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Design, Development of a Diversified Implemention of a Supervisory Control And Data Acquisition based VLSI System (SCADA) framework Utilizing Microcontroller based Programmable Logic Controllers

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Abstract

In this paper, the designing & implementing of a supervisory control and data acquisition system (SCADA) framework utilizing microcontroller based programmable logic controllers is presented in brief with some of the simulated results. This article shows the automation of a process by interfacing a weighing balance with Supervisory Control And Data Acquisition System (SCADA) through a Programmable Logic Controller (PLC). The research work was taken up as a part of the consultation work at a cigarette manufacturing firm. The detailed study of the entire cigarette manufacturing process revealed that after the processing of tobacco, which is the final stage in the production department, the processed tobacco is weighed in bins on a weighing balance and manually recorded by an operator. The operator has to keep a count of the bins and sum them up at the end of the day. This involves consumption of time and human labor. The aim of our research work is to automate this process so that the information regarding various blends of cigarette and their respective weights can be made available at every PC terminal at the end of the day. For storing this information, we are using the MS-Excel spreadsheet and writing in it with the help of SCADA script. The work discusses in detail the design, architecture, programming and implementation of a PLC. It also covers the various features offered by the SCADA software and also deals with the interfacing of the PLC and SCADA. The interface RS232C / RS485 is used. This work is an online research project which has now been implemented in the firm and yielding desired results. The simulated & experimental results shows the power of the methodology that has been developed in this research paper.

Keywords—Design, Control, SCADA, Microcontroller, Result.

Introductory Remarks

The research work involves the design and implementation of a PLC which has the following features & are presented one below the other as follows [1].

- It offers high reliability due to use of high-quality solid-state components subjected to severe testing during the various stages of manufacturing.
- It provides indicator lights at major diagnostic points to simplify troubleshooting.
- It provides real time on-line programming for maximum flexibility.
- Very good practical implementation of various parameters that too in the industrial environment could be done.
- The versatility to combine discrete & analog logic & to perform arithmetic comparisons is a powerful tool for the control engineers.
- It has smaller cabinet size and floor space requirement that makes it suitable for industrial environment and shop floor conditions.

The designed and implemented PLC consists of following blocks, viz., Power supply module, I/O module, Central's processing units, Memory units, Programming units, PS Module. PLC is programmed in an easy to learn ladder diagram format. Ladder diagram is one traditional method for describing control circuits [2].

Summary of the work - A brief introduction

Modern manufacturing systems depend on the harmonious blending of various technologies. In today's electronic world, new developments come up every day so more stress is given in developing a sophisticated system which withstands the changes and adapts to new developments. Increased automation of processes and machinery is almost the only way to boost productivity in all sorts of industries. This automation may be necessary to enhance output volumes directly or to improve product quality and precision indirectly. Human intervention should be minimal in a process control automation. To achieve the intended control output, a system must be able to initiate, regulate, and stop a process in response to the monitored and measured variables inside the process [3].

Data acquisition and processing, remote control, alarm processing, historical data, graphical human-machine interface (HMI), emergency control switch, demand-side management, and other SCADA system capabilities are included. SCADA stands for supervisory control and data acquisition. It is a software and hardware solution that enables industrial companies to: Control industrial processes locally or remotely. Real-time data is monitored, gathered, and processed. Here, the design and implementation of the project which explains almost every part of the project is presented. It involves partial automation of a manual system. The project aims at conservation of time and labor. The requirement of the company is that at the end of processing of tobacco, the tobacco has to be weighed in the bins of 10 Kg each. This information is required by the management in order to know the total weight of each blend of tobacco processed on a particular day and also the total weight of all the blends together on that day. In order to provide this information to the management, the bins are weighed by the operator in the weighing balance which has a digital display [4].

The operator adjusts the weight, to l0 Kgs, for each bin and writes the exact weight of the bin on a piece of paper and inserts it into the bin. The bin is then forwarded. The operator then adds up the weight of the bins to get the total weight of the tobacco processed for that particular blend in a particular day. This process continues for all the different blends. At the end of the day, the operator provides the information about the total weight of different blends of tobacco processed on that day to the management. In order to partially automate the above manual process, the weighing balance is interfaced to the Supervisory Controls & the Data Acquisition's (SCADA) systems through Programming Logic Controllers, (PLC). Now the operator has to only adjust the weight to 10Kg +/- 50 gm. The PLC is interfaced with weighing balance and is programmed in such a manner that whenever the weight become 10 Kg +/- 50 gm, a coil in PLC is energized and indicator lamp near the weighing balance glows informing the operator that the weight has been passed to the PLC and that he can forward the bin. The operator

then forwards the bin [5].

