STUDY ON AUTOMATED CONTROL OF SINTER PLANT

A thesis submitted towards partial fulfilment of the requirements for the degree of

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Submitted by

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ABSTRACT

The pumping system of the sinter plant takes a major role in the processing unit. In this thesis a section of the pumping system is done with various modes of operations. The local mode operation can be done by the field operators from the local control panel which are situated in the fields and remote mode operations can be done by the master operator from the control room. The automation control process of the pumping system is developed with the help of various softwares. STEP 7 software is used for the programming section and SIMATIC WinCC software is used to simulate and analyze the outputs. The various types of operations with the simulated results are described in the subsequent chapters. This new developed program is more user friendly to the operators so that the overall efficiency of the sinter plant will be increased.

The control rooms are likely to be situated in separate buildings far away from the processing area. The lighting design of control rooms should be done properly so that it ensures the minimum risks at the processing area. In this thesis work an attempt has been made to give a solution towards energy efficient lighting design of the control room by the replacement of the luminaires so that the average illuminance level is increased as well as the Uniformity is also improved in compared to the existing lighting design.

Key words : PLC, Sinter Plant, Sintering Process, Lighting Design, Illumination, Uniformity

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CHAPTER – 1

INDTRODUCTION OF PLC

1.1 INTRODUCTION

A programmable logic controller (PLC) is a computer-based system for industrial automation. These controllers can automate a specific process, machine function, or even an entire production line. They were first developed in the automobile industry to provide flexible, and easily programmable controllers to replace hard-wired relays, timers, and sequencers. Since then, they have been widely adopted as high- reliability automation controllers suitable for harsh environments [1] .

PLCs can range from small modular devices with various of inputs and outputs (I/O), in a housing integral with the processor, to large rack-mounted modular devices with thousands of I/O, and which are often networked to other PLC and SCADA systems. They can be designed for multiple arrangements of digital input/output and analog input/output, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. An example of PLC panel is shown in Fig 1.1.

Fig 1.1 Programmable Logic Controller Panel

1.2 ARCHITECTURE OF PLC SYSTEM

PLC consists many types of software like:-

- SIMATIC MANAGER
  - STEP 7
  - PCS 7
  - TIA (Totally Integrated Automation) PORTAL

- SIMATIC WINCC (Human Machine interface)

A schematic diagram of PLC architecture is shown in Fig 1.2.

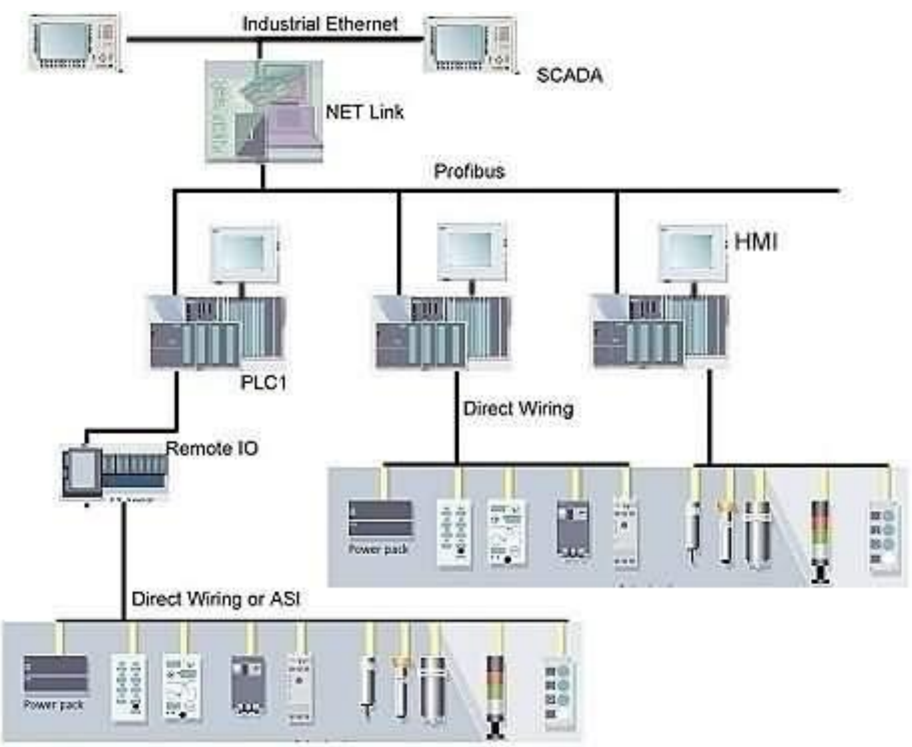


Fig 1.2 Architecture of PLC system

There are two types of PLC systems which are briefly described below:

i) Redundant PLC System

ii) Stand-Alone PLC system

i) <u>Redundant PLC system: –</u>

PLC redundancy in warm systems usually operate in shadow mode where they run the identical software and share a signal from the primary to secondary. An interruption in control with the primary will result in the secondary assuming control. Two identical PLCs run the same software and share the same inputs and outputs. One operates as the primary, the second as a backup. If a heartbeat signal from the first is not received by the second, the backup unit assumes control of the automation system providing uninterrupted operation. These require a bit more design and require an arbitration circuit for the sensors & actuators to avoid conflict [2]. A schematic diagram of redundant PLC system is represented in Fig 1.3.

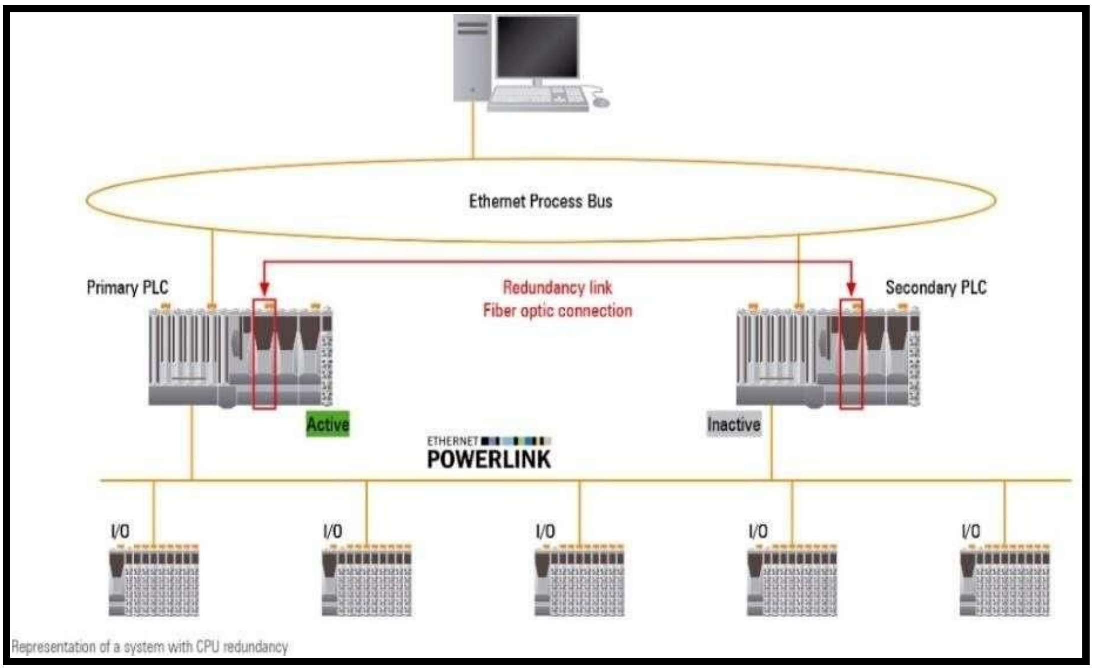


Fig 1.3 Redundant PLC system

ii) **Stand-Alone PLC system: –**

Hot-standby control is not as common in automation panels. However, if the touchscreen or display fails, the system will continue to run. At that point, the operation functionality could be operated through a remote web browser on a PC, or thesystem could automatically go into a controlled shutdown sequence. Either way, the automation panel would need to be replaced and would eventually require a system shutdown. With hot-standby, if the CPU of the controller is somehow failed, the failed component can be replaced while the system continues to operate from the backup CPU, so no downtime is typically required. A schematic diagram of stand-alone PLC system is represented in Fig 1.4.

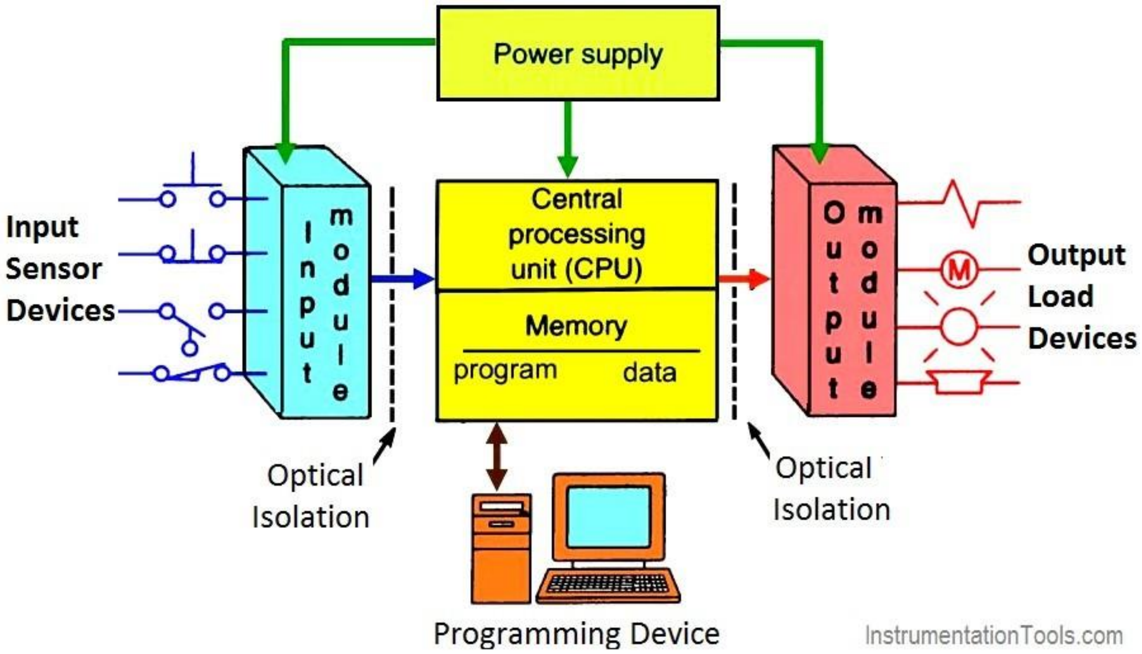


Fig 1.4 Stand Alone PLC system

1.3 OBJECTIVES OF THE THESIS

The main objectives of the thesis work are:

- Develop the pumping system of sinter plant to make the sintering process easier to operate.
- Design a Lighting system to achieve high illumination level in the control room.
- Save electricity consumption as much as possible.

1.4 SCOPE OF THE THESIS

This thesis represents a developed pumping system of sinter plant which is operated in three types of modes. Local mode is used for maintenance purpose whereas manual mode and auto mode is used for operational purpose.

In this thesis an effort has been done to give a solution towards energy efficient lighting design of the control room with higher illuminance level. The modified design achieves it with low energy consumption in compared to the existing design.

CHAPTER – 2

FUNDAMENTALS OF PLC PROGRAMMING

2.1 PLC PROGRAMMING

PLC Programs are written in various software like STEP 7, PCS 7, TIA portals

In STEP 7 and TIA portal the programming blocks are used to implement the logics.

In PCS 7 charts are used to implement the logics [3,4,5] .

Programming blocks are consists of three types of logics :

i) Ladder Logic
ii) Statement List
iii) Function Block Diagram

i) <u>LADDER LOGIC: -</u>

- Ladder logic was originally a written method to document the design and construction of relay racks as used in manufacturing and process control.
- Each device in the relay rack would be represented by a symbol on the ladder diagram with connections between those devices.
- In addition, other items external to the relay rack such as pumps, heaters, etc. would also be shown on the ladder diagram.
- Ladder logic has evolved into a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay logic hardware.
- Ladder logic is used to develop software for programmable logic controllers (PLCs) used in industrial control applications. The name is based on the observation that programs in this language resemble ladders, with two vertical rails and a series of horizontal rings between them [6] .

  A basic ladder logic diagram is represented in Fig 2.1.

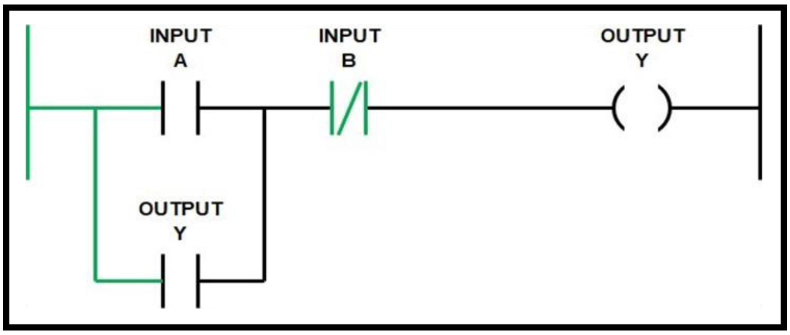


Fig 2.1 Ladder Logic

ii) STATEMENT LIST:

- Statement list (STL) provides another view of a set of instructions. The operation, what is to be done.
- The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure. The set of instructions in this statement list perform the same task as the ladder diagram.
- The basic logic operations like AND, OR, NOT, are represented by **A, O, N,** respectively is described in Table 2.1.

Table 2.1 Statement List

Statement	Remark
A “LSH_1” = #High_LS	High Level Switch of Reservoir
A “LSL_1” = #Low_LS	Low Level Switch of Reservoir
A “V1_OPEN” = #S_Valve_Open	Suction Valve Open Feedback
A “V1_CLOSE” = #S_Valve_Close	Suction Valve Close Feedback
A “V2_OPEN” = #D_Valve_Open	Delivery Valve Open Feedback
A “V2_CLOSE” = #D_Valve_Close	Delivery Valve Close Feedback

iii) FUNCTION BLOCK DIAGRAMS:

- Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side.
- The function block diagram shown below performs the same function as shown by the ladder diagram and statement list [7].

Here two inputs are taken I0.0 and I0.1 and **AND** operation is made between them & the output is denoted by Q0.0. The FBD logics which schematic diagram is given in Fig 2.2.

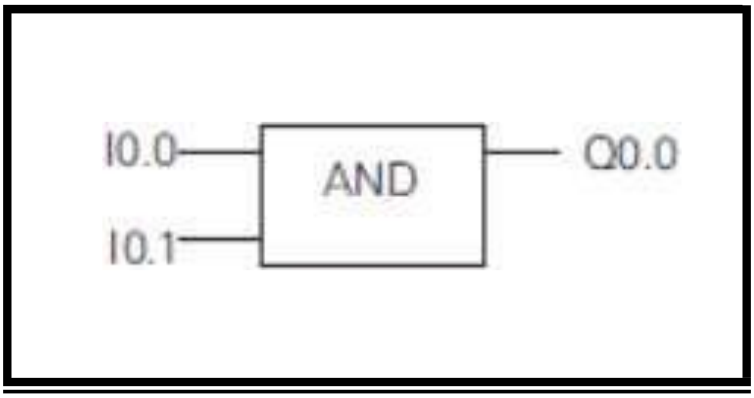


Fig 2.2 Function Block Diagram

2.2 HARDWARE CONFIGURATION

PLC hardware is based on the PC being connected to the PLC using an ethernet cable which is connected to the Interface Module using a Profibus cable. The Interface Module consists of four kinds of input and output cards Digital Input, Digital Output, Analog Input and Analog Output. Signals from the Output cards are sent to field devices and signal from the field devices are sent to the Input Cards. This is done using a twisted pair cable [8,9] . Hardware configuration of a standard program is represented in Fig 2.3.

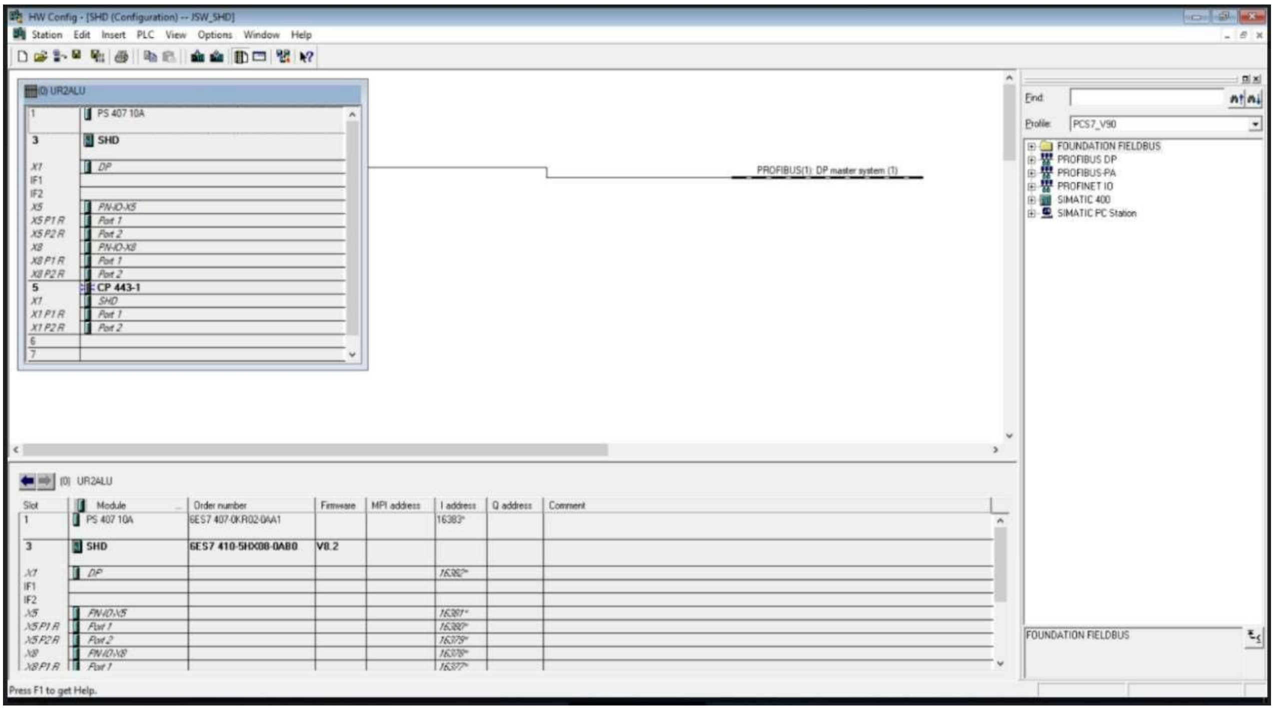


Fig 2.3 Hardware Configuration

In the PLC racks, there is a unique identification number to identify the part components called the MLFB number. An example of MLFB numbers (6ES7400-1JA11-0AA0) is given in Fig 2.4.

Fig 2.4 Sample of MLFB numbers

2.3 GRAPHICS DESIGNER

The Graphics Designer is an editor for creating process pictures and making them dynamic. The graphics designer can only be started for the project currently opened in the WinCC Explorer. The WinCC Explorer can be used to display an overview of the pictures available in the current project. An example of WinCC Graphics Designer is represented in Fig 2.5.

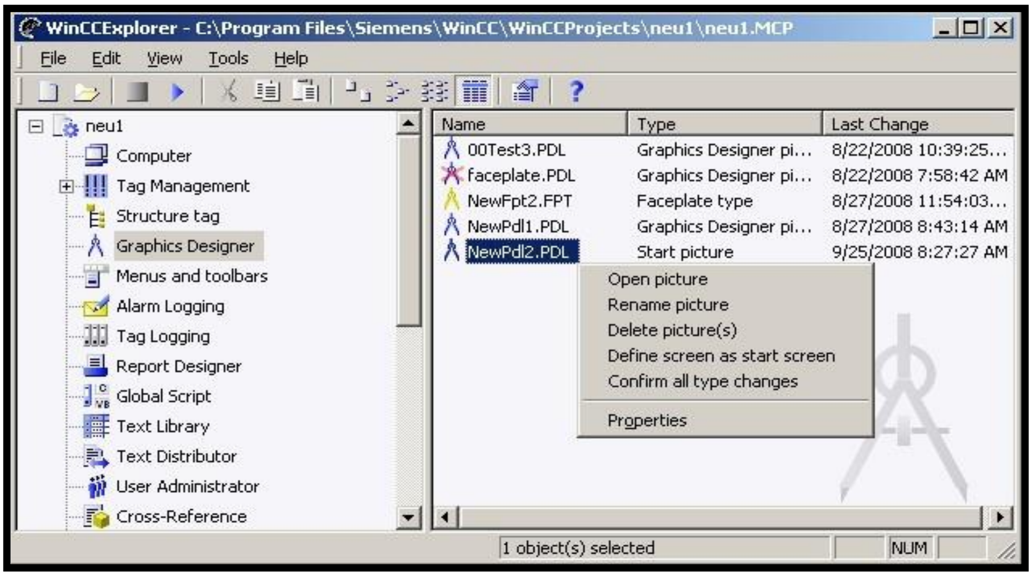


Fig 2.5 WinCC Graphics Designer

For working with the Graphics Designer, the WinCC Explorer [10,11] offers the following functions and configuration options:

- Starting Graphics Designer
- Opening, creating, renaming, and deleting a picture
- Properties of the picture
- Configuring object libraries and ActiveX controls
- Converting libraries and pictures from older program versions
- Configuring and starting Runtime

2.4 CONCLUSION

This chapter briefly described the fundamentals of PLC programming languages i.e., Ladder Logic, Statement List, Function Block Diagram. According to the requirement, the languages could be used to develop a program. Hardware Configuration is used to assign the input/output card to the PLC and WinCC graphics design generates the Human Machine Interface (HMI) to operate the process.

CHAPTER – 3

VARIOUS SECTIONS OF SINTER PLANT

Sinter Plant [12,13] have mainly four sections:

(i) Raw material bedding and blending
(ii) Sinter Machine
(iii) Sinter Cooler and
(iv) Selective Waste-Gas Recirculation System

Four sections [14] are described briefly

3.1 RAW MATERIAL BEDDING AND BLENDING

- **Raw material Proportioning bins**

For the proportioning of the raw mix, Primetals Technology has engineered specially designed raw- material bins. The bins are designed to avoid "bridging" of the materials within the bins and to reduce the segregation of coarse and fine particles during charging and discharging. Segregation inthe bins during charging and discharging occurs in different ways at different bin fill levels.

A higher number of bins allows for the simultaneous discharge of a single ore type from at least two bins with different fill levels, which compensates for the varying segregation of the coarse and fineore particles during charging and discharging. The discharge of raw materials by dosing weigh feeders from the bins is controlled by the "real-time dosing system." With this control system, the desired mixture composition will conform to predetermined ratios throughout the entire operation. Specially designed bins for handling very fine iron ores preventing, bridging is described in Fig 3.1.

Fig 3.1 Proportioning Bins

- <u>**Stockyard and conveyor systems**</u>

Primetals Technology's robust and powerful equipment for the stockyard (stockpiles, stacker, reclaimer/bridge reclaimer), and belt conveyor systems ensure a reliable and efficient piling, reclamation, and transfer of different bulk materials (including iron ore, iron concentrate, limestone, and coke) to the stockpiles and to or from the sintering process. All material-handling systems are designed (Fig 3.2) to minimize and optimize the overall handling operation.

As a result: a significant decrease in investment costs, improved overall logistic process, and homogenized material quantities. The ability to blend different products gives plant operators much more flexibility in securing their plant's future. And all solutions are available from a single source.

