy-to-move, and relatively sensitive portable hydrogen production safety online monitoring system is not only a key technical challenge that needs to be urgently solved for high-altitude meteorological observation stations, but also of great significance for the normal operation of high-altitude weather observation services.

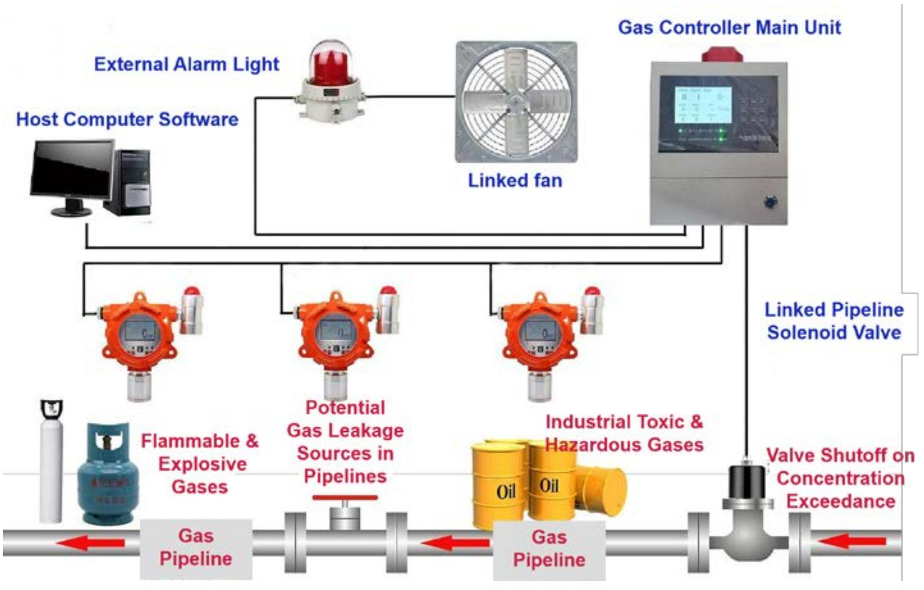

Fig. 1. Example of online hydrogen leak detection alarm installation and testing.

2 Safety risks in hydrogen production processes

Hydrogen is prone to leakage, diffusion, combustion, and explosion during production, storage, and use, and can adversely affect metallic materials. Hydrogen production via water electrolysis mainly includes alkaline electrolysis, PEM (proton exchange membrane), and SOEC (solid oxide electrolysis) technologies. Among these, mature alkaline electrolysis and rapidly advancing PEM are key to scaling green hydrogen production; their systems integrate electrolyzers with auxiliary purification and separation equipment [3]. Currently, large-scale green hydrogen production in China faces challenges such as volatility in renewable power supply and inherent risks in electrolysis systems, which require further resolution [4]. Existing hydrogen storage technologies include organic liquid storage, high-pressure storage, cryogenic liquid storage, and solid-state storage, with high-pressure storage remaining the most widely used.

Although photolytic and electrolytic water splitting are considered ideal green hydrogen production methods, current research focuses primarily on renewable energy integration, optimization, new production technologies, and domestic equipment development. Systematic studies on associated emerging safety risks are insufficient, and related technical research remains limited [5–7]. Therefore, based on the Arduino platform, this project proposes to develop an online safety monitoring system for renewable energy-based hydrogen production, aiming to enhance monitoring effectiveness, ensure process safety and stability, and simultaneously improve production efficiency and quality [8].

3 Design and application of Arduino-based online monitoring system for hydrogen production safety

3.1 System Functional Module Composition

The projects built on the basis of Arduin can include both Arduino and a series of applications that can be run on a PC [9], which can interact with each other through, e.g., Flash, Processing, and MaxMSP. The lead diagram of the Arduino UN0 development board is shown in Fig. 2.

