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KANDÓ KÁLMÁN FACULTY OF ELECTRICAL ENGINEERING
ELECTRONIC AND COMMUNICATION SYSTEMS INSTITUTE
INSTRUMENTATION AND AUTOMATION DEPARTMENT

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STUDENT STATEMENT

I hereby declare that the present final thesis paper is solely my own work and that the references (written and electronic literature and tools used during the process) have been acknowledged and fully cited. I hereby grant the university and the task assigning institution permission to use free of charge the final results of this paper for their own purposes, abiding by the pertaining rules of encryption.

Budapest, 2023.12.15.

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Signature of student

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1. INTRODUCTION

In the world of electrical distribution and low-voltage switchgear panels and control cabinets, there are a multitude of ways a certain project can be approached. Whether it's designing a new system for a commercial building or upgrading existing infrastructure in an industrial facility, careful consideration of factors such as power requirements, space limitations, and safety regulations is crucial. Moreover, the selection of appropriate equipment, integrating smart technology for real-time monitoring, and adhering to sustainability goals are becoming increasingly important in the modern landscape. This blend of traditional expertise and innovative advancements in electrical engineering is paving the way for more efficient, reliable, and environmentally conscious solutions. Therefore, a comprehensive understanding of these varied elements is essential in creating tailored, effective, and future-ready electrical distribution systems.

When it comes to designing and planning a project, adhering to specific protocols and specifications is imperative. These guidelines ensure that the electrical distribution system meets industry standards, safety codes, and operational requirements. From meticulous electrical calculations to selecting the right materials and components, following these protocols helps to ensure the reliability and performance of the system.

Furthermore, the realization of the project relies on skilled technicians who understand the intricacies of the design and possess the expertise to bring it to life. Their technical know-how and practical experience play a crucial role in the successful implementation and execution of the electrical distribution system. Adhering to standards, using proper installation techniques, and following established procedures are essential to ensure the system operates safely and efficiently.

By upholding these protocols and involving qualified technicians, project stakeholders can have confidence in the functionality, durability, and longevity of the electrical distribution and low-voltage switchgear systems. Combining the right design principles, adherence to standards, and skilled execution contributes to the overall success and effectiveness of the project, meeting the objectives of providing reliable power delivery while prioritizing safety and efficiency.

While there may be similarities among projects, it is crucial to acknowledge that most projects differ in terms of capability and application. Consider, for instance, a chemical plant where the designer faces the task of accommodating a wide range of hazardous chemicals. In such cases, the designer must meticulously consider the potential impact of these chemicals on the longevity and functionality of the control cabinet.

The design process for a chemical plant involves specialized knowledge and expertise in handling hazardous substances. The designer must thoroughly assess each chemical's properties, such as its corrosiveness, flammability, toxicity, and reactivity. This information is vital in determining the appropriate materials and construction techniques

necessary to protect the control cabinet from potential damage or failure caused by exposure to these chemicals.

Factors such as chemical compatibility, resistance to corrosion, and containment measures become paramount. The designer must appropriately select the materials that the control cabinet's enclosure is manufactured from that can withstand the corrosive effects of the chemicals involved. This may involve using corrosion-resistant materials, such as stainless steel or specialized coatings, to ensure the longevity of the control cabinet under challenging operating conditions.

Control cabinets and switch panels play a vital role in ensuring the smooth operation of mechanical engineering systems and building systems alike. In both industries, there is a common need to maximize component accommodation within limited space, emphasizing the importance of efficient design and utilization.
The design of control cabinets and switch panels focuses on optimizing space utilization while ensuring the necessary functionality and performance. Every available inch of space is carefully considered and utilized to accommodate as many components as possible. This requires meticulous planning, thoughtful arrangement of equipment, and efficient wiring solutions to optimize the use of available space.

In mechanical engineering systems, control cabinets house various components such as motor controllers, sensors, relays, and Programmable Logic Controllers (PLCs). These components work together to monitor and control the operation of machinery, ensuring precise and efficient functionality. The integration of these components within a compact control cabinet allows for streamlined operation, reduced wiring complexity, and simplified maintenance.