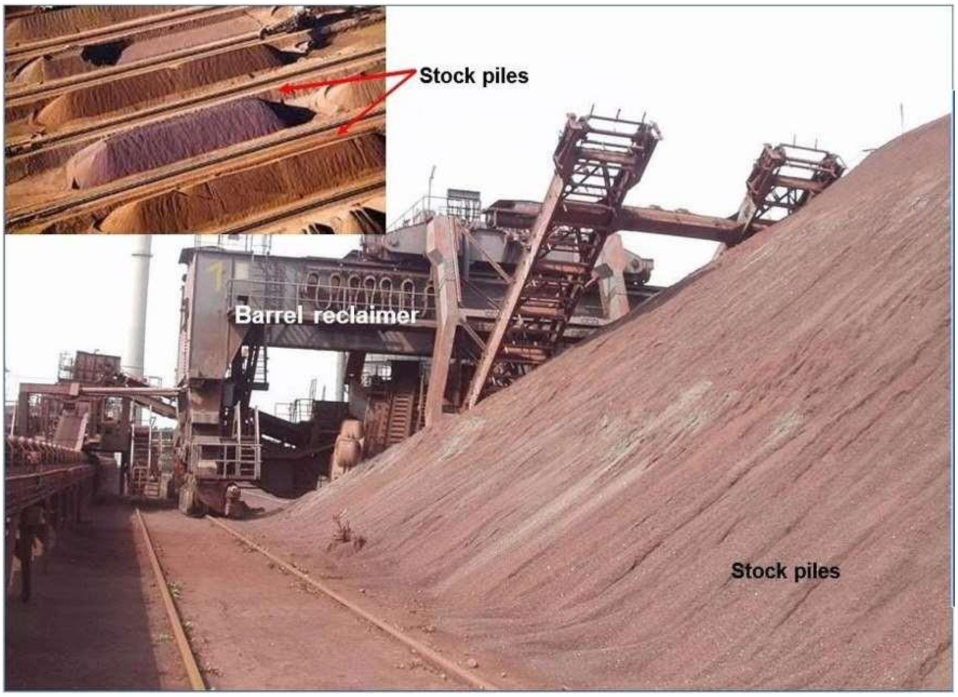


Fig 3.2 Stockyard

- **<u>IMGS – Intensive Mixing & Granulation System</u>**

Excellent homogeneity and high permeability of the sinter raw mix are decisive factors in achieving high sinter productivity and quality with reduced consumption of energy. With a conventional mixing drum, only a very limited homogeneity of the sinter raw mix can be obtained.

To remedy this problem, Primetals Technology developed the intensive mixing and granulation system, which consists of an intensive mixer and granulation aggregate. The sinter raw materials (like coarse as well fine iron ores, ultra-fine ores/pellet feed, additives, dusts, solid fuels, return fines, and recycled materials from the steel plant) are continuously fed into a high-speed intensive mixer where macro- and micro-mixing of the sinter raw mix takes place. After the mixer, the material is transported to the drum or intensive granulator where the material granulation takes place. The mixing devices can be individually adjusted to changing requirements. The schematic diagram of IMGS is shown in Fig 3.3.

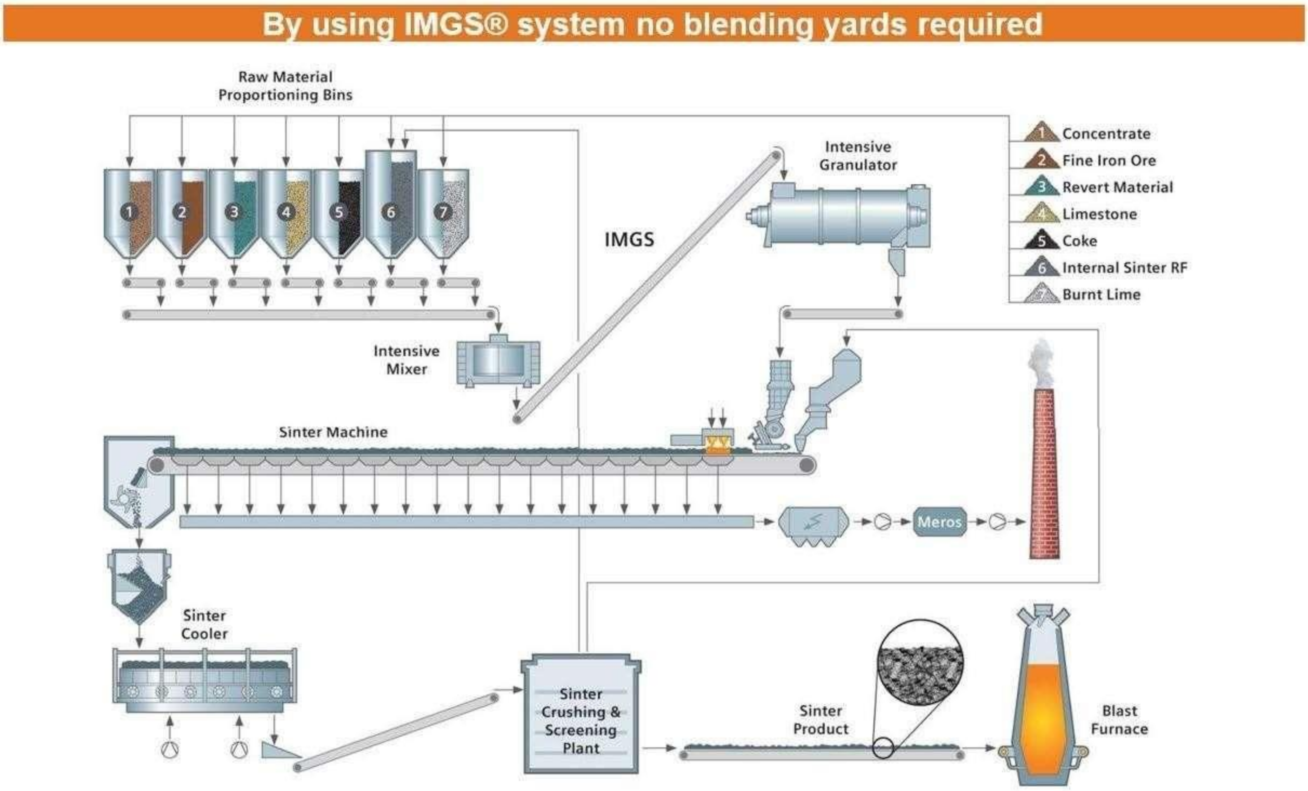


Fig 3.3 IGMS System

3.2 SINTER MACHINE

Sinter machine means equipment that is composed of a continuous traveling grate that conveys a bedof ore fines and other finely divided iron- bearing material and fuel (typically coke breeze), a burnerat the feed end of the grate for ignition, and a series of downdraft wind boxes along the length of the strand to support downdraft combustion and heat sufficient to produce a fused sinter product. A picture of Sinter Machine is given in Fig 3.4.

Fig 3.4 Sinter Machine

There are some general specifications of a Sinter machine is Given in Table 3.1.

Table 3.1 Specification of Sinter Machine

PARAMETER	VALUE
Area under suction	205 m^2
Pallets width	3 m
Pallet length	1 m
No. of Pallet Car	167
Speed Range	1-6 m/min
Types of Drive used	VVVF
High Chrome grate bars	Cr-28-30%
Suction Pressure	170 mbar

- **Pallet car design**

Primetals Technology's pallet design – featuring grate-wing pallet cars – offers a highly economical solution for application in new sinter plants as well as for increasing the capacity of existing plants. Gas-tight rim zone covers significantly reduce the volume of false air in the side-wall areas of the pallet cars compared with conventional designs. This leads to a major reduction in the quantity of waste gas and improved sintering at the side- wall areas. The result is a decreased quantity of return fines, contributing to enhanced sinter plant productivity.

Pallet-car extension technology from Primetals Technology represents a practical and economical solution for increasing the sintering area, and therefore sinter-plant production capacity, by up to 12%. This solution can be applied without modifying the supporting structure of the sinter machine. In Fig 3.5 a picture of Pallet car and Grate Bars are shown.

Fig 3.5 Grate Bars

- **Ignition Furnace**

Primetals Technology’s ignition furnace operates with intensive top burners for better heat distribution on the surface of the sinter strand: and, due to its special design, it also delivers lower fuel consumption compared with the conventional side-burner design. Typically Primetals Technology ignition furnaces have an inner length of approximately 3,300 millimeters when retrofitted in an existing plant, which typically increases the active sintering area (Fig 3.6).

The intensive ignition furnace with state-of-the art top burners features an advancedflame monitoring and gas control and regulation. This enables steady and constant ignition with temperatures of approximately 1,200°C or above. An additional benefit is that a very short installation period is guaranteed thanks to the pre- assembly procedures for the ignition- furnace chamber.

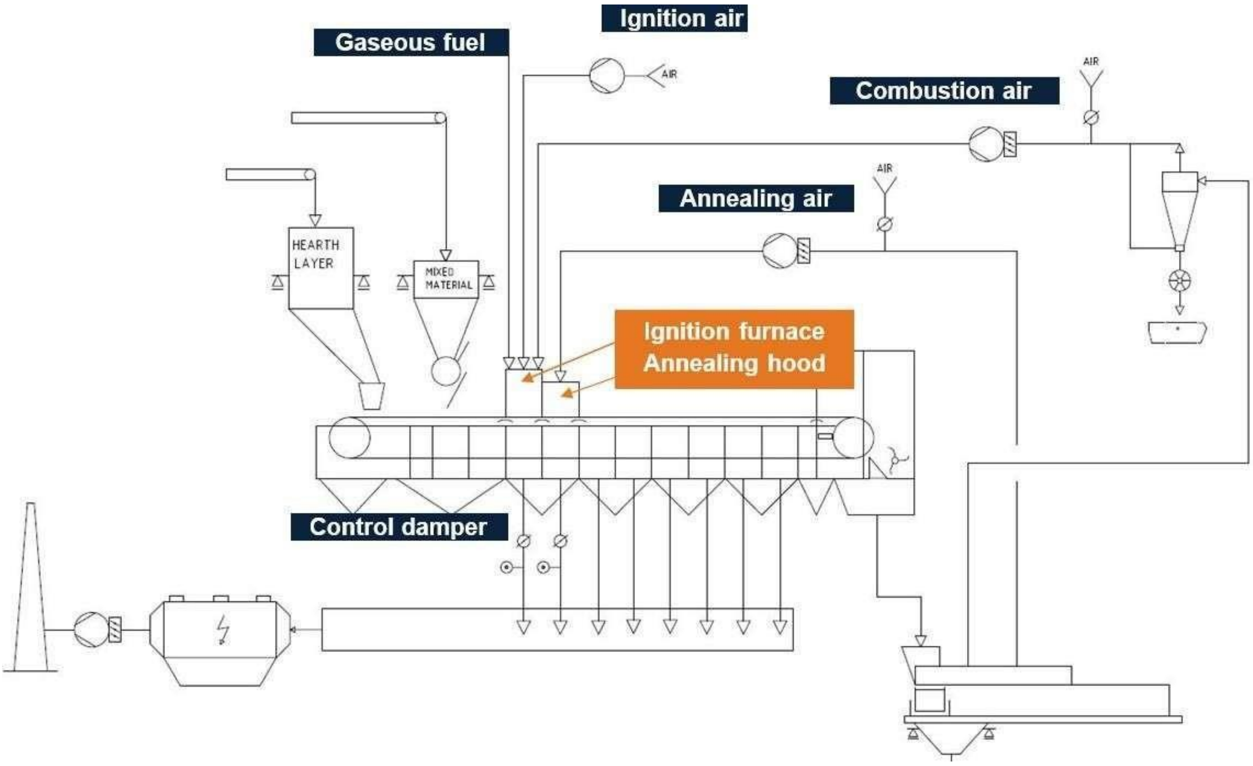


Fig 3.6 Ignition furnace

3.3 SINTER COOLER

- **Cooler charging chute**

  The advanced design of the cooler charging chute ensures a more homogeneous distribution of the sinter onto the sinter cooler, keeping pieces with larger diameters near the bottom and the smaller at the top. This increases cooling performance, reduces fan power consumption, and prevents damage to associated equipment.

- **Circular dip-rail cooler**

  The sinter cooler is designed based on Primetals Technology‘s patented grate-wing cooler trough technology to meet your requirements for higher efficiency and lower electrical energy consumption. The grate-wing design has special rubber seals between the moving cooler trough and the air-channel system that produce a more efficient utilization of the cooling air (Fig 3.7). Applying the new design to an existing conventional circular sinter cooler allows the cooling capacity to be increased by approximately 15 percent without increasing the cooling-air volume, and maintains the existing structure with minor modifications.

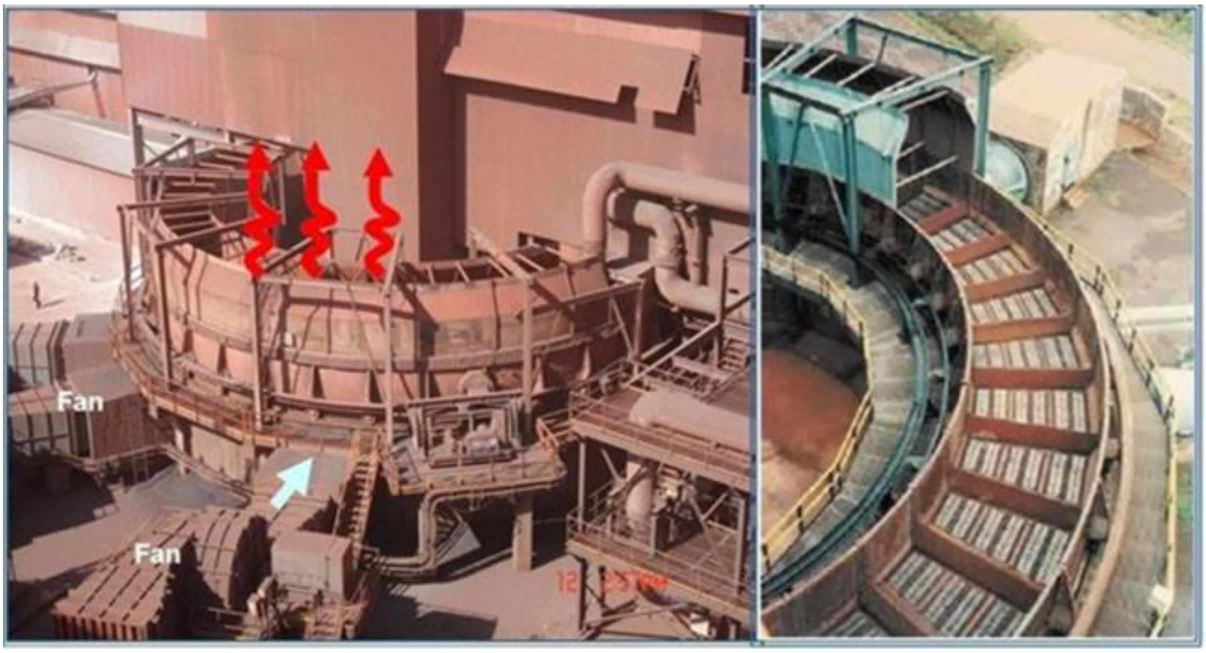


Fig 3.7 Sinter Cooler

3.4 SELECTIVE WASTE-GAS RECIRCULATION SYSTEM

Primetals Technology has developed and implemented new technologies that enable environmental emissions from sinter production to be reduced to heretofore unattained levels. This has been achieved with the introduction of a selective waste-gas recirculation system in which the off- gas from selected zones of the sinter machine is mixed with cooler off-air and is then recirculated to the sinter strand (Fig 3.8).

The selective waste-gas recirculation system was developed primarily to keep the off-gas volume at a constant level while increasing the sintering capacity and decreasing specific emissions. This allows investment and operating costs for gas-cleaning facilities to be held at acceptable levels. The selective waste-gas recirculation system from Primetals Technology can be installed in existing or in greenfield plants with or without capacity increase.

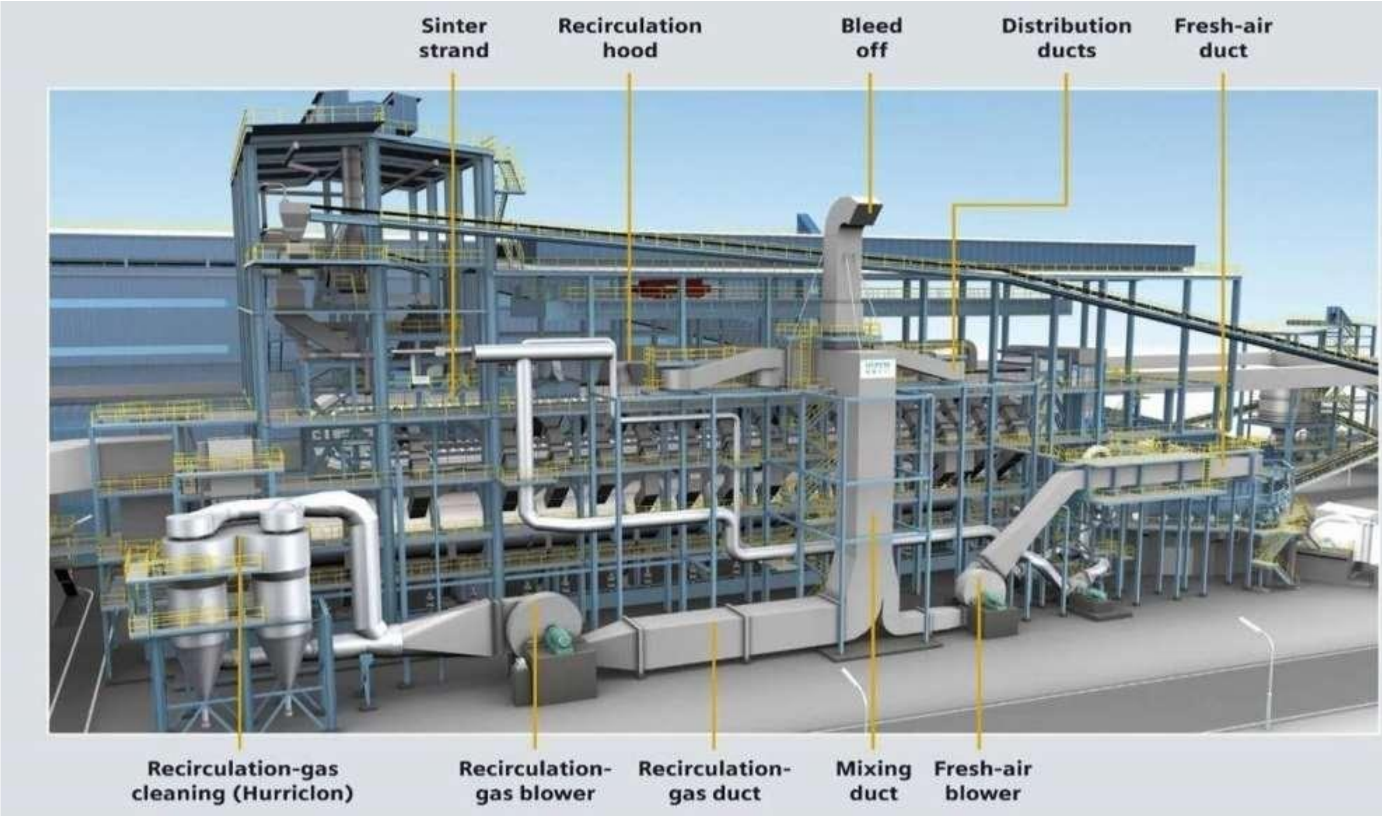


Fig 3.8 Selective Waste-Gas Recirculation System (SWGR)

- **Reasons for SWGR**
    - More stringent environmental regulations
    - Direct usage of process gases in the sintering process
- **Targets of SWGR**
    - Reduction of the off-gas volume to the stack
    - Therefore reduction of the CAPEX & OPEX of gas cleaning facilities
    - Reduction of specific solid fuel consumption and therefore carbon dioxide
- **Benefits of SWGR**
    - Waste-gas volume cut by up to 50 percent
    - Specific solid-fuel consumption decreased up to 10 percent
    - Lower investment and operating costs for waste-gas cleaning plant
    - Level of productivity and sinter quality is maintained

3.5 TECHNICAL SPECIFICATION OF SINTER PLANT

In a Sinter plant there are lots of parameter, which must be maintained in a Standard way. An example of important parameters of sinter plant is given In Table 3.2

Table 3.2 Specification of Sinter Plant

PARAMETER	VALUE
Designed Capacity	2.30 mtpa
Area	204 Sqm
Bed Height	700 mm
Pallet Width	3 m
Pallet Length	1 m
No. of Pallet Cars	167
Burner Type	Side Blown
Machine Length	68 m
Machine Speed	4.0 m/min
Fuel Type	Corex Gas
Wind Box Width	3 m
No. of Wind Boxes	17
Suction Pressure	170 mbar

3.6 SINTER PLANT MAIN MOTORS RATING

In a Sinter plant there are many motors are used in various sections. In Table 3.3 an example of technical specifications of motor used in sinter plant is given below

Table 3.3 Sinter Plant Main Motors KW Rating Details

SL. No	Equipment Details	360 Sqm SinterPlant (KW)	460 Sqm SinterPlant (KW)	490 Sqm SinterPlant (KW)
1	Waste Gas Fans (2 Fan)	2x7300	2x9580	2x10300
2	Cooler Fans (3 Fan)	3x2000	3x2000	3x2000
3	Intensive Mixer (4 Motor)	4x150	4x200	4x250
4	Intensive Granulator (4 Motor)	4x250	4x250	4x250
5	Plant Dedusting Pumps	1500	1500	2400
6	Star Crusher Unit	110	110	132
7	Combustion Air Fan (2 Fan)	2x90	2x200	2x400
8	Annealing Air Fan (2 Fan)	2x90	2x200	2x400

3.7 CONCLUSION

Various sections of Sinter plant are briefly described in this chapter along with the functionality and the types of process done in each section. Technical specification of the important parameters and ratings of the motors are also described in tabular format.

CHAPTER – 4

PROCESS AND CONTROL SYSTEM OF SINTER PLANT

4.1 DESCRIPTION OF SINTERING PROCESS

Sintering process (Fig 4.1) is a metallurgical process carried out on a sinter machine. It is a thermal agglomeration process. The sintering process is an energy intensive process, in which a number of parameters have to be considered. The process involves various physical and chemical phenomena such as heat, mass, and momentum transfer coupled with chemical reactions. This phenomena take place simultaneously which increases considerably the complexity of the process [15] .

Sintering process is basically a pre-treatment process step during ironmaking which is used to agglomerate a mix of iron ore fines, return fines, fluxes, and coke breeze, with a particle size of less than 10 mm, so it can withstand the pressure and the temperature conditions in the blast furnace. The agglomeration in the sintering process is achieved through combustion and suction. In this process air is sucked at the sinter strand through a bed of sinter mix. The fuel particles on the top surface layer are first ignited in a furnace and as the strand move forward, the ignited or combustion front proceeds gradually downwards through the bed until the end [16] .

Sintering process is an essential step in the blast furnace charge preparation where the agglomerate material (sinter) is required to have appropriate properties for the optimized hot metal production at the blast furnace. Further, it is also very important to control sinter plant gas emissions, which are produced in large volumes and contain a high number of polluting substances with different degrees of toxicity.

