Integration of Weighing Indicator with Proprietary Commands into PLC-Based System Using Modbus Protocol

Lerson Chanka, Krit Smerpitak, Prasit Julsereewong, and Amphawan Julsereewong, *Member, IAENG*

Abstract—**This paper presents a technique to integrate a stand-alone weighing indicator with proprietary commands into a monitoring system of industrial production processes. The proposed technique is based on creating a new function block of the programmable logic controller (PLC) used in weighing machine control for converting weighing indicator commands into the Modbus-RTU commands. Creation of the function block operated in the PLC modeled CP1L-M30DR-D for converting commands of the AD-4401 weighing indicator to display on the Panel Master touch-screen monitor is described as an illustrative case study. Based on the proposed method, weighing data at the field site for local readout can be added into process data monitoring at the human machine interface (HMI) station of the PLC-based system. This enables ease of upgrading the weighing machine used, which has weighing indicator with local readout display. Performance of the proposed system integration is verified by experimental results.**

Index Terms—**Modbus, PLC, system integration, weighting indicator**

I. Introduction

WEIGHING process plays an important role in agriculture industry. Production and packaging processes generally require mechanical scales such as bins, hoppers, silos, and trucks to weigh materials. The weighing equipment could be placed on force sensors like load cells for batching and mixing applications, and the force sensors are usually used for automatic weighing and totalizing [1-4]. However, some indicators with proprietary commands still provide local readout for making manual records by operators [1-2]. Some automatic weighing systems using industrial bus communications are designed to provide real-time monitoring capability [3] or to develop supervision [4].

This paper aims to propose a useful technique for improving the monitoring capability of PLC-based automatic weighting systems from local readout at the field site only to remote monitoring at the HMI station. The

proposed technique is an integration of the weighing indicator with proprietary commands into the PLC-based control system. A new function block operated in the PLC is developed for converting the proprietary weighing commands into the Modbus-RTU commands. Experimental results obtained from the case study to demonstrate the performance of the proposed technique are also included.

II. Studied Weighing System for Improvement

Fig. 1 shows a drawing of the studied weighing machine, sometimes called continued dumping scale, which comprises of three main parts; supplying bin, weighing hopper, and receiving bin. Fig. 2 shows a system architecture diagram of the studied weighing machine, which is used to check weighing and totalizing of falling
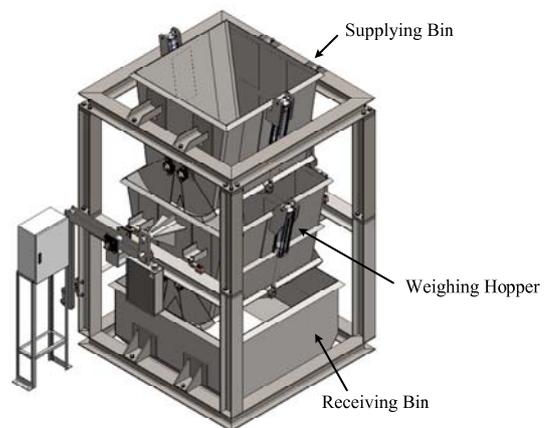

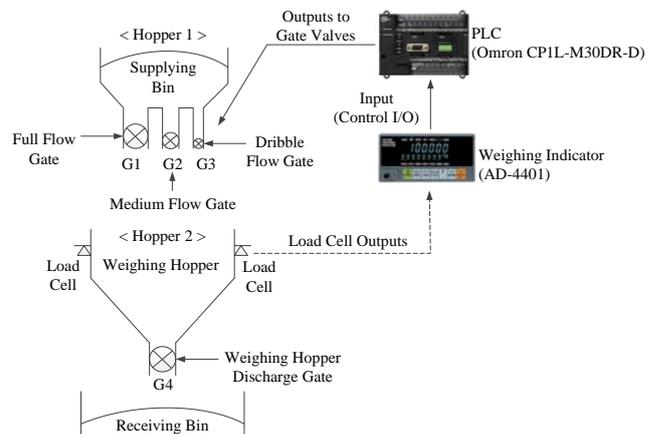Fig. 1. Drawing of the studied weighing machine.

