Real-Time Monitoring and Visualization System for POSAFE-Q Using RS-232C

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Keywords : Real-time Monitoring, Posafe-Q, RS-232c, Windows application, *Visualization*

1. Introduction

POSAFE-Q is a safety-grade control system developed in strict adherence to international technical standards. It has received Class 1E (electrical Class 1E) certification, applicable to critical safety systems in nuclear power plants, thus recognizing its outstanding safety performance[1]. However, the possibility of unexpected errors cannot be entirely ruled out in real operational environments. Particularly in high-safety-demanding environments such as nuclear power plants, real-time error detection and rapid response are crucial. Furthermore, real-time diagnostics and visualized information provision are essential elements for enhancing development and maintenance efficiency.

This research aims to present an innovative solution to further enhance the safety of POSAFE-Q, maximize user convenience, and improve practical benefits in both field and development processes. By developing a system that collects diagnostic data from the POSAFE-Q CPU module in real-time and provides the diagnostic data in a visualized format, we aim to enable immediate detection of operational errors and support operators for quickly and accurately understanding system status.

Specifically, this approach can lead to benefits such as reduced debugging time and improved error analysis efficiency during the development phase, as well as enabling preventive maintenance and rapid fault response in the field, thereby increasing system availability and reducing maintenance costs. This real-time diagnostics and visualization system will significantly enhance the safety of POSAFE-Q, maximize operator convenience, and contribute to improved efficiency throughout the development and maintenance lifecycle, ultimately supporting the reliable operation of nuclear power plants.

2. Benefits of Real-time Monitoring and Visualization System

2.1 System Configuration

The Real-time monitoring and Visualization system is composed of a Windows-based application and POSAFE-Q. The Windows application visualizes real-time diagnostic results through its GUI for the user, while data is exchanged between POSAFE-Q and the GUI via serial communication (RS-232C). By connecting to the CPU module (NCPU-2Q) of POSAFE-Q through serial communication and checking the diagnostic registers, real-time monitoring of diagnostic results becomes possible. Fig.1 below shows a simplified configuration diagram of the system.

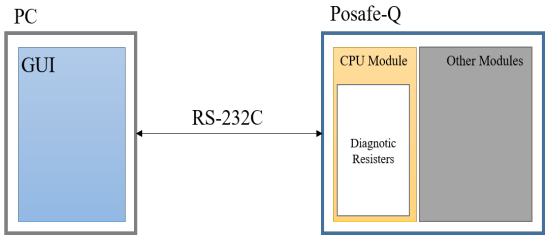

Fig. 1 Real-Time Monitoring and Visualization System Configuration Diagram

2.2 The Necessity of a Real-Time Monitoring and Visualization System for Efficient System Status Diagnosis

The POSAFE-Q NCPU-2Q dual-redundant processor module provides various real-time diagnostic functions to ensure system reliability and safety. These diagnostic functions detect abnormal system conditions and notify users accordingly. POSAFE-Q offers diagnostic registers for various components, including system errors, system warnings, communication modules, application programs, and memory, enabling users to effectively assess the system's status[2].

Manually checking the diagnostic registers in the POSAFE-Q manual, which spans approximately 50 pages, can be highly inefficient for users. To address this issue, the implementation of a Graphical User Interface (GUI) for visualization is required. A GUI-based visualization system allows users to intuitively understand complex diagnostic information, enabling faster and more efficient assessment and management of the system's status.

Figure 2 presents an excerpt from the diagnostic register section of the POSAFE-Q manual, illustrating the inefficiency of searching for diagnostic information through the manual.

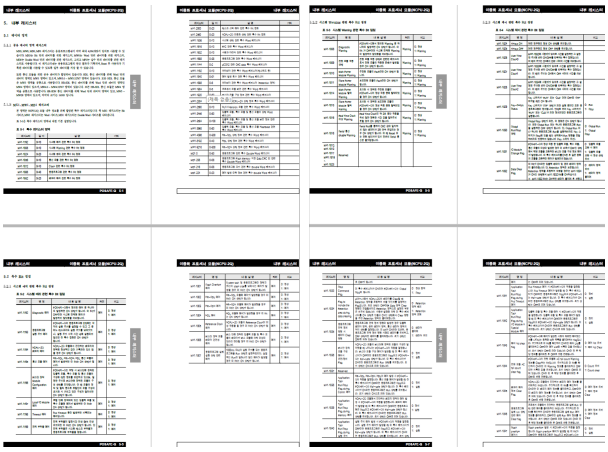

Fig. 2 Excerpt from the diagnostic register section of the POSAFE-Q manual

Visualization through a GUI simplifies the process of analyzing complex data by allowing users to recognize information at a glance. While text-based interfaces have limitations in effectively conveying visual and spatial relationships, graphical elements can efficiently represent concepts such as color, size, and angles, thereby providing a clearer depiction of temporal and spatial information. Additionally, traditional text-based interfaces often require continuous screen transitions, whereas GUI environments enable multi-dimensional information layering within the same interface, maximizing spatial efficiency[3].

From an immediate recognition perspective, GUI-based visual information enhances user comprehension compared to plain text by associating graphical elements with corresponding data. Furthermore, during command execution, users can visually monitor system status and workflow in real time, enabling more intuitive diagnostics and responsive actions.