Now as the bin crosses the beam emitted by photo sensor, the weight is to the SCADA PC. SCADA PC is programmed using Intouch SCADA software in such a manner that it goes on adding the weight of each bin and finally it gives the total weight of each blend at the end of the day (0000 hrs). This information is stored in Microsoft Excel spreadsheet and is available to all the concerned managers and supervisors. This implementation results in conservation of labor and time. The system becomes more efficient. In order to realize the project, it was divided into following phases [6]

Phase 1 : The existing manual process in the factory was studied thoroughly and then analyzed for further improvement and automation.

Phase 2 : After the analysis, the design was laid out in the form of block diagram. The approach to interface the weighing balance with PLC and then pass on the information to the SCADA system.

Phase 3 : The study of PLC was done and PLC software using ladder diagram was developed to store the weight obtained from the weighing balance. Further, the PLC was programmed to pass the weight to the SCADA PC.

Phase 4 : The concept of Supervisory Control. And Data Acquisition (SCADA) system was studied. The logic using Wonderware's lntouch SCADA software was developed to get the weight of each bin from the PLC and store the total weight of each blend of processed tobacco.

Phase 5 : The software for SCADA PC was further developed so as to store the total weight of each blend for each day in the MSEXCEL spreadsheet. Because of use of SCADA system, this spreadsheet is available to all the concerned managers and supervisors.

Phase 6 : The testing of the various software developed was carried out. The tests were carried out for different blends of tobacco for different weights and it was observed that proper results were obtained in MS-EXCEL spreadsheet.

Introduction to the SCADA Framework

SCADA systems are designed as an industry measurements & controlled systems and it acts as a steady transition from the monolithic systems to the flexible real-time systems. The increased power and reliability of the PC has triggered growing acceptance of it as a real-time control device. Secondly, the development of the windows operating system has also contributed to the expanded capabilities of the SCADA systems. The ability of 32 bit systems such as Windows offers to provide pre-emptive multitasking capabilities and the ability to transfer data efficiently and in real-time between enterprise wide databases & provide users with the ability to both control processes and do it with much less operator interaction. SCADA provides this option by linking the factory floor with the boardroom [7].

In today's global business environments, the manufacturing flexibility required depends on both the process data and business plan input. SCADA bridges the gap between office automation and manufacturing automation enabling the flow of information between them. It integrates the factories with offices, allows flow of critical information to manager's finger-tips and simplifies the whole decision making process of the operational functional level managers [8].

Single & Multiple Master : Here, the single mastered unit is connected with a solo or many of the slave products as shown in the Fig. 1. Next, in the Fig. 2, the multiple master is connected to many of the SCADA devices as shown in the pictorial representation [5].

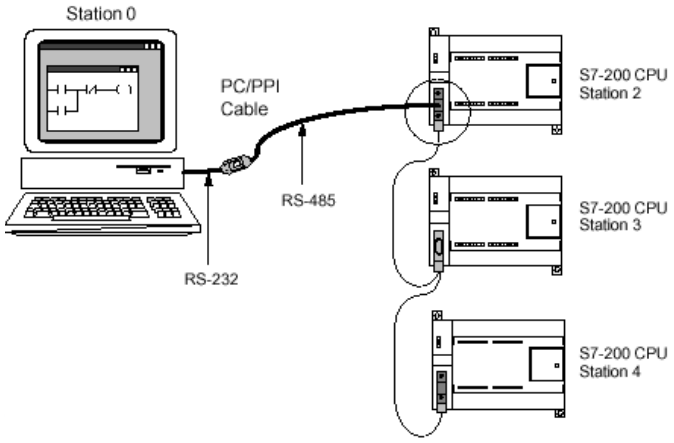

Fig. 1 : Single master connected to many devices [5]

