International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

Technovision-2014: 1st International Conference at SITS, Narhe, Pune on April 5-6, 2014

Survey of PLC Development on Embedded Platform

Ms. Sneha Goyanka
Department of Electronics and Telecommunication,
Smt. Kashibai Navale College of Engineering, Pune, India
Email: snehagoyanka@gmail.com

Prof. Mrs. Rohita Patil
Department of Electronics and Telecommunication
Smt. Kashibai Navale College of Engineering, Pune, India
Email: rohita_jagdale@yahoo.com

***Abstract* – Technological advances in recent years have resulted in the development of the programmable logic controller and a consequential revolution of control engineering. This paper is introduction to programmable logic controllers. A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or nonvolatile memory. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.**

After investigating the conception and features of PLC from different vendors and embedded system, the development of the embedded PLC is proposed here with the seamless combination of the LabVIEW software and the ARM Microcontroller with the LabVIEW embedded module. The flexibility of the proposed PLC makes it relatively easy and less costly. The ARM microcontroller is selected to develop embedded PLC because it is widely used across many embedded designs due to its low price, low power consumption, and wide variety of peripherals for many of the major silicon vendors. In addition, the LabVIEW Embedded Module for graphical programming to ARM microcontroller can be used.

***Keywords* – Programmable Logic Controller (PLC), Lab VIEW, LabVIEW Embedded Module for ARM Microcontroller, ARM Microcontroller.**

I. Introduction

Embedded Systems are hardware and software components working together to perform a specific application. They exist in abundance in our modern society and play a vital role in our everyday lives [1]. They can be found in places such as our automobiles, in the medical field, in industrial control systems, and in entertainment electronics to name just a few. The hardware platform of the embedded system often consists of a microprocessor, on-board memory, an output display, an input device for a user to enter data and application software. Moreover embedded systems are easy to use, low power consuming, less costly for wide variety of applications.

Programmable logic controllers (PLCs) are a specialized type of embedded systems used to control machines and processes [4]. They have been introduced in the early 1970s to replace the existing relay control logic that became obsolete and expensive for implementing systems at that time. On the other hand, PLCs have offered flexibility, higher reliability, better communication possibilities, faster response time, and easier troubleshooting.

II. Literature Review

A. Programmable Logic Controller (PLC)

A programmable logic controller(PLC) is a special form of microprocessor-based controller that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes and are designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages.

The basic structure of a programmable logic controller has four main functional blocks as shown in Fig. 1.

1. Processor
2. Input Module
3. Output Module
4. Programming Software

1. Processor: The processor is a computer that executes a program to perform the operations specified in a ladder diagram or a set of Boolean equation [5]. The processor performs arithmetic and logic operations on input variable data and determines the proper state of the output variables.

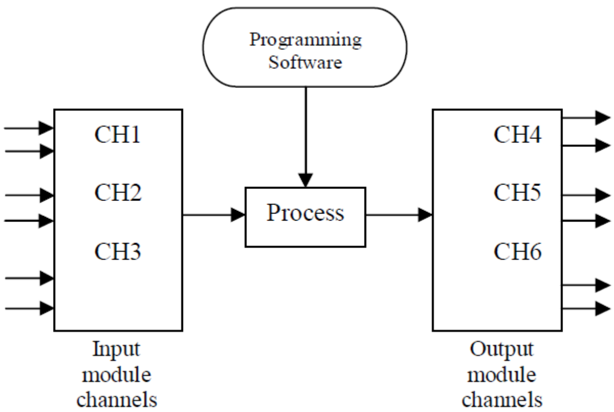

Fig. 1 Basic Structure of Programmable Logic Controller (PLC)

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

The processor functions under a permanent supervisory operating system that directs the overall operations from data input and output to execution of user programs.

Of course, the processor, being a computer, can only perform one operation at a time. That is, like most computers, it is a serial machine [5]. Thus, it must sequentially sample each of the inputs, evaluate the ladder diagram program, provide ach output, and then repeat the whole process. The speed of the processor is important. The heart of a PLC is a microprocessor, much like the one used in the modern personal computers. Because much of the data in PLC is processed bit by bit, special microprocessors optimized for such operation, such as the ADM 2901 and 2903, are often employed. With the great increases in the processor speed, it is now possible to employ a desktop personal computer with data I/O boards running PLC software to emulate PLC operation.

