PROCESS AUTOMATION OF CEMENT PLANT

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Abstract

Cement is an essential component of infrastructure development. It is also the most important input of construction industry, mainly in case of the government's infrastructure and housing programs, which are necessary for the country's socio-economic growth and development. Due to increasing population, various constructional activities are increasing day by day. As a result the market demand of cement is also increasing continuously but still now most of those plants aren't up to the mark technologically. They are very inefficient, not so eco-friendly and have very low production speed. Keeping in mind the importance of those industries, an integrated solution of material handling in cement plant is presented in this paper to meet the increasing production needs. This innovative thinking will help to reduce energy consumption and improve operational efficiency as most of the energy is consumed to transfer the bulk materials between intermediate stages. This PLC or HMI based controls are not only cost-effective method but also improves the control system longevity and ultimately reduces the total cost of operation over the life of the system. The whole automation process is done using programmable logic controller (PLC) which has number of unique advantages like speed, reliability, less maintenance cost and reprogrammability. The whole system has been designed and tested using GE, FANUC PLC.

Keywords

PLC, Level Detector, VRM, Silo, Kiln, ESP, Clinker, Blending.

1. Introduction

The Indian cement industry is the second largest producer of cement in the world, just behind China but ahead of the United States and Japan [1]. In this paper, the overall concept of manufacturing process is taken from ACC CEMENT LTD and various cement manufacturing groups of India. The cement manufacturing process consists broadly of mining, crushing and grinding, blending, pyroprocessing, clinker cooling, clinker storage, finish milling, packing and loading [2,3].The overall plant process flow is shown in the fig 1.This paper only reviews the flow of materials through the various stages to a particular place. The overall operation is timing control so brownout may be avoided. The devices are turned on sequentially one after another by on delay timer and also turned off sequentially one after another by off delay timer. There are various types of sensors and level detectors are used in each and every critical point to control the entire operation and to reduce the unwanted running of machineries [4]. The entire operation is done part by part and is divided into three segments. Those are raw material transfer from quarry to different silos, raw material transfer from different silos to homogeneous silo and pyroprocessing & finish milling.

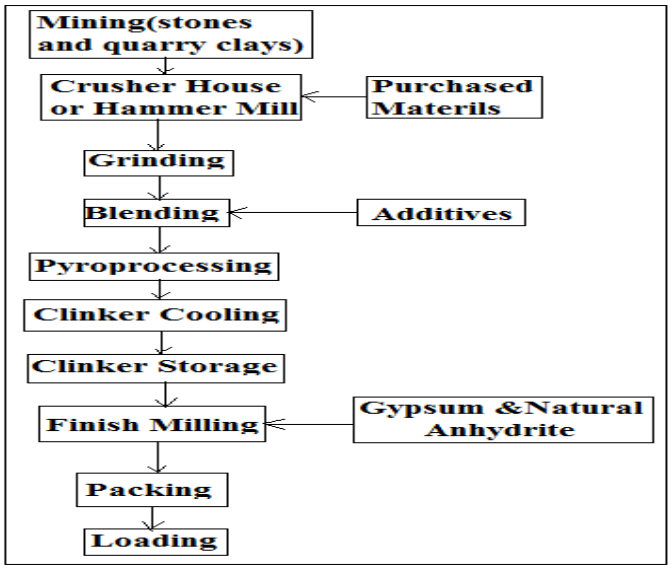


Fig1. Plant Process Flow Diagram

2. Raw Material Transfer from Quarry to Different Silos

Cement industries typically produce Portland cement. Most of the raw materials used are extracted from the earth through mining and quarrying. Those are lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). As limestone is the prime constituent of cement, the major cement plants are located near the good quality lime stone quarry. At first lime stones and quarry clays are fed to primary crusher house for raw crushing. Then the materials are transferred to secondary crusher house. After that the crushed materials are fed to the stock pile. Inside the stock pile there is a stacker/reclaimer which segregates the raw material quality wise in to different stacks. The stacking and reclaiming systems operate independently. There are also four additives- iron ore, bauxite, laterite and flourspar into the stack pile to get required composition of cement. The additives are brought to the stack pile by conveyor C4. Then according to the requirement limestone, iron ore, bauxite, laterite and flourspar are transferred to different silos by their respective conveyors. Inside each silo there are three level detectors which detect the level of materials inside it. The process is shown in fig.2.

