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A Concrete Pipe Manufacturing Control System with a Programmable Logic Controller (PLC) and HMI for Industrial Plants — an Experimental Setup

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Abstract

PLC based concrete pipe manufacturing system which controls the sequential operations involved in process provides levels of safety, reliability and stability, is developed. The brain of system is Programmable Logic Controller (PLC). The control module provides multilevel component fault detection, tolerance in critical areas such as in level detection and motor control circuits. The control module is designed for reliable operation far beyond normal appliance life. The facility of Input/ Output force on, force off, monitoring the inputs and outputs are also provided. Timer provides precise timing for operations of motors. Program minimizes shutdowns by providing recycle under certain conditions to establish normal operation before checking out. Finally this system is factory programmable to provide different warm up time for concrete pipe manufacturing process.

Keywords: PLC, HMI, PLCBCPMP.

1.Introduction

Industrial automation systems give high efficient & high quality production solutions for production processes [1, 4]. Automatic control systems enable a process to be operated in a safe and profitable manner. This can be achieved by continually measuring process operating parameters, such as temperatures, pressures, levels, flows and concentrations [3]. These parameters can be used to automatically make process decisions, for example, actuating motors, valves or pumps, and controlling heaters, so that selected process measurements are maintained at desired values [3, 4]. Primary equipments in modern manufacturing systems are motors, which are use in many industrial production activities, especially for Assembly lines in industries. Motors systems usually exist in the outer parts of the production plants. Motors are generally used for carrying materials, up-down mechanisms, movement of assemblies. Wrong sequential operations of motors creates problem for process, which leads to unwanted result. Recent developments in PLC technology have provided appropriate solutions for this problem [8]. HMI plays an important role in the rapid development of industrial automation systems [9]. Industrial automation systems enable production units to operate & monitor properly [1].

Generally in concrete pipe manufacturing industries, all operations are done manually [2]. So in this paper, we proposed a scheme in which different operations involve in concrete pipe manufacturing process such as feeder belt, distributor, vibrator & assembly movement in reverse-forward and up-down direction. These all operations are sequential & depend on different conditions status from process such as signal status from Level sensor & Limit sensors. As different time delays & safety interlocks provide safety operation of process along with accuracy [7]. This system being referred as PLC-HMI based concrete pipe manufacturing process (PLCBCPMP). PLC based system gives number of advantages over other controller. PLC is widely used for sequential operations [5, 6]. HMI is used to give visualize graphics of actual process [9]. So, PLC-HMI system gives benefits for concrete pipe manufacturing industries.

2. System design

System is designed with due consideration of environmental conditions and process details. Process to be controlled is as shown in Fig. 1. In this process, the material level in hopper measured by a Level sensor and two limit switches (home position and desired position) on the platform, and these values are the input to an automatic controller (PLC) that actuates motor based on the logical sequences provided to controller. As shown in Fig. 1, Assembly 1 move by motor M5 on desired position, then feeder belt (Motor M1) carries material & distributor (Motor M2) fills gap between mould setup is controlled by a controller according to the user's needs given by program. The level of material in the mould setup is controlled according to the set point values and timer preset value to the controller, which takes decision to turn ON-OFF M1 & M2 Motors. Thus, the process control mode is on–off control. This is a discontinuous form of control action and is also referred to as two-position control [5]. In this process, the on–off controller turns 'on' when the hopper level is at its high level detected by level sensor. The controller turns 'off' when the mould setup material level reaches high. Likewise numbers of operations involve in process for manufacturing of concrete pipe [2]. A detail about system and its sub-parts are as per mention in following section.

2.1 PLCBCPMP Components

The basic components of PLCBCPMP as shown in fig (1) are:
1. Assembly-1: Hopper, Feeder belt, Distributor, Vibrator, Assembly-1 movement mechanism;
2. Assembly-2: Profile ring, Jack Assembly and Assembly-2 movement mechanism;
3. Level sensor, Limit switches;
4. Programmable Logic Controller (PLC);
5. Assembly-1 controller;
6. Assembly-2 controller;

A typical application of PLCBCPMP is as shown in Fig. 1 and CATIA V-5 3D-view of the system is illustrated in Fig. 2.

