

Application of Hart Concentrator To Save The Number of Input Analogue Channel Usage in PLC PAC System on SCADA Cimplicity

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ABSTRACTS

The types of inputs and outputs of a control system that exist today are quite varied with their respective advantages and disadvantages that can be adapted to existing needs. So with the complexity of the system, the price is also very expensive. As one option to overcome this problem is to utilize Highway Addressable Remote Transducer (HART) data through the application of the HART Concentrator System (HCS). HART data has four variables, namely Primary Value (PV), Secondary Value (SV), Third Value (TV) and Fourth Value (FV). All this data can be sent simultaneously to HCS and collected. Then the data on the HCS will be sent via RS485 serial communication to the Modbus Gateway TCP/IP. At this Modbus TCP/IP gateway, Modbus data can be sent via an Ethernet network so that it can be accessed flexibly by SCADA.

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1. INTRODUCTION

Rapidly developing science and technology provides opportunities for practitioners, such as programmers and engineers, to always carry out useful research, including to help human work and overcome the problems currently being faced. This can be seen by the emergence of creative and innovative ideas in the fields of science and technology which really help make human life easier. Control systems are a field of science and technology that is currently being developed in many companies to control electronic instrumentation equipment automatically [1]. The control system is the interconnection of components to form a system configuration that will provide the desired system response. So these components can be controlled by the input output relationship which is a cause and effect relationship of a process, which in turn is the processing of the input signal to provide a variable output signal [2][3]. One option to overcome this problem is to utilize Highway Addressable Remote Transducer (HART) data through the implementation of the HART Concentrator System (HCS) [4][5]. HART data has four variables, namely Primary Value (PV), Secondary Value (SV), Third Value (TV) and Fourth Value (FV) [6][7]. All of this data can be sent simultaneously to the HCS and collected. Then the data in the HCS will be sent via RS485 serial communication to the Modbus Gateway TCP/IP. In the Modbus TCP/IP gateway, Modbus data can be sent via the Ethernet network so that it can be accessed flexibly by SCADA [8][9]. Modbus data that already exists in the network can be accessed by SCADA as long as SCADA is also in the network segmentation. The advantage of this system is that data can be obtained remotely so that instruments located in remote locations or locations that are quite dangerous can be acquired easily without having to complete a control system such as a Programmable Logic Controller (PLC) or Distributed Control System (DCS). This system can be a more practical and lower cost option so that it can be applied for many purposes in an industrial operational process [10][11].

2. RESEARCH METHODOLOGY

This system uses a level transmitter and temperature transmitter which supports Hart data communication as a data source for HCS. The hart data from the instrumentation equipment will later be collected until it is connected to one HCS, where the HCS will accommodate all HART data from the industrial instrumentation equipment which can accommodate a maximum of up to 16 hart devices and each hart device can output four data variables or depending on the facilities provided by the instrumentation tool. The data that has been collected in HCS will communicate with the Modbus gateway so that from the Modbus gateway Modbus TCP IP data is obtained which can later be accessed via the network by SCADA. If it is connected to the network, it will be easier for SCADA to communicate so that it can reach distant areas or what can be called remote areas. PLC is outside

this system because this system does not require a PLC to connect data from instrumentation to SCADA. In general, this system can be depicted in the block diagram shown in Figure 1.

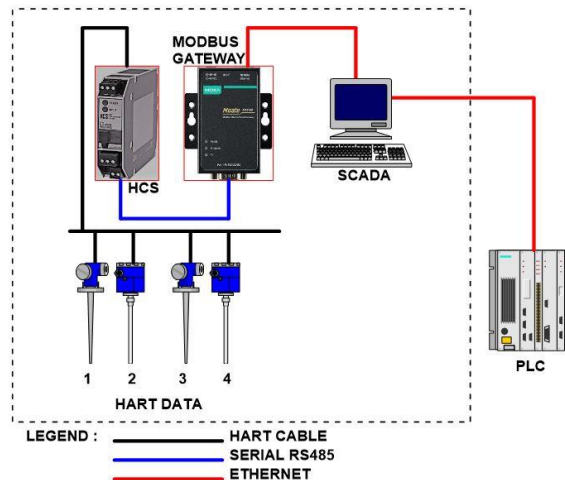


FIG 1. Block diagram of the system

Based on Figure 1, each instrumentation tool that supports data hart must be given a unique address, which means there cannot be the same address in a loop. In order to setup the address for each instrument, use a Hart Communicator which functions to communicate point to point with the instrument. One of the hart communicator models used is shown in Figure 2.



