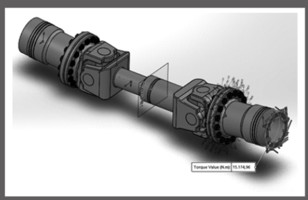
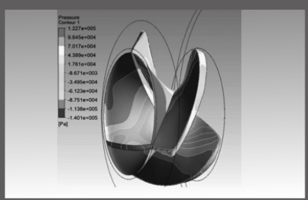
e-ISSN 2088-6985
p-ISSN 2087-3379

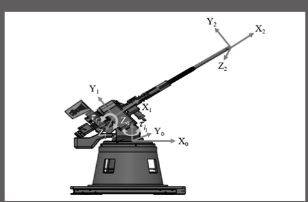
MEV

Journal of Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, Issue 2, 2022







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J. MEV	Vol. 13	Iss. 2	pp.101-221	Bandung, 2022	ISSN 2087-3379

Journal of

Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, Issue 2, 2022

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Journal of Mechatronics, Electrical Power, and Vehicular Technology (MEV) is an internationally peer-reviewed journal aims to provide authoritative global source of scientific information for researchers and engineers in academia, research institutions, government agencies, and industries. The Journal publishes original research papers, review articles and case studies focused on:

Mechatronics: including control system, robotic, CNC Machine, sensor, signal processing, electronics, actuator, and mechanical dynamics.

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MEV is published by National Research and Innovation Agency (BRIN) - *formerly* Indonesian Institutes of Sciences (LIPI).

ISSN print: 2087-3379
ISSN electronics: 2088-6985

Electronics edition is available at: https://mev.lipi.go.id

All published article are embedded with DOI number affiliated with Crossref DOI prefix 10.14203

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MEV is managed to be issued twice in every year. The first issue should be in the mid of the year (July) and the second issue is at the end of the year (December).

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Business hour: Monday to Friday 08:00 to 16:00 GMT+7

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e-ISSN 2088-6985
p-ISSN 2087-3379

Journal of Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, Issue 2, 2022

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e-ISSN 2088-6985
p-ISSN 2087-3379

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FOREWORD FROM EDITOR-IN-CHIEF

Welcome to the latest issue in 2022 of the Journal of Mechatronics, Electrical Power, and Vehicular Technology (MEV), a peer-reviewed and broad-scope international journal. This issue consists of ten papers written by authors from different countries, such as Australia, China, India, Indonesia, Japan, Malaysia, Philippines, Taiwan, United Kingdom, and Vietnam.

We are pleased in this issue to present a diverse range of articles and papers that cover a wide range of topics within the field of Mechatronics, Electrical Power, and Vehicular Technology. One of the standout contributions in this issue is a paper by Rupesh and Tegampure on the DNN control technique in the photovoltaic system. This research has the potential to significantly impact the way we approach treatment in this area, and we are thrilled to have the opportunity to share this work with our readers.

We are also pleased to feature an article by Ramadiansyah et al. on the numerical investigation of the effect of ocean depth variations on the manipulator joint torque. This work provides development a mathematical model of a ship mounted two-DoF manipulator considering the ship dynamics and characterization of the ship motions.

In addition to these articles, we have several other papers that cover a wide range of topics, including an overview of early termination of PV-DG microgrid system, a method to find pump performance specifications when using a pump with a mixed flow type as a turbine for micro hydro power plants, investigation the impact of lightning masts placement on underground cables within high voltage substations, examination the strength of the universal joint after it was loaded with torsion, long-term forecasting for growth of electricity load based on customer sectors, optimization take-off position control of the bicopter model by investigating LQR cost matrices variation in actual experiments, plumbing leakage detection system with water level detector controlled by programmable logic controller, and a novel solution to deal with the complicated electronic circuitry for speed controller and too complex mechanical design of rotating mechanism of an orbital shaker.

We hope that you will find this issue to be a valuable resource, and we look forward to continuing to bring you the latest research and insights in the field of Mechatronics, Electrical Power, and Vehicular Technology.

Bandung, December 2022

Editor-in-Chief

Journal of

Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, Issue 2, 2022

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e-ISSN 2088-6985
p-ISSN 2087-3379

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Journal of

Mechatronics, Electrical Power, and Vehicular Technology

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ABSTRACTS SHEET

e-ISSN: 2088-6985
p-ISSN: 2087-3379

Jalu Ahmad Prakosa [a], Hai Wang [b], Edi Kurniawan [a], Swivano Agmal [c], Muhammad Jauhar Kholili [c] ([a] Research Center for Photonics, National Research and Innovation Agency (BRIN), Indonesia; [b] Discipline of Engineering and Energy, Murdoch University, Australia; [c] Research Center for Quantum Physics, National Research and Innovation Agency (BRIN), Indonesia)

Experimental studies of linear quadratic regulator (LQR) cost matrices weighting to control an accurate take-off position of bicopter unmanned aerial vehicles (UAVs)

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 101-112, 17 ill, 5 tab, 27 ref.

Controller design for airplane flight control is challenged to achieve an optimum result, particularly for safety purposes. The experiment evaluated the linear quadratic regulator (LQR) method to research the optimal gain of proportional-integral-derivative (PID) to hover accurately the bicopter model by minimizing error. The 3 degree of freedom (DOF) helicopter facility is a suitable bicopter experimental simulator to test its complex multiple input multiple output (MIMO) flight control model to respond to the challenge of multipurpose drone control strategies. The art of LQR setting is how to search for appropriate cost matrices scaling to optimize results. This study aims to accurately optimize take-off position control of the bicopter model by investigating LQR cost matrices variation in actual experiments. From the experimental results of weighted matrix variation on the bicopter simulator, the proposed LQR method has been successfully applied to achieve asymptotic stability of roll angle, although it yielded a significant overshoot. Moreover, the overshoot errors had good linearity to weighting variation. Despite that, the implementation of cost matrices is limited in the real bicopter experiment, and there are appropriate values for achieving an optimal accuracy. Moreover, the unstable step response of the controlled angle occurred because of excessive weighting.

(Author)

Keywords: experimental evaluation; cost matrices; LQR; bicopter; MIMO flight control.

Mohamad Luthfi Ramadiansyah [a], Edwar Yazid [a], Cheng Yee Ng [b] ([a] Research Center for Smart Mechatronics, National Research and Innovation Agency (BRIN), Indonesia; [b] Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Malaysia)

Numerical investigation of the effect of ocean depth variations on the dynamics of a ship mounted two-DoF manipulator system

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 113-124, 10 ill, 7 tab, 32 ref.

The dynamics of a ship need to be considered in the development of a manipulator system that will be applied to the ocean-based operation. This paper aims to investigate the effect of ocean depth variations on the ship motion as disturbances to a ship-mounted two-DoF (Degrees of Freedom) manipulator joint torque using an inverse dynamics model. Realization is conducted by deriving the mathematical model of a two-DoF manipulator system subject to six-DoF ship motion, which is derived by using Lagrange-Euler method. It is then combined with numerical hydrodynamic simulation to obtain the ship motions under ocean depth variations, such as shallow (50 m), intermediate (750 m), and deep (3,000 m) waters. Finding results show that randomness of the ship motions appears on the manipulator joint torque. In the azimuth link, maximum joint torque is found in shallow water depth with an increment of 8.271 N.m (285.69 %) from the undisturbed manipulator. Meanwhile, the maximum joint torque of the elevation link is found in intermediate water depth with an increment of 53.321 N.m (6.63 %). However, the difference between depth variations is relatively small. This result can be used as a baseline for sizing the electrical motor and developing the robust control system for the manipulator that is mounted on the ship by considering all ocean depth conditions.

(Author)

Keywords: two-DoF manipulator; inverse dynamics; ship motion; ocean depth; hydrodynamic response.

Sarid Mejiartono [a], Muhammad Fathul Hikmawan [b], Aditya Sukma Nugraha [b, c] ([a] Faculty of Mechanical and Aerospace Engineering, Bandung Institute of Technology, Indonesia; [b] Research Center for Smart Mechatronics, National Research and Innovation Agency (BRIN), Indonesia; [c] Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taiwan)

Numerical and experimental study of mixed flow pump as turbine for remote rural micro hydro power plant application

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 125-136 15 ill, 11 tab, 26 ref.

