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PLC Based Automated Clinker Cooling System for Cement Manufacturing Industry

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ABSTRACT: Cement Industry is a very big Industry. It has many sub-units, in which some are fully automated and some are semi-automated. These fully automated sub-units are controlled by Programmable Logic Controller (PLC). The aim of this paper is to convert the semi- automated clicker cooling systems into clicker cooling fully. Pre-Heater is a process in which materials are subjected to high temperatures at 1400 to 1500^{o}C to bring a chemical change. This is fed into the Kiln. Kiln is a hollow cylinder with refractory lining rotating at variable speed. The temperature inside the kiln is 1300 to 1400 ^{o}C and the material undergoes various reactions. The product obtained from the Kiln is called Clinker. Coolers are used to cool the clinkers to a temperature of about 300^{o}C. This automated system is automated using PLC. The proposed system is simulated using INDRA WORKS Engineering, which is firmware of BOSCH REXROTH PLC's.

I. INTRODUCTION

Cements Industry was a very big fully automated industry and it is controlling by PLC. The raw materials of cement are calcium carbonate, Silica, alumina and iron which are generally extracted from Limestone rock [1], chalk, and clay. These raw materials are extracted from the quarry by blasting. Some of the processes of cement industry are as follows:

A. Raw material (Limestone) Crush

Capacity: 950 tons per hour. To crush the raw materials Hydraulics of 150 bar pressure is used the crushed lime stone of size less than 10mm is transported through conveyor to the limestone stock pile to stack under covered shed through tipper conveyor. From the limestone stock pile material with uniform quality will be transported to hopper through belt conveyor.

B. Hoppers

There are three Hoppers in which two bigger hoppers are limestone hoppers and comparatively small hopper is iron hopper [2]. If the iron content is less in the mixture, then it automatically adds iron in the required quantity.

C. Raw mill and Ball meal preparation

Raw mill is a ball mill meant for grinding limestone, latertite and iron ore of size below 10mm to less than 212 micron size this powdered material is called "raw meal" and is transported to storage silo.

D. Blending Silo and Kiln feed extraction system

Silo is meant for the storage of raw meal powder produced by raw mill and also facilitates blending through aeration system to homogenize and maintain consistent quality of raw meal. Homogenized raw mill from the silo transported to kiln feed bin. From kiln feed bin the raw mill conveyed to the top of the pre heater through belt conveyor.

E. Pre-Heater and Cooler

Pre-Heater is a 7 storey building with Pre-calciner, cyclones, mixing chamber, feed pipes and ducts. This is heated from 70 degrees to 1000 degrees. Calcinations are the dissociation of limestone into lime and carbon dioxide.

This entered hot material in converted at 1350- 1400 degrees to clinker after passing through various phases.

The cooler is meant for cooling hot clinker which is discharged from with 1100 to 150 degree centigrade by centrifugal fans. Ambient air is pumped into cooler through fans at bottom side of grate pass through hot clinker bed.

Fly ash is added to clinker as per required percentage in the process of cement grinding. Cement mill is meant for grinding the clinker, fly ash and gypsum to a powder from around 320 sq.mt/kg. The fine powder is called cement. All over, this Industry is controlled by PLC which can be seen in lab.

In this paper we are controlling automated clinker cooling system using PLC.

Section 2 presents the proposed work, section 3 gives the various sensors used in the proposed system, section 4 describes the block diagram for clinker cooling system using PLC. In section 5 PLC based ladder diagram for the automation of clinker cooling system is presented. Section 6 concludes the work.

II. PROPOSED WORK

This section presents the three sub parts of proposed system, section 2.1 describes the Clinkerisation, 2.2 presents Clinker Coolers, and 2.3 presents Flow Chart.

A. Clinkerisation

Materials fed to the pre-heater tower are allowed to pass through a four stage suspension pre-heater which consists of several cyclones. The cyclonic action is generated with the help of suction of pre-heater fan. The hot gases from the kiln are sucked and passed such that the materials are heated to a temperature of about 300 to 400^{0}C at the top and 900 to 1000^{0}C at the bottom.

Due to gravitational effect in the material discharged downwards are fed to the kiln. Kiln is a hollow cylinder with refractory lining rotating at variable speed [2]. Inside the kiln the materials undergo various reactions. The process taking place inside the kiln is called calcinations. Inside the kiln the temperature is about 1300 to 1400 ^{o}C. The product obtained from the kiln is called clinker. Grate cooler cools the clinker to a temperature of about 100 to 150 ^{o}C. The clinker is transported to the stockpile through bucket conveyor and stored there.