FIG 2. Hart Communicator

To be able to connect the point to point hart communicator with the instrumentation equipment, the wiring setup is then carried out as shown in Figure 3.

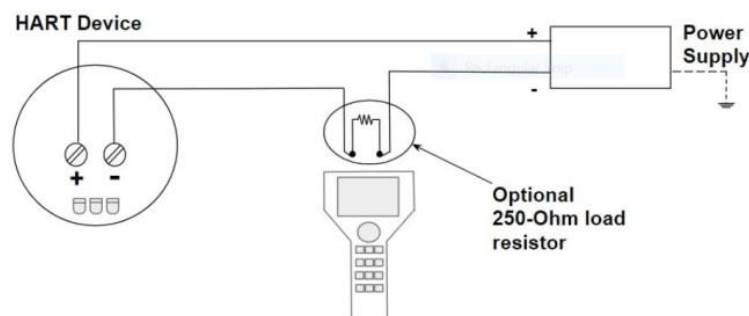


FIG 3. Wiring point to point hart communicator with hart instrumentation tools

The level used in this system uses a level transmitter model FMP51 with the Endress Hauser brand and a temperature transmitter model TMT182 with the Endress Hauser brand, the physical form of the FMP51 and TMT182 is shown in Figure 4 and Figure 5.



FIG 4. FMP51 TRANSMITTER LEVEL



FIG 5. Temperature Transmitter TMT182

After each instrument is given a unique address, the next step is to configure the Hart data that will be issued by the instrument. The transmitter level for the FMP51 model is set up as shown in Table 1, the temperature transmitter setup is as shown in Table 2

TABLE 1. FMP51 hart configuration

Variabel	Parameter
PV	Level linierized
SV	Terminal voltage
TV	Electronic temperature
FV	Noise signal

TABLE 2. TMT182 hart configuration

Variabel	Parameter
PV	Measured temperature
SV	Internal temperature
TV	N/A
FV	N/A

Then a circuit is made according to the multidrop termination wiring as shown in Figure 6 [12].

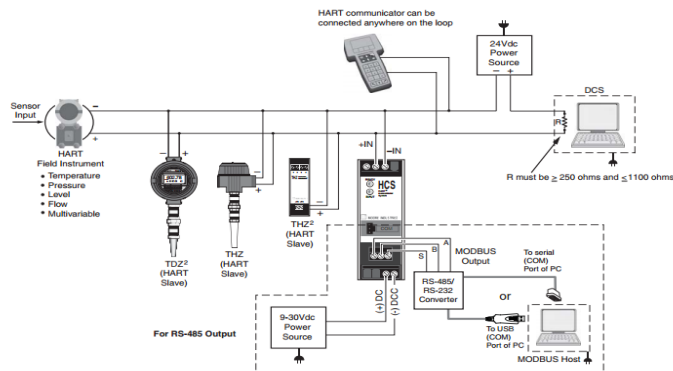


FIG 6. Hart multidrop termination wiring circuit

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The Hart circuit generally uses a resistor with a value of 250 ohms as its impedance. The value of 250 ohms is given to communicate with one Hart instrument and if you want to communicate with a Hart instrument with a multidrop circuit, the amount of resistance will be different. In hart multidrop mode the minimum current value must be met. The default corresponds to the instrument's datasheet. Look at Figure 7 for more details. The minimum current that must be met for Hart multidrop communication is 11 mA, which means that if it is below 11 mA, Hart multidrop communication will not occur [13].

Communication	Current consumption	Terminal voltage
HART	4 mA	16 V to 36 V
	20 mA	7,5 V to 36 V
Fixed current, adjustable e.g. for solar power operation (measured value transferred at HART)	11 mA	10 V to 36 V
Fixed current for HART Multidrop mode	4 mA ¹⁾	16 V to 36 V

1) Start up current 11 mA.