Similarly, in building systems, switch panels serve as centralized control hubs for electrical distribution and automation. They house circuit breakers, switches, meters, and other essential components required for safe and efficient electrical operation within a building. The compact design of switch panels enables convenient access to various electrical controls and minimizes the amount of space required for equipment installation, making them suitable for installations where space constraints are a consideration.

Efficient space utilization in control cabinets and switch panels not only allows for a smaller footprint but also enhances system reliability and accessibility. By having components in close proximity, wiring connections are minimized, reducing the risk of signal interference and improving maintenance access. This compact arrangement also simplifies troubleshooting and diagnostics, as components are organized and easily identifiable.

2. LITERATURE OVERVIEW

When designing and building a control cabinet, it is crucial to adhere to certain principles and rules to ensure compliance with regulations. This includes considering factors such as enclosure sizes, cable routing, grounding, ventilation, labeling, and safety precautions. By following these guidelines, we can create control cabinets that meet industry standards and ensure efficient and safe operation. Let's take a look at some important aspects of control cabinet.

2.1 Wire sizes

When sizing wires in a control cabinet, it is crucial to consider factors such as current carrying capacity and voltage drop. To determine the appropriate wire size based on current carrying capacity, calculate the maximum expected current by considering the connected devices and their current ratings. IEC 60204-1: This International Electrotechnical Commission (IEC) standard, titled "Safety of machinery - Electrical equipment of machines - Part 1: General requirements," covers various aspects of electrical equipment used in machinery. It includes guidelines for wire sizing and current-carrying capacity in control circuits and control cabinets. [1]

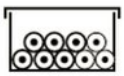
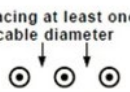
Conductor arrangement		 Single-core cables in a cable trunking on a wall, run horizontally and vertically. 6 of the cables (2 three-phase circuits) continuously loaded		 Single-core cables, touching free in air or on a perforated tray. 6 cables[e] (2 three-phase circuits) continuously loaded		Spacing at least one cable diameter  Single-core cables, spaced horizontally in free air	
Cross-sectional area of conductor	Resistance of conductor at 20°C, R_{20} [a]	Max. operating current, I_{max} [b]	Power-losses per conductor, P_v	Max. operating current, I_{max} [c]	Power-losses per conductor, P_v	Max. operating current, I_{max} [d]	Power-losses per conductor, P_v
mm²	mΩ/m	A	W/m	A	W/m	A	W/m
0,5	36,0	3,5	0,6	-	-	-	-
0,75	24,5	5,0	0,7	-	-	-	-
1,0	18,1	6,0	0,7	-	-	-	-
1,5	12,1	7,5	0,8	9	1,3	15	3,2
2,5	7,41	10	0,9	13	1,5	21	3,7
4	4,61	14	1,0	18	1,7	28	4,2
6	3,08	18	1,1	23	2,0	36	4,7
10	1,83	24	1,3	32	2,3	50	5,4
16	1,15	33	1,5	44	2,7	67	6,2
25	0,727	43	1,6	59	3,0	89	6,9
35	0,524	54	1,8	74	3,4	110	7,7
50	0,387	65	2,0	90	3,7	134	8,3
70	0,268	83	2,2	116	4,3	171	9,4
95	0,193	101	2,4	142	4,7	208	10,0
120	0,153	117	2,5	165	5,0	242	10,7
150	0,124			191	5,4	278	11,5
185	0,099 1			220	5,7	318	12,0
240	0,075 4			260	6,1	375	12,7
300	0,060 1			301	6,6	432	13,5

Figure 1- Wire size chart [1]

Additionally, consider factors like temperature ratings, insulation types, and specific requirements mentioned in applicable electrical codes or regulations while selecting wire sizes for a control cabinet.

For my control cabinet, the appropriate wire sizes can be found in figure 1. and are the standard sizes we use when wiring said cabinet. Since the designer of wiring schematic has specified all outgoing wire sizes that will be connected to the cabinet, we only need to consider the sizes inside the cabinet.

Since the voltages inside the cabinet don’t exceed 500 V AC, we will use H05V-K wires only, but if the need arises to use double insulated wires, we can also use NSGA-FOU cables.

