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AUTOMATION OF THE PRODUCTION OF SPONGE IRON BY USING PLC AND SCADA SYSTEMS.

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ABSTRACT

In this project, the production of Sponge Iron in an industry is taken into consideration and the entire process involved in the production of Sponge Iron is automated. The process of sponge iron manufacturing involves removal of oxygen from iron ore. When that happens, the departing oxygen causes micro pores in the ore body, turning it porous. When the eventual product is observed under a microscope, it resembles a honeycomb structure, which looks spongy in texture. Hence, the name “Sponge Iron”. Sponge Iron itself having many advantages and application oriented uses, is thus commercially finding its place at the top in Iron Industries. Sponge iron industries are very big and processes involved in the entire production are divided into many sub categories. These are taken into account while automating such industries. Each sub systems are going to have separate Programs when automating. The project is going to involve a programming which is PLC based and written to an ABB PLC (AC500 series, PM590-ARCNET-V14x). Importantly, we are choosing a functional block programming to program the process. The Entire process of automation is going to be demonstrated in an ABB simulation platform which is written in software named „CODESYS‟. “Automation” of this process is carried out using Program Logic Control systems (PLC). The PLC is going to be used in many phases in the entire project. The PLC presently is the Heart of Automation and hence, we are using PLC when going to automate this process.

Index Terms- Sponge Iron, Automation, CODESYS.

I. INTRODUCTION

India is the world's largest producer of sponge iron, most of which is produced primarily through the coal based method of production. Growth in the sponge iron production can be attributed largely to the popularity of secondary steelmaking route, which has shown a phenomenal growth in India.

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Automation is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. Some processes have been completely automated. The biggest benefit of automation is that it saves labour; however, it is also used to save energy and materials and to improve quality, accuracy and precision.

PLC are industrial microcontroller systems (in more recent times we meet processors instead of microcontrollers) where hardware and software are specifically adapted to industrial environment. The key to their success is the fact that you don't have to learn a new programming language to program them.[3] Therefore now-a-days whenever the term automation comes then it is associated with PLC. Thus, it made us to follow the same path, of using PLC in our automation system.

The combination of every paragraph in the above introduction itself is the title of the project chosen that is “Automation of the Production of Sponge Iron Using PLC & SCADA Systems”.

II. SPONGE IRON

The process of sponge iron manufacturing involves removal of oxygen from iron ore. When that happens, the departing oxygen causes micro pores in the ore body, turning it porous. When the eventual product is observed under a microscope, it resembles a honeycomb structure, which looks spongy in texture.

Direct reduction is basically a chemical process occurring at high temp in which oxygen is removed from the iron ore converting the ore, practically entirely to metallic iron. The Direct Reduction Process Consists of Reducing iron ore with solid Carbonaceous material such as coal in a rotary kiln heated to a temperature of about 1000 deg. After reduction the products are cooled to room temp in the rotary cooler with indirect cooling system. The products are then screened and magnetically separated into sponge iron, char ash, etc., high degrees of reduction & thermal efficiency can be obtained by controlling the process parameters such as reduction temperature of feed size of feed, grade of feed etc. In the process for the production of sponge iron, the raw materials viz., iron ore, coal and dolomite are charged into rotary kiln from the inlet end by means of a feed tube in a pre-determined ratio by electronic weighing equipment. The Rotary kiln is of 3.00 mts. The fine coal is blown from the discharge end of the kiln to maintain the required temperature profile.

III. Overview on the Sponge Iron Plant

Sponge iron system basically consists of following circuits-

1. Kiln circuit
2. Kiln Feed circuit.
3. Iron ore Circuit
4. Product circuit
5. Injection Coal Circuit
6. Cooler circuit
7. Waste Gas Circuit.

The Basic Overview of a Sponge Iron Plant is shown in Fig.1.The process of sponge iron manufacturing involves removal of oxygen from iron ore. In the process for the production of sponge iron, the raw materials viz., iron ore, coal and dolomite are charged into rotary kiln from the inlet end by means of a feed tube in a pre-determined ratio by electronic weighing equipment.