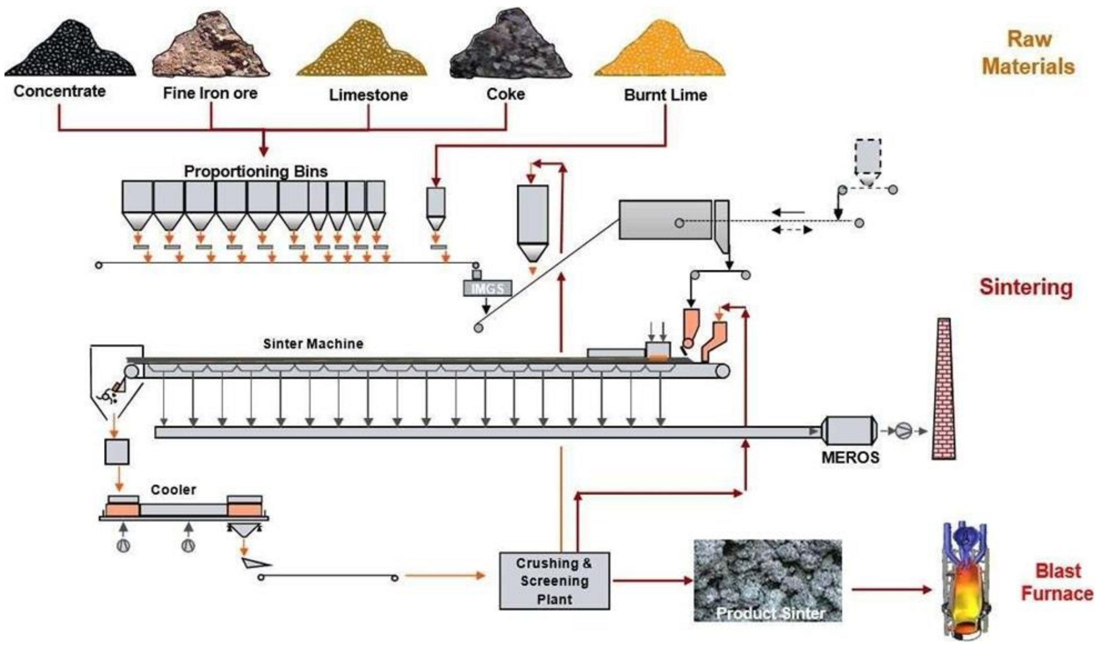


Fig 4.1 Sintering process

4.2 WORKING PRINCIPLE OF SINTER FURNACE

In the process of sintering, iron ore fines convert into lumped mass by incipient fusion. The term incipient fusion is used because the process takes place by partial combustion of ore with a fuel within the mass itself. The produced sinter possesses strength, permeability and fluxing agents that are beneficial to steel- making operations. It is a pre-processing step for blast furnace melting operations. The process starts with proportioning in which raw materials (Iron values, flux and fuel) are blended carefully in a fixed proportion. Usually metallurgical-grade coke is used as a fuel. The proportioned material is then sentto mixing drums for granulation. Granulation takes place in one or two mixing drums with addition of water and steam to help in mixing. The granulated micro- pellets are then fed to a sinter machine. Sinter machine is typically a continuous car-type furnace where each end corresponds to feeding and discharge, respectively. The pallet car consists of grates or strands connected through a belt and has a depth of 0.4–0.7 m and width of 1 m. typically, it moves at a speed of2–3 m/min . Granulated material is fed into those strands and are heated through a series of gas burners generating carbon content to combust and derive heat fromthe process. Atmospheric oxygen helps in exothermal combustion resulting in heat that allows the peak temperature to reach 1300 °C . A series of wind boxesare also connected with each strand that provides suction. The car moves horizontally and the process takes place vertically. A process of suction draws hot air and transmits heat to downward layers of the sinter bed.

Sintering provides heat only to combust the upper layer of the sinter bed. The rest of the layers are sintered with the heat provided by suction. Suction is powered by induction draught (ID) fan connected to an electrostatic separator (ESP). The waste flue gas is sucked through the ID fan and released free through chimney. At the end point, sinter cake falls from the strand through a roll breaker to cooler cars. The sintered product is cooled and then transferred to the screening section where it is classified by size fraction. While 5 mm material is transferred back to the proportioning Section, 5–40 mm material is forwarded to the blast furnace operations. A schematic diagram of the sintering furnace is given in Fig 4.2.

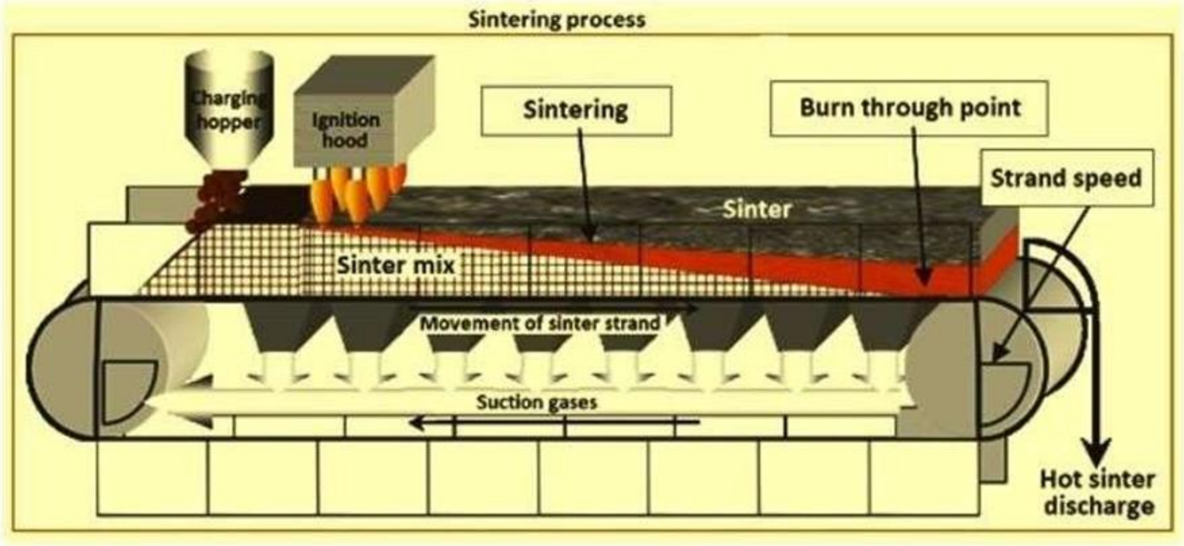


Fig 4.2 Sintering Furnace

Partial combustion of iron content takes place just below the melting point resulting in agglomeration of the fine iron particles into a porous mass. Sintering can be considered to be an energy-intensive, complex, non-linear and parallel process in which various parameters are necessary to determine the quality of sinter. A quality sinter can be ensured when parameters, such as, vertical sintering speed, flame front speed, burn-through temperature and sintering time are consistent in nature.

The sintering process involves a large number of parameters, each of which exerts a greater or lesser influence and is needed to be controlled, within the possible limits, in order to optimize productivity, process stability, and standardize the composition and quality of the sinter produced. Also, for meeting the statutory environmental requirements, a pollution control system is needed to monitor the particulate matter and gases generated and emitted into the atmosphere by the sinter plant. Further, year by year, improvements are being made to the sintering process because of the accumulated experience of plant operators and the evolution and progress in sintering.

Air suction system (Fig 4.3) in sinter plant is needed for meeting the above requirements. It is needed for ensuring effective control of systems, timely supply of the process information, and total cost minimization, while meeting the production and quality requirements. Further, automation and control system is needed for building a data base necessary for the data analysis and to incorporate the analytical tools for this purpose.

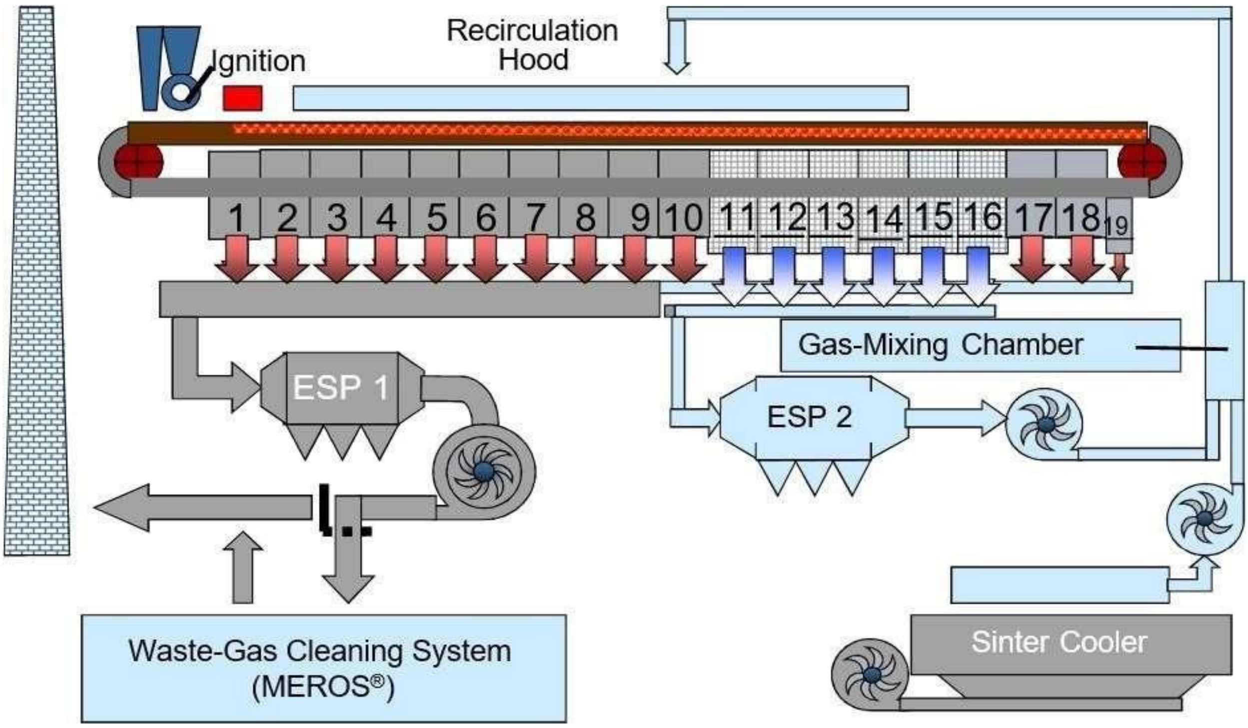


Fig 4.3 Air suction process Overview

A reliable and well proven basis automation control system is the backbone of modern sinter plant operation (Fig 4.4). The main objectives of the sinter plant process control system are:

- Minimizing fuel consumption since the fuel rate is a key factor in production costs
- Avoidance of heavy control actions since if only minor control actions are necessary, the sinter machine performance is stabilized considerably
- Avoidance of critical process situations because the sooner the system reacts tocritical process situations, such as an in homogeneous mixture, poor surface ignition, or incomplete burn through of the sinter mix, the smoother the overallsintering process is, resulting in a more uniform product quality
- Coordinated operational decisions throughout all the shifts result into constant operating conditions throughout all the shifts which increase the lifetime of the equipment and reduce production costs.
- Reduction of emissions since with the closed-loop operation mode of the process control system, the production parameters can be optimized within the environmental emission limits, in particular, SO_2 emissions.

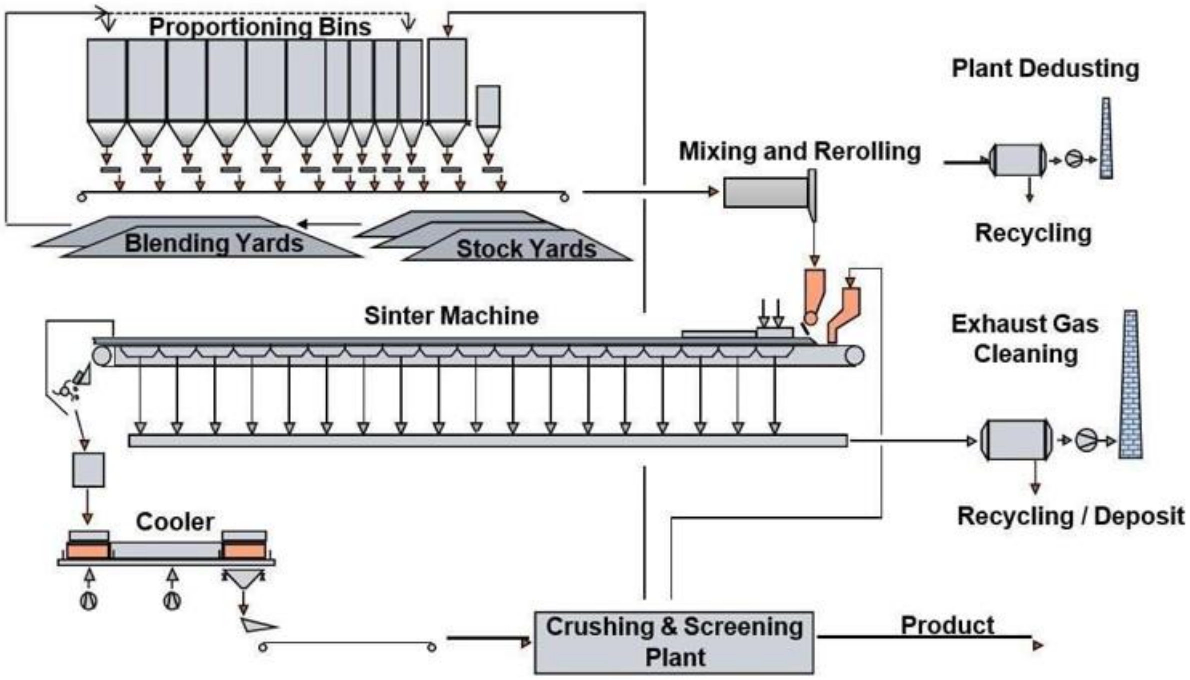


Fig 4.4 Conventional Flow Sheet of Sinter Plant

In the sintering process, chemical and physical parameters such as product sizesare to satisfy preset target values within defined standard deviations to meet the quality requirements of the blast furnace. The chemical properties are to be homogenized by an automatic adaptation of the raw material mix. An enhanced ‘burn- through point’ (BTP) control system (Fig 4.5) which considers physical and chemical properties of the sinter mix is to be incorporated in the system [17].

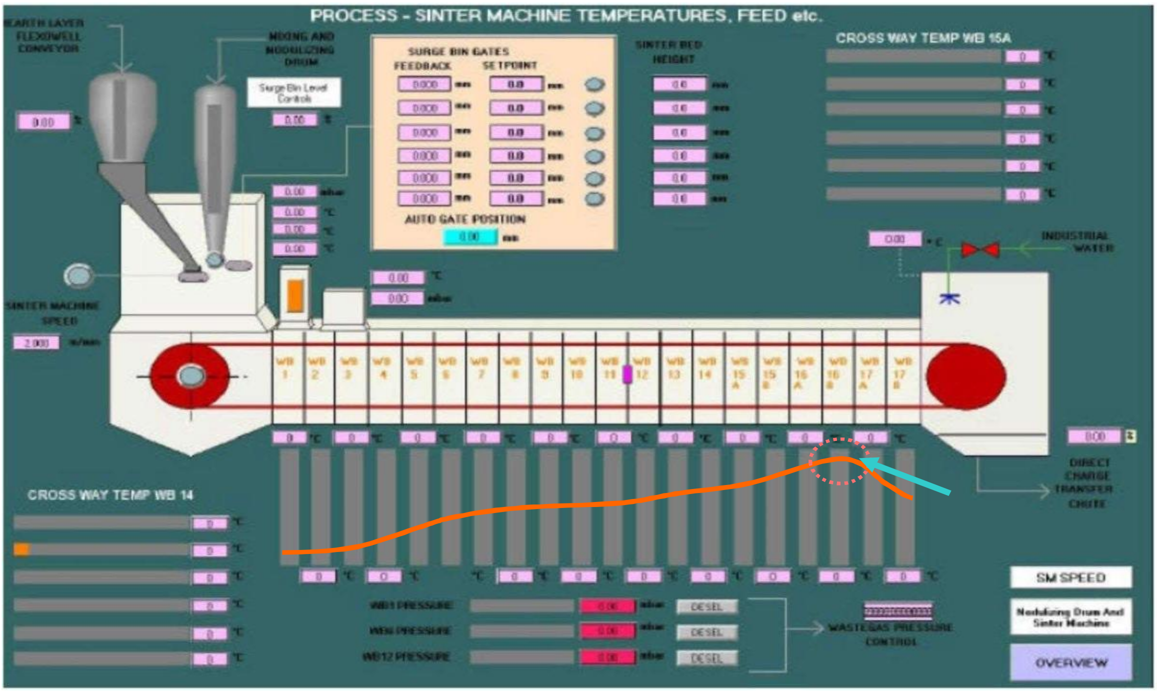


Fig 4.5 Burn Through Point control

The automation and control system of the sinter plant is a modern user friendly tool which helps in improving the productivity and stability of the sinter plant. It helps in improving the performance of the sinter plant by addressing to the needs of the plant. It stabilizes production of sinter, helps in reaching of the anticipated result and has an immense practical value [18] .

4.3 BENEFITS OF SINTER PLANT

There are some advantages of sinter plant is mentioned below.

(i) High productivity since it keep the sinter plant running at peak performance while minimizing consumption of electric energy and fuel.
(ii) Product quality which means that the sinter maintains the chemical, physical, and mechanical properties sinter at the desired levels.
(iii) Reduced fuel consumption which is due to the result of the precise mixing of charged materials and the ideal control of the quantity of return fines considering the thermal conditions of the sinter on the strand.
(iv) Easy integration of a comprehensive range of metallurgical models intothe automation and control system.
(v) Fast response to the demands of blast furnace.

4.4 CONCLUSION

The working principle of sintering process is explained in this chapter. The main objectives of the sinter plant are discussed along with the benefits of sintering process. Burn Through Point control, which is the most crucial part of this process is described here with schematic diagram.

CHAPTER – 5

DEVELOPMENT OF PUMPING SYSTEM OF SINTER PLANT USING PLC PROGRAMMING

5.1 PROBLEM NAME: - PUMPING SYSTEM OF SINTER PLANT

- **Problem Statement: -**

Reservoir is the main source of water supply. It consists of both high level and low level switch. A water tank also consists of both high level and low level switch. Water is transferred from reservoir to tank until it reaches to the high level switch. The low level switch is activated when the water level reaches the minimum position and the high level switch is activated when the water level reaches the maximum position for both reservoir and tank. Suction valve and delivery valve are also attached to the pipeline consisting of open limit switch and close limit switch. The running feedback of the pumps checks the continuous flow of water and after the specific time the pressure switch attached to the line starts working accordingly. When the water level of the tank reaches the low level switch Pump 2 have to be start to avoid drained out condition. Here there are two modes in which the pump can be operated, it can be done either in Local mode or Remote mode. Local mode is used when the pump needs to be operated locally from the Local Control Panel. Remote mode consists of two others modes, Auto mode and Manual mode. Manual mode is used when the pump is operated manually by seeing all the conditions from HMI. Auto mode is used when the pump is operated automatically.

5.2 DEVELOPMENT STEPS

- **Step 1 :**

Initially prepare the **I/O list** for the required project.

There are Digital Input, Digital output, Analog input are present in the I/O list

- Table 5.1 shows the Digital inputs
- Table 5.2 shows the Digital Outputs
- Table 5.3 shows the Analog inputs

Table 5.1 Digital inputs

S/L No	Symbol	Address	Description	Location
1	P1_START	I 10.0	Reservoir Pump Start	LCP BOX
2	P1_STOP	I 10.1	Reservoir Pump Stop	LCP BOX
3	P1_ESTOP	I 10.2	Reservoir Pump Emergency Stop	LCP BOX
4	P1_LOCAL	I 10.3	Reservoir Pump Local	LCP BOX
5	P1_REMOTE	I 10.4	Reservoir Pump Remote	LCP BOX
7	P1_RUN	I 10.5	Reservoir Pump Run Feedback	MCC Panel
8	P1_MCCOK	I 10.6	Reservoir Pump MCC Healthy	MCC Panel
9	P2_START	I 10.7	Tank Pump Start	LCP BOX
10	P2_STOP	I 11.0	Tank Pump Stop	LCP BOX
11	P2_ESTOP	I 11.1	Tank Pump Emergency Stop	LCP BOX
12	P2_LOCAL	I 11.2	Tank Pump Local	LCP BOX
13	P2_REMOTE	I 11.3	Tank Pump Remote	LCP BOX
15	P2_RUN	I 11.4	Tank Pump Run Feedback	MCC Panel
16	P2_MCCOK	I 11.5	Tank Pump MCC Healthy	MCC Panel
17	V1_OPEN	I 11.6	Suction Valve Open Feedback	Field JB
18	V1_CLOSE	I 11.7	Suction Valve Close Feedback	Field JB
19	V2_OPEN	I 12.0	Delivery Valve Open Feedback	Field JB
20	V2_CLOSE	I 12.1	Delivery Valve Close Feedback	Field JB
21	LSH_1	I 12.2	High Level Switch of Reservoir	Field JB
22	LSL_1	I 12.3	Low Level Switch of Reservoir	Field JB
23	LSH_2	I 12.4	High Level Switch of Tank	Field JB
24	LSL_2	I 12.5	Low Level Switch of Tank	Field JB

Table 5.2 Digital Outputs

S/L No	Symbol	Address	Description	Location
1	P1_ON_CMD	Q 10.0	Reservoir Pump ON Command	MCC Panel
3	P1_RUN_IND	Q 10.1	Reservoir Pump Run Indication	LCP Box
4	P1_FLT_IND	Q 10.2	Reservoir Pump Fault Indication	LCP Box
5	P2_ON_CMD	Q 10.3	Tank Pump ON Command	MCC Panel
7	P2_RUN_IND	Q 10.4	Tank Pump Run Indication	LCP Box
8	P2_FLT_IND	Q 10.5	Tank Pump Fault Indication	LCP Box
9	V1_OPN_CMD	Q 10.6	Suction Valve Open Command	Field JB
10	V1_CLS_CMD	Q 10.7	Suction Valve Close Command	Field JB
11	V2_OPN_CMD	Q 11.0	Delivery Valve Open Command	Field JB
12	V2_CLS_CMD	Q 11.1	Delivery Valve Close Command	Field JB

Table 5.3 Analog Inputs

S/L No	Symbol	Address	Description	Location
1	LT_RESV	IW 512	Reservoir Level Transmeter	Field Instrument
2	LT_TANK	IW 514	Tank Level Transmeter	Field Instrument
3	FT_SUC	IW 516	Suction Line Flow Transmeter	Field Instrument
4	FT_DEL	IW 518	Delivery Line Flow Transmeter	Field Instrument
5	PT_SUC	IW 520	Suction Line Pressure Transmeter	Field Instrument
6	PT_DEL	IW 522	Delivery Line Pressure Transmeter	Field Instrument

- **Step 2 :**

  Open the **Simatic Manager Software**

- In the 'New' option, a new Project "**THESIS**" is created, the name and the location is specified.
- When the project is created, a dialogue is opened in the left side of the screen.
- Data blocks are now created in the same window.
- When all the blocks are made, then they are saved individually and downloaded (Fig 5.1).

