DESIGN AND IMPROVEMENT OF A CONTROL SYSTEM FOR A WET MIX PLANT WITH IOT CONTROL

Zaid S. Al Shattle[1], Senthil A. Muthukumaraswamy[2]
Heriot Watt University Dubai Campus, Heriot Watt University Dubai Campus

Abstract
This paper will discuss the methodology for designing a system for a factory. The system creation will be discussed including initial design, improvements and results. The system will be implemented using a Programmable Logic Controller (PLC) incorporating a Supervisory Control and Data Acquisition (SCADA) interface for monitoring and control which will be connected to the Internet of Things (IoT). The goal of the implementation of the system is to increase stability, reduce error and implement safety measures for the plant.

Index Terms: Automatic control, Control design, Control systems, SCADA, PLC

I. INTRODUCTION

Nowadays Control Systems are one of the most discussed topics in different fields. Most modern applications and appliances are working to implement more efficient control systems to improve the system as required by the design requirements.

However, the design of a Control System does not stop at making a system operational, but instead should extend at finding the best algorithm which will achieve the best results for the system.

With that consideration this paper will discuss the process that was followed during the design of a control system for a Wet Mix Plant, the system should achieve the following:

- Allow the factory run dependently during automatic mode
- Have individual controls for each individual component in the factory if needed (manual mode)
- Implement an alarm at operation of any component in order to ensure that safety requirements are met
- Create a feedback loop to optimize the output and decrease the error percentage
- Create an emergency system that will stop the operation in case of emergencies

The system will be applied using a FMD1616-10 PLC. We will be using the improved Wet Mix Plant Design discussed in [1] and is used in the factory whose data was obtained in [2].

This paper will be concerned about improvements for a continuous mixing plant which has several pros and cons which will be discussed later. [3]

II. FACTORY DETAILS

The factory considered is a Concrete Stabilizing Plant (Also known as a Wet Mix Plant) where 4 feeders will feed in different types of materials into the main mix which will later be mixed with water and cement, those materials are fed into the main belt which will drive them into the rising belt which takes the materials into the mixer where they are mixed and water / concrete are added as required to get the correct mix requirements, Finally when the mix required is completed it is later released into a truck/container to be used for whatever purpose it was required for. Figure 1 below shows the main process of the factory

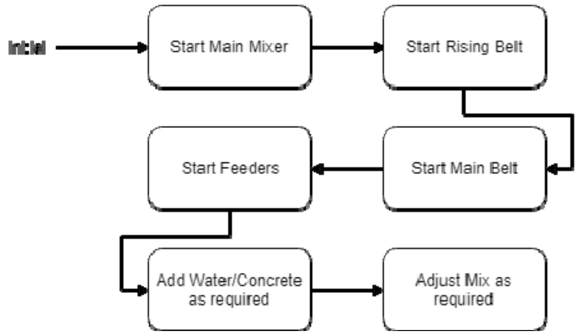

Figure 1: Wet Mix Plant Process

For this system we will consider the following individual components to be configured and controlled:

- 3-phase squirrel cage induction motors with Variable Frequency Drives (VFDs) for speed control
- Loadcells with Loadcell Controllers
- Flowmeters
- Pump for Water
- Contactors and Different Types for Relays (Overload relay, etc.)
- Al alarm system (Horn, etc.)
- Emergency Trip-wire system

At start up a warning horn will start in order to clear the personnel near the factory, after a few seconds of delay the mixer will first start in order to clear any residues from the last operation. Next will be the rising belt followed by the main belt which will clear off the process to prepare for a new mix. Next the feeders will start inputting materials at the required intensity to create the mix as needed. Water and concrete are added as needed and finally using feedback controls the mix will slowly be adjusted depending on the readings and the current state of the mix.

Safety trip wires will be used as discussed in [1] which will be connected to a safety system. How that system will work is that it will stop all the system previous to the affected component in order to make sure that whatever process is currently in-going is not affected negatively by the issue, later on the system will go to shutdown until and engineering checks the system out. The shutdown will be done in reverse order from the start up with the load of reducing the left-overs from previous operations. [4] Factory designs for feeders/main belt are attached below [1][2].

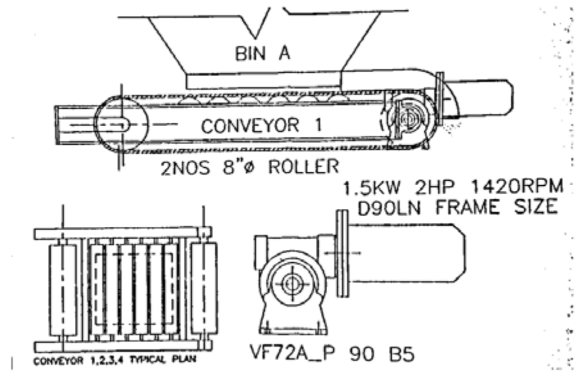

Figure 2: Feeder Design [1][2]

