International Journal of Emerging Science and Engineering (IJESE)
ISSN: 2319–6378, Volume-1, Issue-11, September 2013

Application of MODBUS to Communicate the PLC and Lab VIEW for Real Time Process Control

Anjali S. Ashtekar, Bhagsen J.Parvat, Chandrakant B. Kadu

Abstract— This paper presents the State-of-the-Art and recent trends of SCADA system Architecture, which is usually three layer SCADA system architecture depending on open system technology rather than a vendor controlled, Proprietary technology. A Real-time Industrial process is simulated (water level controller), and a complete three-layer model SCADA system is developed for this process: supervision control layer, Process control layer and field Instrument layer. National Instrument's LabVIEW with the associated Data Logging and Supervisory Control Toolset (DSC) is used to develop the SCADA/HMI in supervision layer. Industrial Programmable Logic Controllers (PLCs) from Delta, DVP 14SS and related software package are used to build up process control layer. Finally simulation unit is designed and developed to be used as field instrument layer. MODBUS protocol is used to solve compatibility problem raised from different vendors' tools. This work represented the real time implementation of water level application and gives its results for showing its effective implementation. This is made by communicating Delta DVP-14SS PLC to the PC with LabVIEW 2011 via MODBUS for controlling water level.

Index Terms—SCADA, DCS, RTU, LabVIEW.

I. INTRODUCTION

In traditional industrial automation, it is assumes that the operator is responsible to monitoring and controlling of processes in real time. Remote controlling facilitates, to handle greater complexity of industrial processes and remote controlling and monitoring from a central location. This will make the operator function easier and proficiently. A SCADA "Supervisory Control and Data Acquisition" is the generic terms for the hardware, software and procedures used to control and monitor industrial process. SCADA systems are widely used in most industrial processes: e.g. steel making, power generation etc. It can provide information in a real-time environment that identifies problems as they occurred and can take corrective action when assistance is needed. Proper monitoring of process can maintain operations at an optimal level by identifying and correcting problems before they turn into significant system failures. SCADA systems have made substantial progress over the recent years in terms of functionality, scalability, and performance. The MODBUS protocol is employed while communication among the multilayer SCADA architecture. A prototype of water level control is designed and implemented based on the three-layer SCADA architecture.

Manuscript received September, 2013.
Anjali S. Ashtekar, Instrumentation and Control Dept., Pravara Rural Engineering College, Loni, Ahmednagar, India.
Bhagsen J.Parvat, Instrumentation and Control Dept., Pravara Rural Engineering College, Loni, Ahmednagar, India.
Chandrakant B. Kadu, Instrumentation and Control Dept., Pravara Rural Engineering College, Loni, Ahmednagar, India.

II. THREE LAYER SCADA SYSTEM ARCHITECTURE

SCADA systems have evolved in parallel with the growth and sophistication of modern computing technology. Its architecture has been improved depending on technology revolutions. The latest trend of SCADA system is the three layer SCADA architecture which depending on open system technology rather than a vendor controlled proprietary environment. There are various vendors for PLCs, industrial networks, SCADA systems and HMIs which need to communicate with each other. There are also still RTUs (Process Control Layer/Remote Terminal Unit) utilizing protocols that are vendor-proprietary. But the major improvement in the last generation is that of opening the system architecture, utilizing open standards and protocols, generations of SCADA systems. Fig. 1 illustrates the three-layer SCADA system architecture [1]-[4].

A. Supervisory Control Layer (Master Station)

Master stations have two main functions:
1) Periodically obtain data from RTUs/PLCs (and other master or sub-master stations).
2) Control remote devices through the operator station.
Master stations consist of one or more personal computers

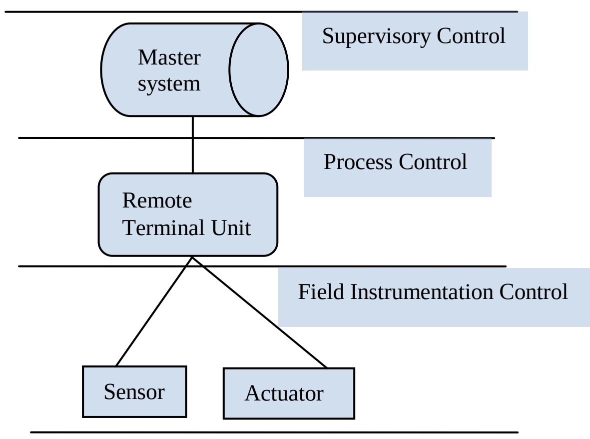

Fig 1. The 3-layer SCADA system architecture.

