AUTOMATION OF A PROTOMATIC LABELLER OF A BREWERY USING SIEMENS SIMATIC STEP 7 CONTROL SOFTWARE: A CASE STUDY OF ACCRA BREWERY LIMITED (ABL), GHANA

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ABSTRACT
In this study, Siemens Simatic Step 7 control software was considered and used to make the labelling of bottled beer faster; make the operations effective and efficient to meet the current line demand of 30,000 bottles per hour. A Siemens Step 7 Control Software based automated Protomatic labeller ensures the targeted 30,000 bph. For the automation, inputs and outputs were established leading to choice of I/O modules. A PLC ladder logic program was developed and simulation was conducted using Simatic PLC SIM. Simulation results validated the applicability of the ladder logic program. Protomatic labeller automation guaranteed reduction in downtime, realization of targeted production, easier troubleshooting and maintenance.

Keywords: Automation, Brewery, Protomatic labeller, PLC programming, Simulation, Software, Accra Brewery Limited (ABL).

1. INTRODUCTION
In 1999, Webb and Reis in their book titled “Programmable Logic Controllers: Principles and Applications” emphasized extensively on PLCs as replacements for traditional relay-contactor logic, which were still in use at most Plants or Industries. PLCs have become favourite tools in the control industry because of their simplicity, robustness, I/O interface and reliable performance. The traditional relay-contactor logic systems have proven to be information barriers to enterprise-wide data access. Evidence shown by Bryan and Bryan (1997) in their book “Programmable Controllers, Theory and Implementation” that even though PLCs had no communications capability, they can be used in situations where communications was a desirable feature. At the time being, manufacturers of PLCs have devised many Communications techniques and pseudo-standard protocols, which are utilized in industry (Johnson, 1994, Clements-Jewery and Jeffcoat, 1996, Baily and Nipenz, 2003). The belief is that the inherent proprietary design of PLCs has limited data access for a number of reasons, such as limited amount of memory, the nature of programming language and the data access. In the light of the above talked about so far we shall now look into the Protomatic labeller of ABL, as one of the main machines at the packaging section of a Brewery. It is used to label bottled beer after filling and pasteurization by the filler and pasteurizer plants respectively. The former electrical design of the Protomatic labeller at its electrical panel at the packaging hall is a big issue as it does not enable the labeller to meet the current line design of 30,000 bottles per hour; evidence has shown that the current production output of 12,000 bottles per hour is starving the packer plant of labelled bottles. Some of the design problems are leveled below:

- The electrical panel is purely based on relay logic controls, making troubleshooting more difficult and time consuming due to its inherent complexity.
- The control of speed is through a mechanical gearing system and it is not time and event driven. This makes dynamic speed control more difficult.
- The shift registers for determining bottle position are complex and hard wired and does not synchronize properly with the speed of the labeller.
- Difficulty in synchronizing the hard wired controls of labeller with the programmable logic controllers which run the bottle conveyor lines for speed and interface controls.
- The protomatic labeller currently does some void labelling due to lack of speed synchronisation between it and the conveyor system. This negatively affects the packaging process, thereby drastically reducing the entire packaging efficiency.

The aforementioned problems are a canker eating deep into the production and performance targets of the entire packaging system. A fully automated labeller using SIEMENS SIMATIC STEP 7 control software (Simatic Manager) mitigates these problems.

This paper is meant to:
- Automate the protomatic labeller to meet the current line design of 30,000 bottles per hour.
- Enable easy troubleshooting of fault so as to reduce troubleshooting time.
- Electrically control the speed and cause it to change dynamically.
- Give proper determination of the bottle position using soft shift registers.
- Increasing the production rate and output per hour.
- Increasing the operational flexibility of the labeller system.

Automation of the labeller plant is therefore imperative as it will improve its operational efficiency to meet the current line demand of 30,000 bottles per hour.

Major developments have occurred in the area of automation in recent years. Industrial automation therefore, offers the advantages of Quality factor, improved productivity, optimization of manufacturing operations, reduction of waste and labor costs (Bryan and Bryan, 1997, Webb and Reis, 1999, Erickson, 2005). Notwithstanding the merits automation provides, its demerits cannot be overlooked: technology limits, unpredictable development costs, relatively high initial costs (Parr, 2001).

