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Development of DCS SCADA Module for Factory I/O Pick and Place XYZ Case Based on Siemens S7-1200 PLC and HMI Excel Link

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Abstract—**The DCS SCADA course plays a significant role in the latest curriculum introduced at Politeknik ATI Makassar in 2022. However, the utilization of real plant instrumentation in industrial environments often proves costly. To overcome this cost barrier, this research develops a DCS SCADA module employing an industrial simulation application, namely the virtual plant Factory I/O, with a case study involving Pick and Place XYZ. This scenario entails the placement of boxes onto pallets using a three-axis robotic manipulator. The module utilizes the PLC Siemens S7-1200 as the control device and HMI Excel Link as the supervisory device. To detect the boxes and parts, two retroreflective sensors are employed, with three conveyors facilitating transportation and a robotic pick and place arm moving in three XYZ axes. Through integrated procedural testing, the system's performance evaluation demonstrates a 100% success rate (OK status).**

Keywords—DCS, SCADA, PLC Siemens S7-1200, HMI Excel Link, Pick and Place

I. Introduction

DCS SCADA course has become an integral part of the 2022 curriculum at Politeknik ATI Makassar. The primary focus of this course is to deepen the understanding of human-machine interface (HMI) design and the connection of controllers such as PLC to HMI using Open Protocol technologies like Modbus and OPC. Over time, PLCs have evolved rapidly from simple smart relays to complex systems with features such as process control, distributed control systems, motion control, and increasingly complex networks [1].

There is a growing interest in connecting PLCs across vendors, especially through the utilization of Modbus protocol, which allows efficient communication across various network architectures, including serial connections like ethernet TCP/IP [2], [3]. The use of Modbus protocol enables effective interaction among various devices such as PLCs, HMIs, control panels, drivers, motion controls, and other I/O devices [4]. Additionally, the use of gateways facilitates communication between different bus types or networks using the Modbus protocol, with potential applications including areas such as Pick and Place XYZ.

On the other hand, Microsoft has developed Object Linking and Embedding (OLE) Automation, replacing Dynamic Data Exchange (DDE). OLE enables communication between application objects between clients and servers [5]. With this technology, application programs within the Microsoft environment can interact with each other, providing extensive interaction capabilities between different programs. Therefore, this research focuses on exploring the potential of PLC Siemens S7-1200 and HMI Linking Excel in the automation industry.

Several previous studies have highlighted the importance of integrating PLCs with virtual plants and other communication technologies in the automation industry. For instance, research by Sudirman [6] developed DCS SCADA teaching materials using Virtual Plant Factory I/O, specifically a Color Sorter Station controlled using PLC Siemens S71200. However, this study integrated Factory I/O with PLC without computer monitoring. Similarly, research by Buwarda [7] developed DCS SCADA teaching materials

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using Virtual Plant Factory I/O for a water tank with control and monitoring using NI LabVIEW. However, this study integrated Factory I/O with NI LabVIEW on the same computer.

Additionally, research by Sukirman [8] developed DCS SCADA teaching materials using Virtual Plant Factory I/O for a palletizer controlled by PLC Siemens S7-1200 and monitored using Aveva Intouch. This study applied state diagram algorithms as logic ladder and integrated Factory I/O, PLC, and Aveva Intouch on the same computer. However, the development of HMI using Aveva Intouch HMI was not familiar to teachers and students, thus deemed unsuitable for laboratory learning processes.

Based on this complexity, this research aims to design a DCS SCADA learning module with a "Pick and Place XYZ" case study, based on PLC Siemens S7-1200 and HMI Linking Excel. This research will integrate Factory I/O, PLC, and HMI with Excel Link using state diagram methods as its ladder logic. The use of HMI technology in the form of Excel Link is highly suitable for laboratory learning as it is already familiar to both teachers and students.

II. Research Methodology

This research was conducted between August and December 2023 at the Control and Automation Laboratory, Politeknik ATI Makassar. The study involved various software and hardware components. In terms of software aspects, TIA Portal, PLC SIM, Factory I/O, KEPServerEX, and Excel were used for system simulation and analysis.