2.1.1 Current standards that refer to wire sizing

In Hungary, wire sizing for control cabinets is typically governed by national standards issued by the Hungarian Electrotechnical Association (MEE). The following standards can be referred to when facing such a task [35] :

- MSZ EN 60204-1: This Hungarian standard is based on the European standard EN 60204-1, titled "Safety of machinery - Electrical equipment of machines - Part 1: General requirements." It provides guidelines for electrical equipment used in machinery, including wire sizing for control cabinets;

- MSZ EN 61439-1: This standard, based on the European standard EN 61439-1, focuses on low-voltage switchgear and control gear assemblies. It includes requirements for electrical switches and control devices used in control cabinets, which indirectly influence wire sizing;

- MSZ HD 60364-5-52: This Hungarian adoption of the harmonized European standard HD 60364-5-52 covers electrical installations in buildings, with Part 5-52 specifically addressing selection and erection of electrical equipment. It provides guidance on wire sizing for different applications, including control cabinets in building installations.

2.1.2 Wire sizes in the case of this thesis work

In the context of using wires in a control cabinet, standard wire sizing is crucial. It provides guidelines for determining the appropriate wire gauge or cross-sectional area for different electrical connections within the cabinet. This sizing information ensures proper electrical conductivity, minimizes voltage drop, and ensures the safe and efficient operation of the control cabinet.

This table serves as a reliable reference to determine the suitable wire sizes for power conductors, signal wires, grounding wires, and other connections within the control cabinet. Since for most control cabinets the factors that influence wire sizing remain relatively the same, our biggest concern is the maximum operating current the wire must withstand. [2]

Cross section (mm^2)	Max operating current (A)
0,75	4
1	6
1,5	10
2,5	16
4	20
6	35
10	50
16	63
25	80
35	100
50	125
70	160
95	200
120	250
150	250
185	315
240	400
300	400
400	500
500	630

Figure 2 - Wire size chart used in this thesis [2]

2.2 Wire coloring

In the context of control cabinets, wire colours serve various purposes and play a crucial role in identifying and organizing wires effectively. They can be differentiated based on factors such as voltage value, AC or DC voltage, and whether they are phase or neutral wires. By using distinct wire colours for different use cases, it becomes easier to understand and work with the electrical connections inside the control cabinet.

2.2.1 Current standards that refer to wire colours

- MSZ EN 60446: This Hungarian adoption of the European standard EN 60446, titled "Basic and safety principles for man-machine interface, marking, and identification - Identification of equipment terminals, conductor terminations, and conductors," provides guidelines for wire colour coding and identification. It includes recommendations for identifying different types of wires, such as phase conductors, neutral conductors, protective conductors, and more;

- MSZ HD 361 S2: This Hungarian standard, based on the harmonized European standard HD 361 S2, focuses on electrical installations of buildings. It covers various aspects of electrical wiring, including wire colour coding and identification. It provides guidance on the use of specific colours for different types of wires, ensuring consistency and clear identification within control cabinets and other building installations.

Efficient communication, troubleshooting, and maintenance within control cabinets are contingent upon appropriate wire colour identification, which is ensured by these standards. [35]

2.2.2 Wire colours in the case of this thesis work

In the context of my thesis work, which goes beyond the scope of my university studies, I have the opportunity to apply my knowledge and skills in a professional setting. I am fortunate to be employed by a company that has established a specific standard for wire colours. This standard plays a crucial role in ensuring clear differentiation and identification of wires within various applications.

By adhering to the predefined wire colours, we maintain consistency and promote efficient communication and understanding among team members. This standardization simplifies the wiring process and reduces the risk of errors or confusion during installation, maintenance, and troubleshooting. [3]

