Design and Implementation of RS-485/MODBUS based Automatic Batch Weighing System using LabVIEW

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Abstract—Automatic Batch Weighing System incorporates various technologies at different hierarchical levels for automation of batch weighing process. The paper reports the work carried out at PG dissertation level and presents the detailed design and implementation of the system for process industries. Sensors and MODBUS-compliant modules are wired to form an RS-485 network at field level, which is connected to a PC based main controller. The design incorporates DataSocket Server, along with HMI based indication and control system. Remote access and control are also availed through intranet/internet. Various functionalities of the proposed system have been validated through laboratory implementation.

Keywords—Automation, Human–Machine Interface Design, MODBUS, RS-485, Virtual Instrumentation

I. INTRODUCTION

Automatic Batch Weighing System (ABWS) is a Supervisory Control and Data Acquisition (SCADA)\textsuperscript{1}\textsuperscript{2} system that incorporates various functionalities provided by the auto/manual control system of a batch weighing process. ABWS is a computerized, intelligent network of electronic devices, designed to monitor and control the batch weighing process for creating optimized weight (load) control, safety, security, information, report generation and communication facilities.

ABWS maintains the start, stop, pause and throw actions of particular hoppers loaded with specific materials used for batch-wise mixing, filling and bagging processes. It controls different parameters like set-point value, fast set-point value, process value, pulse ON/OFF time, throw ON/OFF time, etc. It continuously monitors these parameter values and also provides their settings by manual intervention or automatically.

Set-point value is the actual value of the weight that has to be fed from screw feeder of the hopper on the conveyer belt, while the fast set point value is always lesser than set point value somewhat near equal to set point value; Process value is the actual instantaneous weight of the loaded hopper. Pulse ON time is the ON time for opening the gate of the hopper to drop down the material. Pulse OFF time is the OFF time for closing the gate of hopper. Throw ON time is the ON time for which material is being thrown out from hopper on the conveyor while the throw OFF time is the OFF time for which material is not thrown on conveyor belt.

The Batch Weighing System (BWS)\textsuperscript{4} controlled by automation (implemented using either Microprocessor/Microcontroller or using Programmable Logic Controller (PLC))\textsuperscript{3} is often referred to as an Automatic Batch Weighing System (ABWS). ABWS saves upon material consumption and thereby, optimizes operational and maintenance costs as compared to an uncontrolled BWS.\textsuperscript{4}

This paper presents a design of ABWS based on wired RS-485/MODBUS protocols. Although not formally standardized, MODBUS is regarded as an open protocol\textsuperscript{5}\textsuperscript{6}\textsuperscript{7}. The physical layer of communication system is an RS-485 wired network, chosen for its simplicity, low cost and adequate data rate. At the management level, ethernet is used that supports high data rates. Remote operation of the ABWS is provided by the TCP/IP protocol using Intranet/Internet.

The forthcoming sections present detailed design of the proposed ABWS for typical industrial application, including design objectives, functionalities and hardware-software used for the development of the system. The design has been validated by implementing most of the functionalities of the proposed system in the laboratory implementation and its results are generated in reports of different formats. The paper ends with the concluding notes and
identifying future scope of work in form of suggestions for further value addition.

II. ABWS SUBSYSTEMS

A. Automation subsystem

The proposed ABWS system is designed and implemented to handle twelve hoppers of artificial marble manufacturing plant as a case study for experimental validation and testing of the prototype resulted as an outcome of the proposed design. For the process under consideration, each hopper contains different material used for making of composite marbles. The materials from different hoppers are fed to the conveyor belt through the respective screw feeders that finally mix in the mixer. Fig. 1 given below shows the schematic diagram of the typical ABWS.

Fig. 1 Schematic diagram of typical ABWS.

B. Alarm Annunciation Subsystem

Communication subsystem makes necessary provisions for reporting critical alarm annunciation related data. Audio-visual annunciation is generated for the faults configured or operational errors, such as power failure or conveyor belts are stopped or hopper is not loaded with particular load, etc.

III. DESIGN OF ABWS

Typically, the functionalities such as communication and information exchange need high data rates, while the features like automation, safety and load control need low data rates but low latency, high network reliability and data security. Moreover, the designs of ABWS for process industries must be cost-effective and easy to operate without specialized training.

A. Design objectives

Following are the design objectives of proposed ABWS:
1. To handle Start, Stop, Pause, Throw operations
2. To control Pulse ON/OFF timing, Throw ON/OFF timing.
3. Remote operation (control) from central control room.
5. Low cost of the solution.
6. Simplicity, future expandability and interoperability.

B. Functionalities

The proposed system has been designed to implement the functionalities mentioned below:
1. Reporting alarms and status of different areas under coverage in the HMIs.
2. Controlling different parameters like set values, ON/OFF timing for no loss output.
3. Provides control of field controllers via HMIs.
4. Report generation of different recipes provided for specific processes.
5. Security or Interlock provided by HMIs.
6. Item master control provided via HMI for configuration.
7. Recording of important data in MS Access format and maintaining history of batch process and recipes.

