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i-JaMCSIIX
2023

EXTENDED ABSTRACT BOOK

Publication Date: 30 March 2024
ISBN: 978-967-15337-0-3

https://jamcsiix.uitm.edu.my

i-JaMCSIIX 2023

INTERNATIONAL JASIN MULTIMEDIA & COMPUTER SCIENCE INVENTION AND INNOVATION EXHIBITION (I-JaMCSIIX) 2023

EXTENDED ABSTRACT

ISBN: 978-967-15337-0-3
i-JaMCSIIX
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PLC-Based Water Filling Machine Simulator for Teaching and Learning Activities

Kamaru Adzha Kadiran[1], Rozi Rifin[2], Mohamad Zhafran Hussin[3], and Ezril Hisham Mat Saat[4]

[1,2,3,4] Universiti Teknologi MARA, Cawangan Johor, Kampus Pasir Gudang

adzha7379@uitm.edu.my, rozir7625@uitm.edu.my, mzhafran@uitm.edu.my, ezril@uitm.edu.my

***Abstract*— The Omron PLC-Based Water Filling Machine Simulator is an innovative educational tool poised to revolutionize industrial automation education. This simulator offers an immersive and practical learning experience, making it an invaluable asset for educational institutions, trainers, and individuals seeking to gain hands-on expertise in PLC programming and industrial automation processes. The conventional approach to teaching Programmable Logic Controller (PLC) programming and industrial automation has often suffered from a lack of hands-on practice, hindering the development of practical skills among learners. To address this educational gap, this study introduces the Omron PLC-Based Water Filling Machine Simulator, aiming to revolutionize the way industrial automation education is delivered and elevate the effectiveness of PLC programming instruction. The primary objective of this study is to design and create a highly realistic simulator that accurately emulates the operation of a water filling machine commonly found in industrial settings. Besides, it's used to facilitate hands-on PLC programming practice by seamlessly integrating Omron PLC technology and offering diverse programming challenges. A comprehensive review of industrial automation processes, PLC programming principles, and existing simulators informed the design and functionality of the simulator. Utilizing cutting-edge software development tools, a dynamic and user-friendly interface was created, allowing users to interact with the virtual water filling machine. The simulator accurately replicates the behavior of industrial components, including conveyors, sensors, pumps, valves, and tanks. A diverse set of programming challenges, ranging from basic ladder logic to advanced tasks involving timers, counters, and sequential control, was incorporated. The Omron PLC-Based Water Filling Machine Simulator has demonstrated remarkable success in enhancing teaching and learning activities in industrial automation. Learners gain a profound understanding of PLC programming principles and industrial automation processes through interactive, hands-on experience. The simulator effectively fosters users' problem-solving abilities by challenging them to address simulated faults and optimize system performance. Apart from that, users develop practical skills in configuring, programming, and troubleshooting Omron PLCs, preparing them for real-world applications. The Omron PLC-Based Water Filling Machine Simulator has emerged as a transformative tool for industrial automation education. It bridges the gap between theory and practice by providing a realistic, interactive learning environment. This simulator not only enriches educational curricula but also prepares learners to excel in the field of industrial automation, contributing to the advancement of modern manufacturing processes. Embracing this innovation ensures that the future of industrial automation education is dynamic, engaging, and highly effective.**

Keywords—PLC, Simulator, Water Filling Machine, Automation, Education, CX Programmer, CX Designer

I. INTRODUCTION

In the world of modern industry and manufacturing, the integration of automation and control systems is paramount. Programmable Logic Controllers (PLCs) play a pivotal role in ensuring the precision and efficiency of various processes, including those within the domain of liquid filling and packaging. To facilitate effective teaching and learning activities in this dynamic field, the development of a PLC-based Water Filling Machine Simulator is an invaluable resource. This innovative simulator is designed to provide a comprehensive educational platform for students, trainees, and individuals interested in mastering the intricacies of PLC operation and programming in the context of a water filling machine. Water filling machines are representative of a wide range of liquid packaging processes, and understanding their control systems is fundamental to industries such as beverages, pharmaceuticals, and cosmetics. The PLC-Based Water Filling Machine Simulator serves as an interactive and immersive tool that replicates the operation of a real-world water filling machine. It allows users to gain hands-on experience without the need for physical machinery, eliminating potential safety hazards and equipment wear and tear. This simulator offers a dynamic and risk-free environment for learners to explore and apply PLC programming principles, monitor

system performance, and troubleshoot issues. One of the key advantages of this simulator is its adaptability for various teaching and learning scenarios. It can be utilized in educational institutions, technical training centers, and even within corporate training programs. The simulator provides an excellent foundation for beginners to grasp the basics of PLC programming and gradually progress to more complex tasks, while also serving as a valuable tool for experienced professionals seeking to enhance their skills and troubleshoot real-world scenarios.

