

Smart Diesel Generator Control System

Yunju Jeong[†], Md Israfil Ansari^{**}, WooHyeon Shin^{***},
Bonggu Kang^{****}, Jaechang Shim^{*****}

ABSTRACT

This paper introduces a user-friendly PLC (programmable logic controller) monitoring and control system of heavy machinery using Android based smartphone. The proposed system will control diesel generator and many such like machine without a dedicated PC with respect to similar system and offers a new communication protocol for handling it. The smartphone controls the generator via Wi-Fi, through which it connects to the Raspberry pi which will be installed in the PLC panel to setup the communication between them. Furthermore, Raspberry pi connects to two devices, one is PLC which gives the status and current information of the machine and to ON/OFF the machine. This proposed system used RS485 as a key mediator for data exchanging between Raspberry PI(master) and PLC(slave). RS485 allows multiple devices (up to 32) to communicate at half duplex on single pair of wires and provides a long connectivity area (up to 1200 meters) as compared to another device. This proposed system specially focused on accurate data flow between smartphone and PLC panel.

Key words: Android, Smartphone, Diesel Generator, PLC, Raspberry pi.

1. INTRODUCTION

Automation of heavy machinery facilitate the reduction of accident occur in handling those machines manually and tracking the status of those machine without going near to them. To gain full utility and customer protection, smart handling technology are being introduced. The idea of controlling heavy machinery with smartphones attracts for the safety in the industry.

Moreover, the rapid growth of smartphone's popularity and function, demands advance mobile application for controlling almost all machinery. The use of web services is an open and interoperable method for providing remote access service

or application to communicate each other.

Automation of Heavy machinery limits the risk for the worker or the maintainer of those machine. For this purpose, Raspberry pi is used as a mediator between PLC, Relay and Smartphone for data transferring. It is an open source electronics prototyping platform and easy to use hardware and its dedicated software i.e. Rasbian, a Linux based operating system. The specification of used Raspberry pi 3 have 10/100 BaseT Ethernet socket, 802.11 b/g/n Wireless LAN and many more. Raspberry pi helps to setup its IP address which helps to connect other device like smartphone for communication.

PLC is a digital controller which is widely used in automation industry for electromechanical

* Corresponding Author: Jaechang Shim, Address: (36729) Gyeongdong-ro 1375, Andong, Gyeongsangbuk-do, Korea, TEL: +82-10-9770-5645, FAX: +82-54-820-6164, E-mail: jcshim@anu.ac.kr

Receipt date: Jan. 4, 2017, Approval date: Jan. 24, 2017

[†] School of Computer Science & Engineering, Kyungpook National University

(E-mail: vrjung@hanmail.net)

^{**} Department of Computer Engineering, Andong National University (E-mail: israfila3@hotmail.com)

^{***} Department of Computer Engineering, Andong National University
(E-mail: withfox6051@naver.com)

^{****} Department of Computer Engineering, Andong National University (E-mail: dngustls@naver.com)

^{*****} Department of Computer Engineering, Andong National University (E-mail: jcshim@anu.ac.kr)

* This work was supported by a grant from 2016 Research Funds of Andong National University.

processes. PLC is designed for multiple arrangements of digital and analog inputs and outputs which extends temperature ranges, immunity to electrical noise. PLC is mostly used to control machinery, PLC comes with built in communication port, usually 9-pin RS-232, RS-422, RS-485 and Ethernet. Here we will be discussing on RS-485 port. Under the IEC 61131-3[1, 2] standard PLC can be programmed using standard based programming languages, in which ladder logic is most commonly used [3]. Ladder logic some time called “relay logic” was designed to work like relay logic, an old programming language which was already in wide use. It is run by reading and writing from the memory table of inputs, outputs, and intermediate values.

2. RELATED WORK

2.1 Wire Grinding Machine and Wire Stripping Machine Control System Based on PLC

This system introduces PLC control system with the support of relay control circuit[4]. Here PLC obtains the status of sensors in the wire grinding machine such as data of diameter value to control the operation of their corresponding parts to form a close loop between PLC control system, the motor of the machine and the wire diameter grinding detectors to grind the wire into segments with different diameter.

