Design of PLC-Based Airblast Control System as an Industrial Automation Learning Module

Gabriela Zahasyah Nagara Putri, Solly Aryza Lubis, Beni Satria

Abstract

Study This designing module learning automation industry in the form of system control airblast based on a programmable logic controller (PLC) that integrates control sequential , permissive and trip interlocks, process control , human machine interface (HMI), and operational data recording system airblast modeled as air-assisted spraying with variables main pressure air , water pressure , and water flow, as well actuator in the form of pumps and solenoid valves . Operating parameters and test scenarios are defined based literature , including use pressure nominal air 0.4 MPa as setpoint reference and variation corner nozzle installation as variables experiment . Device PLC software built with state machine approach to make it easier tracking start-up shut-down sequence and fault handling . PID control on PLC is used For guard stability variables pressure according to the setpoint, while the HMI provides function settings , monitoring, alarms, trends , and logging. Evaluation module focused on safe and measurable indicators in the laboratory , including time response setpoint change , overshoot, error steady , debit consistency , and accuracy interlock and trip response . Design results show module capable connect draft air-assisted atomization with practice control industry data -based , so that worthy used as a learning medium automation industry that can replicated .

Keywords : PLC, Airblast , Air-Assisted Spraying **,** HMI, PID control

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Introduction

Learning automation industry in college tall often placing PLC as the main platform For control sequential , interlock, and HMI integration . Constraints appear when practical work only emphasize writing ladder or function block without present process dynamics , limitations instrumentation , as well as procedure safety that resembles condition factory . Development of portable PLC kits and approaches laboratory portable at home show need modules that are not stops at programming , but also includes I/O wiring , actuator sensor selection , and verification behavior system in the scenario real learning [1], [5], [6].

System airblast based spraying water with help air under pressure relevant made into module learning Because demand integration control discrete and process control . Atomization performance and effectiveness applications are heavily influenced pressure air and water, nozzle geometry , and condition operation , so that suitable For practical work that connects process parameters with control strategies based on sensing and real-time control [15]. Characteristics This open room learning about HMI -based operating modes , interlocks, alarms, and setpoint settings .

Quantitative evidence from research atomization and dust suppression can made into base compilation scenario practicum . Study air-assisted dust suppression device reports corner nozzle installation affects droplet size and behavior spray , as well as on the configuration studied distance spray reported about 110 m, so that aspect installation become necessary variables controlled and tested [13]. CFD simulation on the combined spraying dust suppression device recommends pressure supply air 0.4 MPa as point balancing operations performance and consumption energy on the tested configuration [14]. Implementation internal mixing nozzle field at the facility processing coal report efficiency decline total dust 90.72% and dust respirable 89.75%, which confirms connection direct between quality atomization , operating strategy , and results performance [16].

Based on context mentioned , the design system control airblast PLC based as module learning need positioning the PLC as controller main For order working , permissive and trip, fail-safe state valves , as well as process control such as regulations pressure or rate flow . HMI integration is required For setting setpoints, monitoring, alarms, and recording operational data so that students can evaluate performance with metric measurable , for example time response fashion change , stability pressure , and consistency rate flow . Implementation PLC- based process control , including PID, is relevant For show relatedness tuning control with response system , as shown in the PLC -based PID implementation on the prototype level control with overshoot below 10 % at the tested setpoint [9].

1.2 Research Objectives

As for the purpose study This is :

1. Designing system control center AirBlast PLC based as module learning automation industry .
2. Help student learn ladder diagram creation and control system using PLC.
3. Increase understanding writer about use of PLC in automation industry .

Literature review

2.1. PLC learning modules and trainer designs

PLC education studies emphasize the need for practice media that integrates device hardware and devices software for students train wiring , I/O mapping , verification signals , and testing logic in the system physical . Portable PLC kit for automation industry designed covers Basic I/O, sensors, and systems automatic in one platform, so that in accordance For module airblast that requires integration actuators (valves , pumps , compressors) and sensors (pressure , flow) as well interlock testing and start-up shut-down sequence [1].