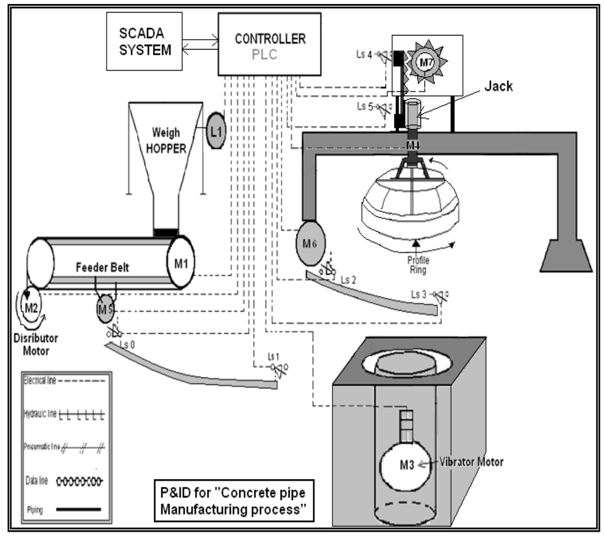

Fig.1 P&ID diagram of Control Process.

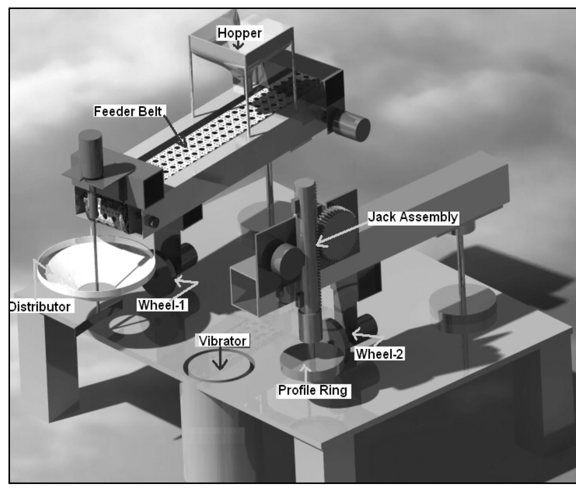

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Fig.2 CATIA V-5 3D-view of the system

For experimental set up we have designed platform of 40 X 100 Cm. On which Assembly-1 & 2 are mounted. Details about these Assemblies as per shown in Fig.7:

2.1.1. Assembly-1

Assembly-1 contains sub-part as hopper, feeder belt, distributor and vibrator, assembly-1 movement mechanism, which are mounted on area of 30 x 50 Cm^2. This Assembly carries concrete material from hopper to mould set-up. Following section gives detail about sub-part;

A. Hopper

This is used for storing concrete material, which is raw material for concrete pipe manufacturing process. Dimension of hopper used are: 24 X 11 X 11 Cm^3. Bottom section of hopper is conical shape with height of 13 Cm.

B. Feeder belt

The main function of feeder belt is to carry concrete material from hopper to distributor to feed in mould set-up. Dimensions of channel in which feeder Belt mounted are: length: 44 Cm, width: 2.5 Cm and height: 4.8 Cm. Pulley of inner diameter 16 mm is fixed in bearing, which are fixed at both end of channel. Belt used in this assembly is of cotton material. DC permanent magnet motor with 30 RPM is used for feeder belt.

C. Distributor

Distributor is used to distribute concrete material in mould set-up. Distributor assembly is of conical shape with dimensions of: Outer diameter=12 Cm, Inner diameter=6 Cm. This assembly is fixed to main channel for support. For distributor DC permanent magnet motor with 20 RPM is used.

D. Vibrator:

Vibrator assembly vibrates continuously, which cause to fill gap in concrete material present in Mould-setup. DC permanent magnet motor with 120 RPM is used in vibrator assembly. High RPM of motor and weight put on one side cause vibration in assembly. Dimensions of vibrator used are: 11 X 16.5 Cm.

E. Assembly-1 movement mechanism:

The main function of this is to move Assembly-1 from home position to desired position. For this we have used wheel of 7 Cm diameter joint to DC motor of 10 RPM. Wheel-motor assembly mounts on below side of main channel with support of 4.5 Cm height.