In this system, PLC obtains the status of sensors, diameter value and the motor, basically it only deals with the internal work of the system. In our proposed system, we have included third party device to monitor and control the diesel generator. Here we are not only taking the data of the running machine but also alerting the machine handler through smartphone in any malfunction is going or started occurring and controlling it, which helps to minimize the Accident occurs by heavy machine.

2.2 Smart Home Intelligence

Smart home refers an automatic system for controlling home appliances, multi-media equipment for monitoring and activating security apparatus associated with different areas and devices[5, 6, 7]. There are many systems came into existence, some system uses smartphone to interact with devices and some uses AI (Artificial Intelligence) mechanism to work as per changing conditions and events. It also provides an immediate automatic response to unexpected events.

But in this system, sometime geographical area creates a big issue for functioning the operation. Keeping it in mind our proposed system focused can operate in wide area and be a user-friendly system which can be install and operate any other such device.

3. MODBUS PROTOCOL OVERVIEW

Modbus protocol is a serial communication protocol where digital communication networks can be implemented over long distance effectively and also in electrically noisy environments. Here multiple receiver can be connected in a linear network where only one will be master device and rest will be slave. Slave can't transmit data without a request from the master node, and can't communicate with another slave. The master node issues a MODBUS request to the slave nodes in two modes i.e. unicast mode and broadcast mode[8].

Modbus protocol takes place at level2 of the OSI model. At physical level, MODBUS use different physical interface like RS485, RS232 etc. RS485 is Two-Wire interface which is most commonly used. At Data link layer MODBUS Serial Line Protocol is defined[9].

In Table 1 we have presented the difference between Modbus ASCII and Modbus RTU.

3.1 MODBUS Addressing

The MODBUS address space includes 256 dif-

Table 1. Comparison of Modbus ASCII and Modbus RTU

	MODBUS ASCII		MODBUS RTU	
Characters	ASCII 0...9 and A... F		Binary 0...255	
Error check	LRC (Longitudinal Redundancy Check)		CRC (Cyclic Redundancy Check)	
Frame start	Character ':'		3.5 chars silence	
Frame end	Characters CR/LF		3.5 chars silence	
Gaps in message	1 sec		1.5 times char length	
Start bit	1		1	
Data bits	7		8	
Parity	Even/odd	none	Even/odd	none
Stop bits	1	2	1	2

ferent address. The Address 0 is for broadcast purpose and all slave must recognize broadcast address. The Master node has no specific address.

3.2 MODBUS Frame Structure

Modbus frame is composed of ADU(Application Data unit) which encloses a PDU(Protocol Data Unit). ADU composed of Address, PDU and Error check. PDU is composed Function code and Data. Table 3 represents the frame structure of Modbus.

For T1-T2-T3-T4*, 3.5 character times at no communication.

The address field contains the slave address

The function code indicates server for kind of action to perform

CRC (cyclic redundancy checking) checks the content of entire message.

4. MODBUS Function Codes

The second byte sent by the Master is the Function code. This number tells the slave which

Table 2. MODBUS Address

0	1 - 247	248 - 255
Broadcast Address	Slave Address	Reserved

Table 3. MODBUS Frame Structure

START	ADDRESS	FUNCTION	DATA	CRC CHECK	END
T1-T2-T3-T4*	8 BITS	8 BITS	N*8 BITS	16 BITS	T1-T2-T3-T4*

table to access and whether to read from or write to the table. MODBUS has 10 function codes as shown in Table 4. In this proposed system, we have used two codes i.e. 04 and 05.

4.1 Function 04: Read Holding Registers

The Modbus RTU function 04 is used to read Input registers from a Modbus Slave device. Function 04 reads the contents of the 3X registers. Here the address starts from 0(zero), for example 1-10 are addressed as 0-9. Function 04 includes the quantity of registers to read from the Modbus Slave device. With Function 04 master used to request one or more holding register value from the

Table 4. MODBUS Function Codes

CODE	Description
01	Read coil status
02	Read input status
03	Read holding registers
04	Read input registers
05	Force single coil
06	Present single registers
07	Read exception status
15	Force multiple coils
16	Write holding/multiple registers
17	Report slave ID

device but only one slave device can be addressed in a single query. Frame structure of query and response are shown in Table 5 and Table 6.