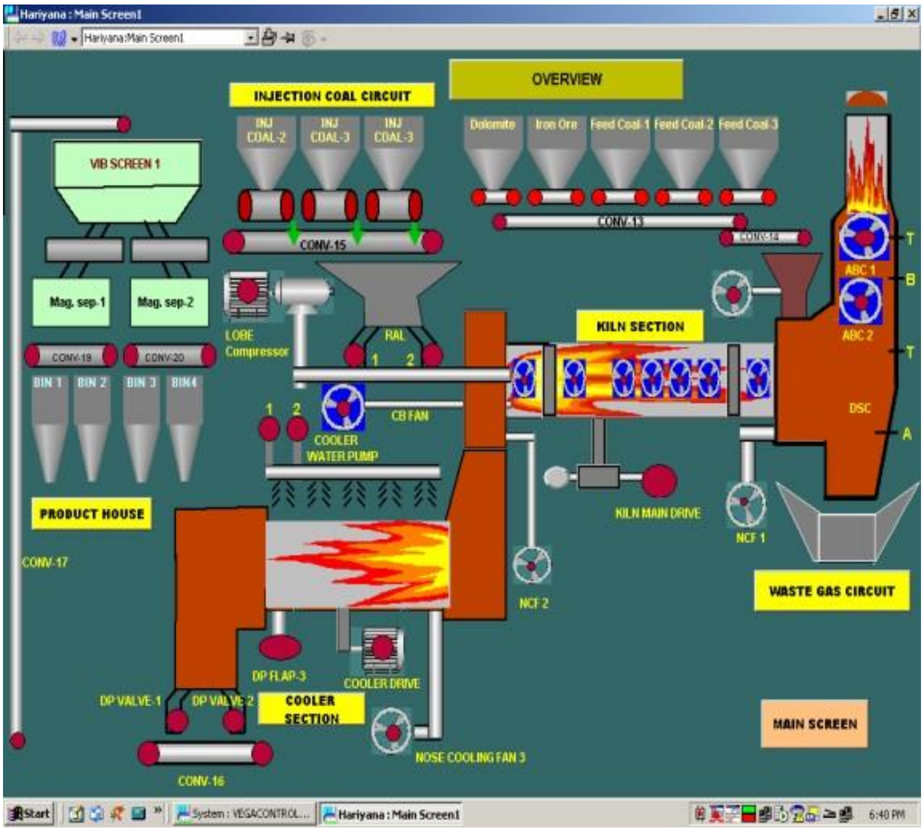

Fig. 1. overview of Sponge Iron Plant.

IV. Basic Operation

The basic operation is going to include two modes:

1. MCC Mode- In this Mode all the operations(Feeder Start & Stop) are controlled by MCC. Only run feedback is Transferred to PLC.
2. PLC Mode- The PLC Mode is divided into two modes as follows-

a. Individual Mode.

b. Group Mode.

In Individual Mode only single feeder can be made on/off individually. In Group Mode we can start all the feeder of particular circuit.

MCC mode is Motorised Control Mode, in which the control is done using wiring system which is man power controlled and complete manual.

The process flow diagram of conventional coal based sponge iron plant is shown in figure 2.[1]