Load HART
Minimum load for Hart communication: 250 Ω

Cable entry

- Cable gland: M20x1.5
- Cable entry: G½ or ½NPT

Supply voltage
The following values are the voltages across the terminals directly at the instrument:

Power consumption
min. 60 mW, max. 900 mW

Current consumption
3.6 V to 22 mA, for HART Multidrop: start up current is 11 mA

FIG 7. Default condition of multidrop hart

After configuring the multidrop hart hardware, then proceed with the HCS software configuration. This configuration is intended so that the HCS can receive multidrop hart input from field instrumentation. To setup the HCS, you can use the existing serial cable, pay attention to the schematic diagram in Figure 8 for installing the serial cable so you can start the HCS setup.

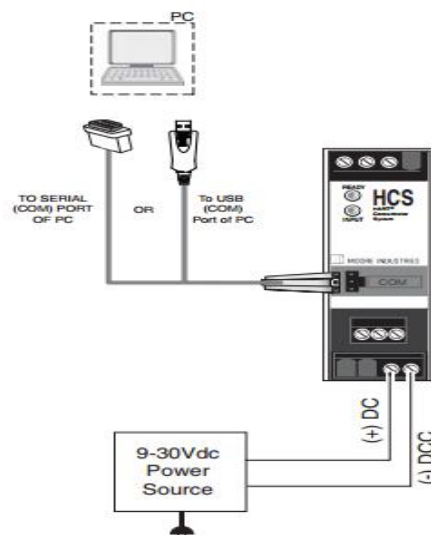


FIG 8. HCS to PC connection scheme

To convert serial modbus data into tcpip midbus data, a modbus gateway is needed to convert the data. One device that can be used to change this data is the Moxa Mgate MB3180. Moxa Mgate MB3180 is a 1-port Modbus gateway that converts between Modbus TCP Protocol from Modbus ASCII/RTU. This can be used to give the ethernet master access to control the serial slave. This Modbus gateway is designed for 12V to 48V DC and 0.25A. To find out the physical form of the Moxa MGate MB3180, it is shown in Figure 9.



FIG 9. Moxa Mgate MB3180

After the modbus gateway configuration is complete, modbus TCPIP data is available on the network. To ensure the correctness of the data, testing can be carried out using modscan32 software. The modscan32 display is shown in Figure 10.

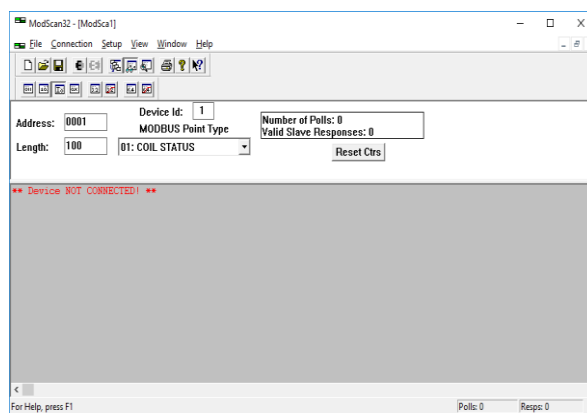


FIG 10. Modscan32 display

Next is displaying in scada. The scada used is the GE Cimplicity scada. This software can be used to create Human Machine Interface (HMI) visualizations so that it can automate the operation of an industrial process. In Figure 11 below you can see a simple scada design which displays hart data from the instrumentation tool.