B. Clinker Coolers

Clinker coolers are classified into different types based on their design and operation. The classification of clinker cooling mechanisms is as given in figure 1.

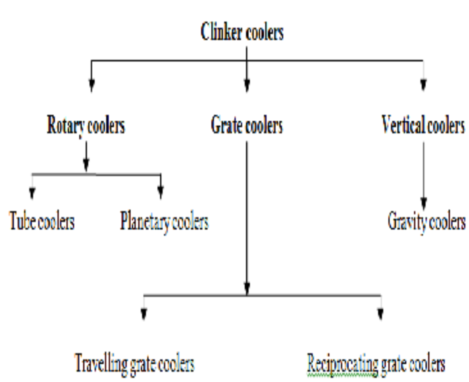


Fig. 1. Classification of Clinker coolers.

Grate Cooler. Grate coolers are extensively used in cement industry to recover heat from hot clinkers coming out of rotary kilns. Heat transfer in coolers indirectly controls the performance of the rotary kiln and is therefore crucial in a cement industry. The outlet temperature of hot clinkers and a part of melt coming out from the rotary kiln is approximately 1673 K. These hot clinkers should be cooled to a temperature around 400 K, by recovering heat from them, which can be used for any other process [3][4]. In the same time the combustion air required for the burning process should be preheated to a temperature level that the fuel consumption for clinker formation in the rotary kiln is minimum. So to fulfil both the purposes grate coolers are used in cement industries.

Working

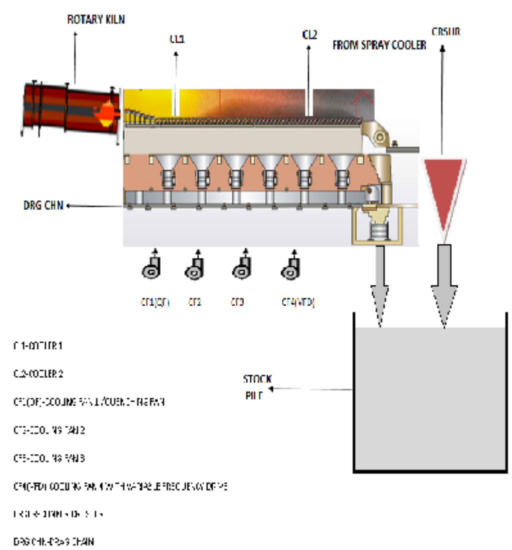


Fig. 2. Schematic diagram of grate cooler.

Figure 2 shows the schematic diagram of grate cooler. Reciprocating grate cooler is one of main equipments for cement production burning system; its function is cooling hot clinker, reclaiming clinker sensible heat and conveying clinker. It works in a condition of high temperature and variability.

The cooler grate is composed of overlapping rows of perforated grate plates. Half of the rows are static, fixed to the casing of the cooler [4]. The alternate rows are carried on a movable frame to which a reciprocating movement is imparted by an eccentric drive or hydraulic rams. The overlying bed of clinker is pushed forward on the forward stroke, and the plates slide beneath the bed on the return stroke. Fine clinker can fall though the grate holes, and so the under-grate chamber contains drag-chain conveyor(s) to move the spillage to the outlet end of the cooler. For most of its history, a crusher, usually in the form of a hammer mill, has been placed at the end of the cooler.

Larger clinker lumps, with a low surface area, are less effectively cooled, and having been crushed, the rotary action of the hammer mill hurls the fragments back up the cooler for further cooling.

The under-grate chamber is generally divided into a number of compartments, each with its own fan, which can be separately pressurised. The chamber above the grate is refractory lined. Areas of cold, "dead" clinker are provided at the sides of the grate to protect those areas from over-heating. The hot air emerging from the bed passes out to the kiln, and the hot-end grate pressure is controlled to provide a small negative pressure in the kiln hood. Because, in general, more air passes through the grate than can be used by the kiln, outlet ducts are provided on the side of the cooler parts of the over-grate chamber[5]. The hot air passing out through these may be used productively for process operations - e.g. for fuel or raw material drying - or may simply be run to waste through an exhaust stack. The hot air is inevitably heavily loaded with fine clinker grit, and so some sort of gas cleaning is provided prior to the stack. Both sloping and horizontal grates may be used. The original design had a 12° slope. Since all kilns, irrespective of process, deliver clinker at around 1300°, the size of cooler required is solely related to the expected kiln output, and grates are typically designed for a loading of 30 t/d per m^2 - i.e. a kiln making 1800 t/d would require a grate area of 60 m^2.