2. Input Module: The input module examines the state of physical switches and other input devices and put their state into a form suitable for processor. The PLC is able to accommodate a number of inputs, called channels [5].

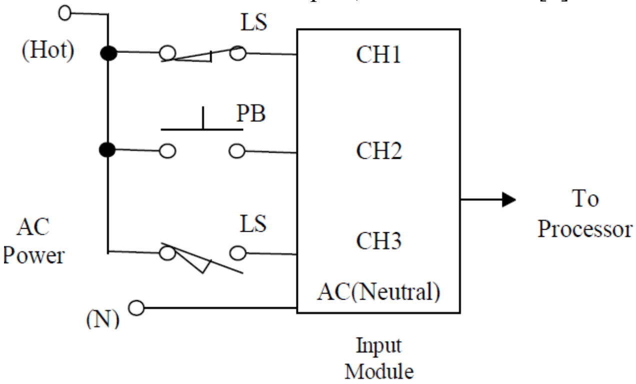

Fig.2. Typical wiring to PLC input module

In keeping with the industrial settings of most PLC applications and the history of relay control, the input state systems are often designed to provide 0 or 110V ac to the input module. This type of connections assumes that switches, for example, are wired to the PLC as shown in figure 2. If the switch is closed, the input will be 110V ac, and if open, the input will be 0 V ac. The input module converts this into the 1 or 0 state needed by the processor. In many cases, PLCs are now being designed to operate from dc voltages for which the switch is connected to the input with a dc supply. The input module have a certain number of channels per module. Each channel is often equipped with an indicator light to show if the particular input is ON or OFF. Fig 2 shows a input module.

3. Output Module: The output module supply ac power to external devices such as motors, lights, solenoids, and so on, just as required in the ladder diagram. The output module can supply a certain maximum power. If the required power is greater, an external relay may be used, as shown in Fig 3.

Internally, the output module accepts a 1 or 0input from the processor and uses this to turn ON or OFF an AC power-control device such as a TRIAC. In this sense, the output module is a solid-state relay [5]. Programmable Controllers also are designed with output modules to provide other outputs, such as dc voltages or variablerate pulse outputs (such as would be required by a stepping motor).

An output module can have one or several channels per unit. Each channel is usually provided with an indicator light to show whether that particular channel is being driven ON or OFF.

4. Programming Software: The logic in which the processor has to process the input and produce the desired output is loaded into the processor by programming through the programming software. All the PLC vendors have their own programming softwares for their PLC's. these softwares are vendor and processor specific. Some softwares support one languge and some support all the languages.

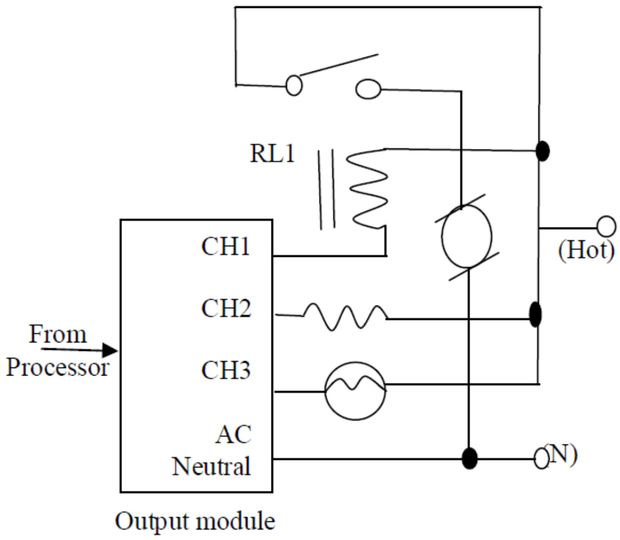

Fig.3. Typical wiring to PLC output module

B. PLC market survey

Some of the different PLC available in market are as follows

1. Micrologix 1000: Micrologix 1000 control system is the one of the PLC from Micro & Nano systems from

Fig.4. (a) Micro Logix 1000 Fig.4. (b) SIMATIC S7-200

Rockwell Automation. It is the most compact of the micrologix family. This controller fits a wide variety of applications upto 32 I/O points, while using a fraction of the space of a full-size controller. It contains embedded analog I/O, providing compact and cost-effective analog performance [7].