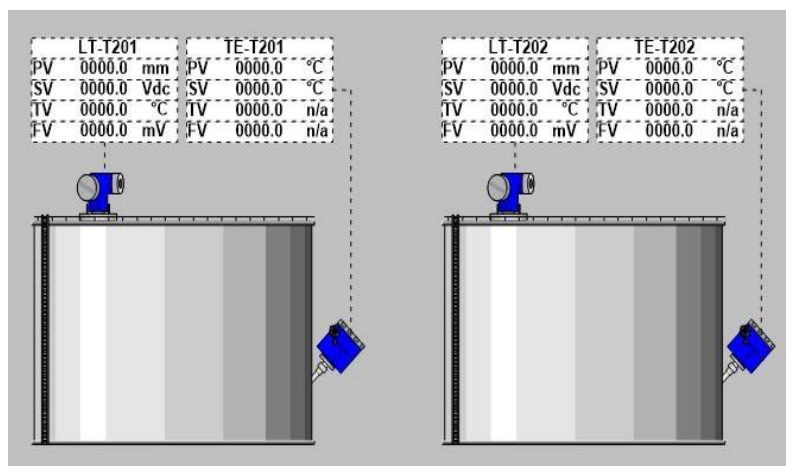


FIG 11. Simple scada design for data mart

3. RESULTS AND DISCUSSION

A. Multidrop voltage testing

This test is carried out so that the minimum multidrop hart voltage has been met so that the hart data can be received by HCS. The image of the multidrop voltage measurement results is shown in Figure 12.



FIG 12. Multidrop voltage measurement results

Based on Figure 7, it can be seen that the minimum current to be able to communicate with the device is 11 mA (0.011 A) and the results of multidrop voltage measurements are as in Figure 12. The minimum current required in the multidrop circuit has been fulfilled because the minimum current is 11 mA and the minimum impedance is of 250 Ohms.

B. Testing chart data from instruments and HCS.

Table 3, Table 4, Table 5 and Table 6 show comparison data from hart data from level transmitters LT-T201, LT-T202 and temperature transmitters TE-T201, TE-T202 with data received by HCS from these instrumentation tools.

TABLE 3. Comparative data on hart values from LT-T2 01 and TE-T201 instrumentation

Variabel	Instrument	
	LT-T201	TE-T201
PV	10178	52.18
SV	14.009	33.77
TV	38.241	N/A
FV	3.663	N/A

TABLE 4. Comparative data on property values received by HCS from LT-T201 and TE-T201

Variabel	HCS	
	LT-T201	TE-T201
PV	10177.7	51.373
SV	13.794	35.527
TV	38.255	N/A
FV	2.93	N/A

TABLE 5. Comparative data on hart values from LT-T2 02 and TE-T202 instrumentation

Variabel	Instrument	
	LT-T202	TE-T202
PV	8134.89	51.37
SV	13.973	35.53
TV	38.288	N/A
FV	4.396	N/A

TABLE 6. Comparative data on property values received by HCS from LT-T202 and TE-T202

Variabel	HCS	
	LT-T202	TE-T202
PV	8140.46	51.373
SV	14.166	35.514
TV	38.288	N/A
FV	5.128	N/A

In collecting this data, there is a slight shift in the values because the value of the process results will continue to move according to conditions in the field so that when the data is collected the value displayed will also look slightly different. In actual circumstances, the data is close to the conditions that occur in the field.

C. Testing data from HCS and modbus gateway.

Table 7, Table 8, Table 9 and Table 10 show comparison data from HCS data originating from the level transmitter LT-T201, LT-T202 and temperature transmitter TE-T201, TE-T202 with data received by the modbus gateway. In comparing this data there is a slight difference in the value after the comma for each variable value, this is because HCS by default displays data with a total of only seven digits and includes a comma, while the Modbus gateway with floating point data type displays precision 4 data with four. the number after the comma. The data in modbus tcpip is actually available in the form of binary bits so that it can be more easily converted into other forms of data such as integers or floating points. Likewise with scada, scada receives each binary bit and then converts it according to the appropriate data type. The data types provided by HCS are integer and floating point, because the data issued by HCS from the transmitter level and transmitter temperature used is not more than 65535, so between integer data and floating point data will not be too different, only floating point can provide detailed data down to comma values while integers are only whole numbers. because we need more detailed values, it is better to use the floating point data type register provided by HCS. Figure 13 is an HCS data register which provides data in floating point type.

