Automated Coal Crushing and Conveyor System Using PLC and HMI

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Abstract—The main idea of our project is implementation of modern PLC and HMI technology in coal transportation area where coal level detection is an important aspect to improve coal handling system in thermal power plants and coal mining areas. For this real time operation of coal handling and coal level detection in storage tanks, we use the modern PLC technology which uses wide range feedback sensors and performs automatic operation in respective areas. The coal handling and safe operation are summed up and the whole system is monitored and controlled by PLC technology. Our project uses photoelectric sensors for coal level detection which controls the system operation. We used HMI technology to interface man with machine, in case any problem occurs in automation process human can control working of that device on HMI screen so that process doesn't stop.

Keywords-PLC;HMI;automation;feedback sensors

I. Introduction

Over time, the control engineering underwent rapid change and development with new inventions and technology. In the past, the main source for controlling a system was humans. More recently, relays have replaced human work through the use of electricity. These relays allow the switching on and off of power without a mechanical switch. Using relay is popular for making quick, rational control decisions. PLC technology advancement started in the year 1970 and is still being built to provide low cost activity. PLC 's broad range of features and operating capabilities, PLC has become a preferred option within the industry.

II. Problem Statement

Usually a thermal power plant and coal mining area has reservoirs, bunkers, and stockpiles where coal is stored. In coal handling system due to lack of infrastructure, human labour is involved in the continuous monitoring of coal storage tanks. The ambient environment near the coal mining area includes toxic chemicals and gaseous liquids which are detrimental to labour safety. Despite changes in pollution assessment and ventilation controls and the presence of government protective legislation, coal miners remain at risk for respiratory diseases caused by coal mine dust, strain and risk factors. Human beings, too, could cause few mistakes. So automating the above process without any intervention of human beings can be the solution to above problem. To automate any process, we require a controller. Due to the capabilities and features of PLC we selected PLC as our controller.

III. Block Diagram

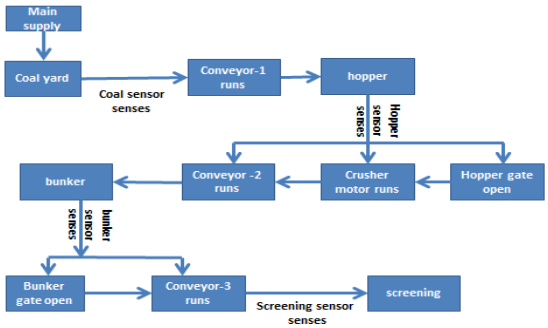


Figure 1: Block Diagram

IV. Components

A. PLC

As we are implementing automation process the basic component which we need is a controller. There are many types of controllers present such as microcontroller, Arduino, PLC and so on. But in our project we prefer PLC as our controller because compared to microcontroller it has many input and output modules, withstand to high temperatures (-45 to 70-degree C), also its speed of operation remains constant irrespective of number of inputs and outputs connected, but it Arduino that is not the case, as the number of inputs and outputs increase its speed of operation decreases. So we prefer PLC.

A programmable logic controller is a controller that continuously monitors the input devise state and makes decision based on the program to control the state of the output devices. They meet the requirement of modularity expandability, programmability and ease of use in an industrial environment. The PLC cable can be easily understood and mounted, less space is u sed. The PLC method is commonly used in food processing industries, paper, iron, beverage and manufacturing, etc.

Figure 2: PLC

Specifications:

Manufacturer series: SIMATIC S7-1200

CPU Type: 1214C series

Inputs :2 analogs, 14 digital

Outputs: analog, relay

Input voltage: 230 V AC

Output voltage 24V DC

B. HMI

A Human Machine Interface a graphical interface which allows humans and machines to interact. It is a software application that provides information about the state of a process to an operator and accepts and implements instructions for the control of operations. For a manufacturing line to be integrated with an HMI, it must first be working with a PLC. It is the PLC that takes the information from the sensors, and transforms it to Boolean algebra, so the HMI can make decisions.

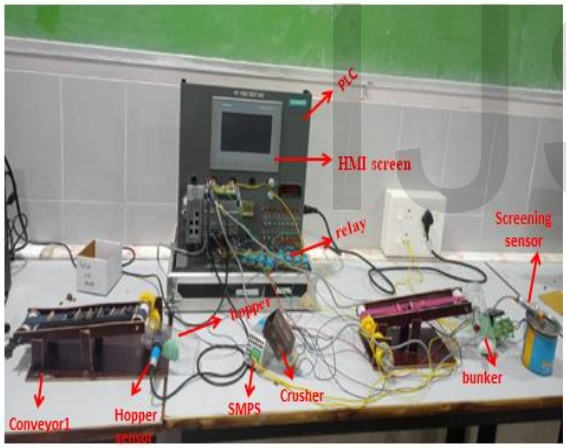


Figure 3: HMI screen

C. Photo Electric Sensor

In our project we use photo electric sensor to monitor the level of coal. It consists of a transmitter and a receiver. Based on principle of operation a photo electric sensor is classified into 3 types.

