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Industrial Electrical Engineering and Automation

Analysing an automated filtration system

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Analysing an automated filtration system

Studying and documenting the automated Smart-Filter system at Demab AB

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Abstract

Filtration systems are critical to many industries, such as wood, metal, composite processing, agriculture etc. The dust filter removes contaminated harmful particles from the air and protects against explosions caused by combustible dust. A filtration system is essential for the safety of the environment and workplace.

The purpose of the report is to analyse and document the automated Smart-Filter system at Demab AB. Demab AB delivers automation equipment to Nederman AB regarding their filtration systems, called Smart-Filter System. The control system was implemented in the Siemens S7-1200 Programmable logic controller (PLC), through verbal dialog between people. This resulted in the lack of documentation of the system.

The first step in this thesis was to study the general description of the physical system and its presentation in the Siemens totally integrated automation portal (TIA Portal) software. The main functions for the filtration system were described, physical (hardware part) against implementation (software part). Then, a more detailed description of the implementation was documented, consisting of tables for inputs and outputs, algorithms and functions used in the TIA Portal.

The PLC (Siemens S7-1200) is the hardware used to control the system. This hardware with 8 signal modules, represents all the inputs and outputs. Most of the functions are manipulated through the Nedermans control panel with human machine interface (HMI) TP-700 Comfort, consisting of several screens that are described briefly in the thesis.

The result of the thesis is a design specification, with a detailed description of the Smart-Filter system, and suggestions for improvements when implementing a new application.

Keywords: Filtration System, Design specification, PLC, HMI, Smart-Filter System, documentation of control system, standardisation of control system

Sammanfattning

Filtreringssystem är avgörande för många industrier, såsom trä, metall, komposit bearbetning, jordbruk och mer. Den tar bort skadliga partiklar från luften och skyddar mot explosioner orsakade av brännbart damm. Ett filtreringssystem är avgörande för säkerheten för miljön och arbetsplatsen.

Syftet med rapporten är att analysera och dokumentera det automatiserade Smart-Filter systemet hos Demab AB. Demab AB levererar automationsutrustning gällande deras filtreringssystem, så kallat Smart-Filter System. Styrsystemet är implementerat i Siemens S7-1200 PLC, genom verbal dialog mellan två personer som skrev applikationen. Detta resulterade i bristande dokumentation av systemet. Det första steget i detta examensarbete var att studera den allmänna beskrivningen av det fysiska systemet, och hur det presenterades i mjukvaran Siemens TIA-portal. Huvudfunktionerna för filtrering systemet beskrevs, fysisk mot implementering.

Därefter dokumenterades en mer detaljerad beskrivning av implementeringen, bestående av tabeller för in- och utsignaler, algoritmer och funktioner som används i TIA-portalen.

PLC Siemens S7-1200 är hårdvaran som används för att styra systemet. Denna hårdvara är utökad med 8 signal moduler för att representera alla in- och utgångar. De flesta av funktionerna manipuleras genom Nedermans Control Panel med HMI TP-700 Comfort, bestående av flera skärmar som beskrivs kortfattat i rapporten Resultatet av examensarbetet blev en designspecifikation, med en detaljerad beskrivning av Smart-Filter-systemet och förslag på förbättringar vid implementering av en ny applikation.

Nyckelord: Filter System, design specifikation, PLC, HMI, Smart-Filter System, Dokumentation av automationssystem, Standarisering av automationsssystem

Foreword

We would like to thank our supervisor Janne Mujunen at Demab AB, for his help and assistance throughout this project, and for this opportunity that we got. Thanks to him, we were introduced to how an automation engineer really works. Special thanks to the staff at Demab AB and Nederman AB for providing us with the essential tools for this project.

We would also like to thank our supervisor Ramesh Saagi and our examiner Morten Hemmingsson at Lund university for their tips and advice during the period of the project work.

List of contents

1 Introduction

This chapter contains information about the company and its automation products, particularly their SmartFilter system. It also has an overview of the thesis.

1.1 Background

1.1.1 The company

Demab AB was started in 2007 and is active in industrial automation technology [11]. The company's office and workshop are located in Helsingborg. The customers are both locally and internationally spread all over the world. Local customers are often export companies but also facilities in for example energy industries, power industries, air filtration etc. Demab takes the responsibility for their customers' projects from planning to delivery.

Nederman AB is also called the clean air company that provides industrial air filtration products to many industries around the world [15]. The Nedermans head office is located in Helsingborg. They provide their products to a large variety of industries(companies, hospitals etc).

Demab AB has worked closely with Nederman regarding the delivery of automation equipment for Nederman's special filtration systems, called as Smart-Filter systems. Nederman's Smart-Filter systems are suitable for a variety of industries such as wood, metal, composite processing and agriculture. The equipment consists of a pulse jet collector for welding fumes, a high-vacuum separator for tool processing or a bag filter for furniture manufacturing.

1.2 Purpose

The purpose of the thesis is to improve the existing documentation and understanding of the system for people working with it, both Demab AB and Nederman AB. Since there is no clear design specification for the product, documentation is essential. Additionally, methods to modularize both hardware and application to increase the flexibility of the system are evaluated and suggestions are made.

1.3 Goals

The goal of the project is to establish and analyse a design specification for a Smart-filter system of an available implementation in the Siemens S7-1200 series control system and establish suggestions for how an improved modularity and configurability can be achieved when implementing a new application for control and monitoring of the filtration system in the Siemens S7-1200 or S7-1500 system.

The design specification should consist of:

1. General description of the object that will be controlled (the physical process)
2. A simple hierarchical block model of identified objects (physical against implementation).
3. The creation of a simple model and structure for the application for control and monitoring of the filtration system in the Siemens S7-1200 and a description of it.
4. A description of identified functions, function blocks in the application.
5. Provide suggestions for improvements to achieve better flexibility.

1.4 Problem formulation

The Siemens S7-1200 system is basically a black box, which does not clarify functions and algorithms that the control system handles. This system probably also contains some built-in functions that are not optimal for the control system's performance and dynamics. The main questions that the thesis will answer are:

1. How to analyse and describe the physical process against objects in the existing application.
2. In what way is it most appropriate to describe the model and structure of the application?
3. What calculations are there in the Siemens S7-1200 control system, for example, flow control of filters that are described in the user manual and how can these be documented.
4. How does the graphical interface (HMI) relate to the control system?
5. To find solutions that increase the reliability and availability of the existing Siemens S7-1200 control system, so that it should be easy to reuse the system, or reuse part of the system or even implement the control system in other platforms than Siemens.

1.5 Motivation of thesis

The motivation with the project is to learn more about automation and control systems as it is an important part of our education, and it is the subject that we find most interesting. We want to examine how such a control system (filter system in this case) is structured, and how it is controlled and automated.
The company's motivation for the project is to document a detailed description of the control system, i.e. a documented design specification that can be reused by people who want to use the filter system.

1.6 Boundaries

The project is limited only to control systems and HMI implementation and does not affect other designs. The design specification will not describe each and every function in detail, but provides an overview and describes the key functions in more detail. Additionally the project is limited to documentation and suggestion, in other words no improvements or modifications are made on the existing implementation.

2 Technical background

This chapter gives an overview of the SmartFilter System and its key functionalities. It also gives information about the Siemens TIA Portal, HMI and PLC. A description of the standarization methods (IEC standards) are also included in this chapter.

2.1 The filtration process

Figure 2.1 shows a typical dust filtration system in a workplace. A Smart-Filter system consists of filters, vacuum units, big-bags, venting panels and the duct system [1]. There are different types of filters. Number of filters and types are customised depending on the workplace requirments. The contaminated air flow from the workplace or industry is let through the ducts to the filters for cleaning with the help of the high vacuum units. The clean air will then be released back to the environment. All dust particles are emptied into the plastic big-bags. Most of the filters consist of explosion relief panels, to direct any pressure or explosion to a safe unmanned area [1].

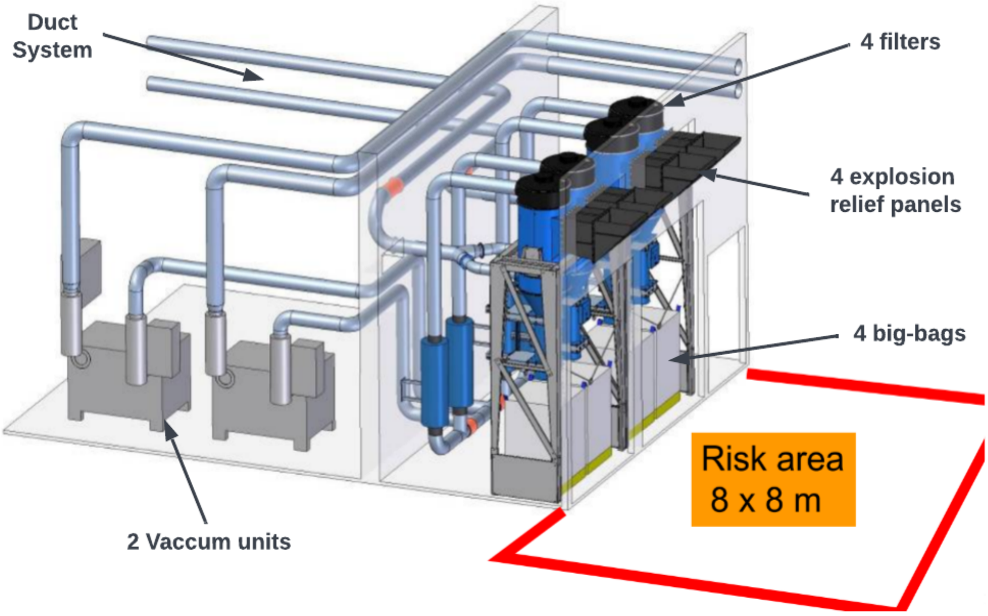


Figure 2.1: General overview of a typical industrial dust filtration system.

The type of filters studied in this thesis are Flexfilters 18 EX from Nederman [1] (see figure 2.2). These types of filters are high vacuum filters with a maximum of 40 kPa working pressure [17]. Flexfilters 18 EX are used when there is a high content of explosive dust particles.The studied system consists of 6 filters of the type Flexfilter 18 and 7 vacuum units.

Figure 2.2: Flexfilters 18 EX from Nederman at an industrial workplace.

This type of VAC (vacuum unit) in figure 2.3 is designed with automatic valves, where the airflow can vary rapidly depending on the needs at the workplace [1]. It is also designed with an automatic start/stop function to stop completely when not used or start automatically when needed. This modern design makes the system very efficient, where some part of the system stops working completely when not used.

Figure 2.3: VAC 20-4000 from Nederman. Max power 45 kW

The key functions for the Smart-Filter system are:

- Cleaning - the dust particles are filtered by the big bags (See chapter 2.1.1)
- Emptying by TVFD (Twin Valve Feed-out Drive) - the dust particles are emptied in a plastic bag (See chapter 2.1.2)
- Flushing - is cleaning of the duct system by the flush valves (See chapter 2.1.3)

Figure 2.4: Flexfilter 18 EX from Nederman (cleaning and emptying areas)

2.1.1 Cleaning with pulse-jet

The cleaning function is the key function of the Smart-filter system. The dust particles in the air flow are separated and only the clean air flow is passing through the cleaning filters out to the environment. The cleaning process and components vary depending on the type of the filter used. In the case studied with flex-filter 18 EX, each filter consists of 4 cleaning bags connected to 4 solenoid valves (See figure 2.5). The contaminated air enters from the bottom of the filters, where the small dust particles accumulate around the filter surface and only the clean air passes through. The heavy particles will fall directly into the hopper. The accumulated particles are then removed by activating the solenoid valves. It is a short duration pulse jet of compressed air that bursts into the filter tubes. This pulse of air creates reverse flow of air to remove the attached particles into the filter bag surface down to the hopper [7].

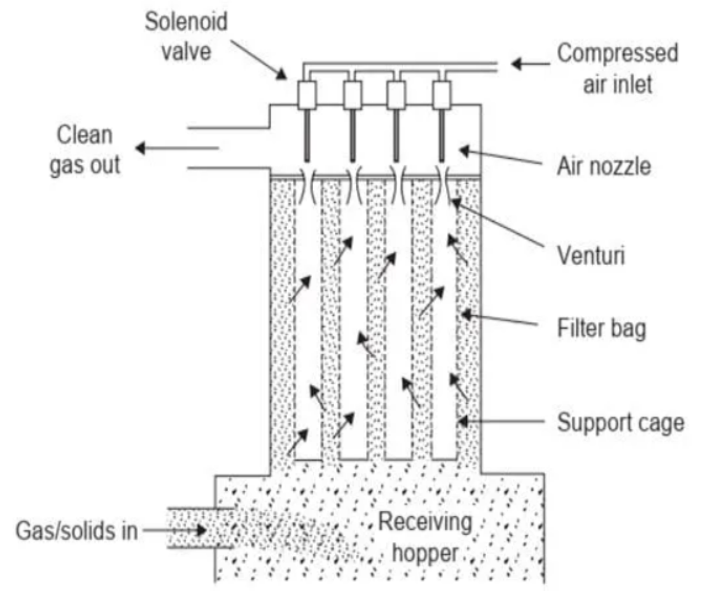


Figure 2.5: Pulse-jet bag filter for cleaning.
(See Figure 4.1 for an overview of the filtration system)

2.1.2. Emptying by TVFD (Twin Valve Feed-out Drive)

Emptying by TVFD functionality (See figure 4.1, point 4) is to move the dust particles collected from the cleaning process to the Big-bag. TVFD consists of two gates (valves) that open and close in a selected sequence so the dust particles fall through these gates to the big-bag.

2.1.3. Flushing

By flushing (See figure 4.1, point 2), all the dust particles accumulated in the duct system will be removed. Specific amount of flush valves are installed in the duct system that are activated in sequences.

2.2 The control system

The control system consists of the main devices that are usually used in industrial automation systems. The purpose of a control system is to control different devices in a system, such as sensors, actuators, valves, motors, switches etc with minimal to no human involvement. Such systems will include computer software (See 2.2.1 Software), hardware PLC (See 2.2.2 PLC) and HMI (See 2.2.3 Control Panel) and the field that needs to be controlled (See figure 2.6). In this case, a PLC from Siemens of the type S7-1200 is used., along with the Human Machine Interface (HMI) of the type TP-700 Comfort. The software Siemens TIA-Portal (Totally Integrated Automation from Siemens) is used to program the PLC and the HMI.

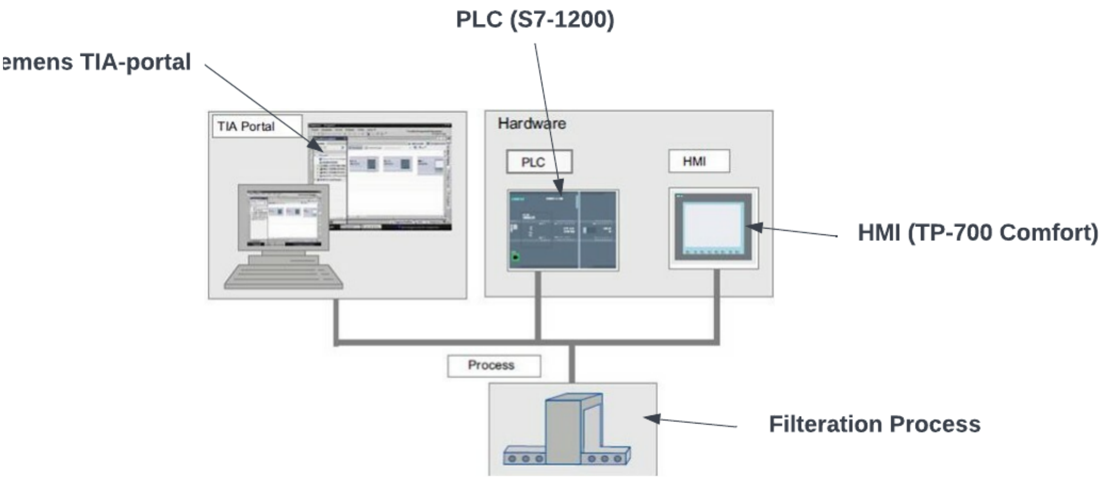


Figure 2.6: Overview of a control system

2.2.1 Software - Siemens Tia Portal

The Totally Integrated Automation Portal (TIA Portal) is a software platform developed by Siemens for programming automation systems [4]. It is responsible for programming and configuring Siemens PLCs and HMIs. The software provides testing and simulation of PLC and HMI. This property makes it possible to test the system virtually without the need of connecting to the physical PLC. Figure 2.7 below shows an example view of TIA Portal that was analysed in this project, where the implementation code is written along with a separate window for the simulated PLC and HMI. The software program

PLCSIM makes it possible to test the program with virtual PLC. The PLC and HMI are simulated separately with two different software programs for each device. The simulation software for the HMI is winCC.