Spray Cooler. Figure 3 shows the schematic diagram of spray cooler. The spray cooler is the emergency cooling system used when the temperature of the clinker exiting the grate cooler is still greater than 600^0 C. The temperature at the exit is sensed by a_J type THERMOCOUPLE. The system is equipped with a water tank, spray pump, a level switch to detect when water level in the tank is low, flow switch to check flow of water through the pump,3 temperature control valves which are opened when clinker temperature exceeds the limit and a flow nozzle to spray water. The flow switch is activated when there is no flow through the pump and generates alarm [5]. Level switch is activated when the water level in the tank is low and generates the corresponding alarm .There is a 3 way valve to provide bypass to the tank which is pneumatically actuated. The other 2 valves are 2 way valves out of which one is pneumatically actuated and the other is electrically actuated .There is a pressure switch used to generate the alarm when the pressure in the compressor is low.

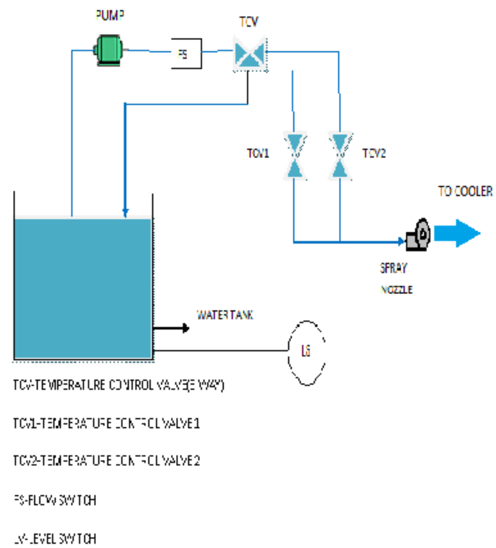
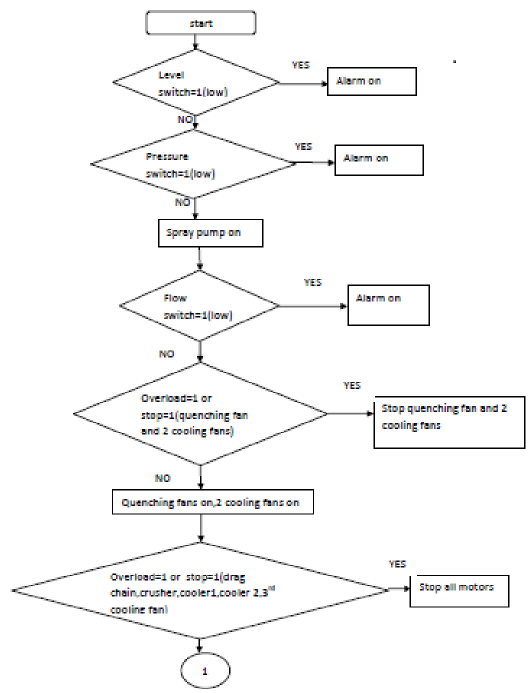


Fig. 3. Spray Cooler.