Figure 1. Portable PLC

Moment access laboratory limited , web modules and virtual systems help exercise programming and debugging through material interactive [2] –[4]. Approach laboratory portable also supports learning based project with emphasis on experimentation and reporting results measure , not simulation only , so that in harmony with need module airblast which requires measurable and reliable test procedures replicated [5], [6].

2.2. Principle air-assisted atomization and key parameters

Air-assisted spraying produces fine droplets through combination of water and air under pressure . Performance is affected pressure air , water pressure , nozzle design (internal or external mixing), and geometry , so that setpoint changes can change distribution droplet size and pattern spray [15]. Characteristics This relevant For practical work that relates arrangement pressure and rate flow with process output that is monitored by sensors and recorded through logging.

Studies Experimental studies on internal-mixing nozzles show pressure air and water affect characteristics atomization and efficiency emphasis dust , so that pressure worthy made into variables control main [18], [19]. The nozzle structure parameters also affect atomization and dust reduction performance , which can used For election trade-off learning components and determination limit operation and alarm [20].

2.3. Dust suppression performance

The air-assisted dust suppression literature provides base quantitative For test scenario . Corner nozzle installation reported influence performance atomization , and in the configuration studied distance spray reported about 110 m, so that installation become variables necessary engineering considered [13]. This can translated become experiment change condition operations and evaluation response system through trend data .

CFD simulation on combined spraying device recommends pressure supply air 0.4 MPa as point balancing operations performance and consumption energy [14]. Field evidence of internal mixing nozzles in facilities processing coal report efficiency decline total dust 90.72% and dust respirable 89.75%, which confirms importance operations and quality strategy atomization [16]. In module learning , evaluation focused on indicators safe like stability pressure , discharge consistency , and response fashion change .

2.4. Architecture PLC, PID, HMI control and data logging

System control airblast PLC based in general combine control discrete (sequencing, permissive interlock and trip, automatic manual mode , fail-safe) and process control (setting pressure or rate flow). PLC -based PID implementation on prototype level control shows tuning can achieves overshoot below 10 % at the tested setpoint , so metric response transient relevant used as a learning target in the module airblast [9].

HMI plays a role For setting setpoints, monitoring status, alarms, and trends , while logging provides data for analysis performance and verification operations . Literature web-based and virtual PLC learning emphasizes importance visualization and feed come back For help understanding program relationship with behavior system [2] –[4]. In the module airblast

, operational dataset like pressure , flow, valve status , and alarm events supported evaluation practical work based proof .

Research Methodology

3.1. Research design and flow Work

Study This use approach research and development (R&D) based prototype , with focus on design system control airblast PLC based and validation functional as module learning automation industry . Workflow consists of from four stage main , namely analysis need learning and needs technical system airblast , design architecture device hardware and devices software , implementation prototype and integration , as well as testing technical and evaluation implementation learning . Selection form prototype portable refers to the practice PLC kit development for education automation that emphasizes Basic I/O, sensor, and system integration automatically on one practice platform [1], as well as approach laboratory portable which makes it easy replication scenario practice when access laboratory limited [5], [6].