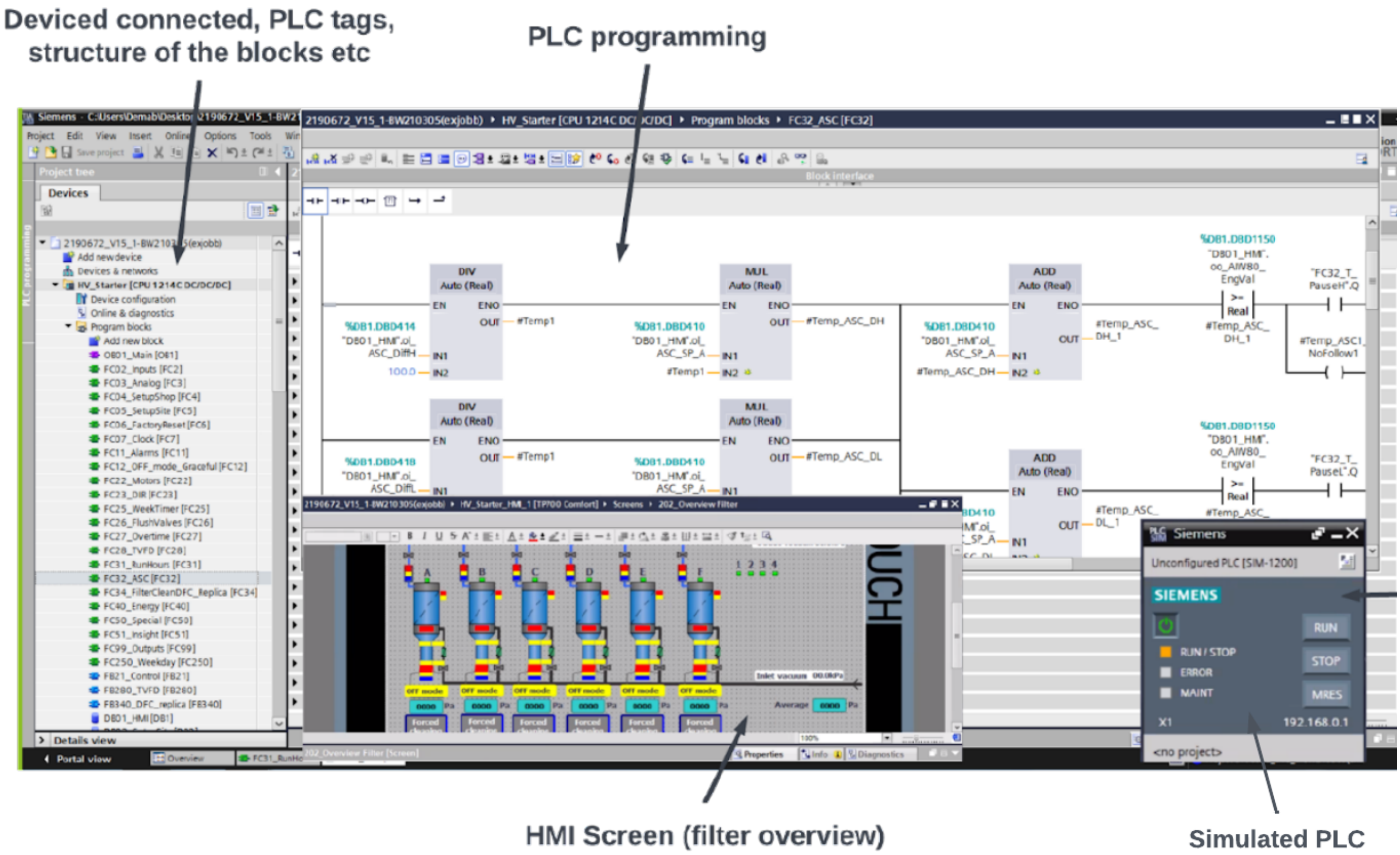


Figure 2.7: TIA Portal environment of the system that was analysed, with separate windows for the simulated PLC and HMI.

Figure 2.8 shows the four program blocks in TIA Portal. The organisation block (OB) is the main block that executes the code. But usually for a good structured program, the code is not written directly in the OB. Because with complex implementation this will make it very difficult to understand and organise the code. Therefore the main use of the two blocks (Function FC and Function Block FB) is to organise and divide the program code to smaller parts that can be easily understood. However these blocks will not be executed unless they are called by the organisation block.

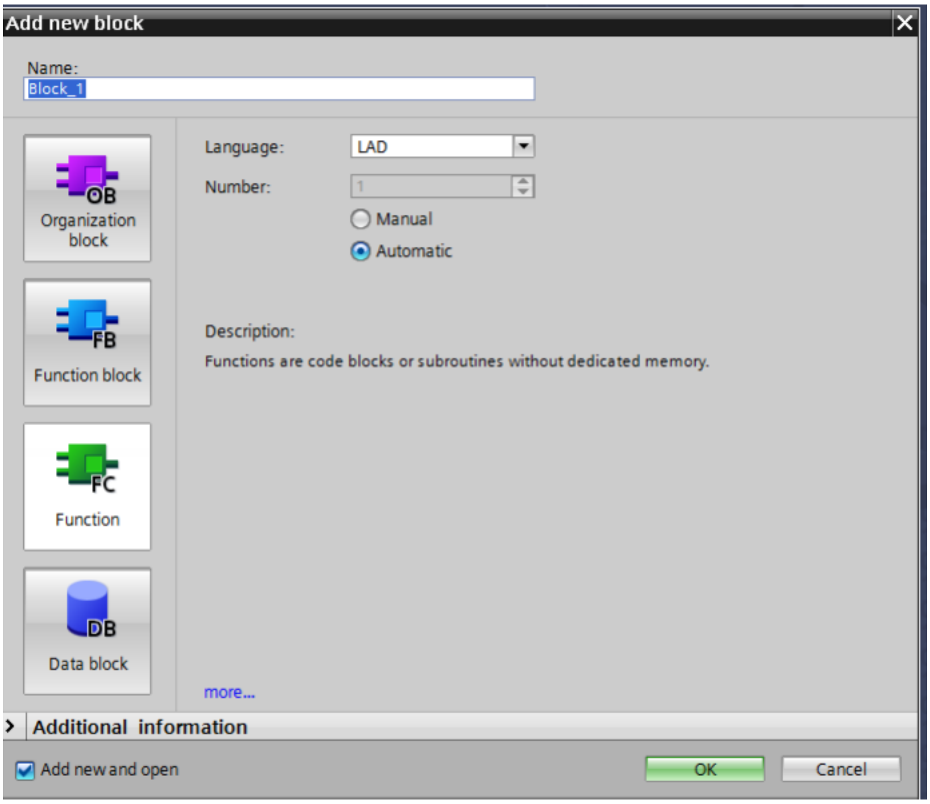


Figure 2.8: All block types in TIA portal(OB, FB, FC, DB)

The block FC is a logic block without memory. The diffrence between FC and FB, is that the FB has a memory, and whenever the block is called it creates a database memory called instance data block (iDB). This means that data in iDB can only be changed, deleted, added by the associated function block, unlike the global data block, where all the blocks can read and write the data in the global block [8] (see figure 2.9).

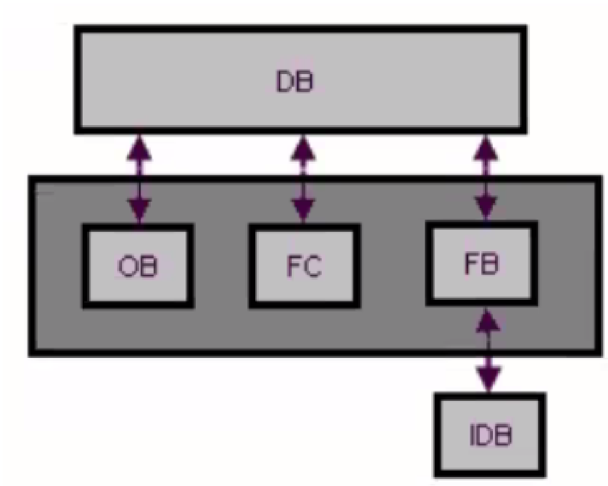


Figure 2.9: Global data DB block and instance data block iDB

2.2.2 Hardware - Programmable Logic Controller PLC (Siemens S7-1200)

PLC stands for Programmable Logic Controller, and is used as a programmable computer in automation industries [10]. The PLC hardware consits of different parts, see figure 2.10. The figure shows a PLC type from Siemens. Input signal modules are connected to the sensors, and the output signal modules are connected to the acutators. With this type of PLCs more signal modules can be added to the PLC hardware if needed.

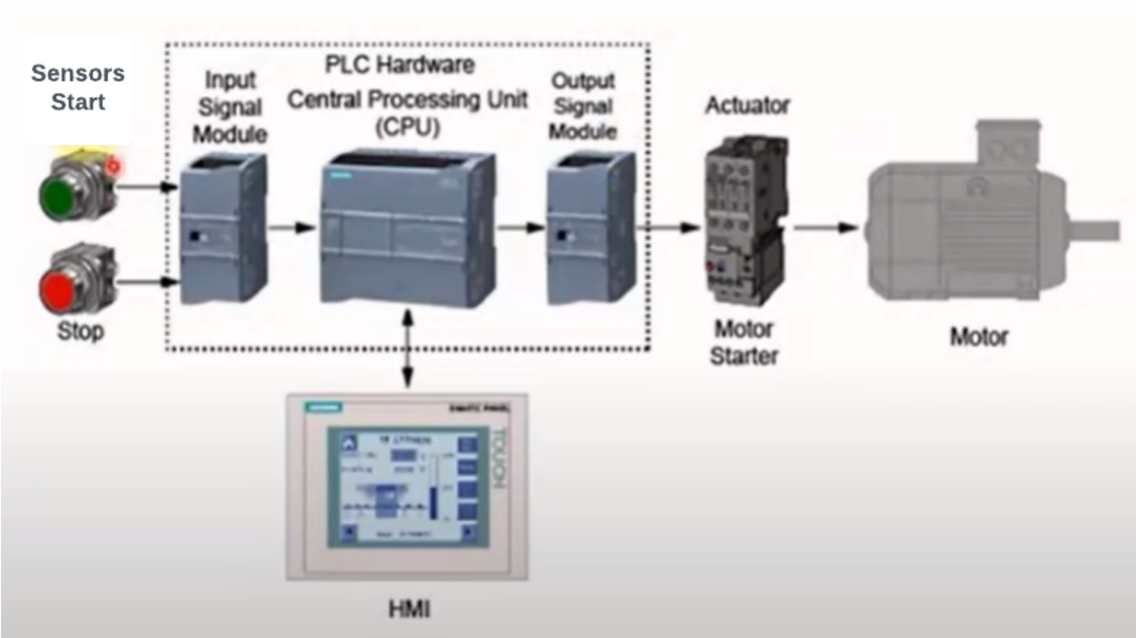


Figure 2.10: PLC hardware parts

PLC can be programmed using standard programing languages IEC 61131-1 standard. Five languages are used in this standard [4] :

- Functional Block Diagram (FBD)
- Ladder Logic (LAD)
- Structured Text (ST)
- Instruction List (IL)
- Sequential Function Chart (SFC)

In the analysed implementation, both LAD and FBD have been used in programming the system. Figure 2.11 shows an example of a very simple logic. The same logic is written in two different languages.

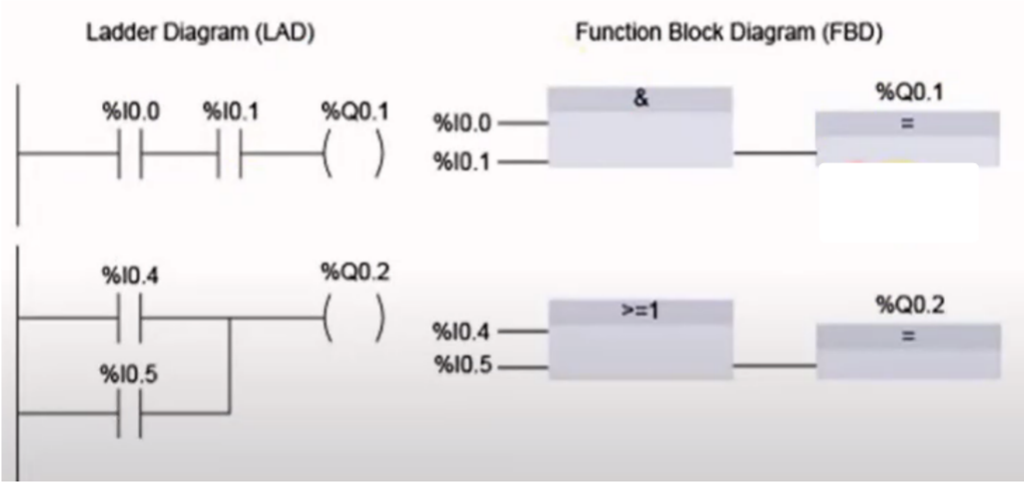


Figure 2.11: Ladder Diagram (LAD), Funktion Block Diagram (FBD)

The type of PLC used in the analysed implementation is Siemens S7-1200 [3] (See figure 2.12). This PLC CPU can be connected to both digital inputs, analog inputs and digital outputs. The data types that are supported in S7-1200 are more than 15 data types. But the most used data types in this case are : boolean, byte, word, Int, Dint, real, and string.

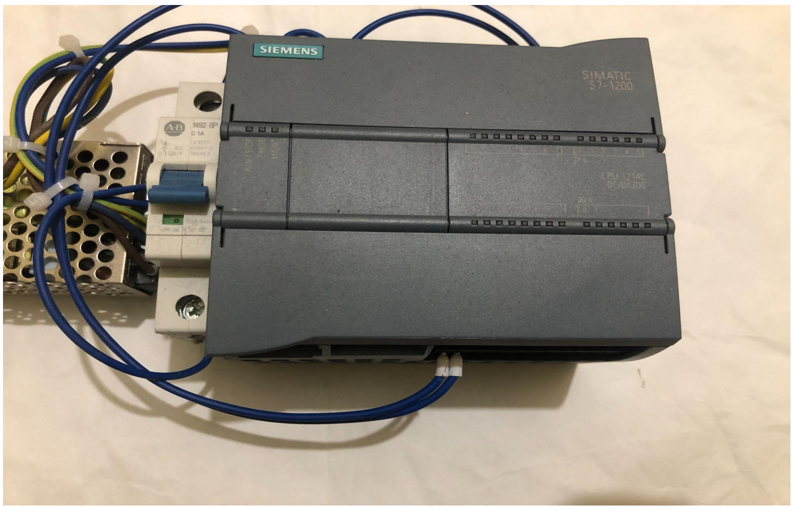


Figure 2.12: Siemens PLC S7-1200

2.2.3 Hardware - Control Panel - Human Machine Interface HMI (TP-700 Comfort)

HMI (Human Machine Interface) is an interface between a user and a machine. It is used in automations industries to provide a clear visual represenation of the status of the control system in real time. The type of HMI that has been used in this system by Nederman is called HMI TP-700 Comfort [9]. Figure 2.13 shows a control panel from Nederman with a touch screen (HMI screens) from Siemens. These types of control panels are usually connected to the Smart-filter system.

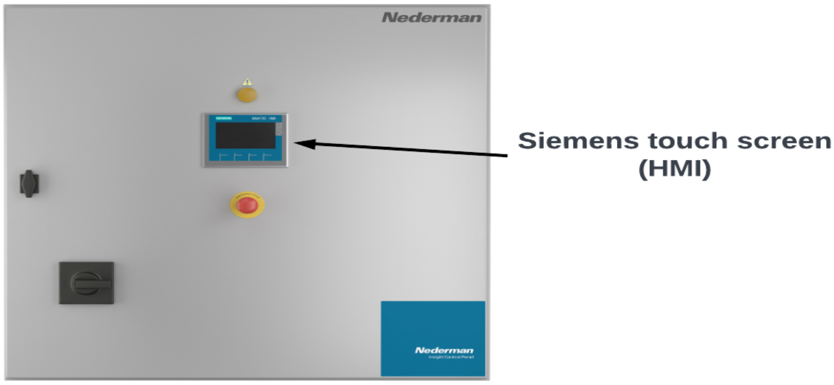


Figure 2.13: Control panel from Nederman

2.3 IEC standards (International Electrotechnical Commision)

IEC standards are technical performance standards for electronics that are developed by expert members from the international electrotechnical commission (IEC). There are several standards that each apply to specific product types, specific components, modules, systems etc. The standard discussed in this project beside the IEC 61131-1 standard, is the ISA-88 [12] (See chapter 2.3.1). The last mentioned one is applied for standardisation guidelines when implementing a control system. Standardisation guidelines give the programmer recommendations and guidelines for a well structured programming when implementing a new control system.

2.3.1 IEC 61512-1 (ISA-88)

ISA-88 is a standard published 1995 by the international society of automation (ISA) and in 1997 by IEC, under the name ”Batch control: Models and terminology”. It was originally designed for batch controlling, as a way to simplify and standardise the way that batches are organised in many industries [5].The purpose of the standardisation is to provide better communication between people working in these industries. Today the standard is applied among manufacturers and automation industries by using models. One model will be introduced in this chapter : the physical model (See figure 2.14). The physical model is a hierarchical model of 7 layers. The first three layers will not be discussed, since they are considered as business, and therefore only the lowest four layers are relevant to the process. The enterprise is the largest unit in the heirechy, which contains sites. It can be for example a company that makes cookies. A site is a physical location which contains one or more process areas (area for baking, packaging etc). Area is made of one or more process cells. A process cell must contain one or more units. In the case of the baking area (the kitchen), process cells could be : material prep, mixing, baking etc. A unit is made of one or more equipment modules. A unit could be an oven with the equipment module burners. An equipment module may contain one or more control modules. The control modules could be: the right burner, the left burner etc.

The physical model is a hierarchical model starting from the biggest unit as the highest level, to the smallest unit the control module.

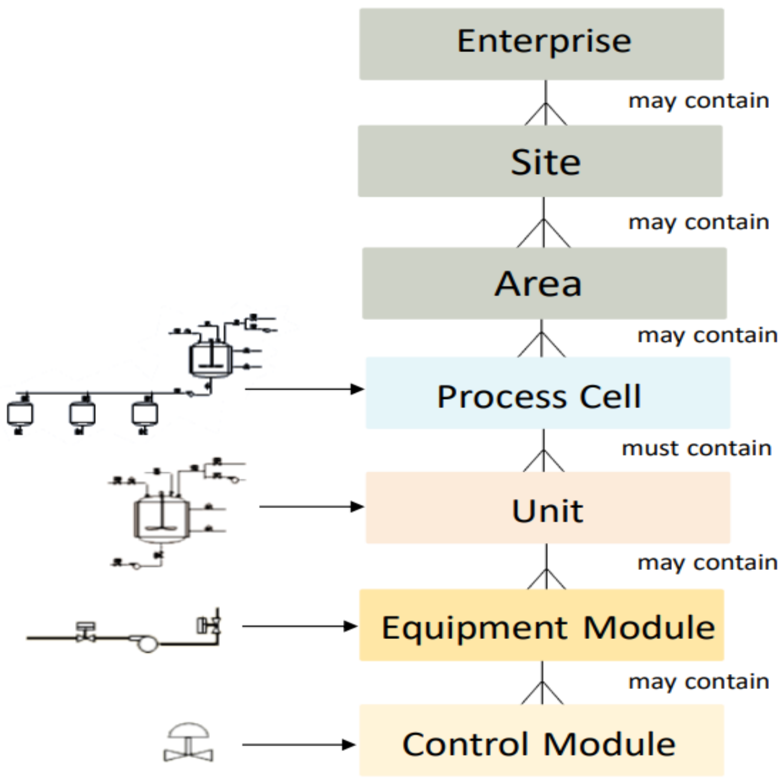


Figure 2.14: Example of how the physical model (ISA-88) is applied

3 Method

The method is divided into 3 phases. The first phase was mainly understanding the problem and the purpose of the thesis. This was done with the help of the supervisor at Demab AB. The second phase is the collection of details, where information about the different components in the system were gathered. And the last phase was analysing and documenting the system.

