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RESEARCH ARTICLE

Design and Implementation of a Human Machine Interface Control System for Power Plants

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ABSTRACT - The Industrial Revolution (IR) 4.0 gave birth to various kinds of technology that can be used in applications in various industrial sectors, electricity, energy, and so on. One of them is the world of automation which can make it easier to handle a complex system. Virtual operation and monitoring technology has become a mainstay today, one of which is the Human Machine Interface (HMI). In this research, we will discuss the design and implementation of HMI in electrical power installation system applications which include a three-phase induction motor starting system. The aim of this research is to change the conventional installation system to an integrated digital system where later the system can be operated and monitored with the same devices. The research method used was the initial stage of designing hardware and software in the power system wiring section along with the HMI and PLC programs, and then the final stage was through testing at both stages. The results show that the system can operate the induction motor starting system and provide a trouble alarm with four notifications displayed on the HMI layer when a system failure occurs.

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1.0 INTRODUCTION

In the industrial revolution 4.0, automation systems have been present in the industrial world, commercial buildings, electricity, and homes. In the industry, the system is to support production facilities or production support. Automation is always related toand monitoring systems [1-4]. With the increasing variety of industrial facilities that require automation, a universal control media, which can be applied to all industrial fields becomes a crucial needs [5-8].

In the industrial sector, the application of automation systems has experienced very rapid development. The concept of smart industry is the forerunner of the advancement of the concept of industry 4.0 which is a new bridge to solve various problems in the industry, in terms of technological architecture. The Human Machine Interface (HMI) has undergone significant development over time. It began with basic HMI.1 systems featuring buttons and indicator lights. Subsequent versions include **HMI 2.0**: Based on desktop computerized visualization and touch panels, **HMI 3.0**: An advancement with IoT integration, allowing connectivity with portable devices like mobile phones, and **HMI 4.0**: The pinnacle version, incorporating virtual and augmented reality features. In this type, virtual objects have real effects within the integrated system[9-12].

The world of power plants using HMI can be applied for system monitoring purposes such as detecting temperature, pressure, cooling indicators and so on [13]. For the smart grid field, in monitoring electric power, the system is equipped with Global System Mobile (GSM) as the tools for the data communication [14], HMI is applied to display the electricity stations / solar power plants on the screen including the electrical parameters such as active, reactive power, power factor, voltage waves, rms voltage and current values [15].

This research aims to change the concept of conventional industrial electrical installations (relay-based) to automation based on centralised control. Where in the implemented system there is a monitoring device as well as an HMI-based operation integrated with a control device in the form of a Programmable Logic Controller (PLC) as a setting for various kinds of three-phase induction motor starters such as star/delta, forward/reverse, and Direct ON-Line (DOL).

2.0 METHODS AND MATERIAL

In this research, a system consisting of several types of three-phase induction motor starters is designed. This system will be controlled by using a PLC type Omron CP1L. The PLC is connected via HMI type Omron NB10W-TW01B with RS-232C serial communication cable media. This system can be operated in three conditions. The first condition is that the system is operated manually using a push button mounted on the wall. The second condition is that the system is operated automatically using a PLC by pressing the push button mounted on the control panel. The third condition is that

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the system can be operated and monitored using PLC and HMI. User can operate the system using the push button on the control panel and using the HMI touch screen.

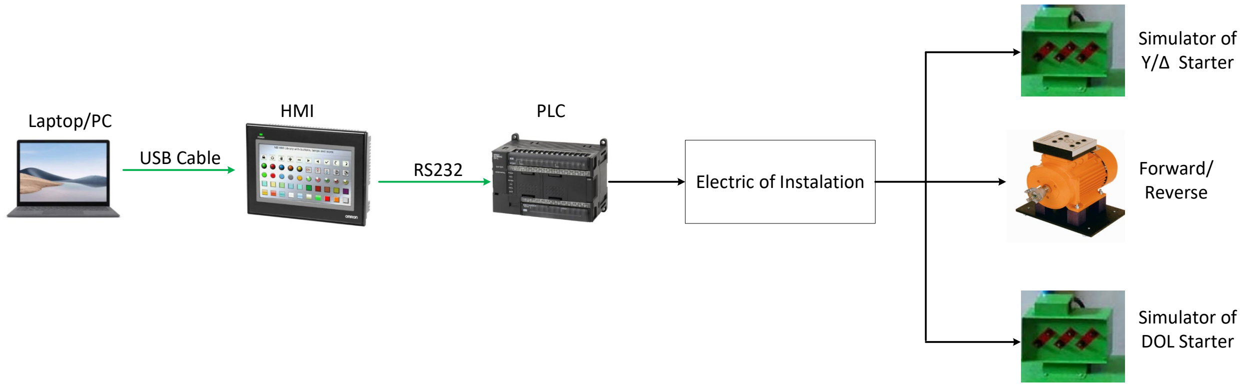

Figure 1. System BlockDiagram

Figure 1 shows the block diagram of the system to be implemented. There is a computer as the main control unit, HMI which is functioned as a medium of monitoring and operation by touch screen, PLC as a control device for various types of ignition, electric of installation is the wiring of the three-phase induction motor ignition system. The operation and monitoring of the power electrical installation system consists of a PLC and HMI circuit as well as a series of induction motor starters in star-delta, forward-reverse, and DOL. PLC and HMI are used to control and monitor induction motor starting through a program that has been designed through CX- Programmer and NB-Designer software.

The program will be uploaded to the CP1L PLC, which communicates via the Human Machine Interface (HMI). The HMI has also downloaded a system overview display using an RS-232C serial cable. This program is designed for operating and monitoring induction motors, as well as motor simulator lights, to determine their operational status. In this methodology section, discuss two main subtopics: hardware design and software design.