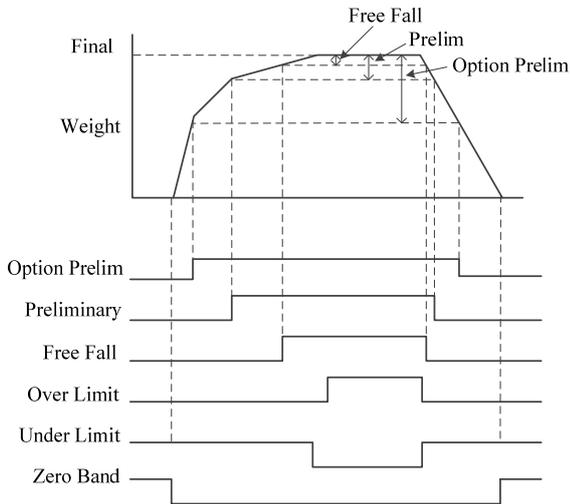Fig. 2. System architecture of the studied weighing machine.

Fig. 3.   Sequential operation of the studied weighing machine.

TABLE I.   CONDITION PARAMETERS FOR WEIGHING SEQUENCE.

Output Terminal	Output Condition
Zero Band	Gross ≤ Zero Band
Full Flow	Net ≥ Final – Optional Preliminary (Option Prelim.)
Medium Flow	Net ≥ Final – Preliminary (Prelim.)
Dribble Flow	Net ≥ Final – Free Fall
Over Limit	Net > Final + Over Limit
Under Limit	Net < Final – Under Limit

materials from the supplying bin. Four load cells are installed in the weighing hopper. The load cell outputs are sent to the weighing indicator with local user interface and readout like AD-4401 to perform weighing sequence. The control input/output (Control I/O) of the weighing indicator is passed to the PLC modeled CP1L-M30DR-D for controlling the pneumatic gate valves (G1-G4) to open or close. Fig. 3 displays a sequence diagram of the target weight (or 'Final' weight) required for weighing sequence of the AD-4401, where the condition parameters are given in Table I.

From Fig. 3, the functional description can be briefly explained as follows.

1. Clear the display on the AD-4401 to zero.
2. Open the gate valves G1 (full flow), G2 (medium flow), and G3 (dribble flow), the display on the AD-4401 is incremented, and when it reaches the 'Option Prelim', its output is turned on and sent to the PLC for closing the gate valve G1.
3. When the display reaches the 'Prelim', its output is turned on and passed to the PLC for closing the gate valve G2.
4. When the display reaches the 'Free Fall', its output is turned on and passed to the PLC for closing the gate valve G3. Now one weighing cycle is completed, and the AD-4401 display shows the 'Final' value, indicating the weighing hopper has been loaded with that weight.
5. Use the 'Over Limit' and 'Under Limit' setting to check whether the weight value is within these limits.
6. When the gate valve G4 is opened to discharge material into the receiving bin, use the setting of the 'Zero Band' to confirm that the material has been completely discharged.

III.   PROPOSED SYSTEM INTEGRATION

Fig. 4 shows the proposed system integration by connecting the HMI station and the weighing indicator with proprietary commands to the PLC at Port 1 and Port 2, respectively, using the RS-485 network. In order to transfer the measured data from the weighing indicator with local readout to be monitored at the HMI station in real time, a concept to realize the new function block for being operated in the PLC is depicted Fig. 5. The data communications between the HMI station and the PLC are based on the
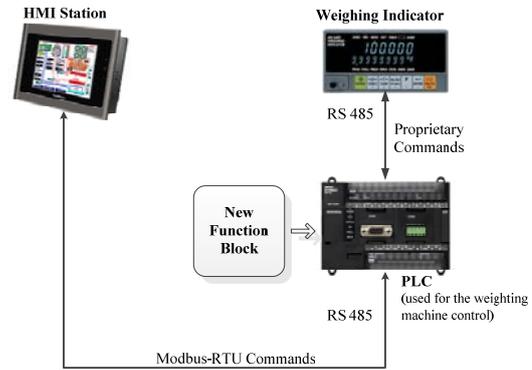