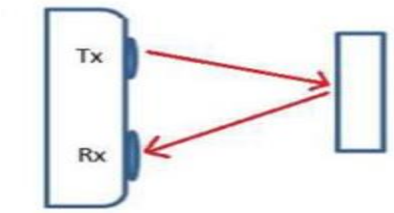


Figure 4: Principle of working of photo electric sensor

Here we use diffuse beam type photo electric sensor, in this type both the transmitter and receiver are present on same side. Its working principle is when the transmitter transmits the rays(infrared) and if there is no object then receiver will not receive the rays and sensor will have 0(low state). Suppose the rays transmitted by transmitter hit any object, the ray gets reflected and reaches the receiver. Then it has high (1 state). and that is sent to PLC and based on program output operates. They are used in many industries.

Figure 5: Photo Electric sensor

Features:

Voltage :6-to6V DC

Output current :300Ma

Polarity: NPN

Detection distance: 30 cm

Output status: Normally Open

D. DC Gear Motor

In our project we require a motor to run our conveyor belt and transport coal from one place to other. If we use a high speed motor there might be a chance of slipping of coal pieces, so based on our application we need a motor which has low speed and high torque capabilities. So we prefer a DC gear motor. These type of motors have a hole (a thread drilled hole) in middle of the shaft so that we can easily make mechanical assembly (here we connect to gear wheels). These motors are mostly used for robotic applications.

Figure 6: DC Gear motor

Features of our DC gear motor:

Voltage: 12V DC

Speed: 30 RPM

Current: less than 1 ampere

Power: 12W (approx.)

E. SMPS

In our project the outputs(motors) are connected to PLC (indirectly with help of relay). The output of PLC is 24V DC but we have chosen a 12V DC gear motor for our application. So we require a 12V DC source. We can either select a 12V DC battery or an SMPS as a source for this purpose. Here we have selected an SMPS A switched-mode power supply is also called as a switcher. It is an electronic power supply which converts electrical power efficiently. It can convert AC supply to DC supply. In our application we used SMPS to convert a 230V AC supply to 12V DC supply.

Figure 7: SMPS

SPECIFICATIONS:

Input Voltage range: (115 – 230) V, AC supply

Input Current range: (1 – 0.7) A

Output voltage: 12 V DC

Maximum short circuit current: 10A

Output power: (36-72) W

F. Conveyor Belt

Conveyor belts are used for transportation of materials such as coal, bottles, luggage, groceries, based on type of application it is used for. A conveyor system consists of 2 or more pulleys over which the conveyor belt rotates and transport the material.

Figure 8: Conveyor belt

G. Gear Wheels

We use a motor which converts electrical energy to mechanical energy. But to run a conveyor we have to convert that mechanical energy obtained from motor to a form which helps in running the conveyor belt. The devise which help in utilizing the energy obtained from motor to run a conveyor belt is known as gear wheel. It is also known as cogwheel. It has cut teeth or inserted teeth which can mesh with another toothed part to transmit the torque and thus conveyor runs.

Figure 9: Gear wheels

H. Relay

Automation implies that the process is fully controlled automatically, so we have to control our output based on our input states. To accomplish that purpose we use a relay. It is designed for AC and DC source based on the application it is used for. Here we are using it to control the conveyor motors (which are DC). We can use mechanical or solid state relay to accomplish our task. In mechanical type moving parts will be present which results in sparks, so in our project we prefer a 4 channel solid state relay module which use semiconductors for no contact operation. The maximum acceptable current and voltage are 7A and 240V AC, 14V DC.

