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PLC/HMI CONTROL OF BOILERFOR BREWING AND STERILIZATION

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ABSTRACT

Boiler is one of the most important equipment in many industrial processes which requires continuous monitoring and inspection at frequent intervals. There are possibilities of errors in measuring and various stages involved with human workers. So a reliable monitoring system is necessary to avoid catastrophic failure and this can be achieved by the use a Programmable Logic Controller.In this work operation of boilers and various techniques used in industrial boiler automation were reviewed. Alsoinvestigation of different types of PLCs and other relevant components were made in order to choose the appropriate hardware and software needed to successfully design an industrial boiler automation using PLC/HMI. In addition various activities were carried out to achieve the aim of this research.The simulation result shows that the system produces a desired pressure value of 6bar to be used by Guinness Ghana Limited for Brewing and sterilization.The entire automated process provides an improved overall system efficiency and reduced human labor in the processing industry

I. INTRODUCTION

The use of manually controlled boilers over the years has caused lots of serious problems. Due to poor understanding of the working principles; boilers have resulted in serious injuries, destruction of properties, equipment and system failures even loss of lives as a result of explosion from improper operation of the boiler. Also, because of the use of too much man labour for the operation of the boilers, the cost is on increase and it increases the time consumed for operating the boilers. Too low a level may overheat boiler tubes and damage them. Too high a level may interfere with separating moisture from steam and transfers moisture into the turbine, which reduces the boiler efficiency.

Boilers are required to maintain maximum steam generation efficiency, maximum reliability, and comply with both stringent air emission and safety regulations. To achieve these goals, we need modern control hardware and software. In today's competitive market minimization or reduction of operating costs is a valid method to increase profitability. Reducing fuel expenses associated with the boilers, can directly impact manufacturing costs.

By automating the control of Boiler, the human errors in Calculations which can lead to serious problems and the need of skilled operators can be minimized. The values such as temperature and pressure measured are laid away. This method is cost effective and reduces the time consumed for operating the Boilers [1]

Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provides human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for

human sensory and mental requirements as well. Automation plays an increasingly important role in the world economy and in daily experience.

Automation systems for industrial processes have become increasingly sophisticated over the past 20 years on the back of major advances in computer hardware and software. Some of the automation techniques used in industrial processes include the use of microcontrollers, web based applications, GSM, fuzzy logic, FPGA, and PLC. But for the purpose of this project we will be using PLC because of its robustness, flexibility, reliability, accuracy, efficiency and also real time control.

In a work by**Shital S. Chopade, PradhumanVerma and PrashantVerma,** PLC/SCADA was used to monitor and control the parameters in a water tube boiler.[2]
There system monitors boiler`s temperature, pressure and volume via different sensors which provide input to PLC. The output of the PLC controls the boiler temperature and pressure and gives out the required volume of steam. All pressure and temperature variations are shown on SCADA screen and are controlled through SCADA. Different automated check valves are used to release pressure and to inform the concerned authority through alarm in case of an emergency. This process is described in the figure below. The PLC used was the Allen Bradley PLC because of its better I/O handling capabilities and more programming elements been added to improve communication. This project was aimed at increasing quality and efficiency.