2. SIMATIC S7-200: SIMATIC S7-200 is a micro PLC for basic automation from SIEMENS. This PLC is fast, communication capable and highly productive in real-time mode, the consistently modular design facilitates the creation of tailor-made, expandable solutions in the low-end performance range. The S7-200 Micro PLC from Siemens can be used as either a stand-alone Micro PLC solution or in conjunction with other controllers [8].

3. AC500-eCo PLC: AC500-eCo PLC is supplied by ABB. ABB is the supplier of choice for small equipment control applications to complex systems like web presses and distributed systems. ABB's PLCs are some of the fastest and most reliable available. AC500-eCo PLC is the economical PLC for smaller systems and equipment control.

Fig.5. (a) AC500-eCo Fig.5. (b) Modicon M340

4. Modicon M340: Modicon M340 is a mid range PLC for industrial process and infrastructure from Schneider Electric. Modicon Programmable Automation Controllers (PACs) are built to suit the needs of the process industry and a wide range of demanding automation applicatios. Modicon M340 can be used individually but is also the perfect companion of Modicon Premium and Modicon Quantum, increasing the performance, the quality and the profitability of industrial process, facilities or of machines. Compact shaped Modicon M340 offers in small box flexibility and integrated functions, in the heart of process, it provides Plug & Work solutions with both Schneider Electric and third party devices. The large capacity of Unity Pro is So Collaborative software, ease and shorten the programming and commissioning time.

III. PROGRAMMING LANGUAGES

IEC 61131-3 currently defines five programming languages for programmable control systems:
1. LD (Ladder diagram)
2. FBD (Function block diagram)
3. ST (Structured text, similar to the Pascal programming language)
4. IL (Instruction list, similar to assembly language)
5. SFC (Sequential function chart)

1. Ladder Diagram (LD) programming is commonly used in the industry and even in the academics. It is a symbolic and schematic way of representing both the system hardware and the process controller. It is called a ladder diagram because the various circuit devices connected in parallel across the ac line from something that looks like a ladder, with each parallel connection a ”rung” on the ladder [5].

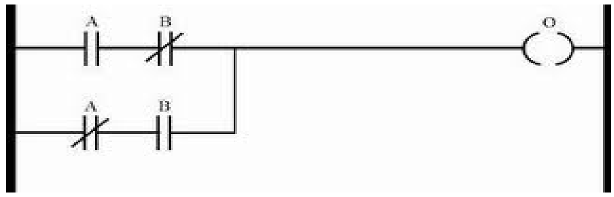

Fig.6. Ex-OR gate representation in a ladder diagram

In the construction of a ladder diagram, it is understood that each rung of the ladder is composed of a number of conditions or input states and a single command output. The nature of the input states determines whether the output is to be energized or not energized.

Special symbols are used to represent the various circuit elements in a ladder diagram. Fig.6 shows a ladder diagram representation of the Ex-OR gate. The output “O” will be energized only if either of the input A or B will be 1 and other will be 0.

2. Function block diagram (FBD) is used for PLC programs described in terms of graphical blocks. It is described as being a graphical language for depicting signal and data flows through blocks, these being reusable software elements. A function block is a program instruction unit which, when executed, yields one or more output values. Thus a block is represented in the manner shown in Fig.7 (a) with the function name written in the box [4].

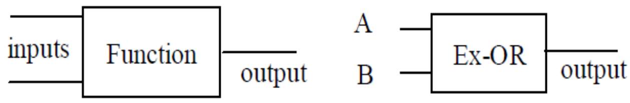

Fig.7. (a) Function Block Fig.7 (b) Ex-OR gate shown in FBD

A function block is depicted as a rectangular block with inputs entering from the left and outputs emerging from the right. The function block type name is shown in the block, e.g. Ex-OR as shown in fig.7 (b). Names of function block inputs are shown within the block at the appropriate input and output points. Cross diagram connectors are used to indicate where graphical lines would be difficult to draw without cluttering up or complicating a diagram and show where an output at one point is used as an input at another.