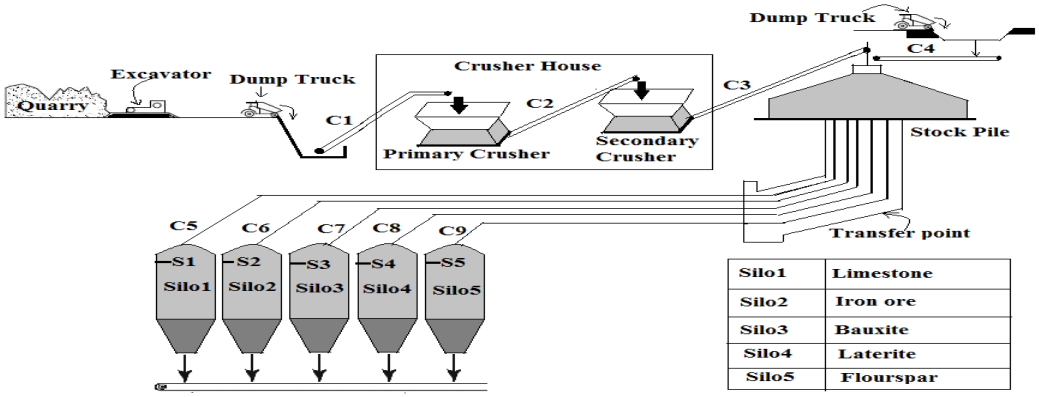


Fig2. Raw Material Transfer from Quarry to Different Silos

2.1 Process Automation

To make this process fully automatic a PLC unit is used. PLC takes real time decision depending upon the various field level input signals from various sensors placed in different critical points and sends the decision to the output devices.

2.1.1 Input

Push button [PB(1-9)], Upper level detector [S(1-5)].

2.1.2 Output

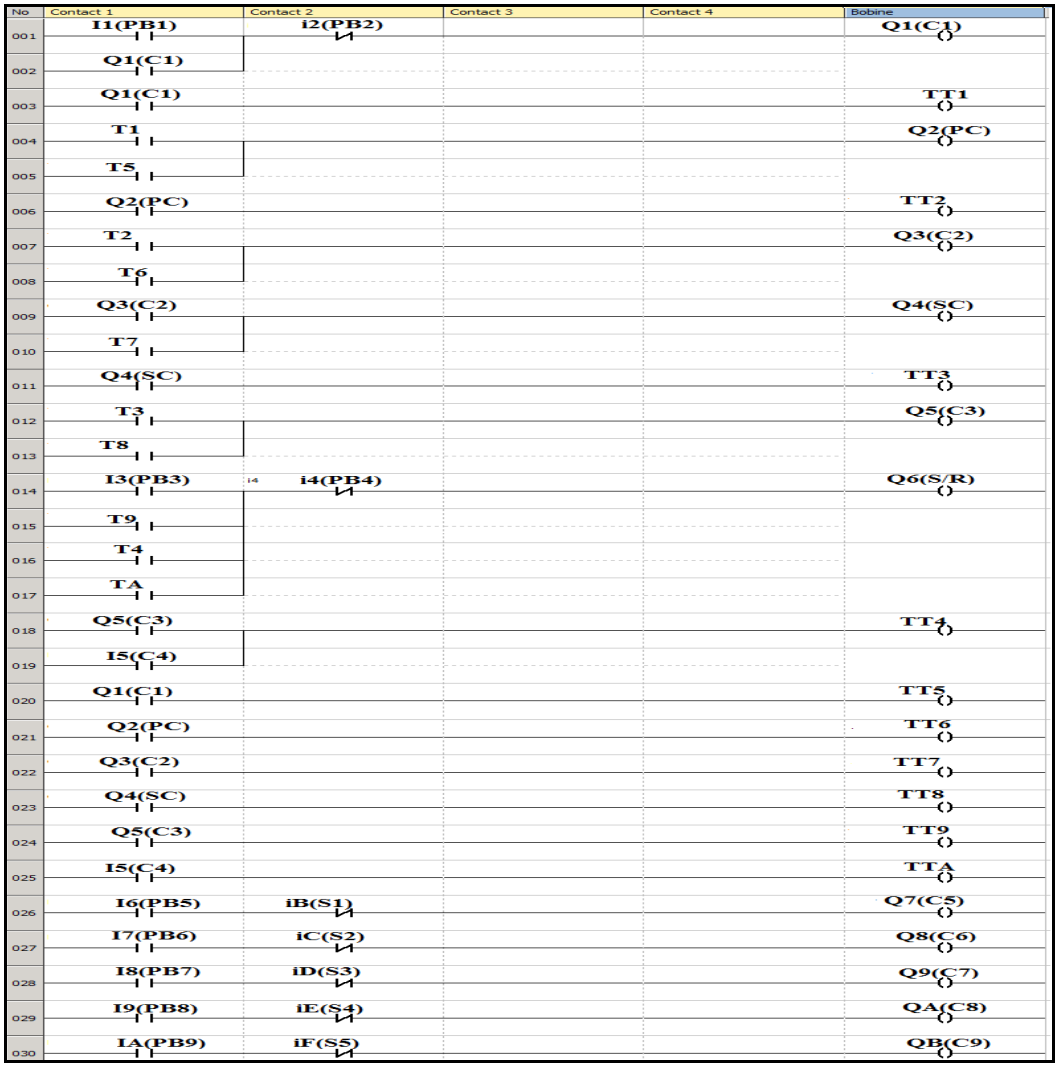
Conveyor [C(1-9)], Primary crusher(PC), Secondary crusher(SC), Stacker/reclaimer system(S/R)