(PC), which, although they can function in a multi-purpose mode (email, word processing, etc), are configured to be dedicated to master station duties. These duties include trending, alarm handling, logging and archiving, report generation, and facilitation of automation. These duties may be distributed across multiple PCs, either standalone or networked.

B. Process Control Layer (Remote Terminal Units (RTUs)

This layer usually consists of more than one device depending on the situation, these devices like:
Programmable Logic Controllers: The modern RTUs typically use a ladder-logic approach to programming due to its similarity to standard electrical circuits. A RTU that

employs this ladder logic programming is called a Programmable Logic Controller (PLC). PLCs are quickly becoming the standard in control systems. The PLC is special purpose computer contains CPU and different kinds of memory.

Analog Input and Output Modules: The configuration of sensors and actuators determines the quantity and type of inputs and outputs on a PLC or RTU. Depending on the model and manufacturer, modules can be designed solely for input, output, digital, analog or any combination. An analog input module has a number of interfaces. Typical analog input modules have 4, 8, 16, or 32 inputs. Analog output modules take digital values from the CPU and convert them to analog representations, which are the sent to the actuators. An output module usually has 4, 8, 16 or 32 outputs, and typically offers 8 or 12 bits of resolution.

Digital Input and Output Modules: Digital input modules typically are used to indicate status and alarm signals. A specialized digital input module is used for counting pulses of voltage or current, rather than for strictly indicating "open" or "closed." This functionality, however, can also be implemented using standard input modules and functions found in the ladder-logic programming language of the PLC.

C. Field instrument control layer (Sensors and Actuators)

This layer mainly consists of sensors and actuators. The Sensors perform measurement and actuators perform control. Sensors get the data (Supervision and Data Acquisition) and actuators perform actions dependent on this data (control). The processing and determination of what action to take, is done by the master control system (i.e. SCADA).

D. Communication Interfaces

Modern RTUs and PLCs offer a wide variety of communications means, either built in directly or through a module. The following list represents a variety of transmission methods supported:

- RS-232/RS-442/RS-485
- Dialup telephone lines
- Dedicated telephone lines
- Microwave
- Satellite
- X.25
- Ethernet
- 802.11a/b/g
- Radio (VHF, UHF, etc) [2].

Each of these methods could be used to communicate with the master station, other PLCs or RTUs, the programming station, or operator consoles.

III. COMMUNICATION AMONG THREE-LAYER SCADA SYSTEM ARCHITECTURE

Communications protocols (especially at the lower layers) are designed to meet the requirement that information arrive without errors in a timely manner (availability and data integrity). SCADA communications at the Field Instrument will normally occur at Layer 1 (Physical) and System Interconnection (OSI) 7-Layer model. Fig. 2 illustrates the typical means of communications between SCADA components, which are detailed below.

A. Communication among Supervisory Control Peers

At the Supervisory Control layer between peers, communications are usually through a standard networking protocol such as TCP/IP or IPX over Ethernet or Token Ring. The SCADA applications involved in the communications are typically installed on standard PC systems capable of using standard operating-system provided protocols. Options exist for employing proprietary protocols between peers from the same manufacturer or SCADA specific, open source protocols between peers of dissimilar manufacturers.

B. Communication between Supervisory Control and Process Control Peers

The means of communications between supervisory control and process Control, as well as among process control peers, vary greatly and are usually dependent on hardware manufacturer. If a suite of RTUs, sensors and actuators is purchased from a single vendor, the protocol may be proprietary. There is a scope to avail the option of using open source protocols like, MODBUS, profibus, and UCA “Utility Communications Architecture”, in order to incorporate a variety of manufacturer's equipment.