Query Table (From PC to Machine)

In Table 5, Top 2 byte is the start address register, the lower two bytes is word units.

Table 5. Query Structure of Function 03

Slave Address	Function	Data	CRC
01	04	00 00 00 02	--

Response Table (From Machine to PC)

In Table 6, the first is the number of data to read (byte unit) and then the top data, sub-data, and lower data.

Table 6. Response Frame Structure of Function 03

Slave Address	Function	Data	CRC
01	04	04 02 2B 00 64	--

4.2 Function 05: Force Single Coil

Function 05 is used to force a Single Coil, or turn ON/OFF a digital output in a Modbus Slave Device. Coils are addressed starting at zero i.e. Coil 10 is addressed as 9.

Turn On/Off coils by specifying a constant in the data field. A value of FF 00 hex turns the coil ON. A value 00 00 turns the coil OFF.

Frame structure of Query. (PC (Master) to Machine (Slave))

The data "00 00 FF 00" from PC represents to ON the machine

Table 7. Query of Function 05

Slave Address	Function	Data	CRC
01	05	00 00 FF 00	--

Frame structure of Response (Machine (Slave) to PC (Master))

The data "00 00 FF 00" from PLC respond that machine has been ON

Table 8. Response of Function 05

Slave Address	Function	Data	CRC
01	05	00 00 FF 00	--

*Normal Response is returned as query.

5. IMPLEMENTATION

5.1 Whole system diagram

Fig. 1 shows how our proposed system communicate each other. SmartPhone uses internet to connect with Raspberry Pi and communication medium between PLC and Pi is RS485.

5.2 Connection of Smart phone with Raspberry Pi

Connection between smart phone and raspberry Pi is done through socket Client-Server module, where raspberry Pi is socket server and smart phone is socket client. A socket is a two-way communication between two programs running on the network. A socket is restrained to a port number so that the TCP layer identify the application that data is destined to be sent to. Here Raspberry Pi receives data from client and passes it to the PLC to control.

5.3 Raspberry Pi to PLC

The connection interface between Pi and PLC is RS485. In figure 2, TX and RX port of Raspberry Pi is connected to DI and RO of RS485 respectively. Whereas RE and DE port of RS485 is combined and connected to port 3 of Pi.

5.4 Screen shot of Android Application

This android App is developed with Android Studio platform. As discussed earlier, through this App user can track the status of machine and also can control through internet. This app is simple and highly interactive so that a person can easily understand and use it.

In fig. 4, (a) is for log in to the management portal. (b) add machine by giving name, ip address

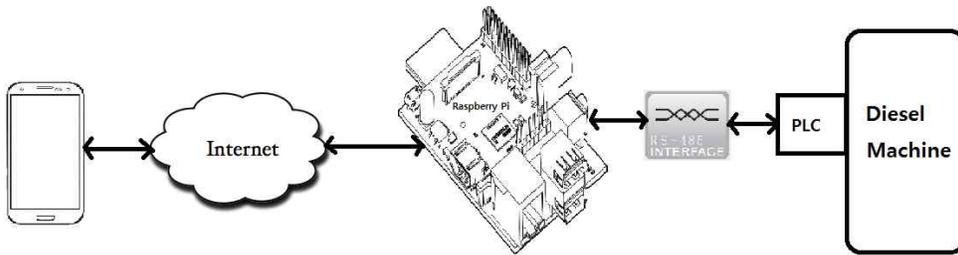


Fig. 1. Representation of Whole System.