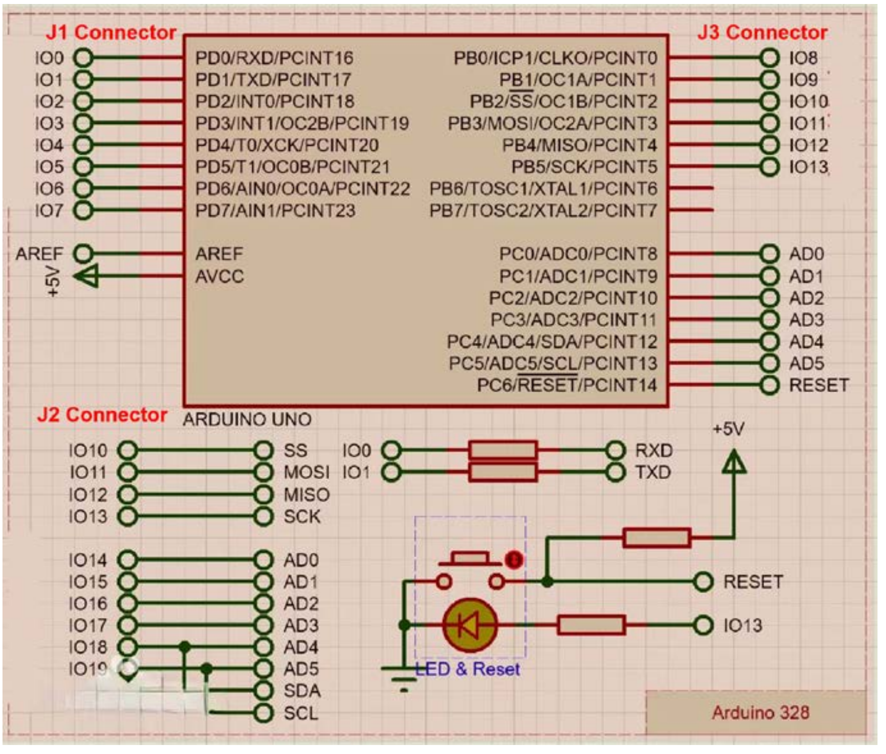

Fig. 2. Lead diagram of Arduino UN0 development board.

Online monitoring system Safety monitoring function module is mainly used for the research and practical application of safety online monitoring system at hydrogen production site, which mainly contains sensors, data acquisition, core analysis, as well as decision-making support, cloud data fusion, human-computer interaction, and data communication module and so on (as shown in Fig. 3).

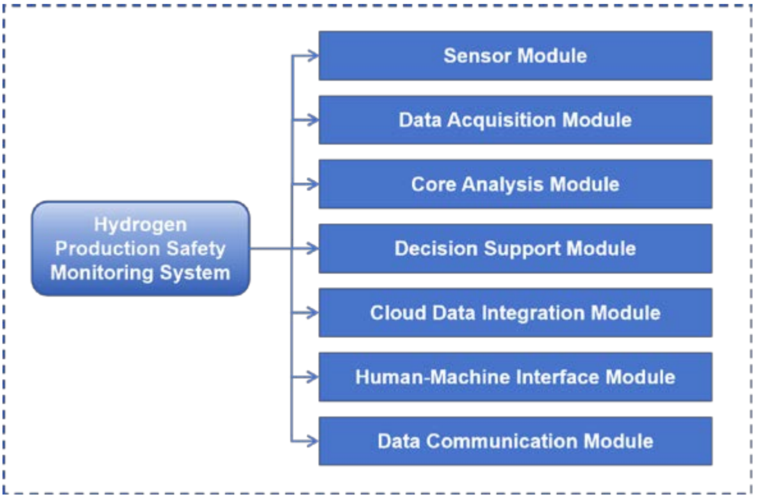

Fig. 3. Example of safety monitoring function module of hydrogen production safety online monitoring system.

The data collection module employs sensors to gather internal hydrogen and production site data, while also transmitting external hydrological, meteorological, geographic, and geological information to the core analysis module. A dedicated meteorological information module automatically acquires reliable weather data from external sources for use in monitoring and processing. The performance of the hydrogen safety monitoring system heavily depends on the sensitivity and range of the hydrogen sensor. The MQ-8 gas sensor, which uses SnO_2 as its sensing material, offers long life, low cost, and a hydrogen detection sensitivity of approximately 0.1‰–1‰, making it the selected sensor for this system. The data processing capability of the microcontroller is critical to system operation. Arduino—an open-source electronics platform based on the AVR core—provides an integrated hardware and software development environment. Users can write control programs to manage signal input and output via the board's pins and interfaces, facilitating external device control. The system utilizes an Arduino UNO R3 development board with an Atmel ATmega328 microprocessor as shown in Fig. 4, chosen for its extensive interface resources and low cost.

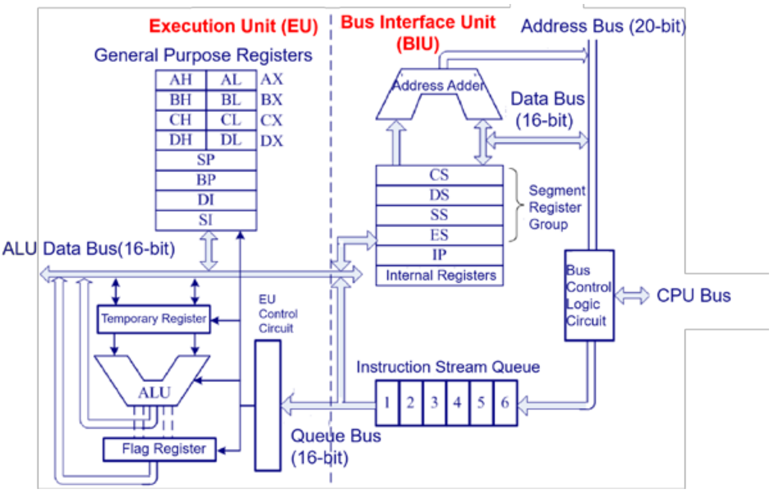

Fig. 4. Example of 32-bit microcomputer principle with AtmelAtmega328 microprocessor.