2.1.3 Process Description

At first an operator starts the entire process by pressing a push button PB1. As soon as the operator presses PB1, conveyor C1 starts rolling and the bulk materials i.e. lime stones are taken from quarry by conveyor C1 to primary crusher (PC). The primary crusher will start by an on delay timer TT1. After some time delay, required for primary crushing C2 starts running and the raw crushed materials are transferred to secondary crusher (SC). This time on delay is defined by timer TT2. The secondary crusher (SC) is started together with C2. Conveyor C3 will start after a time on delay (TT3) of starting the secondary crusher to transfer the material from crusher house to stock pile. There are two pushbutton switches PB3and PB4 inside the stock pile. Now if PB3 is closed manually, the stacker /reclaimer system (S/R) starts directly or after a time on delay(TT4) of starting either conveyor C3 or C4. Pushbutton PB4 is provided to stop the stacker/reclaimer system manually. For safe operation each and every process should be turned off sequentially. So to achieve these five off-delay timers are used i.e. TT5, TT6, TT7, TT8, TT9. When conveyor C1 are on, the timer TT5 is true. The Done bit of TT5 is latched with PC. When the primary crusher (PC) is on, the timer TT6 is true. The Done bit of TT6 is latched with C2. TT7 is latched with the secondary crusher (SC) which remains true till C2 remains on. Timer TT8 remains true till SC is running. The done bit of TT8 is latched with the C3. TT9 remains true till conveyor C3 is on. There are also an off delay timer TT10 which remains true till C4 is on. Now due to any fault or any other reason if emergency plant shutdown is required, the operator presses PB2. As soon the operator presses PB2 at first conveyor C1 will stop. Then according to the PLC programming the primary crusher(PC), conveyor(C2), secondary crusher(SC), conveyor(C3) and S/R will goes off sequentially. The same things will happen in case of conveyor C4. Push button switches PB5, PB6, PB7, PB8, PB9 are the operating switches of limestone conveyor (C5), iron ore conveyor (C6), bauxite conveyor (C7), laterite conveyor(C8),fluorspar conveyor(C9) respectively. Through these conveyors the materials are transferred to their respective silos. S1, S2, S3, S4, S5 are the upper level detectors of different silos. If upper level detector is high, the corresponding conveyor i.e. C5, C6, C7, C8, C9 will be off.

2.1.4 PLC program

Here the PLC is programmed using ladder logic method. The programming required to control the overall process is shown in the ladder diagram1.



Ladder diagram1.PLC programming required to transfer the raw materials from quarry to silos.