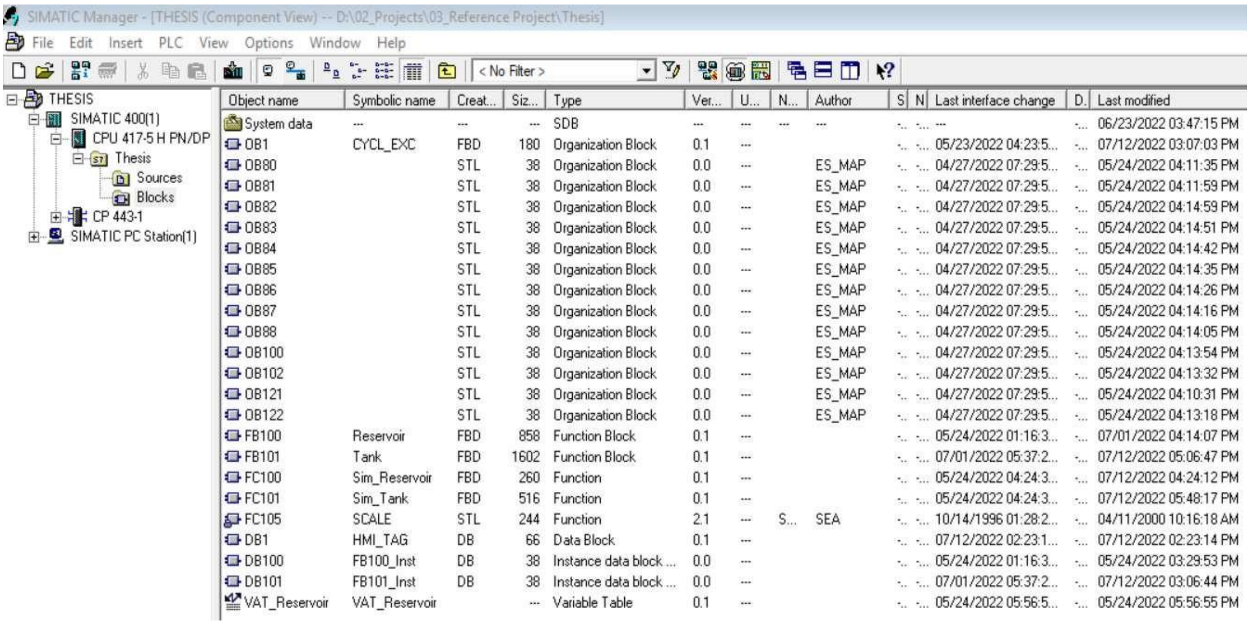


Fig 5.1 Simatic manager

➢ Step 3 :

Hardware configuration needs to be configured for established the connection between PLC and Engineering Station (Fig 5.2).

- For the PLC Programming part, we need to create a RACK which can hold the Power Supply, The Interface Module, and The RIO Cards and in case the Project is large redundant modules is needed to be created [19] .
- So, in Simatic Manager Software, there is an option Called Hardware Configuration, which makes the Simulation Hardware for PLC.
- Select real life PS models, CPU, DP, MPIs, Industrial Ethernet and Profibus for PLC communication. Mostly Ethernet (TCP / IP) is used.
- Here searching for RACK NO. using this 6ES7153-1AA-0XB0. Then a dialogue box will appear->Here we search for PS, CPU, and CP using their respective MLFB numbers.
- All of them are dragged to the table by clicking on Insert Object.
- Now in the Simatic Manager, in Options, in PG/PC interface, the required mode of connection is selected like TCP/IP or PROFIBUS, or MPI or TCP/IP Internal, MPI internal, or PROFIBUS Internal.
- It needs to select the CPU, right click on the DP part of it. A dialogue box will appear with the name PROFIBUS. We need to get it networked by giving it an address [20].
- After making these connections, the Hardware is saved, compiled, and downloaded in the PLC.

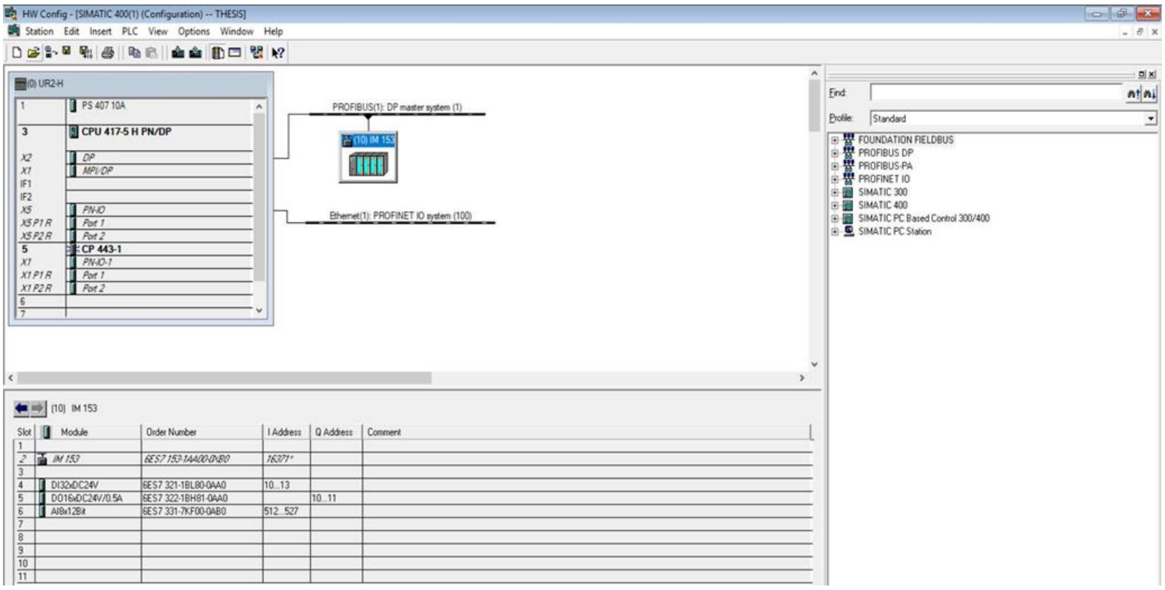
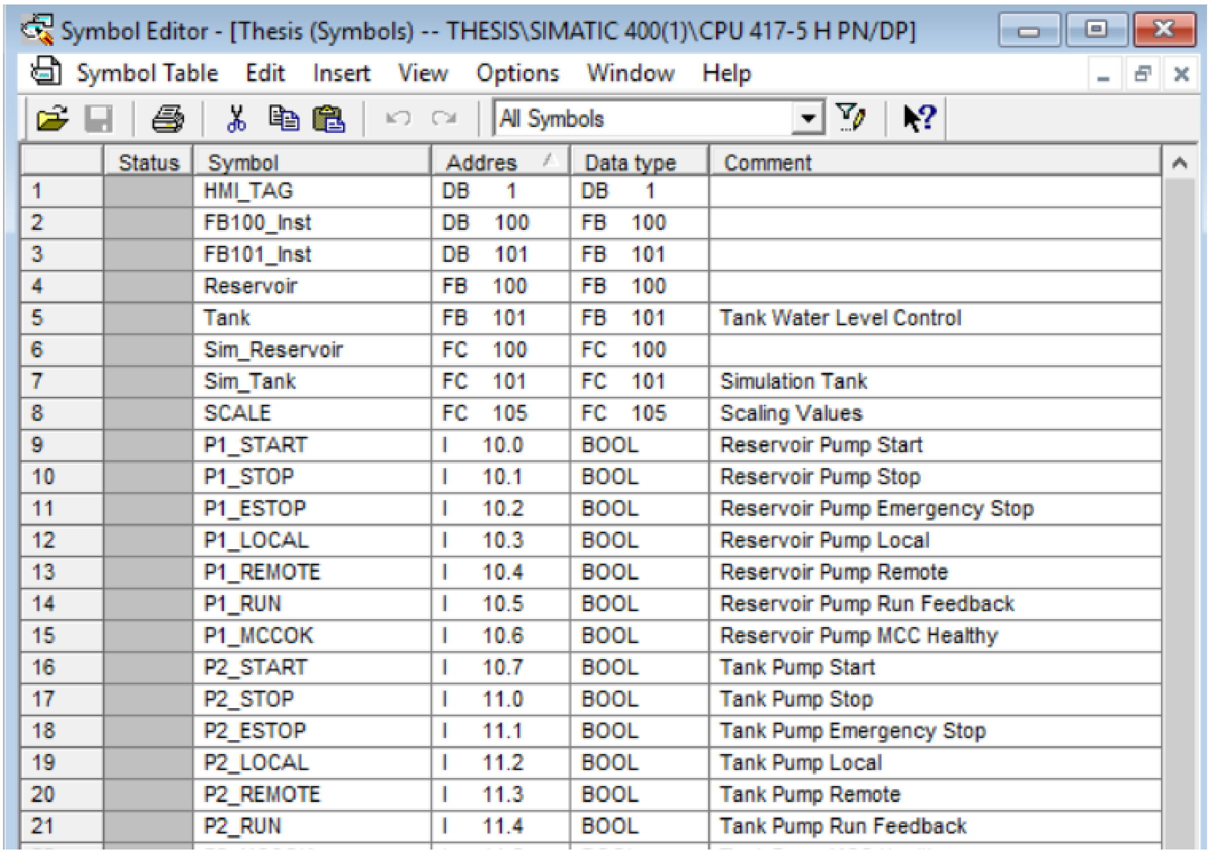


Fig 5.2 Hardware configuration.

➢ Step 4 :

After Hardware configuration the I/O list to be implemented in the **Symbol table**. So that by writing the program we used the address of the signals [21] .

In this program the implemented symbol list is shown in Fig 5.3.



	Status	Symbol	Addres	Data type	Comment
1		HMI_TAG	DB 1	DB 1	
2		FB100_Inst	DB 100	FB 100	
3		FB101_Inst	DB 101	FB 101	
4		Reservoir	FB 100	FB 100	
5		Tank	FB 101	FB 101	Tank Water Level Control
6		Sim_Reservoir	FC 100	FC 100	
7		Sim_Tank	FC 101	FC 101	Simulation Tank
8		SCALE	FC 105	FC 105	Scaling Values
9		P1_START	I 10.0	BOOL	Reservoir Pump Start
10		P1_STOP	I 10.1	BOOL	Reservoir Pump Stop
11		P1_ESTOP	I 10.2	BOOL	Reservoir Pump Emergency Stop
12		P1_LOCAL	I 10.3	BOOL	Reservoir Pump Local
13		P1_REMOTE	I 10.4	BOOL	Reservoir Pump Remote
14		P1_RUN	I 10.5	BOOL	Reservoir Pump Run Feedback
15		P1_MCCOK	I 10.6	BOOL	Reservoir Pump MCC Healthy
16		P2_START	I 10.7	BOOL	Tank Pump Start
17		P2_STOP	I 11.0	BOOL	Tank Pump Stop
18		P2_ESTOP	I 11.1	BOOL	Tank Pump Emergency Stop
19		P2_LOCAL	I 11.2	BOOL	Tank Pump Local
20		P2_REMOTE	I 11.3	BOOL	Tank Pump Remote
21		P2_RUN	I 11.4	BOOL	Tank Pump Run Feedback

Fig 5.3 Symbol table

➢ Step 5 :

After that the program is written in either Ladder logic or Statement List or Function block Diagram.

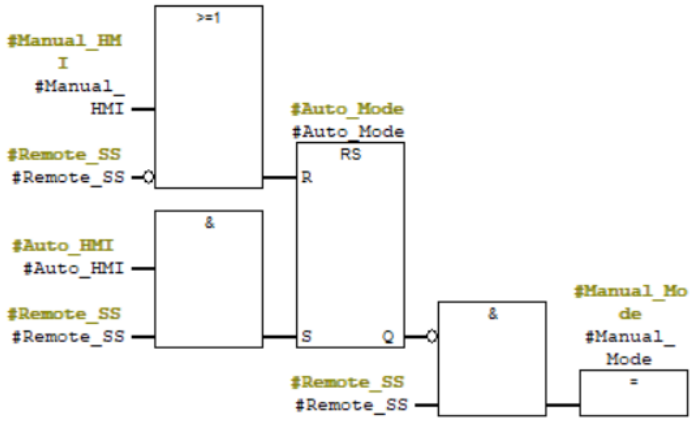
- In this problem **Statement List** is used for variable declaration[22]
- **Function Block Diagram** is used is implemented the logical flow [23].

The program of Reservoir and Tank are described in next page.

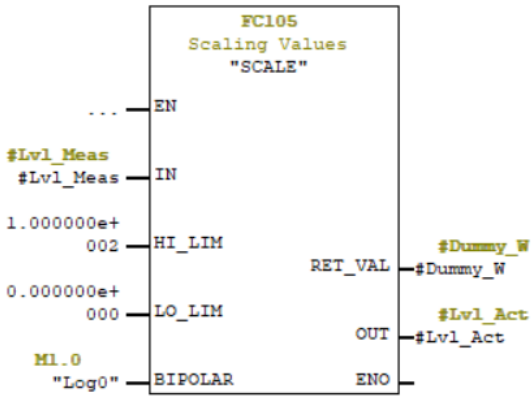
❖ Reservoir water level Control Program:

```
FB100 : Reservoir Water Level Control

Comment:

⊟ Network 1 : Read Inpts from LCP

      A     "P1_START"          I10.0          -- Reservoir Pump Start
      =     #Start_PB           #Start_PB

      AN    "P1_STOP"           I10.1          -- Reservoir Pump Stop
      =     #Stop_PB            #Stop_PB

      AN    "P1_ESTOP"          I10.2          -- Reservoir Pump Emergency Stop
      =     #ESTOP_PB           #ESTOP_PB

      A     "P1_LOCAL"          I10.3          -- Reservoir Pump Local
      =     #Local_SS           #Local_SS

      A     "P1_REMOTE"         I10.4          -- Reservoir Pump Remote
      =     #Remote_SS          #Remote_SS


⊟ Network 2 : Read Inpts from MCC
      A     "P1_RUN"            I10.5          -- Reservoir Pump Run Feedback
      =     #Run_FB             #Run_FB

      A     "P1_MCCOK"          I10.6          -- Reservoir Pump MCC Healthy
      =     #Mcc_OK             #Mcc_OK
⊟ Network 3 : Read Inpts from Field JB
      AN    "LSH_1"             I12.2          -- High Level Switch of Reservoir
      =     #High_LS            #High_LS

      AN    "LSL_1"             I12.3          -- Low Level Switch of Reservoir
      =     #Low_LS             #Low_LS

      L     "LT_RESV"           IW512          -- Reservoir Level Transmeter
      T     #Lvl_Meas           #Lvl_Meas

⊟ Network 4 : Read Inpts from HMI
      A     "HMI_TAG".AUTO          DB1.DBX3.0     -- Auto Mode
      =     #Auto_HMI               #Auto_HMI

      A     "HMI_TAG".MANUAL        DB1.DBX3.1     -- Manual Mode
      =     #Manual_HMI             #Manual_HMI

      A     "HMI_TAG".P1_START_HMI  DB1.DBX3.2     -- Reservoir Pump Start from HMI
      =     #P1_start_HMI           #P1_start_HMI

      A     "HMI_TAG".P1_STOP_HMI   DB1.DBX3.3     -- Reservoir Pump Stop from HMI
      =     #P1_stop_HMI            #P1_stop_HMI

⊟ Network 5 : Read Inpts from Other Modules
      A     "Res_Lvl_Lo"        M400.0
      =     #Res_Lvl_Lo         #Res_Lvl_Lo

      A     "Res_Lvl_LoLo"      M500.0
      =     #Res_Lvl_LoLo       #Res_Lvl_LoLo
```

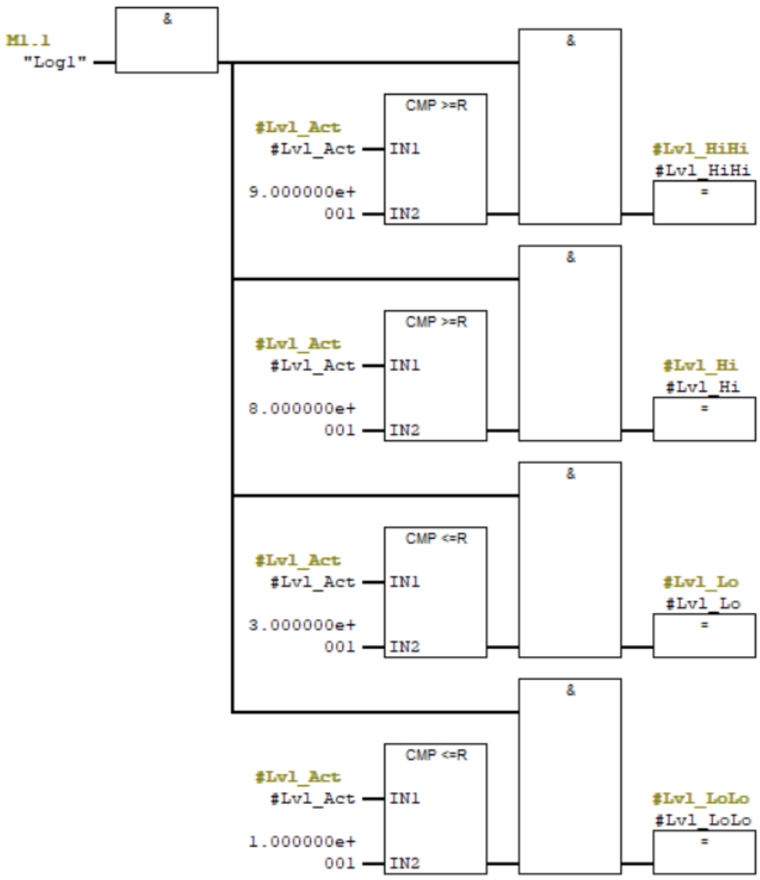
⊟ **Network 6** : Auto/Manual Selection from HMI



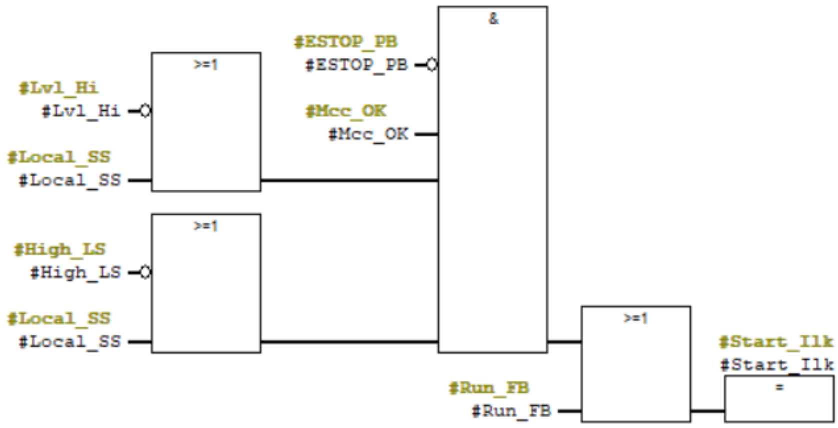
⊟ **Network 7** : Level Measurement Scaling



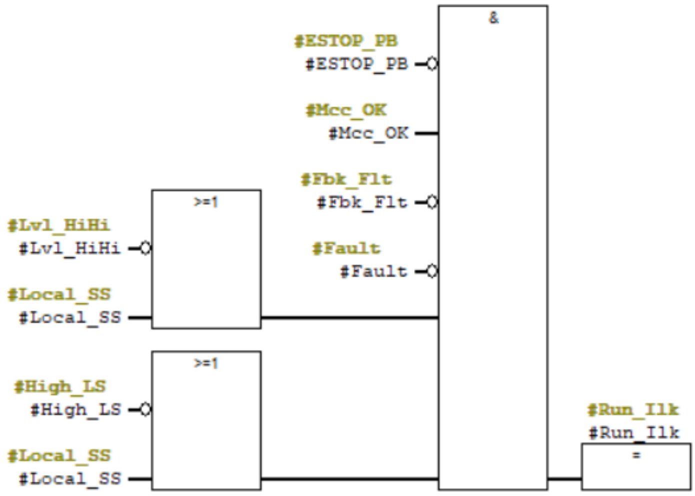
⊟ **Network 8** : Alarm, Warning from Level Measurement



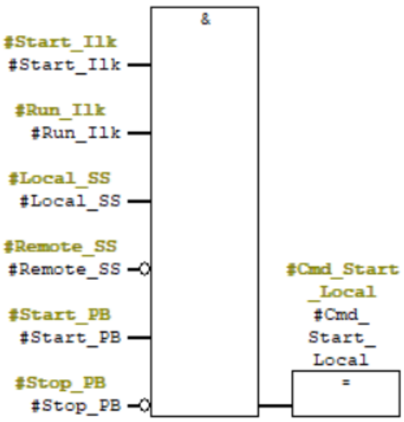
⊟ **Network 9** : Start Interlock



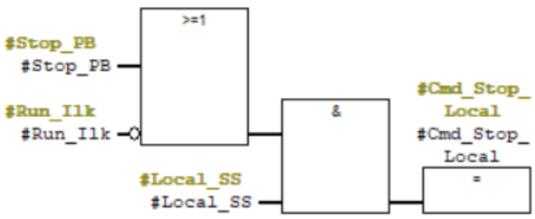
⊟ **Network 10** : Run Interlock



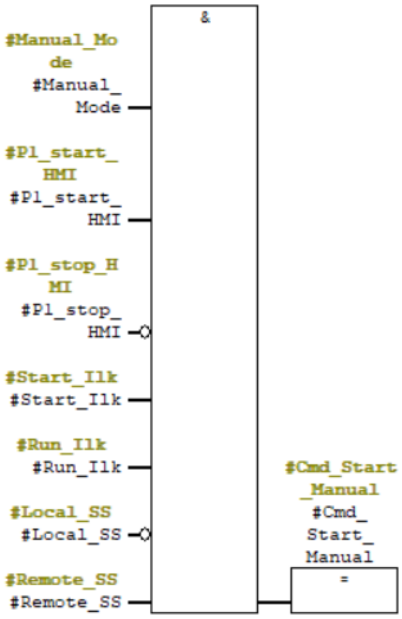
⊟ **Network 11** : Local Start Command



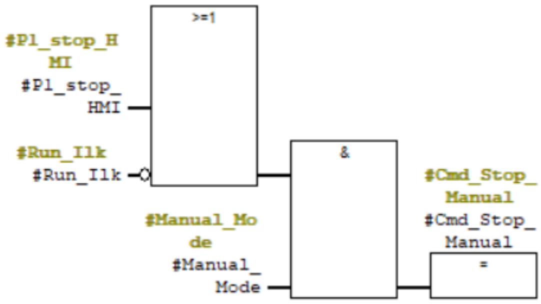
⊟ **Network 12** : Local Stop Command



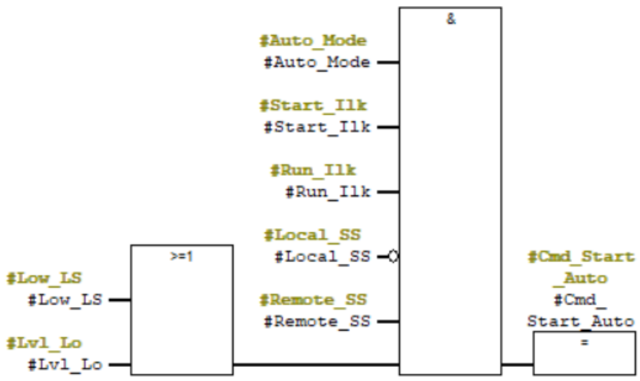
Network 13 : Manual Start Command



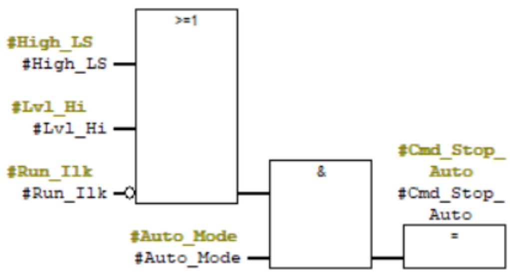
Network 14 : Manual Stop Command



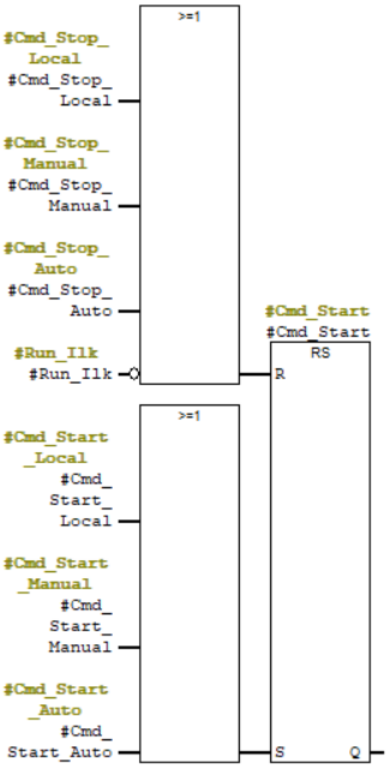
Network 15 : Auto Start Command



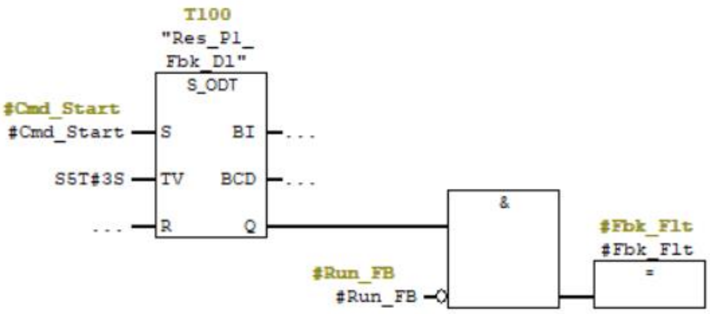
Network 16 : Auto Stop Command



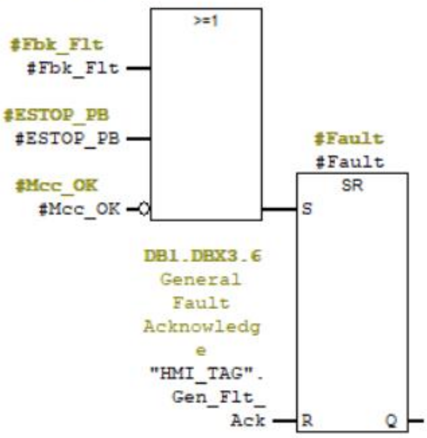
⊟ **Network 17** : Start/Stop Command



⊟ **Network 18** : Feedback Fault



⊟ **Network 19** : Fault



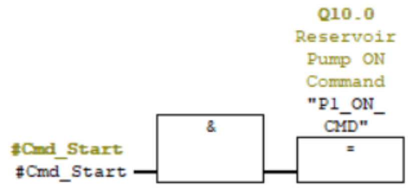
Network 20 : Write Outputs to LCP

```
A      #Run_FB                      #Run_FB
=      "P2_RUN_IND"                 Q10.4          -- Tank Pump Run Indication


A      #Fault                       #Fault
=      "P2_FLT_IND"                 Q10.5          -- Tank Pump Fault Indication
```