II. MATERIALS

In Fig. 1, the block diagram representation of the Water Filling Machine is illustrated. This project entails the utilization of numerous input and output elements. On the input side, it includes push buttons, proximity sensors and an ON-OFF switch, while the output section comprises a DC motor for conveyor, a green indicator light and control valves for water tanks. The microcontroller employed for this project is the OMRON CP1H. Within the OMRON PLC CP1H controller, Table 1 furnishes the essential address allocation for both input and output components. This allocation plays a pivotal role in facilitating accurate ladder programming, thus guaranteeing the precise functionality of input buttons and output components, while simultaneously averting the occurrence of errors that might stem from any incorrect address assignments. The construction of the system model was accomplished using the OMRON CX-Designer and CX-Programmer software tools. Omron CX-Designer focuses on the creation of the graphical user interface (GUI), making the simulator visually and functionally resemble a real water filling machine. On the other hand, CX-Programmer is responsible for developing the underlying logic that controls the simulator's operation, enabling it to respond to user inputs and generate realistic outcomes. Together, these software tools create an immersive and educational experience for users learning about water filling machines and industrial automation.

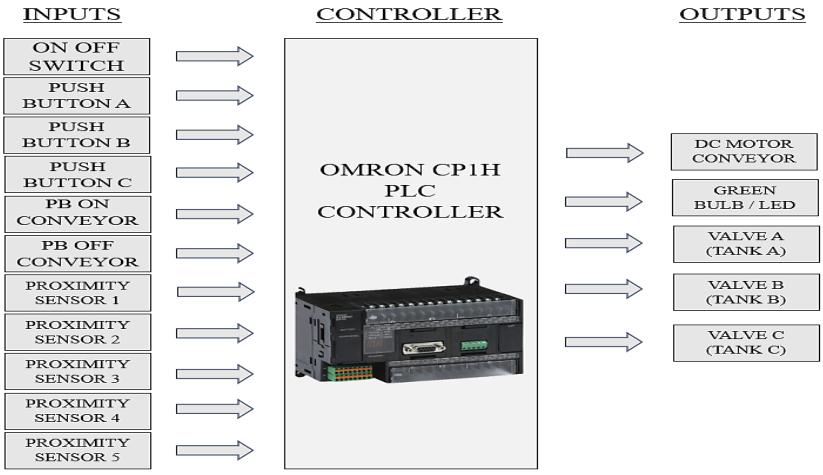


Fig. 1: Block diagram of the PLC-based water filling machine simulator

Table 1. PLC Omron CP1H address assignment for input and output components

Inputs and outputs assignment					
Inputs	**Address**	**Inputs**	**Address**	**Outputs**	**Address**
ON and OFF switch	0.00	Proximity sensor 1	111.06	DC Motor (conveyor)	212.00
Push button A	0.02	Proximity sensor 2	111.03	Green bulb	100.00
Push button B	0.03	Proximity sensor 3	111.04	Valve A (Tank A)	100.01
Push button C	0.04	Proximity sensor 4	111.05	Valve A (Tank B)	100.02
Push button ON (conveyor)	0.05	Proximity sensor 5	0.11	Valve A (Tank C)	100.03
Push button OFF (conveyor)	0.06				

III. METHODS

The graphical user interface (GUI) of the water filling machine simulator was meticulously designed to faithfully replicate an authentic automation system commonly found in the food and beverage industry. The design process commenced with the initial phase of identifying the system's components, which were subsequently translated into a comprehensible block diagram, as visually represented in Fig. 1. The simulator encompasses a total of eleven input components, featuring ON and OFF switches, push buttons labeled A, B, and C, conveyor activation and deactivation switches, and a set of five proximity sensors (1 to 5). Complementing these inputs is an OMRON PLC controller, specifically the CP1H model. The simulator's output components include a DC motor for conveyor operation, a green indicator light, and three control valves designated for tanks A, B, and C, respectively. The development of the simulator's graphical user interface (GUI) was executed using the CX-Designer software, as depicted in Fig. 2, based on the block diagram and input-output address assignment previously illustrated in Fig. 1 and Table 1, respectively. The GUI was fashioned to emulate the controls and displays of a typical water filling machine found in the food and beverage industry. To activate the simulator's operational capabilities, it necessitates the

implementation of ladder diagram programming through the CX-Programmer software. Students are assigned the task of formulating a comprehensive water filling process and associated algorithm using ladder logic programming. This algorithm's design should conform to predefined specifications, while students are encouraged to employ ingenuity by leveraging timer and counter functions and structuring the sequence within the ladder diagram programming. Fig.3 shows some part of logic diagram sample for water filling simulator developed by the students using CX-Programmer.