3. Raw Material Transfer from Different Silos to Homogeneous Silo

Normally there are various types of lime stone quarry so the quality of limestone does not remain same. In order to get homogeneous mixture those four additives with required percentage, as suggested by the quality control department are mixed with the lime stone[5]. This is done using a RBF placed in each silo and with the help of conveyor C15. The RBFs and corresponding conveyors (i.e.C10,C11,C12,C13,C14) will move in such a speed to maintain the actual ratio of the five components i.e. user defined[6]. C15 transferred the raw materials to the vertical roller mill (VRM) as the raw materials should be finish-ground before being fed into the kiln for clinkering. This process is done in the VRM. The raw materials are simultaneously dried using hot air in order to get good quality cement. The Hot air is coming from conditioning tower or from grate cooler. Hot air along with the dust is introduced in the electrostatic precipitator (ESP). Then the exhausted air is removed in the air through a stack, called chimney with the help of ID Fan. After grinding, the materials are transferred to homogeneous silo with the help of bucket elevator (BE). There is a screen vibrator (SV) in between the BE and homogeneous silo for

proper blending and to sort-out the large granules. Then the large granules are feedback to the VRM by Feedback conveyor C18. The process is shown in the fig3.

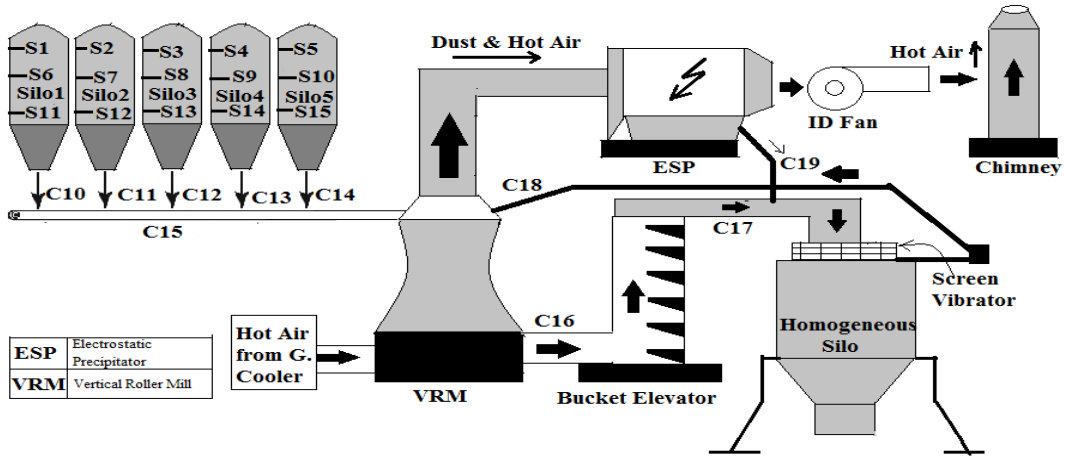


Fig3. Raw Material Transfer from Different Silos to Homogeneous Silo

3.1 Process Automation

3.1.1 Automation in Raw Material Transfer from Different Silos to VRM

3.1.1.1 Input

Push button (PB10,PB11), Middle level detector(S6,S7,S8,S9,S10), Lower level detector(S11,S12,S13,S14,S15)

3.1.1.2 Output

Conveyor (C10,C11,C12,C13,C14,C15,), RBF(L), RBF(I), RBF(B), RBF(Lt), RBF(F), Vertical roller mill(VRM).