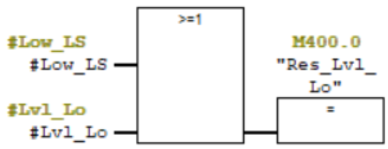
Network 21 : Write Outputs to HMI

```
A      #Run_FB                      #Run_FB
=      "HMI_TAG".P1_RUN             DB1.DBX0.5     -- Reservoir Pump Run

A      #Mcc_OK                      #Mcc_OK
AN     #Fault                       #Fault
=      "HMI_TAG".P1_READY           DB1.DBX0.6     -- Reservoir Pump Ready

A      #Fault                       #Fault
=      "HMI_TAG".P1_FAULT           DB1.DBX0.7     -- Reservoir Pump Fault

A      #High_LS                     #High_LS
=      "HMI_TAG".RES_LSH            DB1.DBX2.0     -- Reservoir High Level Switch

A      #Low_LS                      #Low_LS
=      "HMI_TAG".RES_LSL            DB1.DBX2.1     -- Reservoir Low Level Switch

L      #Lvl_Act                     #Lvl_Act
T      "HMI_TAG".RES_LT             DB1.DBD4       -- Reservoir Level Transmeter

A      #Auto_Mode                   #Auto_Mode
=      "HMI_TAG".AUTO_MODE          DB1.DBX28.0    -- Auto_Mode

A      #Manual_Mode                 #Manual_Mode
=      "HMI_TAG".MANUAL_MODE        DB1.DBX28.1    -- Manual_Mode
```

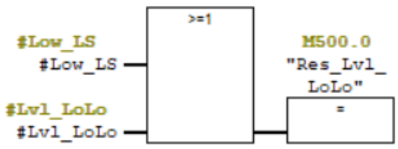
Network 22 : Write Outputs to MCC



Network 23 : Title:



Network 24 : Title:



❖ Tank water level Control Program

```
FB101 : Tank Water Level Control

Comment:

Network 1 : Read Inpts from LCP

      A     "P2_START"          I10.7              -- Tank Pump Start
      =     #Start_PB           #Start_PB

      AN    "P2_STOP"           I11.0              -- Tank Pump Stop
      =     #Stop_PB            #Stop_PB

      AN    "P2_ESTOP"          I11.1              -- Tank Pump Emergency Stop
      =     #ESTOP_PB           #ESTOP_PB

      A     "P2_LOCAL"          I11.2              -- Tank Pump Local
      =     #Local_SS           #Local_SS

      A     "P2_REMOTE"         I11.3              -- Tank Pump Remote
      =     #Remote_SS          #Remote_SS


Network 2 : Read Inpts from MCC
      A     "P2_RUN"            I11.4              -- Tank Pump Run Feedback
      =     #Run_FB             #Run_FB

      A     "P2_MCCOK"          I11.5              -- Tank Pump MCC Healthy
      =     #Mcc_OK             #Mcc_OK

Network 3 : Read Inpts from Field JB
      AN    "LSH_2"             I12.4              -- High Level Switch of Tank
      =     #High_LS            #High_LS

      AN    "LSL_2"             I12.5              -- Low Level Switch of Tank
      =     #Low_LS             #Low_LS

      L     "LT_TANK"           IW514              -- Tank Level Transmeter
      T     #Lvl_Meas           #Lvl_Meas

      A     "V1_OPEN"           I11.6              -- Suction Valve Open Feedback
      =     #S_Valve_open       #S_Valve_open

      AN    "V1_OPEN"           I11.6              -- Suction Valve Open Feedback
      =     #S_Valve_close      #S_Valve_close

      A     "V2_OPEN"           I12.0              -- Delivery Valve Open Feedback
      =     #D_Valve_open       #D_Valve_open

      A     "V2_CLOSE"          I12.1              -- Delivery Valve Close Feedback
      =     #D_Valve_close      #D_Valve_close

      L     "FT_SUC"            IW516              -- Suction Line Flow Transmeter
      T     #S_Flow_Meas        #S_Flow_Meas

      L     "FT_DEL"            IW518              -- Delivery Line Flow Transmeter
      T     #D_Flow_Meas        #D_Flow_Meas

      L     "PT_SUC"            IW520              -- Suction Line Pressure Transmeter
      T     #S_Press_Meas       #S_Press_Meas

      L     "PT_DEL"            IW522              -- Delivery Line Pressure Transmeter
      T     #D_Press_Meas       #D_Press_Meas
```

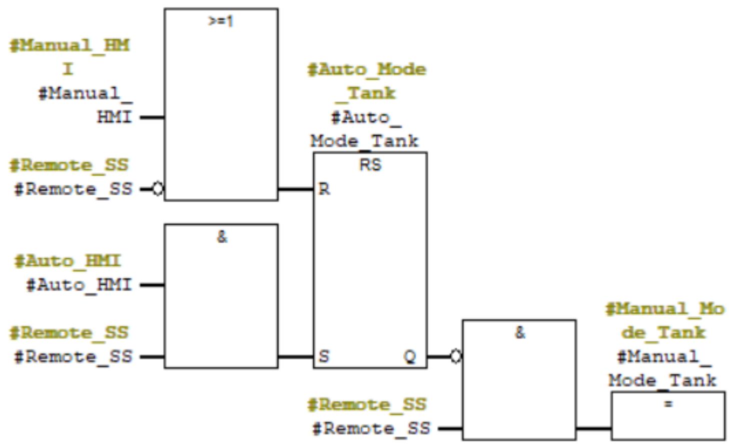
Network 4 : Read Inpts from HMI

```
A    "HMI_TAG".AUTO          DB1.DBX3.0       -- Auto Mode
=    #Auto_HMI               #Auto_HMI

A    "HMI_TAG".MANUAL        DB1.DBX3.1       -- Manual Mode
=    #Manual_HMI             #Manual_HMI

A    "HMI_TAG".P2_START_HMI  DB1.DBX3.4       -- Tank Pump Start from HMI
=    #P2_start_HMI           #P2_start_HMI

A    "HMI_TAG".P2_STOP_HMI   DB1.DBX3.5       -- Tank Pump Stop from HMI
=    #P2_stop_HMI            #P2_stop_HMI

A    "HMI_TAG".V1_OPEN_HMI   DB1.DBX28.2      -- Suction Valve open from HMI
=    #V1_open_HMI            #V1_open_HMI

A    "HMI_TAG".V1_CLOSE_HMI  DB1.DBX28.3      -- Suction Valve close from HMI
=    #V1_close_HMI           #V1_close_HMI

A    "HMI_TAG".V2_OPEN_HMI   DB1.DBX28.4      -- Delivery Valve open from HMI
=    #V2_open_HMI            #V2_open_HMI

A    "HMI_TAG".V2_CLOSE_HMI  DB1.DBX28.5      -- Delivery Valve close from HMI
=    #V2_close_HMI           #V2_close_HMI
```

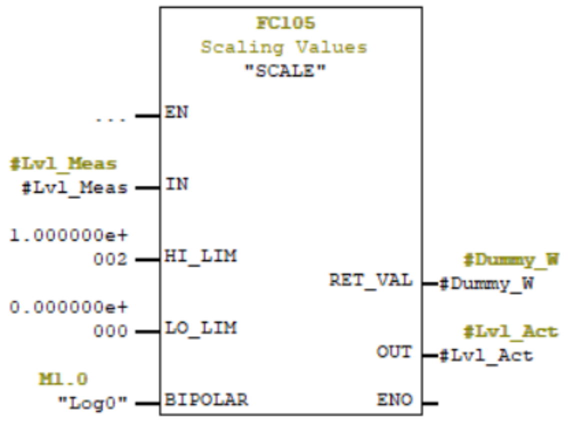
Network 5 : Read Inpts from Other Modules

```
A    "Res_Lvl_Lo"            M400.0
=    #Res_Lvl_Lo             #Res_Lvl_Lo

A    "Res_Lvl_LoLo"          M500.0
=    #Res_Lvl_LoLo           #Res_Lvl_LoLo
```

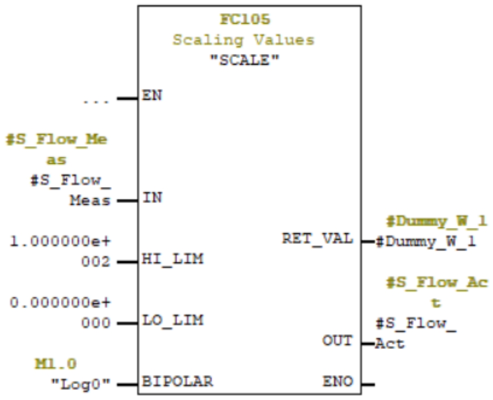
Network 6 : Auto/Manual Selection from HMI



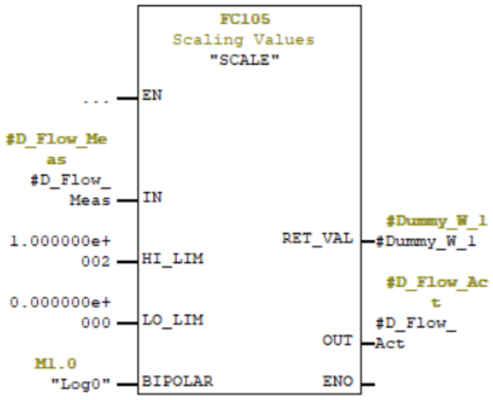
Network 7 : Level Measurement Scaling



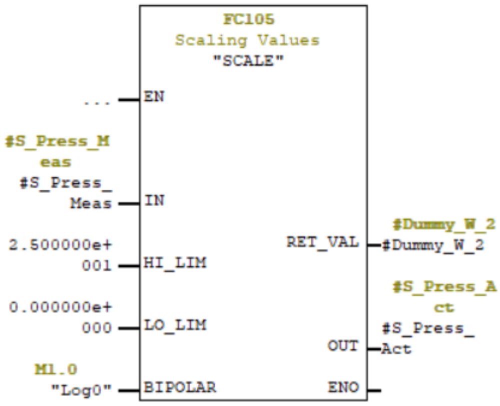
Network 8 : Flow Measurement Scaling



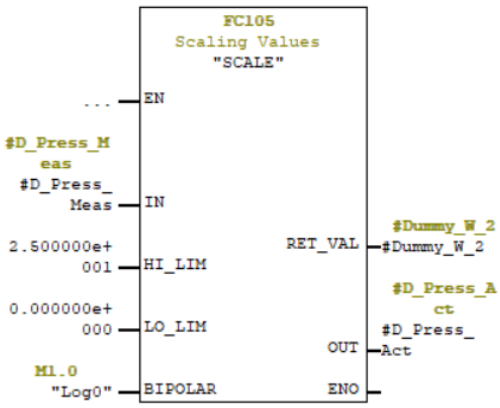
Network 9 : Flow Measurement Scaling



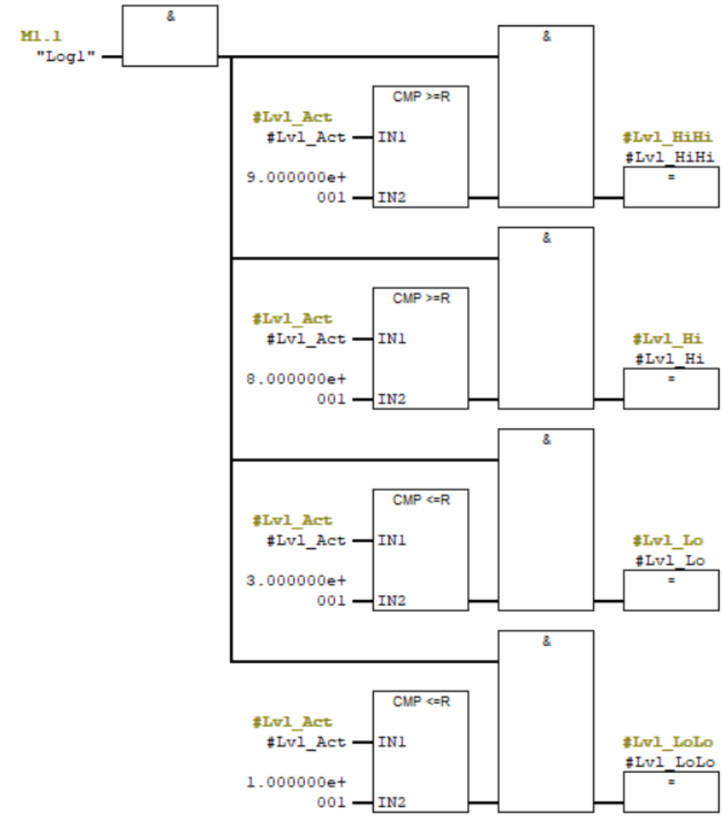
Network 10 : Pressure Measurement Scaling



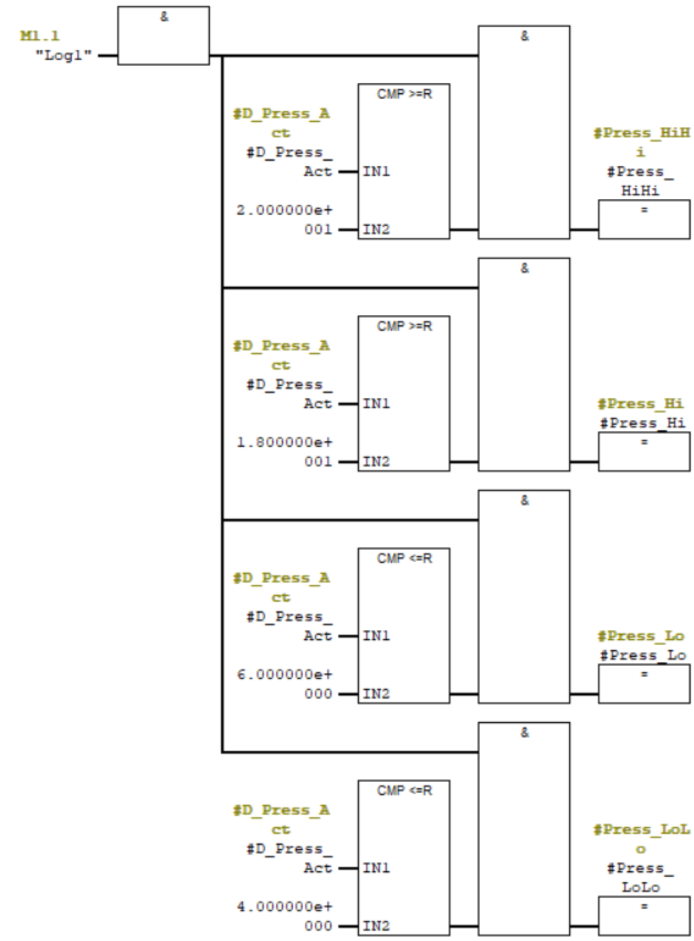
Network 11 : Pressure Measurement Scaling



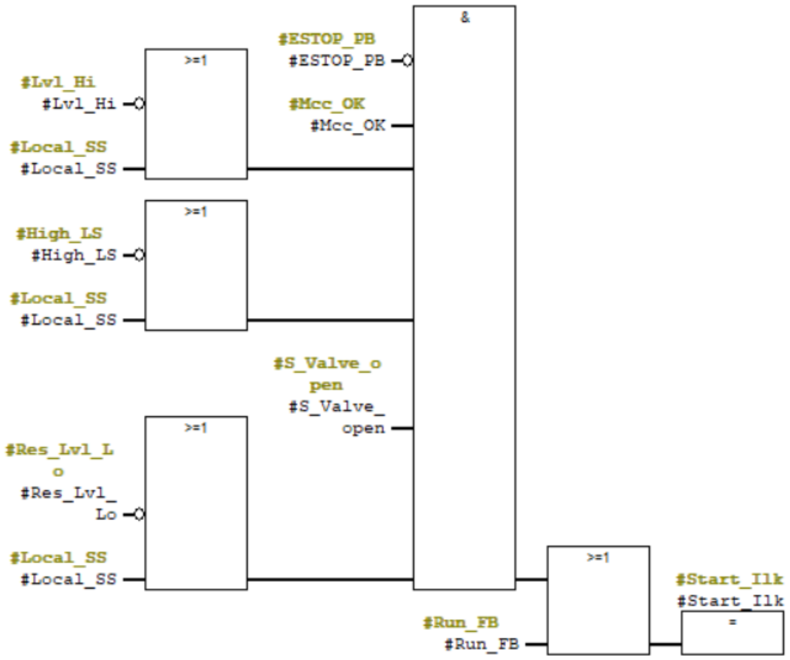
⊟ Network 12 : Alarm, Warning from Level Measurement



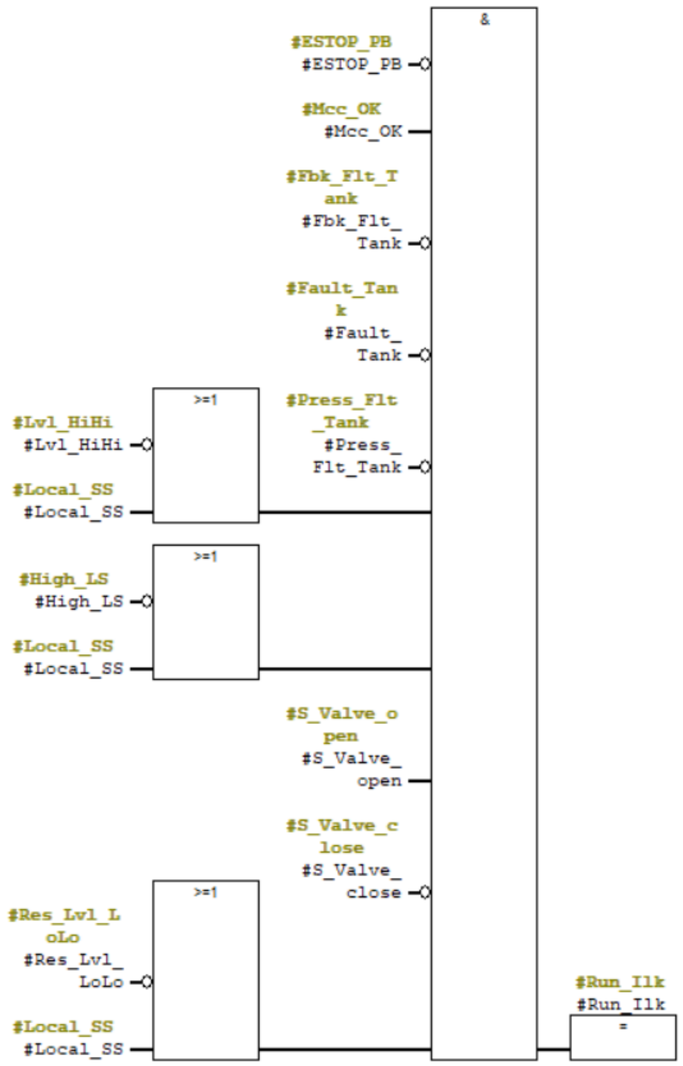
⊟ Network 13 : Alarm, Warning from Pressure Measurement