2.1.2. Assembly-2

Assembly-2 contains sub-part as Profile ring, Jack Up-Down mechanism and Assembly-2 movement mechanism, which are mounted on area of 30 x 50 Cm^2. This assembly is use to apply pressure on concrete material in mould set-up. Following section gives detail about sub-part;

A. Jack up-down mechanism

This mechanism is used to up-down movement of profile ring, which cause to apply pressure on concrete material in mould set-up. Dimension of Jack used are: platform of 15 X 11 Cm, plastic pipe with threaded rubber cover of height= 20 Cm, wheel with threaded rubber cover of diameter= 5Cm and bearing with 16 mm diameter. Pipe up-down movement is control on signal status given by limit switches Ls4 and Ls5. Dc motor of 6 RPM is used for this mechanism.

B. Profile Ring

This ring is used to apply pressure on concrete material in mould set-up. Rotation of ring caused to press material inside mould. Profile Ring's Dimensions are: Diameter of ring = 10Cm, height of ring= 3 Cm. DC motor is used for this mechanism of 3.5 RPM.

C. Assembly-2 movement mechanism

The main function of this is to move assembly-2 from home position to desired position. For this we have used wheel of 7 Cm diameter joint to DC motor of 10 RPM. Wheel is mounted on below side of main channel with support of 7.5 Cm height.

2.1.3. Sensors

A. Limit switches

These are used detect position of assembly-1 & 2 and of Jack. They have to type of contact No & Nc. Signal status of limit sensors are used to decide control action for motors operation.

B. Level sensor circuit

Level sensor is used to detect high level of concrete material store in hopper. Level sensor circuit consists of two units.

(i)LDR: light dependent resistor is a resistor whose resistance decreases with increasing incident light intensity.

(ii) Laser light source.

Fig.3 shows details about configuration of system.

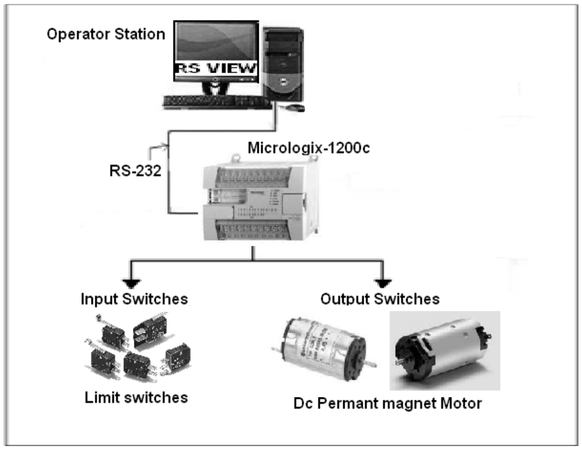


Fig.3 PLCBCPMP System configuration diagram.

2.1.4. Programmable Logic Controller (PLC)

PLC is controller module used for controlling various sequential operation of concrete pipe manufacturing process. Fig.4 shows block diagram of PLC.

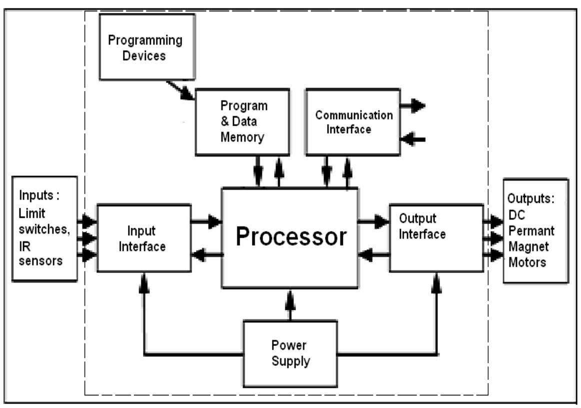


Fig.4 Block diagram of PLC.

Specifications for Micrologix-1200c:
I/O capacity: 14 Inputs, 10 Outputs
Input type: 24V Dc sink/source.
Output type: Relay/FET: 8 A/common.
Timers: high-resolution, 1 ms [10].
Communication: DF1 full-duplex & half-duplex slave, DH-485, DeviceNet and Ethernet/IP.