The use of a pump as opposed to a turbine/pump as turbine (PAT) for off-grid electrification applications is one of the important ways to be considered in efforts to equalize electrical energy in Indonesia. The main problem in PAT applications is how to predict pump performance if applied as a turbine to find out its best characteristics and efficiency points. This study discusses a method to find pump performance specifications when using a pump with a mixed flow type as a turbine for micro hydro power plants. The numerical method by utilizing computational fluid dynamics (CFD) based software simulations that have been proven to be accurate according to previous studies was selected for use in obtaining predictions of the pump characteristics as turbines. Then the PAT characteristics of the CFD simulation results are validated by conducting direct testing. The results of the CFD numerical simulation using ANSYS Fluent software show the performance curve of a mixed flow pump operated as a turbine at various rotating speeds. The highest efficiency for each rotating speed ranges from 35-40 %. The test results directly show the PAT characteristics, that the performance range is close to the numerical simulation results with a difference of 10 %.

(Author)

Keywords: pump as turbine (PAT); micro hydro power plant; computational fluid dynamics (CFD).

Sri Hartanto [a], Desmayadi [b] ([a] Teknik Elektro, Universitas Krisnadwipayana, Indonesia; [b] Nissinbou Industries, Inc, Japan)

Plumbing leakage detection system with water level detector controlled by programmable logic controller type Omron CPM2A

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 137-146, 10 ill, 5 tab, 26 ref.

There is a chance of leakage in the plumbing caused by water pressure in the pipes, improper installation of pipe connections, or external influences, such as earthquakes. Plumbing leakage that is detected too late can cause damage to other systems. It is necessary to have a plumbing leakage detection system to detect a leak in the plumbing. Therefore, in this research, a plumbing leakage detection system is designed with a water level detector (WLD) controlled by a programmable logic controller (PLC) type Omron CPM2A. The method used in this research is designing the optimal model form of the system, which is distinguished by designing hardware and software, testing the devices, such as power supply, WLD, and channel relay module (CRM), and making conclusions. From the results of this research, it was found that the system works well in detecting leakage of plumbing, as indicated by all transistors' ability to work well where the electrodes (E1 and E2) are connected by water. The transistor in the WLD module will work as a switch or transistor in the saturation position. In this research, it can be seen that even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module, a minimum of 12 VDC is required. In addition, when the relay is not working or off, the measurement at the normally closed (NC) terminal is 12 VDC.

(Author)

Keywords: channel relay module (CRM); leakage detection; programmable logic controller (PLC); water level detector (WLD).

Edwin Romeroso Arboleda (Department of Computer and Electronics Engineering, Cavite State University, Philippines)

Design, construction, and evaluation of transformer-based orbital shaker for coffee micropropagation

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 147-156, 23 ill, 2 tab, 25 ref.

This study offers a novel solution to deal with the complicated electronic circuitry for speed controller and too complex mechanical design of rotating mechanism of an orbital shaker. The developed prototype used a transformer that varies the supply voltage to control the speed of rotation of the orbital shaker. The prototype has five speed levels which depend on the input voltage. These speeds are 180 rpm at 12 V, 258 rpm at 15 V, 360 rpm at 18 V, 427 rpm at 21 V, and 470 rpm at 24 V. The prototype was tested to run continuously for 48 hours for each speed level, with speed being measured every hour using a tachometer. Statistical computation shows that the speed remains constant for the entire 48 hour period. Evaluation of results shows that the speed controller and the novel mechanical design for the orbital shaking motion achieved their functions. For this reason, it can be concluded that the prototype is durable and safe for use in orbital shaking applications.

(Author)

Keywords: DC motor; orbital shaker; rotating mechanism; speed controller; step-down transformer.

Mailugundla Rupesh [a], Vishwanath Shivalingappa Tegampure [b] ([a] Department of Electrical & Electronics Engineering, India; [b] Department of Electronics & Communication Engineering, India)

Cascade feedforward neural network and deep neural network controller on photovoltaic system with cascaded multilevel inverters: Comparison on standalone and grid integrated system

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 157-178, 31 ill, 2 tab, 21 ref.

The introduction of a micro-grid-based power generation network will help to meet the demands of consumers while reducing environmental impact. Several industrialized and emerging countries allocate considerable resources to renewable energy-based power generation and invest significant sums of money in this area. This study examines the challenges involved with electricity generation through photovoltaic (PV) systems and the integration of the same with the grid to mitigate power quality issues and improve the power factor for various loading conditions. An innovative multilayer inverter for grid-connected PV systems has been developed to enhance the voltage profile and resulted in a drop in total harmonic distortion (THD). A cascade multilevel inverter (associated with a grid-integrated PV system and managed using multiple innovative artificial intelligence controllers) was developed in this research project. Various advanced intelligent controllers, such as cascade feedforward neural networks

(CFFNN) and deep neural networks (DNN), have been analyzed under various operating situations and observed that the THD of voltage, current at the grid, and the load is less than 3 % as per the IEEE 519 standards along with this power factor is maintained nearly unity for the grid-connected system. The quality of power in terms of voltage, frequency, total harmonics distortion, and power factor are improved by using a novel deep neural network algorithm in a cascaded multilevel inverter and verified according to IEEE 1547 and IEEE 519 standards to determine the efficacy of the proposed system.

(Author)

Keywords: cascaded feedforward neural network; deep neural network; multilevel inverter; photovoltaic system; total harmonics distortion.

Hartono Yudo [a], Andi Setiawan [a], Ocid Mursid [a], Muhammad Iqbal [b] ([a] Department of Naval Architecture, Faculty of Engineering, Diponegoro University, Indonesia; [b] Department of Naval Architecture, Ocean, and Marine Engineering, University of Strathclyde, United Kingdom)

Torsional strength analysis of universal joint's ZP-11A due to yokes modification and materials

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 179-188, 15 ill, 8 tab, 20 ref.

The study examined the strength of the universal joint after it was loaded with torsion. It used different materials that can withstand tensile stress in accordance with accepted principles and made modifications to the yoke as a result of the topology optimization process. The topology optimization determined that the yoke's part needed to withstand load without changing its dimensions and minimize stress distribution. According to the results, the maximum shear stress on the spider of the original universal joint model made of JIS-SF590A steel was 84.57 MPa, the shear stress on the yoke component was 30.84 MPa, and the maximum von Mises was 341.1 MPa. As a result of using JIS-SF590A steel, yoke modification 3 has produced a reduction in shear stress of 12.97 % and a reduction in von Mises stress of 35.33 % from the original yoke. This is the most efficient design of yoke and also this modified yoke form provides a wider elevation angle and is easier to manufacture.

(Author)

Keywords: shear stress; topology optimization; universal joint; von mises.

Mostafa Nazih (Future Energy, GHD Pty Ltd, Australia)

Effect of lightning mast placement on underground power cable jacket stress within high voltage substations

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 189-200, 17 ill, 1 tab, 30 ref.

This study aims to investigate the impact of lightning masts placement on underground cables within high voltage substations. While the subject of lightning discharges near to underground cables has been covered with open cable runs and wind farms in many papers, this study focuses on lightning events within high voltage substations considering the associated effective zones, which were not covered in the available literature. Substations built within areas prone to high lightning activity experience frequent discharges that cause the potential rise of the earthing system into hundreds of kilovolts. The potentials propagating within the soil and the earthing grid affect underground cables jackets terminated within the substation. The numerical analysis of the problem is carried out using Current Distribution, Electromagnetic fields, Grounding and Soil structure analysis (CDEGS) software engine for different configurations of lightning mast placements with varied separation, electrode placement and length, soil resistivity, and lightning current. Study findings indicate that provision of lightning masts/down conductors as far as possible or at least twice the effective zone radius from cable termination/route electrodes ensures relatively lower stress voltages. Electrodes with effective zone radius length placed as close as possible to lightning masts further reduce the attainable jacket stress voltages.

(Author)

Keywords: substation earthing; lightning mast placement; high voltage; underground cable; effective zone radius.