2.1 Hardware design

A suitable design is needed to fulfil the desired functionality and is useful for future research development. Figure 2 shows the layout of the hardware design

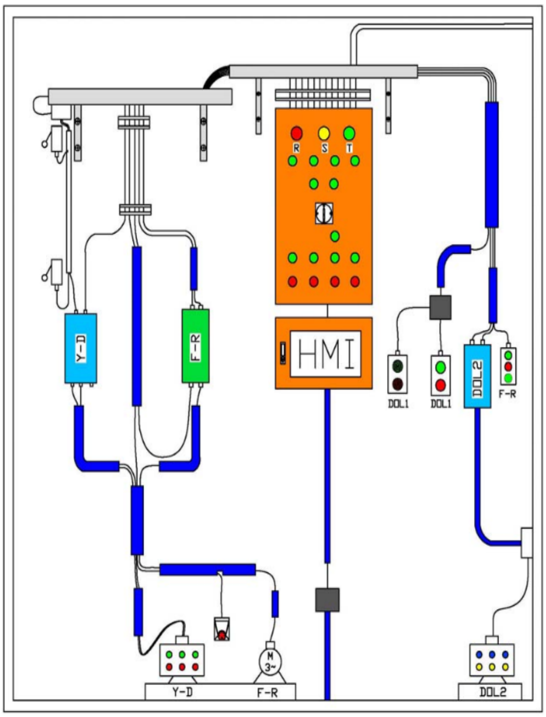

Figure 2. Hardware Layout of Electrical Power Installation System

Figure 2 shows the components for starting the induction motor in star-delta, forward-reverse and DOL modes. Control components include cables, push button, limit switches, indicator lights, contactors, timers, relays, lamp simulators, and induction motors. While the protective part is made of MCB and TOLR.

2.2 Software design

In the software design phase, create a seamless interface for real-time operation and monitoring. When we want to control and observe the system, the Human Machine Interface (HMI) will display a PLC program ladder image alongside relevant information. Figure 3 illustrates the flowchart of operations facilitated by the HMI.

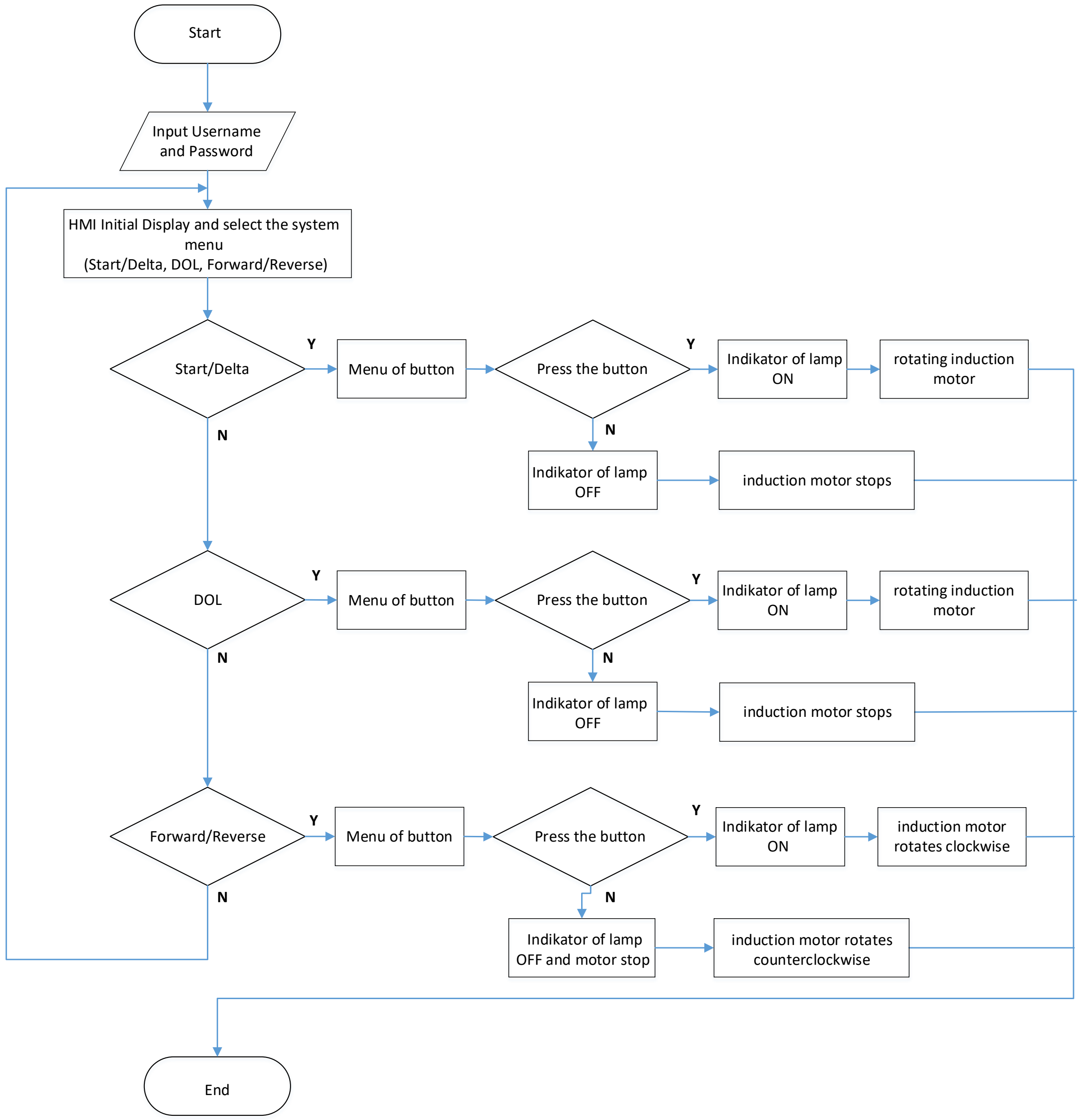

Figure 3. Flowchart on Operation Via HMI

Figure 3 depicts the flowchart for operating the system using the Human Machine Interface (HMI). Within this flowchart, three distinct starting modes are available, including virtual stop and start push button. Here is the detail of the process.