3. Structured Text (ST) is a programming language that strongly resembles the programming language PASCAL.

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

Programs are written as a series of statements separated by semicolons [4]. The statements use predefined statements and subroutines to change variables, these being defined values, internally stored values or inputs and outputs. Assignment statements are used to indicate how the value of a variable it to be changed, e.g. Light := Switch A; is used to indicate that a light is to have its 'value' changed, i.e. switched on or off, when switch A changes its 'value', i.e. is on or off. The general format of an assignment statement is: X := Y; where Y represents an expression which produces a new value for the variable X.

4. Instruction List (IL) is a programming method, which can be considered to be the entering of a ladder program using text. Instruction list gives programs which consist of a series of instructions, each instruction being on a new line. An instruction consists of an operator followed by one of more operands, i.e. the subjects of the operator [4]. In terms of ladder diagrams an operator may be regarded as a ladder element. Each instruction may either use or change the value stored in a memory register.

For this, mnemonic codes are used, each code corresponding to an operator/ladder element. The codes used differ to some extent from manufacturer to manufacturer, though a standard IEC 1131- 3 has been proposed and is being widely adopted.

5. Sequential Function Chart (SFC) is used for a pictorial representation of a system's operation to show the sequence of the events involved in its operation [4]. The operation is described by a number of separate sequentially connected states or steps which are represented by rectangular boxes, each representing a particular state of the system being controlled. Each connecting line between states has a horizontal bar representing the transition condition that has to be realized before the system can move from one state to the next. Two steps can never be directly connected; they must always be separated by a transition. Two transitions can never directly follow from one to another; they must always be separated by a step. When the transfer conditions to the next state are realized then the next state or step in the program occurs. The process thus continues from one state to the next until the complete machine cycle is completed. Outputs/actions at any state are represented by horizontally linked boxes and occur when that state has been realized.

6. Comparison of different PLC: Each of the PLC vendors has their own programming software for their PLC. The programming languages these software support depend on the processor used and the applications. Some programming software support additional tools like SCADA, Offline simulation of program etc. A table of the programming software, language supported by them for the above discussed PLC is as follows.

Table I. Comparision of Programming Software for different PLC

Company	PLC Model	Programming Software	Languages Supported
Rockwell Automation	Micrologix 1000	RSLogix 500	LD
Siemens	SIMATIC S7-200	STEP 7-Micro/Win	LD, FBD, ST
ABB	AC500-eCo	PS501	LD, FBD, ST, IL, SFC
		CoDeSys	LD, FBD, ST, IL, SFC
Schneider Electric	Modicon M340	Unity Pro	LD, FBD, ST, IL, SFC

IV. Application of PLC

A Programmable Logic Controller, PLC is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. PLC has a wide range of application in all the industries. Some of the industries where PLC is used are listed below.

i. Material Handling
ii. Packaging Applications
iii. General Industrial Machinery
iv. Printing
v. Food and Beverage
vi. Pharmaceutical
vii. Water Wastewater / SCADA
viii. Clutch/Brake control
ix. Position Control - Pick-and-place / Conveyor

Case Study: Continuous Bottle Filling System In food and beverage industry a very common application is continuous bottle filling system. It is most important application in whole plant, where bottles are moving on a conveyor belt, to be automatically detected and filled by any liquid. This example is considered and explained here.

Objective: Empty bottles are moving on a conveyor belt. The position of the bottle is detected via a limit switch. The quantity of the liquid is controlled by a photo detector which checks if the bottle is full or empty. Once the bottle is filled a buzzer sounds. The filled bottle is then moved further and the next empty bottle is moved forward for filling. A diagram of this example is as shown in figure 8.

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

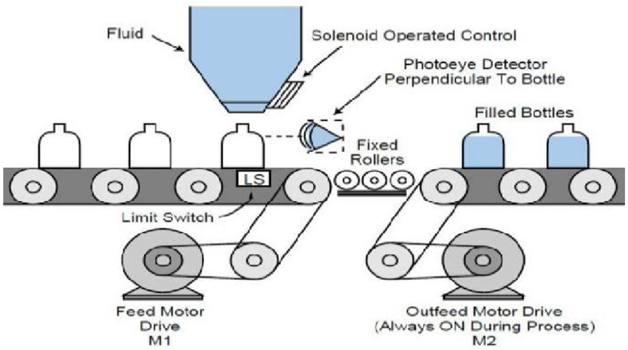

Fig.8. Automatic Bottle Filling System

The ladder diagram for execution of the bottle filling system is as shown in figure 9