Wire colour chart				
Main circuit 400/230V AC (L1, L2, L3, Lights on the door)				BLACK
Main circuit neutral (N)				BLUE
Protective conductor (PE)				GREEN-YELLOW
Control voltage	230V AC	Phase		RED
		Neutral		BLUE
	220V DC	+		PINK
		-		WHITE-BLUE
	24V AC	Phase		BROWN
		Neutral (GND)		GREY
	24V DC	+		PURPLE
		-		WHITE
	Foreign voltage from outside source			ORANGE
DDC (Direct Digital Control)	Input	Analog	(AI)	YELLOW
		Digital	(DI, BI)	Colour dependent on switched voltage.
		GND		GREY
	Output	Analog	(AO)	GREEN
		Digital	(DO, REL)	Colour dependent on switched voltage.
		Zero potential		ORANGE
	V_{aux}	DDC outputs the supply voltage (5V, 10V, etc.)		GREEN
BUS (2x2x0,8)	Positive branch			RED
	Negative branch			BLACK
	0V			YELLOW

Figure 3 - Wire colour chart in my workplace [3]

2.3 Power supply and earthing methods

The basic power supply system utilized in both control cabinet and construction projects encompasses variations such as three-phase three-wire and three-phase four-wire systems. However, the precise definitions of these terms may not be uniformly strict. To address this, the International Electrotechnical Commission (IEC) has established standardized provisions, categorizing power supply systems into three main types: TT, TN, and IT systems. Within the TN system, further subdivisions exist, namely TN-C, TN-S, and TN-C-S systems, all which I'm going to discuss later. In this section, I will provide a comprehensive overview of these different power supply systems, focusing on their distinctions in terms of earthing and protection.

Based on the diverse grounding methods and protection techniques defined by the IEC, low-voltage power distribution systems are classified into the following three types: TT, TN, and IT systems. Understanding the characteristics and nuances of each system is crucial for ensuring the safe and efficient operation of electrical installations.

2.3.1 Importance of proper earthing

In an electrical network, the implementation of a reliable and effective earthing system plays a crucial role in ensuring the safety of human life and protecting electrical equipment. As earthing systems can vary significantly from one country to another, it becomes paramount to possess a comprehensive understanding of the different types of earthing systems, particularly when involved in the design process of control cabinets. This section aims to provide a detailed exploration of the various earthing systems in accordance with the guidelines set forth by the International Electrotechnical Commission standard.

By delving into the intricacies of earthing systems, it becomes possible to comprehend their fundamental principles and the specific requirements dictated by the IEC standard. A robust understanding of these diverse earthing systems allows designers and engineers to make informed decisions when it comes to the configuration and installation of control cabinets within electrical networks.

The exploration of different earthing systems encompasses a wide range of aspects, including the grounding techniques employed, the specific connections between exposed conductive parts and protective lines, the overall topology of the earthing system, and the implications for safety during potential faults or short circuits. It is essential to recognize that the selection of an appropriate earthing system for control cabinet design has far-reaching consequences, influencing not only the performance and reliability of the electrical equipment but also the overall safety of personnel operating within the network. [4]

2.3.2 The meaning of the letters I, T, N, C, S

In the symbol system established by the International Electrotechnical Commission for power supply methods, the first letter plays a significant role in denoting the relationship between the power system and the ground. Specifically, the letter "T" signifies that the neutral point of the power system is directly connected to the ground. On the other hand, the letter "I" indicates that the power supply is isolated from the ground or that one point of the power supply is linked to the ground through a high impedance, commonly around 1000 Ω. The letter "I" represents the word "isolation" and is derived from the French word "Isolation."

The second letter in the symbol system pertains to the electrically conductive device that is exposed to the ground. For example, "T" implies that the device shell or enclosure is directly grounded, without any direct connection to other grounding points within the system. Conversely, "N" signifies that the load is protected by the neutral point.

The third letter in the symbol system indicates the configuration of the combination between the working neutral line and the protective line. For instance, the letter "C" denotes that the working neutral line and the protective line are integrated as a single conductor, forming the TN-C system. Conversely, the letter "S" suggests that the working neutral line and the protective line are strictly separated from each other, thereby designating the protective earth (PE) line as a dedicated protection line. This configuration is known as the TN-S system.

Understanding these symbolic representations is essential for discerning the characteristics and grounding arrangements within different power supply systems, enabling proper interpretation and implementation of electrical installations.