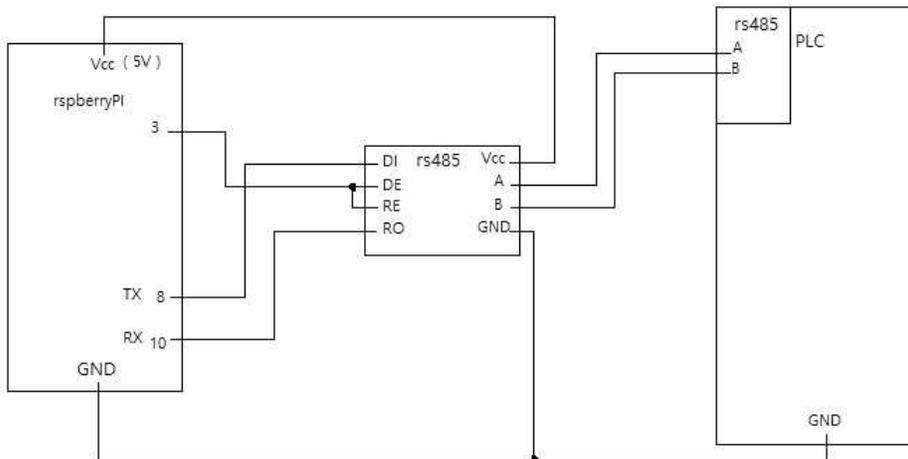


Fig. 2. Raspberry Pi and PLC connection.

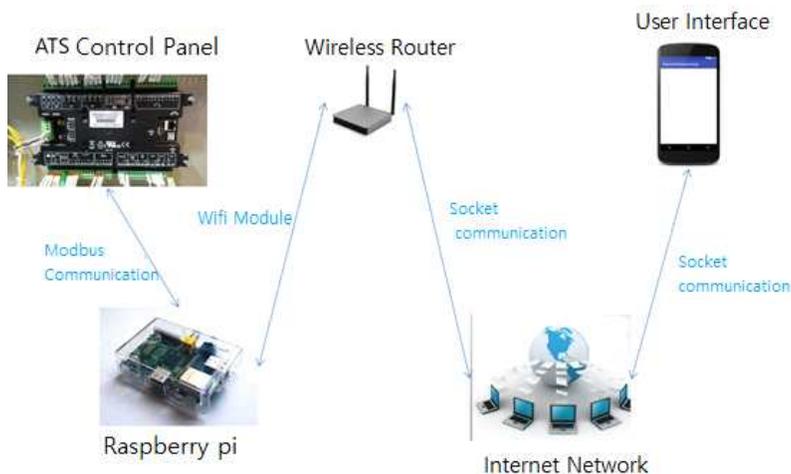


Fig. 3. System configuration diagram.

and port number. (c) for safety click on safety button to control machine. (d) controlling portal of machine where we can ON/OFF the machine and also view the status of the machine.

6. TESTING

We have successfully tested our system with diesel generator. Fig. 5 shows the generator where

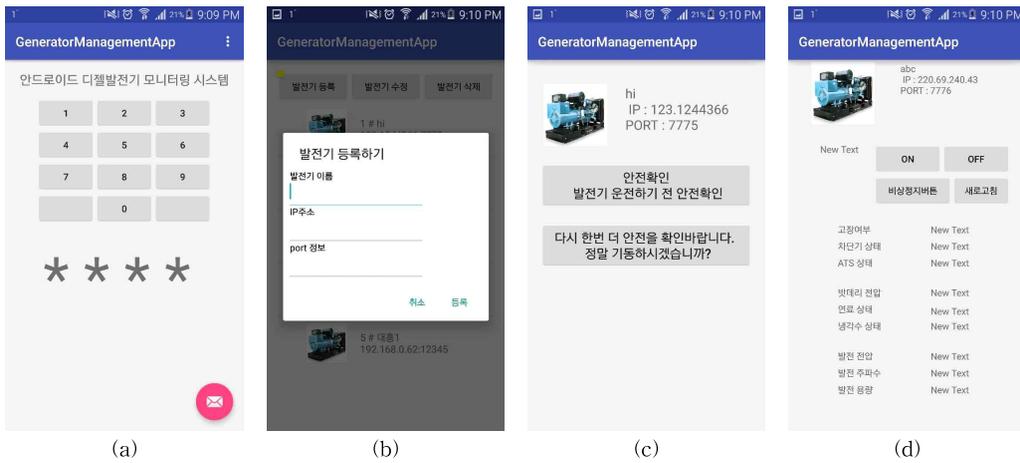


Fig. 4. App Screen Shot. (a) login, (b) add generator, (c) safety confirm, (d) controlling portal.