1) Authentication

- The process begins by entering a username and password. These credentials were previously configured through the program script.
- Upon successful login, the user gains access to the system.

2) Motor start menu

- After authentication, the HMI displays the three-phase motor start menu
- Users can select the desired start mode using virtual buttons

Figure 4 represents the initial HMI display following successful login.

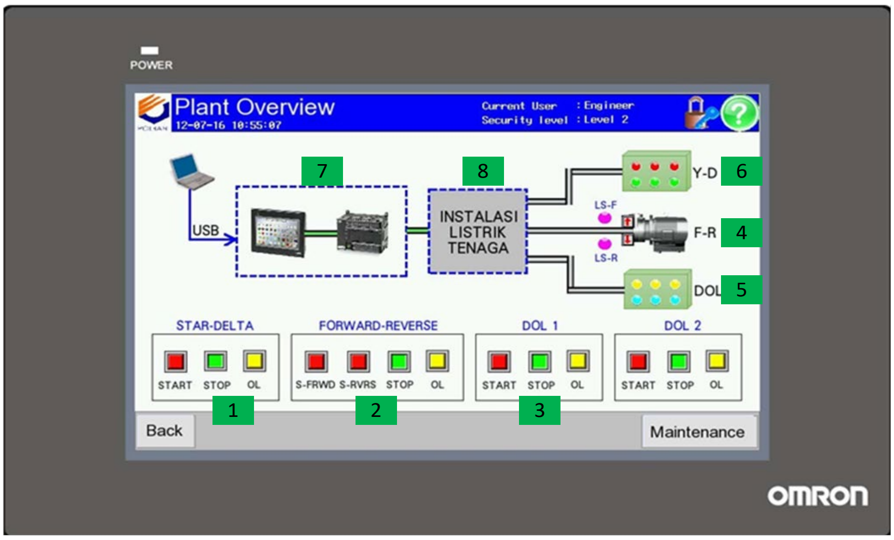

Figure 4. Plant Overview HMI Page

Figure 4 is a display of the plant overview page is the main display of the system created. On this page, users can operate and monitor the system in real time. In this system there are push button and indicator lights as well as virtual motor simulations that show the mechanism of the system. In addition to the monitoring display, another feature is designed to add an event history display to record interference events on the system. The image is on the same page but using a different user. Figure 7 above uses an engineer user while the image below uses an operations user. In the green box, number one is the button display for starting Y/D, number two is the start, stop, forward, reverse, and overload (OL) button, number three is the button for starting DOL 1 and DOL 2, number four is a motorbike visualization image three-phase induction for forward-reverse, numbers five and six are the Y/D and DOL starting simulator in the form of a lamp, number 7 is the control and monitoring system in the form of an HMI and PLC, and number eight is the starting power wiring in a panel.

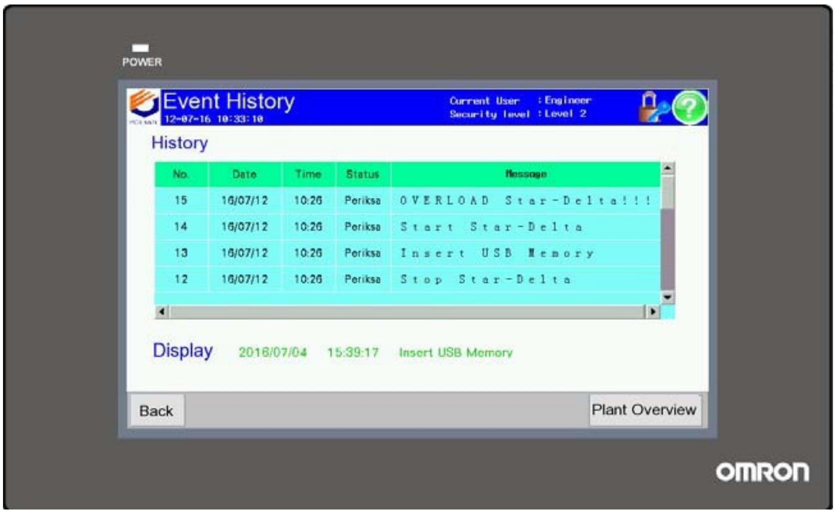

Figure 5. Event History page

Figure 5 shows the page for displaying events in the system. To save events to the history, the event parameters are defined in the database, by selecting Project Database in the Event Setting section. Next is the design of the PLC program which is designed through CX programmer software using a ladder program as shown in Figure 6.