3.1 Phase 1 Problem understanding

Meetings with Demab AB were made to discuss the purpose of the thesis. Then a thesis description was written and sent to the examiner. The next meetings were held to discuss the dust filtration system and collect some information to begin with, since there was a lack of documentation regarding the Smart-Filter system. At the second meeting an electrical drawing was handled from the company. This electrical drawing that consisted of components like filters, motors, sensors, ventiles etc was an important part of studying the system and understanding it.

3.2 Phase 2 collection of details:

Information was collected, mainly from Nedermans homepage and their documents to understand how a dust filtration system works,and what components of their products were used in the Smart-Filter system (Particularly the Flex-Filters). Every part of the electrical drawing was studied and information gathered in a document, after searching information about each part of the drawing in the Nedermans documents.
Additionally information was collected to study and learn more about the Siemens TIA Portal environment, and the Siemens PLC hardware, particularly the S7-1200.

3.3 Phase 3: System analysing and documentation

A Siemens S7-1200 was received from the company, with the implementation of the Smart-filter system. With the help of a virtual desktop from Demab AB, a simulated PLC and HMI were studied. The TIA portal consisted of several functions and function blocks. There were more than 500 different PLC tags. Only the functions that were relevant to the key functions of the system were analysed and documented. The main functions were for example the cleaning, emptying, flushing etc. Functions for clock settings, setup settings etc. were not considered important for the purpose of this thesis. Analysing and documenting the system were made simultaneously. The result was a complete design specification including a description of the physical system and how it was represented in the PLC.
At last the company wished for suggestions for improvements. This was discussed with Demab AB and they suggested looking at the different standarization methods in industrial automation. After searching and getting advice from the company an isa-88 standarization model was suggested to use when implementing a new program in the PLC.

3.4 Evaluation of sources

[1], [2], [9] and [15] are all sources from Nederman AB. These are all official sources including information about the companies products and services, and are therefore considered trustworthly.

[3], [4], [5], [6], [8] and [10] are all sources from Siemens AB. Siemens AB is a well known company worldwide. They have thousands of documents on their webpage. Their documents consist of their products information and services information. The Siemens official website is considered trustworthy.

[7] is a source from the company Pneumatic Conveying Solutions that is based in the USA. The company sells electronic components for the automation industries. Therefore there is no reason to not trust the information published on the webpage.

[11] includes information from the Demab AB. Therefore It's considered trustworthy.

[12] ISA (International Society of Automation) is an international organization and the information from their official website is considered trustworthy.

[13] Consists of information about the IEC 61499 standard. This webpage belongs to the International Electrotechnical Commission and therefore is considered trustworthy.

[14] Sveriges ingenörer is an official organisation for the engineers in sweden, and their official website is considered trustworthy.

[16] Codesys is an automation software for engineering control systems that is widely used by engineers worldwide. Their official website is considered trustworthy.

4 Analysis and result

This chapter will include a detailed description of the control system. First part of this chapter gives a general description of the process, with an overview of the Smart-Filter system, associated products and key functionalities. Then the hardware (S7-1200) will also be analysed. Next step is analysing all functions and function blocks in the TIA Portal enviroment. Last step is a brief description of the main HMI screens in the implementation.

4.1 General description of the process

The Smart-Filter system is equipped with 6 filter units of the type Flexfilter 18 EX. The Flexfilter 18 EX is a model type that is used in industries with a high vacuum working space (max 40 000 Pa). This filter is also suitable for environments with high risk of dust explosions, caused by high concentration of dust particles in the air (combustible dusts) [2]. 7x Vac 20-4000 vacuum units are installed for the high vacuum extraction. The filter systems main functions are: Cleaning of filter by PulseJet valve, emptying by TVFD and flushing.

4.1.1 Overview of the filter system

The figure below shows the system with filters, motors, valves, sensors etc (To read the expanded words of the abbreviations, see figure 9.1 in appendix)

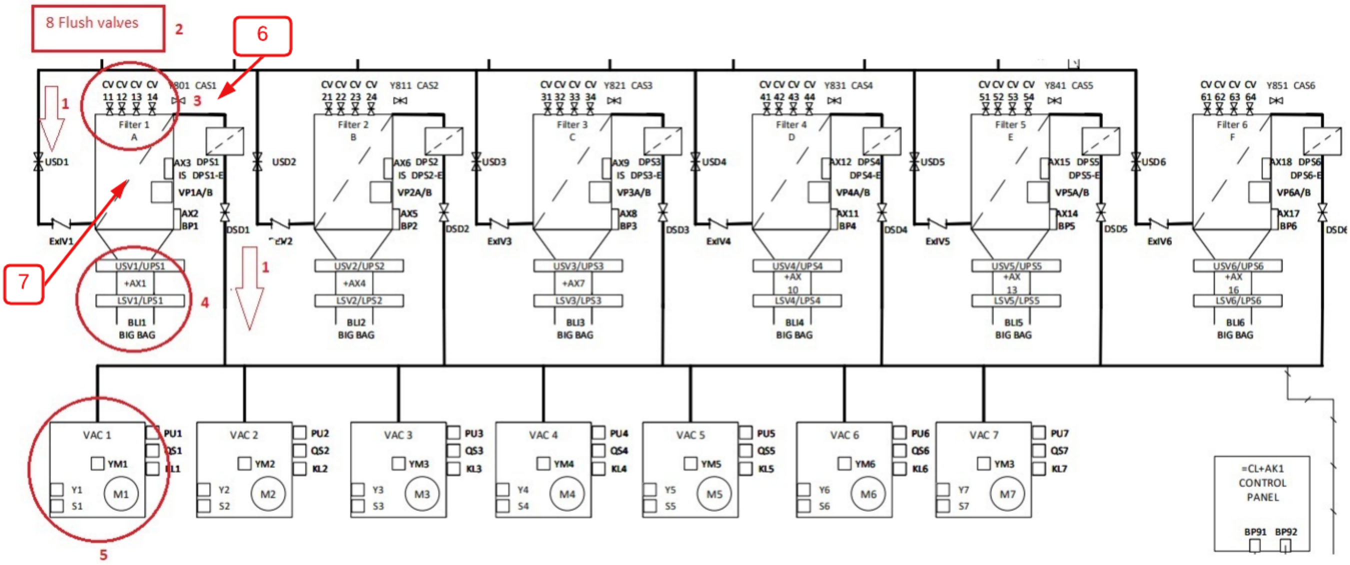


Figure 4.1: Design of the Smart-Filter system

1 This is the air flow direction, the contaminated air so called inlet vacuum passes through the upstream damper (USD1) up to the filter. The clean air so called outlet vacuum passes out to the environment through the downstream damper (DSD1). A damper is a mechanical device to regulate the air flow by changing the size of the opening.

2 Flush valves that are used to reduce dust accumulation in the duct system. 8 valves are used for this purpose.

3 Cleaning of filters by PulseJets, 4 cleaning valves for each filter. Pulses are made via selector relay for each valve. The cleaning process removes the dust and particles that have accumulated at the surface of the filter.

4 Emptying the dust particles from the filters to the Big bag by TVFD.

5 High vacuum units.

6 Tank filled with compressed air.

7 Cleaning with pulse jet (See figure 2.5)

4.2 PLC (S7-1200)

The type of PLC used in the studied implementation is PLC S7-1200 [10] 1214c dc/dc/dc. The first dc corresponds to the type of power signal that gives power to the CPU. The second dc corresponds to the type of inputs in the CPU. The last dc corresponds to the type of outputs in the CPU. The CPU is connected to 8 expansion modules (see figure 4.2). CPU I/Os are the connected digital inputs and digital outputs to the system: alarms, warnings, buttons, flash lights etc (see table 9.1 in appendix). The expansion modules I/Os 2-7 correspond to filters 1-6, the inputs and outputs from these modules are connected to the filters 1-6 (see table 9.2 in appendix). Only table 2 that corresponds to filter 1 is represented in the thesis, because the same type of inputs and outputs are found for filters 2-6. The expansion modules I/Os 8-9 are connected to the analog inputs in the system (see table 9.3 and 9.4 in appendix).

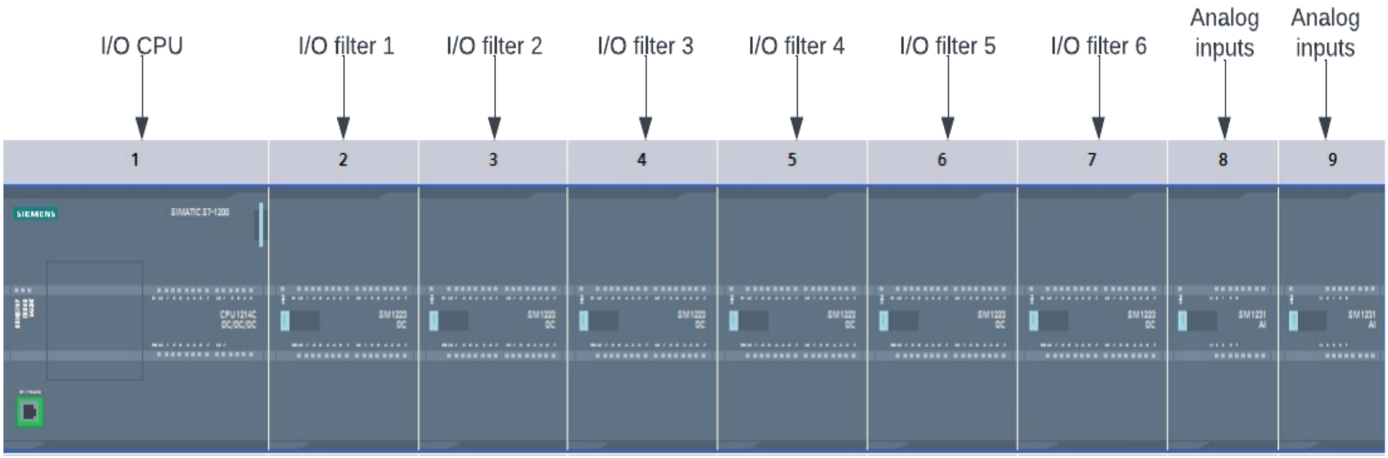


Figure 4.2: PLC S7-1200, the CPU with 8 expansion modules

4.3 Overview of the key functions of the SmartFilter system

4.3.1 Flushing

The flush valves are normally installed in the upstream end of the ducts. The 8 valves open in sequence when the function flushing has started. The sequence of flushing starts after the interval time has ended. The interval time is the time between the end of the cycle to the start of the next cycle. Pause time is the time between the end of a flush valve pulse to the start of the next flush valve pulse. Pulse time = 0 means there is no pulse.

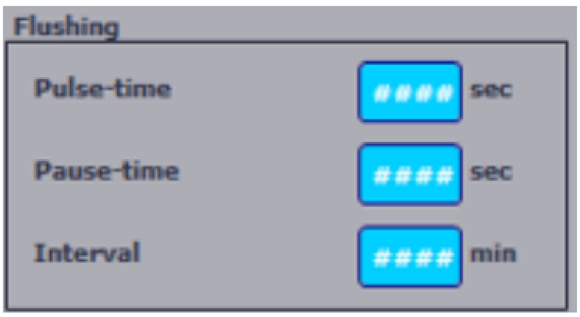


Figure 4.3: HMI screen, selecting time intervals for flushing

4.3.2 Cleaning

Cleaning valves (Pulse jets) are running in a sequence when cleaning. The pulses are made via the selector relay. When selecting valve 1, a pulse is active from valve 1 for each filter and so on. There are two ways of cleaning: normal cleaning and DTC (Down Time Cleaning). Normal cleaning starts after a calculated interval time, depending on the pressure (dp) in the filters. The cleaning cycle interval can be between two defined values (interval 1 and interval 2). DTC starts when all VACs stop. The normal cleaning can also start by clicking the manual cleaning button in HMI. Forced cleaning is manual DTC that starts by clicking the forced cleaning button in HMI. Only one filter at a time can be cleaned by forced cleaning.

	Range	Default
Pulse	0-99.9 s	0,1 s
Pause	6-999 s	10 s
Interval 1	0-9999 m	20 m
Interval 2	0-9999 m	0 m
High dP	0-9999 Pa	1500 Pa
Low dP	0-9999 Pa	200 Pa
dP average time const.	0-999 s	120 s
Delay before	0-99 s	5 s
Delay efter	0-99 s	10 s
DTC	0-9	3 s

Table 4.1: values for starting the cleaning cycle

- Pulse time : cleaning pulse for each valve (1-4). When valve x is active, a pulse is activated for valve x in each filter with a time gap to avoid noises.

- Pause time: Pause-time is the time needed for filling the tank (See Figure 4.1 for an overview of the filtration system) with air, minimum 6 sec.
- Interval 1 : is the interval between each cleaning cycle when the filter pressure is normally low. (The air flow is passing through with low resistance, because of the low volume of dust particles in the filters)
- Interval 2 : is the interval between each cleaning cycle when the filter pressure is normally high. (The air flow is passing through with high resistance, because of the high volume of dust particles in the filters)
- Delay before: delay time to start DTC after closed section dampers.
- Delay after: Delay time to open section dampers after DTC.
- DTC : Numbers of complete DTC cycles.

4.3.3 Emptying

Emptying by TVFD is a function to move the dust particles to the Big-bag. Normal position for the gates is that the upper gate is open and the lower gate is closed. The emptying sequence starts after an interval time, by first closing the upper gate and opening the lower gate. Then the dust particles will fall through the gates to the Big-bag. The emptying can start manually by clicking the emptying button in HMI. Manual emptying can also be activated when the system is in Standby or OFF mode.

Figure 4.4: HMI screen, selecting time intervals for emptying by TVFD

- Open time: open time is the time the TVFD lower is open.
- Pause (Move time): the time between closing of upper to opening of lower gate in TVFD.
- Interval sequence: How often the emptying is activated.

4.3.4 ASC (Anti Surge Control)

ASC (Anti Surge Control) means controlling the motor damper in VACs by measuring the actual motor current. The purpose is to control the airflow in the vacuum system and to prevent damage to the motor. The motor damper is controlled with pulses for opening and closing. The pulse and pause are set depending on the current difference in % (See figure 4.5 below) . It is the difference between the actual current that is measured and the setpoint current (See section 4.5.5 ASC).

Figure 4.5: HMI screen, settings for ASC

- Setpoint: the target value for the motor current.
- Setpoint + Diff. high speed means closing the damper using high speed pulse/pause.
- Setpoint + Diff.low speed means closing the damper using low speed pulse /pause.
- Setpoint - Diff. high speed means opening the damper using high speed pulse/pause.
- Setpoint - Diff.low speed means opening the damper using low speed pulse /pause.

4.4 System design

This chapter will include a hierarchical block model of identified objects (physical against implementation). The main functions are included with the identified objects. Also a model structure of the function blocks in the implementation is shown in this chapter.

4.4.1 Model and structure

The system model reflects an overall view of the filter system areas which is divided into layers, to give a better overview of the entire system. The system is divided into several blocks, each block representing a certain functionality of the system (Flushing, cleaning, emptying etc) with the main components mentioned in each block. This model will give a good understanding of the transition from the physical model to the implementation model (See chapter 4.4.2).

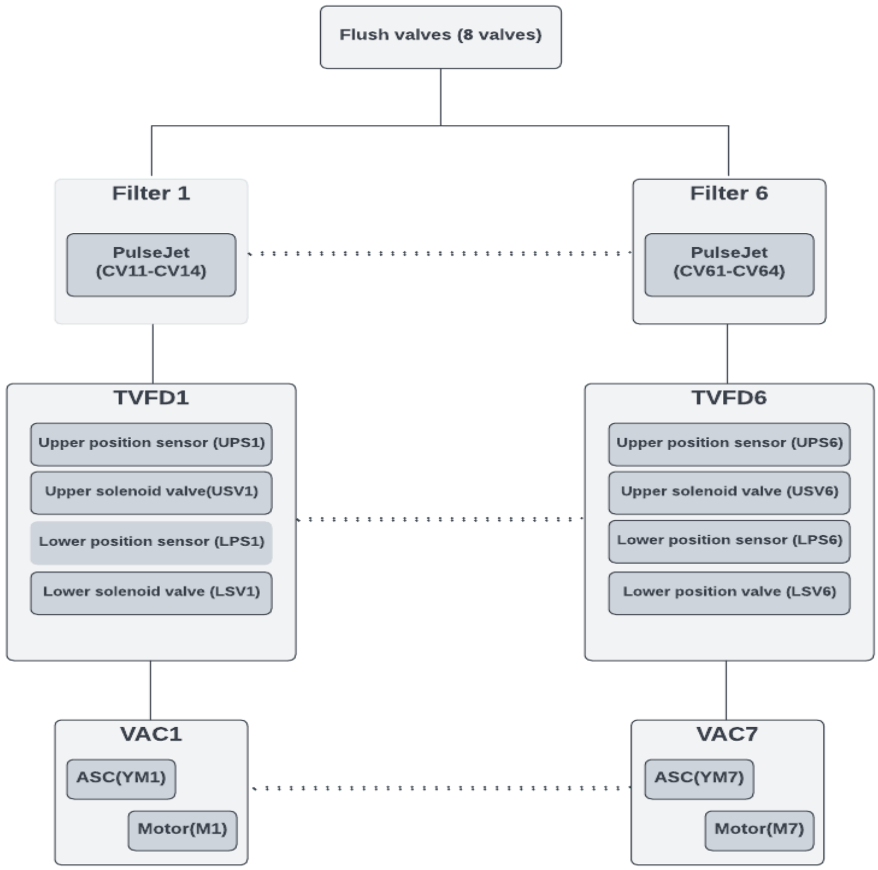


Figure 4.6: The structure of the functions in the system

4.4.2 Model units

As a transition from the physical model representing the system, this model below shows the main function blocks with the names and the objects (devices) used in the implementation part of the system (Siemens TIA Portal).