Fig. 5. Test Machine.

we tested proposed system.

The following table represents the data transfer and receive between master and slave. Here Raspberry Pi is a master and PLC is a slave.

From Table 8 we can see four data row from which first two is data address and next two is data which are to be transfer.

First address with function 05 i.e. 0×00 is to “on” the machine, 0×01 “off” the machine. with function 04 Raspberry Pi reads data from PLC, ad-

dress 0×02 is for “Voltage” of the machine, 0×03 for “Power status”, $0 \times 0F$ is for “battery voltage” of the machine, 0×10 for “oil pressure” of the machine.

In Table 9, function 05 return same as it is for ON/OFF the system. But function 04 return in different form with one extra data at beginning which is number of data to read, followed by first data, second data and lower data. Here both the request and response CRC should match otherwise there will be error in communication.

7. FUTURE ENHANCEMENT

As we know that automation in all fields are in great demand. To fulfill the customers, need electronic and mechanical companies adopted automation for their various product.

In future, we would like to study more about the

Table 8. Request from Raspberry Pi to PLC

Address	Function Code	Data	Data	Data	Data	CRC LO	CRC HI
0×01	0×05	0×00	0×00	$0 \times FF$	0×00	0×18	$0 \times F0$
0×01	0×05	0×00	0×01	$0 \times FF$	0×00	0×19	0×60
0×01	0×04	0×00	0×02	0×00	0×02	0×19	0×90
0×01	0×04	0×00	0×03	0×00	0×02	0×19	0×00
0×01	0×04	0×00	$0 \times 0F$	0×00	0×02	$0 \times 1A$	0×30
0×01	0×04	0×00	0×10	0×00	0×02	$0 \times 1A$	0×61

Table 9. Reply from PLC to Raspberry Pi

Address	Function Code	Data	Data	Data	Data	Data	CRC LO	CRC HI
0 × 01	0 × 05	--	0 × 00	0 × 00	0 × FF	0 × 00	0 × 18	0 × F0
0 × 01	0 × 05	--	0 × 00	0 × 01	0 × FF	0 × 00	0 × 19	0 × 60
0 × 01	0 × 04	0 × 04	0 × 00	0 × 02	0 × 0F	0 × FF	0 × 19	0 × 90
0 × 01	0 × 04	0 × 04	0 × 00	0 × 03	0 × 00	0 × 0A	0 × 19	0 × 00
0 × 01	0 × 04	0 × 04	0 × 00	0 × 0F	0 × 0F	0 × 01	0 × 1A	0 × 30
0 × 01	0 × 04	0 × 04	0 × 00	0 × 10	0 × FF	0 × FF	0 × 1A	0 × 61

initial power supply technique. Initial power supply to start machine is differ from machine to machine. It will help us to test our same system in some other machine so that we can bring out the difference. Then our target will be to change this system to work on all such kind of machines. This will help to reduce the development cost for many such company.

8. CONCLUSION

In this paper, we studied various components required to build this system. Automation, the technique of making an apparatus, process or a system operate automatically is demanded in every mechanical and such like company to saves labor cost and time. However, still many automation companies trying to increase the accuracy and reduce the risk while operating those systems. In this proposed system, we have used PLC (Programmable logic controllers) with raspberry Pi connected with Android phone to control diesel generator. One of the most benefit of this system is that it can be connected to all such kind of machine integrated with PLC like devices. We also came out with an issue of initial power supply to start the machine. To start diesel machine power supply should not be constant and this gave us any opportunity to study about initial power supply mechanism for various machines.

Acknowledgement

Our deepest gratitude and warmest affection go

to advisor Prof. Shim Jaechang, for his generous advice, inspiring guidance, encouragement, and professional assistance.