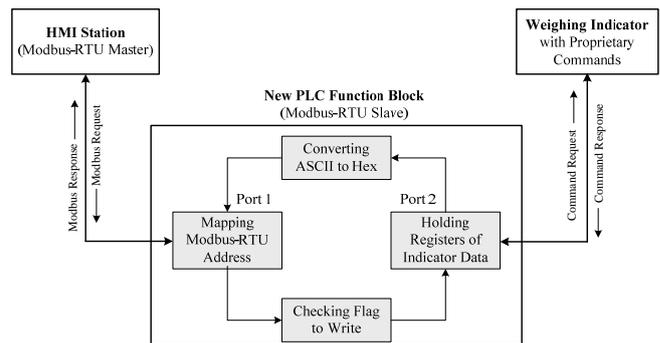Fig. 4.   Proposed system integration.

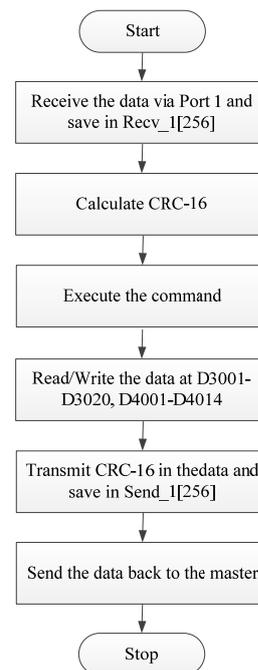Fig. 5.   Concept for realizing the new function block of the PLC.
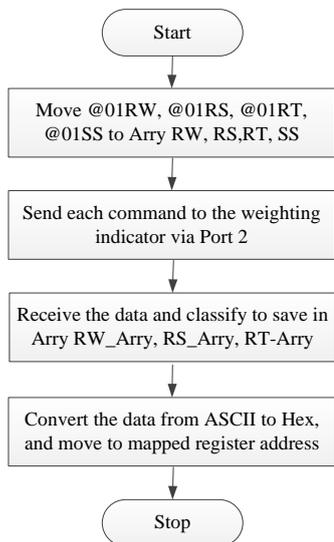

Fig. 6.   Flowchart diagram for the PLC Port 1.

Fig. 7. Flowchart diagram for the PLC Port 2.

TABLE II. MAJOR PARAMETERS FOR DATA EXECUTION IN THE PROPOSED FUNCTION BLOCK OF THE PLC

Parameter	Description
Recv_1[256], Send_1[256]	Received and sent messages at Port 1
Recv_2[256], Send_2[256]	Received and sent messages at Port 2
RW[4], RS[4], RT[4], SS[4]	Saved request-weight commands for sending to the weighting indicator
RW_Arry[30], RS_Arry[30], RT_Arry[30]	Received messages from the weighing indicator
Final_Arry[2], Free_Fall_Arry[2], Prelim_Arry[2], Over_Arry[2], Oplim_Arry[2], Under_Arry[2], Zero_Arry[2], Accu_Weigh_Arry[2], Accu_Count_Arry[2], RW_H[2]	Required weighing data for sending to the HMI station

Modbus-RTU master/slave protocol. Flowchart diagrams for representing the sequence of steps to perform data processing at the Port 1 and Port 2 are shown in Figs. 6 and 7, respectively. Table II summarizes the major parameters for data execution in the proposed PLC function block.

IV. APPLYING PROPOSED TECHNIQUE FOR CASE STUDY

In order to improve the weighing system as discussed in Section II for providing the real-time monitoring capability, the proposed technique is used to integrate the AD-4401 weighing indicator, the Omron PLC modeled CP1L-M30DR-D, and the Panel Master touch-screen monitor for working together. Fig. 8 shows a wiring diagram for device physical connections. Based on the proposed concept in Fig. 5, the function block is built for being operated in the Omron PLC used and for converting the commands of the AD-4401 weighing indicator to display on the Panel Master touch-screen monitor (or HMI station).