C. Hardware

The proposed ABWS includes load indicators as major hardware. These load indicators have Atmel 8955 programmed controller. Data communication between the controller and the corresponding HMI is established through RS-485 based RTU/MODBUS communication. The output of the controller is interfaced with computer running LabVIEW[8] HMIs. Main HMI is used for monitoring and control using the data collected from all the load indicators in a typical network. RS-485 network is implemented to construct the physical layer, while MODBUS is chosen to implement the application layer for the laboratory implementation of the ABWS. RS485-to-USB converter[9] shown in Fig. 2 has been used for protocol conversion as well as matching and time sync by interfacing it with load indicator as shown in Fig. 3.

Fig. 2 RS485-to-USB converter[9]
D. Software

1) DataSocket Server[10]:

DataSocket Server[10] is used for establishing connection between Auto/Manual modes through LAN cable. The DataSocket Server is a lightweight, stand-alone software component that executes programs that use DataSocket. National Instrument’s DataSocket broadcasts live measurement data at high rates across the internet to multiple remote clients concurrently. The client applications use DataSocket to subscribe to the live measurement data. Since the DataSocket Server is a stand-alone software component, it simplifies network (TCP/IP) programming by automatically managing connections to clients as well as converting measurement data to and from the stream of bytes sent across the network. For such data communication, efforts in writing parsing code could be saved. DataSocket Server can be run on any machine on the TCP/IP enabled network.

2) LabVIEW[8]:

The application software for the ABWS are developed using LabVIEW[8] platform in form of HMIs. They can be operated in either of the two modes; i.e. the Auto Control Mode or the Manual Control Mode.

For development of HMIs, We have used Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW)[8], which is a high-level programming language with Graphical Language developed by National Instruments, USA. It can support interfaces such as GPIB, USB, IEEE1394, MODBUS, SERIAL, PARALLEL, IRDA, TCP/IP, UDF, Bluetooth., .NET, ActiveX, SMTP, etc. LabVIEW is usually used for data acquisition, instrument control, and industrial automation on all kinds of platforms including Microsoft Windows, various flavours of UNIX, Linux, and Mac OS.

Using LabVIEW, we have integrated the wired network consisting of RS-485 compatible load indicators and an RS485-to-USB converter for real-time parameter acquisition and monitoring of Batch Weighing process. The HMIs prepared in form of Virtual Instruments (VIs) using LabVIEW help to acquire, analyse, record and report live data acquired using load indicators deployed at different geographic locations.

The LabVIEW Internet Toolkit[11] provides the ability to make the VIs Internet compatible. We have used LabVIEW Internet Toolkit to publish VIs to the Web and remotely access as well as control the system using Web browser.

IV. LABORATORY IMPLEMENTATION

The proposed ABWS design has been validated by implementing most of its functionalities in laboratory. By writing different values into the controller memory of load indicator using HMIs, the batch process can be monitored and controlled. Fig. 4 shows the Auto control Front Panel HMI, while Figs. 5 and 6 shows the Main screen and Parameter configuration screen for the manual control applications respectively.
Fig. 7 given below shows the laboratory implementation with six load indicators connected with their respective load cells.

![Load cells connected with load indicators](image)

Figs. 8 and 9 given below show the computer running LabVIEW HMIs connected to load indicators via USB to RS-485 converter.

![Computer running LabVIEW HMI connected to load indicators](image)

V. RESULTS AND DISCUSSIONS

The proposed system is capable to present the results of data acquisition using different HMIs in suitable customizable report formats that are efficient as well as informative.

Figs. 10 and 11 show the acquired data in forms of Recipe and Block type reports. These reports can evaluate and display the useful information about loss identification and efficiency of the ABWS that can be used for future system maintenance.

![Acquired Data displayed in Recipe type report format](image)

VI. CONCLUSIONS

The design implemented in laboratory employs RS-485 for establishing connection between load indicators and the computer running HMIs. Data acquisition and recording in field utilize the industry standard, protocols of RS-485 and MODBUS protocols. In this design, applications are implemented using LabVIEW HMIs. MODBUS is selected because of interoperability, vendor independence and similar other relative advantages.

RS-485 network is used for the time-critical process-alarm data exchange for high speed client-server communication. Automation based on vendor independent automation protocols such as RS-485 and MODBUS as well as HMI development technology using LabVIEW platform results into fully scalable, reliable and future expandable cost-effective solution for automation.

VII. FUTURE SCOPE

For rapid growth of ABWS, enhancement of each and every facet is critically important. Serious efforts should be made to make ABWS more rugged, reliable and cost-effective.

This work can be further extended by –

1. Connecting GSM Modem with PC hosting LabVIEW HMIs to enable them to send SMS alerts in case of critical alarms/events.
2. Adding more and more functionalities to the HMIs to make them more informative and user-friendly.
ACKNOWLEDGMENTS

The first author thankfully acknowledges the support and co-operation provided by Dharmshinh Desai University, Nadiad, Gujarat, India and M/s Vbtech Automation, Ahmedabad, Gujarat, India in development of this work.

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