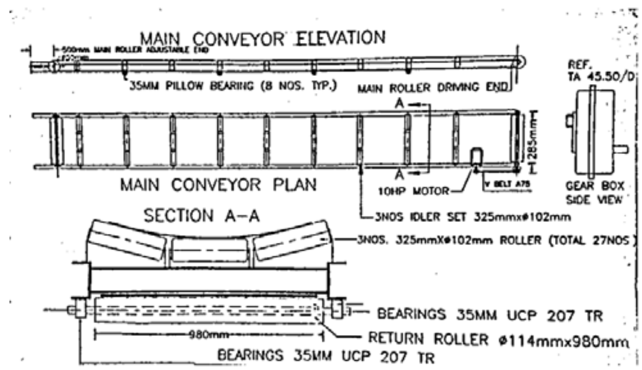

Figure 3: Main Conveyer Belt [1][2]

III. METHODOLOGY

The system will be controlled by the PLC discussed previously. The PLC will be using Ladder Logic alongside BASIC coding for control which will be used to optimize the readings and make the control system much more efficient and controllable. [5] The design of the system will be connected into two main branches, manual mode design and automatic mode. The system will also have a startup phase where the data is loaded and a calibration mode in order to setup the program.

A. Startup Phase

During startup phase the factory will load the setup data that was previously loaded during the setup of the factory. It will first load the modifiers for the load cells which have been already calibrated. Data is then used for configuration of load cells reading and flow meter reading. A simple equation for the materials will be used which was previously discussed in [1] which is:

$$Produce(feeder) = (w(current) - w(previous)) * v \quad (1)$$

B. Calibration Mode

When in the calibration mode the system will be focused on getting the readings of the load cells to get the correct values. The calibration process is used by supplying known weight/minute and taking the reading, the value is then recorded as a modifier for the weight/sec. The weight/min is used in order to increase the accuracy as weight/sec is much more inaccurate. We have two main methods of calibration, using hardware switches to calibrate which is the emergency mode used and using the SCADA system to control the calibration including starting and stopping calibration and entering the exact amount of materials used for the calibration which makes the result much more accurate.

C. Manual Mode

The manual mode of the system is concerned with activating individual parts of the factory without concern to the total process. It will concern the activation of:

- Each individual feeder
- The Pump
- The Main Belt
- The Rising Belt
- The Mixer

The activation of each individual component will follow the following sequence:

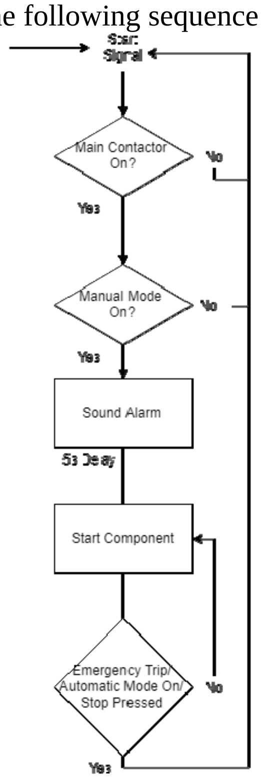

Figure 4: Component startup flow chart

In the beginning the system will send a signal, that signal will be checked if both the main contacted is engaged and the manual mode is on. If that case was true, the alarm will sound for 5s before the component is started. Finally, the component will start and will continue running unless either a trip happens, or the manual mode is disengaged. Or if the stop button is pressed for the control. The system will not run if any fault is currently noted as a safety measure, And the only way to reset a fault is to get a certified engineer to check and fix the fault.

While the factory can run in manual mode it is mostly used for either diagnosis or for very specific mixes that are not configured in the system.

D. Automatic Mode

The automatic mode will use the same process startup mentioned in figure 4 in the manual mode section. However, it will also control the process of the factory to run in the sequence described in figure 1.

The main objective of the automatic mode however is to implement the Closed Loop Control System (CLCS) in order to solve one of the main issues of the continuous feeding model: Accuracy. [6] A very simple CLCS will be used for each feeder which is shown below in figure 5.

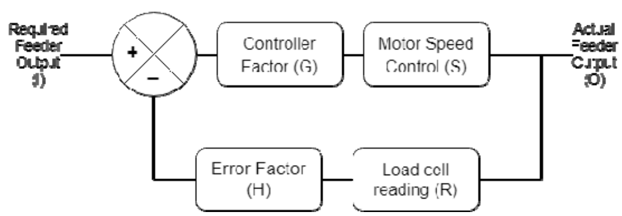

Figure 5: Feeder Control diagram

The system equation of the feeder control is described in equation 2 below

$$O = I.G.S/(1+I.G.S.H.R) \quad (2)$$

Where O is the output of the system, I is the input of the required material quantity, G is the output of the controller for the input quantity, S is the speed of the feeder for the value of G, R is the factor of the load cell reading difference, and H is the ratio to use to correct the controller input.

If the Error Factor (H) exceeds a certain limit then it will stop the process gradually and the process will need to checked by an engineer to fix the issue.

As discussed previously during turning off the automatic mode it will not immediately shutdown (unless it is an emergency trip which is to be discussed further in a later section) but instead will start a gradual shutdown of the factory in reverse order. An alarm horn will start during both the start and finish of the process.