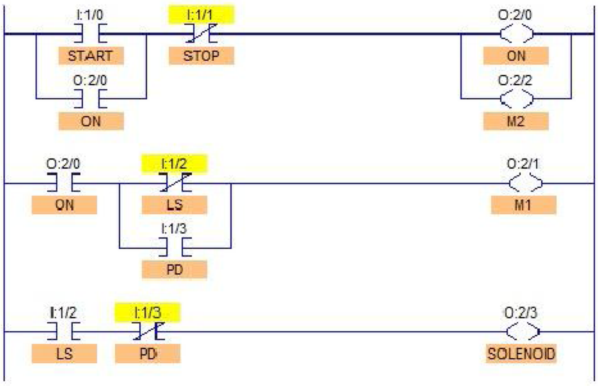

Fig.9. Ladder Diagram for Automatic Bottle Filling System

Execution of Ladder: When the START switch is pressed a light ON glows till STOP is pressed. The START switch also activated out feed motor M2. The feed motor M1 is activated moves till limit switch detects a bottle and gets activated. Then the SOLENOID valve of the liquid tank activates to fill the bottle. The level of liquid in bottle is continuously checked by a photo detector PD which activates after the liquid in bottle is filled to its mark. This turns off the SOLENOID valve and turns on M1 and the bottle moves further to next conveyor. The positions of limit switch and photo detector control M1 and SOLENOID.

V. System Design

PLC based on ARM 7 processor is designed. The system has all the basic features of a PLC with 8 digital input, 8 digital output, 4 analog input and 1 analog output. ARM 7 will act as the processor for processing the instructions. Input and output module will be designed to support analog and digital I/O. LavView embedded module will serve as the programming software for the PLC. Fig 10 shows the block diagram for embedded PLC. It consists of the following blocks:

1. ARM processor
2. Input Module
3. Output Module
4. LabVIEW s/w for Programming

Except the fourth block which is the software part rest all are the hardware parts of the PLC.

A. Hardware Design

1. ARM Processor: The ARM microcontroller is selected to develop embedded PLC because it is widely used across many embedded designs due to its low price, low power consumption, and wide variety of peripherals for many of the major silicon vendors. In addition, the LabVIEW Embedded Module for graphical programming to ARM microcontroller can be used. Block diagram of the embedded PLC is shown in fig 10. Besides the LabVIEW Embedded Module for ARM Microcontroller includes support for the RealViewμVision ARM simulator, which provides cycle accurate timing and logic simulation. With this capability, a large portion of the application could be developed and tested before the hardware design is complete.

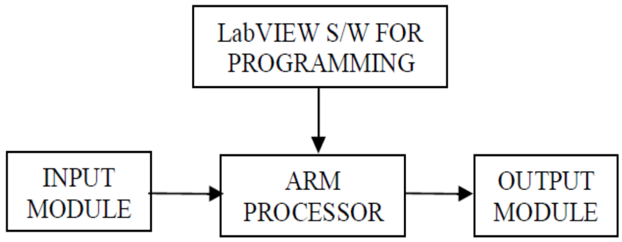

Fig.10. Block Diagram of an Embedded PLC

This is the main reason that ARM is most suitable for developing the embedded PLC. Moreover large functionality can be implemented using the ARM processor which makes the use of this PLC possible in wide range of applications [1]. The ARM processor will do the processing on the input signals and depending upon the program will produce the output.

2. Input Module: The input to the processor will be from the input module. The input signals can be analog or digital depending upon the input device connected to the input module. The ARM processor works on 3.3V but the analog input devices work in the range of 0-10V so a voltage divider circuit has to be added between the input module and ARM processor and for digital input the voltage is generally use 24V so there is a need to add an isolator circuit to reduce the signal to 3.3V.

3. Output Module: The ARM processor gives the processed output to the output module which in turn connects to the output devices such as relays, bulbs, motors etc. These devices may be analog or digital devices. As the output of the ARM processor is 3.3V there is need of an isolator circuit to isolate and amplify the output voltage to 24V for digital devices and a voltage amplifier to amplify the voltage for the analog devices to 0-10 V.

