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Cost Effective Monitoring and Automation of Concrete Plant Using PLC

Osama Mahfooz[*], Mudassir Himayat[**], Muhammad Faraz[***] and Fakhruddin Aqeel

ABSTRACT

A PLC is a digital computer used to automate electromechanical processes. This research is based on automation and real time monitoring of concrete plant by using Siemens PLC. Automatic plants can work continuously and can decrease the gap between demand and supply. For such plants there is no need of labor so there is no human error. Without human error the quality of product is better and the cost of production would definitely decrease. The main motivation factor of this research is cost effective automation and real time monitoring of plant.

Key terms: Programmable Logic Controller, concrete plant, automatic control.

PIC: Programmable Interface Controller

I/O: Input Output Devices

HMI: Human Machine Interface

Psi: Pound per square inch

[*] Engr. Osama Mahfooz is Laboratory Engineer, Department of Telecommunication Engineering and Management at Institute of Business Management, Karachi, Pakistan. Email: osama_mahfooz14@hotmail.com

[**] Engr. Mudassir Himayat is Planning Engineer at Indusmens Corporation, Karachi. .

[***] Engr. Muhammad Faraz is Electronics Engineer at KHAS Pvt Ltd, Karachi.

1. INTRODUCTION

A PLC or programmable logic controller is a digital computer used for automation of electromechanical processes. It is used to convert the previously used "Relay Logic" or "Wired Logic" for automation of an industrial process into Ladder Logic as done in PLC-Based Monitoring Control System for Three-Phase Induction Motors in (Birbir.Y, Nogay, 2008) and Automation Control in Painting Line of Steel Plant in (Hao.L, Ruilin.P, 2005). It is used to automate respective processes but in this research Siemens LOGO is used which lie in the cheapest category or entry level of PLC. The reason of it being cheap is that it has limited number of input and output ports (I/O's). A concrete plant is taken into consideration for this research whose input and output devices matched LOGO's configuration. This plant comprises of three gates for ingredients of concrete, a conveyor belt to pour the ingredients into mixer and a water tank and storage for cement. Gates are controlled through pneumatic jacks that are operated by a compressor. Motors drive the conveyor belt and rotate the mixer.

2. PROBLEM

Concrete is the main part for construction. The existing plants work manually which take a lot of time for production that results in a gap between demand and supply. Manual plants need a lot of labor which cause extra cost for production. Labor works in shifts which causes more labor and time. Human intervention in anything may cause human error. The existing plants are totally labor dependant which creates many errors while production thus effects the product quality.

This research provides solution to the problems mentioned above by replacing wired logic with ladder logic. This research is based on PLC to automate the plant so that the gap between demand and supply could be reduced. Without human error the quality of product will be better and the cost of production will definitely decrease. As the plant built in this research is a prototype it was assumed before its construction that the flow of sand and rocks would be smooth and there would be no resistance while opening and closing of gates. There would be no blockage in flow. Timers are used for the pouring cement so it was also assumed that the flow of cement would be according to the calculation. Another assumption that was made was that a reed

switch used for filling of water tank was that there should be no magnet anywhere near the reed switch other wise the reed switch would give the false results.

3. DESIGN ISSUES

3.1 MECHANICAL DESIGN ISSUE

Concrete plant is a mechanical plant which is used to make concrete according to the requirements and formula specified. The concrete plant consists of conveyer belt, motors, pneumatic system, solenoid valves, load cells, limit switch etc. This prototype works on the formula specified for the concrete which is controlled by the PLC. The PLC has inputs and outputs which are used for getting information and sending the signals to the actuators. The actuators then perform the task for certain amount of time or when the sensor senses the limit (LOGO Manual and Bolton.W, 2006). While making this prototype a lot of mechanical problems were faced so while designing the mechanical structure we visited many plants to learn the process of the plant. In the phase of designing and implementation of making a structure too many problems and lots of issues arose. The major issue with the plant was that the plant was a prototype of a concrete plant and most of the parts available in market are for large scale plants so they were modified according to the requirements. Many of the mechanical processes were very costly like transferring of cement from hopper to mixer. This process needs a screw system which was very much costly. It is costly because it needs a delicate mechanical work to make a perfect screw. Then phasing the screw is also necessary, without phasing, the cement will not move. As it is known that cement is a costly product so it needs best isolation from air, water etc. These factors increase the cost of screw system. In this prototype by making a screw the budget was crossing its limits so a different idea for cement was implemented. A hopper for cement that directly dumps the cement in the mixture by using pneumatic system with timer is used. The flow of cement was tested at least 20 times to get the perfect relation with the weight and timing of cement.