Table III gives examples of request and response messages based on the Modbus-RTU frame structure for data transfers between the master touch-screen monitor and the slave function block located in the PLC at the Port 1. Fig. 9 shows the response message including the AD-4401 weighing data for holding resisters at the Port 2.
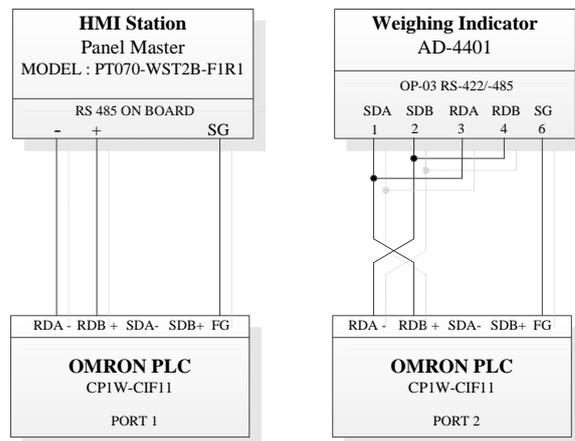

Fig. 8. Wiring diagram for physical connections between devices.

TABLE III. EXAMPLES OF REQUEST AND RESPONSE MESSAGES BASED ON THE MODBUS-RTU FRAME STRUCTURE

| Example of Request Message		Example of Response Message	
Field	Data	Field	Data
Slave Address	01	Slave Address	01
Function Code (Read Hoding Registers)	03	Function Code (Read Holding Registers)	03
Start Address (H)	0B	Number of Data Bytes	04
Start Address (L)	BD	Register Value (H) in DM3005	00
Number of Resisters (H)	00	Register Value (L) in DM3005	00
Number of Resisters (L)	02	Register Value (H) in DM3006	0A
CRC (H)	56	Register Value (L) in DM3006	BE
CRC (L)	0B	CRC (H)	7C
		CRC (L)	E3
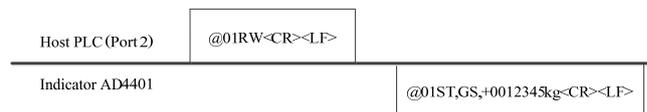
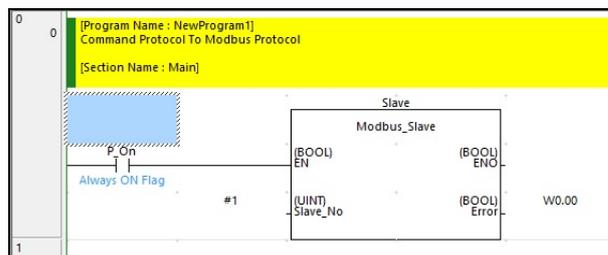Fig. 9. Response message including the weighing data from the AD4401.

Fig. 10. Created function block using the proposed concept of Fig. 5.