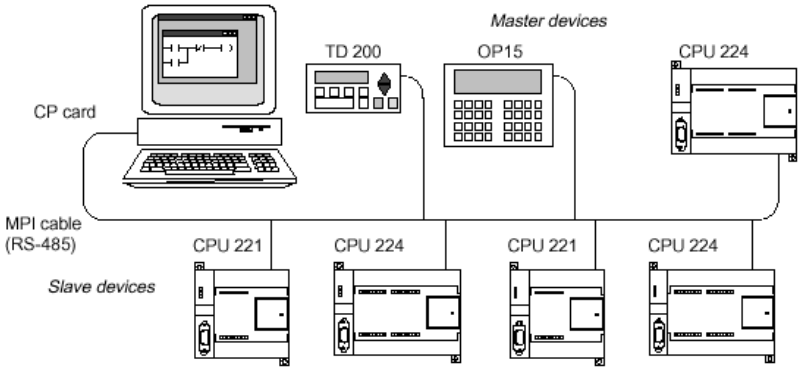

Fig. 2 : Multiple master connected to many devices [5]

PLC design

A Programmable logic controller is a digital operated electronical framework which is designed for using in an industrial zone, which uses a programmed memory units for internal storing of the instructions for implementation of some of the specific function such as logics, sequencings, timings controls, counting & arithmetic's for controlling various type of machine or processing's through analog or digital i/o modules. PLC's are vital components of modern automation systems. It is a software based general purpose equivalent of a relay panel, however it can do many thing that relays can't do, such as counting and timing, Because of the huge rewiring that had to be done every time a model change happened, the car industry encouraged the development of PLC. All automation duties such as logic control, PID control, computing, coordination, communication, operator control, and monitoring are made simple and cost-effective with them [9].

The controllers are suitable for areas such as machine control system, process automation, process monitoring. PLC can be programmed using easy to learn programming language which programs it to control variety of systems or machines. The programming of PLC is done through a device known as Hand-Held Programmer (HHP). The software that is entered into the HPP is called a ladder diagram. PLC is designed to accept inputs from pushbuttons, limit switches, pressure levels etc. and sends out outputs to solenoid valves, indicating lamps, alarms etc. depending on the logic programmed. A typical PLC consists of following blocks : Power supply module, I/O module, CPU unit, an Memory units, Programming units [10].

In PS (Power Supplying) Module, the supply gives an isolation for the protection of some of the solid state units from HV line spike. The power supply may be integral or separately mounted. The I/O modules, the CPU, the memory unit, and various peripheral devices are all powered by the power supply. The additional power supplies are used to maintain proper power levels when the I/O is extended. In Input/ Output Module, inputs are field level signal giving the controlling unit the RT status of the variable. These parameters can be analogue or digital,

moderate or high frequency, constant or variable, and constant or variable. Analog signals include signals from thermocouples and resistance temperature sensor. Variable frequency signals are provided by some flow metres and strain gauges, while digital signals include pushbutton, etc. The register input signal is an additional sort of input signal that comes in handy when the process condition is represented by a group of digital signals provided to the PLC at about the same time [11].

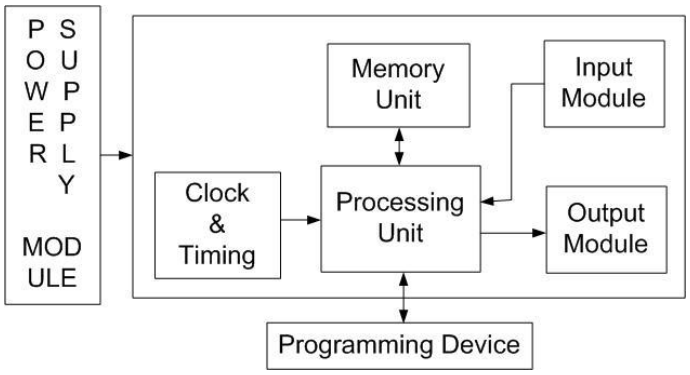

Fig. 3 : Pictorial representation of the architecture of the PLC module

Design of the Scada System

The designed SCADA system consists of 3 major components, viz., Central hosting / master control unit (PC), Two or maybe more field harvesting and control units (e.g., PLC), as well as a collection of standard software for monitoring and controlling field data elements that are located remotely. The PLC is interfaced with the field elements. It is programmed according to the required logic. It scans the field inputs connected to it and acquires the data. It performs the required operations on the acquired data and gives the required output. The PC is interfaced with PLC. The PC is programmed according to the requirement using the software for SCADA application. The PC scans the PLC outputs and acquires the data. It then processes the data and gives the required output in the required form as per the programming done. The designed SCADA has the following features, viz., Alarm Processing, Object Oriented Graphics, Standard User Interface, Real-time Database, Script Editors, Powerful animation features, Device and controller connectivity, Script language, Security, Database connectivity, Statistical Process Control, Dynamic Resolution Conversion, Factory Focus. The overall designed block diagram of the system is shown below and has the following individual blocks [12].