C. Flow Chart

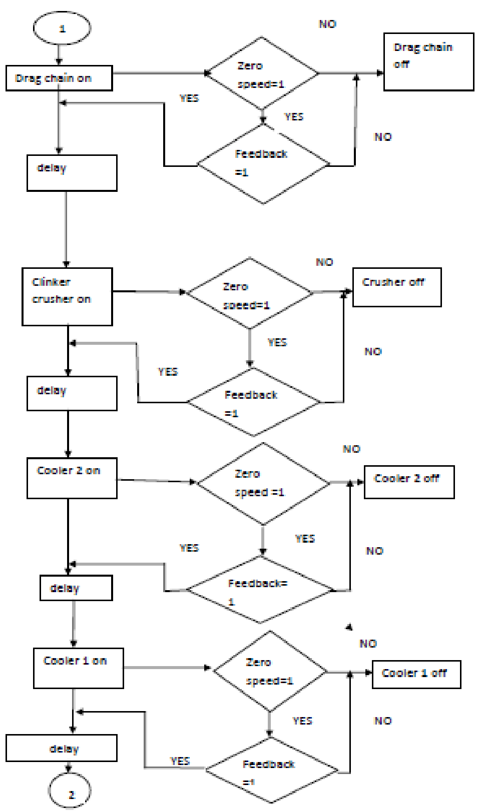


Explanation of Flowchart

Figure 4 shows the flow chart of proposed work. The first step is to the level is. If it is low, the alarm turns on. Then next the pressure is checked. If it is low, the alarm turns on, and spray pump is also turns on. The flow is checked. If the flow is low, the alarm turns on. The running sequences of cooler parts are fixed as cooling fan1, 2, 3&4. Drag chain, clinker crusher, cooler1 &cooler2.The stopping sequence are in the reverse order. This is so that the motion of the parts is not obstructed by the clinker remains if any.

The overload and stop criteria of the quenching fan and two cooling fans are checked. If both are on the quenching fan and the two cooling fans are turned off. Otherwise it is turned on. The overload and stop criteria of the drag chain, crusher, cooler1, cooler2, and the third cooling fan are checked. If both are on the drag chain, crusher, cooler1, cooler2, and the third cooling fan are turned off. Otherwise it is turned on. Drag chain is turned on. Zero speed is checked. If it is on, the drag chain is turned off. If zero speed is off, a feedback is given and then delay is given. Clinker crusher is turned on. Zero speed is checked. If it is on, the drag chain is turned off.

If zero speed is off, a feedback is given and then delay is given. Cooler 2 is turned on. Zero speed is checked. If it is on, the drag chain is turned off.



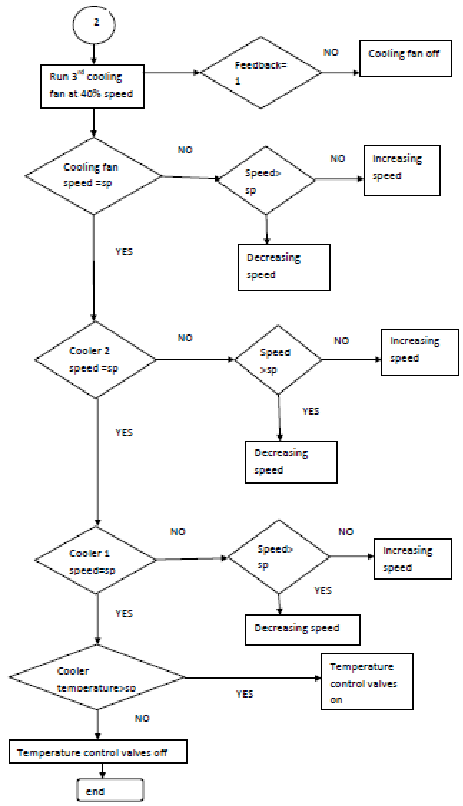


Fig. 4. Flow chat.

If zero speed is off, a feedback is given and then delay is given. Similarly cooler 1 is turned on. Run the third cooling fan at 40% speed. Then a feedback is given and then the cooling fan is turned off. The cooling fan is given the set point speed. If the speed is greater than the set point speed then a decreasing speed is given otherwise an increasing speed is given. Cooler 2 is given the set point speed. If the speed is greater than the set point speed then a decreasing speed is given otherwise an increasing speed is given. The same check is done for cooler 1 also. If the cooler temperature is greater than the set point, temperature control valves are open otherwise it is closed.

III. SENSORS USED

This section explains the four types of sensors used in the cooler system. Section explains the thermocouple sensor, describe the RF level detector sensor, presents bellow type pressure sensor, and paddel type flow switch.

A. Thermocouple

J type thermocouple is used near to the exit portion of grate cooler system to measure the temperature. The output of thermocouple is used to actuate the spray cooler system under emergency conditions.

Type J (iron–constantan) has a more restricted range than type K (−40 to +750 °C), but higher sensitivity of about 55 µV/°C. The Curie point of the iron (770°C) causes an abrupt change in the characteristic, which determines the upper temperature limit.

B. RF Level Detector

Capacitance level detectors are also referred to as radio frequency (RF) or admittance level sensors [5]. They operate in the low MHz radio frequency range, measuring admittance of an alternating current (ac) circuit that varies with level.