As for hardware components, they included laptops/PCs, screwdrivers, crimping pliers, and multimeters. The main modules used were the Siemens S7-1200 PLC CPU 1214C AC/DC/RLY, along with other devices such as the TL-SF1008D switch, Belden Cat 5E UTP cable, and the I/O Trainer module with four 24VDC push buttons and four 220VAC pilot lamps. The integration of these tools and materials was carefully executed to support the development of the tested system.

This research employed an experimental approach conducted in two phases: the tool design phase and the tool testing phase.

A. Design Technique

The hardware consisted of two main modules, namely the Siemens S7-1200 PLC Trainer Module and the I/O Trainer Module, which included four 24VDC push buttons, four 220VAC pilot lamps, and terminal blocks for easy wiring. The connection between the PLC and the Virtual Plant Sorting Station in Factory I/O was established via a cross-type Ethernet LAN cable, linking the PLC to devices such as the belt conveyor (box feeder), roller conveyor (pallet feeder), two roller conveyors (exit conveyor), and Pick and Place for material transfer from one location to another. The system design was illustrated in block diagrams, Factory I/O I/O List, flowcharts, and state diagrams (Figures 1, 2, and 3).

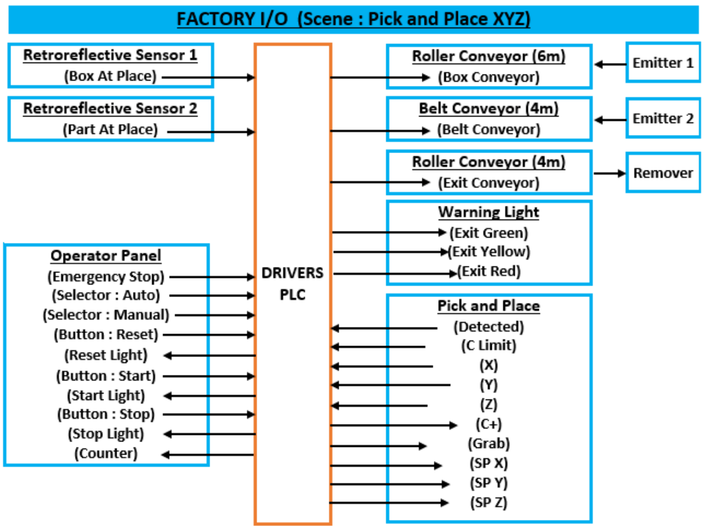

Figure 1. System block diagram

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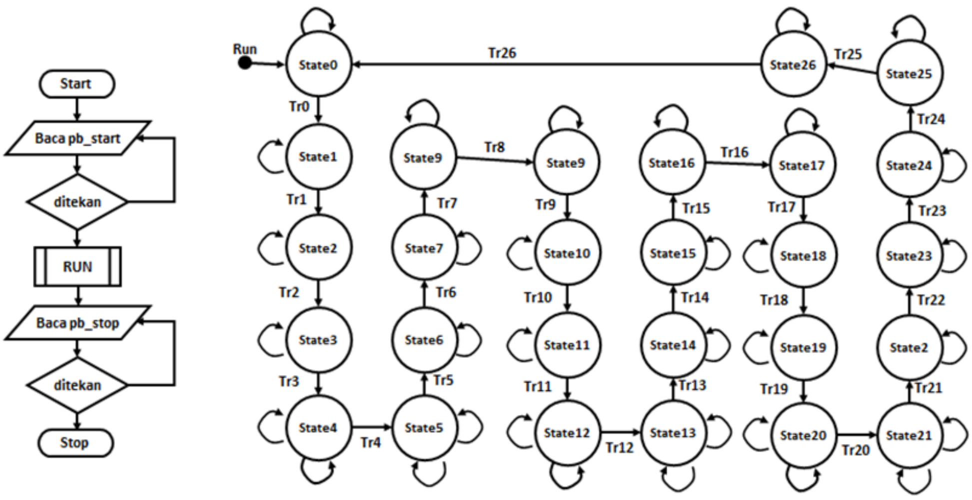