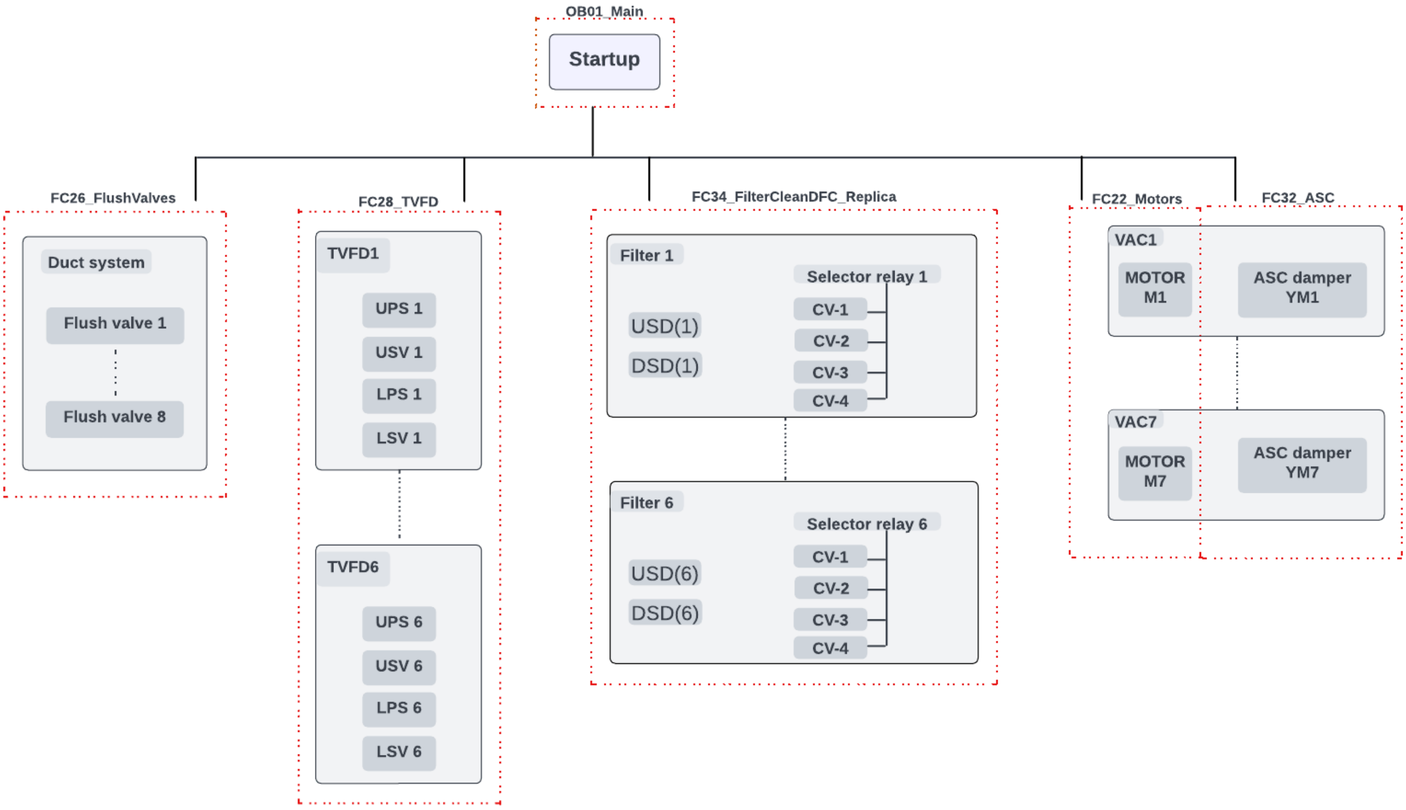


Figure 4.7: Model units and name of function blocks used in the implementation.

FC26_Flushvalves : The logic for flushing using 8 flush valves.

FC28_TVFD: The logic for emptying by TVFD.

FC34_FilterCleanDFC Replica: The logic for cleaning of filter 1 to filter 6 using the 4 PulseJets (CV-1 to CV-4) in each filter. Also the logic for DTC (Down Time Cleaning) using upstream damper (USD) and lowstream damper (DSD).

FC22_Motors: The logic for controlling the motors 1 to 7 in VAC 1-7.

FC32_ASC: The logic for controlling the ASC dampers 1 to 7 in VAC 1-7.

4.5 The function blocks and the logics

The implementation consists of 22 functions and 3 function blocks. In this chapter, the main functions will be described in more details with inputs and outputs tables for each function. DB01_HMI is the database name for storing all values from/to the HMI panel. It also makes the connection between the HMI and PLC. See figure 9.2 in appendix.

4.5.1 Flushing

The function name is FC26_FlushValves. Flush valves are used to reduce dust accumulation in the duct system. 8 valves are used for this purpose. This function is the logic for flushing by using the valves. The flushing function is activated after interval time. These valves are running in a sequence: pause time, pulse time. Flushing is also manually activated from the HMI panel or by measuring the motor current. If a vacuum unit reaches a certain value the flushing will be activated (See figure 4.8)

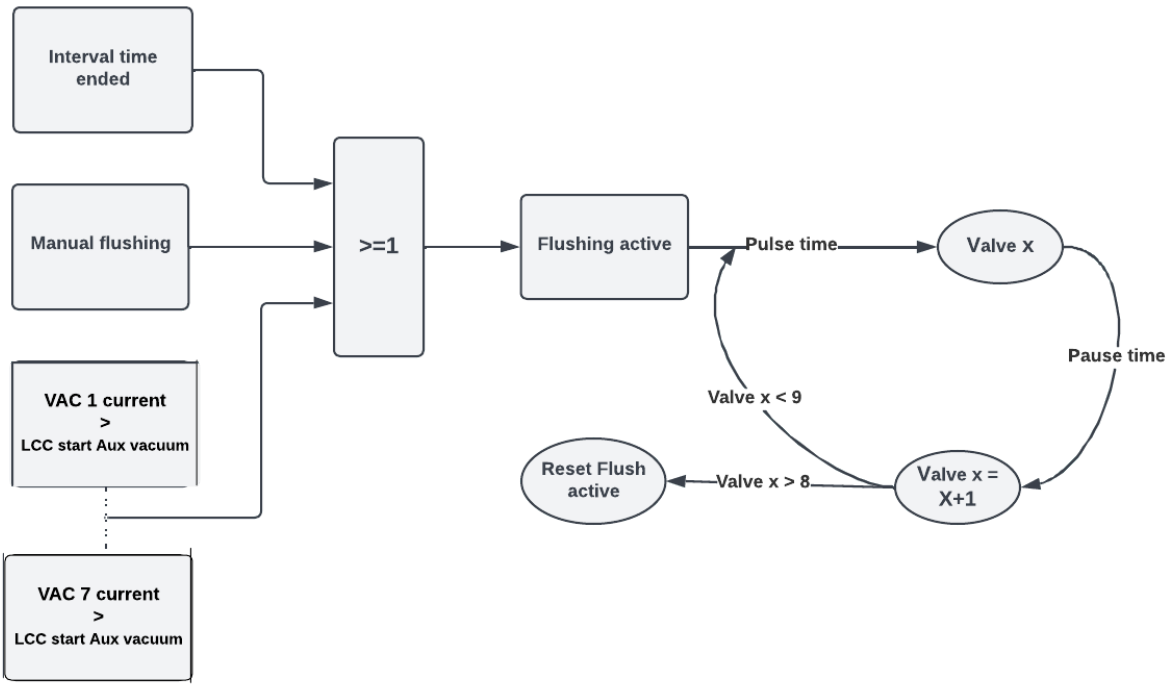


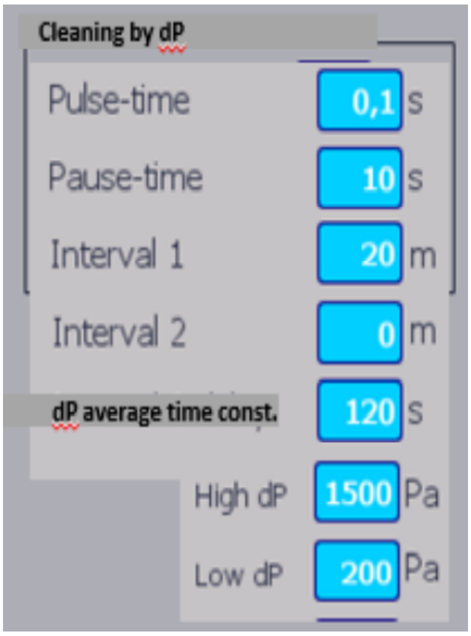
Figure 4.8:The sequence for flushing

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oi_FlushInterval_time	DInt	the running time between flush cycles, from the end of one cycle to start of the next cycle
"DB01_HMI".oi_ManFlushStart	Bool	Flush activation with push button
"DB01_HMI".oo_AIW80_EngVal	Real	Vac x current (x:1-7)
"DB01_HMI".oi_LCC_FlushStartLvl	Real	LCC start Aux vacuum
"DB01_HMI".oi_FlushPause_time	IEC_Timer	time between the end of pulse to next Flush valve pulse
"FC26_T_FlushPulse"	IEC_Timer	Pulse time for flush valve
Outputs		
"DB01_HMI".oo_FlushActive	Bool	Flush activation
">Flush1"	Bool	Flush valve x (x:1-8)
"DB01_HMI".oo_Flush_Num_flushSequence	DInt	Total number of flush sequence

Table 4.2 : Inputs and outputs for FC26_FlushValves

4.5.2 Cleaning

The function name is FC340_FilterCleanDFC_Replica. In this function block, the logic is about filter cleaning with pulse Jet. There are two ways of cleaning for this system : Normal cleaning and DTC (Down Time Cleaning). The function block FB340_DFC_replica is used to describe the cleaning sequence for each filter. First in the logic is initiating the values from the HMI. Then calculating the interval used based on the pressure in the filters. Interval time is the time used between each cleaning cycle. Interval 1 is the time used at lower dP and interval 2 is the time used at higher dP. Interval 1 and 2 are chosen from the user and the values are initiated from the HMI. The calculated interval will be in the time range between interval 1 and interval 2 (see figure 4.9 a).

a 

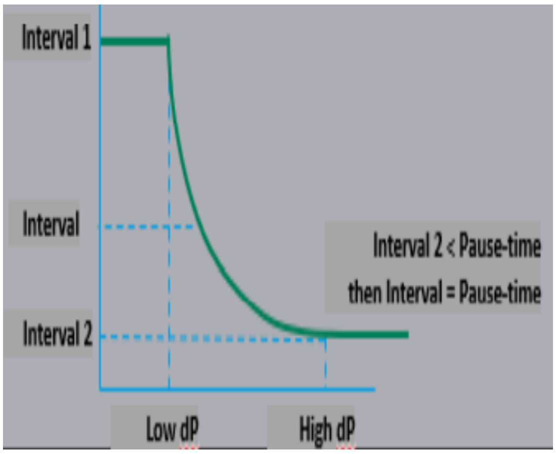
b 

Figure 4.9 a: Values chosen in HMI screen for the cleaning cycle, 4.9 b: the Interval time range and the dP range

Above (figure 4.9 b) is an example from the HMI with the set values. The interval will change between the interval range (0-20 m in this case), depending on the dP average variations in the range between High dP and Low dP (200-1500 in this case).

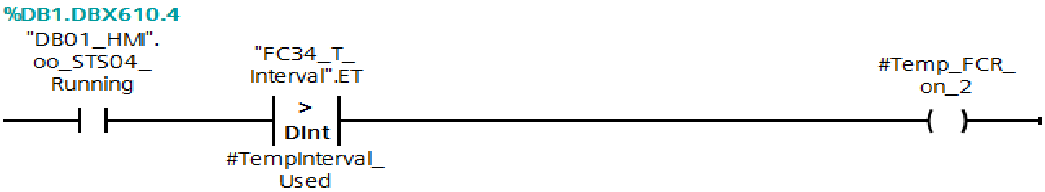


Figure 4.10: Ladder logic for interval timer

FC34_T_interval_ET (figure 4.10) is the timer for the used interval to start the next cleaning cycle. #Tempinterval_Used is the calculated new interval based on the pressure changes. If the calculated new interval time is shorter than the actual interval,, it means that the pressure in the filters is higher now, and the cleaning cycle should start even if the used interval time has not ended. This method using intervals for cleaning is called normal cleaning. And the interval is called normal cleaning interval, since after each interval a new cycle of normal cleaning will start. Normal cleaning can also start by clicking the manual cleaning button.

The ladder code below (figure 4.11) shows a timer to start DTC (Down time cleaning). DTC is executed when all filters stop, it means all VACs have stopped. The DTC starts as soon as the system is off and the average pressure in filters (dP average) is higher than Low dP. DTC is also executed in forced cleaning.

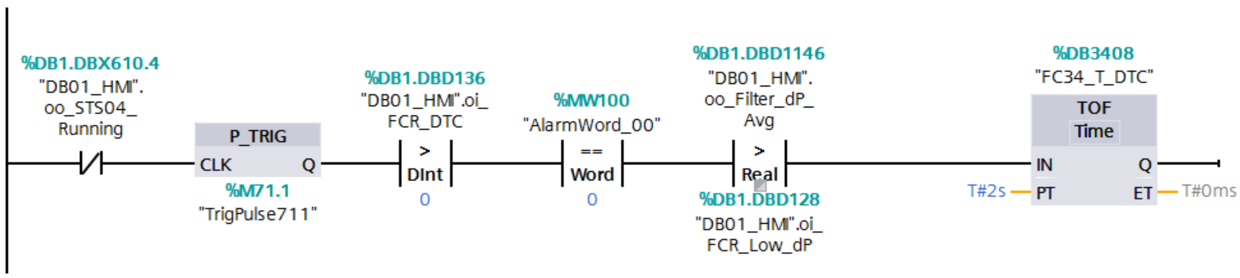


Figure 4.11 : Ladder code for DTC timer

FB340_DFC_replica is the block with programming code for how the cleaning sequence is executed for each filter from the start of the cycle to the end of the cycle. The normal cleaning cycle starts after the interval time. Valv x (1-4) in each filter makes pulses to clean the filters (1-6), and after a pause time the next valve (x+1) will make pulses. The pulses are activated with 1 s gap time, not all filters at the same time to prevent noises. The pause time is at least 6 seconds. The time to fill the tank is 6 seconds. See figure 4.12 below.

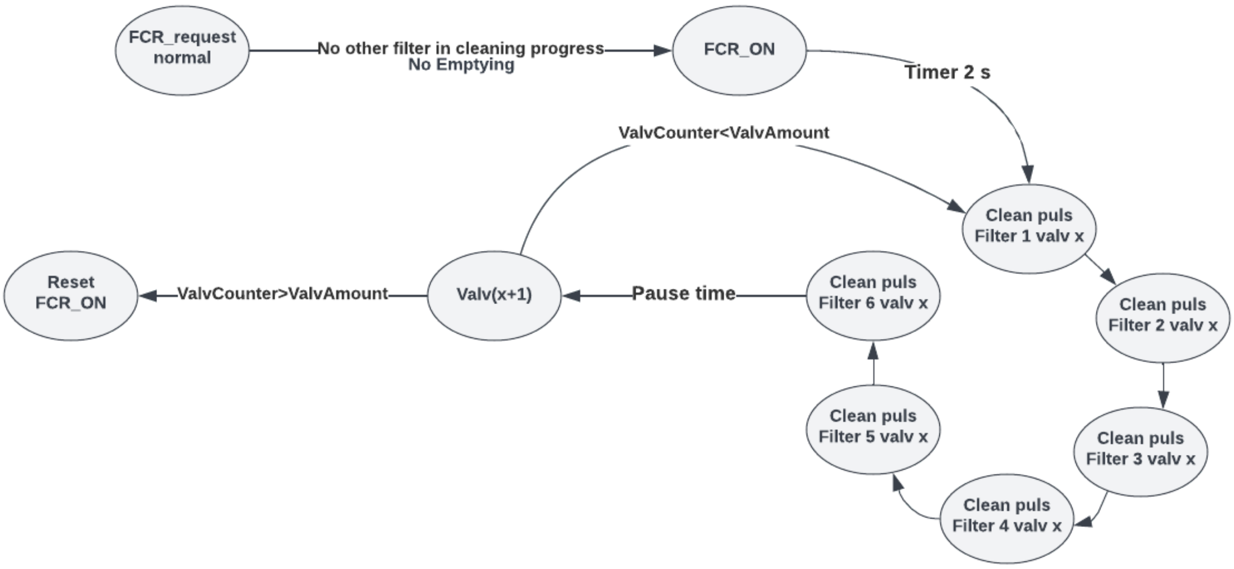


Figure 4.12: Normal cleaning cycle

Forced cleaning is a button from HMI to execute DTC manually. Only one filter at a time should be able to be forced cleaned. The process starts by first closing the section dampers and after the cleaning, the dampers open in a right sequence to prevent locking the isolation valve**.** See figure 4.13 below.