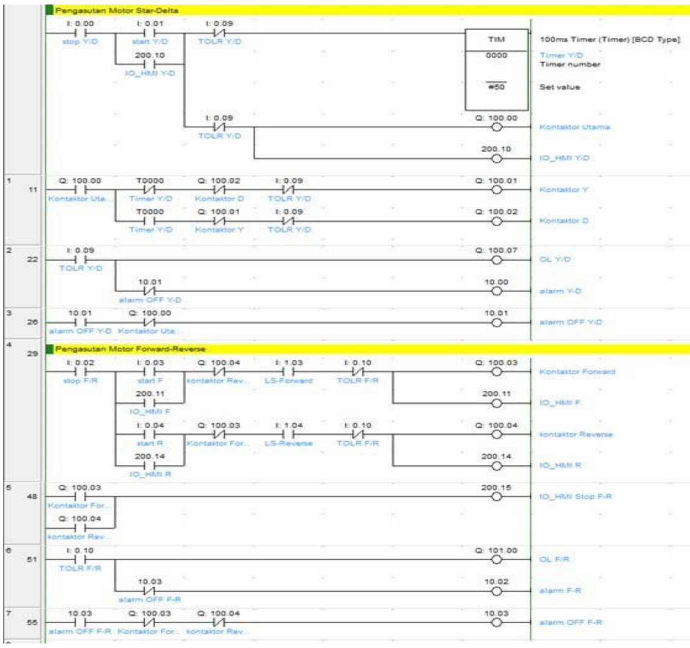

Figure 6. Y/D and F/R Starting Program Ladder

Figure 6 is a ladder program designed by the CX programmer to start a three-phase induction motor with Y/D and F/R starting types. The input codes in the ladder start with the signs 0.01 to 0.04, while the output codes are 100.1-101.0 and 200.01-200.11 and 10.00-10.05. Each input and output code has a different task. The input is assumed to be a push button or switch and the output is a coil to turn on the contactor. Figure 7 is a ladder program for DOL 1 and DOL 2 starting types.

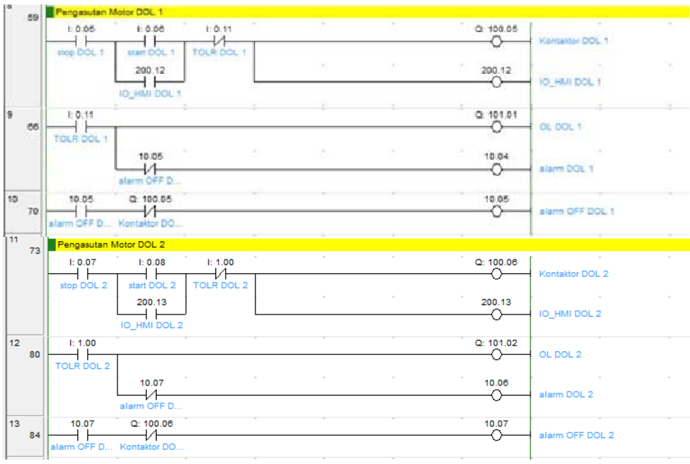

Figure 7. DOL 1 and DOL 2 Startup Program Ladder

Figure 7 is a ladder program designed by the CX programmer to start a three-phase induction motor with DOL starting type. The input codes in the ladder start with the signs 0.05 to 0.11, while the output codes are 100.1-101.0 and 200.01-200.12 and 10.00-10.05.

3.0 RESULTS AND DISCUSSION

Figure 8 shows the implementation of the power electrical installation automation system control panel, which includes an HMI display for total system integration and a system simulator.

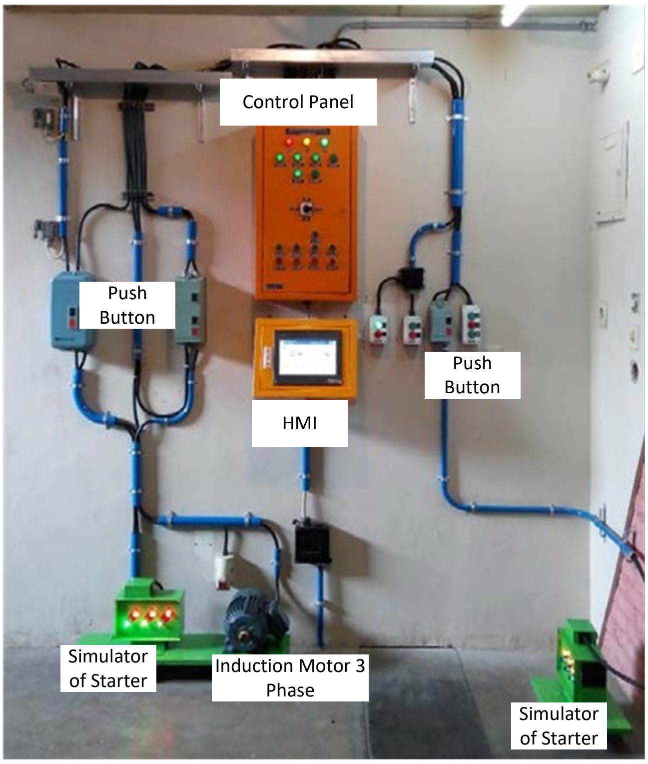

Figure 8. Implementation of Automation System for Electrical Power Installation

To evaluate the effectiveness of our proposed power system installation automation design, present the results in two distinct parts which are Case 1 control panel implementation result and Case 2 overload alarm testing results.

In Case 1, successfully implemented the designed control panel, which serves as the central interface for managing the power system. Testing involved assessing the functionality and responsiveness of the control panel. This included verifying user authentication, navigation, and interaction with various system components. Additionally, rigorously tested the plant overview display. This display provides a comprehensive visual representation of the power plant's status, including critical parameters such as voltage, current, and load distribution.

In Case 2, our system underwent thorough testing to evaluate its behavior during overload conditions. Specifically, examined how the display responded when an overload alarm was triggered. This assessment included visual cues, alerts, and appropriate actions taken by the system. The detail experimental result is discussed below.

3.1 Testing the Plant Overview Display

The tests included operating the on/off button to operate the system, testing the system monitoring indicator lights, testing the operation of the resume button that can only be accessed by new users and maintenance technicians, checking the end-of-trip indicator and finally checking the overload warning. Figure 7 below is the result of testing the operation of the on/off button and indicator lights.