Figure 10 : 4 channel relay motor

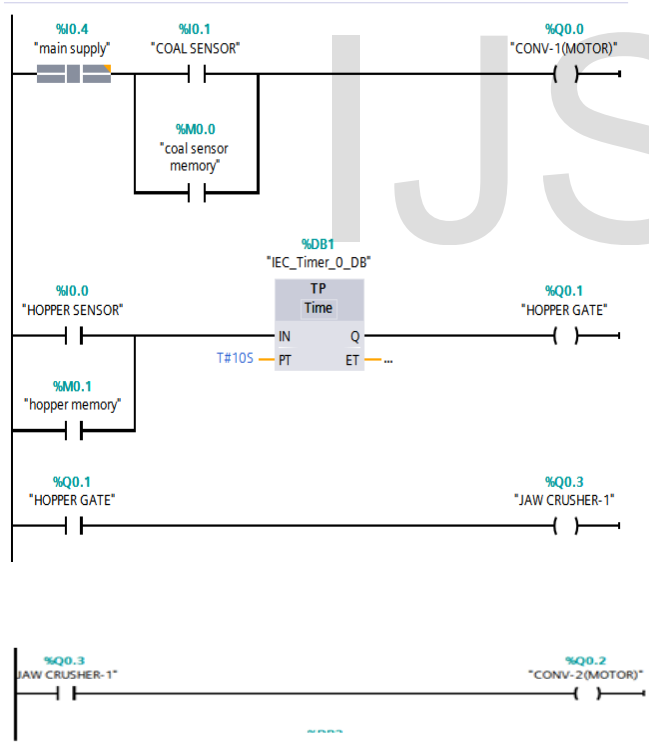
V. Working

The working of our project summed up by the two operations. The first operation is monitoring the coal level in the storage tank by locating photo electric sensors at different height in the coal storage tanks. They give the signal to PLC for start and stop of the conveyor motor and also to crusher for crushing into small pieces. The second operation is screening, which includes the separation of powdered coal pieces based on their size and sending back the coal pieces of a bit large size to yard or to crusher. When the coal is not present in the yard, the sensor will detect its absence and as a result the conveyor 1 do not run. As conveyor 1 do not run the remaining process will also be automatically stopped.

When the coal is detected by the photo photoelectric sensor it gives signal to the PLC as a result conveyor 1 runs as it is connected to PLC. The coal from the coal yard is transferred to hopper with the help of conveyor 1 and once the hopper is filled the hopper sensor will detect and opens the hopper gate. The time for which the hopper gate will be opened depends on the size of the hopper that is the time taken to unload the coal from the hopper is given to TP block and thus the coal will be transferred. Here it is roughly taken as 10 seconds. As long as the hopper gate is opened the jaw crusher will be running and the crushed coal will be transferred to bunker by conveyor 2. The crushed coal from conveyor 2 falls into the bunker and once the bunker is filled the bunker sensor will detect and gives signal to bunker gate so that it automatically opens. The time for which the bunker gate will be open depends up on the size of the bunker (here it is assumed to be 20 seconds). The coal from bunker is transferred to screening process with the help of conveyor 3. Once the coal is detected by screening sensor it starts creating vibrations based on the ladder logic and thus the different levels of coal is detected.

VI. LADDER DIAGRAM

The software used for PLC programming is TIA (Totally Integrated Automation). PLC can be programmed in many languages, but in our project we are designing our program based on a special language known as the ladder diagram. The ladder diagram is a simple language to program, since it is based on Boolean logic functions. That makes it much simpler and more cost-effective to change any device.



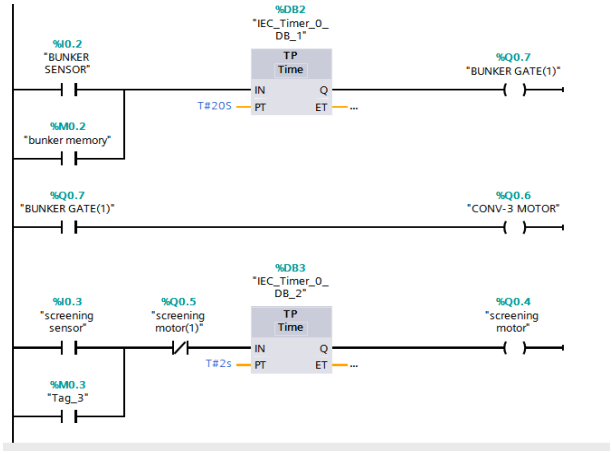


Figure 11: Ladder diagram

VII. SIMULATION

Simulation of the above ladder diagram in PLC can be done by a software known as TIA (Totally Integrated Automation). Open TIA portal →create new project →configure device→controller→ select the controller model number which you have →start→program blocks → main OB1

After following above steps draw ladder diagram and save project.

Save→compile→load program to PLC→go to online mode →monitor mode (to see ON/OFF status of our devises connected).

Here is an image showing the ON/OFF status of the devises connected to PLC.