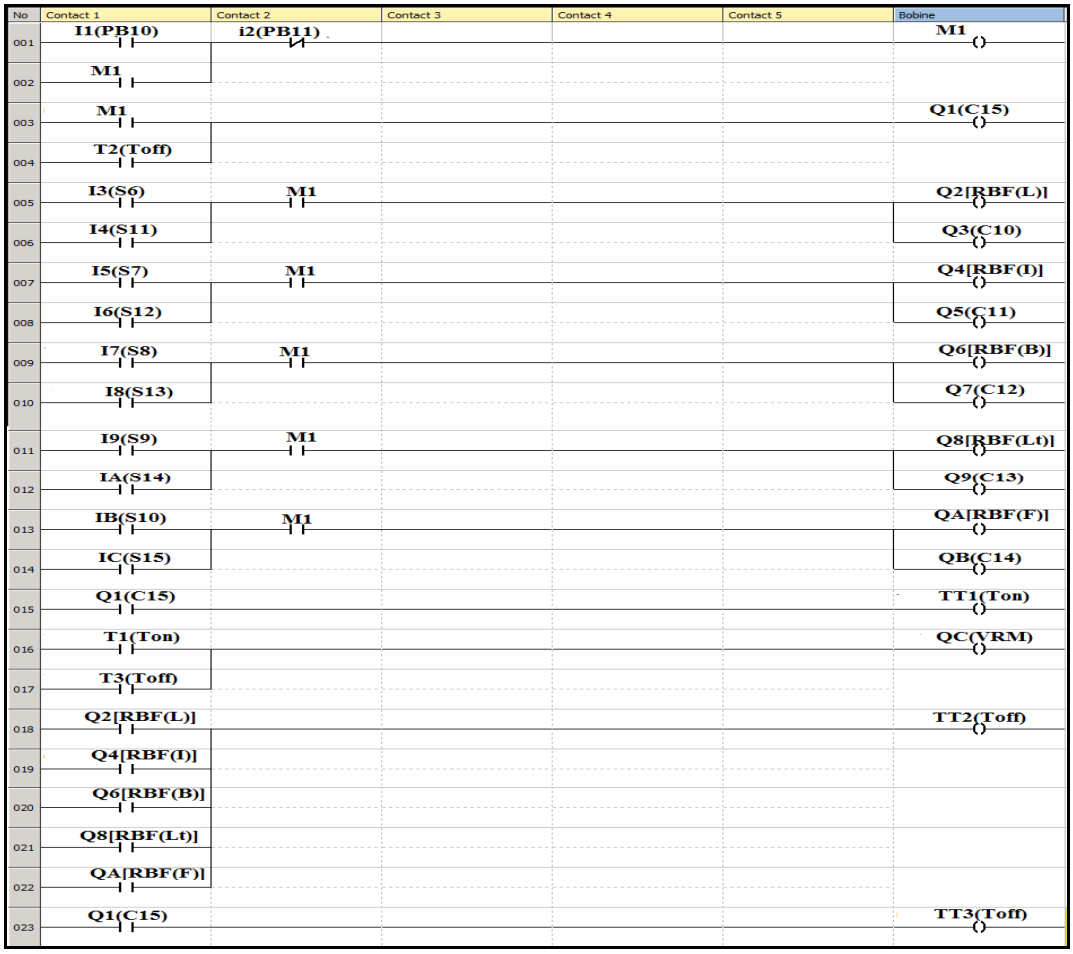
3.1.1.3 Process Description

After pre-running inspection of machineries, an operator starts the entire process by pressing a pushbutton PB10. As soon as the operator presses PB10, conveyor C15 starts rolling. Now if the middle level detector S6 and lower level detector S11 of silo1 (i.e. limestone silo) are high then RBF of Lime stone silo i.e. RBF(L) starts to vibrate and at the same time conveyor C10 also starts rolling. The same thing happens in case of other four silos also. If the middle level detector S7 and lower level detector S12 of silo2 (i.e. iron ore silo) are high then RBF of iron ore silo i.e. RBF(I) and conveyor C11 will start. If the middle level detector S8 and lower level detector S13 of silo3 (i.e. bauxite silo) are high then RBF of bauxite silo i.e. RBF(B) and conveyor C12 will start. If the middle level detector S9 and lower level detector S14 of silo4 (i.e. laterite silo) are high then RBF of laterite silo i.e. RBF(Lt) and conveyor C13 will start. If the middle level detector S10 and lower level detector S15 of silo5 (i.e. flouspar silo) are high then RBF of flouspar silo i.e. RBF(F) and conveyor C14 will start. When the material of any silo reaches below the corresponding lower level detector then the RBF and conveyor of that silo goes off automatically. The materials are then transferred to VRM by conveyor C15 from the conveyors C10,C11,C12,C13,C14. The VRM will be start after a time on delay(TT1) of starting conveyor C15. TT2 is an off delay timer which is used to turn off the C15. TT2 remains in logic zero state till the RBF(L)/ RBF(I)/RBF(B)/RBF(Lt)/RBF(F) is in logic high state. When all the RBFs goes off then the timer TT2 starts counting and after the specified time delay it stops the conveyor C15. There is also an off delay timer TT3 which will be activated when conveyor C15 goes off.

This timer is latched with the VRM to turn off the VRM after a time delay of closing conveyor C15. Push button PB11 is provided to stop the process manually.

3.1.1.4 PLC program

The programming required to control the overall process in shown is the ladder diagram2.



Ladder diagram2. PLC program required to transfer the raw materials from Different Silos to VRM

3.1.2 Automation in Bucket Elevator, Screen Vibrator, ESP and ID Fan Control

Bucket elevator, screen vibrator and conveyor C16 are used to transfer the raw materials to Homogeneous silo. The large granules are fed back to the VRM by Feedback conveyor C18. As releasing, hot and dusty air in the environment is not an eco-friendly job. So to remove the dust particles, exhausted gas which produced during cement making is sent to electrostatic precipitator (ESP). Then the gas is sent to the co-generation power plant for captive power generation [6]. Then the exhausted clean gas is removed by ID fan (IDF) through chimney. The fine dust is then fed back to the homogeneous silo through conveyor C19 as shown in the fig3.