Register Range	Description
256-257	HART Device 1 PV floating point value stored in 2x16-bit register per float
258-259	HART Device 1 SV floating point value stored in 2x16-bit register per float
260-261	HART Device 1 TV floating point value stored in 2x16-bit register per float
262-263	HART Device 1 FV floating point value stored in 2x16-bit register per float
264-265	HART Device 2 PV floating point value stored in 2x16-bit register per float
266-267	HART Device 2 SV floating point value stored in 2x16-bit register per float
268-269	HART Device 2 TV floating point value stored in 2x16-bit register per float
270-271	HART Device 2 FV floating point value stored in 2x16-bit register per float
272-273	HART Device 3 PV floating point value stored in 2x16-bit register per float
274-275	HART Device 3 SV floating point value stored in 2x16-bit register per float
276-277	HART Device 3 TV floating point value stored in 2x16-bit register per float
278-279	HART Device 3 FV floating point value stored in 2x16-bit register per float
280-281	HART Device 4 PV floating point value stored in 2x16-bit register per float
282-283	HART Device 4 SV floating point value stored in 2x16-bit register per float
284-285	HART Device 4 TV floating point value stored in 2x16-bit register per float
286-287	HART Device 4 FV floating point value stored in 2x16-bit register per float

FIG 13. List of modbus HCS data registers

Based on Figure 13, the left column is the register where variable data is stored. If you look at the floating point data registers above, you can see that one hart data variable is contained in two registers. This can be explained that each register stores 16 bits of data and because floating point is a data type that has a length of 32 bits, the data is divided into two registers. For example, the PV variable for HART device 1 is stored in data registers 256 and 257, this means that 16 bits of data are stored in register 256 and the next 16 bits are stored in register 257. In the scada data system, 2x16 bit floating point data will be combined in 32 bits by combining registers. first and second register. The explanation can be seen from Figure 14.

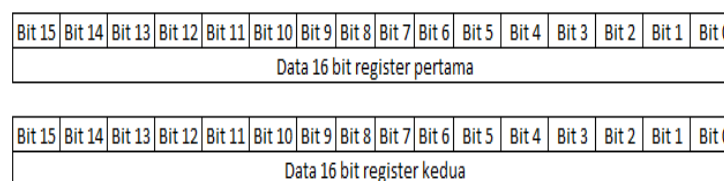


FIG 14. Bit arrangement of the 16 bit floating point register of the HCS

Two floating point registers stored in 2x16 bits. From the scada side, data conversion still uses 32 bit data and the arrangement will depend on the floating point data configuration of the HCS. The following is a comparison of the data issued by the Modbus gateway and the SCADA conversion data.

TABLE 7. Comparative data on modbus gateway values from LT-T201 and TE-T201 instrumentation

Variabel	Modbus Gateway	
	LT-T201	TE-T201
PV	10513.9268	45.5409
SV	15.4020	36.6390
TV	40.7053	N/A
FV	2.9304	N/A

TABLE 8. Comparative data on scada values from LT-T201 and TE-T201 instrumentation

Variabel	Scada	
	LT-T201	TE-T201
PV	10513.9	45.5
SV	15.4	36.6
TV	40.7	N/A
FV	2.9	N/A

TABLE 9. Data comparison of values at Modbus gateway from LT-T202 and TE-T202 instrumentation

Variabel	Modbus Gateway	
	LT-T202	TE-T202
PV	3469.1626	48.9738
SV	15.3810	40.1967
TV	40.9496	N/A
FV	4.3956	N/A

TABLE 10. Data comparing values in scada for LT-T202 and TE-T202

Variabel	Scada	
	LT-T202	TE-T202
PV	3469.2	49.0
SV	15.4	40.2
TV	40.9	N/A
FV	4.4	N/A

In comparing this data there is a slight difference in the value after the comma for each variable value, this is because SCADA is configured to display data with a precision of 1, which means only one number after the comma is displayed and the values are rounded.

D. SCADA data testing

Scada uses the floating point data type to get more accurate data values. Floating point consists of 32 bits, the 32 bit data arrangement can be seen in Figure 15.