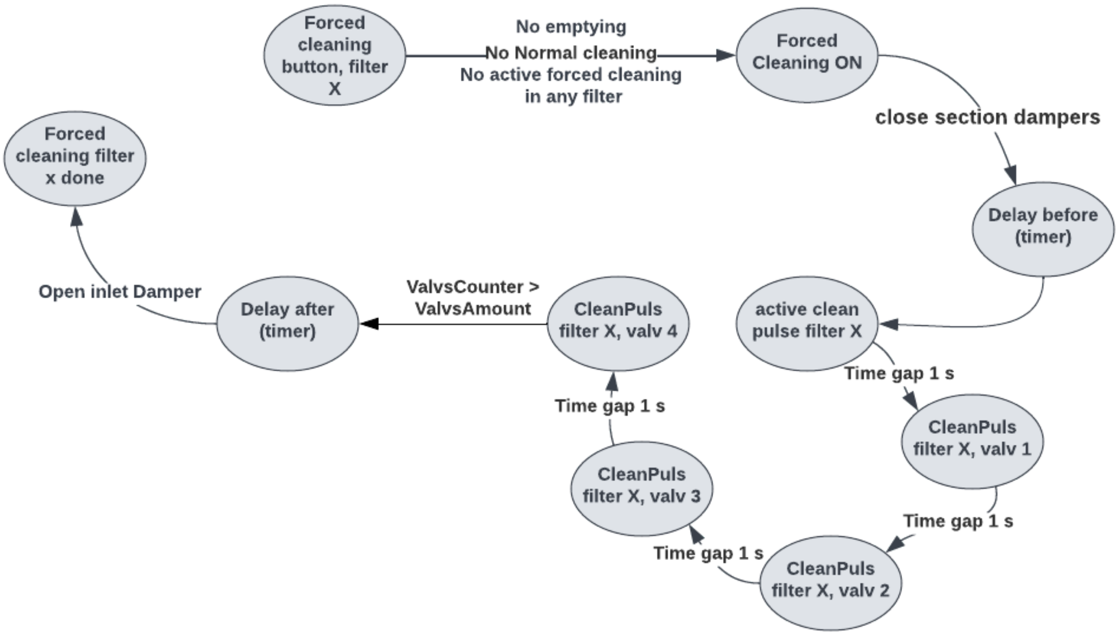


Figure 4.13: Forced cleaning cycle

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oi_FCR_Interval_time1	**DInt**	**Cleaning interval 1 (min)**
"DB01_HMI".oi_FCR_Interval_time2	**DInt**	**Cleaning interval 2 (min)**
"DB01_HMI".oi_FCR_Pulse_time	**DInt**	**Cleaning pulse (sec)**
"DB01_HMI".oi_FCR_Pause_time	**DInt**	**Cleaning pause(sec)**
"DB01_HMI".oi_FCR_High_dP	**DInt**	**Filter cleaning high dP (Pa)**
"DB01_HMI".oi_FCR_Low_dP	**DInt**	**Filter cleaning low dP (Pa)**
"DB01_HMI".oo_Filter_dP_Avg	**Real**	**Average pressure for filter system (Pa)**
"DB01_HMI".oi_SectionDampers_DelayBefore	**DInt**	**Wait after closing section dampers (sec)**
"DB01_HMI".oi_SectionDampers_DelayAfter	**DInt**	**Wait after cleaning ,then open the inlet damper (sec)**
"DB01_HMI".oi_FCR_DTC	**DInt**	**DTC cycles amount**
Outputs		

Signals	Datatype	Comment
">FF1_CleanPulse"	**Bool**	**Filter x clean pulse (x:1-6)**
">Pulse_1"	**Bool**	**Cleaning valve 1**
">Pulse_2"	**Bool**	**Cleaning valve 2**
">Pulse_3"	**Bool**	**Cleaning valve 3**
">Pulse_4"	**Bool**	**Cleaning valve 4**
">Section1_open_IN"	**Bool**	**Inlet damper for filter x open (x:1-6)**
">Section1_open_OUT"	**Bool**	**Outlet damper for filter x open (x:1-6)**

Table 4.3: Inputs and outputs for FC34_FilterCleanDFC_Replica

4.5.3 Emptying

The logic for emptying is in a function named FC28_TVFD. This logic is for emptying the dust into the Big-bag. The code in FC28_TVFD is mainly about the emptying process that is made in sequences. When the “TVFD_ON” input signal is true then the sequences of controlling each filter will start for the emptying process. Next step regarding the sequence handler is checking each filter, and only if the requirements are fulfilled, then the next filter will be ready for start and the TVFD will be set in home position (upper valve opened, lower valve closed). The requirements to start emptying filter 2 are shown in figure 4.14. The same requirements are applied for filter 3-6. But since filter 1 is the first filter in the cycle, the only conditions for the startup of the emptying of filter 1 are that filter 1 is not in OFF mode. One filter at a time will be emptying the dust (Note: the emptying so far has not started).

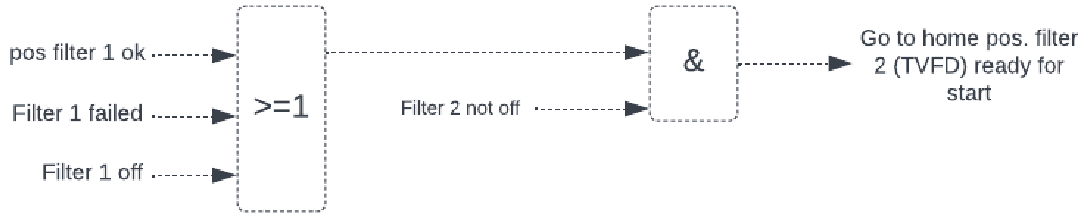


Figure 4.14: sequence handler for filter 2 (checking if filter 2 is ready for emptying)

If the manual emptying button is on or when interval time has ended, the next cycle for emptying will start. Emptying by TVFD (TVFD_ON) must be delayed 10 seconds after the cleaning process (See chapter 4.5.2)

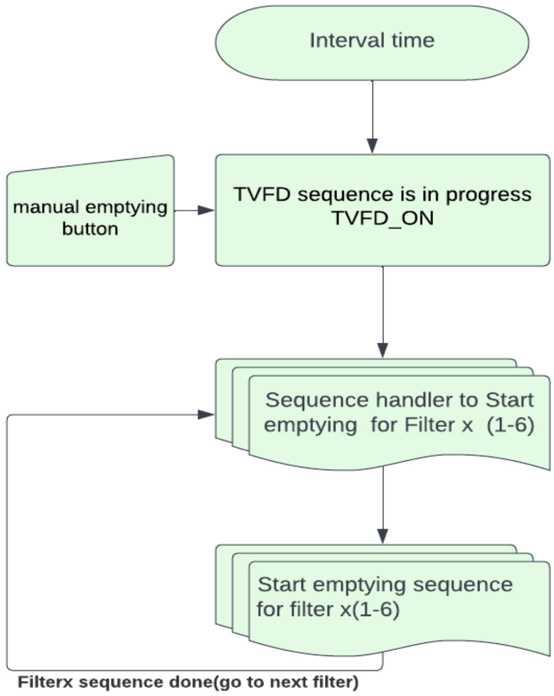


Figure 4.15: emptying sequence by TVFD

Each filter has an emptying sequence before starting with the next filter. The logic for this sequence is coded in the FB block (FB280_TVFD). It is critical that opening and closing of TVFD upper valve and TVFD lower valve is working according to figure 4.16 below. The lower can only open if the upper is closed. The upper can only open if the lower is closed. Warning will be activated if the lower or upper valve for filter x does not open/close. If it's still failing after a number of tries,the alarm will be activated after an alarm delay and the filter x goes into off mode.

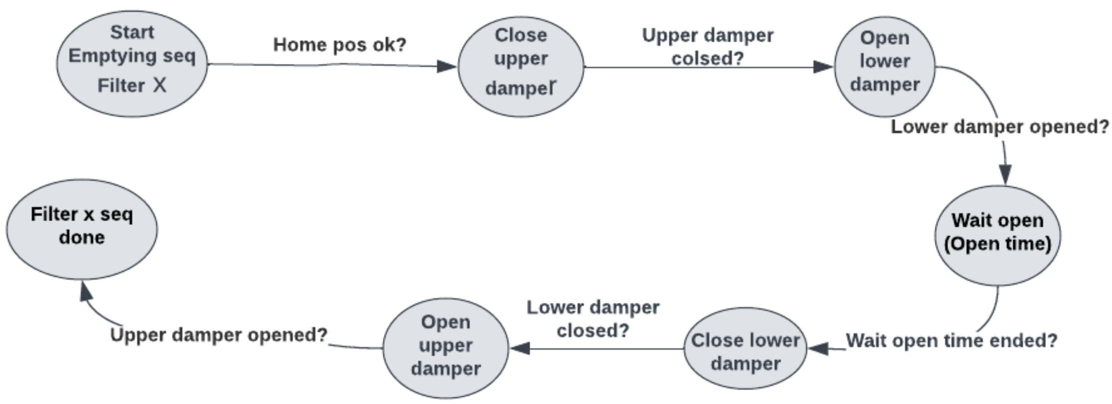


Figure 4.16: Emptying sequence for filter x

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oi_TVFD_Interval_time	Dint	Filter TVFD sequence delay (min)
"DB01_HMI".oi_TVFD_Open_time	Dint	Filter TVFD open time (sec)
"DB01_HMI".oi_TVFD_Pause_time	Dint	Filter TVFD pause time between valves (sec)
"?S1_ManEmpty"	Bool	Manual emptying TVFD - Button
"DB01_HMI".oi_TVFD_retry_amt	Dint	Number of attempts to open/close TVFD before warning
"DB01_HMI".oo_Filter1_Off	Bool	Filter x OFF (x:1-6)
Outputs		
"DB01_HMI".oo_Empty_TimeLeft	Dint	Time until next emptying cycle

Signals	Datatype	Comment
"TVFD_ON"	Bool	TVFD relay ON
"DB01_HMI".oo_1_Pos_Ok	Bool	Damper position ok- ready for operation
"DB01_HMI".oo_1_Seq_Done	Bool	Emptying Sequence filter x done (x:1-6)

Table 4.4 : Inputs and outputs for FC28_TVFD

4.5.4 Motors

The logic for the VAC motor is in FC22_motors. This part of the function defines the logic and the conditions for starting the motors (VAC1-VAC7). The logic defines how many motors are needed and in what priority. A motor can either start automatically or by force start. The motor won't start when it's in service or the motor is not in auto mode. To start the next motor, the current in all VAC will be measured. If one VAC or more reaches above the limit current, the next motor will start after a delay timer. The logic compares each VAC (1-7) with the limit value (see figure 4.17).

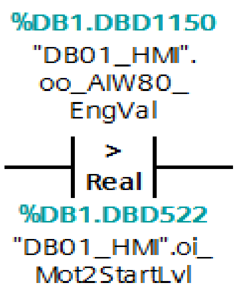


Figure 4.17: Ladder code for comparing the actual current at a motor with the limit value chosen in the HMI panel.

Which VAC will start next, is depending on a priority list. The priority list is depending on the motors run hours. If there is a fault or a motor x is not active, then RunHourMeterx_memory is set to= 999999999 h, that means motor x will always be the last in the priority list. The priority list switches everytime there is a motor stop, fault or reset.

Figure 4.18 below shows the logic for reducing one VAC depending on the current. If all VACs are below stop limit current, then the VACs will be reduced by one.

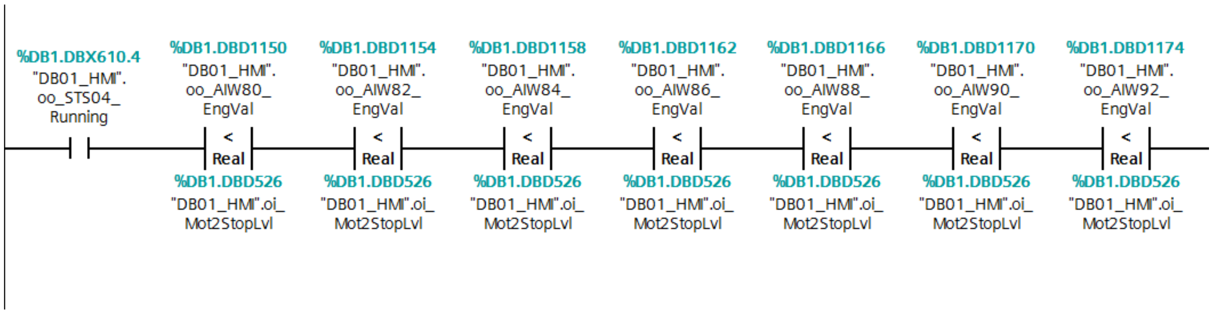


Figure 4.18: Ladder code for comparing each motors actual current with the limit value

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oo_TVFDposOK_startRBU	Bool	VAC can start even if not all TVFD is in OK-position.
"DB01_HMI".oo_Motor1_Prio	DInt	Priory for motor x (x:1-7)
"DB01_HMI".oo_MotAmtReq	DInt	Amount motors required
"DB01_HMI".oo_VAC_1_not_active	Bool	Vac x in service mode (x:1-7)
"DB01_HMI".oi_VAC_1_ForceStart	Bool	Forced Start button in HMI Panel
"?VAC1_Auto"	Bool	VAC x in auto (x:1-7)
"DB01_HMI".oo_AIW80_EngVal	Real	Vac x Current (x:1-7)
"DB01_HMI".oi_Mot2StartLvl	Real	Start next motor (Limit value)
"DB01_HMI".oo_RunHourMeter1	DInt	Run hours total Mx (x:1-7)
"DB01_HMI".oi_VAC_1_off	Bool	Set Vacx in service (x:1-7)
Outputs		
">VAC_1_Start"	Bool	Vacuum x start (x:1-7)

Signals	Datatype	Comment
"DB01_HMI".oo_Number_of_Starts1	DInt	Total number of motor starts
"DB01_HMI".oo_TrendMotor	DInt	0=Stopped, 1=running
"DB01_HMI".oo_VAC_PrioList_Pos1_ number	DInt	Which Vacuum has least run hours
"DB01_HMI".oo_VAC_1_not_active	Bool	Vac x in service mode (x:1-7)

Table 4.5 : Inputs and outputs for FC22_motors (Motor 1)

4.5.5 ASC

The logic for ASC (Anti Surge Control) is in the function named FC32_ASC. ASC is used for preventing damage to the motor, by controlling the motor damper. The motor damper is controlled with pulses for opening and closing. The pulses and pauses are set depending on the current difference in percent. Depending on the type of the VAC used, it has a current setpoint (See table 4.6).

Opening : Actual current < Setpoint + (low diff, high diff)	
Low speed pulse for opening	The damper will open but with shorter pulse time and longer pause time because the difference between the setpoint current and actual current is low(ASC low diff. level).
High speed pulse for opening	The damper will open but with longer pulse time and shorter pause time because the difference between the setpoint current and actual current is high(ASC high diff. level).
Closing : Actual current > Setpoint - (low diff, high diff)	
Low speed pulse for closing	The damper will close but with shorter pulse time and longer pause time because the difference between the setpoint current and actual current is low(ASC low diff. level).

High speed pulse for closing :	The damper will close but with longer pulse time and shorter pause time because the difference between the setpoint current and actual current is high(ASC high diff. level).

Table 4.6: Speed pulses for closing/opening the motor dampers

The diagram below shows the logic and conditions for closing/opening the motor dampers. As shown in the figure after a time delay, a warning will be activated if no pulses for closing/opening are made when the actual current is lower/higher then it is supposed to be.

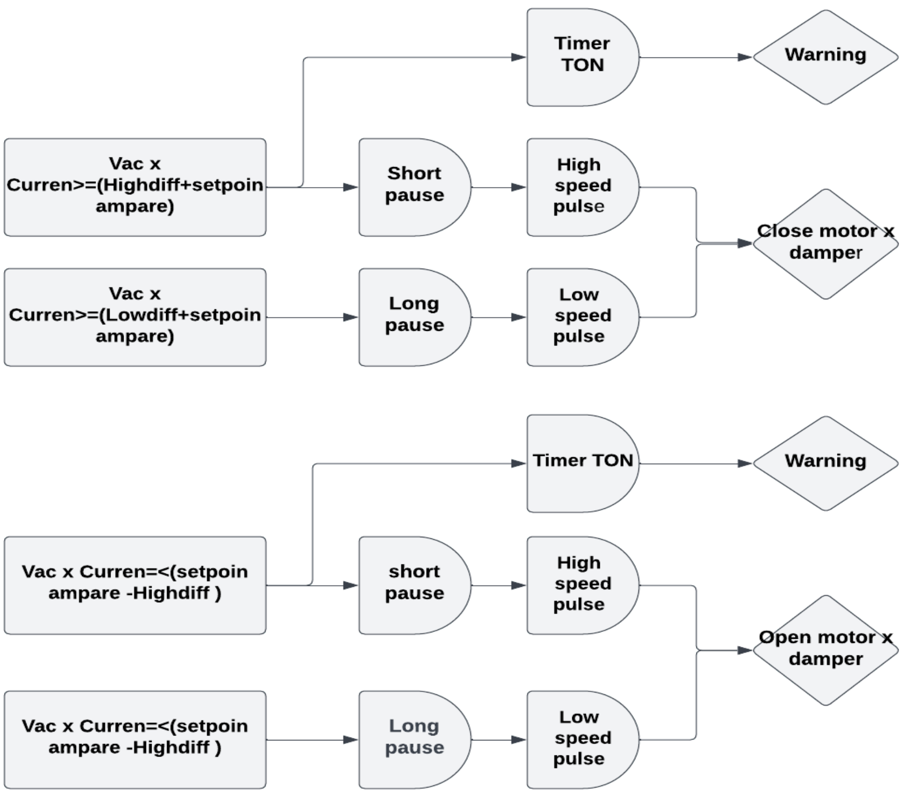


Figure 4.19: The logic for closing and opening the motor dampers (ASC)

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oi_ASC_PauseTimeH	**Dint**	**ASC pause time high speed**

Signals	Datatype	Comment
		(large difference)
"DB01_HMI".oi_ASC_PulseTimeH	Dint	ASC pulse time high speed (large difference)
"DB01_HMI".oi_ASC_PauseTimeL	Dint	ASC pause time low speed (low difference(
"DB01_HMI".oi_ASC_PulseTimeL	Dint	ASC pulse time low speed (low difference)
"DB01_HMI".oi_ASC_DiffH	Dint	ASC High diff level (%)
"DB01_HMI".oi_ASC_SP_A	Dint	ASC setpoint Ampere
"DB01_HMI".oi_ASC_DiffL	Dint	ASC Low diff level (%)
"DB01_HMI".oo_AIW80_EngVal"	Real	VAC x current (x:1-7)
Outputs		
">ASC1_Open"	Bool	VACx ASC open (not close) (x:1-7)
">ASC1_Move"	Bool	VACx ASC move (x:1-7)
"FC32_T_ASC1_Warning"	IEC_Timer	ASCx more than 10% off for long time = warning (x:1-7)

Table 4.7: Inputs and outputs for FC32_ASC (for ASC 1)

4.5.6 Run hours

The function name is FC31_RunHours. In this function, the motor run hours and motor service hours are calculated. The run hours are the total run hours for the motor . The motor service run hours are the total run hours since last reset (last service).