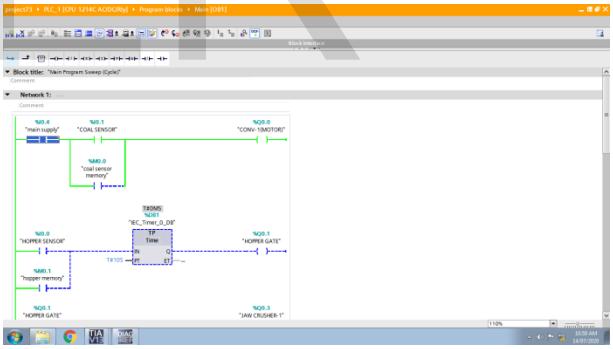


Figure 12: Simulation screen in PC

The process to get simulation screen is same as that described above but , instead of selecting controller select HMI→ HMI model based on which model you have. Remaining process is same as that mentioned above. But here instead of main OB1 we will get a root screen where inputs and outputs are to be represented. Here is an ultimate visual of HMI screen on PC

Open TIA portal →create new project →configure devise→HMI→ select the HMI model number which you have →configure PLC to HMI →root screen

here instead of main OB1 we will get a root screen where inputs and outputs are to be represented. Give required data to inputs and outputs based on our requirement.

Save→compile→load program to PLC→go to online mode →monitor mode(to see ON/OFF status of our devises connected). Here is an image showing the ON/OFF status of the devises connected to PLC.

Here is an ultimate visual of HMI screen on PC

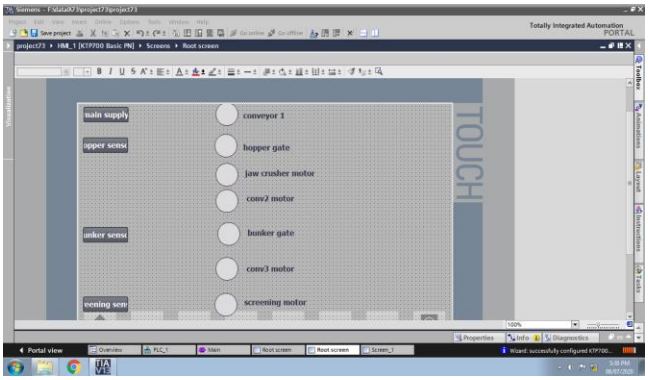


Figure 13: Simulation screen of HMI in PC

VIII. RESULT

When the coal is detected by the photo photoelectric sensor it gives signal to the PLC as a result conveyor 1 runs as it is connected to PLC.

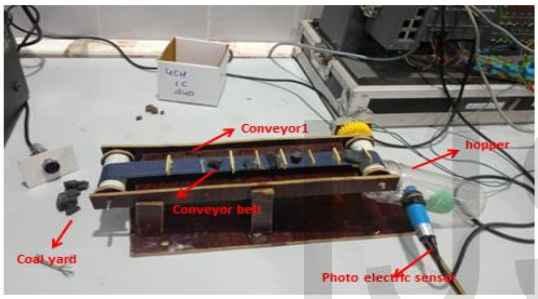


Figure 14 : Transportation of raw coal through conveyor-1

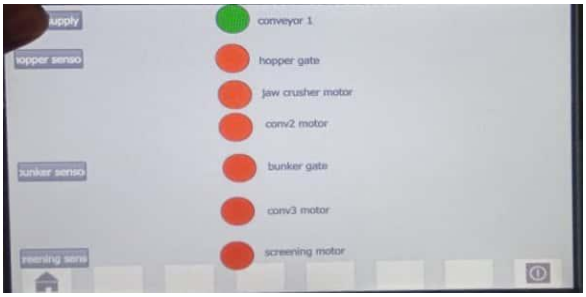


Fig 15 : HMI screen showing ON state of conveyor-1

The coal from the coal yard is transferred to hopper with the help of conveyor 1 and once the hopper is filled the hopper sensor will detect and opens the hopper gate. The time for which the hopper gate will be opened depends on the size of the hopper that is the time taken to unload the coal from the hopper is given to TP block and thus the coal will be transferred. Here it is roughly taken as 20 seconds. As long as the hopper gate is opened the jaw crusher will be running and the crushed coal will be transferred to bunker by conveyor 2.