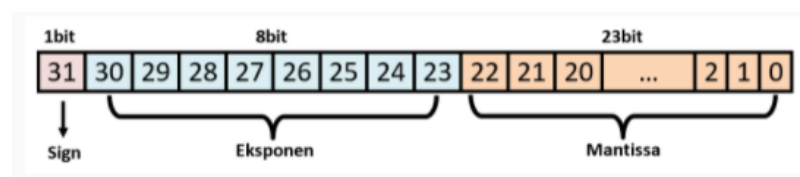


FIG 15. 32 bit floating point bit arrangement.

The floating point representation itself has two parts, namely the mantissa part and the exponent part. The mantissa part determines the digit, while the exponent determines the value of the power of the mantissa. The

writing format is $\pm S * B \pm E$, where, S = Significant also called mantissa E = Exponent B = Base For broad purposes, a standard was formed for the representation of floating point numbers, namely the IEEE 754-2008 (ISO/IEC/IEEE 60559:2011) standard, one of which is for writing 32 bits. In Figure 16 and Figure 17 below are examples of data collection and comparison of conversion results.

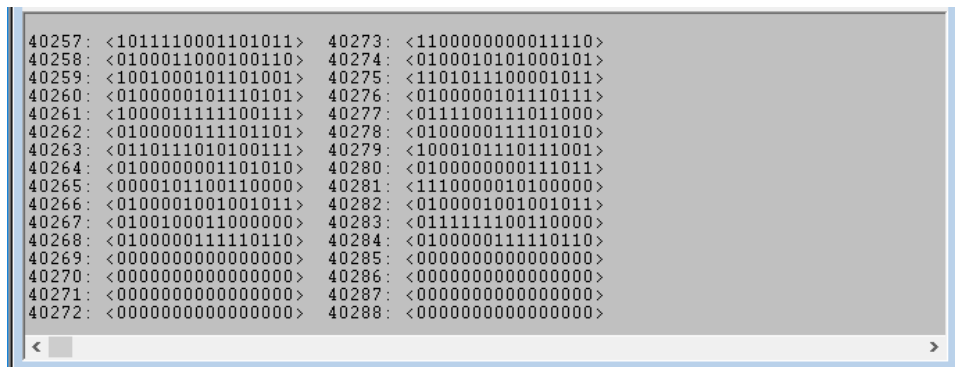


FIG 16. Binary data collection in modscan32

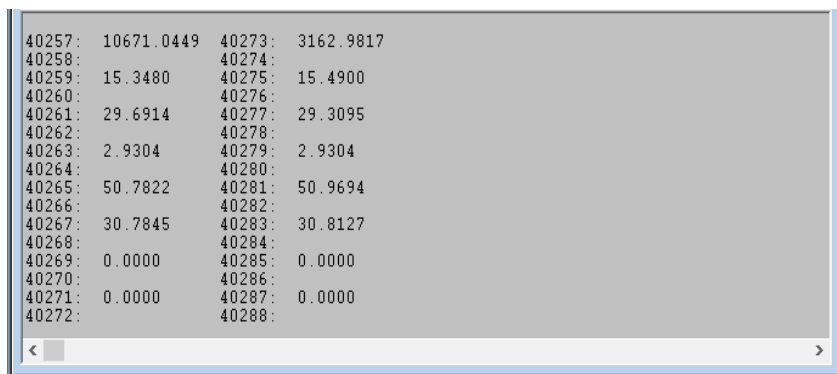


FIG 17. Floating point data collection in modscan32

Based on the register data in Figure 13, the PV variable value data is stored in registers 40257 and 40258 because HCS starts the data register from 0 but the scada and actual from modscan start from register 1 so that the register sequence is added by 1 (+1). If HCS is setup with standard floating point data then the first data is in register 40257 and the next is in 40258. In scada simplicity the 32 bit data arrangement will be composed of binary 40258 and then binary 40257. To prove the correctness of the data resulting from the floating point conversion, it is wrong one can use a floating point calculator which can be accessed online at the following website, <https://www.h-schmidt.net/FloatConverter/IEEE754.html>. To prove this, we can take an example of binary data such as PV on the LT-T201 in registers 40258 and 40259. The two 16 bit data are combined to form 32 bits.