2.1.5. Assembly-1 controller

This controller is required to control sequential operations of feeder belt, distributor, assembly-1 movement and vibrator. For this on-delay timer of PLC is used to control the operation of motor.
Limit switches Ls0 and Ls1 are mounted on platform to detect position of assembly; this is input to PLC, for start of assembly-1 movement.
For sensing level of concrete material level switch L1 is mounted on hopper upper side, which checks high level of material in hopper, this is input to PLC, a safety interlock for start of assembly-1 movement. When PLC gives start command, relay of 24VDC gets energized.

2.1.6. Assembly-2 controller

This controller is required to control sequential operations of Jack mechanism, profile ring and assembly-2 movement. For this on-delay timer of PLC is used to control the operation of motor.
Limit switches Ls1 and Ls2 detect position of Jack up or down position, this is input to PLC, which is a safety interlock for start of assembly-2 movement.
Limit switches are mounted on platform detect position of assembly, this is input to PLC, for start of assembly-2 movement in forward and reverse direction as per logic.

3. Design of software of the system

The PLC is programmed to provide system operation in a manner illustrated, in the flowchart of Fig. (6). whole software is grouped into following parts.
Before develop logic, system is communicated using RS Linx software [12] as shown in fig.5.A.

Initialization and Power ON system

In this phase system is power ON by start PB, by operator. System ON indicates on control Panel and also on HMI screen. There is also one PB for emergency stop of all operations. This logic is given in RS Logix-500 as shown in fig.5.B [13].

Controller Program for Assembly-1

If level of concrete material in Hopper is high and Assembly-1 is on home position then PLC sets output for buzzer, till operator press acknowledge PB. When operator acknowledge condition then process start. Assembly-1 move to desired position then PLC sets timer for ON of feeder, distributor and vibrator motors. This is off delay timer.

When timer attains preset value, then feeder, distributor and vibrator motors stop. After some time delay Process-1 completion indicator ON and assembly-1 move in reverse direction to home position. Fig.5.C shows LAD view, while fig.5.E. Show HMI (RS-view32) [11] view for Process-1.

Controller Program for Assembly-2

As process-1 completed and Profile Ring on home position then Process-2 start. Assembly-2 move to desired position then PLC sets output ON for Jack and Profile Ring operation. When Jack attains low position, then movement of Jack stop and sets timer. This is off delay timer.
When timer attains preset value then Profile Ring stop rotate and reverse movement of Jack till home position. After some time delay Process-2 completion indicator ON and assembly-2 move in reverse direction to home position. Indicator ON to indicate completion of all processes. Fig.5. D and F show LAD and HMI for process-2.

Safety Interlocks

Operations relating to safety, start-up, shut-down and different processes sequencing are basically digital in nature. The following are basic safety interlocks.

Hopper Level Interlock

This interlock prevents start up of Process-1. If level of material in hopper is low than desired then no operation start, either other conditions are satisfied.

Limit Switches in Assembly-1and 2 Interlock

This interlock prevents start of operations in Assembly-2 when Assembly-1 is in working phase and vice-versa.

Limit Switches in Jack mechanism Interlock

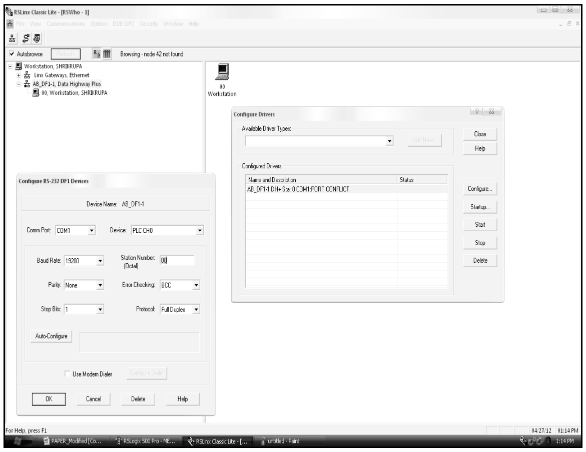
This interlock prevents start of operation of Assembly-2 movement motor; either all other conditions are satisfied.