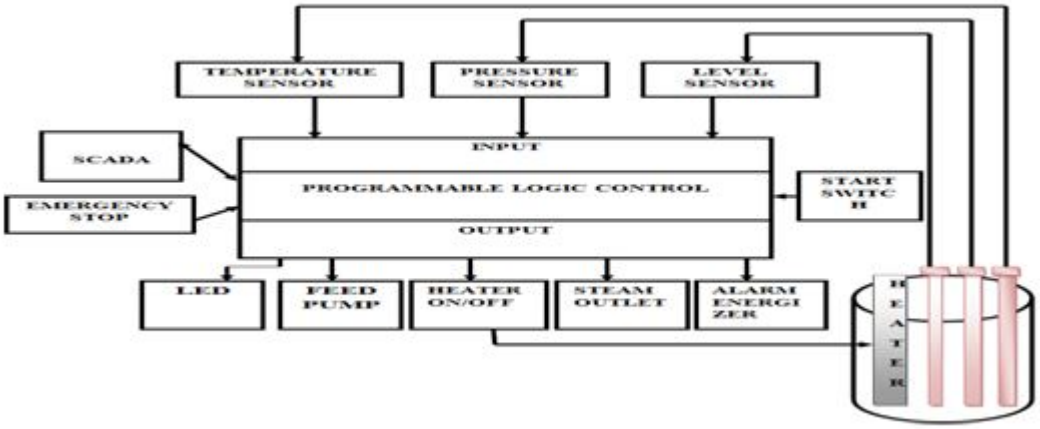

Figure 1: block diagram of boiler control using PLC and SCADA

*Another PLC based system was done by **Rishabh Das and SayantaDutta** in 2013 and it was aimed at implementing an automated water level control in multiple tanks. The main system components were:*

- Level sensors
- Programmable Logic Controller
- Relay and motor
- HMI

*The SIMENS S7-300 universal controller was used. Three low-level and high-level sensors were used to provide level data to the PLC. The PLC used this data to take the required decision and thereby turning ON and OFF a pump with the help of a relay switch. The system was implemented in SCADA to provide the Human Machine Interface (HMI). The system offered the following **advantages***

- The high number of I/O ports of the SIMENS S7-300 PLC enables the system to monitor a large number of tanks single handedly
- Efficient and cost effective
- No human supervision was necessary

The only disadvantage was that the system was that leakage was not monitored [3]

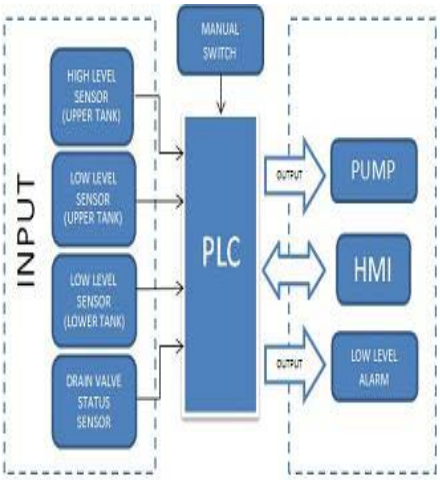

Figure 2: BLOCK DIAGRAM OF THE SYSTEM

KEY BOILER COMPONENTS

- burner,
- combustion chamber,
- heat exchanger,
- controls -Controls regulate the ignition, burner firing rate, fuel and air supply, exhaust draft, water temperature, steam pressure and boiler pressure.

GENERAL BOILER OPERATION

The exhaust steam is allowed to condense in a unit called steam condenser. The condensate (condensed steam) is then fed back into the boiler. This helps to reduces the running cost (i.e. the amount of fresh water that is needed to top the boiler called the make-up water and the amount of fuel needed) because the condensate tube has a lagging round it which helps to maintain the temperature of the condensate around a temperature of about 95^{o}C therefore little fuel is needed to heat it back to 100^{o}C. The condensate together with the make-up water is fed into the boiler by a pump called the feed water pump. The water level inside the vessel is controlled by a limit switch. The flue gas comes out of the boiler into atmosphere through exhaust stacks.

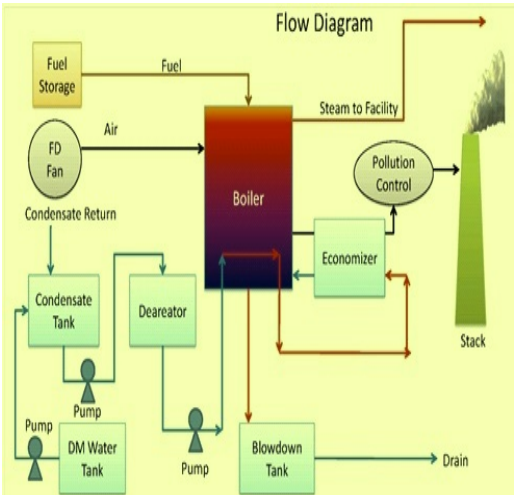

Figure 3: Schematic Diagram of General Operation Of Boiler

CRITICAL CONTROL PARAMETERS IN BOILERS

- Temperature Control:
  Steams drum temperature, under bed boiler temperature, Force draft temperature, Flue gas temperature, Induced draft temperature, feed water temperature.