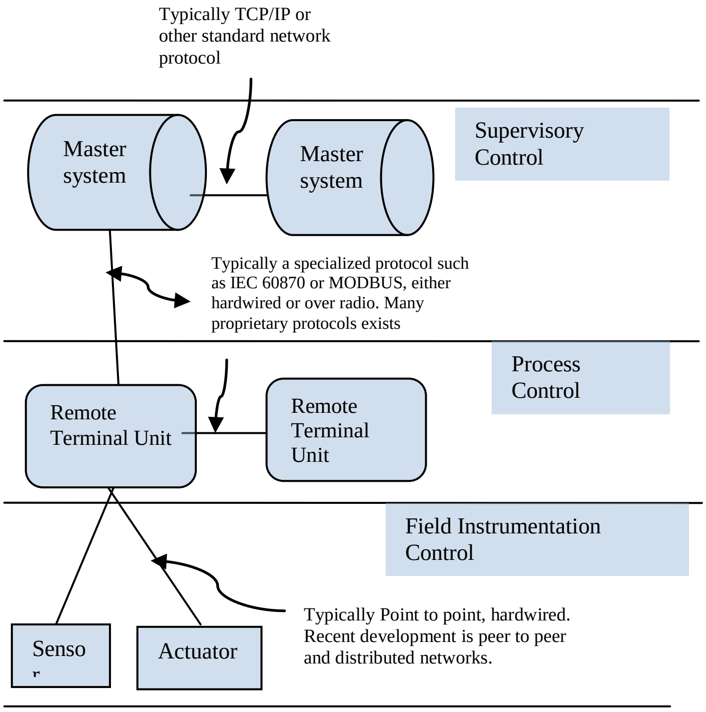

Fig 2. The typical means of communications between SCADA components

C. Communication between Process Control and Field Instrumentation Control

As communications between process control (RTU) and field instrumentation control is typically a point to point running over wire pairs, transmitting voltage pulses or current level (4-20mA) that are interpreted by the RTU based on how it is programmed. Recent trends in "intelligent" sensors and actuators provide more capabilities, and allow for peer to peer or distributed networks among sensors and actuators; protocols in intelligent sensors used today are Foundation Fieldbus, and profibus-AS[1]-[4].

D. Software Communication Tool (MODBUS)

As there are numerous vendors of automation equipment which all use their own protocols to communicate with, in addition to the large variety of network interfaces, it is difficult to carry out software which can be used for all variations. To make it easier for software developers to communicate with this large variety of automation equipment, a standard communication interface was needed. MODBUS is the most popular industrial protocol being used. The main reasons for the use of MODBUS in the industrial environment are: easy to deploy and maintain, developed with industrial applications in mind, openly published and royalty-free and it moves raw bits or words without placing many restrictions on vendors. MODBUS is a serial communications protocol, originally published by Modicon (now Schneider Electric) in 1979 for use with its PLCs. MODBUS allows the communication between many devices connected to the same network [5]-[6].

The MODBUS is an application layer and stateless client-server protocol similar to HTTP, for communication between devices, mainly to exchange data. Fig. 3 shows, the MODBUS transaction and Master-Slave in terms of the Client-Server paradigm. The MODBUS protocol follows a master/slave architecture, where a master will request data from the slave and can also ask to perform some action. The master initiates a process by sending a function code that represents the type of transaction to perform. During communication on a MODBUS network, the protocol determines how each controller will know its device address, recognize a message addressed to it, determine the kind of action to be taken, and extract any data or other information contained in the message [7].

IV. DESIGN AND DEVELOPMENT OF THREE-LAYER SCADA PROTOTYPE

A prototype has been implemented based on the three layer SCADA architectural. This prototype helps to Visualize real-time process data, and enables to configure and monitor process status (data input/output), and information archives, remotely from master station [8].

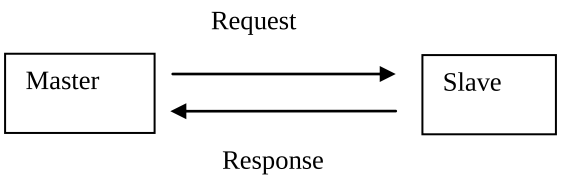

Fig. 3 MODBUS Transaction

A. Industrial Process (Water Level Control) function description

Water level process is very common in the industrial applications such as chemical or power plants and a very important parameter. The typical applications for liquid level measurement are lift stations in wastewater treatment systems, bore hole or well level measurement, level of a liquid in a tank, etc.