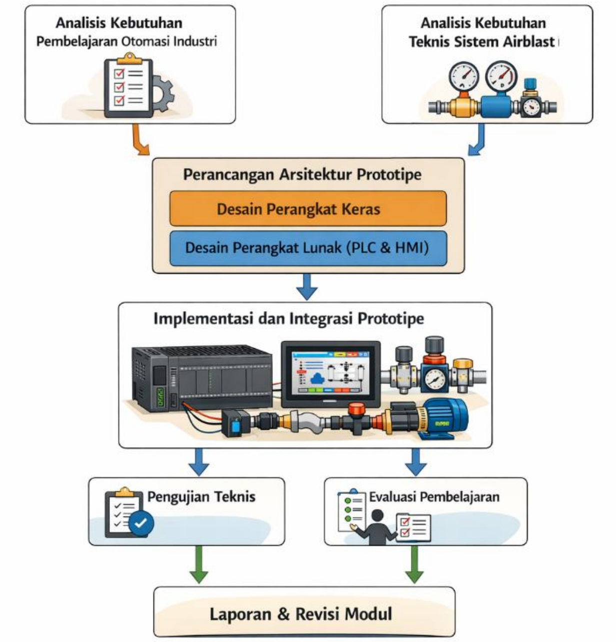

Figure 2. Workflow Study

Stage analysis need collect achievement data learning eye studying automation industry , the minimum competencies that must be achieved , and limitations safety practice . From the side technical analysis need set process variables that must be measured and controlled , namely pressure air , water pressure , and actuator status main . From the side learning , analysis need set task practical work that tests ability student in PLC programming , I/O wiring , interlock verification , tuning base process control , as well as design HMI display and data logging .

3.2. Design system airblast and specifications functional

System airblast in research This modeled as air-assisted spraying system with two track supply , namely waterways and routes air pressurized , which meets at the nozzle to produce atomization . Literature show that performance Atomization and application are greatly influenced by operating parameters and nozzle design [15]. In addition that , the corner nozzle installation reported influence performance atomization in air- assisted dust suppression devices [13]. Therefore that , module designed own nozzle holder with a number of position angle that can chosen For test and learning scenarios , as well as own point measuring pressure and flow that can monitored via HMI.

Specification functional control lowered be a list of operating modes and conditions Safety . Minimum operating modes include OFF, AUTO, MANUAL, and EMERGENCY STOP. Conditions safety includes permissive before start, for example minimum pressure available , protective status active , and not there is a critical alarm , as well as a trip for stop system when pressure beyond limit safe , water supply is cut off , or the main sensor failed . Pressure setpoint nominal air pressure is set based recommendation pressure supply air 0.4 MPa from studies CFD simulation on a combined spraying dust suppression device [14]. Variation of the setpoint around nominal value used For evaluate response control and stability operation .

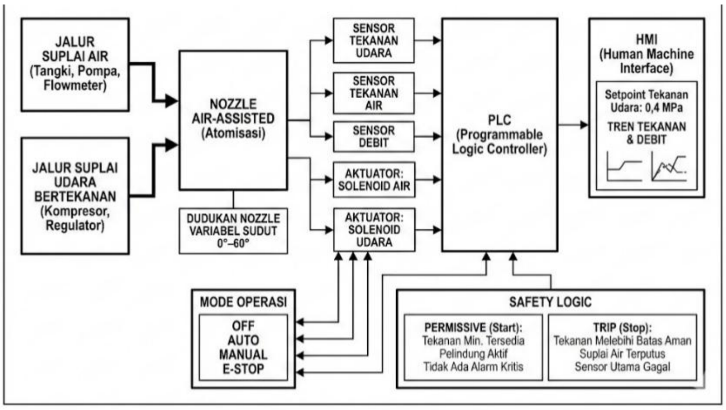

Figure 3. System Model Airblast

3.3. Implementation device hardware , instrumentation , and calibration

Prototype built using PLC as controller main , digital I/O module for actuation solenoid valve and pump start control or compressor , as well as analog I/O for pressure sensor and flow sensor readings . Actuator main covers water line solenoid valve , water line solenoid valve air , water pump , and regulator supply air that can controlled or arranged through the regulator. Minimum instrumentation includes a pressure sensor air , water pressure sensor , and water flow sensor. Components chosen based on availability industry and convenience integration with PLC, so that the module resemble field practice .

Sensor calibration is performed before control test . Pressure sensor validated use comparator in the form of a manometer or pressure gauge on several test points , for example 0.2 MPa, 0.4 MPa, and 0.6 MPa, according to limit safe equipment used . Flow sensor validated use method volumetric , namely measure the volume of water collected at time intervals certain , then compare with sensor output . Calibration results saved as a scale parameter on a PLC or HMI, so that displayed reading in accordance unit techniques used in practicum .