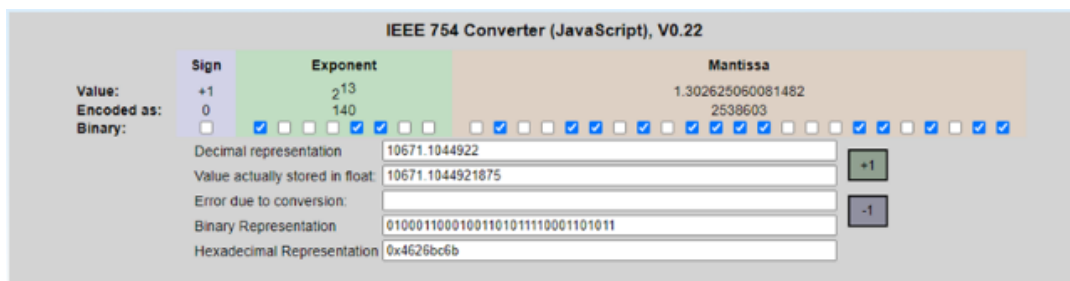


FIG 18. RESULTS FROM THE ONLINE FLOATING POINT CALCULATOR

Based on the binary conversion results in Figure 18 the result is 10671.0449. There is a slight difference in the conversion data. However, this is actually due to a slight difference in time in data collection and the value changes because the PV data is in operational running condition so the value changes continuously. The data that has been obtained and has been initialized in the logger database can then be displayed in the form of a trending curve. In

this trending you will see changes in the recorded values so that they form a curve and the curve points are adjusted to the configured database scan rate time.

E. Cost Efficiency

There are several ways that can be done to get Hart data so that it can be connected to SCADA on this system, but with several considerations so that this system is felt to be the most efficient compared to other systems. The following system options that can be used that are compatible with the PLC GE PAC system are shown in Table 11.

TABLE 11. System options and prices that can be used that are compatible with the GE PAC PLC system

System	cost	System configuration of the comparison system
HCS + MB3180	<ol style="list-style-type: none"> 1. The maximum number of input devices is 16 devices. 2. Can be used for remote areas 3. Maximum scan rate 19200 bps, if the cable is 50 m 4. Price Rp. 6,965,428 5. Flexible, can be used for control systems and other brands of scada. 6. Wide reach while on the network 	<p>The diagram shows an HCS (Hart Concentrator System) unit connected to a MODBUS GATEWAY, which is in turn connected to a SCADA system. The HCS is connected to four HART DATA input devices (labeled 1, 2, 3, 4) via HART cables. The MODBUS GATEWAY is connected to the SCADA via an Ethernet cable. A legend indicates: HART CABLE (black), SERIAL RS485 (blue), and ETHERNET (red).</p>
IC695ALG626	<ol style="list-style-type: none"> 1. Price Rp. 22,000,000 2. The number of module uses is limited because it can only be installed in the main PLC rack. 3. Difficult to apply to remote areas because costs will be higher 4. Not connected to an Ethernet network 5. Scan rate 1200 bps 6. Limited to PLC PAC systems only. 7. Max range. 3Km 	<p>The diagram shows a PLC rack (IC695ALG626) connected to a SCADA system via an Ethernet cable. The PLC rack is connected to four HART DATA input devices (labeled 1, 2, 3, 4) via HART cables. A legend indicates: HART CABLE (black) and ETHERNET (red).</p>
HCS + IC695CMM002	<ol style="list-style-type: none"> 1. Prices are more expensive. 2. The number of module uses is limited because it can only be installed in the main PLC rack. 3. Difficult to apply to remote areas because costs will be higher. 4. Not connected to an Ethernet network 5. Scan rate 19200 bps for 50 meter cable only 6. Limited to PLC PAC systems only 7. Max range. 3Km 	<p>The diagram shows an HCS unit connected to a PLC rack (IC695CMM002), which is connected to a SCADA system via an Ethernet cable. The HCS is connected to four HART DATA input devices (labeled 1, 2, 3, 4) via HART cables. The PLC rack is connected to the SCADA via an Ethernet cable. A legend indicates: HART CABLE (black), ETHERNET (red), and RS485 (blue).</p>