Figure 2. Flowchart and state diagram

	State	Condition	Output Devices								Output Transition	
			Box Conveyor	Part Conveyor	exit conveyor	C+	Grab	SP X	SP Y	SP Z		
Start (FE)	0	Standby Mode	0	0	1	0	0	0	0	0	T0 = 1 dtk	
	1	Box to Robot Arm	1	0	1	0	0	0	0	0	Box at Place (FE)	Tag_1
	2	Part to Robot Arm	0	1	1	0	0	0	0	0	Part at Place (FE)	Tag_2
	3	Moving XY (Ambil 1)	0	0	1	0	0	8.1	5.5	0	X <= 8,1 & Y <= 5,5 & T0b = 1dtk	
	4	Moving Z (Ambil 1)	0	0	1	0	0	8.1	5.5	4.8	Detected	
	5	Grab ON	0	0	1	0	1	8.1	5.5	4.8	T1 = 1 dtk	
	6	Z Up	0	0	1	0	1	8.1	5.5	0	Z == 0	
	7	Moving XY (Simpan 1)	0	0	1	0	1	3.1	3.4	0	X >= 3,1 & Y >= 3,4 & T1a = 1 dtk	
	8	Moving Z (Simpan 1)	0	0	1	0	1	3.1	3.4	0	Z <= 10	
	9	Grab OFF	0	0	1	0	1	3.1	3.4	10	T2 = 1 dtk	
	10	Part to Robot Arm	0	1	1	0	0	0	0	0	Part at Place (FE)	Tag_3
	11	Moving XY (Ambil 2)	0	0	1	0	0	8.1	5.5	0	X <= 8,1 & Y <= 5,5 & T2a = 1 dtk	
	12	Moving Z (Ambil 2)	0	0	1	0	0	8.1	5.5	4.8	Detected	
	13	Grab ON	0	0	1	0	1	8.1	5.5	4.8	T3 = 1 dtk	
	14	Z Up	0	0	1	0	1	8.1	5.5	0	Z > 0	
	15	Moving XY (Simpan 2)	0	0	1	0	1	3.1	6.4	0	X >= 3,1 & Y <= 6,4 & T3a = 1 dtk	
	16	Moving Z (Simpan 2)	0	0	1	0	1	3.1	6.4	0	Z < 10	
	17	Grab OFF	0	0	1	0	1	3.1	6.4	10	T4 = 1 dtk	
	18	Part to Robot Arm	0	1	1	0	0	0	0	0	Part at Place (FE)	Tag_4
	19	Moving XY (Ambil 3)	0	0	1	0	0	8.1	5.5	0	X <= 8,1 & Y <= 5,5 & T4a = 1 dtk	
	20	Moving Z (Ambil 3)	0	0	1	0	0	8.1	5.5	4.8	Detected (Z=4,8)	
	21	Grab ON	0	0	1	0	1	8.1	5.5	4.8	T5 = 1 dtk	
	22	Z Up	0	0	1	0	1	8.1	5.5	0	Z > 0	
	23	Rotate Gripper	0	0	1	1	1	8.1	5.5	0	C Limit (N)	
	24	Moving XY (Simpan 3)	0	0	1	1	1	3.1	5	0	X >= 3,1 & Y <= 5 & T5a = 1 dtk	
	25	Moving Z (Simpan 3)	0	0	1	1	1	3.1	5	0	Z <= 5	
	26	Grab OFF	0	0	1	1	1	3.1	5	5	T6 = 1 dtk	
			Counter Up for Jumlah Box									

Figure 3. State table

B. Data Analysis

Data analysis was conducted through a series of integrated tests on the Siemens S7-1200 PLC in the XYZ pick and place system. These tests included evaluating the interconnection of the Siemens PLC with Virtual Plant Factory I/O, KEPServerEX, as well as the connection to KEPServerEX and Excel.

III. Results and Discussion

A. Device Design

The hardware module of the Siemens S7-1200 PLC Trainer, as developed, is depicted in Figure 4. In this image, it can be observed that the Siemens S7-1200 PLC can communicate with a computer via Ethernet cable,

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switch, and Access Point. The I/O Trainer module also enables the powering on and off in the PLC. Figure 5 illustrates the interface of the Virtual Plant Pick and Place XYZ software in Factory I/O.