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

B. Software Design

LabVIEW s/w for Programming: The PLC needs software to provide a platform for the user to program the processor so as to produce the desired process for the input and output devices. To program the ARM processor the LabVIEW Embedded Module and the PLC programming language FBD is used. The LabVIEW Embedded Module for ARM Microcontrollers is a comprehensive graphical development environment for embedded design. This module seamlessly integrates the LabVIEW graphical development environment and ARM microcontroller. This module builds on LabVIEW Embedded technology, which facilitates dataflow graphical programming for embedded systems and includes hundreds of analysis and signal processing functions, integrated I/O, and an interactive debugging interface. With the Embedded Module for ARM Microcontrollers, optimize linking and viewing live front panel updates using JTAG, serial, or TCP/IP can be done [2]. The Embedded Module for ARM Microcontrollers includes the LabVIEW C Code Generator, which generates C code from the LabVIEW block diagram. For the creation of FBD language blocks, the available tools in LabVIEW can be used and a basic function of FBD language according to IEC 61131-3 standards required for PLC can be created.

The decision to use the FBD language for programming the PLC because LabVIEW is a graphical development environment and it is easy to program using *function blocks* for any desired function of the PLC.

First step in software design is to design the standard function blocks of FBD language in number of sub VI and integrate them into a pallet so that they can be used for PLC application.

VI. Result

Various function blocks such as AND, OR, INV, ADD, SUB, CTU, TON etc are designed using LabVIEW and these block are called for creating a simulation of a automatic bottle filling plant disscussed in section IV. These blocks are designed as per the function block diagram programming language of PLC.

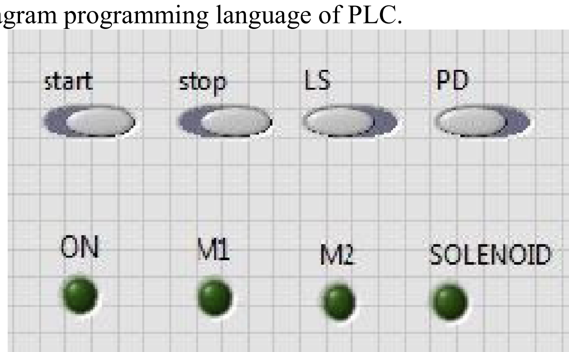

Fig.11. Front Panel View of Automatic Bottle Filling System

The input to the system is given through switches and output is displayed using LED. Fig. 11 shows the front panel view of the automatic bottle filling system in LabVIEW. The block diagram view of the same system is as shown in Fig. 12 with reference to Fig. 9.

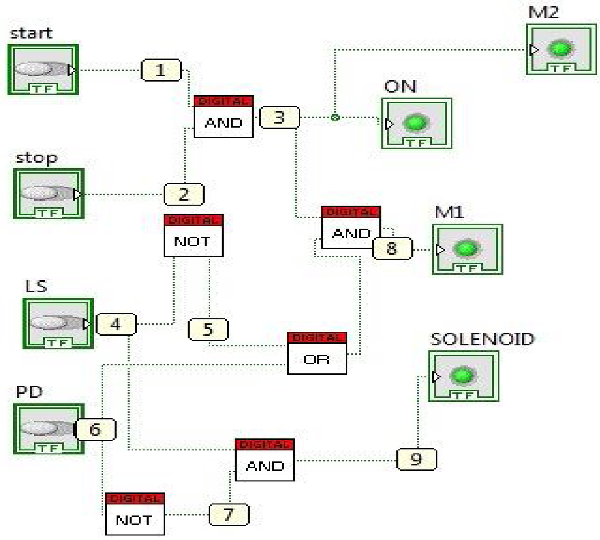

Fig.12. Block Diagram View of Automatic Bottle Filling System

The system consists of four inputs and four outputs which are controlled using function blocks designed in the LabVIEW. Table II gives the description of input and output of the system.