4. Results

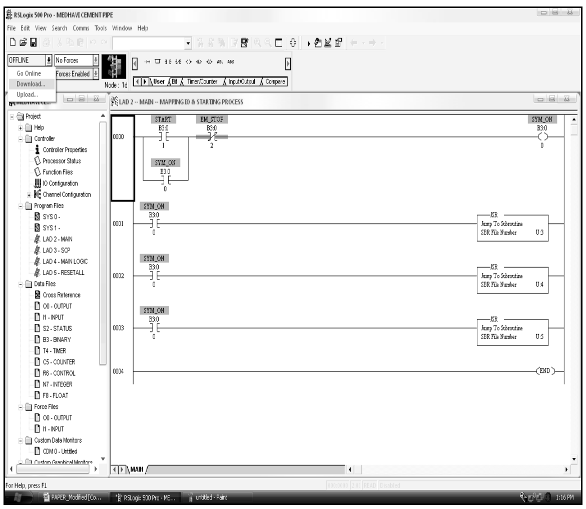
After designing hardware setup and drawing ladder diagram and HMI, we have tested the system in totality. We found that system is working as per the sequence of the process. For ex. When level in hopper reaches up to 25 cm, then motor M5 starts; likewise all the limit switches and level switch as well as motors are working as per requirement of process. The designed setup is cost effective solution for the industry as this type of setup cost in crores rupees in industry.

5. Conclusion

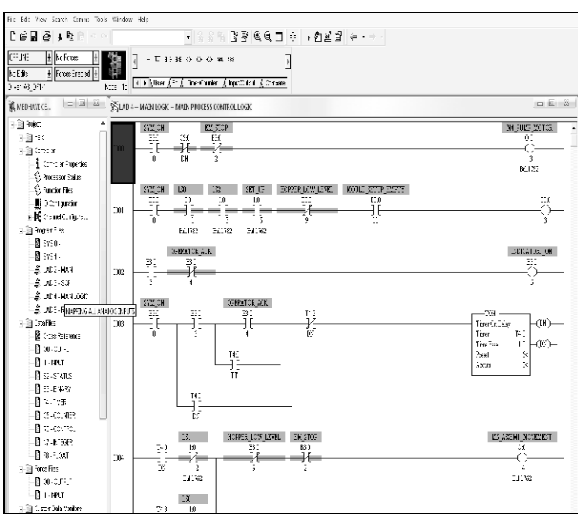
PLC controllers are the primary technology choice for process automation and control. Above system provides the needed flexibility, low maintenance cost and scalability in the design. In this work, we discussed the design and implementation of a system to monitor and control of concrete pipe manufacturing process. The system was tested and it had a very satisfactory performance. Conventional methods of manufacturing required more manpower. In this study, PLC-HMI based system for the concrete pipe manufacturing process solved these problems and provided a clear advantage over conventional systems as more safety of plant, low cycle time, increase in quality of products and many more.



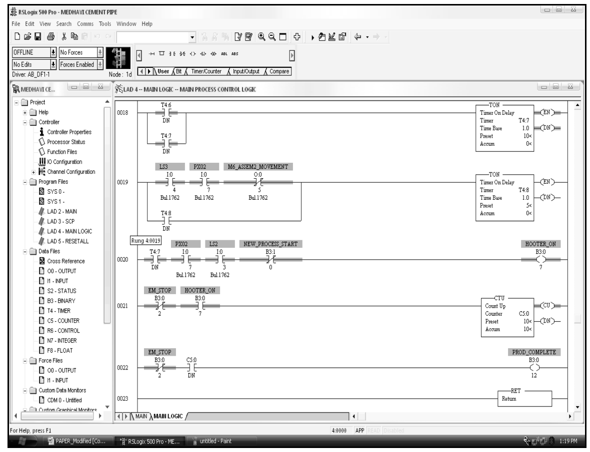
A. Hardware configuration in RS Linx classic.