3.1.2.1 Input

Push button (PB12, PB13, PB14, PB15)

3.1.2.2 Output

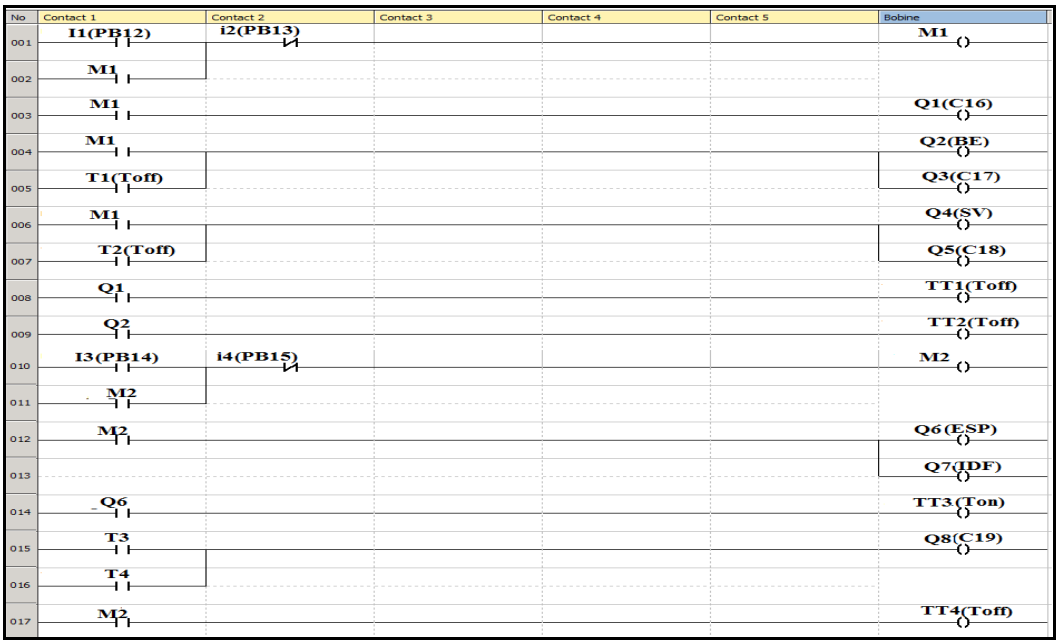
Conveyor (C16,C17,C18,C19), Bucket Elevator(BE), Screen Vibrator (SV), Electrostatic precipitator (ESP), ID fan(IDF)

3.1.2.3 Process Description

After pre-running inspection of machineries, an operator pushes PB12. As soon as he presses PB12 conveyor C16, bucket elevator (BE), conveyor C17, screen vibrator (SV) and feedback conveyor C18 starts working. There is a time off delay timer TT1 that will turn off the BE and C17 after a time delay when C16 will be off. C18 and SV will turn off after a time delay(TT2) when BE will be off. Here TT2>TT1. Now If all the previous processes are already in running condition then operator starts ESP and ID fan(IDF) using a push button PB14. After a time delay(TT3) of ESP starting, conveyor C19 will start automatically. Push button P15 is provided to stop the ESP and ID fan manually. When PB15 is pressed an off delay timer TT4 is activated which helps to stop the conveyor C19. Push button PB13 is provided to manually stop the BE,SC and conveyors(C16,C17,C18).

3.1.2.4 PLC program

The programming required to control the bucket elevator(BE), screen vibrator(SV), ESP and ID Fan is shown in the ladder diagram3.



Ladder diagram3.PLC program required to control the bucket elevator(BE), screen vibrator(SV), ESP and ID Fan

4. Pyroprocessing and Finish Milling

In pyroprocessing, the raw mix is heated upto (1600-1700) °C to produce Portland cement clinkers. Clinkers are created from the chemical reactions between the raw materials. The pyroprocessing takes place in a kiln. A kiln is the heart of any cement plant. It is basically a long cylindrical pipe which rotates in a horizontal position having (1600-1700) °C temperature. The output of kiln is called clinker. Then the clinker is sent to the cooling section for cooling it to room temperature. After that the cooled clinker is transferred to the clinker storage silo. The Clinkers are hard, gray, spherical nodules with diameters ranging from 0.32 - 5.0 cm. So to reduce the size and to impart special characteristics to the finished cement, the clinker is ground with other materials such as 5% gypsum and other chemicals which regulate flowability [2]. At last the finished cement is transferred to the packaging section. The overall process is shown in the figure4.