3.2 Design and Implementation of Hydrogen Production Safety Monitoring System

As the signal analysis and processing, core control components of the hydrogen production safety monitoring system, the Arduino UNO R3 development board is designed with a 16 M crystal oscillator, on-chip programming memory, and start-up-reset. The whole machine is designed with certain self-testing functions; at the same time, in order to facilitate portability and application, the system is mainly connected to the battery and the power connector's GND, VIN pins, in order to provide current support; in the MQ-8 sensor to start the hydrogen production safety on-line monitoring, the analogue signals will be monitored and controlled through the analogue input interface A5 input to the system. And by AtmelAtmega328 micro-processing controller for hydrogen production for the location of the monitoring data for comparison and analysis, if in the detection of clean air in the hydrogen volume concentration has reached a safe critical value, then through the digital output interface D4 to send a low-level signal, D5 and D6 will send a high level signal, so that the system's acoustic and optical warning device to sound a bell and glow. The main circuit block diagram of the system is shown in Fig. 5.

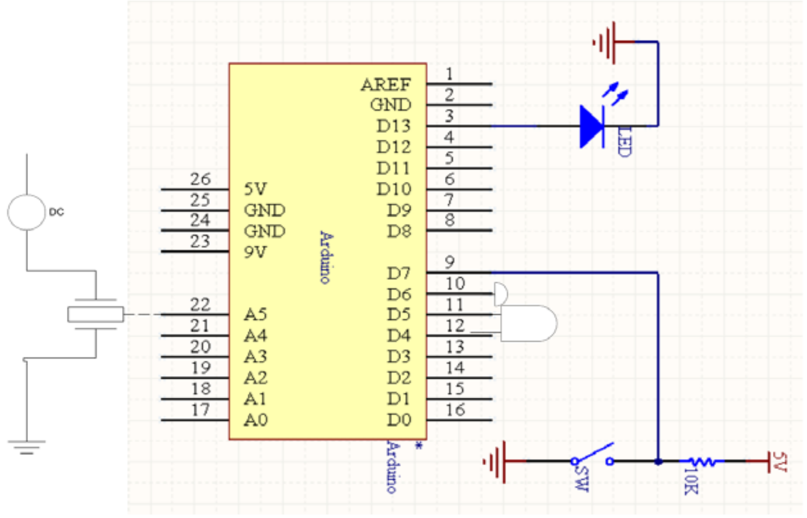

Fig. 5. Example of the main circuit principle architecture of the monitoring system.

3.3 System Application

As shown in Fig. 5, the system design is based on the explosive limits of hydrogen: ignition will cause explosion within volumetric concentrations of 4.0% to 75.6% in air, but not below or above this range [10]. The system uses Arduino to configure digital output ports (D4–D6) and analog input port (A5). The analog signal from the sensor, which varies in conductivity with hydrogen concentration, is converted into concentration data. This value is compared to the explosion threshold to determine control actions.

Using internal and external data, the system computes reliability levels for the hydrogen facility. A failure threshold is set based on acceptable risk. Exceeding this value triggers alerts and assisted decisions from the decision support module; otherwise, normal operating conditions are displayed via the human-machine interface. The system provides real-time feedback and supports managers through multimedia warnings (text, audio, visual) in case of anomalies. User interaction is supported via C-S or B-S architectures, with information presented through integrated diagrams (structural, distribution, tree, etc.) for clear visualization and efficient response.

The decision support module synthesizes operational reliability data, site conditions, adjacent facility features, and external environmental factors (e.g., hydrometeorological and geological conditions) to assist in operational efficiency, failure early warning, accident disposal, and emergency response, providing managers with critical reference information.

4 Conclusion

The Arduino-based online hydrogen safety monitoring platform enables centralized management and real-time monitoring of hydrogen production processes across multiple stations. Using a distributed framework with one dispatch center and 15 collection nodes reduces network and server load. Broadband networks transmit real-time data to central control, allowing rapid response by personnel at all levels. This system enhances the timely detection and handling of hydrogen production issues, ensuring the safety of modern facilities and staff while supporting continuous and efficient meteorological operations.

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