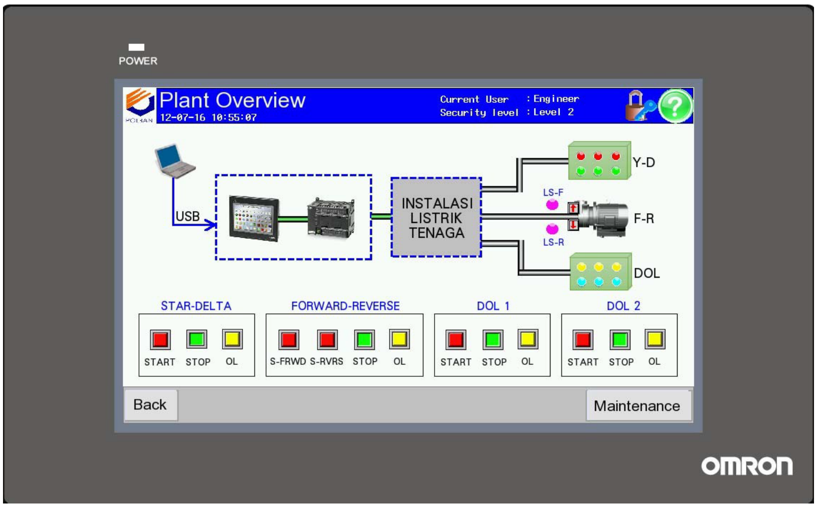

Figure 9. Testing the On/Off Function and Indicator Light

In Figure 9 you can see the power button and indicator light changing color after being pressed. This shows that the power button and indicator lights are working properly. Next is the continue function which can only be accessed by maintenance users and engineers. The images above and below. There is a difference in the image below: the Continue button is not displayed. This shows that the resume function is working properly.

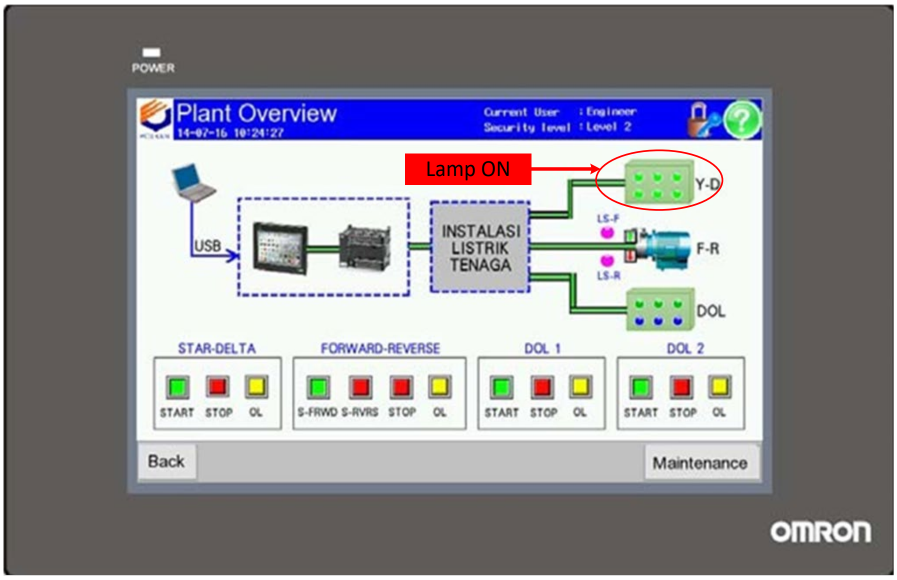

Figure 10. Continue Button Function Testing

Figure 10 shows the test of the continue button with the simulator lights marked at Y/D on the red arrow that all six green lights are on. Then the next test is the limit switch indicator function which will change color to orange when the forward/reverse motor is turned off using the limit switch.

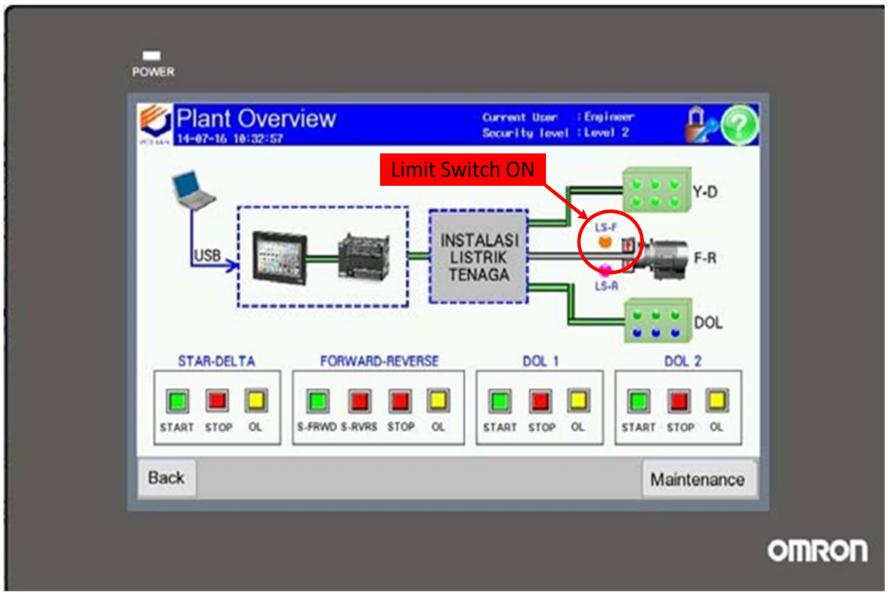

Figure 11. Limit Switch Indicator Function Testing

Figure 11 is a test of the limit switch which indicates a color change on the HMI indicator that the limit switch is working. The image shows a red arrow indicating that the limit switch is active.