Fig. 4 shows the photograph of prototype setup. This setup involves two tanks namely sump and tank, sump is used to store the water. In this setup, three levels are identified as Extreme Lower Level (LZ), Low Level (LL) and High Levels (LH). Extreme Low (reference) is always immersed in water. The different levels are sensed from the tank with the probe type sensors. This setup involves the necessary circuitry, electrical connections, power supply and water connections.

B. Field Instrument Control Layer (Sensors and Actuators) Design and Development

A prototype is designed and developed to simulate this process status, Motor, Valve, and Tank Level. Table I and II below shows the I/O status of the process. The RTU (PLC) contains 8 digital inputs, 6 digital outputs. The working of the prototype water level controller is very common and conventional. When level reaches to sensor it gives logic high signal to the PLC input. Then the PLC sensed the water level. These three levels are connected to the Input Module of PLC. Initially, when there is no water in the tank; the Motor should ON, and remains ON until the high level of water reaches. When the high level is sensed, the Motor turns OFF and solenoid valve become ON. This results in drain of water to the sump. This valve remains on till the water level reaches to low level. When low level is sensed, this results in turn OFF and ON of Solenoid Valve and Motor respectively. This continuous process helps to maintain the level in water tank.

C. Process Control Layer (RTU) Design and Development

The main part used in RTU is the Programmable Logic Controller (PLC). Therefore, the design of RTU began with the selection of The PLC unit depending on I\O signals of field instrument control layer. By considering the availability of the PLC, Delta DVP 14SS is chosen for controlling the industrial process. This PLC consists of 8 digital inputs,

Fig. 4 Photograph of Prototype Setup

TABLE I. PLC I/O CONVENTATIONS

PLC I/Os	Prototype Component
I/P - 0	Low Level Probe Sensor
I/P - 1	High Level Probe Sensor
I/P - 2	Zero Level Probe Sensor
O/P - 0	Water MOTOR
O/P - 1	Solenoid Valve

TABLE II. PROCESS STATUS

Sr. NO	Status description	Simulated Indication	RTU Connection
1	MOTOR On/Off	Green LAMP	Digital-Output
2	Solenoid Valve	Green LAMP	Digital-Output
3	Level sensor	Green LAMP	Digital -Input

6 digital outputs, and which are sufficient for this industrial process. The AC power supply version is selected to avoid need of extra DC power supply.

This work intended to communicate Delta PLC to PC using RS 232 serial communication. National Instrument's

LabVIEW is used as programming tool and MODBUS protocol as a communication media. In MODBUS communication, LabVIEW acts as a Master and Delta PLC as a slave. A Personal Computer (PC), with Standard programming software WPLSoft is helps to develop a Ladder Logic Diagram (source code) in PLC to control the water level process.

Delta DVP 14SS PLC has default two communication ports i.e. RS-485 and RS-232. According to the port, configuration settings are necessary as shown in Table III. This prototype is communicated with RS-232 port i.e. COM1. Communication parameters are set as: Mode- RTU, Data Length- 8, Parity -Even, Stop Bits -1Bit and Baud rate -19200 bps [9]-[10].

In this communication, incorporation of special auxiliary relays (special M) and special data registers (special D) are essential. Fig. 5 shows the communication ladder diagram for delta DVP 14SS PLC for communication with MODBUS. These RS 232 MODBUS setting in the PLC are same the LabVIEW MODBUS. The whole developed RTU and associated components is depicted and listed in Table III and IV.