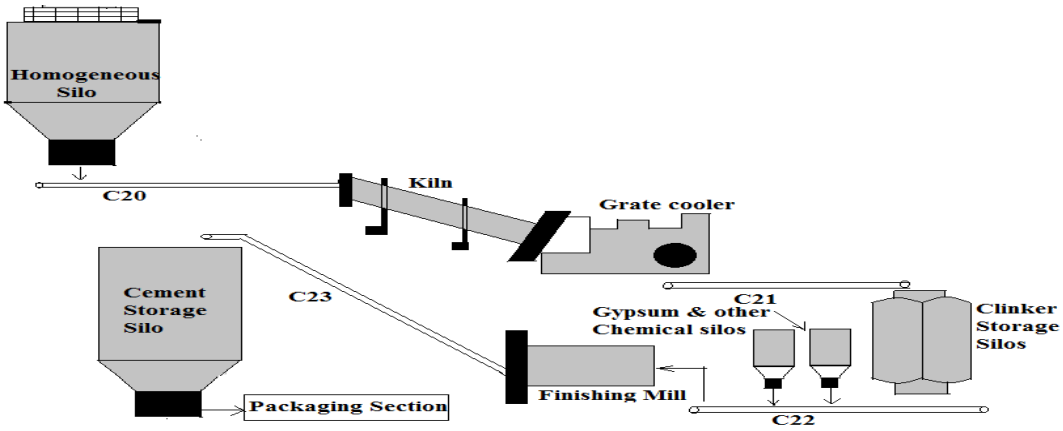


Fig4. Pyroprocessing and Finish Milling

4.1 Process Automation

4.1.1 Input

Push button (PB16,PB17,PB18,PB19)

4.1.2 Output

Conveyor (C20,C21,C22,C23), Kiln, Grate cooler(GC), Finishing Mill(FM)