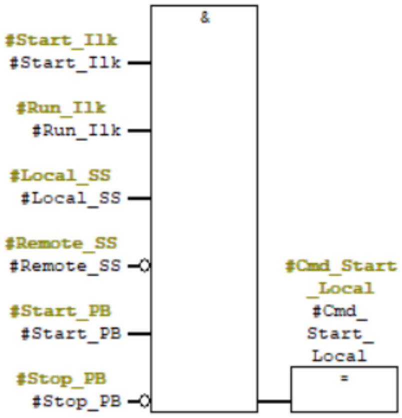
⊟ **Network 14** : Start Interlock



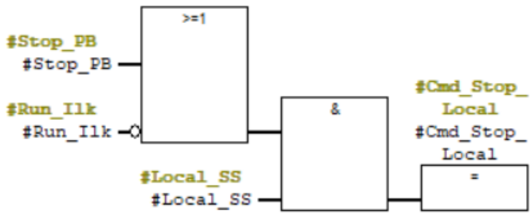
⊟ **Network 15** : Run Interlock



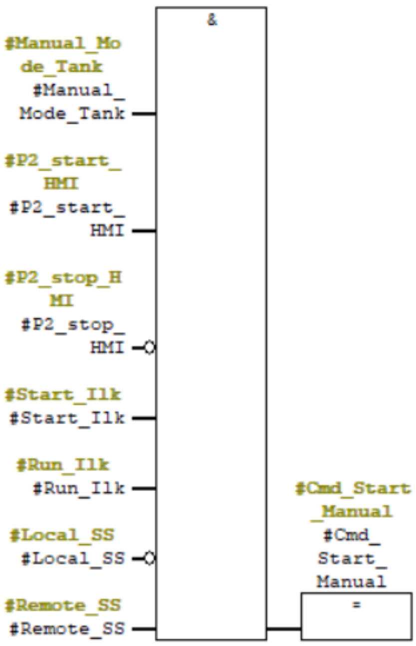
Network 16 : Local Start Command



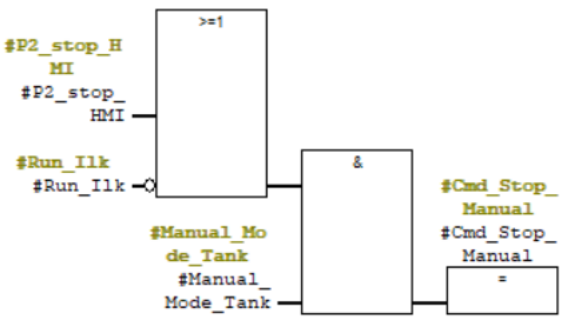
Network 17 : Local Stop Command



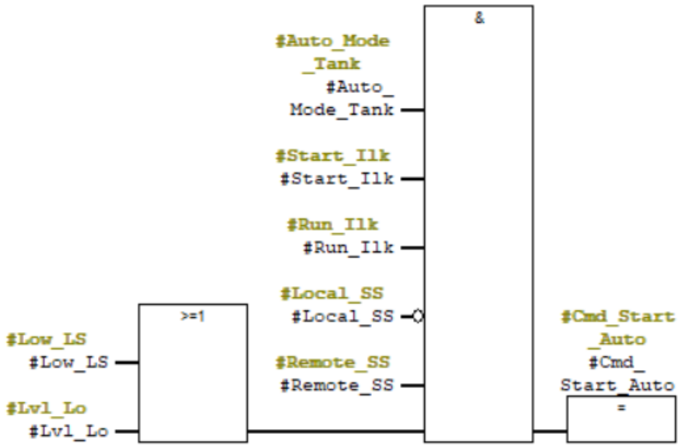
Network 18 : Manual Start Command



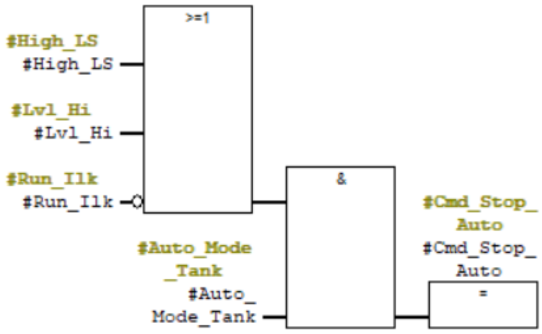
Network 19 : Manual Stop Command



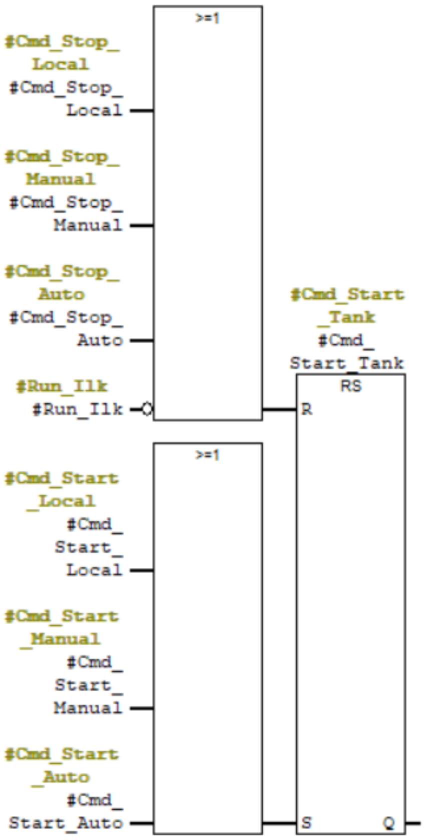
⊟ **Network 20** : Auto Start Command



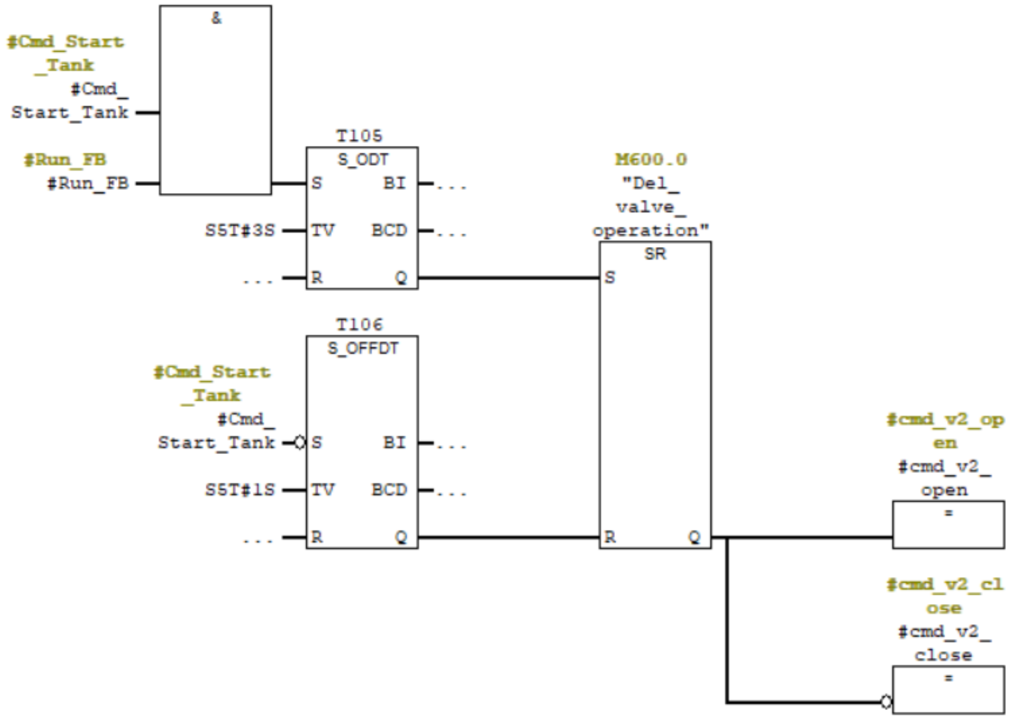
⊟ **Network 21** : Auto Stop Command



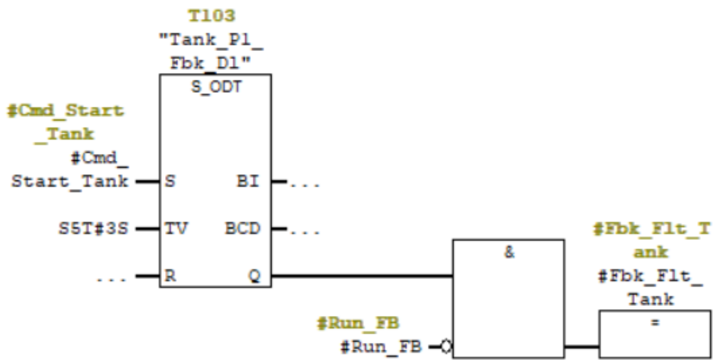
⊟ **Network 22** : Start/Stop Command Pump



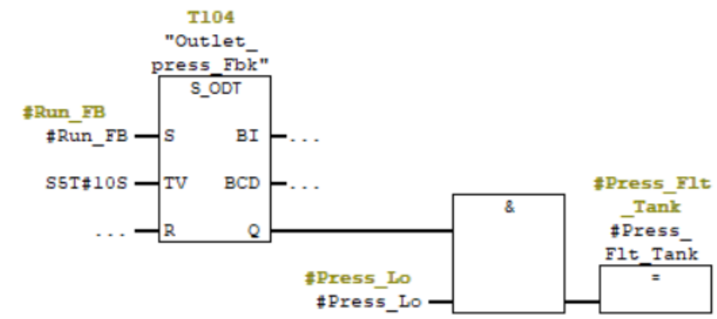
⊟ **Network 23 : Start/Stop Command Valve**



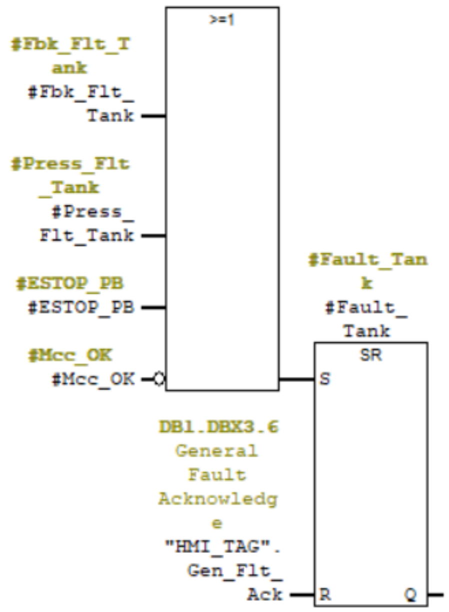
⊟ **Network 24 : Feedback Fault**



⊟ **Network 25 : Pressure Fault**



Network 26 : Fault



Network 27 : Write Outputs to LCP

```
A      #Fault_Tank           #Fault_Tank
```

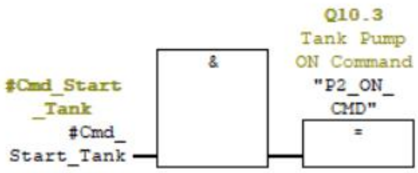
```
A      #Run_FB               #Run_FB
=      "P2_RUN_IND"          Q10.4             -- Tank Pump Run Indication

A      #Fault_Tank           #Fault_Tank
=      "P2_FLT_IND"          Q10.5             -- Tank Pump Fault Indication
```

Network 28 : Write Outputs to HMI

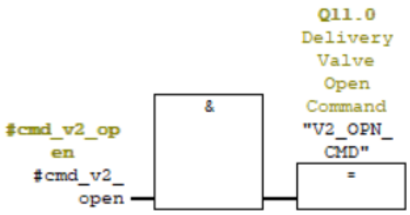
```
A      #Run_FB               #Run_FB
=      "HMI_TAG".P2_RUN      DB1.DBX1.5        -- Tank Pump Run

A      #D_Valve_open         #D_Valve_open
=      "HMI_TAG".V2_OPEN_HMI DB1.DBX28.4       -- Delivery Valve open from HMI

AN     #D_Valve_open         #D_Valve_open
=      "HMI_TAG".V2_CLOSE_HMI DB1.DBX28.5      -- Delivery Valve close from HMI

A      #Mcc_OK               #Mcc_OK
AN     #Fault_Tank           #Fault_Tank
=      "HMI_TAG".P2_READY    DB1.DBX1.6        -- Tank Pump Ready

A      #Fault_Tank           #Fault_Tank
=      "HMI_TAG".P2_FAULT    DB1.DBX1.7        -- Tank Pump Fault

A      #High_LS              #High_LS
=      "HMI_TAG".TANK_LSH    DB1.DBX2.2        -- Tank High Level Switch

A      #Low_LS               #Low_LS
=      "HMI_TAG".TANK_LSL    DB1.DBX2.3        -- Tank Low Level Switch

L      #Lvl_Act              #Lvl_Act
T      "HMI_TAG".TANK_LT     DB1.DBD8          -- Tank Level Transmeter
```

```
L     #S_Flow_Act                 #S_Flow_Act
T     "HMI_TAG".V1_FT             DB1.DBD12          -- Suction Line Flow Transmeter

L     #S_Press_Act                #S_Press_Act
T     "HMI_TAG".V1_PT             DB1.DBD16          -- Suction Line Pressure Transmeter

L     #D_Flow_Act                 #D_Flow_Act
T     "HMI_TAG".V2_FT             DB1.DBD20          -- Delivery Line Flow Transmeter

L     #D_Press_Act                #D_Press_Act
T     "HMI_TAG".V2_PT             DB1.DBD24          -- Delivery Line Pressure Transmeter

A     #Auto_Mode_Tank             #Auto_Mode_Tank
=     "HMI_TAG".AUTO_MODE         DB1.DBX28.0        -- Auto_Mode

A     #Manual_Mode_Tank           #Manual_Mode_Tank
=     "HMI_TAG".MANUAL_MODE       DB1.DBX28.1        -- Manual_Mode

A     #S_Valve_open               #S_Valve_open
=     "HMI_TAG".V1_OPEN           DB1.DBX2.4         -- Suction Valve Open

A     #D_Valve_open               #D_Valve_open
AN    #D_Valve_close              #D_Valve_close
=     "HMI_TAG".V2_OPEN           DB1.DBX2.6         -- Delivery Valve Open

AN    #D_Valve_open               #D_Valve_open
A     #D_Valve_close              #D_Valve_close
=     "HMI_TAG".V2_CLOSE          DB1.DBX2.7         -- Delivery Valve Close
```

Network 29 : Write Outputs to MCC



Network 30 : Write Outputs to HMI



Network 31 : Write Outputs to HMI

- **Step 6 :**

  - After doing this, the program need to compile the program. As **compiling** [24,25] the program the software generates the corresponding machine data and **download** [26,27] to CPU For test cases, simulation PLC or Hardware PLC can be used. Hardware PLC is configured using Ethernet.
  - And after that the program is selected by using **'Select All'** options, then **'Test mode'** to keep it in **'Watch on'** mode. This is done to keep the program in online mode.
  - Then, open the Simulation from Simatic Manager. The CPU dialogue box will appear and we need to keep it in Run or Run– P mode as shown in the below for running the logic in charts.

- **Step 7 :**

- For designing of graphics, go to SIMATIC MANAGER. And click on **SIMATIC 400(1) -> WINCC application->OS1->Compile** and compile the HMI.
- FromOS1 we need to **'Open Object'**. The graphics designer dialogue box will appear and new project can be created.
- Then go to OS1, then OS(1) and compile the HMI.
- Then open the GRAPHICS DESIGNER [28,29] .
- After that go to '**Tag Management**' and connect all the tags related to the process of the program. (Fig 5.4).

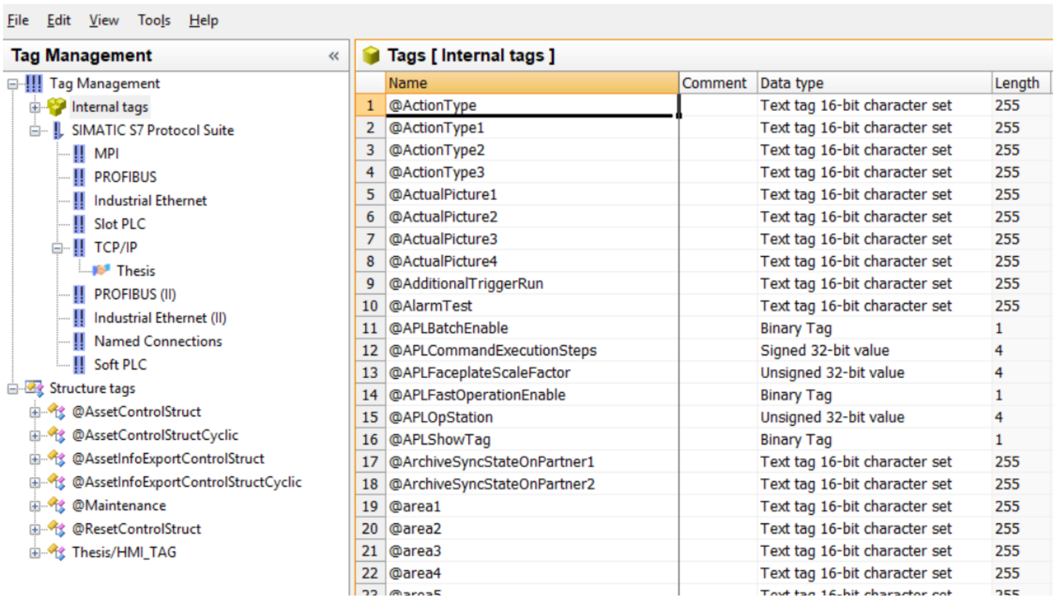


Fig 5.4 Tag Management

- **<u>Step 8:</u>**
  - After connecting all the tags, the project is ready to go to the runtime mode
  - So start the runtime mode first the projects is Activated [30] (Fig 5.5).
  - After opening the runtime window, the program is ready for operations.

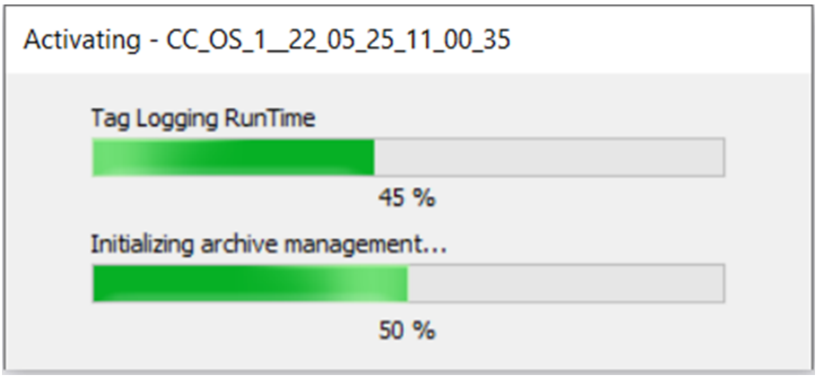


Fig 5.5 WinCC Runtime Activation

After activated runtime window the simulation of the program have to be done. The simulated Analysis is done in detailed in the next chapter.

5.3 CONCLUSION

In this chapter the program of pumping system is developed by eight steps. Each step is explained in detail. The program is written in Statement List and Function block diagram both languages. Statement List is used for Variable declaration of the program and Function block diagram is used for the execution. The program of reservoir and tank are written separately because tank system have some interlocks with the reservoir.

CHAPTER – 6

SIMULATED RESULTS AND MODES OF OPERATION

6.1 LOCAL MODE OPERATION

- In Local Mode, the operator Manually operates the system from **Local Control Panel.**
- In Local Mode, the selector switch must have in **“LOCAL MODE”**
- In Filling time, When the water level reaches the 80% to generates the Level High Alarm of Reservoir (Table 6.1) and Tank (Table 6.2).

Table 6.1 Local Mode Operation For Reservoir

State	Reservoir Water Level	Reservoir Pump Status	Remark
Reservoir Pump is Standstill	0%	Stop	Pump 1 is ready for Start
Reservoir pump Starting Conditions	10%	Start	Pump 1 is ready for Run
Reservoir pump Running Conditions	Below 80%	Run	Pump 1 is Running
Reservoir pump Stopping Conditions	80%	Stop	Pump 1 is Stop

Table 6.2 Local Mode Operation For Tank

State	Outlet Valve Pressure	Outlet Valve Flow	Delivery valve Status	Tank Water Level	Tank Pump Status	Remark
Tank pump Starting Conditions	14.5 Bar	57.90%	Open	10%	Start	Pump 2 is ready for Run
Tank pump Running Conditions	14.5 Bar	57.90%	Open	Below 80%	Run	Pump 2 is Running
Tank pump Stopping Conditions	Below 14.5 Bar	Below 57.90%	Close	80%	Stop	Pump 2 is Stop

- At High level switch activated the operators must stop the pumps to avoid overflow condition shown in Fig 6.1.
- In Draining time, when the water level decreases below the 30%, it generates Level Low Alarm of the Reservoir and Tank. So, at this condition both pumps are running represented in Fig 6.2.

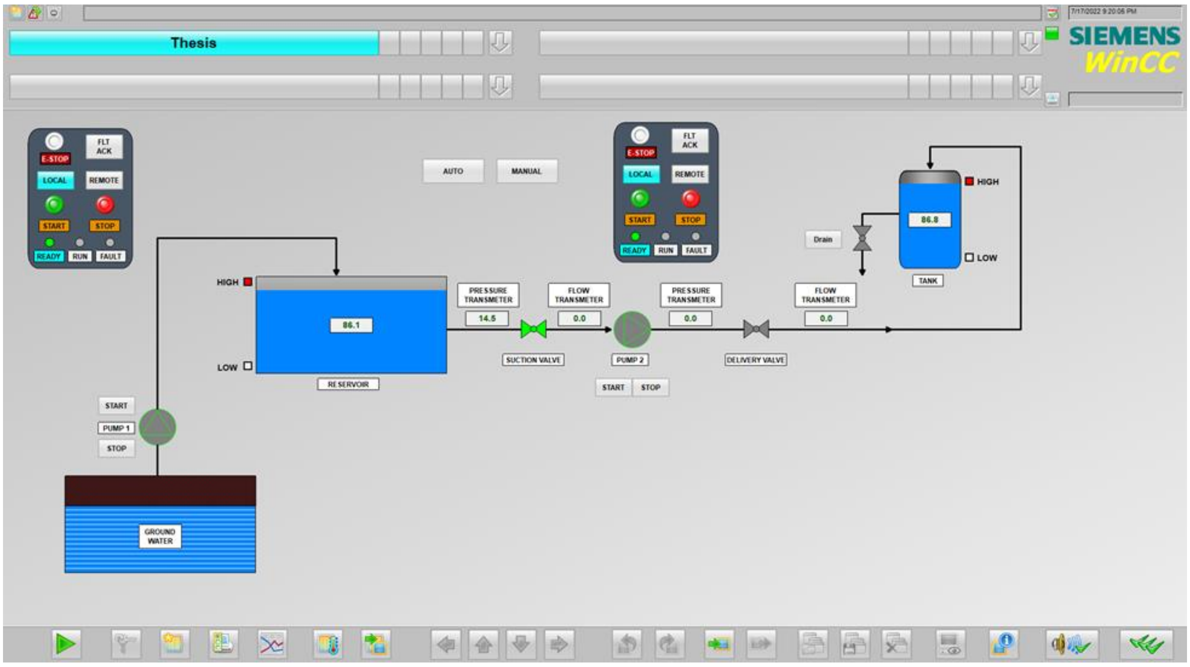


Fig 6.1 Stop in Local Mode

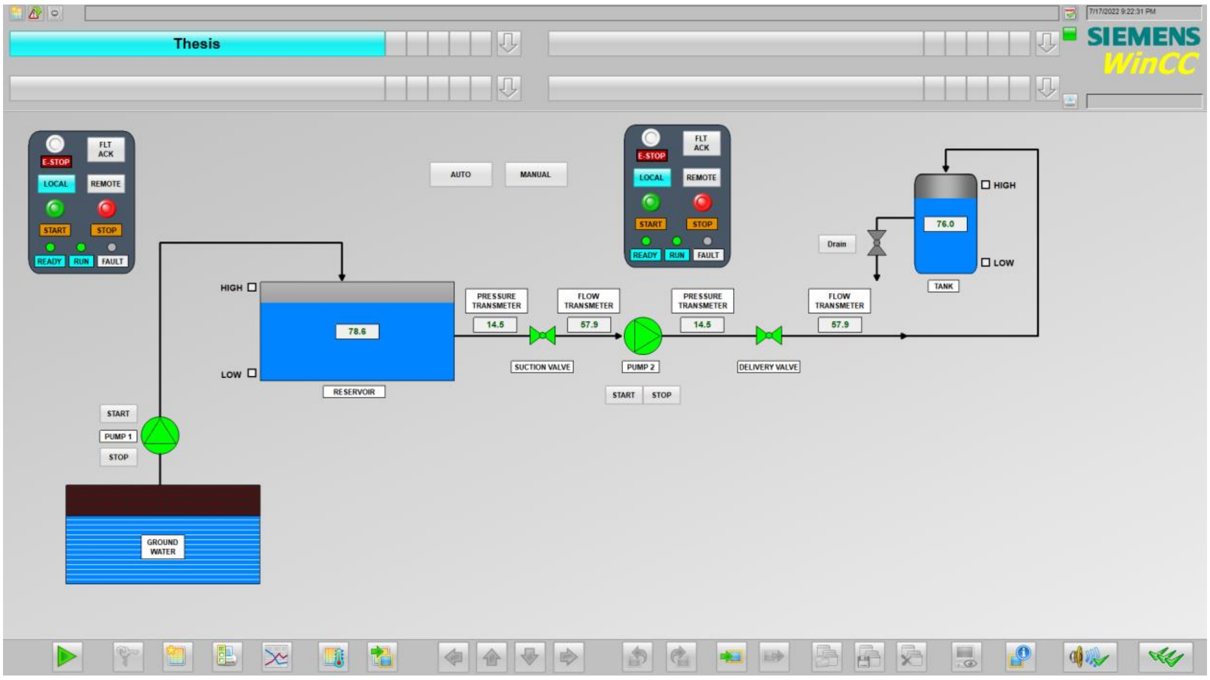


Fig 6.2 Run in Local Mode

6.2 MANUAL MODE OPERATION

- In Manual Mode, the operator Manually operates the system in control room from **HMI** [31] .
- In Manual Mode, the selector switch must have in **"REMOTE MODE"**
- In Filling time, When the water level reaches the 80% to generates the Level High Alarm of Reservoir (Table 6.3) and Tank (Table 6.4).