Signals	Datatype	Comment
Inputs		
">VAC_1_Start"	Bool	Start motor x (x:1-7)
"DB01_HMI".oi_ResetServiceInterval 1	Bool	Reset service run hours for motor x (button in HMI) (x:1-7)
"DB01_HMI".oi_ServiceInterval	DInt	Max run hours then service
Outputs		

Signals	Datatype	Comment
"DB01_HMI".oo_RunHourMeter1	DInt	Total run hours motor x (x:1-7)
"DB01_HMI".oo_ServiceHourMeter1	DInt	Run hours since last rest motor x (x:1-7)
"DB01_HMI".oo_ServiceHoursLeft1	DInt	Hours left until service

Table 4.8: Inputs and outputs for FC31_RunHours (for motor 1)

4.5.7 OFF mode

The name of the function is FC12_OFF_mode_Graceful. In this function, the logic is regarding the several situations that cause the filter x to go in off mode. There is only one output in this function block: "DB0x_HMI".oo_Filterx_Off (x=1-7).

Signals	Datatype	Comment
Inputs		
"DB01_HMI".oi_Filter1_SetOff	Bool	Set filter x in OFF mode (x:1-6)
"DB01_HMI".oo_1_Failed	Bool	TVFD dampers had failed
"A038_IsolValve_A_Locked"	Bool	Alarm 038 for the isolation valve if locked
"A033_BLI1"	Bool	Alarm 033 High level of dust in dust bin (Big bag)
"A036_DPSA"	Bool	Alram 036 System dP high
"A046 Isolation valve dirt sensor A"	Bool	Alarm 046 for the isolation valve when dirty
"A047_dP_Analog_High"	Bool	Alarm 047 high dp in filter x (x:1-7)
Outputs		
"DB01_HMI".oo_Filter1_OffT	Bool	Filter x in off mode (x:1-7)

Table 4.9: Inputs and outputs for FC12_OFF_mode_Graceful

4.5.8 Energy

The name of the function is FC40_Energi. In this function, the power for each vacuum(motor) and total energy for vacuum units is calculated. Calculations for vacuum power are depending on actual current for vacuum and three factors(a,b,c); these three factors are decided depending on which vacuum sorts are used in the filter system. Figure 4,20 shows an example of which factors are selected when the motor has a rated power of 45.

For VAC x: electric power = (a* I + b) *I + c), I = actual vacuum x current,

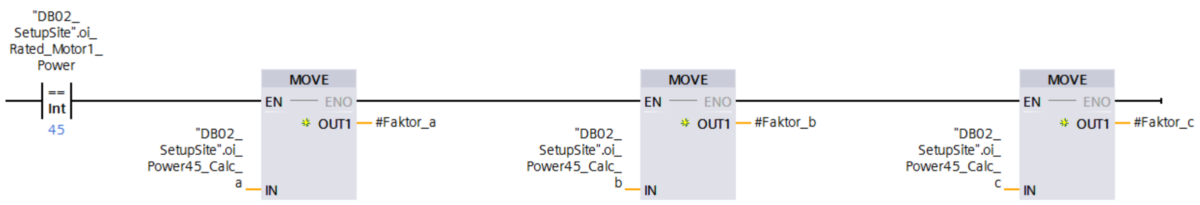


Figure 4.20: Selecting factors a, b and c for motor with rated power 45.

4.5.9 Alarms

The name of the function is FC11_alarms. There are two types of alarm, alarm and trip alarm. Alarms will lead to a part of the system that goes in off mode whereas trip alarm will lead to that the whole system will go in off mode. For example, if the TVFD gates in a filter in the system have failed, then only that filter will be set in off mode. But if there is a crucial alarm like E-stop or fire, the whole system will shut down. Alarms are activated after a warning delay. The HMI screen below (figure 4.21) displays two examples from the alarm settings. There is a warning delay and an alarm delay before the alarm is triggered.

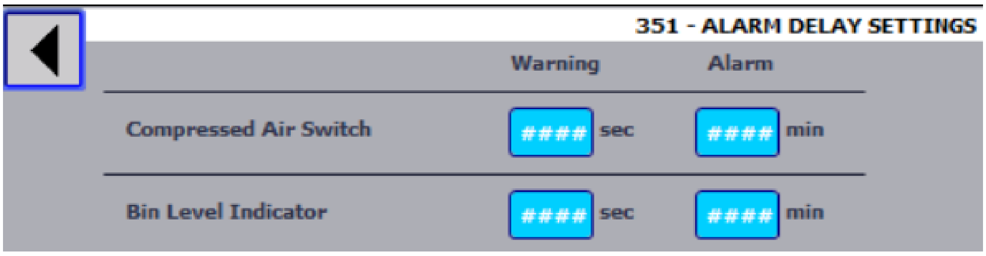


Figure 4.21: Warning and alarm delays for a switch and an indicator.

4.5.10 Other function blocks

The other functions in the application are mainly logic for the settings,setup, clock settings, resetting and analog signals scaling.

- FC02_Inputs: Digital inputs stored in memory addresses
- FC03_Analog: Analog inputs converted to engineering units and stored in memory addresses.
- FC04_SetupShop: Boolean variables in DB04 if hardware is installed
- FC06_FactoryReset: Reset all settings and values to reset values.
- FC07_Clock: Settings for real time clocks in both PLC and HMI.
- FC23_DIR: Starting up VAC valve after a delay.
- FC25_WeekTimer: Time for running and standby during the week.
- FC50_Special: Outputs for some flash lamps.
- FC51_Insight: Storing values from HMI to the data block “insight”.
- FC99_Outputs: Digital outputs
- FC250_WeekDay: Run hours and stop hours for the system during the week.
- FB21_Control:Controls the status of the system, running, standby and off mode.

4.6 The HMI screens

This chapter gives an overview of the main HMI screens and how the screens relate to the function blocks.

4.6.1 101_Main_01

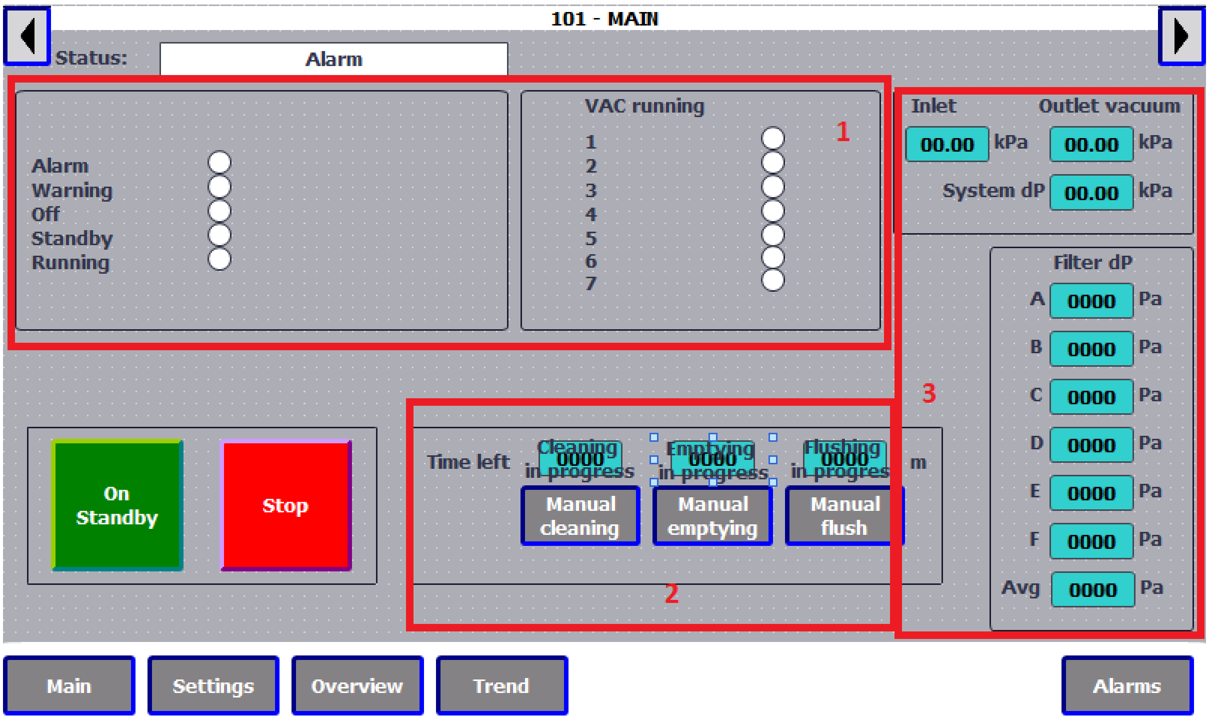


Figure 4.22: HMI screen 101_Main_01

1.Status of the VACs are shown: Alarm (red indicator)and warning(yellow indicator), as well as modes : off, standby and running (all three green indicators).

2. Buttons:
Manual cleaning: FC340_FilterCleanDFC_Replica.
Manual emptying: FC28_TVFD.
Manual flush: FC26_FlushValves.

3. Analog signals calculated to engineering values in function FC03_Analog. The signals are for inlet vacuum, outlet vacuum, system dP, average dP and dP for each filter.

4.6.2 202_Overview Filter

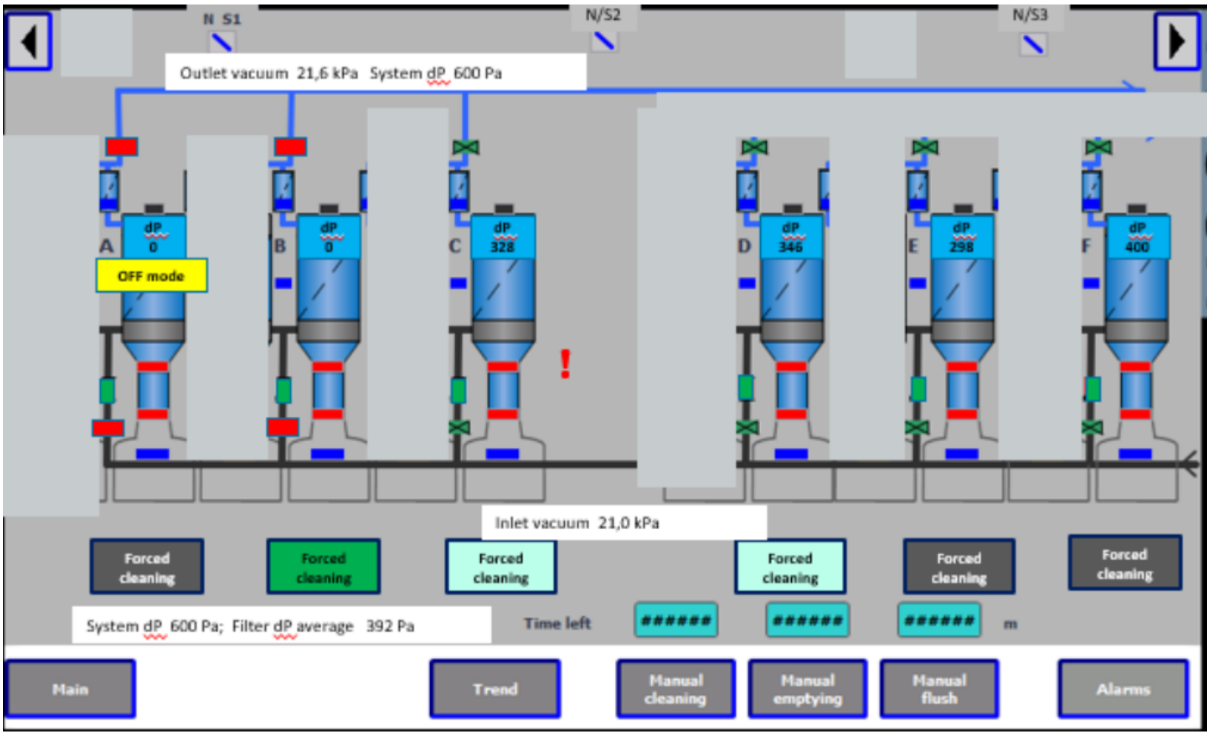


Figure 4.23: HMI screen 202_Overview Filter

The screen above shows all 6 filters, the status of each filter, the pressure for each filter and the pressure for the system. Filter 1 is in off mode so there is no vacuum and the dampers are closed. Filter 2 is being cleaned by forced cleaning, that's why the forced clean button is indicating green colour, and the section dampers are closed as well. Filters 3-6 are running normally.

4.6.3 203_Overview VAC

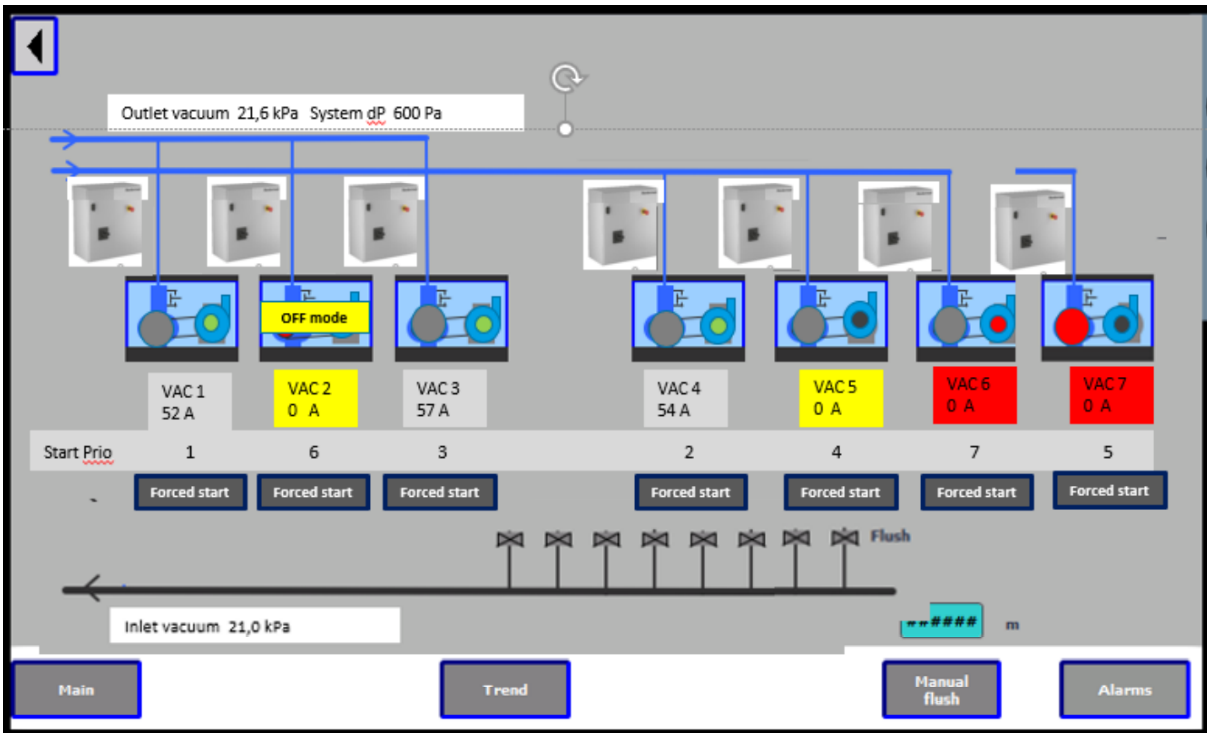


Figure 4.24: HMI screen 203_Overview VAC

The status and units for each vacuum are shown in figure 4.24 above, as well as the priority for each VAC. The direction of the inlet vacuum and outlet vacuum is also displayed. From this screen the user can always force start vacuum by force start button. This HMI screen is related to the function block FC22_motors, where the logic for starting the motors and the priority is defined.