4. CONCLUSIONS

Hart multidrop mode with a voltage of 16.32V DC with an impedance of 420Ω can be used to support Hart data because the minimum current is 11mA. The correctness of floating point data from HCS can be proven by decoding binary numbers. Modbus gateway uses a class A IP address with a class C subnet mask, this is because the IP address has been prepared for a wider scale but is currently limited to a class C subnet mask. Scan rate of hart device is 1200bps and then goes to HCS and outputs with a scanrate of 9600bps. The result is that there is no data loss in device communication

REFERENCES

- [1] A. Visioli, "Maximizing the Impact of Control at All Levels," *Front. Control Eng.*, vol. 1, no. September, pp. 1–3, 2020, doi: 10.3389/fcteg.2020.602469.
- [2] W. Liu *et al.*, "Review on control systems and control strategies for excavators," *J. Phys. Conf. Ser.*, vol. 2301, no. 1, 2022, doi: 10.1088/1742-6596/2301/1/012023.
- [3] P. K. Juneja *et al.*, "A review on control system applications in industrial processes," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1022, no. 1, 2021, doi: 10.1088/1757-899X/1022/1/012010.
- [4] C. H. D. Chelace, J. Friska, and S. Anusha Priya, "Automatic performance evaluation of smart transmitters using highway addressable remote transducer communication," *Proc. Int. Conf. Smart Syst. Inven. Technol. ICSSIT 2018*, no. Icssit, pp. 311–315, 2018, doi: 10.1109/ICSSIT.2018.8748414.
- [5] H. Zhang, D. Yue, and X. Xie, "Robust Optimization for Dynamic Economic Dispatch under Wind Power Uncertainty with Different Levels of Uncertainty Budget," *IEEE Access*, vol. 4, pp. 7633–7644, 2016, doi: 10.1109/ACCESS.2016.2621338.
- [6] A. Gunjal and S. R. Gaware, Suruchi, Mane, P. P., Borkar, V.V., Aherrao, "HART Communication Based Distributed Measurement System," *IJRAR- Int. J. Res. Anal. Rev.*, vol. 6, no. 2, pp. 196–200, 2019, [Online]. Available: http://ijrar.com/upload_issue/ijrar_issue_20543720.pdf.
- [7] R. Sindhu, J. Mathew, L. R. Sreedhanya, and C. S. Lajitha, "Design of HART compliant analog input module for indigenous SCADA system," *2017 IEEE Int. Conf. Signal Process. Informatics, Commun. Energy Syst. SPICES 2017*, 2017, doi: 10.1109/SPICES.2017.8091345.
- [8] K. Mak and A. Manikas, "A Superresolution Wide Null Beamformer for Undersampled Signal Reconstruction in SIMO SAR," *IEEE J. Sel. Top. Signal Process.*, vol. 9, no. 8, pp. 1548–1559, 2015, doi: 10.1109/JSTSP.2015.2465308.
- [9] L. Xuan and L. Yongzhong, "Research and Implementation of Modbus TCP Security Enhancement Protocol," *J. Phys. Conf. Ser.*, vol. 1213, no. 5, 2019, doi: 10.1088/1742-6596/1213/5/052058.
- [10] J. Luswata, P. Zavarisky, B. Swar, and D. Zvabva, "Analysis of SCADA Security Using Penetration Testing: A Case Study on Modbus TCP Protocol," *29th Bienn. Symp. Commun. BSC 2018*, no. Bsc, pp. 1–5, 2018, doi: 10.1109/BSC.2018.8494686.
- [11] L. Rosa, M. Freitas, S. Mazo, E. Monteiro, T. Cruz, and P. Simoes, "A Comprehensive Security Analysis of a SCADA Protocol: From OSINT to Mitigation," *IEEE Access*, vol. 7, pp. 42156–42168, 2019, doi: 10.1109/ACCESS.2019.2906926.
- [12] "HCS HART to MODBUS RTU Converter Moore Industries."
- [13] P. S. Services, "Description of Device Parameters Levelflex FMP5x Guided wave radar."