3.2 Overload Alarm Page and Display Setting

This test carries out an overload simulation by pressing the test button on TOLR. When an overload disturbance occurs, the HMI will respond by providing a warning in the form of an overload alarm page display to notify the system that is experiencing a disturbance as indicated by an indicator light that is on. The following are the results of testing the normal condition and overload alarm pages.

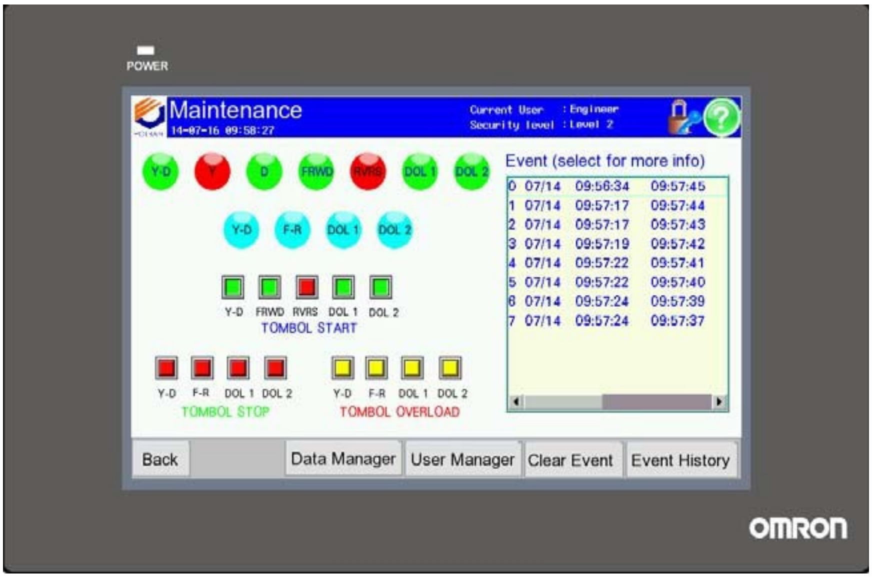

Figure 12. Testing Under Normal Conditions

Figure 12 is a test when the induction motor is in normal condition, as can be seen that when conditions are normal on the motor, the HMI will send a notification with a short message in the form of a time recording when the system condition is running normally.

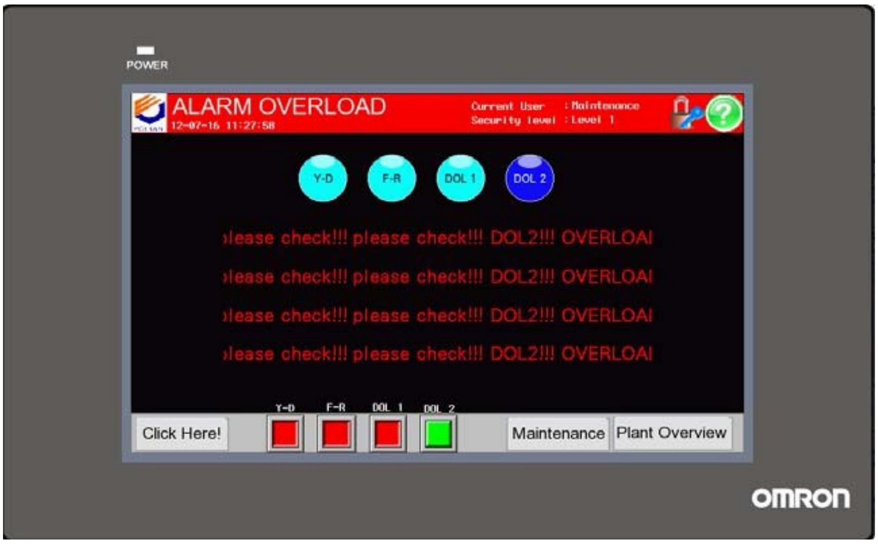

Figure 13. Testing the Overload Alarm Page

Figure 13 is a test when the induction motor is in an overload condition, as can be seen that when a disturbance occurs in the motor, the HMI will send an alarm with a short message in the form of a warning. Warning messages are sent and displayed by the HMI four times.

3.3 Testing Ladder Program PLC in CX Programmer Software

This test displays timing diagrams of the operation of various types of Y/D, F/R, and DOL motor starting. By displaying the timing diagram, you will see an outline of the system operation using the CX programmer software simulation. Figure 12 is a timing diagram for starting Y/D and F/R motors.

