Jurnal Teknologi dan Manajemen

ISSN (Print) 1693-2285 ISSN (Online) 2808-9995

Research Article

Design and Development of a Pipeline Maintenance System for Pipe Surge and Water Hammer Equipment Based on Siemens S7-1200 PLC

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ARTICLE INFO

Received : 07 June 2024
Accepted : 29 August 2024
Published : 30 August 2024

KEYWORDS

Water Hammer, Pipe Surge, PLC, Pipe Monitoring System

KORESPONDENSI

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A B T R A C T

Fluids play a crucial role in the lives of living beings, as they are substances that can flow. In a piping system, a common issue is water pressure fluctuation caused by sudden closures of water flow (Idul, 2021). Pipe surge and water hammer equipment are utilized to demonstrate the transient pressure effect resulting from abrupt changes in flow velocity within pipes (David, 1981). Water hammer can lead to pressure surges throughout the piping system, potentially causing failures that result in leaks in pipes, valves, pipe joints, and even pumps if the pressure exceeds the pipe's capacity (Prasetya, 2016). The likelihood of pipe ruptures or leaks at joints increases significantly. Additionally, equipment movement, slope, and precision of pipe installation can also contribute to leaks during water hammer events.

This research aims to develop a pipe leakage monitoring system to address the impact of water hammer. The system will be installed in areas deemed susceptible to this phenomenon, along with a periodic maintenance indicator system to minimize the impact of pipe leaks. The research will also investigate the potential risks associated with varying fluid flow rates in the piping system. The monitoring, indicator, and sensor systems will be integrated into a PLC and HMI system for data processing.

The research concludes that the implementation of a piping maintenance system for pipe surge and water hammer equipment, based on the SIEMENS S7-1200 PLC, operates as intended. The system can detect leaks using a raindrop sensor. Real-time pipe leak data can be utilized to guide periodic maintenance. These findings have potential applications in the industry, such as a pipe leak monitoring tool, or for use in student practicums as case studies.

INTRODUCTION

Piping systems are designed to transport fluids from storage tanks or other sources to various equipment that require them (Firmansyah, 2022). In a water supply system, not all of the water reaches the consumer. Leaks often occur along the way, resulting in water loss. These leaks typically originate from the system itself, such as broken pipes, faulty valves, or other disruptions, hindering fluid distribution (I Wayan Diaasa, 2019). A common issue in piping systems is water pressure fluctuation caused by sudden closures of water flow, commonly referred to as water hammer (Idul, 2021).

In 2017, authors Anton Kornilov, Sergey Y. Yurish, and Pavel V. Nikitin discussed water leakage sensors in their article titled "Water Leakage Monitoring System Based on Wireless Sensing Nodes." The article was published in the journal "Sensors and Actuators A: Physical" in volume 266 in 2017. In this article, the authors discuss the development of a water leakage monitoring system based on wireless sensors. They describe the use of wireless sensor nodes consisting of a water leakage sensor and wireless communication to detect and track water leaks in piping systems. This system can provide early warning of water leaks, which can prevent further damage and potential water waste (Anton Kornilov, 2017).

In light of the aforementioned, numerous studies have been conducted to investigate the effects and phenomena of water hammer using various methodologies. The Department of Chemical Engineering Technology at the Polytechnic of Industrial Petrochemicals Banten has a testing apparatus called "pipe surge and water hammer" to examine fluid fluctuations within pipes. This device has experienced frequent leaks in pipe joints or other hard-to-detect locations due to frequent relocations, dismantling and reassembly, and the unevenness of the installation site. The lack of regular maintenance and repairs at leak sites has rendered the device unusable, hindering water hammer testing by students during laboratory exercises.

One significant advancement in sensor technology is the use of mechanical sensors, which monitor variations in amplitude and frequency of vibrations used for detecting water droplets. This method is complemented by acoustic sensors that detect the sound produced by water droplets using electret microphones, offering a dual approach to rain detection (K.Choi, 2014). Additionally, recent developments have introduced electronic water detection sensors, such as the Arduino-based raindrop sensor module, which converts the mechanical energy of raindrops into sound vibrations, thus indicating the presence of rain (Hendry, 2023).