3.4. Implementation device PLC, HMI, and data logging software

Device PLC software developed with state machine structure for make it easier learning order work , interlock, and mode transition . Logic control discrete includes permissive before start, sequence opening valve , filling delay pressure , and shut-down procedures . The alarm logic is divided be a warning alarm and a trip alarm. When the trip alarm is active , the system must return to condition safe , for example close solenoid valve and stop pump . Structure like This in harmony with need PLC learning that emphasizes I/O, sensor, and system interrelationships automatic in one platform [1].

Process control is applied to variables pressure air or pressure mixed , depending on configuration prototype . The PID controller on the PLC is used For guard pressure at setpoint, with output in the form of control relevant actuators , for example valve settings or control device supply through analog signal . Practice tuning PID basics and overshoot and time evaluation steady state refers to the PLC -based PID implementation on the prototype level control that shows importance metric transient moment evaluate quality control [9]. HMI is designed For displays mode status, sensor values , setpoints, active alarms , buttons manual operations , as well as page trend . Data logging at a minimum records timestamp, pressure , flow , actuator status , setpoint, and alarm events , with rate established records consistent , for example 1 Hz, to make it easy analyzed in task practicum .

3.5. Procedure testing technical and evaluation as module learning

Testing technical done in three test group . First test is a functional I/O and sequencing test , which verifies that every sensor is read right , every actuator respond commands , as well as start-up and shut-down sequence running in accordance design . Second test is a safety and interlock test , which verifies response system when permissive no fulfilled and when trip condition triggered . Third test is a performance test process control , with scenario pressure setpoint change air from nominal value 0.4 MPa to variations above and below , according to range safe prototype . Metrics recorded covers rise time to 90 percent of setpoint, maximum overshoot , error steady state , and the amount oscillation . Variable nozzle installation was also tested on several position corner Because literature show corner installation influence characteristics atomization and behavior spray [13].

Evaluation module learning done through package task practical work that includes wiring , programming , testing , and data analysis . Measurement results Study use rubric performance appraisal accuracy I/O mapping , interlock correctness , quality program structure , capabilities read trends and logs, as well as ability interesting conclusion based on test data . The data collected covers time settlement task , amount wiring error detected moment verification , success fulfil criteria performance established controls , and quality report analysis . Approach This consistent with idea that module portable and laboratory portable effective when student still do experiment measurable and reporting data- based , not only exercise simulation [5], [6]. In addition that , the context of operating parameters and recommendations pressure in dust suppression studies is used For give reference realistic moment formulate test scenarios and limits operations on modules [14], [16].

Results

4.1. Design results module control airblast PLC based

Main results study in the form of design module learning that integrates PLC, digital I/O for actuation (solenoid valve , pump start , supply enable) air), analog I/O for sensor reading (pressure air , water pressure , and discharge), as well as HMI for operations and monitoring . Structure module follow the principle of a portable trainer that encourages device interfacing exercises , I/O wiring , and testing system automatic based scenario .

PLC program is designed with state machine approach so that the sequence work and conditions transition easy tracked moment practicum . Operational status includes OFF, READY, STARTING, RUN, and FAULT. Interlock (permissive) is placed on the READY to STARTING transition , while trips are placed on all active states to ensure the system is running smoothly. return to condition safe when happen violation limits . Approach This put learning on aspects that are often appears in the system industry , namely start-up shut-down sequence , fail-safe output, and alarm management , not just writing ladder instructions .

4.2. Results of determining operating parameters based literature air-assisted atomization

Basic setpoint pressure air and water are determined follow findings numerical on the combined spraying dust suppression device , which reports optimum conditions for application field under pressure air pressure of 0.4 MPa and water pressure of 2.0 MPa. Selection This make module own base quantitative moment student requested compare performance system in several modes, for example nominal mode (0.4 MPa) and test mode (below or above nominal) in limit safe equipment .