Tinton Dwi Atmaja [a, b, c], Dalila Mat Said [a, c], Sevia Mahdaliza Idrus [a, c], Ahmad Fudholi [b, d], Nasarudin Ahmad [a], Dian Andriani [e, f], Ahmad Rajani [a, b, c], Sohrab Mirsaeidi [g], Haznan Abimanyu [h], ([a] Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Malaysia; [b] Research Centre for Energy Conversion and Conservation, National Research and Innovation Agency, Indonesia, [c] Centre of Electrical Energy System, Institute of Future Energy, UTM, Malaysia; [d] Solar Energy Research Institute, Universiti Kebangsaan Malaysia, Malaysia; [e] Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia; [f] Research Organization for Life Sciences & Environment, National Research and Innovation Agency, Indonesia; [g] School of Electrical Engineering, Beijing Jiaotong University, China; [h] Research Organization for Energy and Manufacture, National Research and Innovation Agency, Indonesia)

Component degradation and system deterioration: an overview of early termination of PV-DG microgrid system

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 201-213, 9 ill, 3 tab, 100 ref.

Degradation of components and system failure within the microgrid system is deteriorating the performance of electrification. The aim of this study is to discuss the relationship and connections between issues resulting from degradation and deterioration in the microgrid system, in addition to introducing the prominent impacts which may eventually lead to the premature termination of the microgrid system. This study explored the microgrid degradation and deterioration issues within four microgrid sections: generation section, storage section, transmission section, and distribution section. Subsequently, this study analyzes, derives, and classifies all emerging issues into four types of prominent impacts. The degradation and deterioration invoked many component performance issues into four main damaging outcomes, namely (i) deteriorated transmission line yielded issues regarding expected energy not achieved; (ii) energy deficit and unpredicted blackout come after the depth of discharge (DOD) reduction and invoke a loss of power supply; (iii) a shorter battery life cycle, shorter transformer lifespan, and decreased DG lifetime concluded as a shorter microgrid life expectancy; and (iv) rapid microgrid broke down and the crash of the key component inadvertently fastened the time to failure and gave rise to the early failure of a microgrid system. It is envisaged that the discussion in this study can provide useful mapped information for the researcher, stakeholder, operator, and other parties for thoroughly addressing various degradation and deterioration issues and anticipating the early termination of the microgrid system.

(Author)

Keywords: expected energy not achieved; shorter lifespan; early failure; microgrid termination; loss of power supply.

Sujito [a], Ridho Riski Hadi [b], Langlang Gumilar [a], Abdullah Iskandar Syah [b], Moh. Zainul Falah [b], Tran Huy Duy [c] ([a] Intelligent Power and Advance Energy System, Jurusan Teknik Elektro, Universitas Negeri Malang, Indonesia; [b] Electrical Engineering, Electrical Engineering Department, Universitas Negeri Malang, Indonesia; [c] Electrical Engineering Department, Dalat University, Vietnam)

Long-term forecasting for growth of electricity load based on customer sectors

Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2022, vol. 13, no. 2, p. 214-221, 2 ill, 7 tab, 37 ref.

The availability of electrical energy is an important issue. Along with the growth of the human population, electrical energy also increases. This study addresses problems in the operation of the electric power system. One of the problems that occur is the power imbalance due to scale growth between demand and generation. Alternative countermeasures that can be done are to prepare for the possibility that will occur in the future or what we are familiar with forecasting. Forecasting using the multiple linear regression method with this research variable assumes the household sector, business, industry, and public sectors, and is considered by the influence of population, gross regional domestic product, and District Minimum Wage. In forecasting, it is necessary to evaluate the accuracy using mean absolute percentage error (MAPE). MAPE evaluation results show a value of 0.142 % in the household sector, 0.085 % in the business sector, 1.983 % in the industrial sector, and 0.131 % in the total customer sector.

(Author)

Keywords: district minimum wage; gross regional domestic product; long-term forecasting; mean absolute percentage error; multiple linear regression.

Journal of Mechatronics, Electrical Power, and Vehicular Technology 13 (2022) 137-146

Journal of Mechatronics, Electrical Power, and Vehicular Technology

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e-ISSN: 2088-6985
p-ISSN: 2087-3379

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Plumbing leakage detection system with water level detector controlled by programmable logic controller type Omron CPM2A

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Received 27 November 2021; Revised 21 December 2021; Accepted 20 January 2022; Published online 29 December 2022

Abstract

There is a chance of leakage in the plumbing caused by water pressure in the pipes, improper installation of pipe connections, or external influences, such as earthquakes. Plumbing leakage that is detected too late can cause damage to other systems. It is necessary to have a plumbing leakage detection system to detect a leak in the plumbing. Therefore, in this research, a plumbing leakage detection system is designed with a water level detector (WLD) controlled by a programmable logic controller (PLC) type Omron CPM2A. The method used in this research is designing the optimal model form of the system, which is distinguished by designing hardware and software, testing the devices, such as power supply, WLD, and channel relay module (CRM), and making conclusions. From the results of this research, it was found that the system works well in detecting leakage of plumbing, as indicated by all transistors' ability to work well where the electrodes (E1 and E2) are connected by water. The transistor in the WLD module will work as a switch or transistor in the saturation position. In this research, it can be seen that even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module, a minimum of 12 VDC is required. In addition, when the relay is not working or off, the measurement at the normally closed (NC) terminal is 12 VDC.

Keywords: channel relay module (CRM); leakage detection; programmable logic controller (PLC); water level detector (WLD).

I. Introduction

Plumbing leakage is a problem because whenever there is a leakage somewhere, it cannot be found at an early stage and can become a big problem, leading to water wastage [1]. The basic principle of leakage detection is the loss of pressure on one of the sensors at a fast rate. The use of the pressure transmitter sensor changes it from a sensor to a signal that can be decoded by the controller [2]. The liquid level (as in, e.g., water level) is the height associated with the liquid-free surface, especially when it is the topmost surface. It may be measured with a level sensor [3]. The water level control is a tool that can make it easier to identify the water level in the water reservoir [4]. The automatic water level controller minimizes the need for manual switching and human interference. The machine helps to detect the level of water or any liquid [5]. Water flow sensors detect a different value during water leakage occurred [6]. The sensor module collects the relevant data to decide whether the applications to be monitored are working effectively under certain threshold values [7].

The water leakage detection system can be deployed in the already existing plumbing with flow rate sensors attached to the path of the water flow [8]. Constant leakages through pipes in walls lead to water seepage, which may damage the structural components of the building [9]. The control of all equipment has been performed through the use of computers. Most equipment uses

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doi: https://dx.doi.org/10.14203/j.mev.2022.v13.137-146
2088-6985 / 2087-3379 ©2022 National Research and Innovation Agency

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How to Cite: S. Hartanto and Desmayadi, "Plumbing leakage detection system with water level detector controlled by programmable logic controller type Omron CPM2A," *Journal of Mechatronics, Electrical Power, and Vehicular Technology*, vol. 13, no. 2, pp. 137-146, Dec. 2022.

programmable logic controller (PLC) to connect with computers to monitor each load and electricity-consuming devices [10].

The PLC constitutes one of the main architectures of manufacturing system control and is programmed with standardized languages [11]. By integrating motion control into the PLC, the control system was greatly simplified because simple motion control can be realized by the PLC without a special motion controller [12]. PLC is time-driven with time stamps defined by the input/output (I/O) scanning and does not receive/emit events but logic variables. Hence, the input and output events must be defined from combinations of variables [13].

PLC plays a significant role in automatic control systems. A ladder diagram is the most widely used programming language for PLC, which is transparent and intuitive since the variables are represented as graphical symbols and each instruction is graphical [14]. PLC projects commonly use five programming languages including two textual languages, i.e., structured text (ST) and instruction list (IL), and three graphical languages, i.e., function block diagram (FBD), ladder diagram (LD), and sequential function chart (SFC) [15]. PLC application program development is becoming crucial due to the growing complexity of control problems associated with the demand for high-quality solutions [16].