Based on the above description, the researcher will employ an experimental method referencing pipe leakage maintenance systems, considering aspects that require further investigation. The researcher will develop a design to monitor pipe leakage conditions caused by water hammer and other factors. This will be achieved by installing a leakage sensor on areas deemed susceptible to these phenomena. Additionally, a periodic maintenance indicator system will be implemented to minimize the impact of pipe leaks. The research will also examine the potential risks associated with varying fluid flow rates in pipes. The monitoring, indicator, and sensor systems will be integrated into a PLC and HMI system for data processing.

METHOD

This research will employ an experimental method and will be conducted entirely in the Automation and Digitalization Laboratory of the Banten Polytechnic of Petrochemical Industry. The laboratory is already equipped with a mini-plant scale equipment in the form of a pipe surge and water hammer, so that additional equipment that will later support this research is expected not to interfere too much with the existing system on the pipe surge and water hammer equipment. In carrying out the research, it follows the product development process, where the process begins with planning, developing a development concept, design, and simulation. Furthermore, experimental testing is carried out to determine and establish the results of the prototype design which is analyzed based on output or real-time.

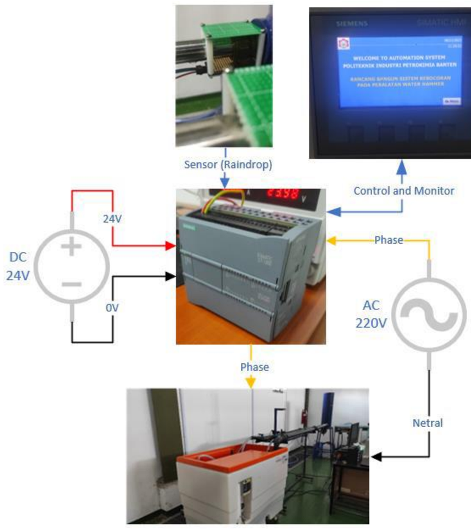

Fig. 1. Overall System Design

The stages of the research carried out refer to Figure 1, with the initial stage being a literature review focused on the extent to which technology is related to maintenance and monitoring systems when water hammer occurs. The second stage is mapping areas that are potentially affected by the water hammer phenomenon. This is done through direct visualization of the research object by activating the experimental tool until the leak point is fully detected.

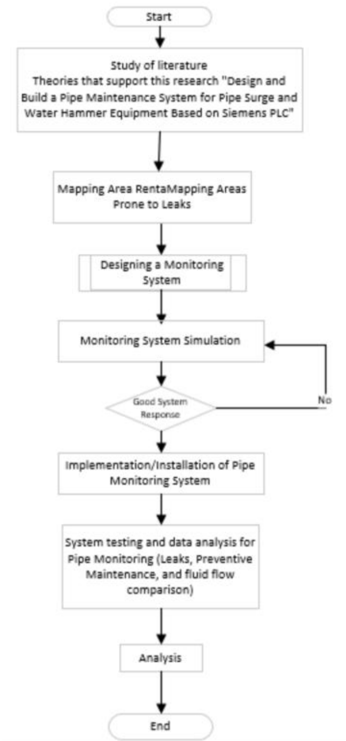

Fig. 2. Research Methodology

The third stage is designing a pipe leak monitoring system as in Figure 2 and adding a periodic maintenance indicator system to the software, starting from PLC programming to HMI design. This is expected to minimize the wider impact before a pipe leak occurs. After the design is complete, the fourth stage is a full system simulation by activating the

DOI: 10.52330/jtm.v22i2.279

tool under normal conditions until the sensor detects a leak in the pipe. When a leak is detected by the sensor, the sensor system will send a signal to the PLC to put the system on standby, and the HMI will display error data and notify of a leak in the pipe. This test will later be a reference for carrying out preventive maintenance.

The fourth stage is data processing based on test results to identify variables and parameters that affect system failure, followed by analysis to draw conclusions from the research findings.