Table 6.3 Manual Mode Operation For Reservoir

State	Reservoir Water Level	Reservoir Pump Status	Remark
Reservoir Pump is Standstill	0%	Stop	Pump 1 is ready for Start
Reservoir pump Starting Conditions	30%	Start	Pump 1 is ready for Run
Reservoir pump Running Conditions	Below 80%	Run	Pump 1 is Running
Reservoir pump Stopping Conditions	80%	Stop	Pump 1 is Stop

Table 6.4 Manual Mode Operation For Tank

State	Outlet Valve Pressure	Outlet Valve Flow	Delivery valve Status	Tank Water Level	Tank Pump Status	Remark
Tank pump Starting Conditions	14.5 Bar	57.90%	Open	30%	Start	Pump 2 is ready for Run
Tank pump Running Conditions	14.5 Bar	57.90%	Open	Below 80%	Run	Pump 2 is Running
Tank pump Stopping Conditions	Below 14.5 Bar	Below 57.90%	Close	80%	Stop	Pump 2 is Stop

- When High level switch activated pumps are stopped to avoid overflow condition is shown in Fig 6.3.
- The water level of the reservoir is above 30% and the water level of the tank is below 80% then pump 2 can be started manually and it will be running properly.

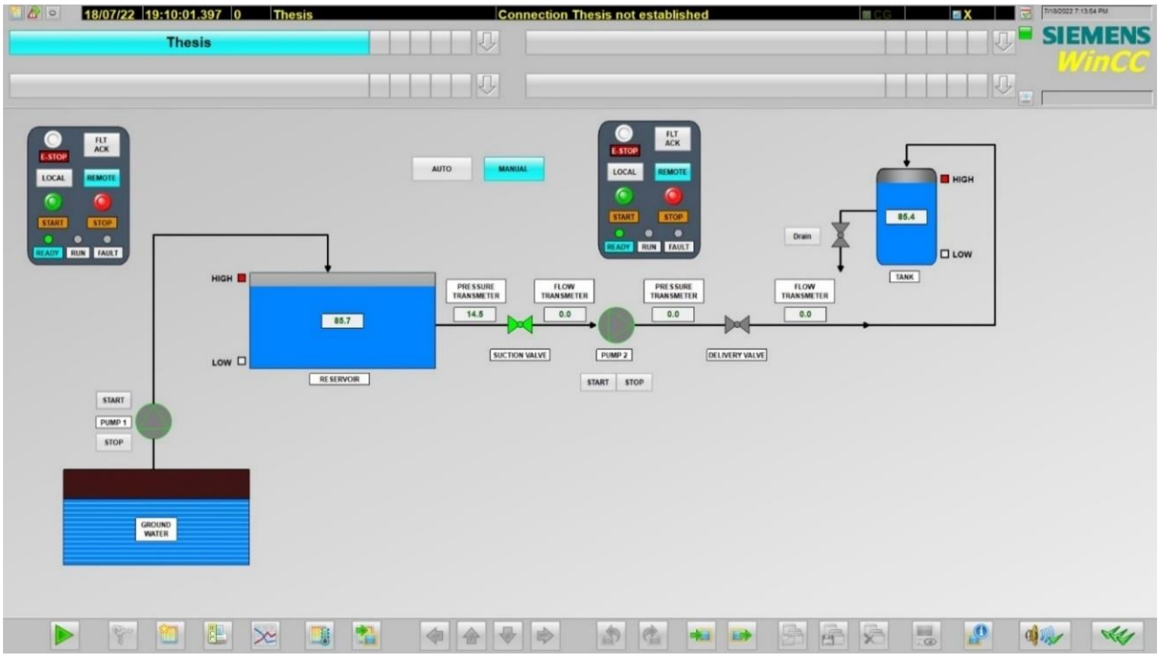


Fig 6.3 Stop in Manual Mode

- In Draining time, when the water level decreases below the 10%, it generates Level Low Alarm of the Reservoir and Tank is shown in Fig 6.4.
- When the Low level indication of tank appears, the operator have to start the pump 2 to avoid drain out condition of tank
- When the Low level indication of reservoir appears, the operator have to be stopped the pump 2 and start the pump 1 to avoid drain out condition.

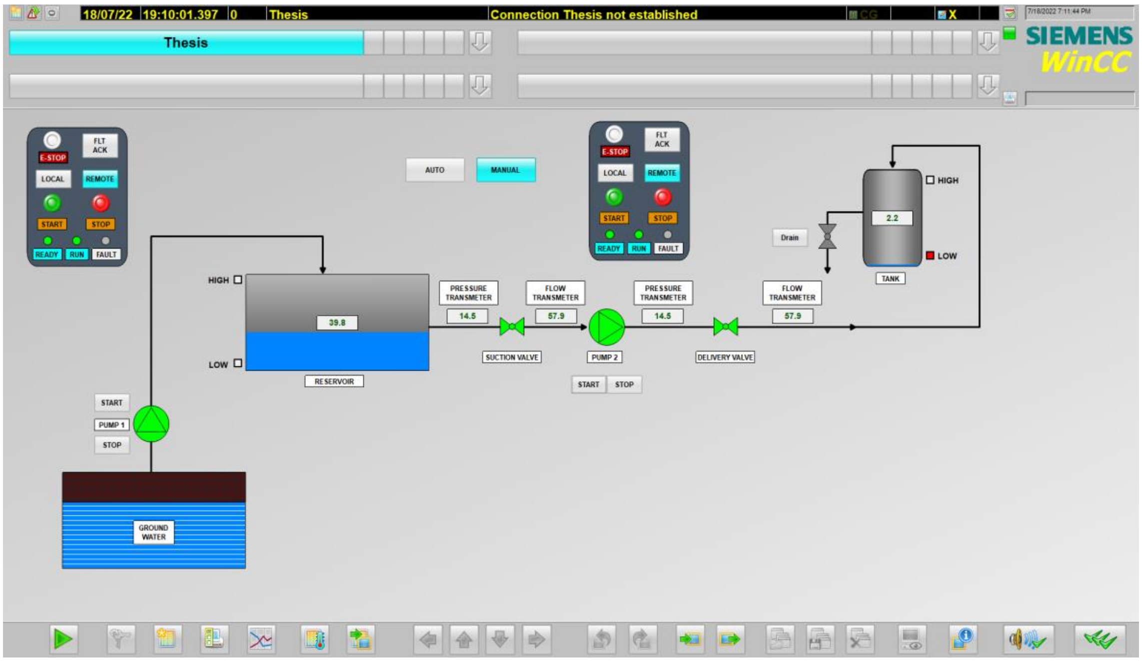


Fig 6.4 Start in Manual Mode

6.3 AUTO MODE OPERATION

- In Auto Mode, both pumps are started automatically. So the operator can only monitor the process [32] .
- In Auto Mode, the selector switch must have in **"REMOTE MODE"**
- When the Reservoir water level goes below 30% , Pump 1 will start automatically (Fig 6.5) to fill the reservoir until the water level reached 80% (Table 6.5).

Table 6.5 Auto Mode Operation For Reservoir

State	Reservoir Water Level	Reservoir Pump Status	Remark
Reservoir Pump is Standstill	0%	Stop	Pump 1 is ready for Start
Reservoir pump Starting Conditions	30%	Start	Pump 1 is ready for Run
Reservoir pump Running Conditions	Below 80%	Run	Pump 1 is Running
Reservoir pump Stopping Conditions	80%	Stop	Pump 1 is Stop

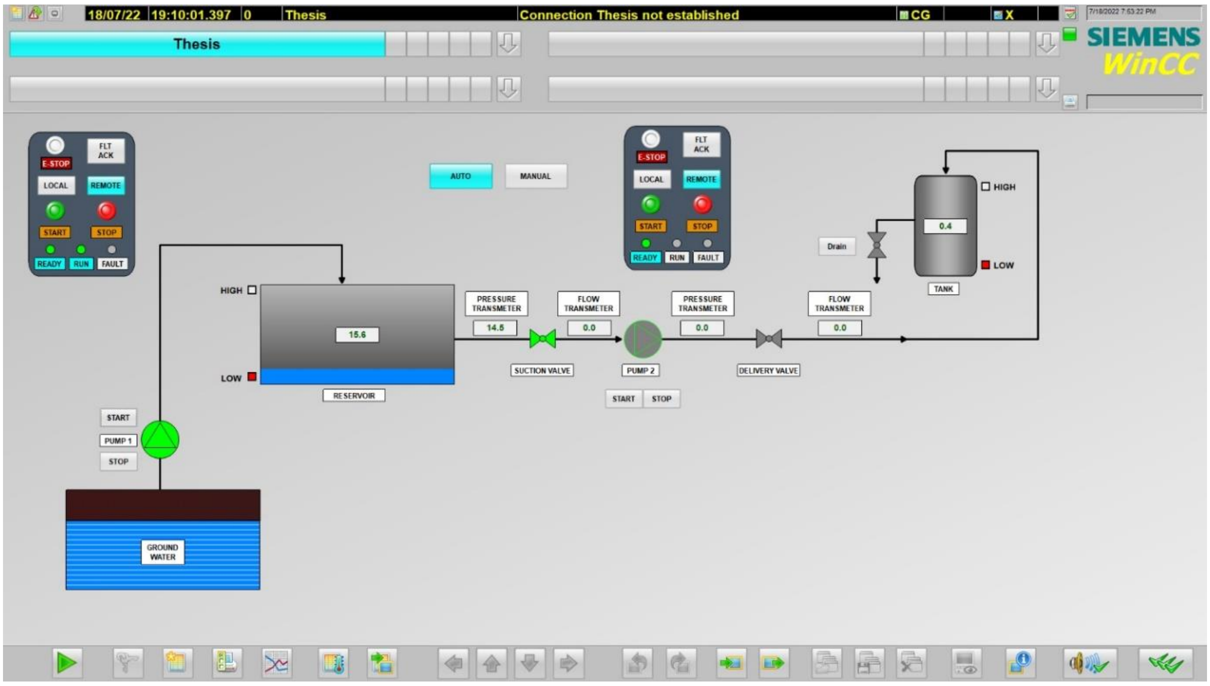


Fig 6.5 Pump1 Start in Auto Mode

- In Filling time, when the water level reaches the 80% then both pumps have to be stopped to avoid overflow condition [33] .
- If the reservoir water level reaches more than 30% and Tank water level does not exceed 80% and the delivery pressure transmitter reaches 14.5 bar pressure, then Pump 2 will start (Table 6.6)

Table 6.6 Auto Mode Operation For Tank

State	Outlet Valve Pressure	Outlet Valve Flow	Delivery valve Status	Tank Water Level	Tank Pump Status	Remark
Tank pump Starting Conditions	14.5 Bar	57.90%	Close	30%	Start	Pump 2 is ready for Run
Tank pump Running Conditions	14.5 Bar	57.90%	Open	Below 80%	Run	Pump 2 is Running
Tank pump Stopping Conditions	Below 14.5 Bar	Below 57.90%	Close	80%	Stop	Pump 2 is Stop

- After Pump 2 has started , delivery valve is opened automatically to fill the Tank until the water level reached 80%.
- When the water level of Reservoir reaches 80% then Pump 1 stop automatically to avoid overflow condition (shown in Fig 6.6).

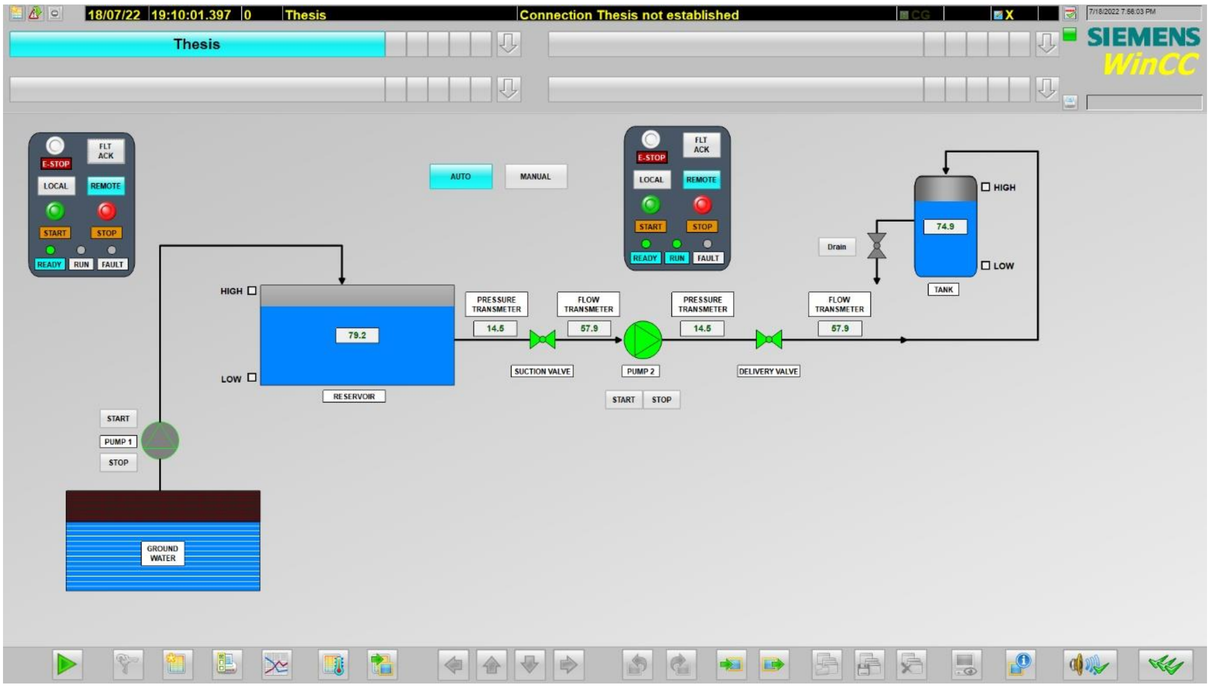


Fig 6.6 Pump1 stopped but the Pump 2 Run in Auto Mode

- In Draining time, When the water level of Tank decreases below the 30% of the Tank, Pump 2 is started first then the Delivery valve should open automatically to avoid the Drain out condition of the tank (Fig 6.7).

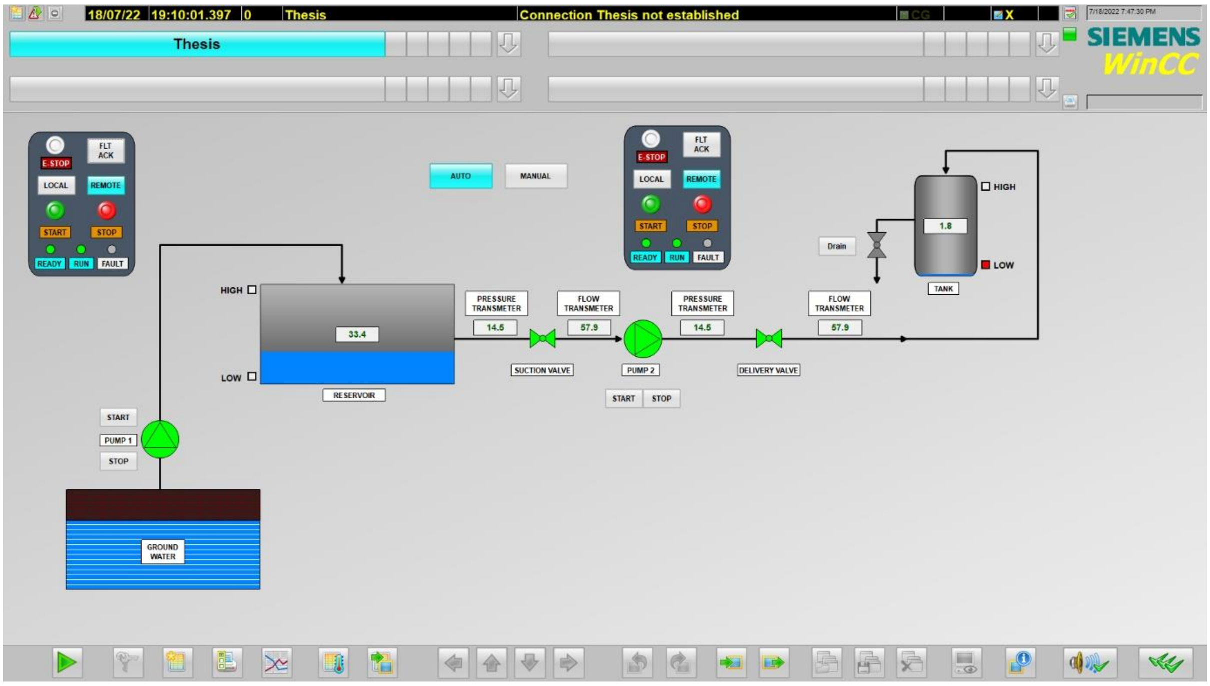


Fig 6.7 Both the Pumps Run in Auto Mode

- The water level of the reservoir is above 30% and the water level of the tank is below 80% then Pump 2 will be started automatically and it will running continuously until the water level reaches 80% .

6.4 CONCLUSION

Modes of operations are discussed in this chapter. Local mode is used for maintenance purpose, but manual mode and auto mode is used for operational purpose. The results are simulated with the help of softwares. The simulated results are also analyzed in tabular format as well as the runtime windows.

CHAPTER – 7

GENERAL THEORY OF LIGHTING DESIGN

7.1 INTRODUCTION

The main purpose of lighting design is to illuminate space according to the standards.There are few objectives of a lighting designer such as –

- The illumination level on the workplace should be good according to the standards.
- There should be proper uniformity (preferably greater than 0.7).
- There should not be any glare.
- To make the lighting energy efficient.
- To make the environment visually comfortable for the viewer.
- To use proper CCT in various spaces according to the type of work.
- To avoid light pollution in outdoor designs.
- To optimize cost without compromising the quality of light.

7.2 LIGHTING DESIGN PARAMETERS

7.2.1 Average Illuminance:

Illuminance is the most important lighting design parameter in the lighting industry. Illuminance is the amount of luminous flux emitting from an illuminant per unit area on a given surface. The SI unit of Illuminance is '**lux**'. With the help of Luxmeter we can measure illumination level in a room [34].

$$\textbf{Illuminance, } E = \varphi / A$$

Where '**φ**' is luminous flux in lumen and '**A**' is surface area. Maintained average illuminance can be achieved by multiplying illuminance with maintenance factor of the application area. .

$$E = (\varphi \times MF) / A$$

Maintenance factor (MF) is considered between 0.8 - 0.9 for LED luminaries according to the areas of application. Generally, MF is considered as 0.85 in office spaces and 0.8 in industries as the lumen depreciation of LED luminaire is less.

7.2.2 Uniformity:

Uniformity is another important parameter which is considered in lighting design. Uniformity is basically the ratio of minimum illuminance to the average maintained illuminance in a given area [35].

$$U_o = E_{min}/E_{avg}$$

Uniformity greater than 0.7 is preferred. For uniformity less than 0.4 can lead to black and white spots in the work plane which can cause eye strain of the room occupant. Often in specialized lighting like sports lighting, uniformity is expressed as the ratio of "**Minimum illuminance to Maximum illuminance**".

7.2.3 Lighting power Density (W/m^2):

Lighting power density is the maximum load of lighting fixture per unit area in a defined space as per its function. Its SI unit is watt/m^2. LPD can be determined in two ways i.e. building area method and space function method [36].

- In building area method, LPD is calculated with respect to the total lighting load of the building area.

- In space function method, LPD is calculated according to the space according to the building type.

7.3 LIGHT SOURCES

Light source can be broadly classified into three groups such as incandescent lamp, gas discharge lamp and LED lamps. Incandescent lamp can be divided into two types such asGeneral Service lamp (or GLS) and Tungsten halogen Lamp. There are various types of gas discharge lamps such as Low pressure mercury vapor lamp (LPMV) and high-pressure mercury vapor lamp (HPMV), Low and high pressure sodium pressure lamp (LVSP,HPSV), metal halide lamp.

7.3.1 <u>LED :</u>

Light Emitting Diode (LED) [37,38,39] is basically a diode that emits electromagnetic waves in the visual spectrum. The working principle depends upon the recombination of electrons and holes. When a voltage (must be greater than forward voltage of LED) is applies across a LED, the electrons from n-region are forced to combine with hole in the p-region. After combination, the energy is converter into light energy. This phenomenon is known as Electroluminescence. Thus LED emits electromagnetic wave which lies in the visible spectrum [40,41]. This photon has a frequency determined by the characteristics of the semiconductor material (usually a combination of the chemical elements gallium, arsenic, and phosphorus). LEDs that emit different colours are made of different semiconductor materials [42,43].

- The advantages of LED are as follows:
    i. They have long life approximately 50,000 burning hours.
    ii. They have good CRI greater than 80.
    iii. Mercury is not used in any LEDs.
    iv. Optical control of LEDs is quite easy. LEDs of various beam angle areavailable in the market.
    v. Dimming can be cone easily to save electrical energy.
    vi. LEDs can be colour tunable. Various CCTs are available i.e. 3000K,4000K, 5600K, and 6500K.
    vii. LED chips are compact and a powerful light source
    viii. It can start instantly and it does not need any time to restrike again. This isone of the biggest advantages in comparison to sodium, high pressure mercury vapour lamp and metal halide lamp.

7.3.2 LED DRIVERS

LED is operated at a low DC voltage range from 12V to 24V. Electricity boards always supply AC voltage of 220V-240V, so it is not suitable for LED. Thus we need a driver to step down the value. The driver should be according to the rating of the LED. The rating of driver is higher than LED rating will become very hot resulting in thermal runaway. Similarly, if driver rating is lower than LED rating, the LED will underperform as it will not glow up to its maximum brightness [44,45].

Generally, voltage rating of a single LED ranges from 1.5V to 3.5V and Current up to 30mA. Now, when we consider an LED module, due to large number of LEDs connectedin series and parallel, the total voltage ranges from 12V to 24V DC. The driver contains rectifier circuit to convert the AC into DC. After converting to DC, a filter circuit is connected to make the voltage ripple free. Then with the help of converters, we can step down the DC voltage to supply the LED module . The circuit diagram inside LED driver is shown in Fig 7.1.

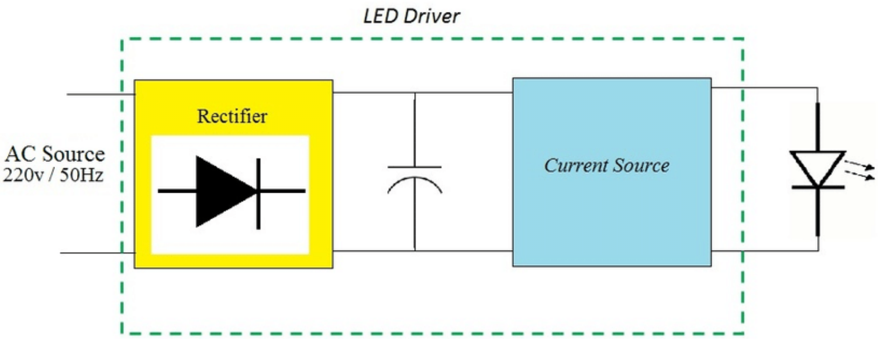


Fig 7.1 LED Driver

7.4 CONCLUSION

General theory of lighting design is explained in this chapter. The working principle of LED is also discussed here along with its advantages. LED is operated at low level DC voltage, but the supply line is in AC. So, its necessary to convert this AC into DC. This conversion is done by using LED drivers. The driver takes an important role in the LED operation by converting AC voltage into DC voltage. The operation of LED driver is also incorporated in this chapter.