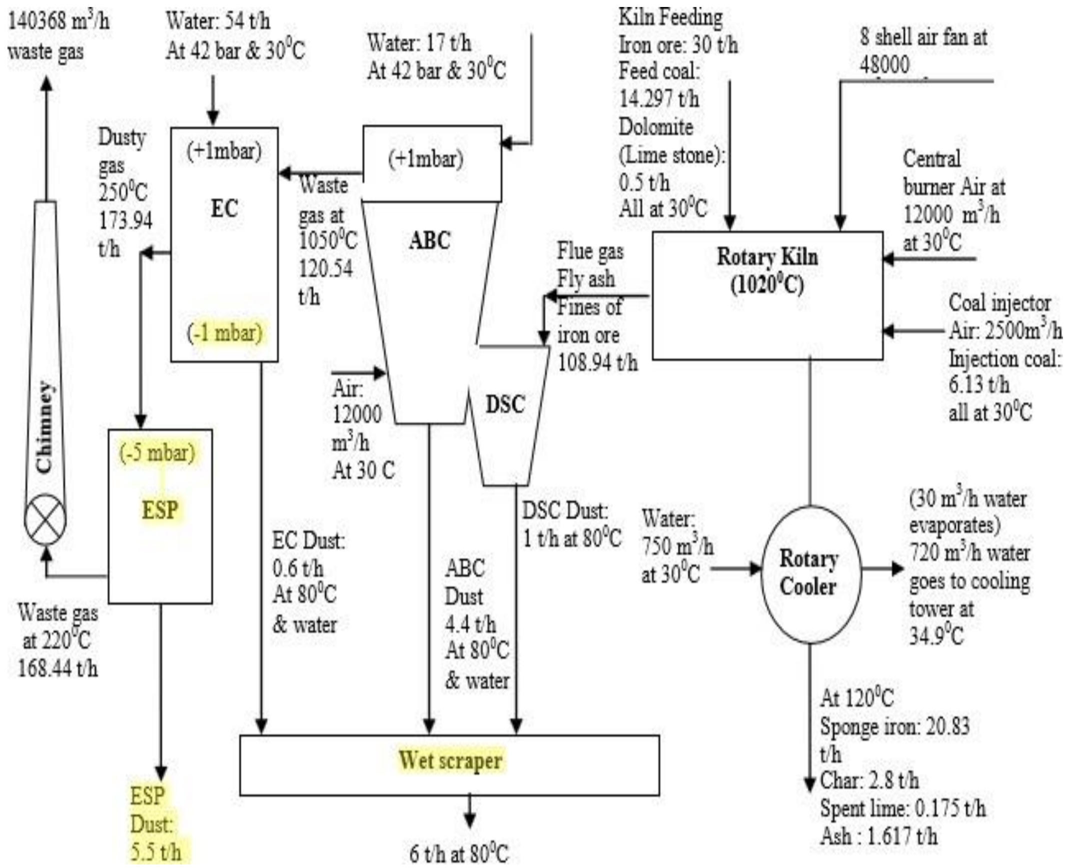

Fig. 2. Conventional Sponge Iron Flow Diagram.

Direct reduction is basically a chemical process occurring at high temp in which oxygen is removed from the iron ore converting the ore, practically entirely to metallic iron. The Direct Reduction Process Consists of Reducing iron ore with solid carbonaceous material such as coal in a rotary kiln heated to a temperature of about 1000 degree. After reduction the products are cooled to room temp in the rotary cooler with indirect cooling system. The products are then screened and magnetically separated into sponge iron, char ash, etc., high degrees of reduction & thermal efficiency can be obtained by controlling the process parameters such as reduction temperature rate of feed, size of feed, grade of feed etc.[1]

In the process for the production of sponge iron, the raw materials viz., iron ore, coal and dolomite are charged into rotary kiln from the inlet end by means of a feed tube in a pre-determined ratio by electronic weighing equipment. The rotary kiln is of 3.00mts. The fine coal is blown from the discharge end of the kiln to maintain the required temperature profile.[1]

The operating data, shown in figure 1, is taken from a typical Indian coal based sponge iron plant where iron ore, feed coal and dolomite are fed to the rotary kiln. A separate conveyor collects different size fractions of coal for injection into the kiln with the help of pressurized air from discharge end side. All along the kiln length air is injected through air fans and each of them can be adjusted separately. Further, air is injected at the kiln outlet by central burner pipe, which during normal operation serves as process air inlet.

The inside kiln is lined with refractory and supported on three piers called support rollers with an inclination of 2.5%. Rotation is given by the girth gear. Due to its inclination and rotation material in the bed of the kiln moves along the axis. Both end of the rotary kiln is provided by the mechanical air sealing so that no ingress of air takes place. As the charge moves through the kiln, it is heated by the gases which flow in opposite direction to the charge.

Inlet side of the kiln, blowing of a controlled amount of air into the material charge increases the material temperature by direct combustion of volatiles within the charge.

The first section approximately half of the kiln is called preheating zone where iron ore, coal and dolomite are heated to reaction temperatures and the second half is the reduction zone. In the preheating zone, the moisture of the materials is driven off along the waste gas. The volatiles of the coal are to one part escaping into the gas space above the material bed and to the other part.

Directly burned within the material charge where they are used for direct heat up. The volatiles in the gas space are burned by the air admitted through the air pipes and thus supply the main energy source for heating up the kiln charge. In the reduction zone, the main portion of the oxygen contained in the iron ore, is removed leaving metallic iron and very few iron oxide behind. The difference of the temperature of the free gas T (gas) and bed material T (charge bed) is shown in figure 2 along the length of the kiln. It is responsible for heating bed charge and metallization of product. Plot of the % of metallization is shown in figure 2. It indicates that the reduction of iron ore starts in the reduction zone and required metallization of the product is achieved at the discharge end of the kiln. The reduced product from the kiln is indirectly cooled in a rotary cooler.