RESULT AND DISCUSSION

This research aims to develop a novel control system for detecting and protecting against water hammer-induced pipe leaks. The initial phase involves simulating a simple water hammer scenario, observing the resulting leakage impact, installing leak sensors at pipe joints, and conducting experiments using a PLC and HMI to detect leaks and implement real-time protection based on sensor outputs.

1. Simple Water Hammer Simulation on a Pipe System

This initial step involves simulating a simplified water hammer scenario on a test pipe rig using the provided software (Figure 3). The objective is to characterize the behavior of the pipe system under water hammer events and establish baseline parameters for leak detection and protection algorithms.

Fig. 3. Pipe Surge and water hammer devices

2. Monitoring the impact of pipe leaks.

In this steps, a trial is carried out to activate the pipe surge and water hammer lines to determine pipe leaks in the water hammer lines. In Figure 4. Monitoring results showed that several pipe connection lines had leaks, such as at the joints of the water tower pipes, the middle pipe connections, and the water hammer pipe connections. This leak will later be used as a reference in system testing.

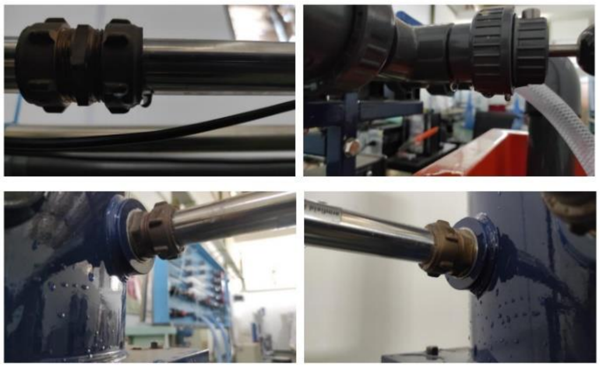

Fig. 4. Pipe Leaks in water hammer equipment

3. Sensor installation on leakage path

In this stage, a raindrop sensor is installed by referring to the pipe leakage path on the pipe surge and water hammer line, with the sensor input directly connected to the PLC. This sensor is made of FR-04 PCB board material with dimensions of 5cm x 4cm, nickel-plated, and of high quality on both sides. The module layer has anti-oxidation properties, making it resistant to corrosion (Figure 5.).

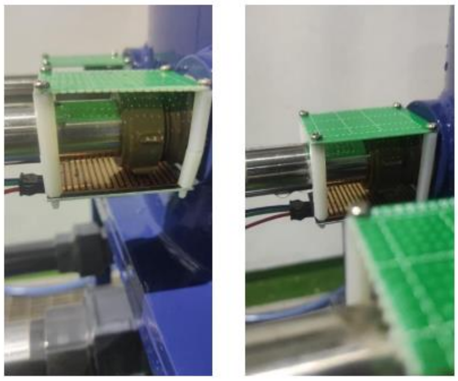

Fig. 5. Installation of raindrop sensors

4. Panel installation and software

The design of the electrical installation is a crucial factor in ensuring the smooth implementation of hardware and software. With proper design, the electronic system can operate optimally and efficiently. This stage involves the design and implementation related to the installation on the main panel and software (PLC & HMI Programs). The equipment used in Figure 7 includes:

a. Siemens S7-1200 PLC, CPU 1214C, DC/DC/Rly
b. Siemens Simatic KTP400 Basic HMI
c. Digital MDB 60V Power Supply
d. 4A MCB
e. Alarm

The electrical installation design, covering the power source, input, and output, has been meticulously planned to ensure the seamless integration of hardware and software. The following diagram shows the installation path used in the system design (Figure 6).

Fig 6. Electrical Installation Circuit

To create PLC and HMI programs, use TIA Portal version 16 software because the Siemens KTP400 Basic HMI has been installed to use the TIA software, so the PLC program needs to be adjusted (Figure 7).

Fig. 7. HMI and Implementation System

Based on the overall system evaluation, the result is that this system is effectively used to detect pipe leaks in water hammer equipment. This system works by monitoring pipe points that experience leaks and uses 5 sensors. When the pipe experiences a leak and the water coming out of the pipe connector touches the raindrop sensor, the alarm will be active and the leak point symbol on the HMI will show the location of the leaking pipe. Figure 8 is a simple program to start-stop the system.