Beer brewing begins with raw material supply to the milling plant, milling, brewing, fermentation, filtration, storage before it is sent to the packaging hall for bottling and finally ends with a palletised beer to the warehouse. Labelling plays a key role in the beer packaging process. The process cannot be complete without the filled bottled beer unlabelled thus identifying a particular beer residing in a filled bottle. Labelling can be done manually or electrically. At Accra Brewery Limited (ABL), it is by electrical means which is accomplished by the “KRONES PROTOMATIC” labeller. Figure 1 shows a picture of a part of the protomatic labeller.

![Figure 1. Part of the Krones protomatic labeller](image1)

The functional block diagram of the Krones Protomatic Labeller is presented in Figure 2.

![Figure 2. Functional block diagram of the Krones Protomatic Labeller](image2)
1.1. Mode of Operation of the Existing Protomatic Labeller System
The filled bottles from the pasteuriser through the conveyors come to the labeller to be labelled. The operator presses the start push button at the console to start the labeller. The labeller runs on idle speed (lowest speed) until the bottles coming are sensed by the in-feed monitoring inductive proximity sensor. The bottles are allowed to accumulate to the next proximity sensor after which the bottle stopper opens automatically (i.e. if bottle stopper is on automatic mode) to allow bottles into the labeller.
The bottle present inductive proximity sensor senses the presence of the bottles which actuates the shift register to start processing the positions of the bottles. The shift register signals the magazine at labelling station 1 to shoot forward if the bottle is almost at the labelling station. The label pallet picks up glue at the glue station and takes a label at the label rail which rides on the magazine. The gripper cylinders pick up the labels from the pallet and when at labelling position release the label on the bottle. This labelling station labels the front and the neck of the bottles. The bottles leave and travel through brushes for smooth labelling to the labelling station 2 where the bottle seat is rotated by mechanisms to position the bottle for back labelling. After bottle rotation and fine tuning, the shift register prompts the magazine at station 2 to shoot for the same process that occurred at station 1 to take place. After the labelling station 2 labels the first bottle, the labeller then builds up speed from the idle run speed to ramp up speed and finally to full speed set by the operator at the console. The speed is measured in number of bottles per hour (bph). The labelled bottles then find their way to the fulls packer through the labeller discharge conveyors. There are label monitoring sensors that check whether the body, neck and back labels are present on the bottles and also broken bottle detection sensors to check for broken bottles. Currently, control and operation of the Protomatic Labeller at ABL is relay-contactor based. Mere looking at the mode of operation of the existing protomatic labeller system, coupled with some of the problems and the disadvantages mentioned earlier gave birth to the relevance of its automation.

2. MATERIALS AND METHODS
2.1. Steps, Components and Analysis
This study was conducted at the Department of Electrical and Electronic Engineering, Faculty of Engineering, University of Mines and Technology, Tarkwa in connection with evidence of what we saw and information gathered at Accra Brewery Limited (ABL) in Accra, Ghana.

2.2. Siemens Simatic Step 7 Software
The Step 7 software is a proprietary software produced by Siemens Automation and Drive. The software is user friendly, which supports the user throughout all phases of automation solutions - from the design and implementation stage through to plant monitoring and failure diagnostics. Step 7 contains numerous tools and functions for the most varied tasks in an automation project. Figure 3 below shows how the hardware and software are combined.

![Figure 3. Components of the hardware and software in using Step 7 control software](image-url)
Applications of the Siemens Step 7 PLC Automation Control Software have been reported in the Literature. In the Industrial Installations, the following works were done using the Siemens Step 7 Control Software: Duangsoithong and Kongnam, (2008), developed a PLC-based turbine control system for small hydroelectric power generation with Kaplan turbine type. Miciu, (2008) developed an automation system for the optimisation of electrical and thermal energy production in cogenerative gas power plants. Li, et al., (2009), designed a remote control laboratory-based network. A gas storage facility was programmed by Strickler, (2000). Ioannides (2004) designed and implemented a monitoring control system for an Induction Motor using PLCs. Goff (1990) reported on the experience gained in automating three skid-mounted reciprocating gas engine compressor packages on Gulf of Mexico remote unmanned platforms. To add to these, the following works have also been done with regard to Brewery Installations: The PLC was used in a yeast cropping system to monitor yeast concentration with the aid of a yeast probe thereby directing a portion of yeast crop to an assigned storage vessel (Carvell and Turner, 2003). Ogawa and Henmi, (2006) employed the PLC in conjunction with the personal computer to automate a major Japanese beer brewery company with the aid of an advanced brewing integrated control systems (ADBIC). Buttrick, (2006) reassured of significant benefits to be gained from installing efficient PLC based automated beer line cleaning equipment.