The sensor and actuator signal data are collected from the PLC memory through a single communication channel (as collecting data from the actual sensors and actuators is extremely costly); and only a fraction of those signals can be accessed at a given time [17]. The essential role of PLC is to interact with sensors and actuators [18]. PLCs are providing the bridge between the cyber and physical worlds by controlling devices such as valves, pumps,

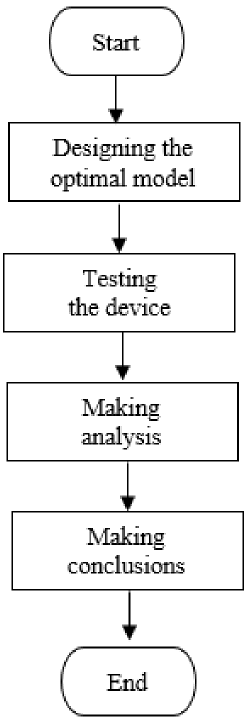

Figure 1. Research methodology flowchart

and motors in response to operator input or their preprogrammed control logic [19]. Input-output specification of the PLC-based function block for considered control law has to be compatible with the specification of the presented "Identification Block" [20]. The goal of PLC data collection is to record both the input and output values whenever there is a change in any of the I/O values [21].

The ladder logic programming language requires the programmer to create diagrams of input and output relays to depict the order and circumstances in which connected devices are toggled and act [22]. Ladder logic is one of the most used programming languages to feed instructions into the PLC [23]. The PLC control logic process deals with the input signals before producing output to regulate the connection and disconnection of the liner circuit [24].

Therefore, in this research, a plumbing leakage detection system controlled by the PLC type Omron CPM2A was designed. In order to determine the location of leakage more precisely, it inserts the detector on the building's water line shaft or at a probable leak. This research is focused on measuring and analyzing the stability of the power supply and measuring the performance of the water level detector (WLD) in the plumbing leakage detection system controlled by the PLC type Omron CPM2A.

II. Materials and Methods

The flowchart of this research methodology that describes the steps carried out in this research is shown in Figure 1. The steps carried out in this research are

- Design; distinguished by designing hardware, which includes making the design of the device to be made, determining the components and dimensions of the device to be made, and designing software, which includes making ladder diagrams on the CX Programmer which the PLC is then programmed with.
- Testing; measures the hardware and software that has been made.
- Analysis; analysing the tests carried out on the system with measurements of the power supply output, electronic circuits on the WLD, and the channel relay module (CRM).
- Conclusion; making a distinguish conclusion from research data that has been previously analysed.

A. Designing the overall model system

A control unit usually consists of three steps: input, computing, and output, and each task is executed cyclically. In the input step, the control unit reads the values of the sensors. In the computing step, the control unit performs some computations such as numerical calculations and conditional judgment, etc. In the output steps, the control unit modifies the values of the variables that are mapped to some output points or control actuators to conduct certain mechanical actions by providing output signals to driver devices [25].

Controllers are generated for random systems with different values of the prediction horizon, the system delay, and the dimensions of the state, control input, and system output. The controller is programmed on the PLC [26].

The design of the plumbing leakage detection system controlled by the PLC type Omron CPM2A can be seen in Figure 2. In Figure 2, the designed system is divided into six parts, namely the input process using a WLD as a water level detector, which then activates the CRM as a direct bit information provider to the PLC type Omron CPM2A to be processed. The results of data processing are displayed by the Omron NB7-TW00B human-machine interface (HMI). In addition, the power supply serves to supply power to the system via the PLC type Omron CPM2A.

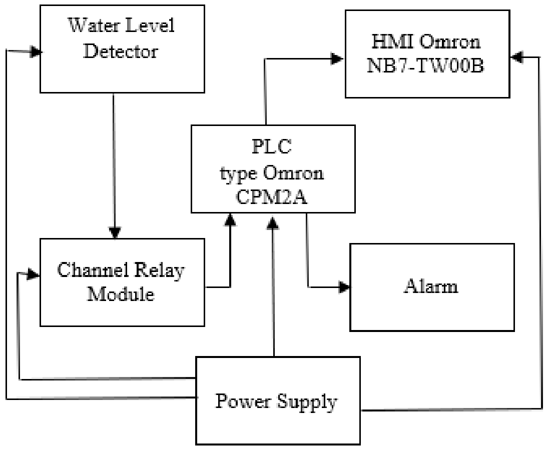

Figure 2. Block diagram of system design

B. Designing the water level detector

The WLD as shown in Figure 3 is made with electronic components including a single pole solid relay 12 VDC as a relay that will activate dry contact normally open (NO)/normally closed (NC), diode 1N4001/4002 as polarity reverse current protection in the relay coil, transistor BD441/D400 NPN as a function switching, resistors, and capacitors. The WLD will work when there is induction in positive and negative polarities. The voltage source used is 12 VDC.

Two copper rods will act as electrodes when immersed in water. The existence of a resistance value of the two copper rods causes the transistor to work to open the channel from the collector to the emitter and activate the 12 VDC relay coil. The dry contact of the relay is used to provide logic 1 as a trigger for the 3B3D Module.

The WLD as shown in Figure 4 requires a standby voltage of 12 VDC which is connected to the (+) and (-) terminals, the voltage polarity must match. At terminals E1 and E2, a cable connection is installed to the electrode stick/copper rod as a water level detector. At the NO terminal when the system is working or the WLD detects water, the terminal will issue 12 VDC which will be used as a trigger, and during normal standby, the NO standby terminal is at 0 VDC.

In this research, 10 WLDs are placed on each floor, and the distance between each WLD is 2.5 meters. All WLDs on each floor work to detect water pipe leakage by detecting waterlogging on each floor.

C. Designing the channel relay module

The circuit of CRM can be seen in Figure 5. In the CRM, there is a 3B3D Module as a digital timer that can be set from 0–999 minutes and there are 4 timer options, namely delay off, delay on, delay on and off, and consistent delays on and off. In designing the plumbing leakage detection system, the 3B3D Module is used to adjust the pulse signal. The COM terminal is the trigger input to activate this module, which is controlled by WLD as shown in Table 1.

D. Designing PLC type Omron CPM2A as controller

PLC used in this system is PLC type Omron CPM2A which has the specifications shown in Table 2. The PLC requires a voltage source of 220 VAC, for the COM terminal and input it uses 24 VDC which comes from the PLC's internal voltage source.

The software used to create the Ladder Diagram is CX Programmer version 9.5 and the type of PLC selected when programming the CX Programmer is PLC type Omron CPM2A. In the ladder diagram of the input detector section as shown in Figure 6 and