Fig. 10 displays the function block created by using the CX-Programmer v9.0, and Fig. 11 shows the software window for setting communication parameters of the created functions block, which are dependent on the PLC model used, such as Baud Rate = 19,200, Data Bit = 8, Parity = None, Stop Bit = 1, and Mode = RS-232C. Fig. 12 displays the flowchart diagram for the sequence of steps needed for data transfers between the HMI station and the PLC using Modbus-RTU commands. Sequential operations of the created function block can be briefly discussed as follows.
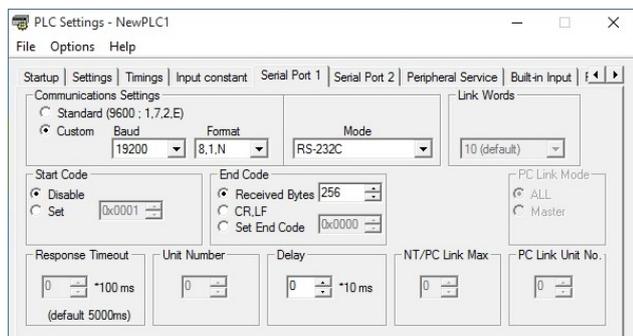
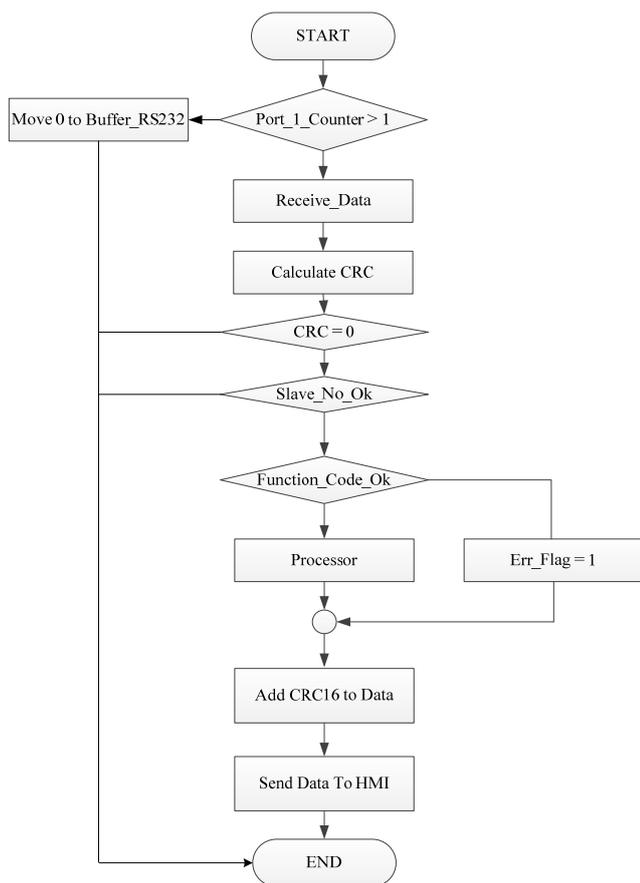Fig. 11. Window for setting parameters of the created function block.

Fig. 12. Flowchart diagram for data transfers between the HMI and PLC.

1. Detect the data transfer at the Port 1.
2. If the data are sent to the Port 1, move the received data to Receive_Data. Otherwise, move 0 to Buffer_RS232, and finish the sequence.
3. Compute the CRC-16, it should be 0.
4. If the computed CRC-16 = 0, then detect the Slave No.
5. Determine the function code, if there is error, then send Err_Flag.
6. Perform the requested action.
7. Add the computed CRC to the processed data.
8. Send the requested data backward to the master HMI.

From Fig. 13 showing the flowchart diagram for data transfers between the weighing indicator and the PLC, the sequential operations of the created function block can be briefly explained as follows.

1. Move the data using the AD_4401 commands (RW (Request Weight), RS (Request Setpoint), RT (Request Total), and SS (Set Setpoint)) to the resisters.
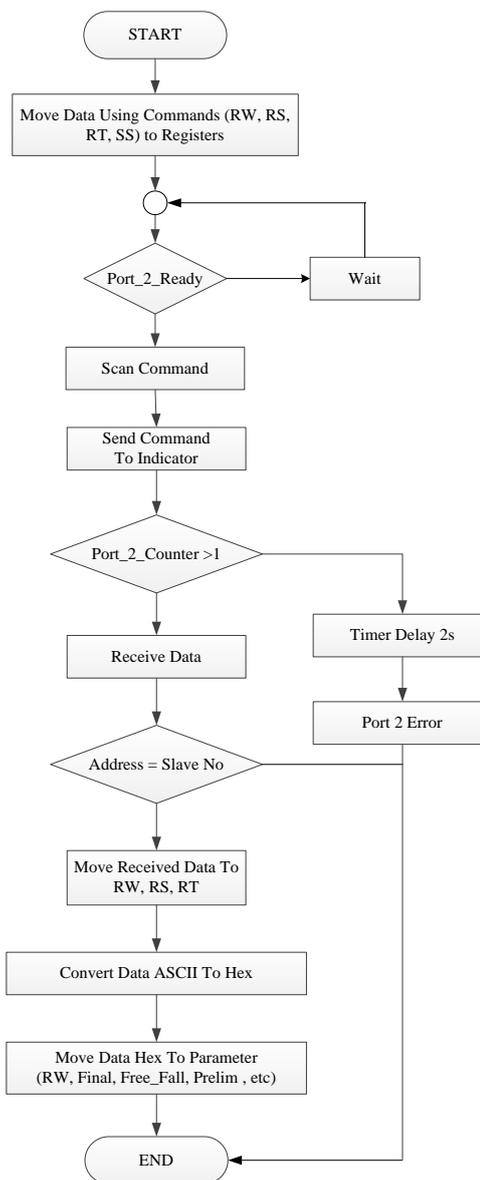2. Detect the readiness of the Port 2.