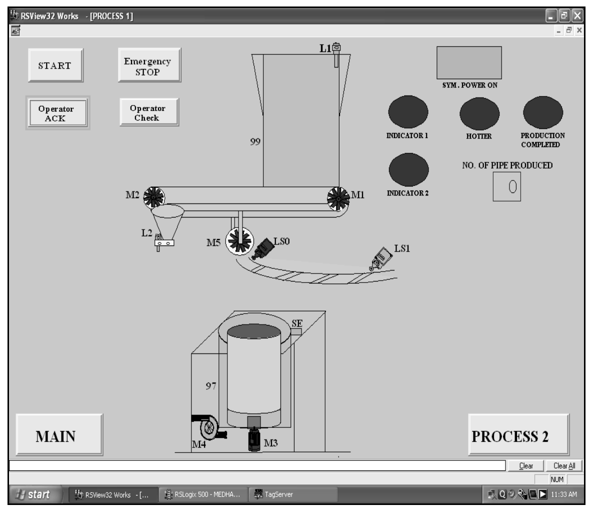
B. LAD view (RS Logix-500) for start-up Process.



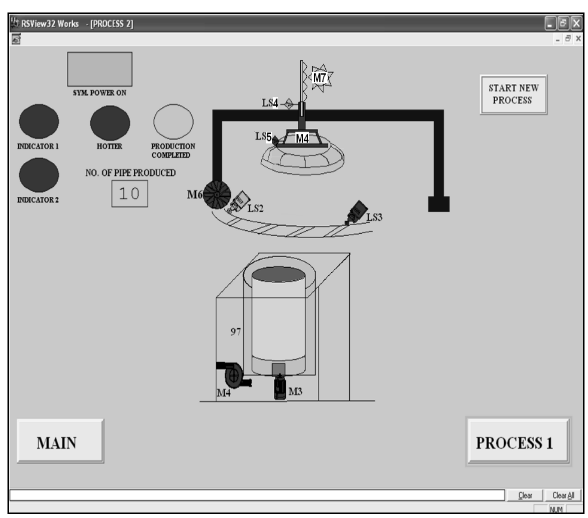
C. LAD view for Process-1.



D. LAD view for Process-2.

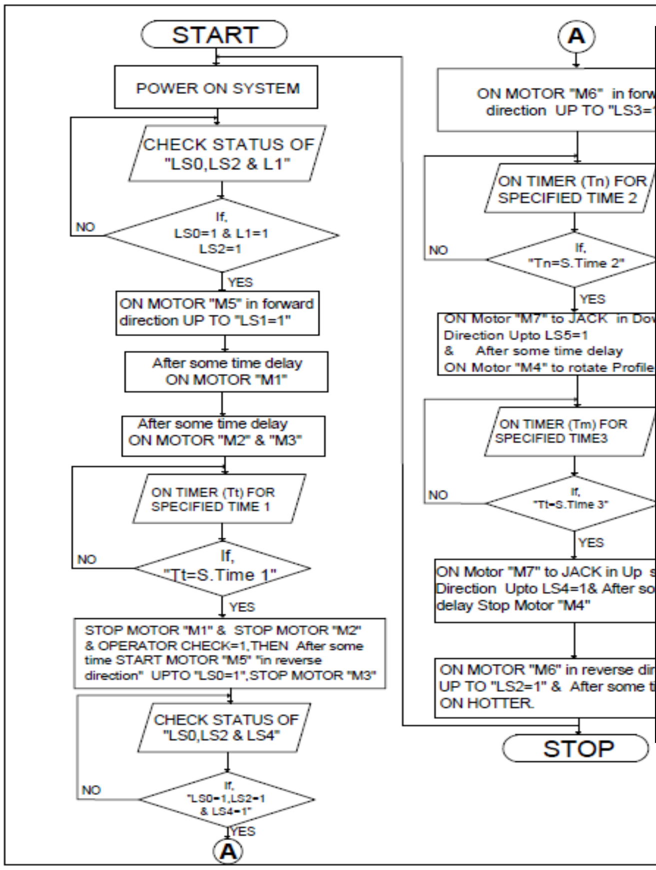


E. HMI screen (RS view-32) for process-1.



F. HMI screen (RS view-32) for process-2.

Fig.5 LADDER and HMI views for concrete pipe manufacturing process control.