In this prototype design there was a problem in gates of hoppers having different kinds of material. While dropping the material there was a chance that materials including fine sand, fine stone and stone could jam the gates. So design changes of gates were urgently needed. The

previous design was to vertically control the gates which increased a lot of chances for material to jam while closing the gates. But then it was decided to control them horizontally so that it could reduce the jamming of gates while closing. Another problem was that in pneumatic system the jacks were controlling the gates very fast opening them fully at very high speed. In this manner springs were placed in the jacks so it could reduce the speed of gates and the process would not be very fast. As a result the flow of material to the conveyer belt was not massive.

3.2 ELECTRONIC DESIGN ISSUES

Since the controlling of the concrete plant is based on PLC, there is not much electronic circuitry involved. The only problem while designing was the conversion of parallel data into serial data which was a part of real time monitoring process of the plant. So for this purpose a microcontroller was used to transfer the data serially. This involved a circuitry which was designed according to the requirements.

4. METHODOLOGY

4.1 WORKING

Working of the concrete plant involved many dimensions (See Figure 4.2). The PLC was programmed on ladder logic. The working of the plant starts as gate 1 is opens and it drops the sand to the conveyer belt. The load cells are attached to the conveyer belt. They sense the load and give output in a form of voltage. This voltage is an input in the analogue module of PLC. In the program of PLC, there is a threshold voltage set as when the load cell exceeds that voltage the PLC that gives a signal to the pneumatic system to close the gate at instant. The load cell was attached to input I5 of the PLC and gates 1,2 and 3 are connected to outputs Q1,Q2 and Q3 of the PLC respectively (See Figure 4.4). Then according to the program PLC gives signal to the conveyer motor and it works for a certain time as specified by the program. The conveyer belt dumps the material which is sand in the mixture. As soon as conveyer belt starts moving the mixture motor also starts at the same time. But the mixture motor does not stop working till the end. Same process repeats for the Gate2 and Gate3 which includes fine sand and rocks. After this the pump connected at port Q5 of PLC gets triggered to pour water in the tank. Inside the tank

there is a water level sensor or upper limit sensor connected at port I1 which will get triggered when the water will reach its limit and then sensor will give signal to the PLC to stop the pump for filling the tank and triggers the solenoid valve at port Q6 pour all the water in the mixture (See Figure 4.3). After the complete flow of water in the mixture the PLC gives signal to the pneumatic solenoid of cement gate that starts dumping the cement for the required amount of time. Then when all the constituents are in the mixture the mixture mixes them for certain amount of time as specified in the program and then the product is dispatched. In our prototype the dispatching is manual.

The pneumatic jacks used are working at 10 psi. The motor of the mixture is induction motor with gears. And the conveyer motor is gear motor by which it moves the conveyer belt with load at constant speed. The solenoid valve for water is operating at 220V and the pump is also operating at 220V. All these actuators are controlled by relays. The relays we are using are of 24V DC and the output of PLC is also 24V DC so the PLC would trigger the relay whenever the actuator has to be switch ON. The 220V AC has been connected to relay which is then connected to actuator whenever relay gets 24V DC from PLC. In the same manner the limit switch of the water level sensor will trigger the relay and then through relay the PLC will get the signal which will be of 24V DC. The PLC takes input of 24V DC. In this manner the whole process works in a closed loop system. (Austin.H, 2005; Jay.H, 2003; Goodman and Robbert.B, 1997; Muller.R, 1998; Henry.F, 1995; Majumdar.S.R, 1995)