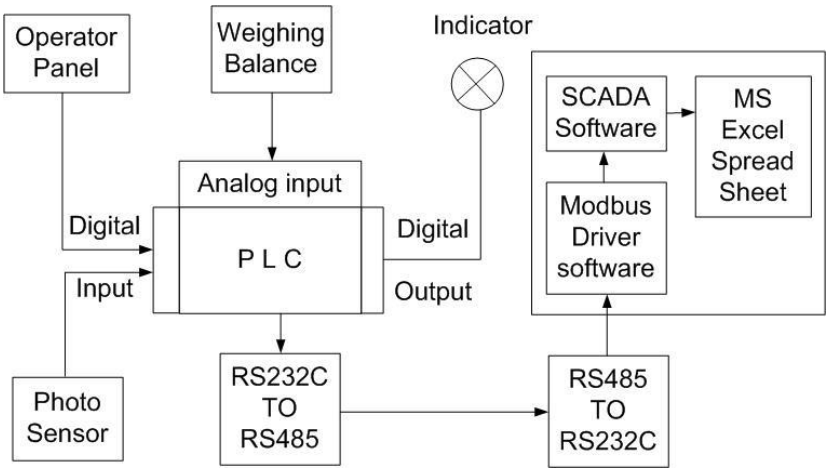

Fig. 4 : Block diagrammatic representation of the entire SCADA framework system design

These features are discussed below one after the other in block-set arrangement forms as follows [13].

In *Alarm Processing*, SCADA supports true hierarchical alarm grouping. Each alarm group is itself a tag that is available for annunciation and acknowledgement purposes. Its decentralised system enables several alarm servers, allowing operators to access and recognise alert information from many places at the same time.

In *Obiect Oriented Graphics*, Using powerful object-oriented design tools, devices & a group of parts that could be moved or sized & could be animated so quickly and that too in a simple manner.

In *Standard User Interface*, Wonderware adheres closely to the standard Windows GUI format, so as to ease communication between lntouch and other Windows programs.

In *RT Databases*, Database tags in Real-time Database can be defined as discrete, real, integer, and string values. There is no limit to how many of each category you can have. Database export/import utilities are included for spreadsheets, other databases, and editors.

In the *script databases*, Intouch offers significant scripting capabilities in Script Editors for rapid prototyping, background calculations, and simulation. Scripting is simple because all functionalities are buttons next to the script window. Point and click is used to select all script functions and data variables.

In *Powerful animation features*, lntouch offers a rich set of animation capabilities. Animation allows object attributes such as visibility, color, size and position to be controlled dynamically.

In *Device and controller connectivity*, Communication with PLC's and other external devices are accomplished using lntouch serves of the DDE's input output i/o's, i.e., they are Wonderware programs that facilitate information exchange between DDE aware Windows programs and other protocols supported by various factory floor devices. DDE stands for Dynamic Data Exchange which is standard communication protocol for Windows environment.

In *Script language*, Programs are written in lntouch scripting language. The language allows calculations, logic execution and communication with other programs. The programs can be triggered by a variety of events including operator actions, process conditions, time of day, time intervals, etc.,.

In *Security*, the user's access to windows can be locked out to prevent untrained users from accessing windows. This is accomplished using powerful animation features in the lntouch software.

In *Database connectivity*, Intouch offers extensive relational database connectivity capabilities via the SQL access option.

In *Statistical Process Control* (SPC), lntouch includes a powerful SPC package supporting automatic and manual sampling of measurement and attributes and full support for chart types.

In *Dynamic Resolution Conversion* (DRC), Using Intouch, applications can be developed in 1 resolution of the screens & then they are going to be run @ another w/o affecting of the original applications.

In *Factory Focus*, this feature allows managers and supervisors, the ability to view a continuous HMI application process on real time.

PLC Architecture and Design PRocess

In this section, we present the architecture & the design processes of the programming logic controller procedural aspects. First, the operator panel is discussed, this is followed by the weighting balance & the PLC design. Finally, the RS232C & the RS485 interfacing units are discussed [14].

Operator Panel : This panel has digits from 0 to 9 and corresponding numbers in binary.