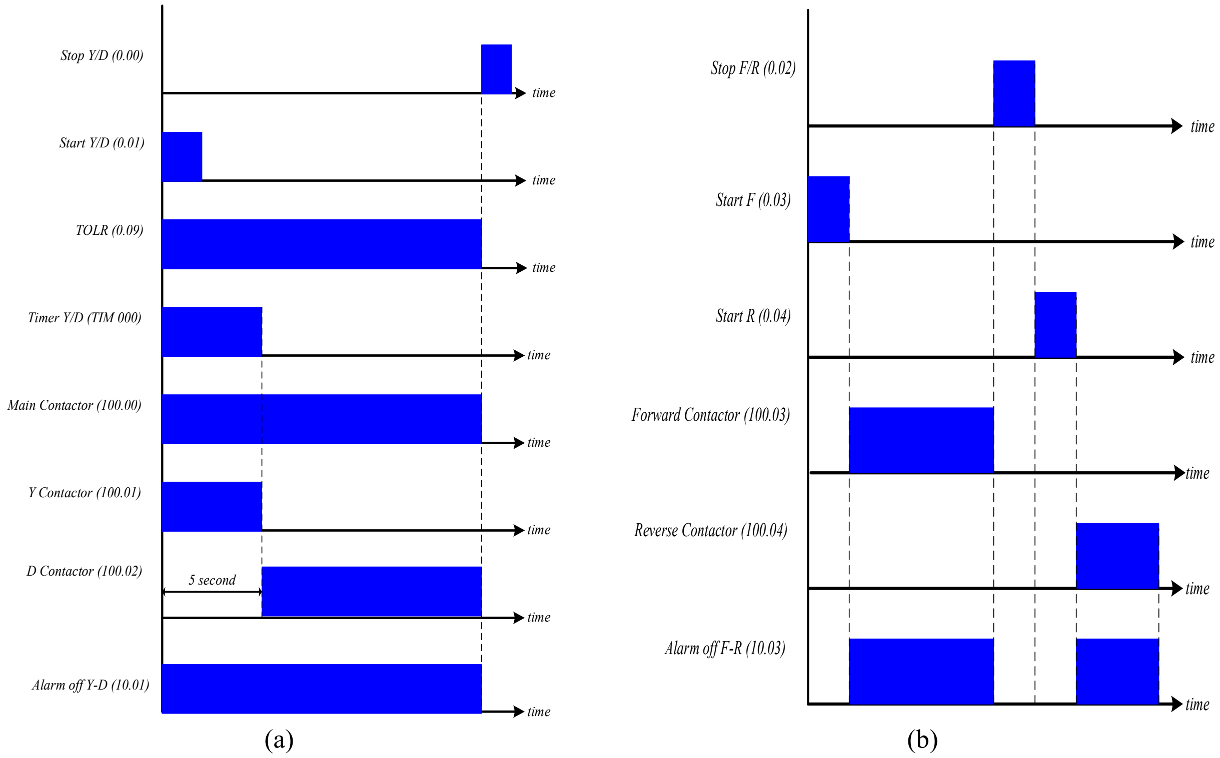

Figure 14. Timing Diagram (a) Starting Y/D (b) Starting F/R

Figure 14 (a) is a form of the Y/D and Figure 14 (b_ F/R type motor starting working system. For Y/D type starting there are two push buttons, namely for start and stop as input, while the output is the main contactor, contactor for Y and contactor for D. When the start push button is pressed it will be active and then the main contactor and contactor for Y will active with a timer that will be active for five seconds, then the starting switch will move from Y to starting D, while the overload and OL (overload) alarms are off, which means the system is in normal condition. Meanwhile, for F/R type starting, there are two start push buttons and one stop push button as input. One push button start for the condition of the motor rotating clockwise which is called start F and a push button start for the condition of the motor rotating anti-clockwise which is called start R. For two contactors, namely the contactor for the motor rotating clockwise (contactor F) and and counterclockwise (contactor R). When the start push button F is pressed, contactor F will be active and contactor R will be off, then the motor will rotate clockwise, when it wants to rotate in the opposite direction then the stop button is pressed then activate the start button R, then the motor will rotate counterclockwise. The overload and OL (overload) alarms are off, which means the system is in normal condition. For timing diagrams, starting types DOL 1 and DOL 2 are as shown in the picture below.

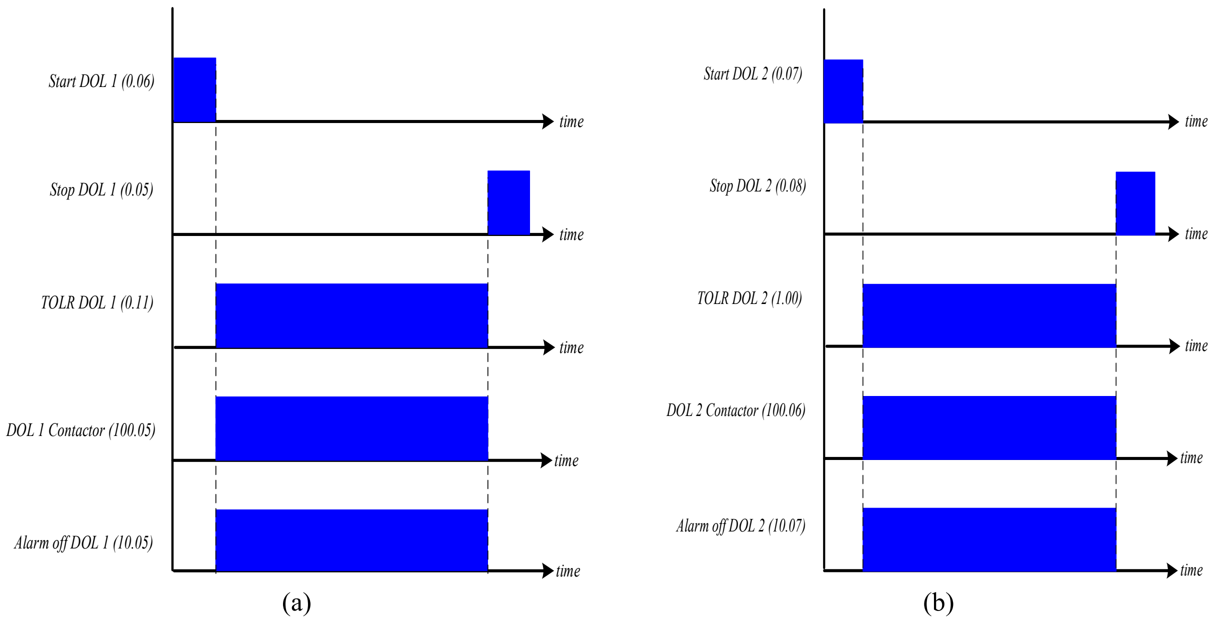

Figure 15. Timing Diagram (a) Starting DOL 1 (b) Starting DOL 2

Figure 15 is a form of the DOL 1 and DOL 1 type motor starting working system. In principle, DOL 1 and DOL 2 have the same operating characteristics. For DOL type starting there are two push button, namely for start and stop as input, while the output is in the form of a main contactor. When the start push button is pressed, it will be active and then the coil on the main contactor is active, then the contact will move to close and current will flow to the three-phase induction motor, while the overload and OL (overload) alarms are off, which means the system is in normal condition. The reliability in terms of device response is very good reaching below two seconds.