Figure 4.1 The Plant

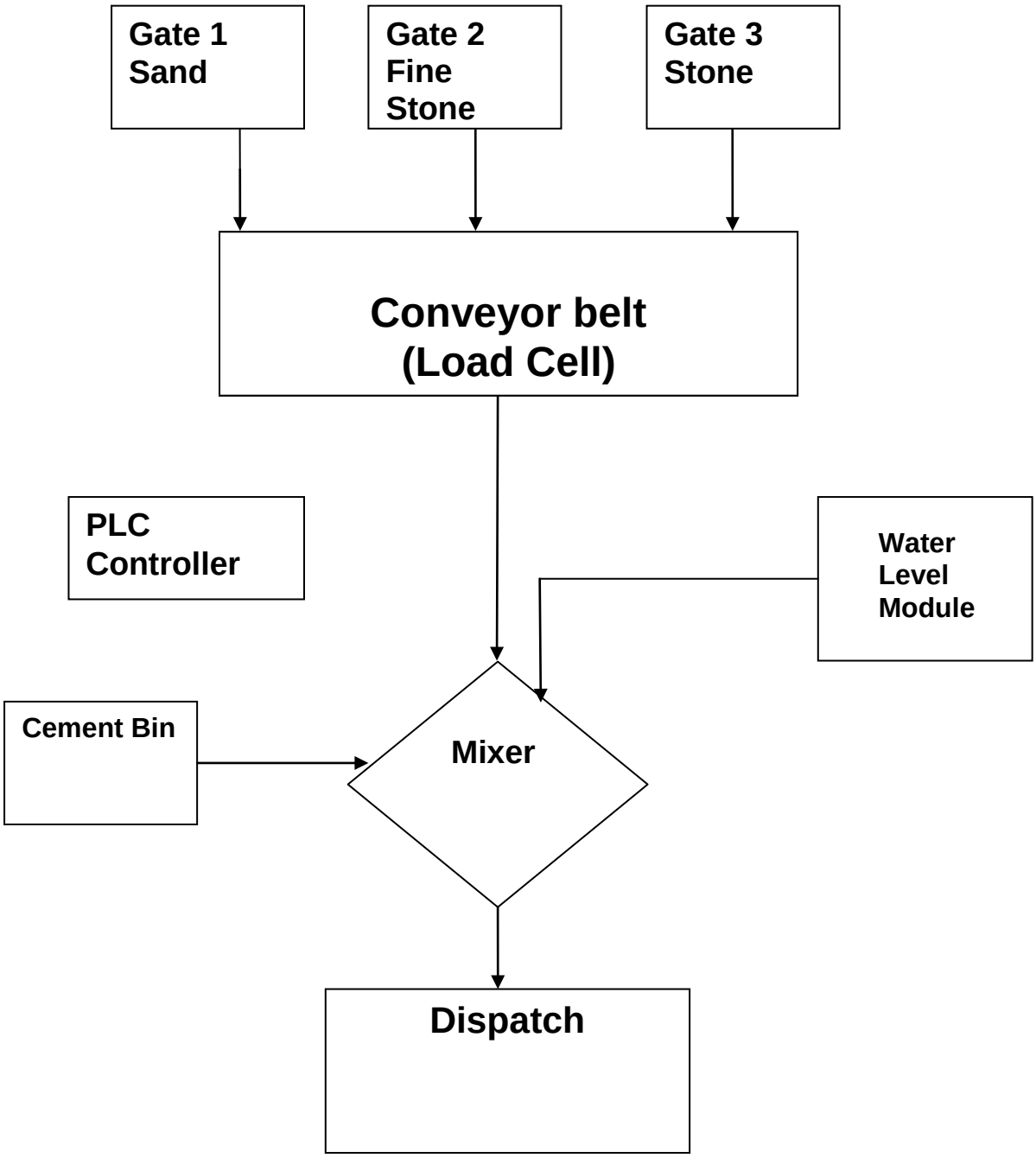

Figure 4.2 Plant Flow Chart

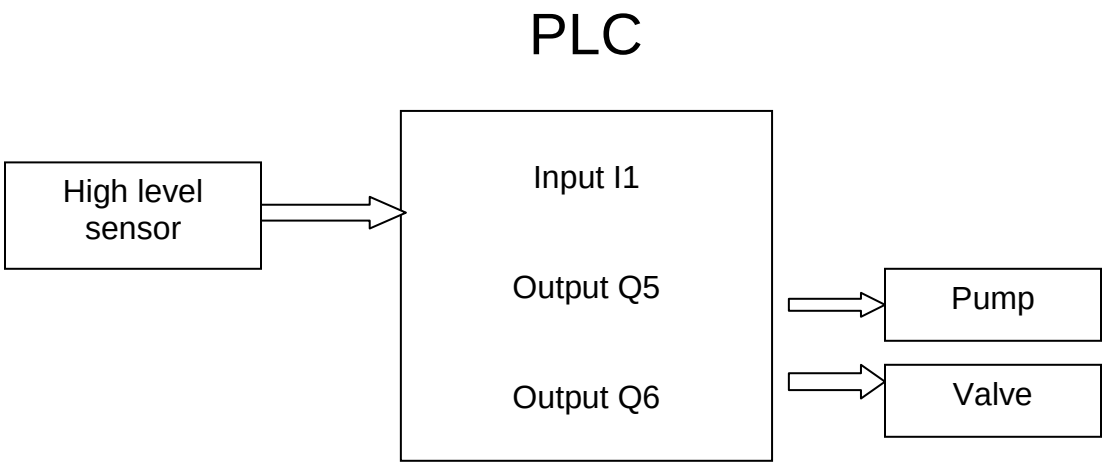

Figure 4.3 Water Level Module

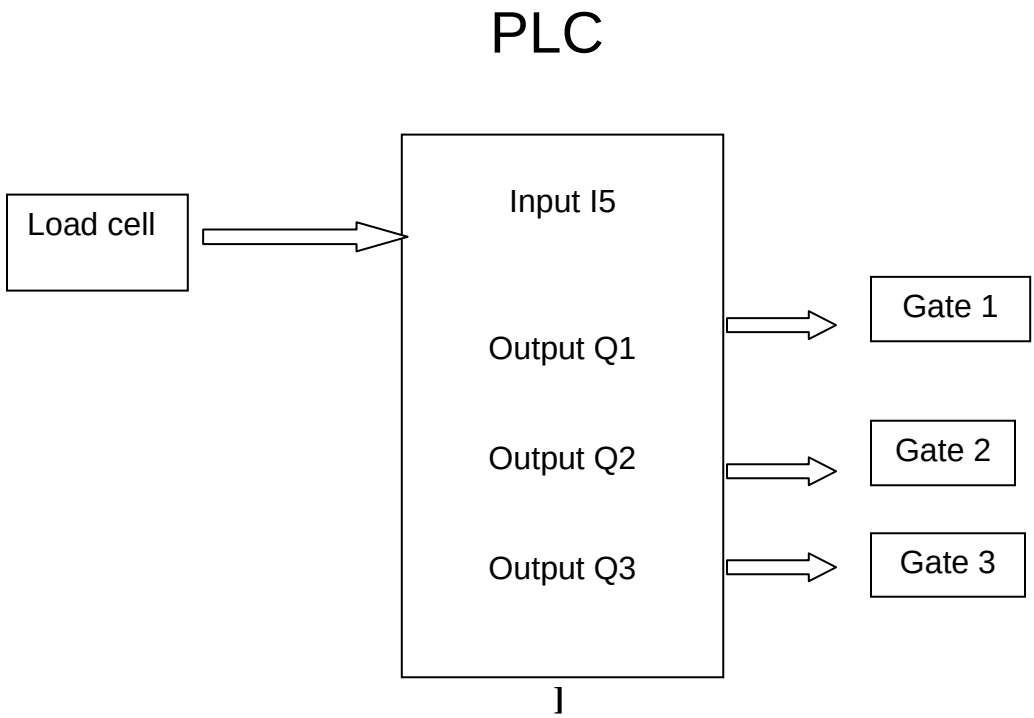

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Figure 4.4 Weighing Module

4.2 REAL TIME MONITORING MODULE

For real time monitoring purpose of the plant a software Macromedia Flash MX 2004 is used instead of traditionally used Siemens Wincc which makes the communication with PLC possible by designing a microcontroller based circuit in spite of the fact that a Siemens PLC can only be interfaced with PC or HMI (Human Machine Interface) by Siemens provided software called Wincc which is quite costly. Every actuating device depends on the relay so the monitoring circuit was designed in such a way that on triggering relay will pass 5V dc to the card which converts parallel data into serial. The main IC is a PIC16876 microcontroller. DB9 connector is used to transfer data serially from controller to the computer.