Weighing Balance : During the last stage of production of tobacco in processed form, the tobacco is weighed in lots of bins on the digital weighing balance giving the precise weight of each bin.

PLC : PLC's are microcomputer like devices designed to control industrial equipment. The output of the weighing balance is fed as an analog input to the PLC. The operating panel gives the blend of the cigarette as digital input to the PLC. The PLC is programmed in such a way that when the weighing balance indicates a weight of 10 kg +/- 50 gms, and indication is given to the operator through the digital output of PLC and the weight is stored in the PLC and then transferred to SCADA.

RS232C : Used for data communication and have a link between the computer and nearby communicating box.

The features are as follows. Data communication refers to the ability of one computer to exchange data with another computer or a peripheral. The ability to communicate with another computer is essential from mainframe to micro. Because of this a standard data communication port. is established. Equipped with this port, interfacing of computer and peripheral becomes a simple matter of plugging a cable into each devices standard data port.

The Electronics Industries Association (EIA) standard RS232C outlines the set of rules for exchanging data between business machines like terminals, printers or other equipments involving serial communication. The prefix RS stands for Recommended Standard. Applications for RS232C have a link between the computer and nearby communicating box which in turn communicates with a distant communication box using some other methods.

This second box then uses RS232C to connect to a nearby terminal. The RS232C interface is a good choice for many applications for data communication where relatively low performance is acceptable to the user or all that can be realistically provided because of cost and technical constraints. RS232C is completely inadequate for applications involving high speed for long distances. This is because the baud rate decreases significantly for long distance communications. Thus, it is being replaced by new standards .to accommodate advanced in an integral circuitry that is designed, to reduce cross-talks b/w the interchanging of the circuitries, to permit a greater distance b/w the equipments & to permit higher datas at signaling sampled rates. Since RS232C cannot be used for long distance communication, we use RS485 EIA standard and a converter from RS232C to RS485.

RS485 : Introduces a new balanced transmission standard and allows multi points & multiple driver & receiver sharing the same line information's transmission of the datas. Upto 32 transmitters and 32 receiver can be connected w.r.t. an single pair of wires as long as these transmitters and receivers meet the RS485 connections. The EIA has introduces a new balanced transmission standard RS485. It solves the problem of data transmission when a party line configuration uses a balanced transmission line. It permits several drivers and receivers to share a single line of data transmission. The RS485 standard merely specifies the electrical properties of the driver and receiver to be utilised at the line interface, not a protocol. It solves the problem of data transmission when a party line configuration uses a balanced transmission line. It permits several drivers and receivers to share a single line of data transmission. The RS485 standard merely specifies the electrical properties of the driver and receiver to be utilised at the line interface, not a protocol.

The RS485 protocol allows for true multidrop operation. Up to 32 transmitters and receivers can be linked to a single pair of wires as long as the transmitters and receivers meet the RS485 requirements. To ensure reliable transmission at high data rates over long distances, toe drivers should have ideal A.C. characteristics. The reaction should be rapid and the output transients should be clean and symmetrical.

Propagation Delay : The data stream should not hit a bottleneck at the driver if the propagation delay across the drivers is modest relative to the bit interval.

Transition Time : The signal at the farthest receiver must have rise and fall times substantially less than the bit interval for distortion-free data transfer.

Balance : The impedances that are seen in looking w.r.t. every complimentary i/p's of the Tx-Rx (transceiver) which could be identical in nature or else the common mode will be degraded. RS485 is tri-state version of the RS422 and can be connected to a RS232C interface. It's use in multi-point / party-line bus systems that enhances it's compatibility. RS485 can be set up to work with RS232C at all bit rates and cable distances that RS232C supports. To convert 25-pin RS232C interfaces to the connector used by RS485, adapters are necessary.

SCADA software

The programming is done in the PC using SCADA software. Modbus driver software is required to drive the SCADA software and it run in parallel with the SCADA software. The PC scans the PLC outputs and acquires the data. But the SCADA is not capable of talking to the PLC directly. The connectivity to the PLC is accomplished through DDE input-output server. DDE is standard Dynamic Data Exchange protocol for the windows environment. The programming is done in scripting language. The programming is done such that whenever the weight of the bin is 10kg +- l50gm, the current weight goes to the SCADA. This current weight is

added to the total weight for that particular blend. In this way, total weight for each blend is calculated by the SCADA software and this information is then passed to the MS-Excel spreadsheet [15].