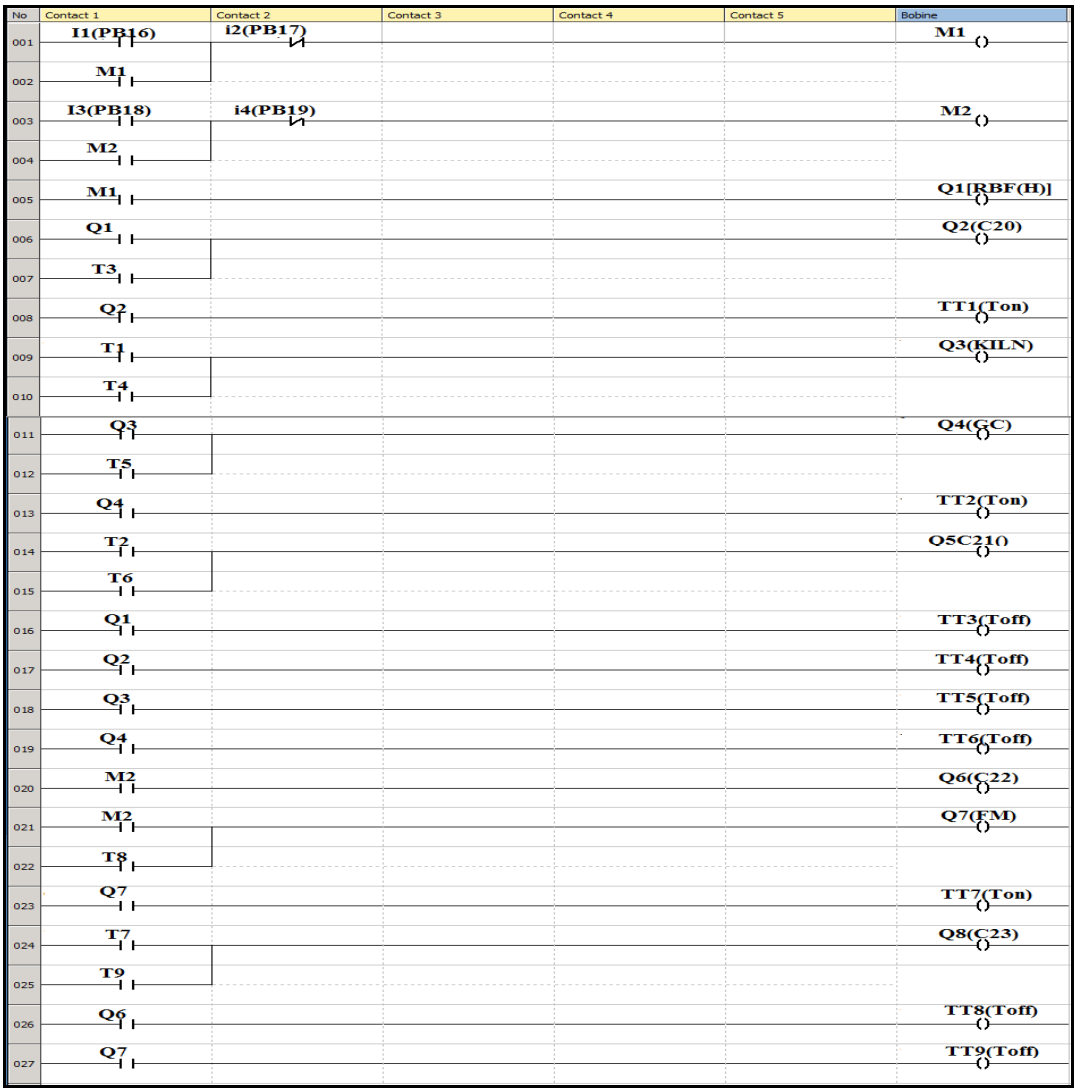
4.1.3 Process Description

After pre-running inspection of machineries, an operator presses a push button PB16. As soon as he pushes PB16 the RBF of homogeneous silo i.e. RBF(H) starts vibrating and conveyor C20 starts rolling which sends the materials to kiln. The kiln starts automatically after a time on delay (TT1) of starting conveyor C20. Grate cooler(GC) starts together with kiln. After some time delay, required for cooling conveyor C21 starts automatically which transfer the clinker from grate cooler to clinker storage silos. This time on delay is achieved by an on delay timer TT2. Push button PB17 is provided to stop the process manually. When PB17 is pressed at first the RBF(H) stops vibrating. After some time delay conveyor C20 will stop. This off delay is done using an off delay timer TT3. There are another three off delay timers TT4, TT5, TT6 which are latched with kiln, grate cooler and conveyor C21 respectively to turn off the above three equipments simultaneously. Then according to the market demand of cement operator starts the finishing mill by pressing a push button PB18. As soon as he pressed PB18 conveyor C22 and finishing mill(FM) starts working. Gypsum and other necessary additives are simultaneously

added to the clinker. After finish ground, an on delay timer(TT7) starts the conveyor C23 which transferees the fished cement to cement storage silo. When pushbutton PB19 is pressed to stop the process manually, at first C22 stopped rolling. Finishing mill will stop after a time delay of stopping C22. This time off delay is achieved using an off delay timer TT8. There is also an off delay timer TT9 which is latched with the conveyor C23. TT9 is activated when finishing mill will stop.

4.1.4 PLC program

The programming required to control the pyroprocessing, finish milling and other supporting machineries is shown in the ladder diagram4.



Ladder diagram4. PLC program required to control the pyroprocessing, finish milling and other supporting machineries

5. Conclusion

Though India is the second largest producer of cement in the world, still those industries need to further concentrate on modernization and upgradation of technology, optimization of operations and increased application of automation and information technology which reduces the energy consumption, production cost and increases the production speed [6]. So this paper is appropriate to fulfil those requirements of the cement industries. This innovative automation process is highly flexible and easily adaptable to new and existing situations. Automation provides some form of monitoring capabilities and provisions for programmable troubleshooting which reduces the downtime. The automation process also has flexibilities in programming and control techniques [8]. The field environment of cement plant is high in temperature, with extensive dust and serious electromagnetic interference (EMI). So the process automation is highly required which provides most accident free environment to the workers and prevents them to come in direct contact with the various noxious gases and dust that are emitted during cement manufacturing. As the PLC does intelligently the overall operation and as it has centralized control futures. So it also helps to reduce the manpower and at the same time it reduces the workers' strain.

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