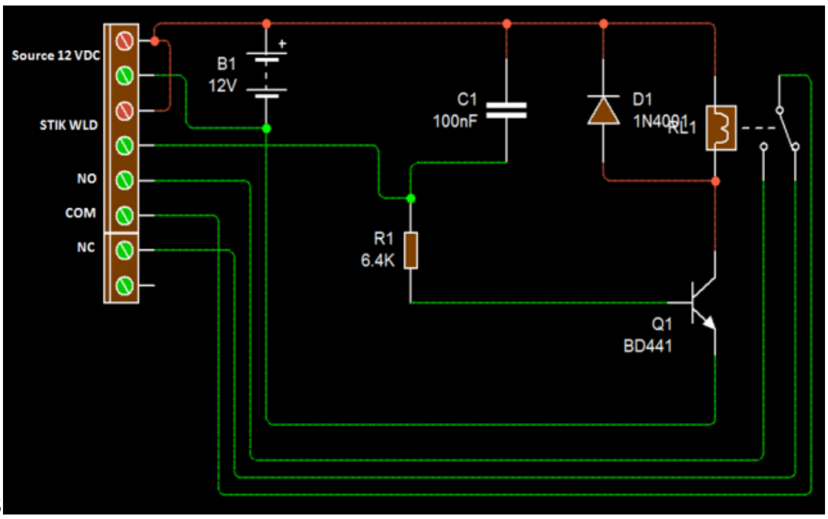

Figure 3. Electronic circuit of WLD

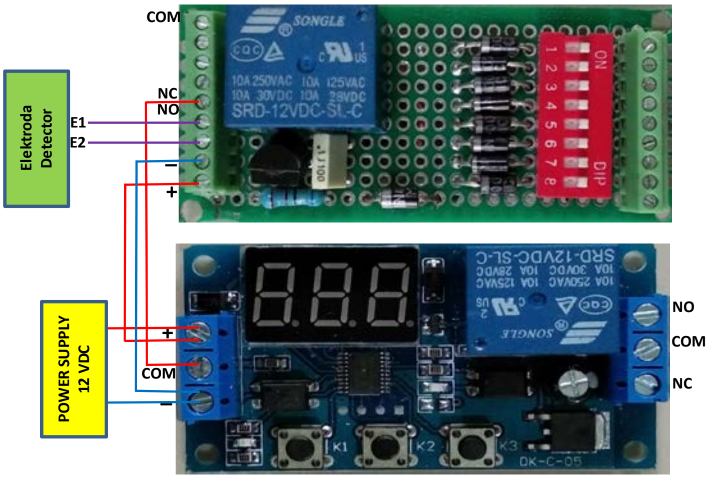

Figure 4. Water level detector

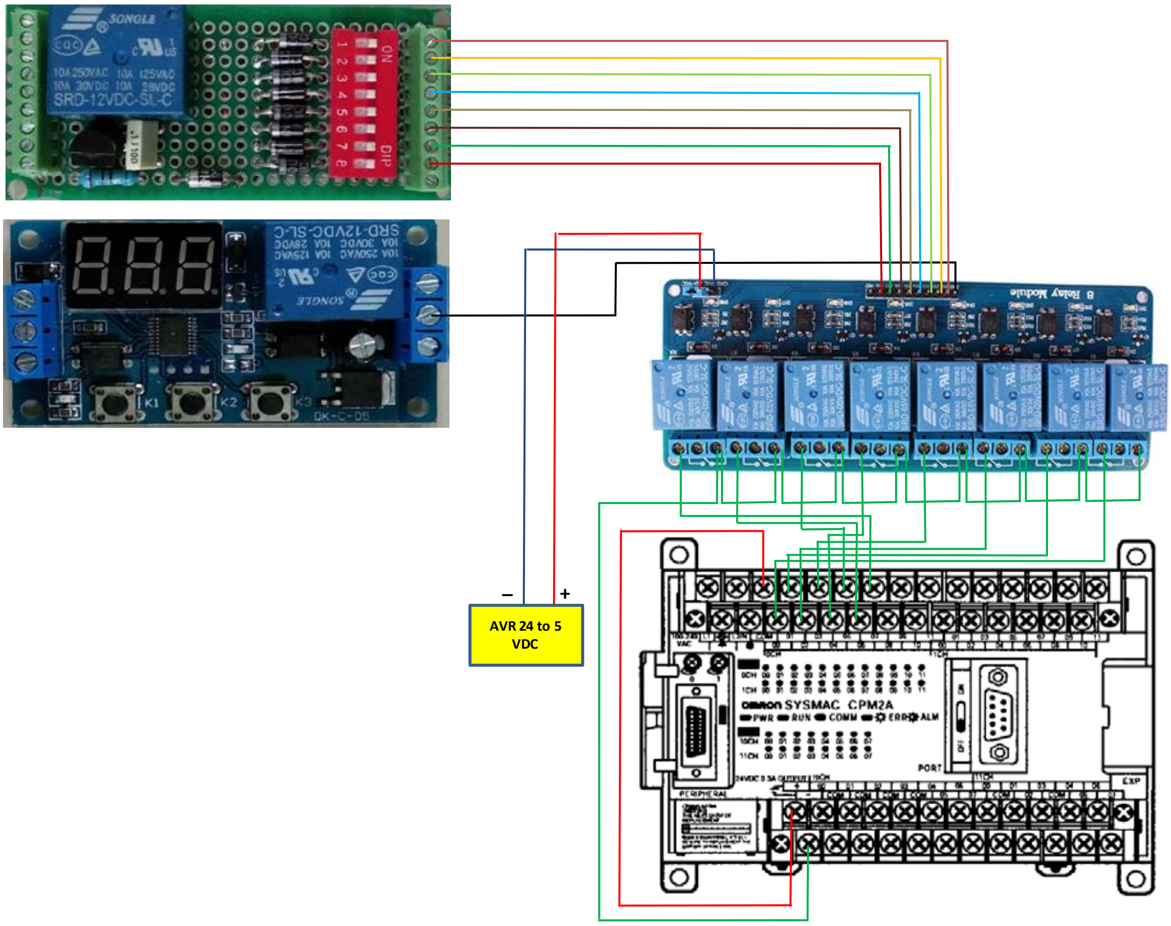

Figure 5. Channel relay module

Figure 7, the bit information that enters both logics 0 and 1 at addresses 0.00 to 0.07 is a binary value that will be converted to hexadecimal with the BCD (24) instruction on Data Memory 0 (DM0). Then the incoming bits for addresses 0.00 to 0.07 can be ascertained apart from binary with a value of 0, a value above 1 then logic 1 will activate LR9.04 which is used as a relay bit to activate the T0003 timer, where this timer functions as a time lag whether the WLD is in the area is a true alarm.

The ladder diagram was created as initials of data representing decimal constant values into initials in the Data Memory (DM), the instructions used is the MOV instruction (21), the value used is #1 to #255 then initialized to DM1 to DM255 which also represents Detector 1 to Detector 255. The P_On instruction is used because the command instructions in this initial data section must always be active or always on the flag as shown in Figure 8 and Figure 9.

To activate the alarm there is only one option, namely when the LR9.04 alarm occurs. On the bell LR9.04 when a logic 1 will activate the 10.00 output, which is the bell output, LR9.02 is used to activate LR.9.03 which will activate T0001, i.e., the timer to pause the alarm time, thereby causing the alarm to

Table 1.
CRM addressing

No.	CRM		Address
	Relay	Logic	
1.	Relay 1	1	0.00
		0	
2.	Relay 2	1	0.01
		0	
3.	Relay 3	1	0.02
		0	
4	Relay 4	1	0.03
		0	
5	Relay 5	1	0.04
		0	
6	Relay 6	1	0.05
		0	
7	Relay 7	1	0.06
		0	
8	Relay 8	1	0.07
		0	

be deactivated. If T0001 is reactivated then the 10.00 outputs will be active again or the bell will ring. When the alarm is in progress and the bell is deactivated, if a new alarm is entered, the bell can be reactivated because LR9.04 is the main input. For

Table 2.
Specification of PLC type Omron CPM2A

Specification	Number
I/O	40
Input	24 DC
Output	16 relays
Power	100-240 VAC

strobe LR9.04 will activate output 10.01 which is the strobe output address on the PLC, output 10.01 will be off if input 1.01 is a logic reset address 1. During the alarm, the strobe will remain active can be seen in Figure 10.

III. Results and Discussions

Testing the device is carried out to determine the performance of each component used. This test is expected to get good results where all components of the plumbing leakage detection system work.

When the start button (channel 1.00) is pressed on the main menu on the HMI screen, the system is completely disabled in monitoring status. While a waterlogging on one floor has crossed the water level limit of 30 mm, the detection rod connected to the water causes a resistance value in the WLD circuit which then puts the transistor in the

