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COMMUNICATION SOLUTIONS IN THE GAS AND OIL INDUSTRY

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ABSTRACT

This paper presents the design and implementation of an automated permeability measurement system for use in the oil and gas industry under extreme laboratory conditions—specifically high pressure (up to 2000 bar) and high temperature (up to 300 °C). The system consists of three measurement nodes, each controlled by a dedicated PLC unit, enabling fully automated operation without human intervention.
A central PC communicates with the PLCs via the Modbus protocol, allowing operators to monitor and control the system remotely using a custom C# interface. The system also includes a web-based telemetry module with GPRS connectivity, supporting real-time data transmission and remote configuration.
Experimental results confirm that the system is reliable, robust, and suitable for industrial applications where safety and automation are critical. The collected measurement data can be exported for further analysis and reporting.

Keywords: Permeability measurement, Automation, PLC, Remote monitoring, Modbus communication, Oil and gas industry

1. INTRODUCTION

The continuous demand for fossil fuels has led to increasingly deep drilling operations in the oil and gas industry. As drilling depths increase, laboratory equipment must simulate more extreme conditions, including pressures reaching up to 2000 bar and temperatures as high as 300 °C. Conducting reliable measurements under such conditions is essential for optimizing extraction techniques, ensuring equipment safety, and validating geophysical models.
Traditional laboratory approaches are no longer sufficient in these scenarios due to the extreme parameters and hazardous materials involved—such as hydrogen or mercury—which pose significant risks to human operators. As a result, there is a growing need for intelligent, automated systems that can perform complex tasks without direct human intervention while still delivering accurate, high-resolution data.
To address these challenges, this paper presents the design and development of an automated permeability measurement system, specifically intended for oil and gas applications under realistic high-pressure and high-temperature conditions. The system consists of three independent measurement nodes, each controlled by an individual Programmable Logic Controller (PLC). These nodes operate in coordination with a centralized control interface developed in C# using the .NET Framework, enabling both local and remote management via Modbus communication protocols.
Furthermore, the system is equipped with a web-based telemetry unit using GPRS technology to allow for real-time remote monitoring, system configuration, and automated alerts in case of failures or abnormal measurements. The integration of such technologies provides a scalable, safe, and reliable solution for modern industrial measurement requirements.
The remainder of this paper is structured as follows: Section 2 discusses the importance and challenges of communication in industrial systems. Section 3 provides an overview of related work. Section 4 presents the system architecture and components. Section 5 discusses the experimental validation and results, followed by conclusions in Section 6.

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2. THE NEED OF COMMUNICATION SOLUTIONS

In complex industrial environments, communication infrastructure plays a central role in ensuring reliability, efficiency, and safety. The ability to control and monitor equipment remotely is not merely a convenience—it is a necessity, particularly when operations involve dangerous materials, extreme environmental conditions, or inaccessible locations.

In the context of oil and gas production, real-time communication is critical for several reasons:

1. Safety: Monitoring and controlling equipment remotely reduces the need for human presence in hazardous zones. This is especially important when dealing with toxic or flammable substances such as hydrogen or mercury.
2. Precision and repeatability: Automated systems require constant feedback to adjust parameters and maintain measurement accuracy. Communication channels ensure that control signals and sensor data are exchanged without delay or distortion.
3. Operational efficiency: With multiple devices or subsystems working in parallel, clear and synchronized communication enables smooth coordination and prevents system conflicts or bottlenecks.
4. Scalability: Communication systems allow for expansion and integration with other industrial infrastructure, including SCADA systems, remote servers, and cloud-based data storage.

However, implementing effective communication in such environments is far from trivial. Harsh conditions can affect signal integrity, equipment compatibility varies, and some controllers (like certain PLCs) have limited support for standard communication protocols. This demands customized, robust communication architectures that combine established protocols (e.g., Modbus RTU) with fallback options such as no-protocol or proprietary solutions.

The system described in this study reflects these needs. It features a hybrid communication design: Modbus protocol for local communication between the PC and PLCs, and GPRS-based telemetry for remote data access. This dual-layered approach ensures both real-time interaction and long-distance supervision, forming the backbone of an intelligent and autonomous measurement platform tailored for the oil and gas industry.

3. RELATED WORK

Information technology has significantly contributed to improving automation in various industrial fields [1, 6]. One of these contributions is the provision of direct communication links for controlling complex systems, especially in environments where human intervention is limited or unsafe, such as manufacturing and oil production [2, 5].

With the advancement of automation technologies, solutions such as Programmable Logic Controllers (PLCs) have been integrated into industrial systems to provide precise, real-time control over various equipment [3]. These devices are capable of operating machines and processes through standardized communication protocols.

PLCs have been implemented across a wide range of applications, including coffee makers [9], liquid level control systems [10], and solar power plants [7]. In oil and gas-related projects, PLCs have shown reliability and robustness in managing Gas Hydrates systems [8] and supporting wireless communication in oil and gas wells [4].

This study builds upon those foundations by contributing a specialized hardware and software system for permeability measurement under extreme conditions in the oil and gas industry. The developed system uses three separate PLC-controlled nodes, each responsible for operating a measurement unit. These units perform

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automated measurements at high pressure and high temperature, making manual control impossible. The solution ensures both reliability and safety through remote monitoring and control.

4. SYSTEM COMPONENTS

4.1. Omron PLC Units

The system was developed specifically for permeability measurements under extreme conditions (high pressure and high temperature) in the oil and gas industry. It comprises three measurement nodes, each independently controlled by a Programmable Logic Controller (PLC). The entire system is designed to operate autonomously and can be remotely monitored and configured.