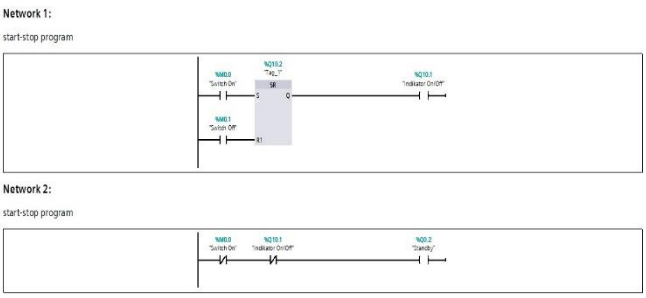

Fig. 8. Start-Stop Program

This system is also used to temporarily stop the water hammer equipment if a pipe leak occurs. The system will resume operation once the issue is fixed, and the equipment can be reactivated by pressing the ON symbol/button on the HMI. This system does not use a contactor to activate the water hammer equipment because the PLC device already supports a relay system that can be used to control the water hammer's electrical components. Figure 9 shows the main program of the system, as well as the program to turn the main pipe surge and water hammer equipment on and off.

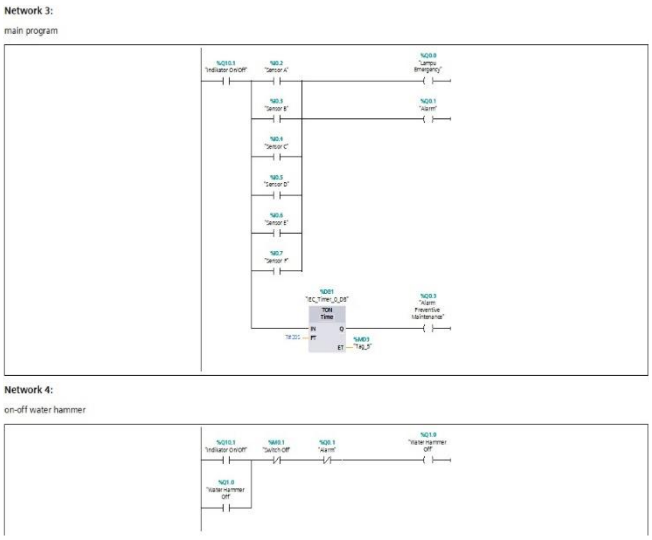

Fig. 9. Main Program

The system created can also monitor leak conditions in real time by storing pipe leak data and also providing warnings for periodic maintenance, so it is hoped that water hammer performance measurements can be seen from the system test results.

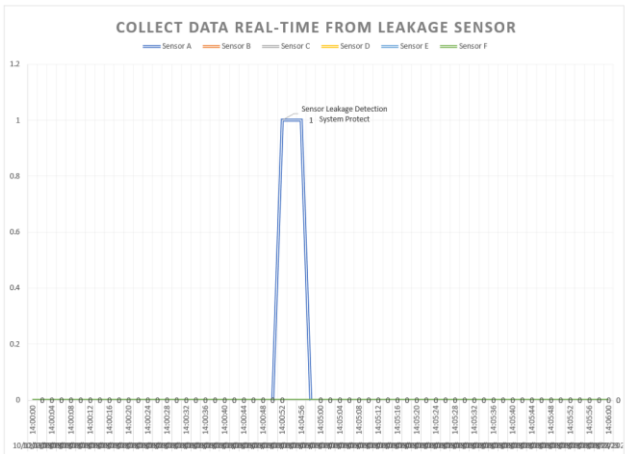

Fig. 10. Quantitative data from experiments

The frequency of leaks detected by the system can be seen in Figure 10. This figure illustrates the process that occurs when there is no leak, the time the leak occurs and its handling, until the system returns to normal operation. The

 DOI: 10.52330/jtm.v22i2.279

designed system has a digital output, which means there are only two conditions: the system is operating normally with logic 0, and standby with logic 1. The standby condition functions as an indicator of repair in the piping system; the system will temporarily shut down until the repair process is complete. In this study, the researcher needed about 4 minutes for repairs until the system returned to normal conditions.