CHAPTER – 8

LIGHTING DESIGN AND ANALYSIS OF CONTROL ROOM

8.1 INTRODUCTION

In this chapter, the steps for lighting design are discussed. This is the most initial part of any lighting design. Here, in this chapter various design aspects and lighting parameters will be discussed.

8.2 SOFTWARE USED IN LIGHTING DESIGN

- **DIALux 4.13:**

This is one of the best software used in the lighting design industries. From this software, we can simulate illumination levels, uniformity, UGR, etc. This is user friendly software and with the help of it the lighting designers can design both indoor as well as outdoor application areas. It is also possible to calculate LPD, sothus by checking it one can design an energy efficient space [46].

8.3 DESIGN PARAMETERS OF CONTROL ROOM

The following design parameters is used in Lighting Design.

8.3.1 Ceiling Height:

This is the first and foremost thing at the beginning of a lighting design project. There are generally two types of ceiling i.e. true ceiling and false ceiling [47,48] .

8.3.2 Reflectance Factor:

Proper reflectance factor has to be considered as it decides the average illumination level. Reflection factor plays an important role in indirect illumination. Normally clients do not mention reflectance factor but as a lighting designer we take some values according to the area and type of work in the area.

8.3.3 Maintenance Factor:

Maintenance factor is the ratio of maintained average illuminance to initial level of illumination. Maintenance factor depends upon 4 factors such as:

- Room Surface maintenance factor (RSMF)
- Lamp survival factor (LSF)
- Luminaire maintenance factor (LMF)
- Lamp Lumen maintenance factor (LLMF)

So, M.F = RSMF * LSF * LMF * LLMF

8.3.4 Work plane Height:

The surface at which the illuminance is calculated is known as work plane. Duringcalculation, we can set the points on the work plane as original grid, point grid andstandard grid. In Dialux 4.13, default height of the work plane is 0.76m. But In this thesis the work plane height is set for 0.941m.

8.4 DESIGN OF CONTROL ROOM

Control Room is the main center where the operators are controlled the sintering process by using HMI. If any abnormal condition happened during processing, then the operator pressed the emergency stop button, then the process is stopped immediately.

So the lighting design of the control room is very important so that the operators are work comfortably [49,50,51] .

In Fig 8.1 shows the overview the control room of the Sinter plant.

Fig 8.1 3D view of Control Room

In the design the dimensions of the control room is:

- Length: 9.14 m
- Width: 6.10 m
- Height: 3.65 m
- Working Plane height form floor: 0.941m

In the Fig 8.2 shows the floor Plan of the control room

Fig 8.2 Floor Plan of Control Room

8.5 EXISTING LIGHTING DESIGN OF CONTROL ROOM

8.5.1 Luminaire Details:

Luminaire Name: Legero MODENA 28W (6000K)

No. of luminaire used: 20

Luminous Flux: 3209 lm

Luminaire Wattage: 28 W

In the existing design, the spacing between two luminaires is 1.83 m.

In Fig 8.3 the existing luminaire layout Plant of control room is given below.

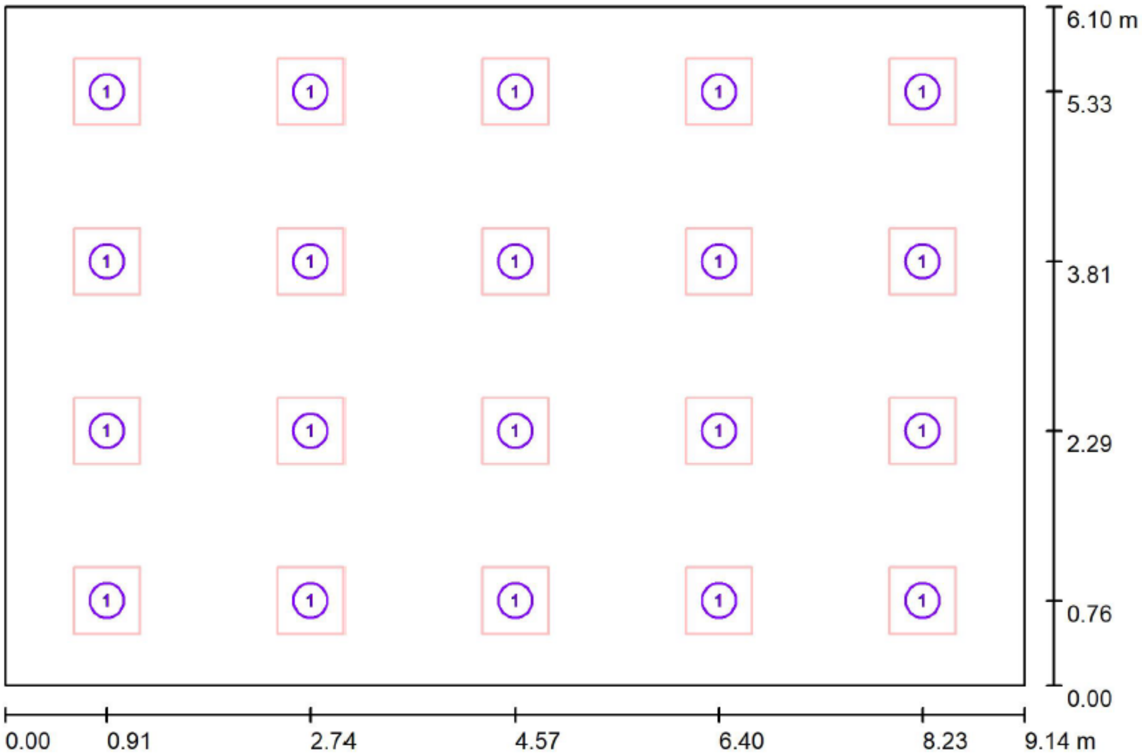


Fig 8.3 Luminaire Layout Plan

8.5.2 Simulated Results of Existing Lighting design:

- **Photometric Results:-**

Total Luminous Flux:	64183 lm
Total Load:	563.4 W
Light loss factor:	0.70
Boundary Zone:	0.000 m

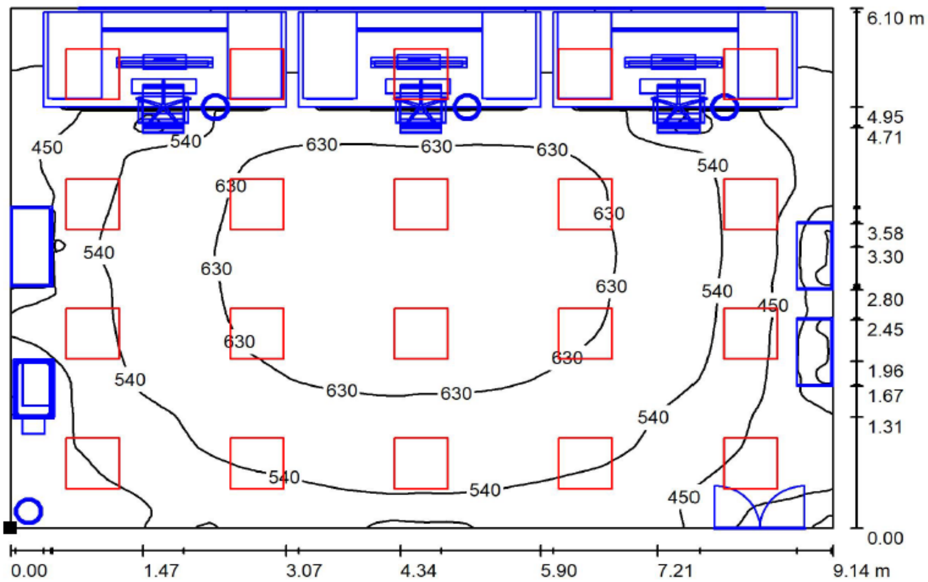
Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	353	197	550	/	/
Floor	235	149	385	63	77
Ceiling	0.00	210	210	80	54
Wall 1	212	225	438	50	70
Wall 2	169	178	347	50	55
Wall 3	153	139	292	50	47
Wall 4	184	194	378	50	60

Uniformity on the working plane
u0: 0.435 (1:2)
E_{min} / E_{max}: 0.351 (1:3)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.763, Ceiling / Working Plane: 0.382.

Specific connected load: 10.11 W/m² = 1.84 W/m²/100 lx (Ground area: 55.74 m²)

- **Isolux Lines:-**



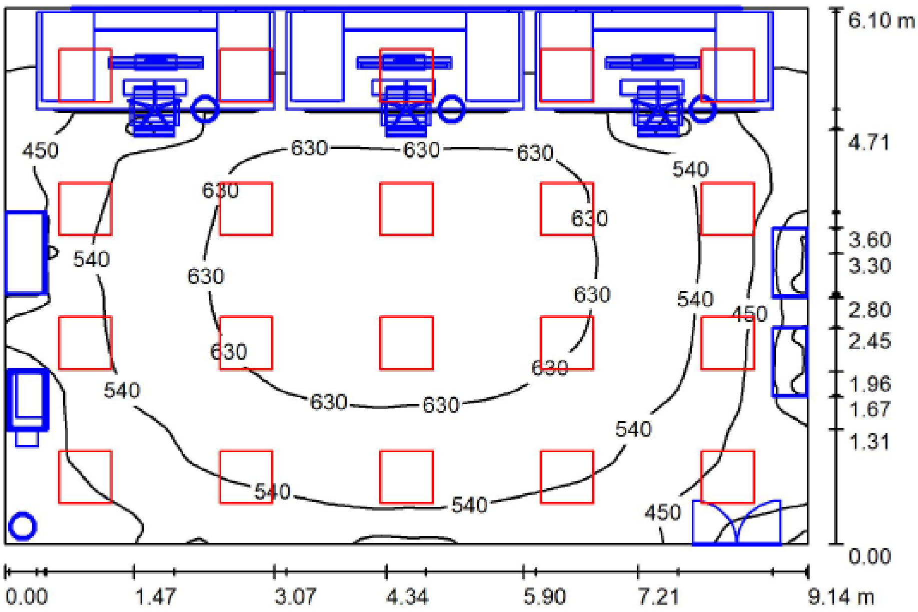
Values in Lux, Scale 1 : 66

Position of surface in room:
Marked point:
(0.000 m, 0.000 m, 0.914 m)

Grid: 128 x 128 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
550	239	682	0.435	0.351

➤ Existing Design Summary:-



Height of Room: 4.572 m, Mounting Height: 4.572 m, Light loss factor: 0.70

Values in Lux, Scale 1:79

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	550	239	682	0.435
Floor	63	385	21	582	0.055
Ceiling	80	210	117	290	0.555
Walls (4)	50	364	35	693	/

Workplane:
Height: 0.914 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.763, Ceiling / Working Plane: 0.382.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	20	Legero Lighting India Pvt Ltd. 28W MODENA (6000K)2X2 (1.000)	3209	3209	28.2
			Total: 64183	Total: 64184	563.4

Specific connected load: 10.11 W/m² = 1.84 W/m²/100 lx (Ground area: 55.74 m²)

8.6 MODIFIED LIGHTING DESIGN OF CONTROL ROOM

8.6.1 Luminaire Details:

Luminaire Name: Philips TLED 16.5W (6500K)

No. of luminaire used: 30

Luminous Flux: 2500 lm

Luminaire Wattage: 16.5W

In the existing design, the spacing between two luminaires is 1.83 m.

In Fig 8.4 the Modified luminaire layout Plant of control room is given below.

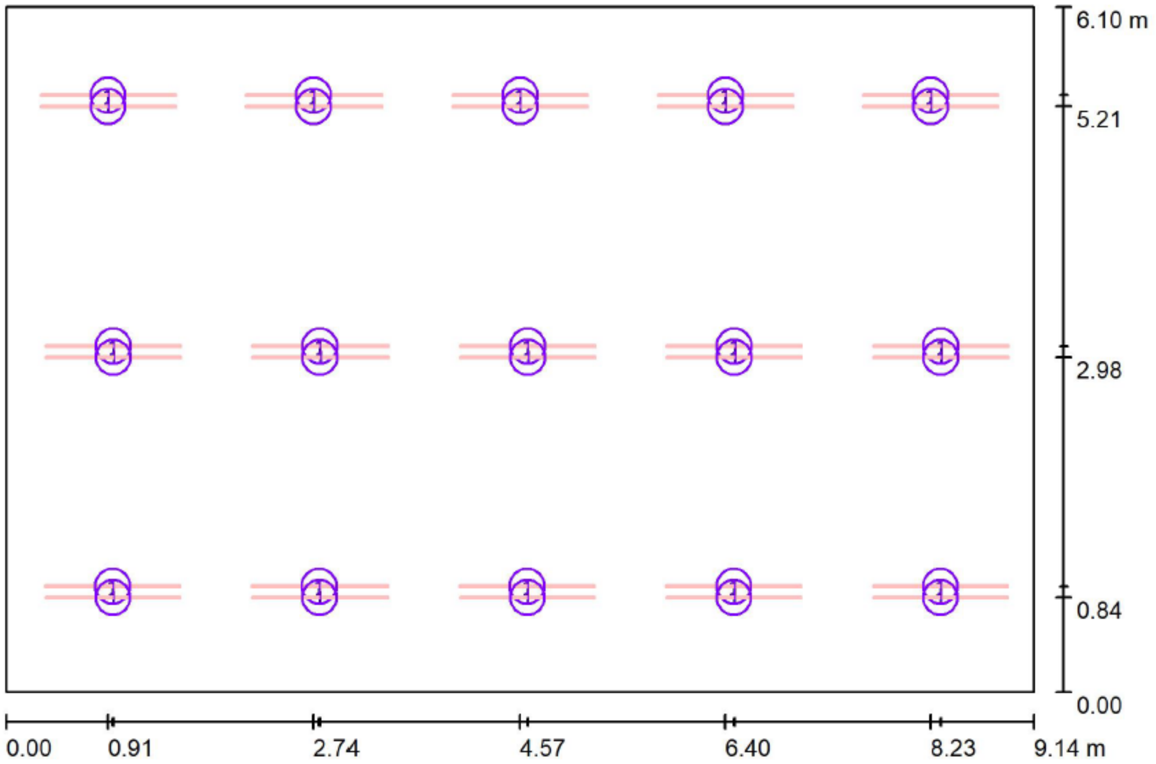


Fig 8.4 Luminaire Layout Plan

8.6.2 Simulated Results of Existing Lighting design:

➢ **Photometric Results:-**

Total Luminous Flux:	74975 lm
Total Load:	495.0 W
Light loss factor:	0.70
Boundary Zone:	0.000 m

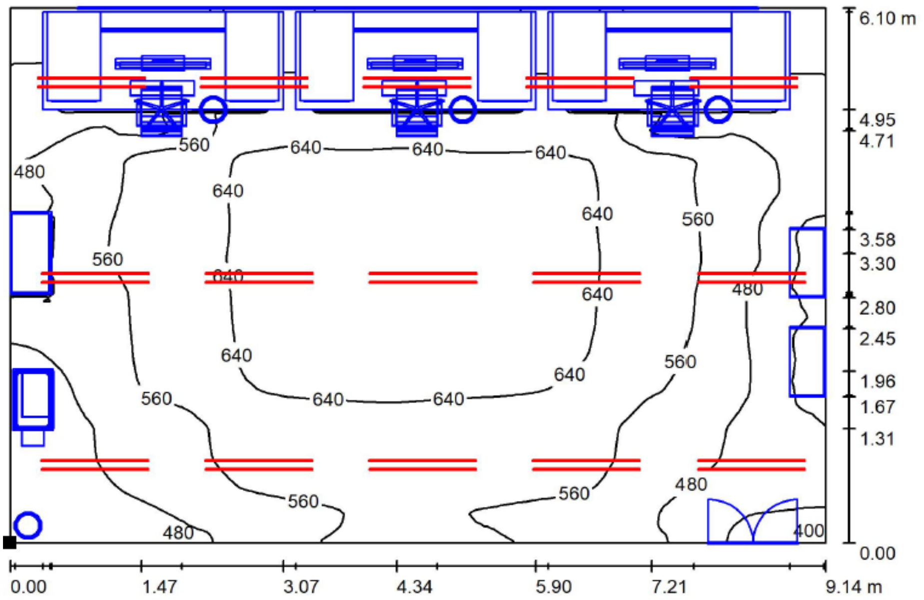
Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	237	325	561	/	/
Floor	156	230	387	63	78
Ceiling	289	281	569	80	145
Wall 1	219	303	522	50	83
Wall 2	139	242	380	50	61
Wall 3	190	188	378	50	60
Wall 4	143	275	418	50	67

Uniformity on the working plane
u0: 0.584 (1:2)
E_{min} / E_{max}: 0.482 (1:2)

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.895, Ceiling / Working Plane: 1.014.

Specific connected load: 8.88 W/m² = 1.58 W/m²/100 lx (Ground area: 55.74 m²)

➢ **Isolux Lines:-**



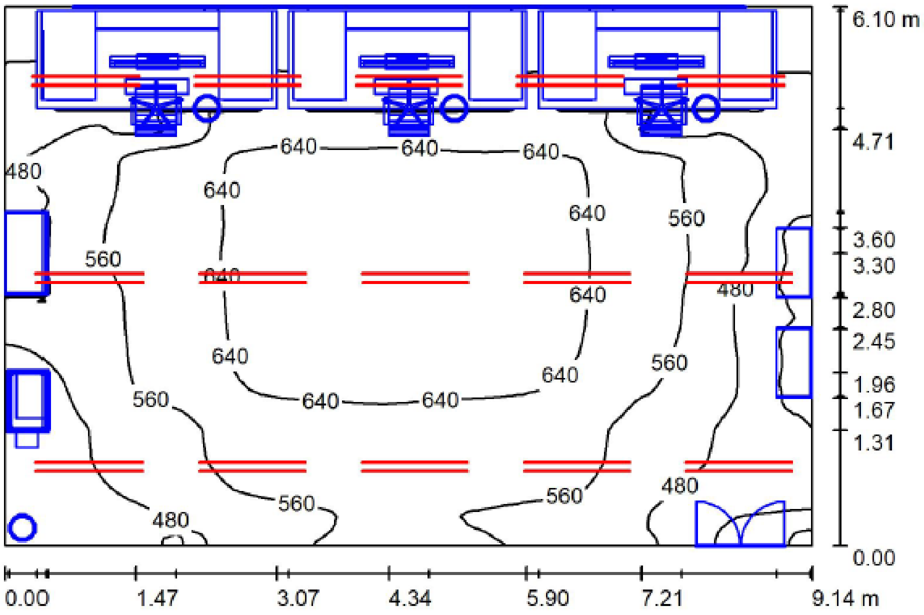
Values in Lux, Scale 1 : 66

Position of surface in room:
Marked point:
(0.000 m, 0.000 m, 0.914 m)

Grid: 128 x 128 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
561	328	681	0.584	0.482

➢ Modified Design Summary:-



Height of Room: 4.572 m, Mounting Height: 4.572 m, Light loss factor: 0.70

Values in Lux, Scale 1:79

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	561	328	681	0.584
Floor	63	387	69	569	0.180
Ceiling	80	569	242	58899	0.425
Walls (4)	50	429	52	912	/

Workplane:

Height: 0.914 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.895, Ceiling / Working Plane: 1.014.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	30	Philips (1.000)	2499	2500	16.5
			Total: 74975	Total: 75000	495.0

Specific connected load: 8.88 W/m² = 1.58 W/m²/100 lx (Ground area: 55.74 m²)

8.7 COMPARISON BETWEEN EXISTING AND MODIFIED LIGHTING DESIGN

Item	**Existing Design**	**Modified Design**	**Remark**
Luminaire	Legero 28W MODENA(6000K)	Philips TLED 16.5W (6500K)	
No. of Luminaire	20	30	Increased
Luminous Flux	3209 lm	2500 lm	Decreased
Luminaire Wattage	28 W	16.5 W	Decreased
Maximum Illumiance	682 lux	681 lux	Same
Minimum Illumiance	239 lux	328 lux	Increased
Avarage Illumiance	550 lux	**561 lux**	**Increased**
Uniformity	0.435	**0.584**	**Increased**
Total Luminous Flux	64183 lm	**74975 lm**	**Increased**
Total Power Consumption	563.4 W	**495.0 W**	**Decreased**

8.8 CONCLUSION

In the modified design although the number of luminaire is increased but the total electricity consumption is decreased so that the modified design is more energy efficient [50] . Average illuminance and uniformity, which are the most important parameters of Indoor lighting design, are also increased in the modified design. So, the modified design gives better output with less electricity consumption.

CHAPTER – 9

CONCLUSION
AND
FUTURE SCOPE OF
WORK

9.1 CONCLUSION

- Introduction of PLC and its various types along with architectures of PLC system are discussed in chapter 1.
- In chapter 2, fundamentals of PLC programming languages i.e., Ladder Logic, Statement List, Function Block Diagram along with the Hardware Configuration and WinCC graphics design.
- Various Sections of sinter plant are discussed briefly along with the technical specification and ratings of the motors is described in chapter 3.
- the working principle of sintering process is explained in detail on chapter 4, along with the benefits of sintering process and burn through point control.
- In chapter 5, the program of pumping system is developed step by step. Program is written in Statement List and Function block diagram both languages. Statement List is used to variable declaration and Function block diagram used to program execution flow.
- Modes of operations are discussed in chapter 6 along with the simulation of program. The simulated results are also analyzed in tabular format as well as the runtime windows.
- General theory of lighting design is explained in chapter 7. The working principle of LED, benefits and the uses of LED driver is also discussed in this chapter
- The detailed analysis of the lighting design of control room is explained in chapter 8. It clearly shows that just by replacing existing fixtures with LED tubes, average illuminance and uniformity is increased and cost saving as high as can be achieved.

Due to technological advantages, the PLC automation system is well on its way toward wide spared implementation within the sinter plant for industry. However, the existing automation system of the sinter plant in the practical field is not more suitable. So, a new design with proper guideline has been conducted in this study. In this work, it is concluded that the new PLC design of sinter plant is effected due to its accuracy performance and better controlling from remote places. It is also depicted that the new design has been fulfilled its objectives. By utilizing the new developed design here in an user can control the sinter plant easily.

The lighting design of control room has been developed by the new upcoming lighting source as Light Emitting Diode (LED). LED has been used for both indoor as well as outdoor/industry lighting application. In the existing lighting design average illuminance and uniformity is low, which need to be improved. So, the modified design has been done using LEDs, which gives the proper lighting accuracy as well as the reliability of the lighting design. This new lighting design has reduced the power consumption and increased lifetime of the luminaires.

9.2 FUTURE SCOPE OF WORK

In this thesis, only a small part of sinter plant is shown in detail. The whole sinter plant automation is very large and complicated. Along with STEP 7 and WinCC other programming softwares are also used. The research and development teams are also associated with this process for continuous monitoring purpose. In near future the automation system of whole sinter plant will be done.

In the sinter plant a lot of instruments, machines are situated in the processing area, so the lighting design is not only limited within the control room. In that case industrial lighting design will take a huge role in indoor and outdoor lighting design like - Road lighting, High mast lighting, Emergency lighting.

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