4.2. C# Software Interface

Each measurement unit is controlled by an OMRON PLC. These PLCs receive signals from sensors and actuators associated with the measurement hardware. Through a custom-developed software interface, operators can monitor sensor data and send commands to the PLCs to initiate or stop specific actions.

4.3. Local communication Setup

The local communication between the central computer and each Programmable Logic Controller (PLC) enables remote operation of the equipment. To establish this communication, an RS-232C or RS-422A/485 Option Board can be used with the OMRON CP1L CPU Unit. This configuration allows the PLC to function as a Modbus-RTU Master, sending commands via Modbus-RTU by adjusting software switches. Through this setup, Modbus-compliant slave devices can be easily controlled over serial communication.
However, the OMRON CP1L CPU Unit does not support operation as a Modbus Slave. In cases where multiple devices must connect to the computer simultaneously, a master-slave communication model becomes essential—where the PC acts as the master and each PLC as a slave.
Since the PLC cannot act as a Modbus slave by default, an alternative communication method is required. To overcome this limitation, a custom no-protocol communication solution is implemented. This method enables unidirectional data transfer to or from standard devices without employing any formal communication protocol.

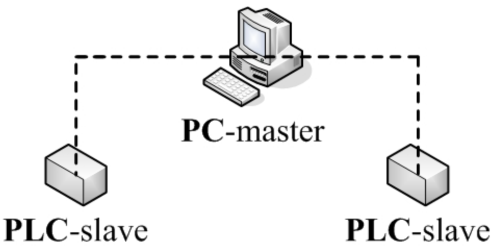

Figure 1: Communication

No-protocol communication allows for sending and receiving raw data without protocol overhead. It omits retry mechanisms, data type conversions, or conditional branching based on received data. This simplicity ensures quick and lightweight data exchange, which is especially valuable in real-time control scenarios. The use of this method provides flexibility in scenarios where standard protocol support is limited or unnecessary.

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4.4. Remote Communication

To extend functionality beyond local access, the system is equipped with a web-based telemetry solution that allows for remote monitoring and configuration. This unit uses a built-in GPRS modem to maintain continuous communication with a central server, enabling several key features.

One of the most important functions is real-time monitoring of the measurement system's status. The device periodically transmits measurement data collected from various sensors and transmitters to the central server. In addition, it can send notifications regarding changes in operational status, such as system startup, shutdown, errors, or communication disruptions.

A second critical function is remote configuration management. Upon each startup, the system downloads its configuration data from the server. This configuration includes key operational parameters, such as the frequency of data transmission and the destination phone numbers for security alerts. For example, in the event of unauthorized access or unexpected startup, the system can send SMS notifications to designated contacts immediately.

This telemetry functionality significantly enhances the safety, security, and responsiveness of the system. It allows operators to intervene promptly, even from a remote location, and ensures that the measurement units operate under strict, pre-approved conditions.

5. RESULTS AND DISCUSSION

To validate the effectiveness of the developed system, multiple test sessions were conducted under laboratory conditions simulating the high-pressure and high-temperature environment typical in oil and gas operations. These sessions focused on evaluating the automated measurement process and the ability of the system to be monitored and controlled remotely.

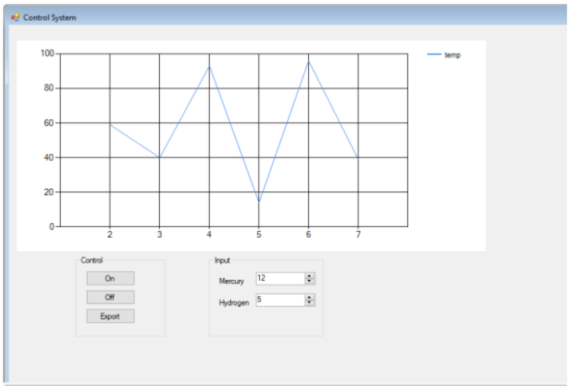

Figure 2. The control interface of the system

The experimental setup involved three permeability measurement units, each governed by its own PLC node. Through the user interface developed in C#, operators were able to monitor real-time sensor data, configure measurement parameters, and execute control commands remotely. Communication was established using the Modbus protocol, which ensured reliable data exchange between the central PC and the three PLCs.

During testing, parameters such as hydrogen and mercury levels were automatically regulated by the system. Operators were able to adjust inputs, monitor ongoing processes, and collect measurement data without manual intervention. This data could then be exported in readable formats for further analysis and reporting.

The results demonstrated the robustness and reliability of the communication infrastructure. The remote control capability via the GPRS-based telemetry system allowed continuous status updates and immediate notifications, which proved valuable for monitoring safety-critical conditions.

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Overall, the system performed as expected, validating its functionality and suitability for high-demand industrial environments.

6. CONCLUSIONS

This paper presented the design and implementation of an automated measurement system for permeability testing in the oil and gas industry. The system successfully integrates three PLC-controlled nodes and enables both local and remote control through Modbus communication.

The automated nature of the system eliminates the need for manual adjustments, making it ideal for hazardous or hard-to-reach environments where extreme pressure and temperature exist. The graphical interface developed in C# provides a user-friendly platform for data visualization, configuration, and control. Moreover, the addition of a web-based telemetry unit extends the system's capabilities by allowing secure remote monitoring and real-time notifications. The flexibility and scalability of the system make it suitable for various industrial scenarios where reliability, safety, and precise data acquisition are essential.

Experimental results confirm that the system is capable of performing continuous, unattended measurements, while also offering an effective remote control and monitoring solution for field applications.

7. ACKNOWLEDGEMENTS

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