Creating Scripts in Intouch

The programs are written in Intouch scripting language. Receiving new programming features enable the execution of instructions and logical processes based on the fulfilment of predefined conditions. For example, a key is pressed, a window is opened, a value is changed, and so on. Scripts can be used to build a wide range of customised and automated system functions.

MS-Excel Spreadsheet : Today's business relies largely on financial analysis. Making informed company decisions and planning strategies necessitates quick and precise data analysis. In order to offer an accurate picture of the business condition, information systems must integrate and evaluate massive volumes of data from multiple sources.

Analysis of data involves

- Performing statistical and mathematical calculations on the data.
- Graphs are created using the datas available and facilitate between two sets of data.
- Relating tables of information from > 1 source to generate a consolidated data set.

Excel allow us to analyse numerical data in great depth. Data is shown in rows and columns on spreadsheets. A cell represents the junction of a row and a column, and data is entered into it. Microsoft Excel is a spreadsheet programme for Windows that was created by Microsoft Corporation. Excel has all of the basic spreadsheet capabilities, such as automated recalculation, graphs, and functions. It also comes with a number of advanced features, such as the ability to integrate other objects in spreadsheets, pivot tables, and form design. This is utilised to deliver a quick and precise data analysis so that corporate decisions and plans may be made with confidence. Then, the features of the designed Excel are, viz., Windows based application, Workbooks, Auditing, OLE support, Data Entry Forms, Large Data Management Capability, Data Analysis Features. The features of the designed spreadsheet by us are as follows.

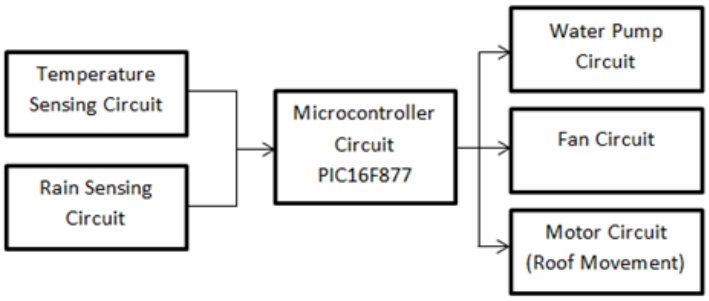

Fig. 5 : Multiple devices connected to the Microcontroller System [6]

In *Windows based application*, MS-Excel has an interface similar to Windows NT. Like all Windows applications, Excel has tool bars, shortcut menus, AutoCorrect, On-line Help and Wizards.

In *Workbooks*, Work-books are enclosures in which one or more worksheets can be stored. Keeping all project-related papers in one file eliminates the need to maintain multiple files.

In *Auditing*, Work-sheet auditing is a feature that checks a worksheet for errors. Auditing is used to relate formulas in different cells and locate the source of a calculation error.

In *OLE support*, Excel worksheets could have any type of objects or documents or pics or a video clip. This feature is known as Object Linking and Embedding (OLE). This capability cart be used to integrate Excel with all other applications.

In *Data Entry Forms*, We can create custom data entry forms within a worksheet. Validation rules and formatting

can be included within a form.

In *Large Data Management Capability*, Microsoft Excel can handle massive amounts of data at once. There are 16384 rows and 256 columns in a worksheet. A single cell can only have 255 characters in it. A work-book can have up to 255 work-sheets in it. Excel is a great spread sheet application because of its data management capabilities.

In *Data Analysis Features*, Excel contains powerful tools that help in data analysis. Pivot tables, Microsoft Query and Data Map tools allow users to present data in different ways to facilitate analysis.

A typical designed worksheet for the work consists of the following sections.

In the *Rows, Columns & Cells* : In a work-sheet, the rows are numbered from top to bottom along the left column. Letters are used to label the columns from left to right.

In the *Menus and Toolbars* : Menus allow you to do a variety of operations in Microsoft Excel, such as open & close of the work-sheets. Toolbars are shortcuts to menu items that are often utilised. The Standard and Formatting toolbars are visible by default.

In the *Sheets* : Excel is set up in the same way as a workbook, with numerous pages called Sheet-1, Sheet-2, and so on. Only six papers are displayed by default.

Designing The PLC Logic

One of the main considerations of the research is to program the PLC to accept the inputs from the weighing balance and consequently add the subsequent weighments. It is also to be programmed to select a specific blend of the cigarette being manufactured in the firm. Finally, it is programmed to transfer the weights of particular blends to the SCADA software. The following PLC logics are designed and implemented.