4.6.4 336 - Settings ASC

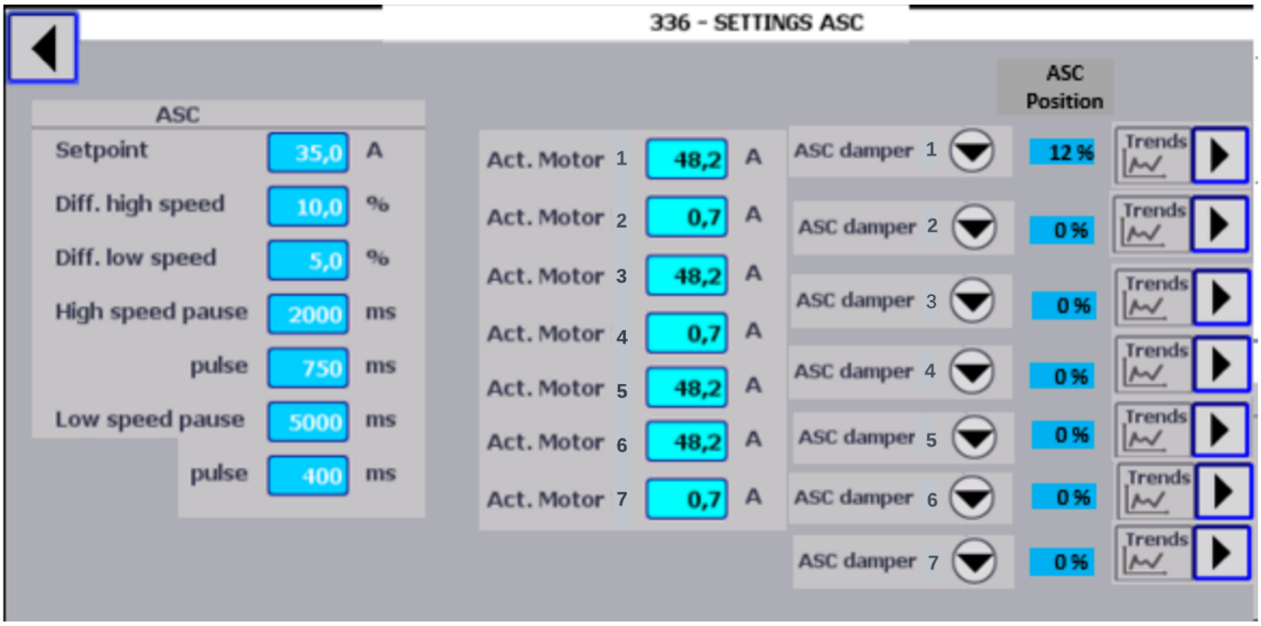


Figure 4.25: HMI screen 336 - Settings ASC

The screen above shows an overview of the ASC for each vacuum. Values to run the ASC are displayed (Stored in DB01_HMI), and each motor's actual current is displayed as well. The status of each damper is shown (open or close). A trend for each VAC is also displayed by clicking on each trend. The logic for the ASC is in function FC_32_ASC.

4.6.5 Other screens

There are other screens for trends, motors run hours, alarms, system settings and more.

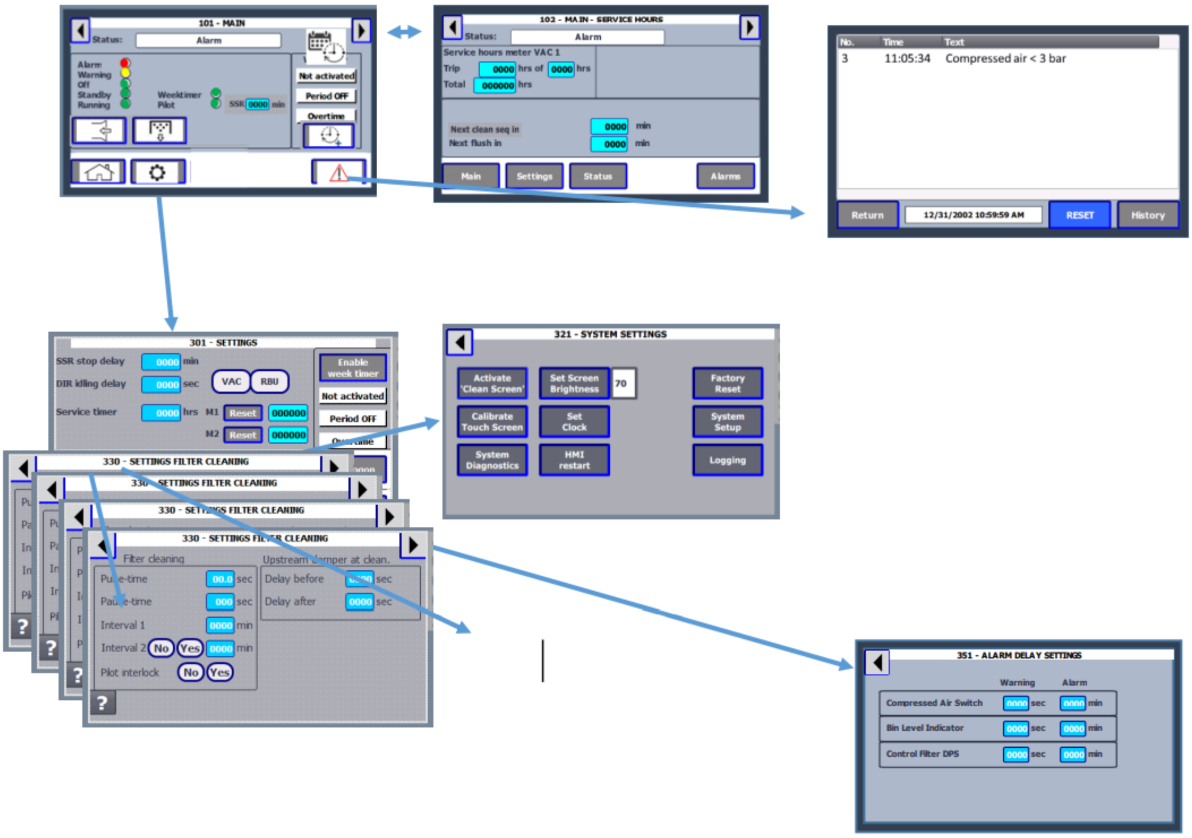


Figure 4.26: other HMI screens.

5 Suggestions for improvements

This chapter includes suggestions for improvements. These are only suggestions and are not yet applied or tested. The improvements that are discussed here are mainly about the standardization approach using the ISA-88 standard (see section 2.3.1). The ladder code itself will not be discussed here. Instead, the overall structure of the implementation (function blocks, databases) will be the focus in this chapter. First the isa-88 and the physical model standard are suggested to the

Smart-Filter system. According to this standard, a new structure is recommended with new function blocks and databases.

5.1 ISA - 88 physical model standard

A physical model from ISA-88 is shown in figure 5.1. The goal is dividing the system into a heirachy of small sections [6]. The model is first divided into 4 units : Flexfilters, TVFDs, Vacs and duct system. Then each unit is divided into 2 or 3 equipment modules. The equipment modules are physical devices that are grouped depending on the functions and the activities. In the case of the filter system, for example all control modules (sensors, actuators and buttons) that are active when cleaning, are grouped under the same equipment module.

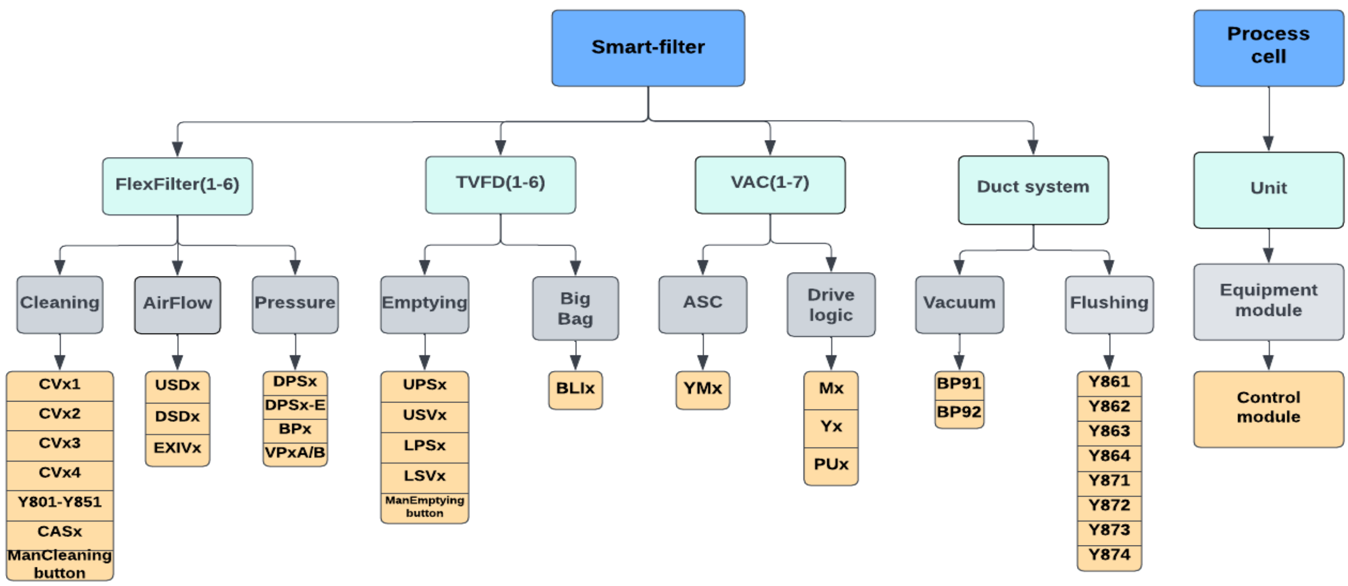


Figure 5.1:ISA-88 physical model of the Smart-Filter system

5.2 Function blocks and databases standarization

This section will include suggestions for a new structure of function blocks and databases when implementing a new control system on the Siemens PLC 17-1200 . According to the physical model in the previous section the following structure will be applied : Units correspond to function blocks, equipment modules correspond to the logic in the function blocks and control modules correspond to the Inputs and outputs for the function blocks.

5.2.1 Flexfilter

The figure below shows the flexfilter with inputs and outputs. The inputs required for the logic in this function block are digital and analog inputs from the PLC, and also inputs from the HMI. In this function blocks all logic regarding the functions of flexfilter should be implemented. The logic is divided into three parts: Cleaning, airflow and pressure. The names for inputs and outputs are according to the current implementation.

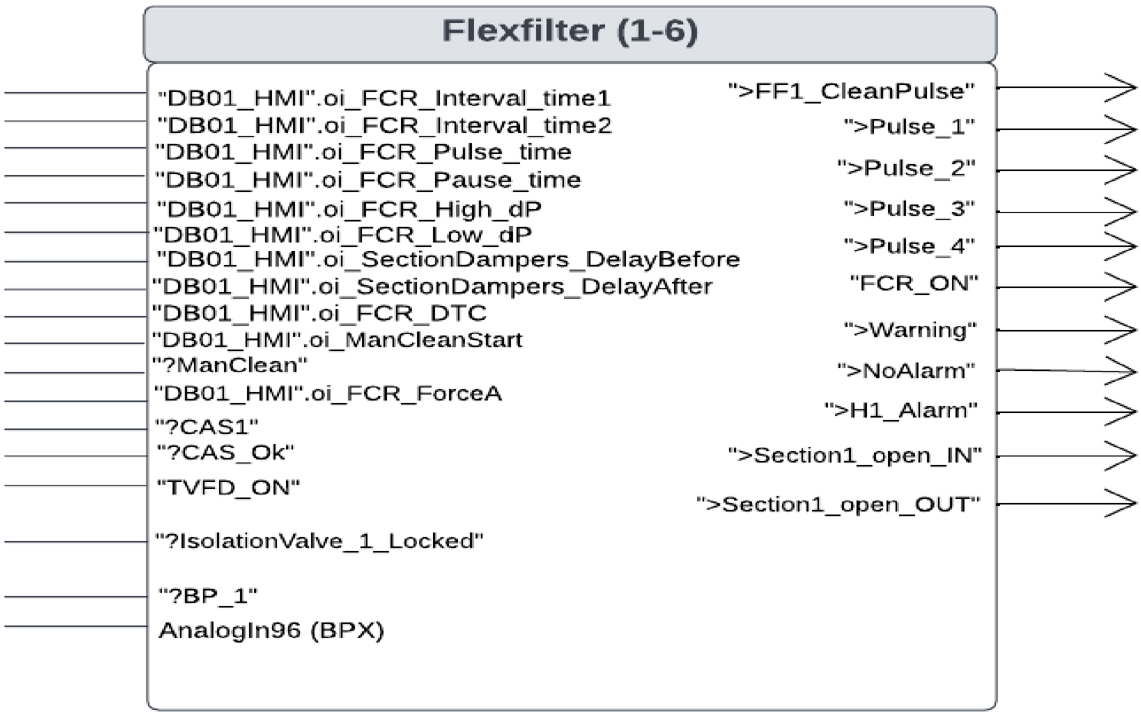


Figure 5.2: Function block Flexfilter with inputs and outputs.

5.2.2. TVFD

The next function block that should be implemented is TVFD and Big-bag. In this function block the logic for emptying is impemented. Outputs and inputs for this function block are from PLC and from HMI (See figure 5.3).

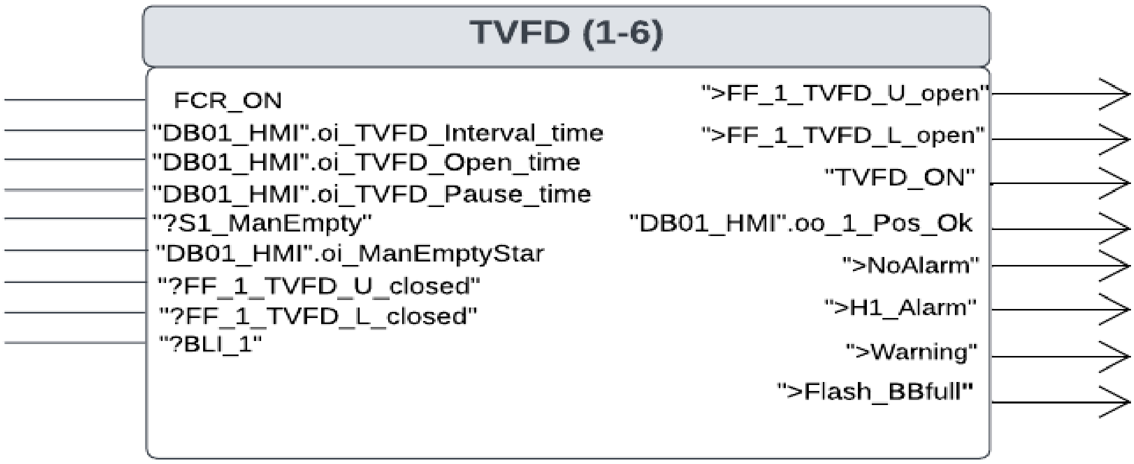


Figure 5.3: Function block TVFD with inputs and outputs.

5.2.3 VAC

The logics for motor drive and ASC are implemented in this function block (figure 5.4). All the seven vacuum units will be controlled with the implementation in this function block.

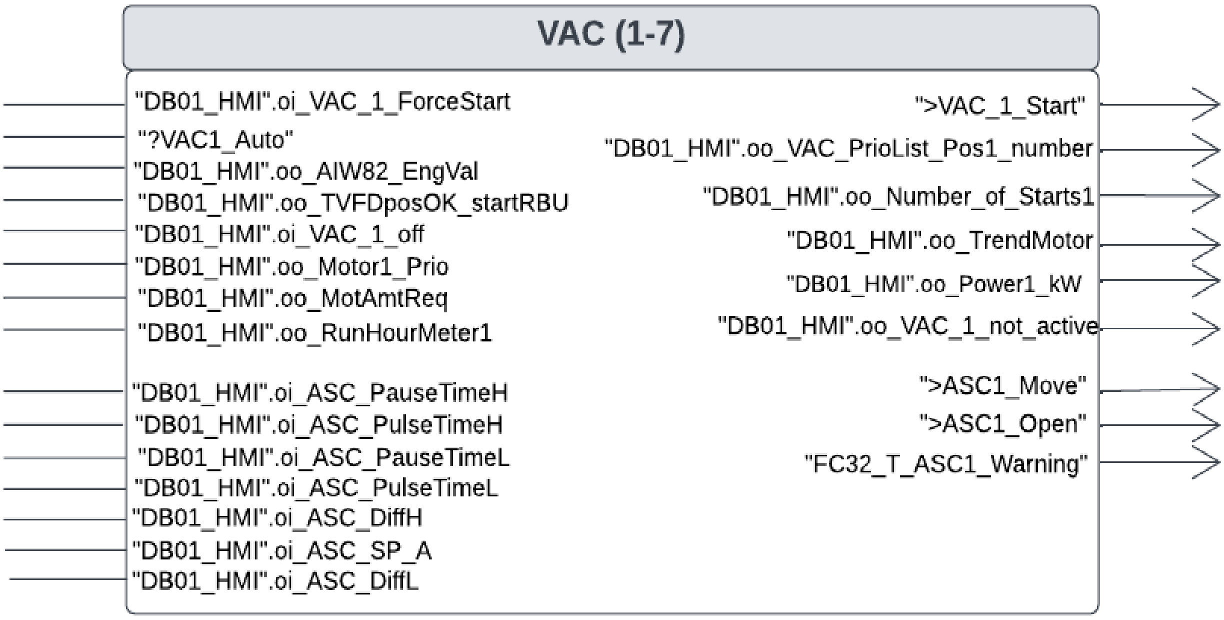


Figure 5.4: Funktion block VAC with inputs and outputs

5.2.4 Duct system

The last function block is for the duct system.The logic for flushing and vacuum measures are implemented in this block (see figure 5.5).