REFERENCE

- [1] IEC, *IEC 61131-3, Programmable Controllers-Programming Languages International Electrotechnical Commission*, IEC 61131-3, 2013.
- [2] E. Tisserant, L. Bessard, and M. Sousa, "An Open Source IEC 61131-3 Integrated Development Environment," *Transactions on Industrial Informatics*, Vol. 1, pp. 183-187, 2007.
- [3] E. Anderson, *Sequential Function Chart to PLC Ladder Logic Translation*, DMC, 2009.
- [4] L. Feiyan, "The Research of Wire Grinding Machine and Wire Stripping Machine Control System Based On PLC," *International Journal of Control and Automation*, Vol. 8, No. 8, pp. 45-56, 2015.
- [5] D. Bregman, "Smart Home Intelligence-The eHome That Learns," *International Journal of Smart Home* Vol. 4, No. 4, pp. 35, 2010.
- [6] S. Folea, D. Bordenca, C. Hotea, and H. Valean, "Smart Home Automation System Using Wi-Fi Low Power Devices," *Proceeding of IEEE International Conference on Automation Quality and Testing Robotics*, pp. 569-574, 2012.
- [7] S.J. Lee, D.H. Kim, "A Study of Standby Power Control Based on Zigbee in Smart Home," *Journal of Korea Multimedia Societ*, Vol. 17, No. 7, pp. 879-885, 2014.

- [8] Modicon Modbus Protocol Reference Guide, http://modbus.org/docs/PI_MBUS_300.pdf, (accessed Nov., 24, 2016)
- [9] MODBUS Over Serial Line Specification and Implementation Guide V1.02, http://www.modbus.org/docs/Modbus_over_serial_line_V1_02.pdf, (accessed Nov., 22, 2016)
- [10] Z. Aspar, N. Shaikh-Husin, and M. Khalil-Hani, "Algorithm to Convert Programmable Logic Controller Ladder Logic Diagram Models to Petri Net Models," *Proceeding of IEEE Student Conference on Research and Development*, pp. 156-161, 2015.
- [11] G. Septiani, R. Tridesman, and E. Ekawati, "Design and Implementation of Biodiesel Washing Automation System with Set of Sensors and Programmable Logic Controller Device," *Proceeding of International Conference on Sustainable Energy Engineering and Application*, pp. 35-41, 2015.



Yunju Jeong

She received the B. S. degree in 1991 from Andong National University. Currently she studies for Ph.D. at Department of Computer Engineering, Kyungbook National University, Korea. Since 1998, she works as

a lecturer in Andong National University. Her research interest include computer vision, image processing, and pattern recognition, Deep Learning, IoT and Networking.



Md Israfil Ansari

He received the BCA degree in Computer Application from Punjab Technical University, Jalandhar, India in 2011 and the MCA degree in Computer Application from Visvesvaraya Technological University, Bangalore, India in 2015. His previous position was a Software Developer as an Intern at Xcelvations Consultancy Pvt Ltd, Hyderabad, India. Currently studies for Ph.D. at Department of Computer Engineering, Andong National University, Korea. He has interest in the areas of computer vision, pattern recognition, Deep Learning and Networking.



Bonggu Kang

He will receive the B. S. and M. S. combine degree in February, 2017 from Department of Computer Engineering, Andong National University, Korea. He has interest in the area of IoT and android application.



Woohyun Shin

He is an under graduated student in Department of Computer Engineering, Andong National University, Korea. He has interest in the area of IoT and android application.



Jaechang Shim

He received the B. S. degree in 1987 and Ph.D. degree from Kyungpook National University, Korea, in 1997. From 1997 to 1999, he worked as a researcher in IBM T. J. Watson Research Center. From 2005 to 2006, he was a visiting Fellow Professor at Princeton University. Since 1994, he has been a Professor of the Andong National University, Korea. He received the best Industrial-Related Paper Award form International Association for pattern Recognition in 1998. His research interests include computer vision, image processing, and pattern recognition.