Figure 16 : Hopper gate ON

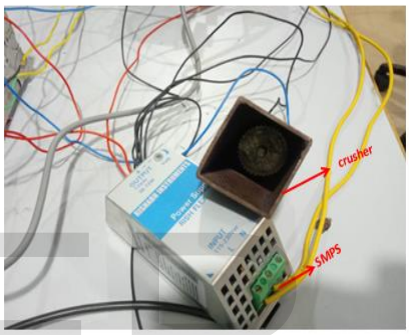


Figure 17 : Coal is being crushed with help of crusher

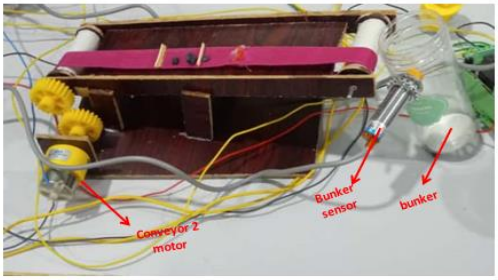


Figure 18 : Transpotation of powdered coal through conveyor-2

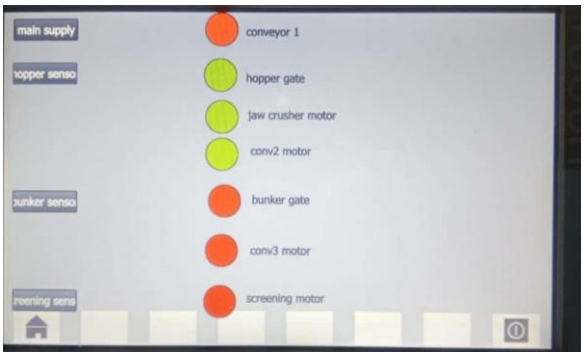


Figure 19: HMI Screen showing ON states of outputs

The crushed coal from conveyor 2 falls into the bunker and once the bunker is filled the bunker sensor will detect and gives signal to bunker gate so that it automatically opens. The time for which the bunker gate will be open depends up on the size of the bunker (here it is assumed to be 20 seconds). The coal from bunker is transferred to screening process with the help of conveyor 3.

Figure 20: Bunker gate ON

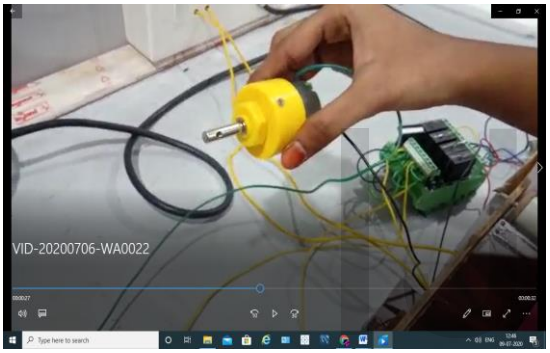


Figure 21: conveyor-3 running

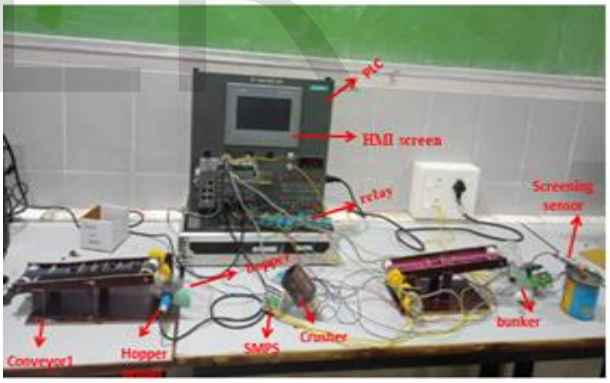
Figure 22 : HMI screen showing ON states of outputs

Once the coal is detected by screening sensor it starts creating vibrations based on the ladder logic and thus the different levels of coal is detected.

Figure 23 : Screening

Figure 24 : HMI screen showing ON states of outputs

Here is the hardware kit of our project



IX. Conclusion

Coal crushing and conveyor system in Thermal power plant are processed, controlled and monitored with the help of programmable logic controller and various types of sensors. In the point of reducing human errors, the main objective behind the project is to avoid the use of human work force in the hazardous remote field. Hence through the project model is designed keeping in mind about the need for mining area and thermal power plant, the use of this technology can also be extended and can be implemented in other industries also. We implemented our idea using HMI so that even if sensors or any other device stopped working due to some repair a human can control working of that device on HMI screen so that process doesn't get stopped..

X. Future Scope

The scope of future industrial automation is sufficient, as all technologies are involved in automation technology. It uses various control devices such as PC, DC, PLC, etc. to control various behaviors in the industry

and provide automatic control performance without human intervention. There are a set of technologies implemented in the industry to achieve the desired performance or production, making automation systems the most vital to the industry. Industrial automation, on the other hand, involves the use of sophisticated control strategies to detect control variables and the like.

XI. REFERENCES

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