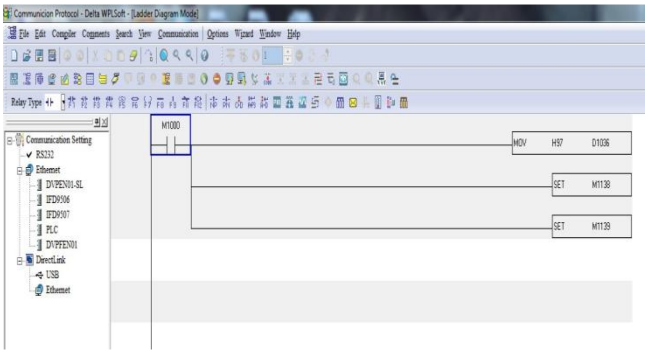

Fig. 5 Communication Ladder Diagram

TABLE III. RTU COMPONENTS

Sr. No	Item	Model
1	PLC	DELTA DVP 14SS
2	Programming Cable	Rs 232 Serial port Cable

TABLE IV PLC SPECIFICATIONS

Sr. No	Feature	Description
1	MPU points:	14 (8DI + 6DO)
2	Max. I/O points	494 (14 + 480)
3	Program capacity	8k steps
4	COM port	Built-in RS-232 & RS-485 ports, compatible with MODBUS ASCII/RTU protocol. Can be Master or Slave.
5	High-Speed Pulse Output	Supports 4 points (Y0 ~ Y3) of independent high-speed (Max. 10kHz) pulse output
6	Supports PID Auto-tuning	DVP-SS2 saves parameters automatically after the PID auto temperature tuning is completed.

D. Supervision Layer (Master Station) Design and Development.

A personal computer (PC), with National Instrument's LabVIEW (2011) is used to develop the SCADA/HMI layer. LabVIEW VI can implement SCADA functionalities such as sense the level, ON/OFF of Motor and Solenoid Valve etc. Also by chosen of LabVIEW from NI vendor which is different from RTU/PLC vendor (DELTA), gives us opportunity to show how MODBUS solve this compatibility problem. The MODBUS protocol is utilized for data exchange between supervision control layer and RTU layer. LabVIEW works like a Master and PLC as Slave. The automation system is developed based on LabVIEW, though the serial communication, issuing commands to the PLC. PLC will work on the control system, real-time access and store various sensor signals after receiving the control command from the PC. It was easy to develop an automated system using PLC and LabVIEW via MODBUS. National Instruments provides a MODBUS Library for LabVIEW that is design to facilitate communication to a device that can use a MODBUS protocol. Table V lists the component of master station layer.

The objective of the VI program is allowed to make the decision of the start and stop operation of the Motor and Solenoid Valve according to the level sensed. Fig. 6 illustrate the VI Block Diagram, the programming part of water level control application VI. Fig. 7 shows Front panel of LabVIEW for water level control. The Front Panel contain five LEDs for representation of; Low Level(LL),High Level (LH), Extreme Low Level (LZ) and ON-OFF status of Motor and Solenoid Valve.

TABLE V MASTER STATION COMPONENT (SUPERVISION LAYER)

Sr. No.	Item	Description
1	PC	Personal Computer
2	Operating system	Windows 7
3	LabVIEW with DSC module	SW package As developer tool for SCADA HMI
4	DVP 14SS PC Access Software package	MODBUS protocol
5	Communications ports	Rs 232 Serial Port

LabVIEW program is designed such as, when the water is at zero level, the Motor will turn ON and remains ON until it reaches the high level. The 'MOTOR ON' LED will turn to green. When the water level reaches to LL and LH, it is sensed by the sensor (LL and LH LED glows)and it gives signal to the Solenoid Valve and Motor to turn ON and OFF respectively, through the LabVIEW program. This ignites 'SOLENOID ON' LED and also depicted the transition on waveform chart as shown in fig 8. The level of the water start falling till it reaches to low level as outcome of above. When it goes below the low level the signal is again fed to the system through the LabVIEW. It results in turn OFF and ON the Solenoid Valve and Motor respectively. These ON-OFF operations are visualized on the front panel in the form of ignition of 'MOTOR ON' LED and represent transition on waveform chart. When the different levels are attained the transition also shows on waveform chart. Program is designed by considering different states to control the water level.