The waste gas in the kiln flows in the opposite direction to the feed material movement. The flow is maintained by induction fan mounted before the chimney. The waste gas coming out from the rotary kiln is processed by the different Equipment before it leaves to the open atmosphere. Generally, waste gas consists of N2, CO2, CO, H2, H2O, O2 and CH4. It comes out of the kiln at a temperature about 9000C and then is taken to after burner chamber (ABC) and a horizontal dust settling chamber which is located beneath the ABC. Dust settling chamber (DSC) reduces the waste gas velocity, removes large dust particles by gravity, retards pressure fluctuation and achieves uniformity of waste gases with regard to temperature and concentration of combustible. At the end of DSC the waste gases change their direction of flow and move upward into combustion area of ABC. Here combustibles are mixed with fresh excess air and burnt completely to acquire temperature in a range between 9500C to 10500C approximately.

To removal dust particles and toxic components from waste gas water is sprayed in the ABC. For this purpose eight to ten numbers of water gun is fitted along the different height. The water guns hold a nozzle at the discharge end for atomization. The pressurized water coming out from the guns falls on the waste gas carrying dust particle. It results the increase in weight of dust particles that helps it to settle down.

The evaporating chamber (EC) is connected with the ABC as shown in figure 2. Here, the waste gas is quenched as temperature of waste gas needs to be brought down to a workable limit for downstream equipment. For quenching eight - ten numbers of water guns are provided at the top position of EC around the circumference at the same height. Water coming out from the guns is sprayed to reduce the temperature of waste gas at desired level. The bottom part of the EC, dust settling chamber and ABC is attached with wet scraper to collect the dust.

Further, waste gas coming out from the EC, is entered the electrostatic precipitator (ESP) for final purification. The desired temperature of the waste gas is to be maintained below 2500C. ESP is considered to be the most effective dust collector in industries. It has gained acceptance over other collectors due to its various advantages like low pressure drop, low sensitivity at high temperature and aggressive gases, high collection efficiency and low maintenance. ESP exit is connected to the chimney through the waste gas carrying duct. Induced direct fan placed before chimney. After ESP, the filtered waste gas goes to the surroundings through Chimney.

V. Automation

Fig.2 AC 500 series, PM 590 PLC fixed with I/O module. Automation is carried out using a PLC. The PLC used in this project is a ABB_PLC which is AC500 series, PM590 model. The PLC image is as shown above in Fig.2.

Features about PM590 are listed below.

Extended PM590-ARCNET-V14x **Product Type:**	PM590-ARCNET-V14x
Product ID: PM590-ARCNET	1SAP150000R0260
ABB Type Designation:	PM590-ARCNET
Catalog Description:	PM590-ARCNET:AC500,Programmable Logic Controller 2MB, 24VDC,ARCNET,2xRS232/485,FBP SD-Card Slot,LCD Display
Maximum	160 AI, 160 AO local max. 10

Number of Analog I/Os:	extension modules
Maximum Number of Digital I/Os:	320 DI, 240 DO/DC local max. 10 extension modules
Memory Size User Data:	2560 kB
Memory Size User Program:	2048 kB
Memory Type User Data:	Flash EPROM
Memory Type User Program:	Flash EPROM, non-volatile RAM, SD Card

VI. RESULTS AND CONCLUSIONS

PROGRAM PLC_PRG

Product House:

Output's: Conveyor17, Conveyor19, Conveyor 20 VAR

stc17 AT %IX0.0: BOOL; c17fb AT %IX0.1: BOOL; spc17 AT %IX0.2: BOOL; em AT %IX0.3: BOOL; ovlc17 AT %IX0.4: BOOL; c17on AT %QX0.0: BOOL; wt1: INT;

END_VAR VAR

spvs1 AT %IX0.5: BOOL; vs1 AT %QX0.1: BOOL; mem1: BOOL; sr1: SR; stfc19 AT %IX0.6: BOOL; c19ffb AT %IX0.7: BOOL; spc19 AT %IX1.0: BOOL; ovlc19 AT %IX1.1: BOOL; c19ron AT %QX0.3: BOOL; c19fon AT %QX0.2: BOOL; strc19 AT %IX1.2: BOOL; c19rfb AT %IX1.3: BOOL; stfc20 AT %IX1.4: BOOL; c20ffb AT %IX1.5: BOOL; spc20 AT %IX1.6: BOOL; ovlc20 AT %IX1.7: BOOL; c20ron AT %QX0.5: BOOL; c20fon AT %QX0.4: BOOL; strc20 AT %IX2.0: BOOL; c20rfb AT %IX2.1: BOOL; pman_sel AT %IX2.2: BOOL; auto_st AT %IX2.3: BOOL; Pauto_sel AT %IX2.4: BOOL;

END_VAR

Injection Coal Circuit:

Outup's: Valve1, Valve2, Valve3, Conveyor 15 VAR

wt2: INT; mem2: BOOL;

sticc AT %IX4.0: BOOL; mem3: BOOL;

v1on AT %QX4.0: BOOL; mem4: BOOL;

v2on AT %QX4.1: BOOL;

sr2: SR; mem5: BOOL; sr3: SR;

v3on AT %QX4.2: BOOL;

Overload Circuit:

Output's: Valve4, Valve5, Valve6, Valve7, Valve8, Conveyor13, Conveyor14

VAR

mem6: BOOL;

stov AT %IX5.0: BOOL; mem7: BOOL;

sr5: SR;

v4 AT %QX5.0: BOOL; mem8: BOOL;

v5 AT %QX5.1: BOOL; sr6: SR;

mem9: BOOL; sr7: SR;

v6 AT %QX5.2: BOOL; mem10: BOOL;

sr8: SR;

v7 AT %QX5.3: BOOL; mem11: BOOL;

sr9: SR;

v8 AT %QX5.4: BOOL; sr10: SR;

c13 AT %QX5.5: BOOL; c14 AT %QX5.6: BOOL;

END_VAR

Compressor circuit:

Output: Compressor VAR

stcomp AT %IX6.0: BOOL; compfb AT %IX6.1: BOOL; spcomp AT %IX6.2: BOOL; emcomp AT %IX6.3: BOOL; ovlcomp AT %IX6.4: BOOL; compon AT %QX6.0: BOOL;

END_VAR

Cooler Drive Cicuit:

Output's:Cooler drive, Pump1,Pump2 VAR

stcd AT %IX8.0: BOOL; cdfb AT %IX8.1: BOOL; spcd AT %IX8.2: BOOL; ovlcd AT %IX8.3: BOOL; stwp1 AT %IX8.4: BOOL; wp1fb AT %IX8.5: BOOL; spwp1 AT %IX8.6: BOOL; ovlwp1 AT %IX8.7: BOOL; cdon AT %QX8.0: BOOL; wp1on AT %QX8.1: BOOL; wp2on AT %QX8.2: BOOL;

END_VAR

Kiln Drive Circuit:

Output's: Kiln Drive, Shaft Refrence speed to the motor. VAR

stkd AT %IX10.0: BOOL; kdfb AT %IX10.1: BOOL; spkd AT %IX10.2: BOOL; ovlkd AT %IX10.3: BOOL; c15on AT %QX4.3: BOOL; sr4: SR; wt3: INT;

END_VAR

kdon AT %QX10.0: BOOL;

temp2: INT; mem20: BOOL;

shafref: INT; temp1: INT; tp1: TP;

dpf3 AT %QX9.0: BOOL; dpv1 AT %QX9.1: BOOL; dpv2 AT %QX9.2: BOOL; tp2: TP; tp3: TP; END_VAR

Cooling Fan's: Output:abc1,abc2,cbf,ncf3,ncf2 VAR

stabc1 AT %IX12.0: BOOL; spabc1 AT %IX12.1: BOOL; ovlabc1 AT %IX12.2: BOOL; abc1fb AT %IX12.3: BOOL;

cman_sel AT %IX12.4: BOOL; auto_cst AT %IX12.6: BOOL; cauto_sel AT %IX12.5: BOOL; abc1 AT %QX12.0: BOOL; stabc2 AT %IX13.0: BOOL; spabc2 AT %IX13.1: BOOL; ovlabc2 AT %IX13.2: BOOL; abc2fb AT %IX13.3: BOOL; abc2 AT %QX12.1: BOOL; stncf2 AT %IX14.0: BOOL; spncf2 AT %IX14.1: BOOL; ovlncf2 AT %IX14.2: BOOL; ncf2fb AT %IX14.3: BOOL; ncf2 AT %QX12.2: BOOL; stcbf AT %IX15.0: BOOL; spcbf AT %IX15.1: BOOL; ovlcbf AT %IX15.2: BOOL; cbffb AT %IX15.3: BOOL;

cbf AT %QX12.3: BOOL; stncf3 AT %IX16.0: BOOL; spncf3 AT %IX16.1: BOOL; ovlncf3 AT %IX16.2: BOOL; ncf3fb AT %IX16.3: BOOL; ncf3 AT %QX12.4: BOOL;

END_VAR

The program for the production unit is written in ABB Codesys software and simulated in the same.

REFERENCES

1. "An investigation for generation of energy conservation measures for sponge iron plants using process integration principles" titled paper presented in IJRRAS 6(1), author being Anilkumar Prasad, Radhakrishna Prasad, Shabina Khanam.