This study is not without limitations, especially related to the diameter of the pipe and pipe connections, which must not exceed 4 inches. This limitation is caused by the relatively simple sensor support mount and has the potential to come off if the pipe diameter exceeds the recommended size. The developed system can of course be applied in industrial settings with a special design that is adjusted to the shape of a particular pipe, ensuring that the sensor used can meet the required needs.

CONCLUSION

The results of the study can be concluded that the implementation of a piping maintenance system for pipe surge and water hammer equipment based on the SIEMENS S7-1200 PLC can operate according to the research objectives, namely the ability to detect leaks using a raindrop sensor. Real-time data on pipe leaks can be used as a guide for regular maintenance. Various types of water detection sensors can actually be used in pipe leak maintenance, one example being sensors that use copper, which can act as a conductive material when exposed to water. The development of this research can also be further enhanced towards IoT to remotely monitor piping systems experiencing leaks by utilizing digital or analog signals input to the PLC. The results of this study can also be implemented in the industry as a cost-effective pipe leak monitoring tool because the sensors used are widely available on the market, making it suitable for use in student practicum case studies.

REFERENCES

Conference Proceedings

Anton Kornilov, S. y. (2017). Water leakage monitoring system based on wireless sensing nodes. Sensors and actuators A:Physical, 266.

Bagi Guru-Guru SMK (pp. 1-24). Yogyakarta: Universitas Negeri Yogyakarta.

Bochari, J. N. (2020). Fenomena Palu Air (Water hammer) Menggunakan Pendekatan Model FIsik. (pp. 1-11). Riau: Universitas Riau.

D, S. (1981). Pipeline Design for Water Engineers. Developments in water science, 53-87.

David, S. (1981). Pipe Line Design for Water Engineers. Developments in Water Science, 53-87.

Firmansyah, H. (2022). Perawatan Sistem Perpipaan. Bandung: Prodi Mesin, Universitas Pasundan.

Hatmojo, Y. I. (2015). Programmable Logic Controller. In Y. I. Hatmojo, Pelatihan Mekatronika.

Hendry, C. R. (2023). Perancangan Prototipe Rain Drop Sensor Berbasis Arduino Uno. Bulletin of Computer Science Research, 315-318.

I Wayan Diaasa, I. K. (2019). ANALISA KEHILANGAN AIR (NON REVENUED WATER) PADA JARINGAN SISTEM PENYEDIAAN AIR MINUM (SPAM). Gradien, 1-19.

Idul, L. K. (2021). Pengujian Water hammer Pada Berbagai Tekanan Hidrostatis. ENTHALPY, 9299.

K.Choi. (2014). Rain sensor with stacked light waveguide heaving titled air gap. Journal of Sensors, 1-9.

Klein, J. (2006). Water hammer. Halle, Germany: KSB Aktiengesellschaft. Manik,

R. G. (2018). RANCANG BANGUN PENDETEKSI KEBOCORAN DENGAN MENGGUNAKAN WATER FLOW SENSOR BERBASIS WI-FI. Surabaya: Institut Teknologi Sepuluh November.

Prasetya, H. (2016). Evaluasi unjuk kerja sistem proteksi water hammer pada sistem perpipaan. Surabaya: Instutut Teknologi Sepuluh November.

Perdeep Kumar, H. K. (2019). Human Machine Interface (HMI). In H. K. Perdeep Kumar, Software Projects (pp. 1-65). Gharuan: LAP Lambert.

Books and Reference Works

Armfield. (2020). c7-mkii pipe surge and water hammer apparatus. Retrieved from Armfield: https://armfield.co.uk/product/c7-mkii-pipe-surge-and-water-hammer-apparatus/

Armfield. (2020). c7-mkii pipe surge and water hammer apparatus. Retrieved from Armfield: https://armfield.co.uk/product/c7-mkii-pipe-surge-and-water-hammer-apparatus/

Webpage on a website

Automation, A. (2021). HMI (Human Machine Interface) Guide. Retrieved from Anaheim Automation: https://www.anaheimautomation.com/manuals/forms/hmi-guide.php

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DOI: 10.52330/jtm.v22i2.279