4.2.1 WORKING OF THE HARDWARE

The pic16876 is the main tool here. This controller is getting vcc on pin no 20 and we can program it directly on pin 27, 28. The inputs to the controller are on pin # 21 to 26 and on pin 15,16 and on pin # 2,3 from pin # 17,18 to the max 232 which is then arranging the voltage from controller to the CPU. The high bit here at microcontroller is 5V and for CPU it is 15V. Here the controller is sending and receiving the data also for synchronization. It is working in active X. The data is sending serial data at 8 bits. There are 8 inputs in the controller for digital. This means every single bit is assigned to each input. As soon as it is getting high means 5V at the input so whenever it gets high at certain input it moves that object in a flash which is design as specified. (S.R. Majumdar,1995),(James.H, 1993),(Electric Drives - AC Motors)

4.2.2 WORKING OF THE SOFTWARE

Flash MX 2004 has a limitation that it does not give serial interface. We used 3rd party plug-ins with Flash to serve this purpose .The plug-in work in a manner that it connects the serial data with the Flash and worked as a driver. It is important to note that it is a processor based monitoring and Flash is very good in graphics. The whole plant was designed on Flash as it made movements in every actuator in terms of animations whenever a high signal was received

through the serial interface. The animations worked only till the Flash was getting the signal from PIC.

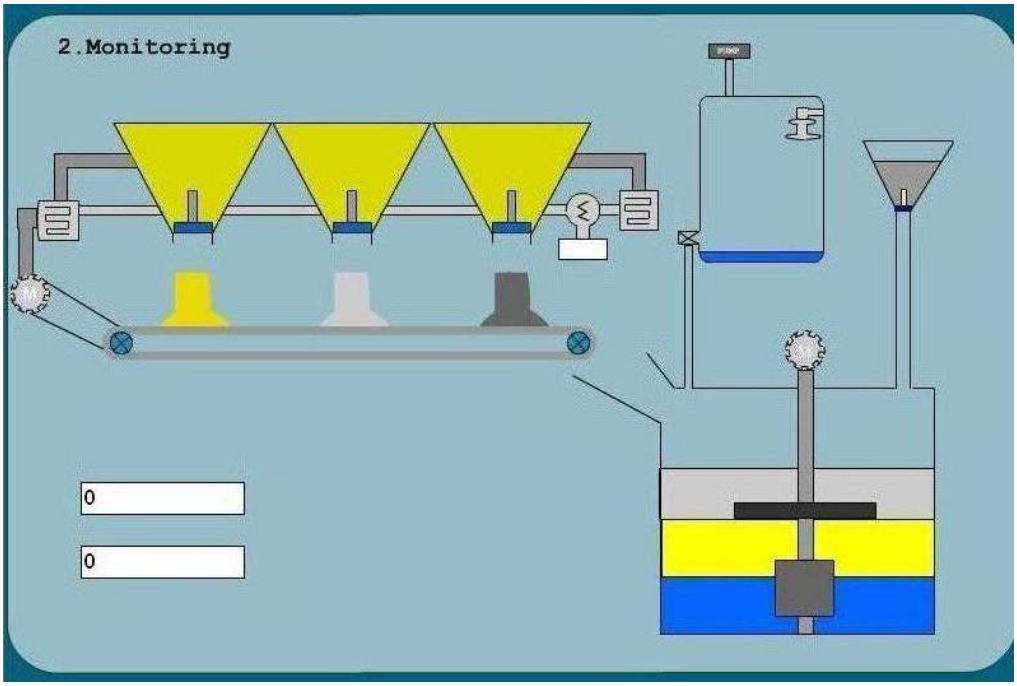

Figure 4.5 Monitoring Software Interface

5. CONCULSION

This plant is specifically designed for the production of concrete but it can be used in numerous industries after modifications. The adaptability in industry of our research is due to its automatic process. It is more probabale that our research is accepted due to ease of usability. Most of the industries through the process of weighing, level sensing, mixing of different raw materials and liquids whereas our plant uses Pneumatic system. Our design works in multiple situations after required modifications. Our concrete plant can also produce concrete in bulk.

In today's world industries can only grow by making themselves advance in technology and by upgrading their machineries and plants. We have proposed an idea of making an automatic concrete plant which is normally manual in Pakistani industry.

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