Fig. 13. Flowchart diagram for data transfers between indicator and PLC.

3. Use the AD_4401 commands for sending the scan data.
4. Send the data to the AD_4401.
5. Detect the data transfer at the Port 2.
6. If the Port 2 has no data received, send Flag_Port2_Error.
7. Otherwise, determine Header Address that is equal to the Slave No.
8. If Header Address = Slave No., then move the received data to save in the resisters RW, RS, and RT.
9. Select only numerical data for converting from ASCII to Hex codes.
10. Move the converted Hex codes to the predefined register for each weighing data.

V. EXPERIMENTAL RESULTS

Experiments were conducted to evaluate the proposed system integration. The experimental setup is illustrated in Fig. 14 using the wiring diagram of Fig. 8. Figs. 15-18 show the results to verify the operations of the created function block for the Modbus-RTU request from the HMI, the Modbus-RTU response, the AD-4401 commands in the PLC registers, and the received data from the AD-4401, respectively.
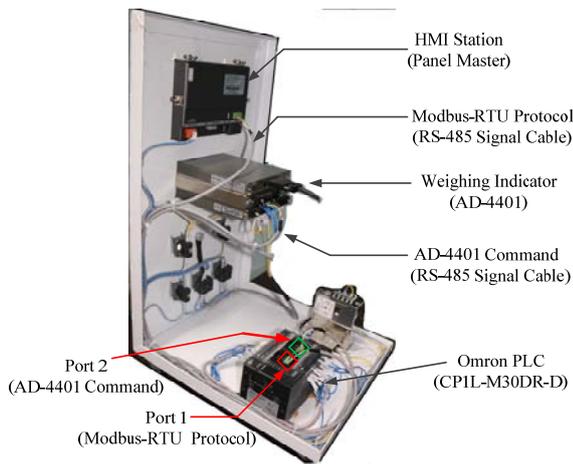
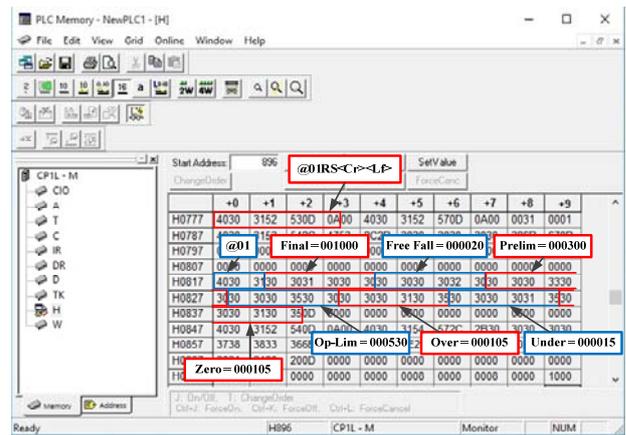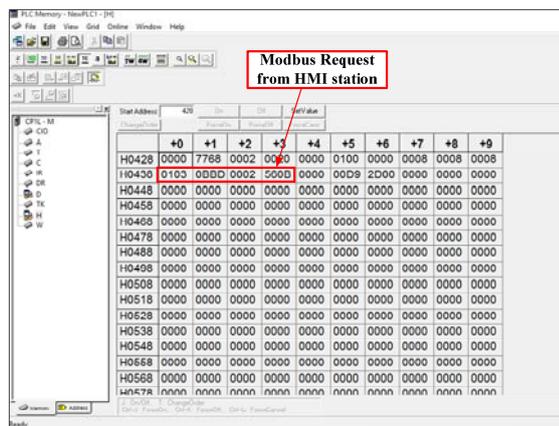Fig. 14.   Experimental setup for overall system.