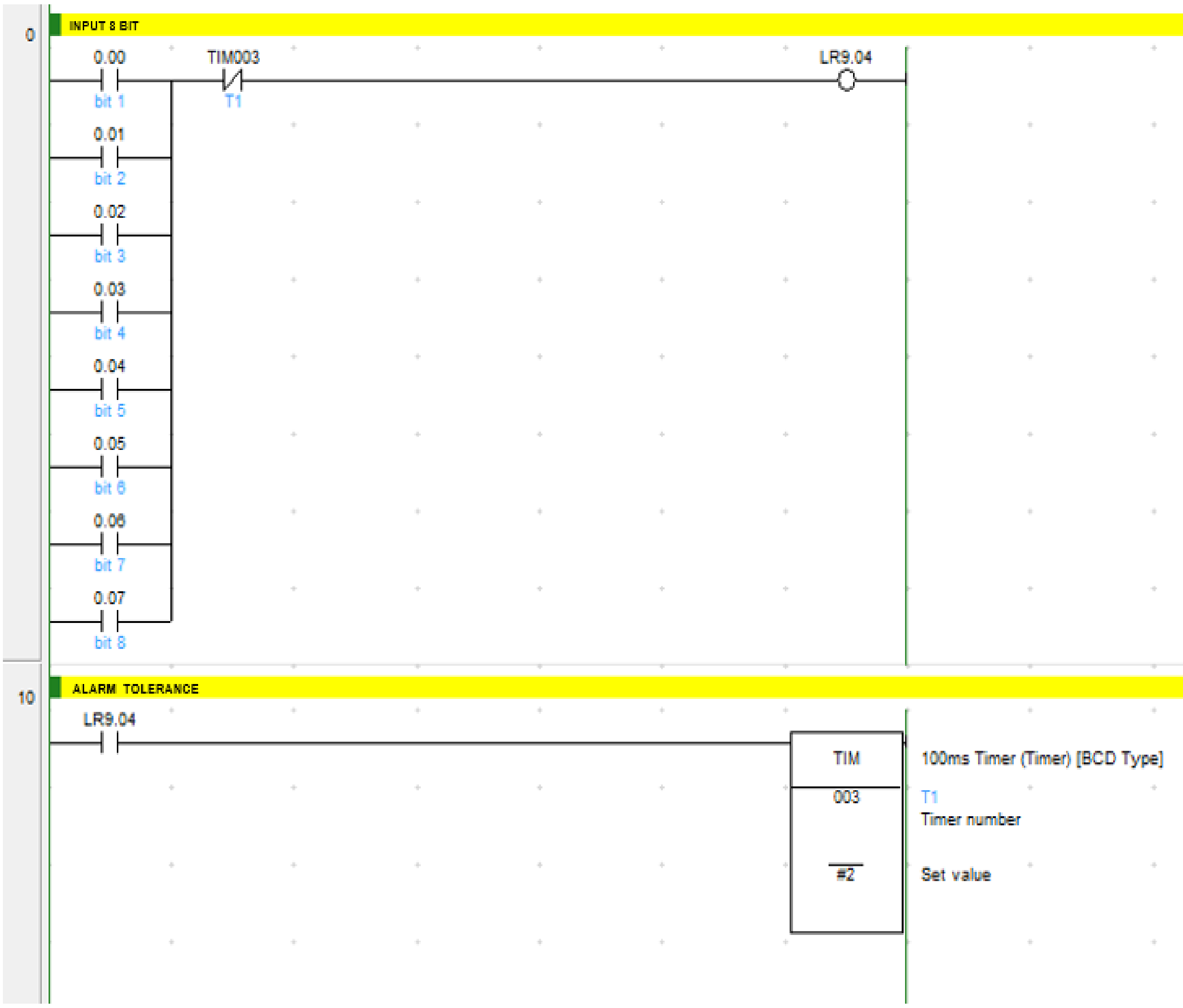

Figure 6. Ladder diagram 1 of detector input

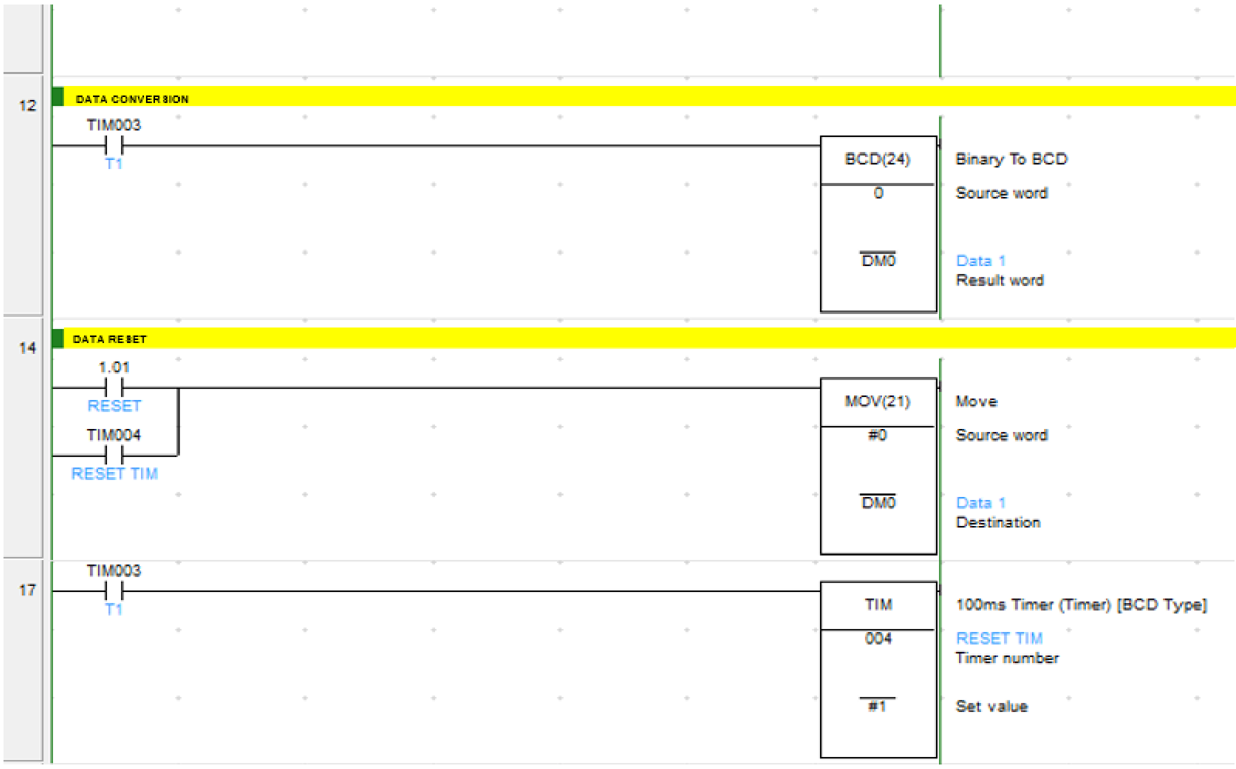

Figure 7. Ladder diagram 2 of detector input

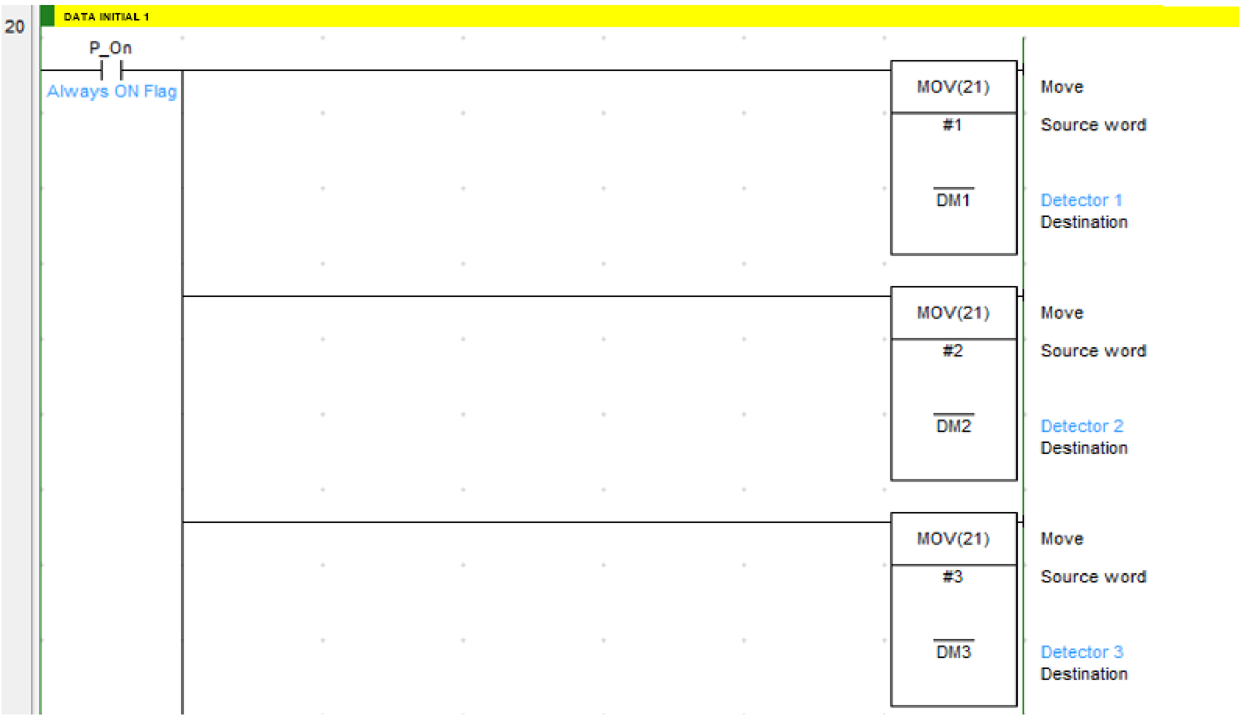

Figure 8. Ladder diagram 1 of initial data

saturation position. This causes the current from the collector of the transistor to flow to the emitter so that the relay coil gets a voltage of 12 VDC and the relay works. Furthermore, the NO terminal on the WLD gives an output of +12 VDC so that it triggers the CRM. The design of this plumbing leakage detection system uses 10 WLDs with addresses 1 to 10.