Table II: Comparison of Programming Software for different PLC

ELEMENT	DESCRIPTION	SYMBOL
START	This is the start switch which turns the system on.	start
STOP	This is the stop switch which turns off the system.	stop
ON	LED to show process is on.	ON
MOTOR 1	Motor to move first conveyor. (in fig. 8)	M1
MOTOR 2	Motor to move second conveyor. (in fig. 8)	M2

Different states of the system are depicted using the probe watch window of LabVIEW. STATE 1 is when the system is turned on i.e. start switch is moved to ON position. In this state the ON (probe no. 3), M1 (probe no. 8) and M2 (probe no. 3) LED glows as can be seen from figure 13 as True. In STAGE 2 as shown in figure 13 the limit switch (probe no. 4) is activated and this has stopped

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

M1 (probe no. 8) and turned the solenoid valve on (probe no. 9). In STAGE 3 as shown in figure 15 when the photo detector (probe no. 6) is turned on the solenoid valve (probe no. 9) turns off and M1 (probe no. 8) turns on so that bottle can move to next conveyor.

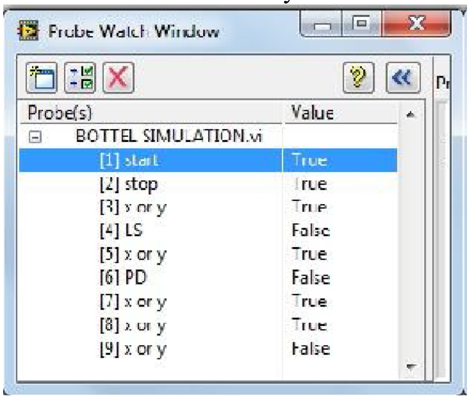

Fig.13. STAGE 1

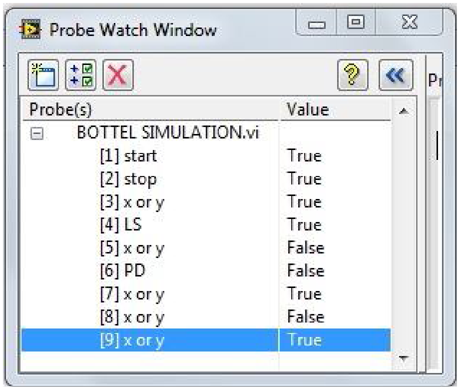

Fig.13. STAGE 2

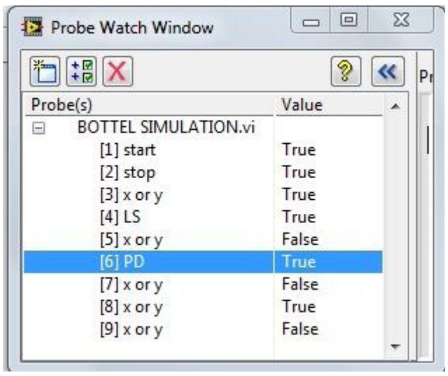

Fig.13. STAGE 3

IV. Conclusion

In this paper the market survey of Programmable Logic Controller is disscussed with the ARM controller platform with full software support of Labview. In addidtion to this the PLC from different vendors and supporting programming languages of PLC were discussed. Different industries where PLC are used were also listed and automatic bottle filling system application which is an important application of food and beverage industry is designed in LabView to implement on hardware platform ARM controller to test real time application.

References

[1] Pornjit Pratumsuwan and Watcharin Pongaen, "An Embedded PLC Development for Teaching in Mechatronics Education", 6th IEEE Conference on Industrial Electronics and Applications 2011 pp.1477- 1481

[2] "Getting Started with the LabVIEW Embedded Module for ARM Microcontrollers 1.1," National Instruments Corporation, 2008.

[3] J. Staunstrup and W. Wolf, " Data books of ARM7/ARM9", Kluwer Academic Publishers, 1997.

[4] W. Bolton,"Programmable Logic Controllers",Fourth Edition, Elsevier Newnes publications..

[5] Curtis D. Johnson ,"Process Control Instrumentation Technology", Seventh Edition , Prentice-Hall, Inc.

[6] "Introducing PS501 Control Builder Plus Common engineering tool for PLC, drives, HMI, field bus, network, web services", ABB corporation.

[7] "Allen-Bradely MicroLogix_ 1000 Programmable Controllers (Bulletin 1761 Controllers)" Rockwell Automation.

[8] "SIEMENS SIMATIC S7-200 Programmable Controller System Manual" SIEMENS, Edition 08/2008.