Fig. 15.   The Modbus-RTU request in the created function block.

Fig. 16.   The Modbus-RTU response in the created function block.

Fig. 17.   The AD-4401 commands in the PLC registers.

Fig. 18.   Received data from the AD-4401 indicator.

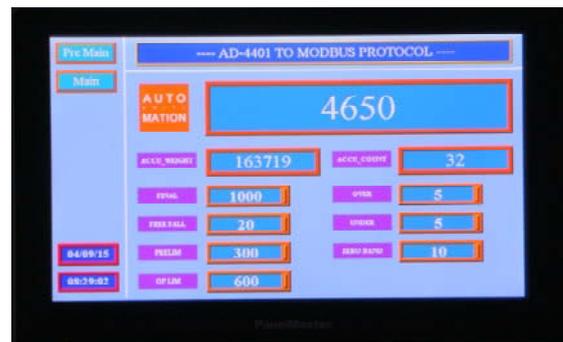Fig. 19.   Weighing data on local readout of the AD-4401 indicator.

Fig. 20.   Weighing data on the HMI station.

From the Modbus-RTU request and response messages as shown in the red frame in Figs. 15 and 16, which are agreed with the fields in Table III, can be classified as follows.

The Modbus-RTU Request; (See Fig.15)
Slave Address: 01, Function Code:03, Start Address (H): 0B, Start Address (L): BD, Number of Registers (H): 00, Number of Registers (L): 02, CRC (H): 56, CRC (L): 0B.

The Modbus-RTU Response; (See Fig.16)
Slave Address: 01, Function Code:03, Number of Data Bytes: 04, Register Value (H): 6C, Register Value (L): 78, Register Value (H): 00, Register Value (L): 00, CRC (H): 67, CRC (L): 7A.

From the AD-4401 commands in the PLC registers as shown the frames in Fig. 17, there are RW (Request Weight), RT (Request Total), and RS (Request Setpoint). From the received data from the AD-4401 via the Port 2 in Fig. 18, there are the values of Final, Free Fall, Preliminary, Option Preliminary, Over Limit, Under Limit, and Zero
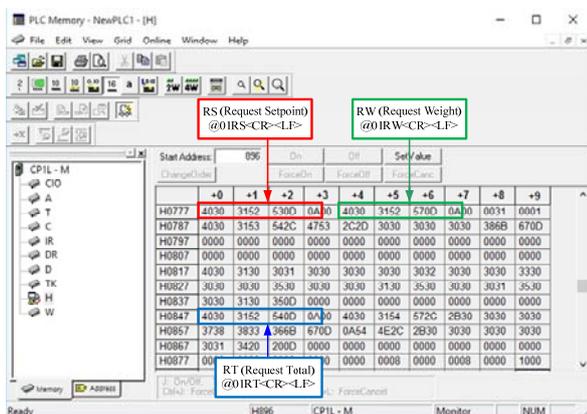
Band. From the experimental results shown in Figs. 19 and 20, it is seen that the weighing values on the HMI station are equal to the measured values on the local readout, for example, the weight and accumulated weight values are 4,650 kg and 163,719 kg, respectively.

VI. CONCLUSION

Integration of the weighing indicator with proprietary commands into the PLC-based system for improving real-time monitoring capability has been proposed in this paper. The concept to build the new function block located in the PLC for converting commands of the weighing indicator into commands of the Modbus-RTU has been introduced. In order to verify the proposed technique, integrating the AD-4401 weighing indicator, the Omron PLC modeled CP1L0N30DR-D, and the Panel Master touch-screen monitor connected on the RS-485 network has been described. Experimental results confirm that the proposed system functions correctly.

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