C. Bellow type Pressure Sensor

A pressure switch is used to detect the presence of fluid pressure. Most pressure switches use a diaphragm or bellow as the sensing element. The movement of this sensing element is used to actuate one or more switch contacts to indicate an alarm or initiate a control action.

D. Paddle type Flow Switch

Gas or Liquid flow is sensed by the freely suspended disc via bellow-sealed designs which create the movement of Disc against the force. A precision spring guarantees repeatability and high effectiveness of operation. To ensure positive isolation between switch assembly and process fluid, bellow is sealed [4]. Flow Paddle Switches are repeatedly tested for maximum pressure of 10 Bar and are highly suitable for temp. Up to 200°C. The process connection for Paddle type is 1" BSP (M) standard and for on-line type is %" BSP (F) std.

IV. AUTOMATED CLINKER COOLING SYSTEM BLOCK DIAGRAM

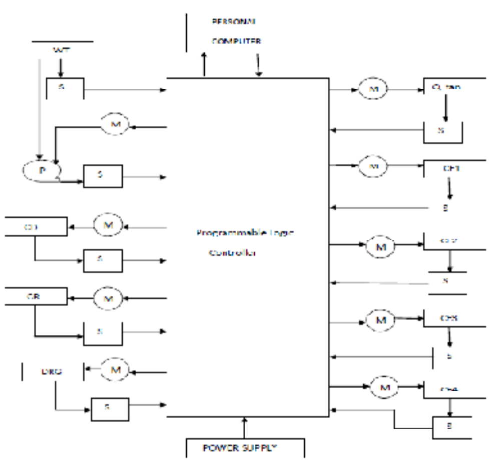


Fig. 5. Automated clinker cooling system using PLC.

V. LADDER DIAGRAM

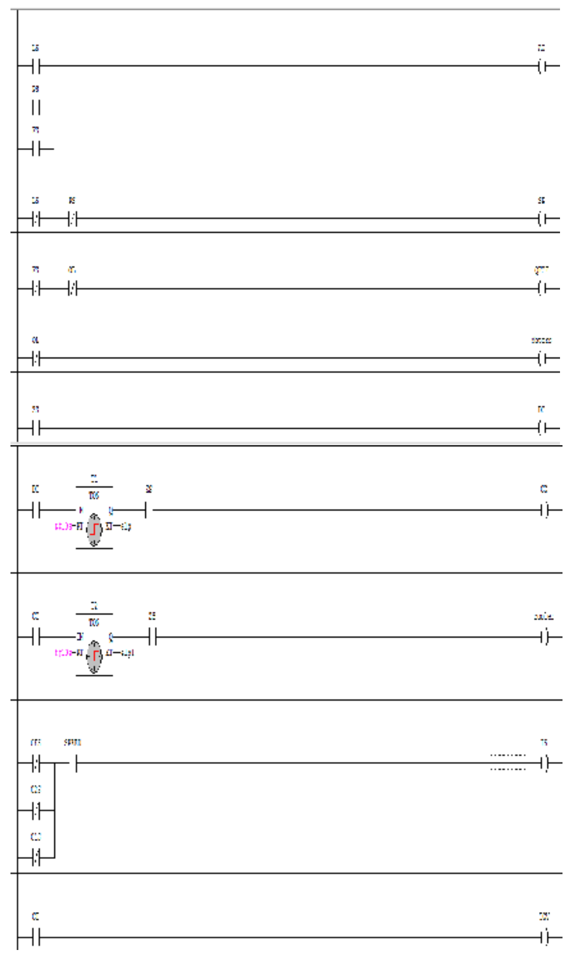


Fig. 6. Ladder diagram of clinker cooling system.

Table 1: Inputs and outputs of proposed work.

Inputs	Outputs
PS: Pressure Switch	SP: Spray Pump
FS: Flow Switch	QFCF: Quenching Fan and Cooling Fans
OL: Overload	IS: Increasing Speed
ZS: Zero Speed	TCV: Temperature Control Valve
CFS: Cooling Fan Speed	CC: Clinker Crusher
C2S: Cooler 2 Speed	Motor
C1S: Cooler 1 speed	DC: Drain Chain
CT: Cooler Temperature	
LS: Limit Switch	AO: Alarm on

VI. CONCLUSION

PLC based automated Clinker cooling system used in cement manufacturing Industry is the application of PLC. PLC and its related circuits provides an options and logical diagnostic so as to provide a reliable, versatile and safety to control various operations of Clinker cooling system.

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