Active relays on the CRM will send bits to the PLC input group, namely addresses 0.00 to 0.07 (8 bits). The 8-bit signal from the sensor circuit to the PLC is initialized with DM0 and will be compared with DM1 to DM255 which is the initial decimal address 1 to 255. If DM0 is the same as data memory 1 to 255 then the alarm will be active on the screen monitoring status of the WLD with the output address used for alarm status is IR20.00 to IR35.14. The new alarm will still be displayed on the HMI screen, even though the alarm on the other WLD is still in alarm status. While the alarm is active, the PLC activates the bell output (10.00) and strobe (10.01).

A. Power supply measurement

When a 220 VAC power supply which is the main power source is supplied to the system by activating a single-phase miniature circuit breaker (MCB) which supplies a 220 VAC voltage source to the power supply, the system works normally. By measuring three types of power supplies that have three types of power supplies, 12 VDC, 24 VDC, and 5 VDC which makes the PLC ON and connected to the CRM.

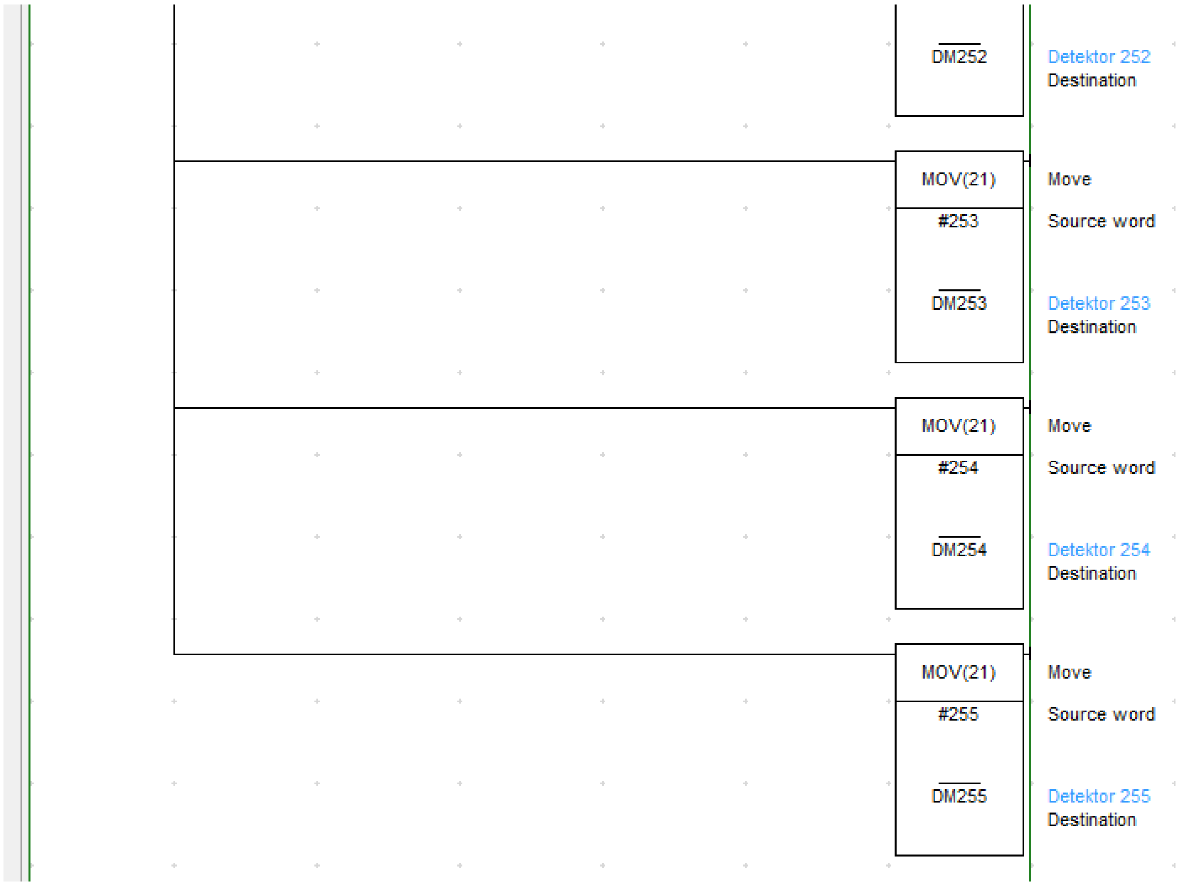

Figure 9. Ladder diagram 2 of initial data

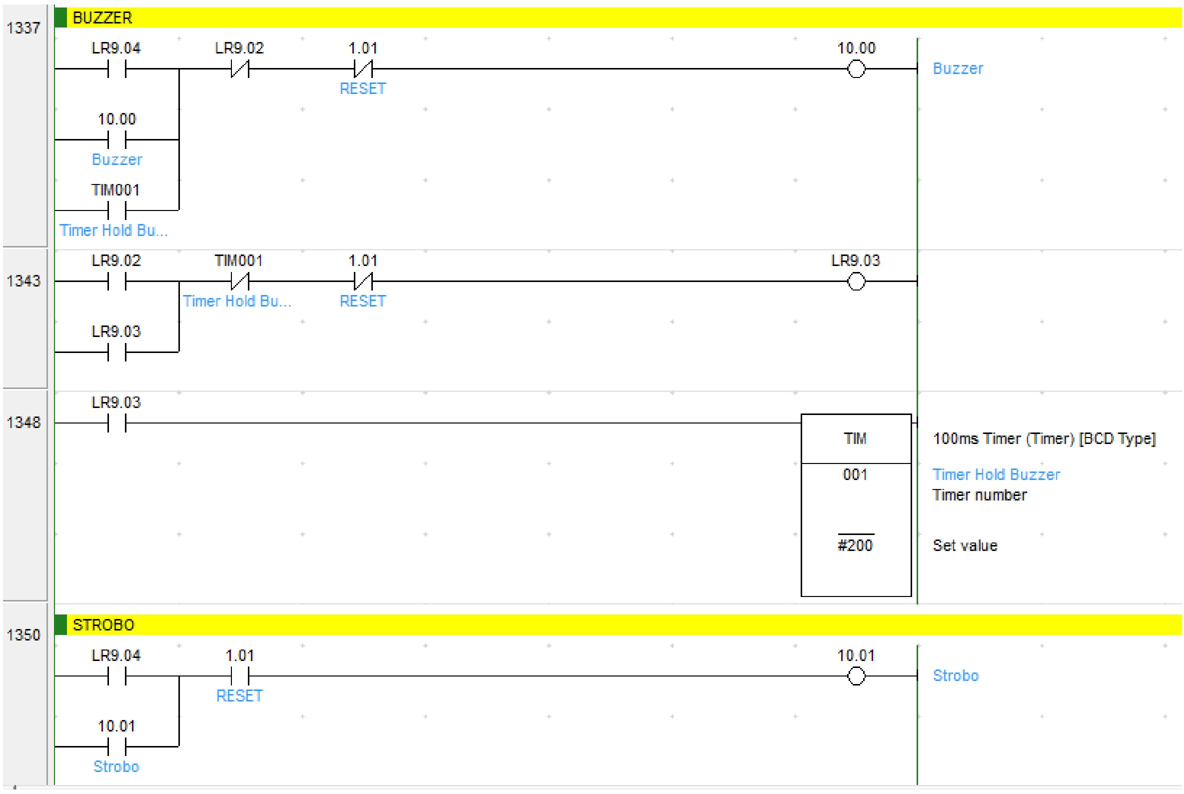

Figure 10. Ladder diagram of alarm

Table 3.
Measurement results of power supply voltage performance

Measurement	V_{input} (V)	V_{output} (V)		Function
		No-load (OFF)	Under load (ON)	
Melan Well LRS-75-24	220	24.2	24	HMI, AVR
Yamasaki	220	12.1	11.8	WLD
ETA-SEI SVM05SC24	24	5.2	5	CRM

In the initial observations, all components after the 220 VAC power supply provided could work well or normally. Measurement of the voltage issued by the power supply is carried out when the system is working (ON) and not working (OFF).