In this paper, use is made of the Siemens Step 7 Control Software to automate the Protomatic Labeller of Accra Brewery Limited. The Step 7 Standard package provides a series of applications within the software. These are: simatic manager, symbol editor, hardware diagnostics, hardware configuration and communication configuration.

2.3. A Siemens Step 7 Software Based Automated Protomatic Labeller

In automating the Krones Protomatic Labeller, the flow chart below gives the operation of Siemens Step 7 control software.

![Flowchart of considerations in automating the protomatic labeller](image)

*Figure 4. Flowchart of considerations in automating the protomatic labeller*

Programming of the Protomatic labeller starts by first (not always the case but it is the best method) configuring the hardware. The total process input signals number 43 whilst total output signals number 33. With 43 input signals needed to the PLC, a total of two (2), 32 channel digital input modules with module number, “DI 32 * DC 24 V, 312-1BL00-0AA0” are selected. With 33 output signals needed from the PLC, a total of two (2), 32-channel digital output modules with module number, “DO 32 * DC 24 V, 322-1BL00-0AA0” is required.

2.4. Programme Simulation

The SIMATIC PLC SIM is the software for simulation of step 7 program without physical hardware. This program can be used to simulate any step 7 program but becomes inconvenient for simulating very large programs as there will be more inputs and outputs. The software is part of the Simatic Step 7 Professional software package.
3. GENERAL REMARKS ON THE STEP 7 PLC PROGRAMS OF THE PROTOMATIC LABELLER

3.1 STEP-7 PLC Program
Samples of Networks of the PLC program using Siemens Step-7 Software are presented in Figures 6 to 15.

**Figure 5. Safety doors healthy and E-stops programming**

**Figure 6. System healthy programming**
Network 4: Machine Run Command

Comment:

Figure 7. Machine run command programming

Network 1: Bottle stopper open

Comment:

Figure 8. Bottle stopper open programming
Network 2: Accumulation Delay

Comment:

Figure 9. Accumulation delay programming

FC4 : HEIGHT ADJUSTMENT

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Network 1: Machine height adjustment up command

Comment:

Figure 10. Machine height adjustment up command programming
Figure 11. Machine height adjustment down command programming

Figure 12. Shift register programming

Figure 13. Front label carriage solenoid valve programming
Figure 14. Front label carriage glue scraper solenoid valve programming

Figure 15. Back label carriage solenoid valve programming
3.2 Simulation Results
Samples of simulation results are presented in Figures 16 to 19.

Figure 16. Simulation of machine height adjustment up program

Figure 17. Simulation of machine height adjustment down program
Figure 18. Simulation of front label carriage glue scraper solenoid valve program

Figure 19. Continuation of simulation of front label carriage glue scraper solenoid valve program
4. DISCUSSION OF RESULTS

In the program simulation, the green light depicts the presence of power and the dotted line an absence of power. The network with all green lights means that there is power through the inputs and output on the rung, hence they are activated. The network with green lights and dotted lines show that there is power although the input/output are not activated. This may happen if the input/output signal that is to energise the device has not been received for action.

5. CONCLUSION

The Protomatic labeller forms a vital part of the packaging section. Its existing system causes a lot of down time which reduces production. Automation of the Protomatic labeller has been successfully undertaken in this paper. The PLC ladder logic program engulfed all listed inputs and outputs. Simulation of the program using "Simatic PLC SIM" was conducted taking one rung at a time since all codes cannot be simulated at a go. Simulation results validated the correctness and applicability of the generated PLC program. The program for the first run took less than 45 minutes to run. From the results of the automated protomatic labeller, the expected production output of 30,000 bph has been met, assured is reduced downtime and ease of troubleshooting. Speed control was effected electrically in order to be able to synchronise with the speed of the bottle conveyors. From the simulation results, the automation of the Protomatic Labeller is possible and when automated will help Accra Brewery Limited to meet and improve their current line design of 30,000 bottles per hour to increase real time production capacity. Aside, easier troubleshooting in less time is assured, speed control becomes time driven, better interface controls, good synchronization of shift registers with labeller speed and conveyor system facilitating void labeling. The automation of the Protomatic Labeller need be considered and accepted by Accra Brewery Limited for full scale implementation.

6. REFERENCES