Variables nozzle installation inserted as part from scenario experiment Because literature show its impact on spray parameters . In the study air-assisted spraying dust suppression devices , variations corner nozzle installation 0°, 15°, 30°, 45°, and 60° shows distance spray maximum relatively still around 110 m, while the falling range increases from 20.31 m at 0° to 29.16 m at 60°. The same study report the mean droplet size at one time cross section increase from 101.3 μm at 0° to 123.7 μm at 60°, and the optimum angle was set at 45° for prevent droplet loss at the outlet as well keep the droplet size small and the falling range large . On the module learning , this data used as reference discussion moment student observe change pattern spray and read trend pressure or debit, then linking results observation with effect corner installation that has been reported .

4.3. Design results process control and criteria tested performance

Process control in the module directed at stabilization air pressure or water, as appropriate configuration actuator) using PID in PLC. Criteria performance used in practicum referring to evidence PLC- based PID implementation on a water level system , which reported overshoot below 10 % on 10 cm and 20 cm setpoint tests . In context airblast , the metrics evaluated on the data log are pressure overshoot , rise time , and error steady state moment done setpoint changes , because third metric This easy counted from HMI trend data and relevant For evaluate quality PID tuning .

Data logging is designed For support discussion based Evidence . The log contains at least timestamp, mode, setpoint, pressure air , water pressure , flow rate, valve status , and alarm status with rate recording fixed . This format make it easier assignment analysis , for example count time response from setpoint changes , identifying trip moment due to pressure pass limits , and verify whether the shutdown sequence is complete close valve in FAULT condition .

Discussion

Discussion confirm that design module airblast PLC- based that combines sequencing, permissive and trip, HMI, and data recording overcomes gap frequent learning appear when practical work stop at ladder programming without present behavior system physical and procedural operations . State machine -based program structure and I/O verification drive student conduct cause tracing consequence between sensor signals , actuator status , and interlock decisions , according to direction portable PLC development kit as well as approach laboratory portable that emphasizes integration device hard and experimental measurable [1], [5], [6]. The use of HMI and logging makes evaluation practical work can based evidence , for example proof start-up and shut-down sequence , time response fashion changes , as well as consistency documented sensor readings .

Discussion of process parameters shows that election test- based scenarios pressure and nozzle configuration have base strong scientific recommendations pressure air 0.4 MPa from simulation dust suppression devices provide nominal setpoint reference for exercise control , whereas variation corner nozzle installation that affects droplet and behavior spray provide context experiments that can associated with trend data pressure and discharge on the module [14], [13]. Efficiency figures decline dust on the application internal mixing nozzle field used as references performance level system , while module learning centralize evaluation of safe and measurable indicators in the laboratory , namely stability pressure , discharge consistency , and accuracy interlock and trip responses [16]. The application of PID to PLC is relevant Because give room exercise tuning based metric transient , with references that PLC -based PID implementation at prototype level can be achieve overshoot below 10 % at the tested setpoint , and the principle This can transferred For set pressure test criteria on airblast [9]. Relationship between operating parameters , characteristics atomization , and the need control still in line with a review of air-assisted spray nozzles that emphasizes sensitivity performance to pressure and nozzle configuration [15].

Conclusion

Study This produce design module learning automation industry in the form of system control airblast PLC based that integrates control sequential , permissive and trip interlocks, HMI interfaces , and operational data recording . The state machine -based program structure makes it easier implementation start-up and shut-down sequence , handling condition fault, as well as verification fail-safe behavior on the actuator , so that module can used For practice competence I/O wiring , PLC programming , and procedures relevant operations with practice industry .

Determination scenario practical work process parameter based supported literature air-assisted atomization , including use pressure nominal air 0.4 MPa as test and learning references , as well variation corner nozzle installation as variables experiments that influence characteristics spray . Evaluation performance module directed at safe and measurable indicators in the laboratory , such as stability pressure , discharge consistency , time response fashion changes , and accuracy interlock and trip responses , as well as analysis response transients in PLC -based PID control . Approach This strengthen connectedness between draft atomization , process control , and implementation automation industry data- based .

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