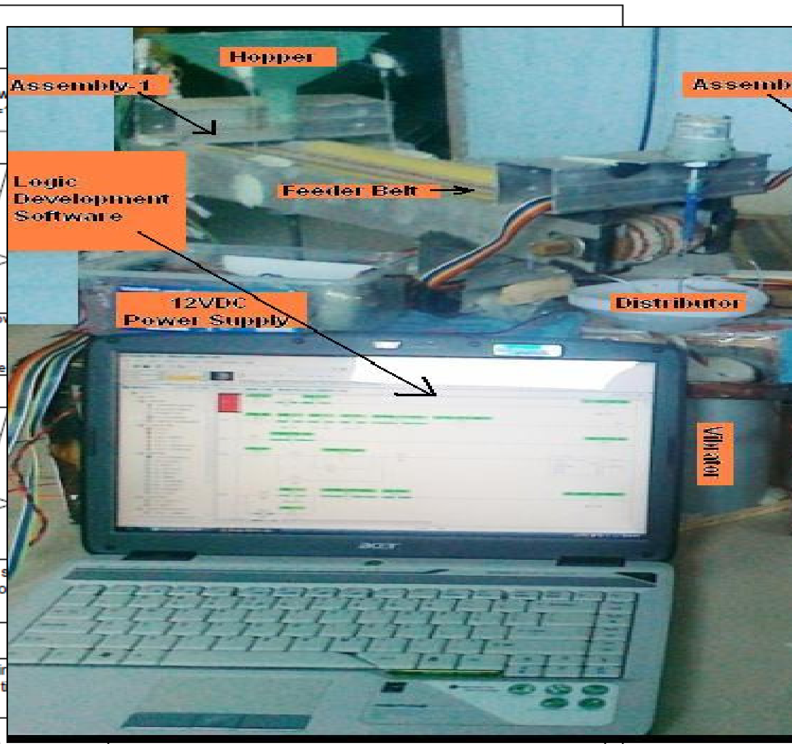


Fig.7 Actual Experimental Setup of PLCBCPMP system.

I/O Details

Fig.6 Flow chart of concrete pipe manufacturing process control.

References

[1] Da'na S, Sagahyroon A, Elrayes A, Al-Ali AR, Al-Aydi R. Development of a monitoring and control platform for PLC-based applications. Computer Standards & Interfaces 2008;30: 157–66.

[2] Robert Ferguson Legget, M.I.C.E. Failure of prestressed concrete pipe at Regina, Saskatchewan.Proc. Instn cio. Engus, vol. 22, May 1962, pp. 11-20.201. Paper No. 6587.

[3] Dongargaonkar.H.D., Jamkar.R.G. Industry Applications Conference, 1999. Thirty-Fourth IAS Annual Meeting. Conference Record of the 1999 IEEE . Volume: 2, On Page(s): 1380 - 1387 vol. 2

[4] Ramazan Bayindir, Yucel Cetinceviz. A water pumping control system with a programmable logic controller (PLC) and industrial wireless modules for industrial plants—An experimental setup ISA Transactions 50 (2011) 321–328.

[5] Parr EA. Programmable controllers an engineer's guide. third ed. Burlington: Oxford; 2003.

[6] Bolton W. Programmable logic controllers. fourth ed. Burlington: Oxford; 2006.

[7] Medida S. Pocket guide on industrial automation. first ed. Perth (Australia). 2008.

[8] Ogawa M, Henmi Y. Recent developments on pc+plc based control systems for beer brewery process automation applications. In: SICE–ICASE international joint conference. 2006. p. 18–21.

[9] Ozdemir E, Karacor M. Mobile phone based SCADA for industrial automation. ISA Transactions 2006; 45: 67–75.

[10] Allen Bradley. Micro Logix 1200 User Manual. Publication 9399-RLD300GR, 1996. http://www.support.rockwellautomation.com/

[11] Allen Bradley. RS View32 Site Edition. Publication Viewse-UM006F-EN-E, 2008. http://www.5software.rockwell.com

[12] Allen Bradley. RS Linx classic User Manual. Publication LINX-GR001G-EN-E, 2010. http://www.support.rockwellautomation.com/

[13] Allen Bradley. RS Logix 500 User Manual. Publication 9399-RLD300GR, 1998. http://www.software.rockwell.com/training/

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