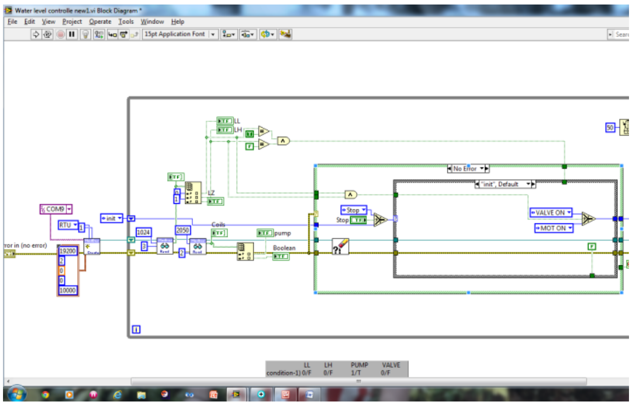

Fig. 6 Block Diagram of water level controller

Fig. 7 Front panel of writing data on PLC output

Fig. 8 waveform Chart for Solenoid

V. RESULTS

In the industrial control process, liquid level is a very important parameter especially in dynamic state. It can have a very good production effect with appropriate methods to test and control the liquid level. Fig. 7 shows, attractive GUI based Front Panel for water level control application using LabVIEW. This Front Panel indicators turn ON and OFF as per the process changes. This shows the proper execution of LabVIEW program and obtains the desired results. These ON-OFF operations are visualized on the front panel in the form of ignition of LEDs and waveform chart. This represents the successful communication of the PC, PLC and Prototype setup using LabVIEW via MODBUS.

VI. CONCLUSIONS

The main objective of this work is to communicate PC and PLC through LabVIEW for more effective and efficient process control. This third party software does not have the device drivers for existing model of PLC. This work inculcates interfacing of two most powerful technologies with most preferable communication protocol MODBUS, by bridging the technological gap.

The plant itself is carefully simulated with a LabVIEW program as Graphic user interface (GUI). This program facilitate the user to implement the following functions; starting and stopping the operation, monitoring the real-time events of process and level, emergency stop, etc.

LabVIEW software enhances the performance of systems without spending development time and enables to handle the complexity of application. Thus the PLC can be interfaced with LabVIEW for controlling several real time applications in industry for effective implementation.

REFERENCES

[1] Mohamed Endi, Y. Z. Elhalwagy and Attalla hashad, "Three-Layer PLC/SCADA System Architecture in Process Automation and Data Monitoring" IEEEC – 2010,Volume 2, 978-1-4244-5586, pp 774-779.

[2] Nargalkar Akshay, K. Uday Sravanth, Rahul Varanasi and J. Ankitha Reddy, "Real Time Automated Control of Industrial Processes with PLC –LABVIEW Communication", International Journal for Research in Science & Advanced Technologies ISSN: 2319-2690 Issue-1, Volume-1, pp 035-038.

[3] Nader N. Barsoum and Pin Rui Chin, "Ethernet Control AC Motor via PLC Using LabVIEW", Intelligent Control and Automation, November 2011, 2, pp 330-339.

[4] R.Shwetanjali, A.Navya and Mrs. Anitha Karthi, "PLC Based Automated Packing Station Using National Instrument's LabVIEW Software Package", International Conference on Computing and Control Engineering (ICCCE 2012), 12 & 13 April, 2012, ISBN 978-1-4675-2248-9, pp 1-7.

[5] "Introduction to MODBUS", http://www.ni.com/white-paper/7675/en/, Publish Date: Nov 21, 2012, pp 1-7.

[6] "MODBUS Application Protocol Specification V1.1b", http://www.MODBUS.org/docs/MODBUS_Application_Protocol_V1_1b pdf, December 28, 2006, pp 1-51.

[7] "Using MODBUS for Process Control and Automation", http://www.isa.org/FileStore/Intech/WhitePaper/Using%20MODBUS%20for%20Process.pdf pp 1-7.

[8] "*Understanding the MODBUS Protocol*", http://jamod.sourceforge.net/kbase/protocol.html.

[9] "DVP-PLC Application Manual", http://www.kalatec.com.br/plc/MANUAL/EXEMPLOS_DE_APLICACAO-CLP_DVP.pdf, pp 1-892.

[10] "PLC RS232/RS485 send frames", http://deltautomation.wordpress.com/2013/04/30/plc-rs232rs485-send-frames/, pp 1-2.