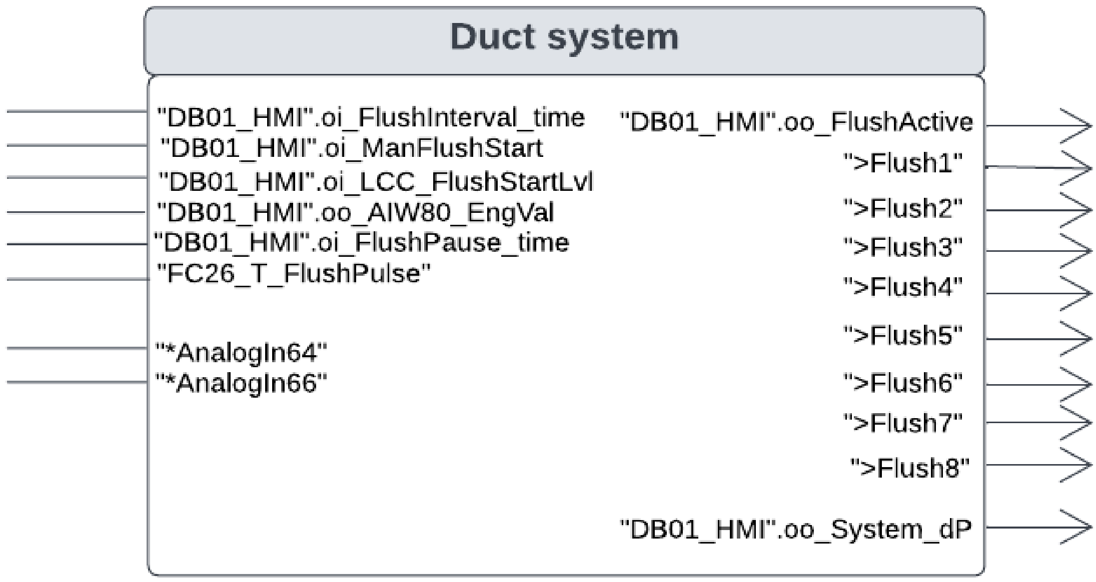


Figure 5.5: funktion block duct system with inputs and outputs

5.3 The Function blocks and databases

The purpose of the standarization as discussed before is to give a well structured standard and modularized system, that is easily reused and understandable. One essential component in the development of a standard system is the implementation of function blocks and databases. The goal is to reach the structure of object oriented programming OOP [16]. A class in OOP corresponds to a function block in the PLC world. And an object of the class in OOP corresponds to iDB in the PLC world. Suggestion of such an approach is shown in figure 5.6. For example, a class is FB01 Flexfilter, and objects are 6 different iDBS. Each iDB will correspond to a filter in the system. When calling the function block in the code, automatically a unique iDB will be stored in the PLC memory with the IN and Out signals. In the case of flexfilter, the logic for cleaning, air flow and pressure (see figure 5.1) is described in the block. THe data that is used by several program parts are stored in GB (Global database).

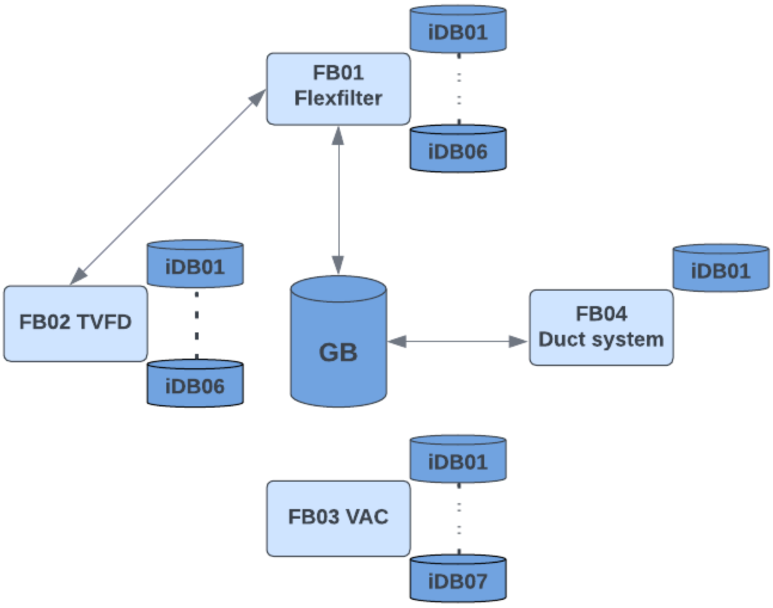


Figure 5.6: The structure of the database and function blocks according to the standardization guideline ISA-88

6 Conclusion

This chapter presents conclusions drawn from the analysis and results. Additionally, it will discuss future work and how further improvements could be made, and ends the thesis by giving an ethical reflection.

6.1 The documentation

The main goals with this thesis were to analyse and document the functions of the Smart-Filter system. This was done by steps following the problem formulation (section 1.4). At first it was essential to study and understand the physical process, and then this was represented with figures showing the key functions and their associated components. Then each function was described in more detail with figures and tables. The figures and tables were important in this thesis because of the complexity of the functions, it made it easy and this was the best way to make the description more understandable.

The analysing and documenting process has taken several months to complete. The reason is that this system lacked documentation. All the implementation process was made in the TIA Portal and was discussed verbally without any documentation. This made it difficult for engineers and for all those concerned with the Smart-Filter system to easily understand the system and even make modifications or add new functionalities.Thats why it is important that every project has to be documented and clearly described even before the implementation. According to the supervisor from Demab AB, when starting a new project 80% of the time is about planning and documenting the project and 20% is for writing the code.

6.2 The improvements

Since the system lacked any documentation nor planning, it also was written without any standardization. The ISA-88 standardization is important and has many advantages. It serves as a common language between the industries, companies and engineers. And now it has become an accepted standard in the automation industry when structuring automation projects. According to ISA [12] 30% savings were measured on the first project when applying the ISA-88 standard and up to 80% savings were measured on the follow up projects due to the reusable approaches and modularity defined in ISA-88. The suggestion for an ISA-88 standard that was given in this thesis (see chapter 5) followed the physical process with the key functionalities and the associated signals for each function. This should give an idea on how this standard can be applied according to the level of information that was given in this thesis.

6.3 Future work

As mentioned above (section 6.2) an ISA-88 standard approach was suggested. As further future work these suggestions and particularly the suggested function blocks could be expanded with additional function blocks to later make a new implementation of the system. A new documented and standardized implementation.

Another suggestion is also a standard approach that is also used in the automation industries, The IEC 61499 standard [13]. This standard provides a guideline when implementing the function blocks. It gives a description on how the logic and inputs/outputs should be implemented for each function block to provide object oriented programming [16].

6.4 Ethical reflections

Since the main purpose of this thesis was a documentation of an existing product instead of development of the product, one of the ten principles of the code of honour was most relevant. The seventh principle of the code of honour is “engineers ought to respect entrusted information of a confidential nature and others' rights to ideas, inventions, studies, plans and blueprints” [14]. The implementation with the complete programming code was received from Nederman AB and Demab AB. Therefore a confidentiality agreement was signed between the three parties. This seventh principle was the purpose of the agreement signed, since the agreement included details about the confidential information shared with the students.The information must not be disclosed to other parties, and that information must be sent back to the company or destroyed and only be available to the students during the thesis period only.

7 Terminology

HMI: Human Machine Interface. It is used in automation industries and refers to the interface between a human operator and a machine.

IEC: International Electrotechnical Commission. It is an international standards organization that is responsible for developing standards for electronic systems.

ISA: international society of automation. It is an organisation that provides a range of resources in the field of automation and control systems engineering.

PLC: Programmable Logic Controller. It is a type of industrial computer used to control and automate different industrial processes.

Siemens TIA–Portal: Totally Integrated Automation Portal. It is a software platform developed by Siemens for programming an automation product e.g. PLCs, HMIs.

Smart-Filter system : It is a type of filtration system that is used in industries, for cleaning the air and for preventing combustible dust explosions.

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9 Appendix

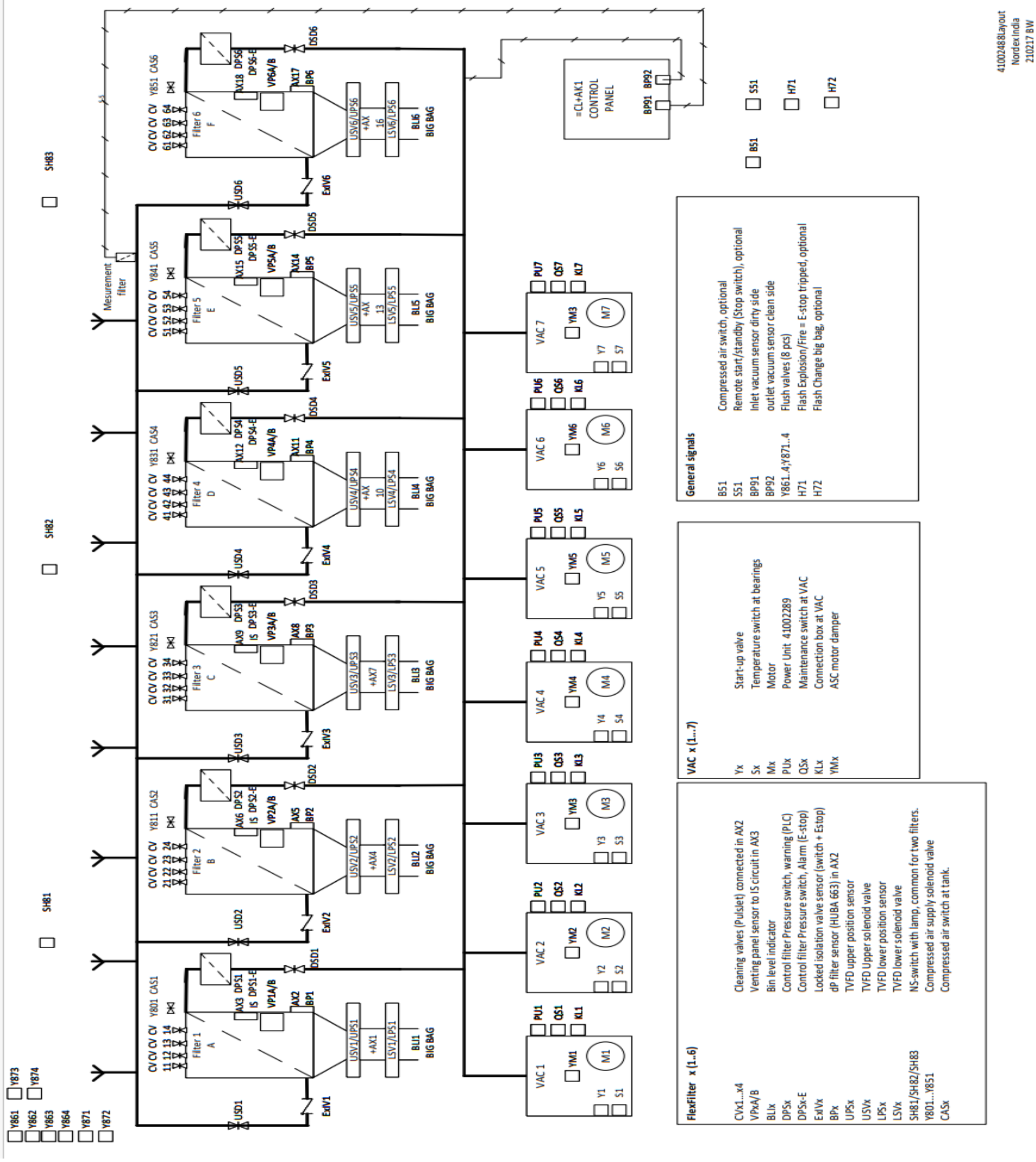

Figure 9.1 : Design of the Smart-Filter system with components names.

Name	Adress	Datatype	Comment	Memory Address
Inputs				
I00_0	%I0.0	Bool	Pilot switches on vacuum valves at work sites- Start unit	%M200.0
I00_1	%I0.1	Bool	Compressed air switch central - not low pressure	%M200.1
I00_2	%I0.2	Bool	Void	
I00_3	%I0.3	Bool	NS-switch activated system 1&2	%M200.5
I00_4	%I0.4	Bool	Void	
I00_5	%I0.5	Bool	NS-switch activated system 3&4	%M202.5
I00_6	%I0.6	Bool	Remote start/bypass/off/overtime - button	%M200
I00_7	%I0.7	Bool	Emergency stop relay	%M200.7
I01_0	%I1.0	Bool	NS-switch activated system 5&6	%M203.5
I01_1	%I1.1	Bool	Void	
I01_2	%I1.2	Bool	Manual filter cleaning	%M201.2
I01_3	%I1.3	Bool	Void	
I01_4	%I1.4	Bool	Manual emptying TVFD - button	%M201.4
I01_5	%I1.5	Bool	Void	
outputs				
Q00_0	%Q0.0	Bool	No summary alarm (Relay)	%M300.0
Q00_1	%Q0.1	Bool	Summary alarm (lamp in front of panel)	%M300.1
Q00_2	%Q0.2	Bool	Warning	%M300.2
Q00_3	%Q0.3	Bool	NS switch light indication system 1&2	%M300.3
Q00_4	%Q0.4	Bool	summary alarm (Relay)	%M300.0
Q00_5	%Q0.5	Bool	NS switch light indication system 3&4	%M302.5

Name	Adress	Datatype	Comment	Memory Address
Q00_6	%Q0.6	Bool	Flash light fire	%M300.6
Q00_7	%Q0.7	Bool	Flashlight big bag full	%M300.7
Q01_0	%Q1.0	Bool	NS switch light indication system 5&6	%M303.0
Q01_1	%Q1.1	Bool	On/standby lamp	%M301.1

Table 9.1 : Inputs and Outputs for the CPU

Name	Adress	Datatype	Comment
Inputs			
AnalogIn80	%IW80	Word	Analog input channel 4/20 - VAC 1 actual current
AnalogIn82	%IW82	Word	Analog input channel 4/20 - VAC 2 actual current
AnalogIn84	%IW84	Word	Analog input channel 4/20 - VAC 3 actual current
AnalogIn86	%IW86	Word	Analog input channel 4/20 - VAC 4 actual current
AnalogIn88	%IW88	Word	Analog input channel 4/20 - VAC 5 actual current
AnalogIn90	%IW90	Word	Analog input channel 4/20 - VAC 6 actual current
AnalogIn92	%IW92	Word	Analog input channel 4/20 - VAC 7 actual current
AnalogIn94	%IW94	Word	Analog input channel 4/20 - Spare

Table 9.3: Inputs for the analog signals in expansion module 8

Name	Adress	Datatype	Comment
AnalogIn96	**%IW96**	**Word**	**Analog input channel 4/20 - Flexfilter 1 dP sensor**
AnalogIn98	**%IW98**	**Word**	**Analog input channel 4/20 - Flexfilter 2 dP sensor**
AnalogIn100	**%IW100**	**Word**	**Analog input channel 4/20 - Flexfilter 3 dP sensor**
AnalogIn102	**%IW102**	**Word**	**Analog input channel 4/20 - Flexfilter 4 dP sensor**
AnalogIn104	**%IW104**	**Word**	**Analog input channel 4/20 - Flexfilter 5 dP sensor**
AnalogIn106	**%IW106**	**Word**	**Analog input channel 4/20 - Flexfilter 6 dP sensor**
AnalogIn108	**%IW108**	**Word**	**Spare**
AnalogIn110	**%IW110**	**Word**	**Spare**

Table 9.4: Inputs for the analog signals in expansion module 9

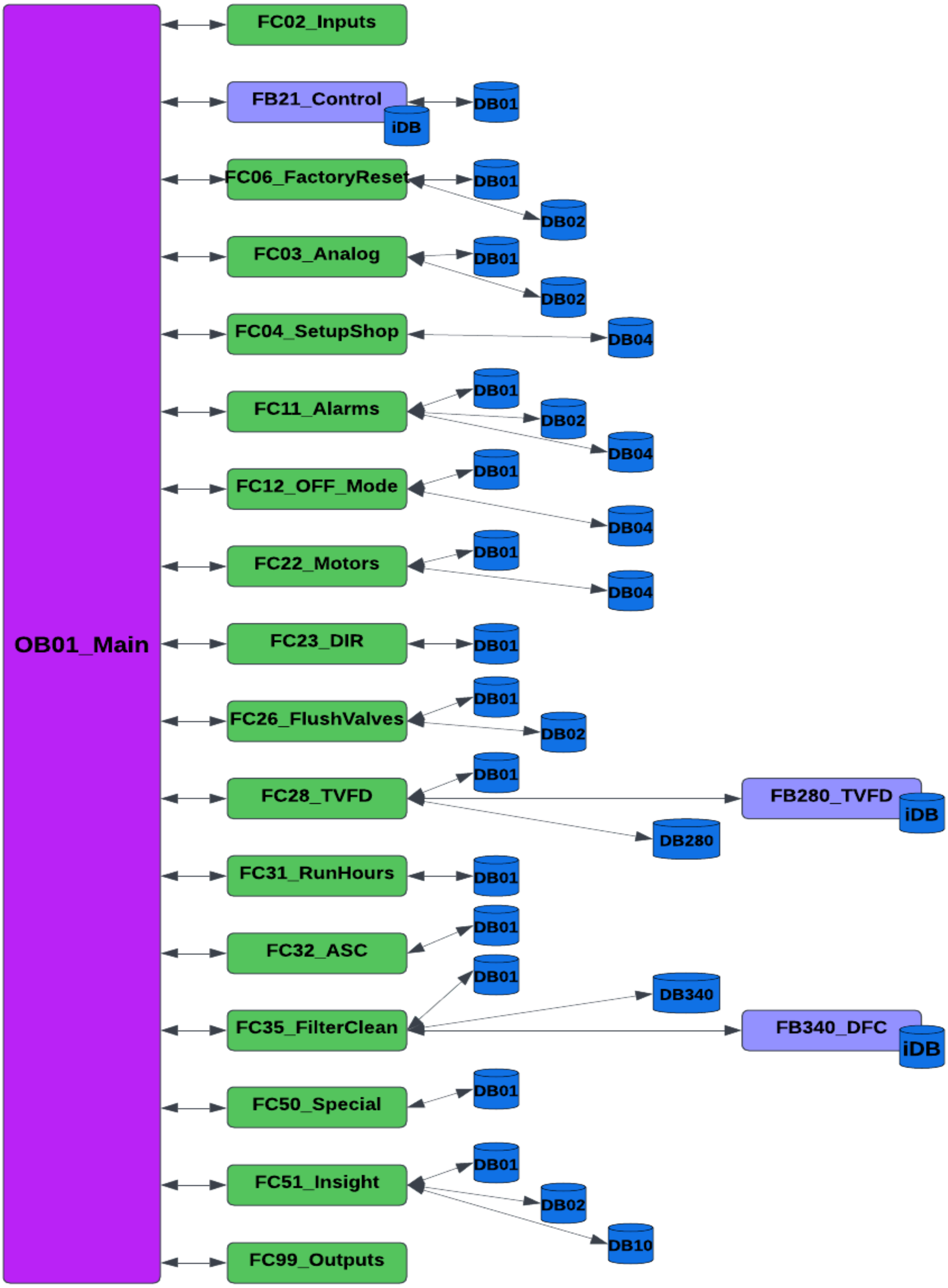

Figure: 9.2 The structure of the program (Functions and databases) in TIA Portal