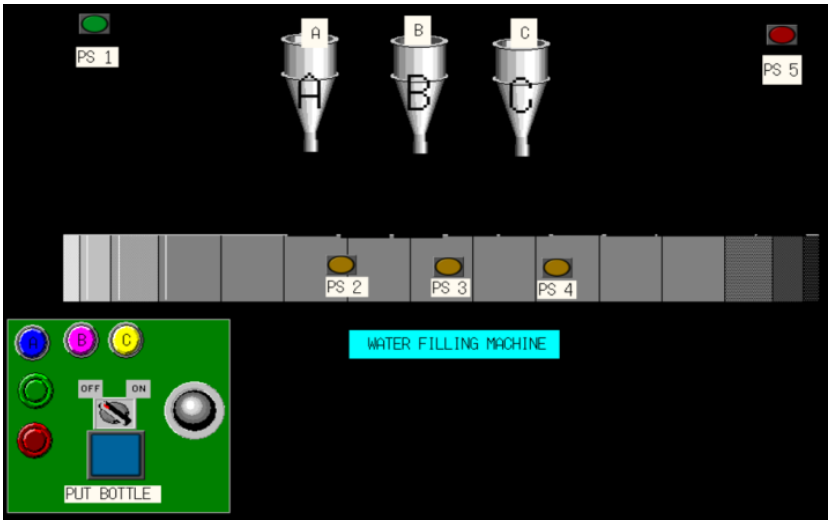


Fig. 2. Graphical user interface (GUI) for PLC-based water filling machine simulator

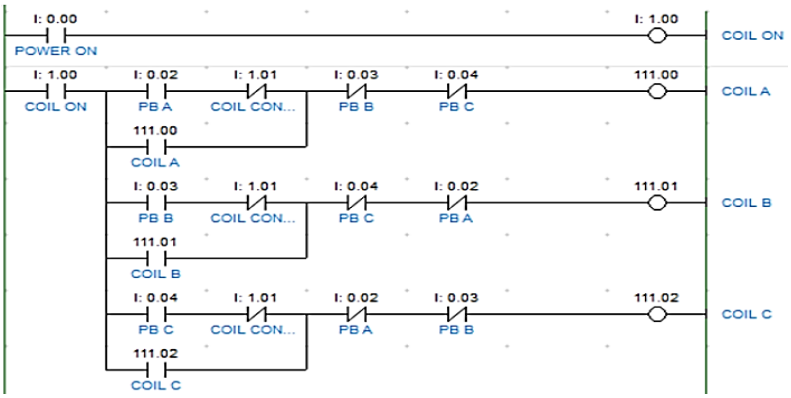
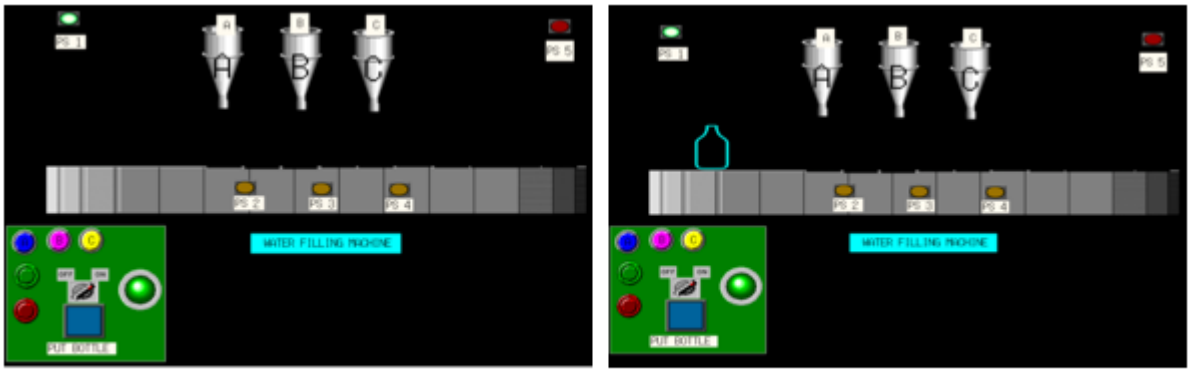