From the results of the power supply measurements in Table 3, it can be analyzed that the output voltage when there is a load (the system is working) decreases by 0.15 to 0.2 VDC when compared to the output voltage when there is no load (the system is not working). This decrease is still within the safe tolerance value of the supply voltage of the components. All power supplies work well because the measurement results in no-load values of 24.2 VDC, 12.1 VDC, and 5 VDC which indicate the output voltage according to the specifications of the power supply.

B. Water level detector measurement

From Table 4, the results of the transistor work measurements can be analyzed. When the electrodes (E1 and E2) are connected by water, the transistor in the WLD module will work as a switch or transistor in saturation position. At saturation, the average collector current (I_c) is 1.73 mA and the base current (I_b) is 117.8 mA while the V_{ce} voltage is 205 mV. In this position, the relay on the WLD will work because the relay coil gets a voltage of 12 VDC. When E1 and E2 is disconnected or not connected, the transistor will be cutoff, i.e., the transistor acts as a switch in the open position. In the cutoff position, it can be seen that V_{ce} has a value of 12 VDC, I_c has a value of 0 mA and I_b has a value of 0 mA. In this position, the relay in the WLD will be off because the relay coil does not get a voltage or 0 VDC.

All transistors can work well because from the measurement results obtained values when saturation V_{cc} has a value of 0.203 to 0.207 VDC, Ic has a value of 116 to 118 mA, and I_b has a value of 1.73 mA and when cut off V_{cc} has a value of 12 VDC, I_c has a value of 0 mA, and I_b has a value of 0 mA which shows the transistor is working properly.

From the measurement results of the CRM in Table 5, it can be analyzed that the relay coil measures 11.8 to 12 VDC. When the relay does not work, the measurement of the relay coil results in 0 VDC, and the breakdown voltage at the NO terminal which should be in the open position is 1.8 VDC.

Even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module with a minimum of 12 VDC. When the relay is not working or off, the measurement at the NC terminal is 12 VDC.

All relays on the CRM are functioning well because from the measurement results, the coil input value is 11.8 to 12 VDC and when the coil does not get a voltage input, the relay will turn off which indicates it is in accordance with the relay specifications.

Table 4.
Measurement results of transistor performance in WLD circuit

WLD	Condition of E1 and E2	Tr	V_{cc} (V)	I_c (mA)	I_b (mA)
1	Connected	Q1	0.205	117.5	1.73
	Disconnected		12	0	0
2	Connected	Q2	0.204	116.8	1.73
	Disconnected		12	0	0
3	Connected	Q3	0.206	117.8	1.73
	Disconnected		12	0	0
4	Connected	Q4	0.205	117.8	1.73
	Disconnected		12	0	0
5	Connected	Q5	0.203	116.8	1.73
	Disconnected		12	0	0
6	Connected	Q6	0.205	117.6	1.73
	Disconnected		12	0	0
7	Connected	Q7	0.206	117.8	1.73
	Disconnected		12	0	0
8	Connected	Q8	0.205	117.8	1.73
	Disconnected		12	0	0
9	Connected	Q9	0.203	117.8	1.73
	Disconnected		12	0	0
10	Connected	Q10	0.206	118.8	1.73
	Disconnected		12	0	0

Table 5.
Measurement results of CRM

WLD	Relay (CRM)	Coil voltage (V)	Contact output (V)	
			NO	NC
1	ON	11.8	12	1.8
	OFF	0	1.8	12
2	ON	11.8	12	1.8
	OFF	0	1.8	12
3	ON	11.8	12	1.8
	OFF	0	1.8	12
4	ON	11.8	12	1.8
	OFF	0	1.8	12
5	ON	11.8	12	1.8
	OFF	0	1.8	12
6	ON	11.8	12	1.8
	OFF	0	1.8	12
7	ON	11.8	12	1.8
	OFF	0	1.8	12
8	ON	11.8	12	1.8
	OFF	0	1.8	12
9	ON	11.8	12	1.8
	OFF	0	1.8	12
10	ON	11.8	12	1.8
	OFF	0	1.8	12

IV. Conclusion

This research resulted in the conclusion that all power supplies work well because the measurement results in no-load values of 24.2 VDC, 12.1 VDC, and 5 VDC which indicate the output voltage according to the specifications of the power supply; all transistors can work well because from the measurement results obtained values when saturation V_{cc} has a value of 0.203 to 0.207 VDC, I_c has a value of 116 to 118 mA, and I_b has a value of 1.73 mA and when cut off V_{cc} has a value of 12 VDC, I_c has a value of 0 mA, and I_b has a value of 0 mA which shows the transistor is working properly, and all relays on the CRM are functioning well because from the measurement results, the coil input value is 11.8 to 12 VDC and when the coil does not get a voltage input, the relay will turn off which indicates it is in accordance with the relay specifications. In this research, it can be seen that even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module, a minimum of 12 VDC is required. In addition, when the relay is not working or off, the measurement at the NC terminal is 12 VDC.

Declarations

Author contribution

Sri Hartanto is the main contributor to this paper, whose role is in designing hardware and software, writing, conceptualization, formal analysis, while Desmayadi helps in designing hardware and software as well as investigations and data validation.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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e-ISSN 2088-6985
p-ISSN 2087-3379

Journal of

Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, 2022

AUTHORS INDEX

The articles in this volume were authored/co-authored by 76 authors from Indonesia, Taiwan, Malaysia, Australia, Germany, South Korea, United Kingdom, Vietnam, Turkey, Thailand, Japan, Philippines, India, and China.

e-ISSN 2088-6985
p-ISSN 2087-3379

e-ISSN 2088-6985
p-ISSN 2087-3379

e-ISSN 2088-6985
p-ISSN 2087-3379

Mechatronics, Electrical Power, and Vehicular Technology

Volume 13, 2022

AFFILIATION INDEX

e-ISSN 2088-6985
p-ISSN 2087-3379

Journal of
Mechatronics, Electrical Power, and Vehicular Technology

INTERNATIONAL PEER REVIEWERS ACKNOWLEDGEMENT

The Editor of MEV would like to thank the wisdom and advice of many individuals who dedicated their considerable time and expertise in safeguarding the quality and high standard of academic integrity of the journal.

We are greatly indebted to the expertise, dedication, and expeditious response of the following individuals for reviewing at least one and, in some cases, many manuscripts for the journal from early 2010 until today.

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e-ISSN 2088-6985
p-ISSN 2087-3379

e-ISSN 2088-6985
p-ISSN 2087-3379

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ISSN 2087-3379
9 772087 337911

Journal of Mechatronics, Electrical Power, and Vehicular Technology, Volume 13, Issue 2, 2022

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5	Ir. Nurhabibah Naibaho, MT	Dosen Tetap Prodi Teknik Elektro
6	Slamet Purwo, ST., MT	Dosen Tetap Prodi Teknik Elektro
7	Lukman Aditya, ST., MT	Dosen Tetap Prodi Teknik Elektro
8	Teten Dian Hakim, ST., MT	Dosen Tetap Prodi Teknik Elektro
9	Bayu Kusumo, ST,MT	Dosen Tetap Prodi Teknik Elektro

Demikian surat tugas ini agar dilaksanakan dengan sebaiknya dengan rasa penuh tanggung jawab.

Jakarta, 5 September 2022
Dekan

DEKAN FAKULTAS TEKNIK * UNIVERSITAS KRISNADWIPAYANA

Dr. Harjono Padmono Putro, ST, M.Kom
NIDN. 0329067102

Tembusan Yth :

1. *Para Wadek FT*
2. *P2M FT*
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4. *Arsip,-*