Figure 4. PLC Trainer hardware module

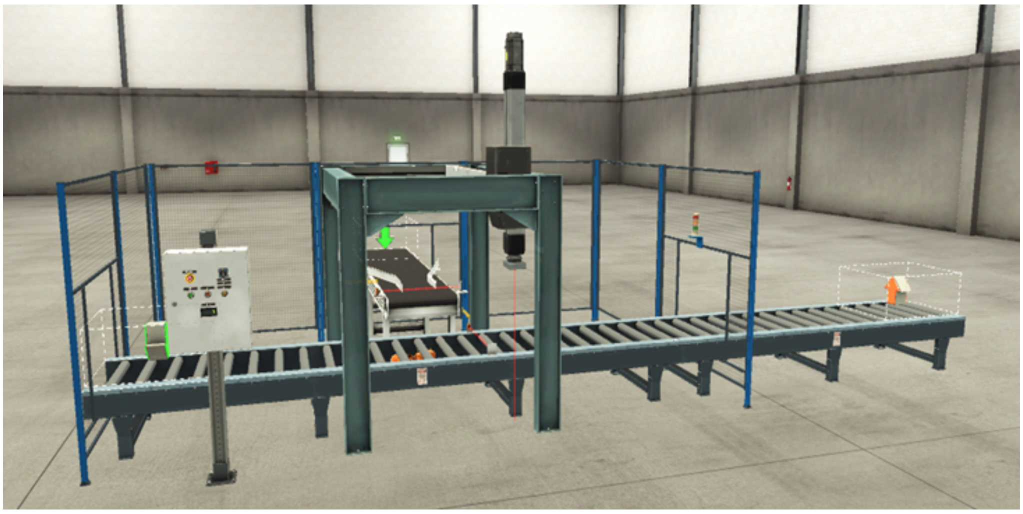
Figure 5. Interface on Factory I/O

B. Device Testing

1. Interconnection of Siemens PLC with KEPServerEX

Observations from the Interconnection Testing of Siemens PLC with KEPServerEX are presented in Figure 6. The connection between the Siemens PLC and the OPC server (Kepware KEPServerEX) successfully linked with a 'good' quality status. This success is attributed to the appropriate driver configuration matching the PLC model and the IP address used.

2. Interconnection of Siemens PLC with KEPServerEX and Excel

The results of the Interconnection Testing of Siemens PLC with Excel are shown in Figure 7. The connection between Excel and Siemens PLC was successfully established, indicated by the input, and output values appearing on the Excel HMI when the start and stop buttons are pressed. This success is due to the correct driver configuration and IP address on Siemens PLC.

3. Performance of the Pick and Place XYZ System

Table 1 presents the results of the Pick and Place XYZ System Performance Testing. The system operated smoothly, marked by "OK" status in all tests. The

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Siemens S7-1200 PLC, Microsoft Excel, and KEPServerEX demonstrated positive responses to start, stop, and indicator light tests.

These test results illustrate the successful implementation of the system and the validity of the proposed concept. The seamless integration between Siemens PLC, KEPServerEX, and Microsoft Excel demonstrates that the DCS SCADA learning module on the "Pick and Place XYZ" case based on Siemens S7-1200 PLC with Excel Linking HMI functions efficiently and reliably in automatic pick and place settings.