- Pressure Control:
  Force draft pressure, Induced draft pressure, Steam drum pressure, Turbine inlet steam pressure, and flue gas pressure.

- Level Control: Steam Drum level, Water level

PLC (PROGRAMMABLE LOGIC CONTROLLER)

Programmable Logic Controller (PLC) is a digital computer used for the automation of various electromechanical processes in industries.
PLC consists of a microprocessor which is programmed using the computer language. The program is written on a computer and is loaded into the PLC via communication cable.

BASIC COMPONENTS OF PLC

- CPU and Memory module.
- Power supply.
- Input and output module.
- Programming device.

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Figure 4: Diagram of a PLC

HMI (HUMAN MACHINE INTERFACE)

HMI stands for Human Machine Interface, it is a software application that presents information to an operator or user about the state of a process, and to accept and implement the operators control instructions. Typically, information is displayed in a graphic format (Graphical User Interface or GUI). An HMI is often a part of a SCADA (Supervisory Control and Data Acquisition) system. . An HMI can increase productivity by having a centralized control center that is extremely user-friendly.

Figure 5: HMI System

OPERATION OF A PLC SYSTEM

A PLC works by continually scanning a program. We can think of this scan cycle as consisting of 3 important steps. There are typically more than 3 but we will focus on the important parts. Typically the others are checking the system and updating the current internal counter and timer values. [4]

The 3 steps are:

- Reading the field status from input devices
- Execution or solving the logic, and
- Updating the output devices status.

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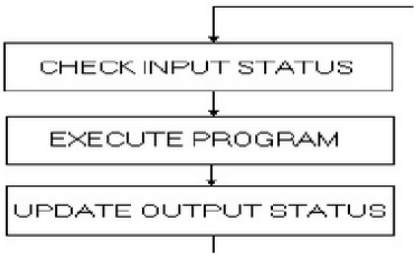

Figure 6: Operation of PLC

II . MATERIALS AND METHODS

DESIGN CONSIDERATION

The aim of the work was to design a boiler automation system that controls and monitors temperature, pressure, the water level. The following components were used to carry out this work:

- A programmable Logic Controller (PLC)
- Pressure Sensors
- Temperature sensors
- relays

- valves
- LEDs
- Digital computer, laptop or any device that with running windows platform.

Siemens S7-300 PLC
We used the S7-300 PLC in our design because of the following reasons

- It is cost effective
- 100% maintenance free[5]
- high processing speeds for short cycle times
- powerful instruction set for complex functions
- It has a lot of program memory for extensive input/output configurations.
- It is also expandable. In cases where additional inputs/outputs are required.

Software Requirements

Some of the Siemens software for automation includes AWL, FUP, Graph, HiGraph, Ladder Logic, STEP 7, System Control
For the purpose of our project we used Siemens Step 7 software Software.

Programming language: **Functional Block Diagram (FBD)**
Reason:

- Visually more understandable to a user who is not versed in relay logic.

Human Machine Interface:
Requirement:

- Compatible with SIMATIC STEP 7 V5.0

Choice:SPS–VISU S5/S7
Reason(s):

- Compatible with SIMATIC STEP 7
- Does not use much memory
- Inexpensive software with ease of operation.

Siemens Step 7 software was used to program the PLC.

IMPLEMENTATION

This area focuses on the methodology used to accomplish the requirements of the work.

Data Collection
• Reviewed related and relevant papers, journals and articles.

• Visited Gusiness Ghana factory to learn manufacturing process

• Designed automated system for the control of a boiler system.

• Programmed the system in simatic manager using functional blocks and simulated it in SPS-VISU.

• Researched several PLC manufacturer sites and recommended PLC, sensors and other equipment needed.