Fig.3. Part of logic diagram sample for water filling simulator developed using CX-Programmer

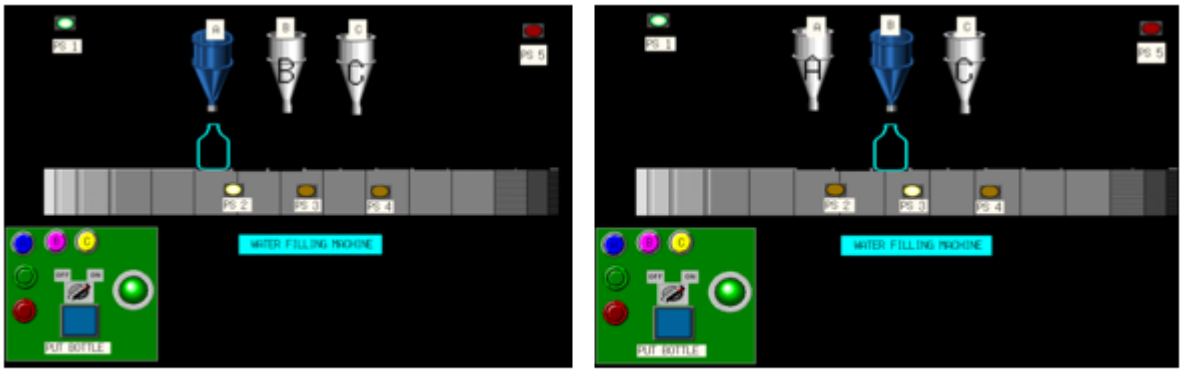
IV. RESULTS AND FINDINGS

Fig. 1 presents the initial interface of the system's graphical user interface (GUI), which was created through the CX Designer software. In this state, none of the components were operational. This aligns with the predefined logic in the PLC ladder diagram, wherein all components are programmed to engage their functionality exclusively upon the activation of the main switch. Fig. 4a illustrates the outcome of the project upon switching it on. As indicated in the figure, the activation of the main switch triggers the illumination of the green LED, signifying that the system is prepared for operation. Upon pressing the 'Put Bottle' button, the Proximity Sensor labeled as PS 1 is initiated. This sensor is responsible for detecting the presence of a prepared bottle, signaling the commencement of the system's processing cycle. In this system, three drink options are made available for user selection. Once PS 1 is activated, users are given the choice to press either Button A, Button B, or Button C, all conveniently located on the control panel as shown in Fig. 4b. Upon making their selection and pressing the Green Button situated on the left side of the panel, the conveyor is set in motion. This action ensures that the bottle will be filled when it reaches the designated water tank chosen by the user. Fig. 5a portrays the scenario when a user selects drink A. As this choice is made, the conveyor is set into motion, and it will come to a halt upon detection by PS 2. In accordance with the PLC ladder diagram, PS 2 serves as the critical sensor responsible for ensuring that the conveyor ceases its movement precisely when it arrives beneath Water Tank A, facilitating the filling of the bottle with drink type A. The timer has been configured to a duration of 5 seconds to complete the filling of a full bottle of the drink.This similar process occurred for the selection of drink B and drink C as shown in Fig. 5b. Finally, the conveyor concludes its operation at PS 5, where a sensor detects the bottle, marking the moment for user retrieval.



(a) (b)

Fig.4.(a) Simulator GUI condition when switch is ON. (b) GUI condition when 'Put Bottle" button is pressed



(a) (b)

Fig.5.(a) Simulator operation when user select a drink A (b) Simulator operation when user select a drink B

V. CONCLUSIONS

The development of a PLC-Based Water Filling Machine Simulator utilizing Omron CX-Designer and CX-Programmer represents a significant step forward in enhancing education and training in the field of industrial automation, particularly in higher learning and Technical and Vocational Education and Training (TVET) institutions. This simulator offers a hands-on and immersive learning experience, providing students with the opportunity to gain practical knowledge and skills in a controlled and safe environment. It equips the future workforce with the skills needed to excel in the field of industrial automation, ensuring that they are well-prepared to meet the demands of the industry and contribute to its continuous growth and innovation.

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