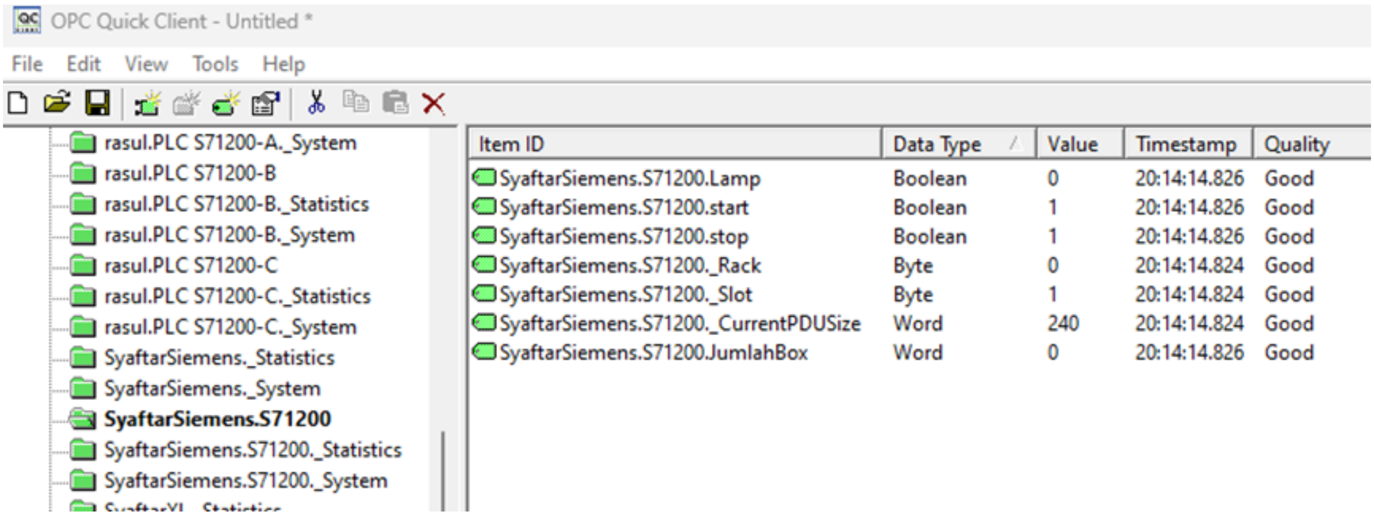

Figure 6. Results of Siemens PLC interconnection testing with OPC Server (KEPServerEX)

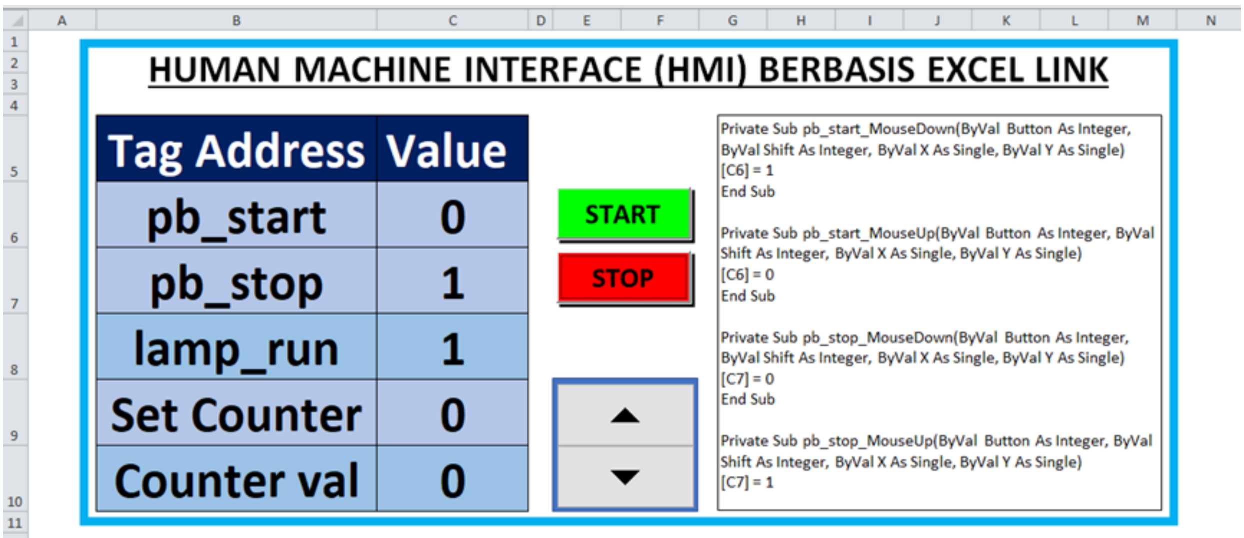

Figure 7. Interface of Excel interconnection with Siemens PLC

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Table 1. Results of the interconnection testing of the pick and place XYZ system

No.	Performance Test	Start		Stop		Lamp	
		ok	fail	ok	fail	ok	fail
1	PLC Siemens S7-1200	✓		✓		✓	
2	Microsoft Excel	✓		✓		✓	
3	KEPServerEx	✓		✓		✓	

IV. Conclusion

This research has successfully developed a DCS SCADA learning module for the Pick and Place XYZ case based on the Siemens S7-1200 PLC with HMI Linking Excel. The results of integrated testing through the Procedure Stage Test indicate a system success rate of 100% with an "OK" status. The integration of Siemens PLC, KEPServerEX, and Microsoft Excel demonstrates the efficiency and reliability of this system in automating the pick and place process. Thus, this learning module can serve as an effective teaching tool for students to understand the concepts of DCS SCADA and its application in automation industries.

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