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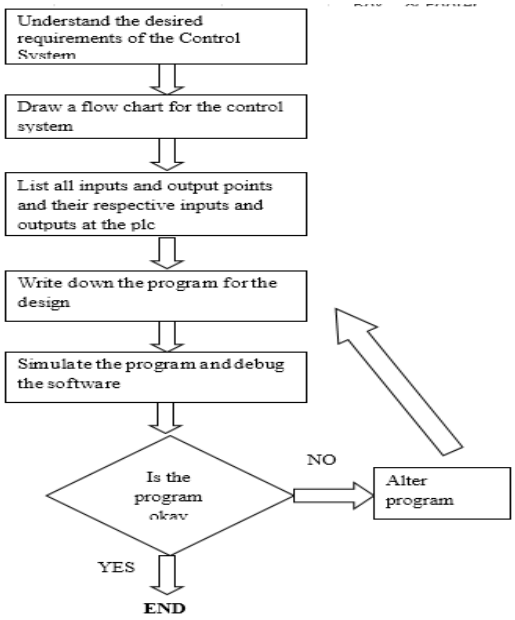


Figure 7: Flowchart for the PLC Program Design

SEQUENCE OF OPERATION OF A BOILER

The main purpose is to have an excellent control on pressure and temperature as well as other parameters in the boiler such as:

- Sequence control
- Feed water level control
- Pressure (firing) control
- Trim control
- Blow down control

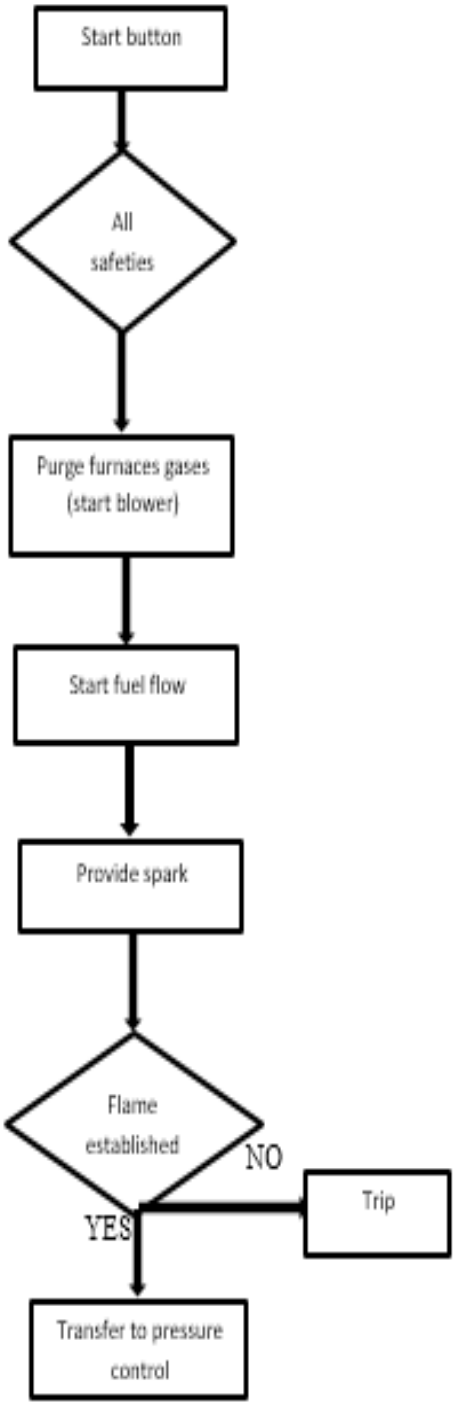


Figure 8: Sequence of Boiler

CONTROL CIRCUIT

The PLC is at the heart of the control circuit. This circuit indicates the connections of the various inputs (sensors, switches) and outputs (actuators, lamps) to the PLC as shown in the figure below:

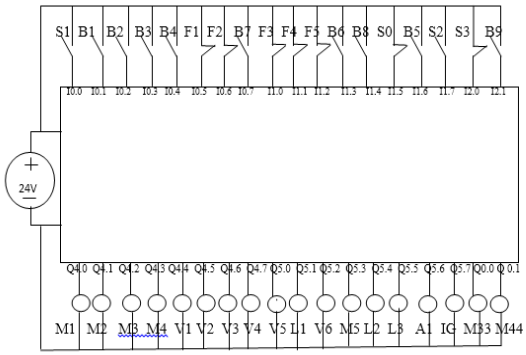
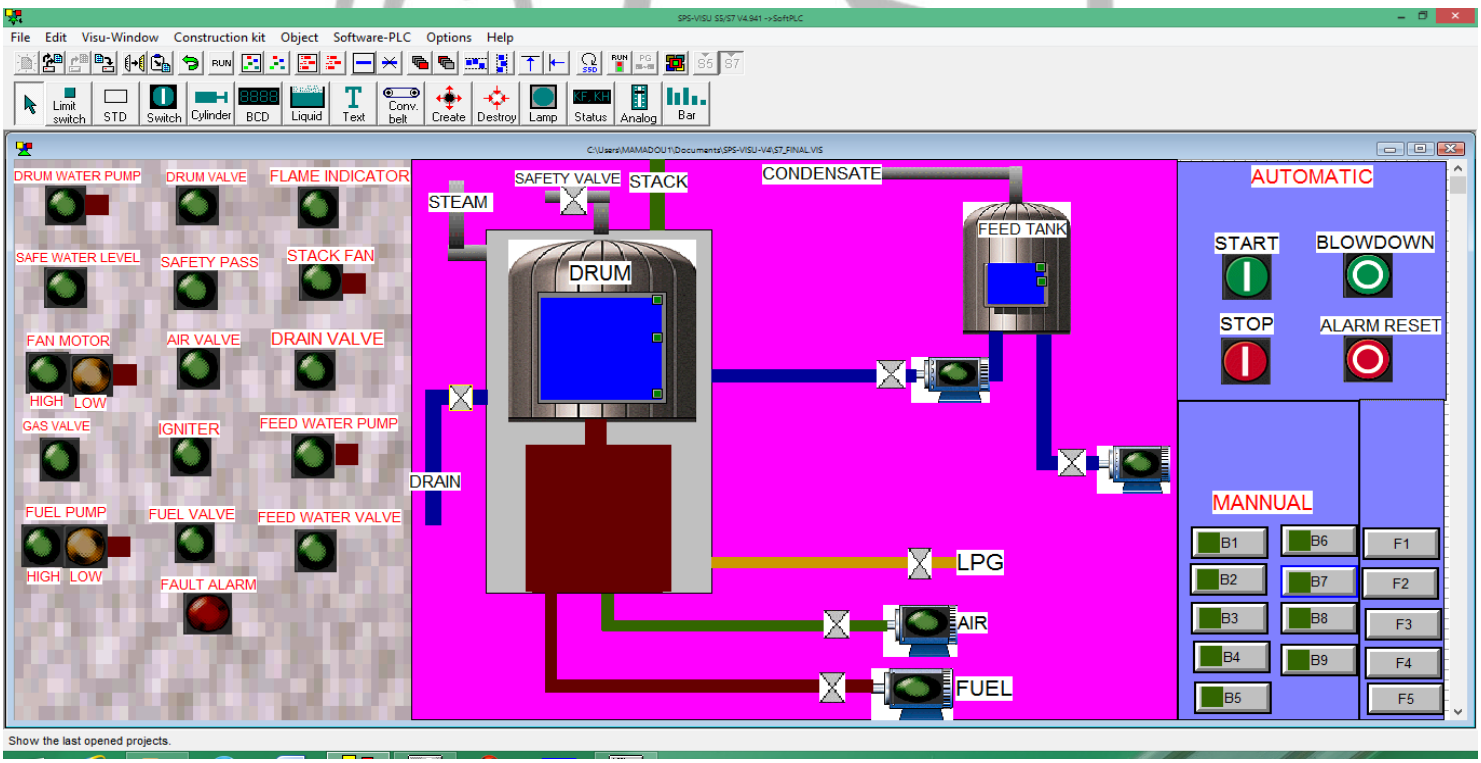


Figure 8: Control Circuit

III. RESULTS AND DISCUSSIONS

The result of the simulation in SPS-VISU is shown below



From the simulation results water level,temperature and pressure can bemonitored and controlled,the system was designed considering the desired pressure, temperature required for brewing and sterilization.

IV. CONCLUSION

This paper presentsthe design of a fully automated boiler with the use of PLC and HMI emphasizing on the control and monitoring of water level, temperature and pressure. The system produces a desired pressure value of 6bar to be used by Guinness Ghana Limited for brewing and sterilization.
The entire automated process provides an improved overall system efficiency and reduced human labor in the processing industry.

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