- Logic to accept a specific cigarette blend,
- Logic to accept the inputs from the weighing balance,
- Logic to transfer the weight in SCADA PC.

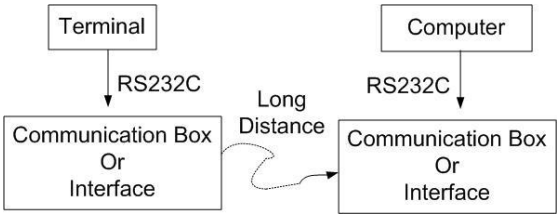

Fig. 6 : Designed SCADA communication system module

Developing The SCADA Software

SCADA software helps to supervise and col1ect data from various remote terminals. The software logic is developed for transferring the weighments in the Excel spreadsheet. A number of logics are developed and implemented using the ladder diagrams for the PLC and SCADA software. The following logic flow-charts are designed for the implementation of the SCADA process

- Logic to get the total weight of each blend,
- Logic to store the total weight of different blends in EXCEL spreadsheets.

Implementation Procedural Aspects

The logic discussed in previous chapters is implemented using the ladder diagrams for the PLC and InTouch SCADA software.

Ladde diagram for the selection of a particular blend

Thumbwheel switch is used to select a particular blend of cigarette. The thumbwheel switch displays the numbers from 1-9. Each number selected corresponds to a particular blend of cigarette. Internally the thumbwheel switch stores the numbers in binary. Hence, the programming is done following the binary number system convention.

Ladder diagram to accept the inputs from the weighing balance.

The PLC is interfaced with the weighing balance through the 4-20 mA electrical signal interface. The weighting balance gives the weight as an analog input to the PLC which is converted to a count using the following conversion. 4 mA current corresponds to 0 kg and 20 mA current corresponds to 60 kgs. The design is such that 60 kgs. corresponds to count of l024 (l0 bit) and hence 10 kgs. corresponds to a count of 170.6. This is the theoretical value. Practically, when the weight is 10 kgs., the count observed in PLC = 166. Providing a margin of +\-50gms, the two other's counts obtained are 165 and 167. The PLC scans its inputs from the weighing balance and stores the count corresponding to the weight in an input register. By the use of SUB function, the PLC compares this count with the pre-setted counts i.e., 165,166 and 167. If the count matches with one of these counts, then the coil in the PLC is energized and indication is given to the operator on the lamp, indicating that the weight has been stored in the PLC.

Ladder diagram to store the weight in the SCADA PC

At the start of the new batch (for new blend of cigarette), the start push button is pressed. This energizes a latch in PLC. Now the bins are weighed on the weighing balance and are moved forward. As the bin moves forward, it crosses the beam. emitted by the photo sensor and as a result, another contact in the PLC is energized. When this happens, the weight gets transferred to the SCADA PC.

Intouch script to get the total weight of each blend

For each blend, initially at the start of the batch, the total weight is initialized to zero. As the bins go on passing the current weight of each bin could be summed up to get the complete weight and finally when the batch end occurs, the total weight of that particular blend is available.

Intouch script to store the total weight of each blend in EXCEL spreadsheet

The total weight of each blend as it is updated, is transferred to the EXCEL spreadsheet using WWPoke() function in the respective cells.

Conclusions

PLC's play a very important role in monitoring and control in manufacturing and production plants. They offer many advantages such as flexibility, fast response, small size etc. which increases the efficiency of the overall system. The role of PLC in the man-machine interface will grow further as company goes in for complete automation. Also, the SCADA system would play a pivotal role in the measurement and control of process in an industrial environment. SCADA system makes the information available to the managers at their fingertips and hence makes the overall system user friendly and more efficient.

The automation results in conservation of labor and time. The system efficiency increases resulting in increasing productivity and overall benefits. With continuously increasing cost of raw materials and capital goods, automation can decide a company's competitiveness not only cost wise but also quality wise. This work is fully automated so that the weight in each bin is automatically adjusted to I0 kg +/- 50 gm, i.e., without the interference of the operator and the bin automatically moves forward without the need of the operator to press the foot switch.

In this paper, finally, the designing & implementing of a supervisory control and data acquisition system (SCADA) framework utilizing microcontroller based programmable logic controllers is presented in brief with some of the simulated results. The work could be extended to multiple units of the devices so that it could be implemented in a real time environment and could be of some practicality in the RT world.

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