4.0 CONCLUSION

Design and Implementation of a Human Machine Interface for Operation and Monitoring in Power Electrical Installation Systems has been successfully designed and implemented which can be automated throughout the system. From the results of the tests that have been carried out, the HMI-based communication system as a monitoring and operating tool between sub-systems has been well integrated, where the control center can monitor the response to the state of each sub-system with indicators in the form of lights on the HMI display during normal conditions or disturbances. When a motor disturbance occurs in the form of overload, the HMI system can display a short message in the form of a warning sign by displaying an alarm four times.

5.0 ACKNOWLEDGEMENT

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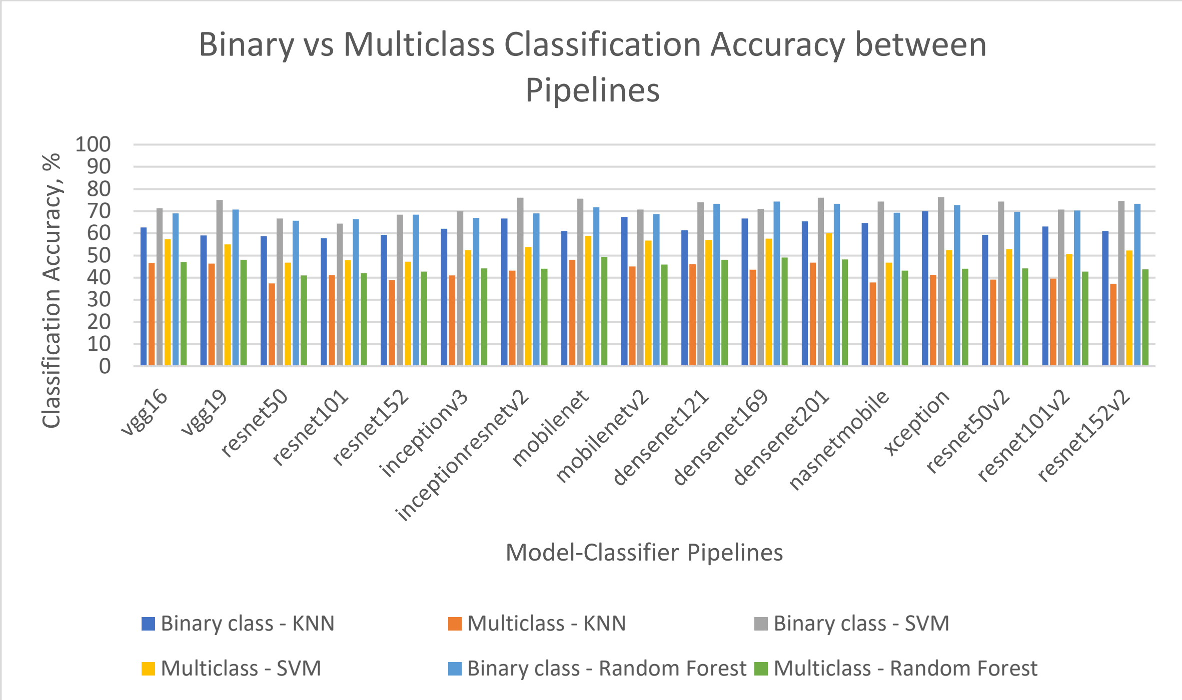

Figure 4. Experiment Results

The careful procedure of dataset optimization and classifier selection was essential for the multiclass categorization of ICH types. A diversified dataset was required, and computational restrictions were balanced by including 1000 images in each class. Strong generalization was demonstrated by MobileNet and DenseNet201, which were found to be promising options. The experiment also brought attention to persistent issues including dataset heterogeneity and class imbalance, highlighting the necessity of constant improvement and optimization. MobileNet distinguished itself in the field of multiclass classification using the KNN classifier by achieving the greatest testing accuracy, demonstrating its capacity to identify a wide range of patterns. The outcomes highlighted how difficult it is to achieve high accuracy in this challenging endeavor. Xception, on the other hand, was the best performance as identified by the SVM classifier, demonstrating its ability to extract and generalize features efficiently. DenseNet201 demonstrated strong performance as well, highlighting the necessity of closely balancing the demands of classifier performance, processing capacity, and dataset features.

The study concludes that, with a classification accuracy of 76.33%, the XceptionSVM pipeline is the most efficient method for binary classification jobs. However, the DenseNet201-SVM pipeline achieves a 60% classification accuracy, outperforming competing models for multiclass classification problems. These results emphasize the significance of choosing the right pipeline based on the particular classification task in order to optimize performance and accuracy.

The study's findings provide potential routes for future investigation. Model refinement could benefit from further investigation, including sophisticated pre-processing approaches and innovative transfer learning architectures. Furthermore, understanding the impact of hyperparameter tuning and optimizing classifier performance may lead to more accurate and reliable ICH detection models. Essentially, the goals of the study are emphasized in the conclusion, which emphasizes the need for ongoing development and improvement in the field of medical picture analysis.

Advancements in technology and complex datasets require continual study and development to provide accurate diagnostic tools for healthcare practitioners detecting intracranial hemorrhages.

4.0 CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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