Therefore, implementing a visualized GUI in the Real-Time Monitoring and Visualization System for POSAFE-Q is essential for efficiently managing extensive diagnostic registers and improving user accessibility. This implementation facilitates more effective system diagnostics, enables faster responses, and ultimately enhances the overall stability and reliability of system operations.

3. Practical Use Cases and Applications

The Real-Time Monitoring and Visualization System currently displays the configuration information of the POSAFE-Q system. The first information provided visually includes the station configuration status, module configuration status per station, and error information for each module (Fig. 3). The station information is presented in a tree structure, showing the number of stations currently configured in the system. By clicking on each node in the tree, the module configuration information for the corresponding station can be accessed (Fig. 4).

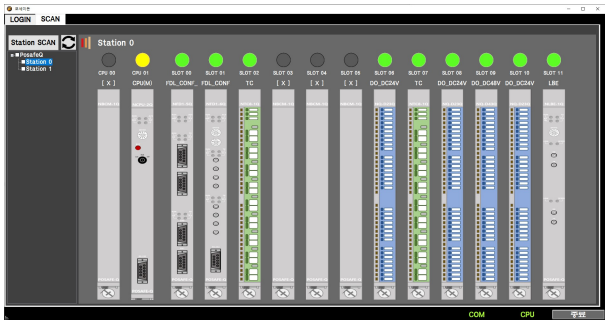

Fig. 3 Station 0 Configuration Information

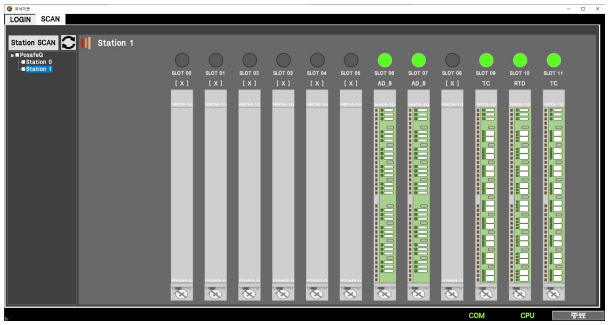

Fig. 4 Configuration Information Other Than Station 0

The module configuration information and error details per module can be monitored and diagnosed in real time. When module configuration errors or other errors occur, the color of the indicator is changed (Green -> Red), providing immediate visual feedback. Fig. 5 demonstrates how the real-time diagnostic information changes when a configuration error occurs in the state shown in Fig. 3.

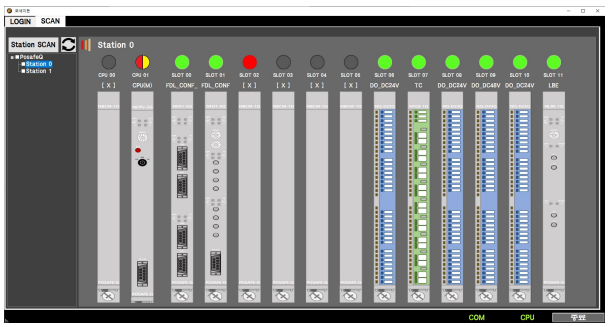

Fig. 5 Example of Error Occurrence Status

Fig. 6 displays a popup window that allows users to view detailed error information when an error occurs. The diagnostic register is automatically scanned, presenting a list of the errors that have occurred. This feature enables users to easily access the error list without the need to manually search through the manual.

Fig. 6 Detailed Error Report Screen

Fig. 7 illustrates how users can effortlessly check the diagnostic results by scanning the diagnostic register for each module, eliminating the need to search through the manual for the information.

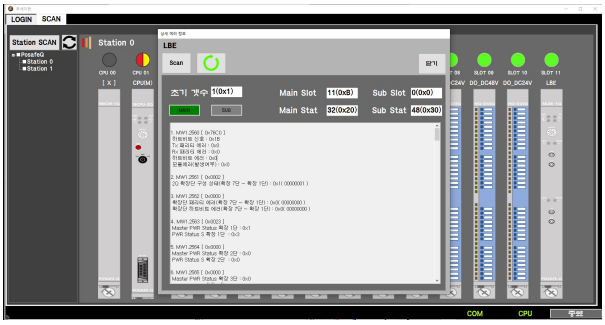

Fig. 7 Diagnostic Register Details

4. Conclusions

This paper presents a real-time monitoring and visualization system for the POSAFE-Q system, utilizing a Windows-based application to provide an intuitive user interface for monitoring and diagnosing system status. The system exchanges data between POSAFE-Q and the application via serial communication, allowing real-time monitoring of diagnostic results by accessing diagnostic registers from the CPU module (NCPU-2Q).

The necessity of a real-time monitoring and visualization System was emphasized, highlighting how the use of a Graphical User Interface (GUI) is crucial for quickly interpreting complex diagnostic data. The real-time monitoring and visualization System provides real-time information on station and module configurations and error detection, improving user efficiency and accessibility. Visual cues, such as color changes (e.g., Green -> Red), provide immediate feedback on system status, enabling users to quickly identify and respond to issues.

Practical applications of the system were demonstrated, showing how it simplifies error detection, reduces the time spent on manual checks, and enhances the overall user experience. The integration of a GUI for visualization not only increases operational efficiency but also ensures faster response times and greater overall system reliability.

In conclusion, the real-time monitoring and visualization system for POSAFE-Q significantly enhances system management in terms of real-time diagnostics, accessibility, and user interaction, contributing to improvements in system performance and reliability.

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