IV. IMPROVEMENTS TO THE SYSTEM

Following the design of the control system discussed in the previous section next the improvements to the system will be discussed. Before discussing the improvements, the pros and cons of the system should first be considered.

A. Pros of the Continuous Mixing Plant Design

The biggest pro of the continuous mix plant design is the sheer output of the plant. While normal batching plants might output 150-300 Tons per hour (Tph) continuous plants might output up to 300-500 Tph. [7] Due to the higher output and the continuous loading it can be more suitable for smaller deliveries and will help in reducing the cost significantly for the output size. [8]

One other advantage is that the continuous design simplifies the system which means much lower costs of maintenance and are much lower overall operation costs. [9]

B. Cons of the Continuous Mix Plant

The biggest con of the Continuous Mix Plant is the final mix quality. Because of the high loading speed, the quality control of the mix is not as tightly controlled [9]. Also, there will be much higher pollution as there will be a lack of a pollution control unit and the falling of materials will cause dust to be created at the plant. [2][8][9]

Also due to how the system works there is a huge need for very accurate measurement system especially at the beginning of operation or else the quality of the mix will be very severely affected. [9]

A diagram showcasing a typical continuous mix plant is shown in figure 6[9].

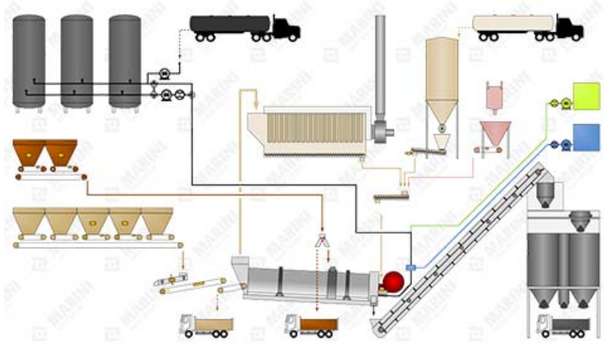

Figure 6: Typical Continuous Mix Plant [9]

C. Improvements to the system

i- Accuracy

After the discussed pros and cons next the improvements for the system will be discussed. As shown previously the main drawback of using continuous mix instead of batching plant is the general quality of the mix and the need for more accurate measurement. [8][9]

We will be using the loadcell placement design discussed in [1][10] in order to increase the accuracy, With the addition of feedback control we are able to somewhat compensate for the accuracy of the system.

ii- Error Control & Monitoring

Next is the emergency trip system. If the error percentage went above a certain amount above a period that indicates that either a critical error is in the system or that a design issue is present, and in that case the system will shut down in the correct order and give a notification to the operator. Furthermore, at the end of operation a report will be issued shown for the expected mix quality and details.

There is an additional trip system installed for the belts in case there is any damage caused to the belts from rocks. [1] The said system will give warning and errors to the main control unit which solves one of the issues of the continuous system where it might be more difficult to find errors during operation.

iii- IoT SCADA integration

The system will be using Modbus TCP/IP to monitor and control the factory. The SCADA system is a custom system that was designed from scratch and can be modified if there is a need for the plant. The interface will help with the following:

- Monitor individual feeder output
- Control and Specify mix details
- Start and stop operation
- Control and specify the calibration mode
- Display any errors or warnings

The system can be easily connected from PCs/Mobile Phones as it will be connected to a central server. For devices outside the plant it will be only limited to monitoring for safety reasons, however plant operators will be able to control and do calibration on-site, A password will be used to limit off-site control.

Another advantage of the IoT integration is the reporting and display of the data. Due to having access of the data and using Cloud Computing Techniques we are able to easily analyze, and display data in many forms as required [11][12][13]

The interface of the system currently implemented can be shown in figure 7.

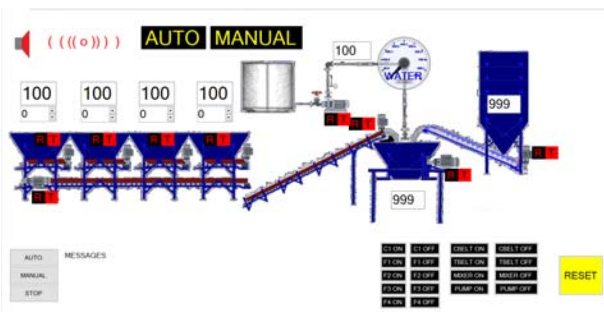

Figure 7: SCADA system of Plant

V. CONCLUSION AND RESULTS

Due to the implementation of the discussed control system and the integration of the control system the stability of the factory has increased significantly, And the error has been reduced by around half following both the control system specifications and the renovation techniques discussed in [1].

The implementation of both the safety and the IoT integration has helped the factory be much safer and be accepted for local governmental requirements.

There are still several issues related to continuous mix plant that have not been discussed or worked on especially for asphalt/concrete plants which are out of the scope of this paper and might be undertaken in another research, however there is a clear indication of the improvements that can be implemented and improve the continuous mix plant.

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