2.3.3 TN-C power supply system

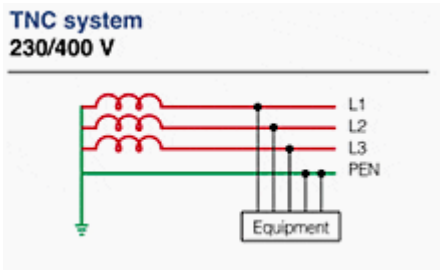


Figure 5 - TNC System earthing [4]

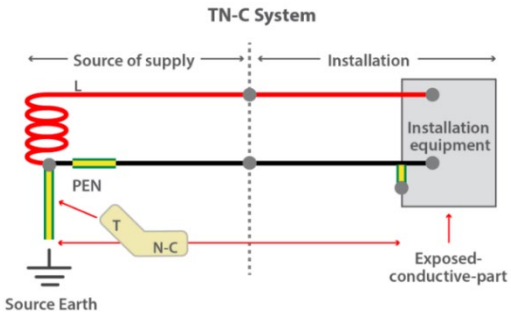


Figure 4 - TNC System earthing [4]

As the letter designation suggests, TN-C system is characterized by the combination of functional and protective neutral conductors. A classical TN-C system is a traditional four-wire power supply circuit with three phases and one neutral wire. In this case, the

main grounding bus is a dead-grounded neutral. All the open parts, housings and metal parts of devices that can conduct electric current should be connected to the bus using additional neutral wires.

This system has several significant drawbacks, and the most serious among them is the loss of safety functions in case of breakage or burn-off of the neutral wire. In such cases, dangerous voltages occur on the bare surfaces of instrument and equipment housings. As a separate PE protective ground conductor is not used in this system, all the connected sockets have no ground. Therefore, all the electrical equipment should be connected to neutral, i.e. the housing parts should be connected to a neutral wire.

2.3.4 TN-C-S power supply system

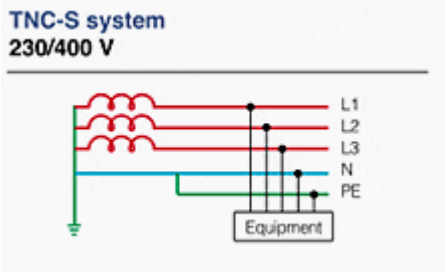


Figure 6 - TNC-S System earthing [4]

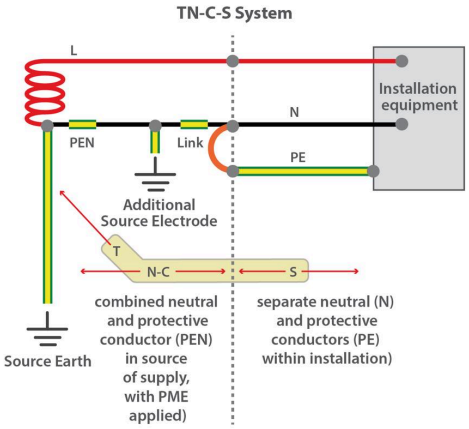


Figure 7 - TNC-S System earthing [4]

In the case of temporary power supply in the TN-C-S system, when the front part is energized using the TN-C method, but the construction regulations mandate the use of the TN-S power supply system at the construction site, the total distribution box can be divided at the rear of the system, excluding the PE line. The distinctive characteristics of the TN-C-S system are characterized by the following:

- Working zero-line N is connected with the special protection line PE. When the unbalanced current of the line is large, the zero protection of the electrical equipment is affected by the zero-line potential. The TN-C-S system can reduce the voltage of the motor housing to the ground, but it cannot completely eliminate this voltage. The magnitude of this voltage depends on the load imbalance of the wiring and the length of this line. The more unbalanced the load and the longer the wiring, the greater the voltage offset of the device housing to ground. Therefore, it is required that the load unbalance current should not be too large, and that the PE line should be grounded repeatedly;

- The PE line cannot enter the leakage protector under any circumstances, because the leakage protector at the end of the line will cause the front leakage protector to trip and cause a large-scale power failure;
- In addition to the PE line must be connected to the N line in the general box, the N line and the PE line must not be connected in other compartments. No switches and fuses shall be installed on the PE line, and no earth shall be used as the PE. line.

Based on the analysis conducted above, it can be observed that the TN-C-S power supply system serves as a temporary modification to the TN-C system. When the three-phase power transformer is adequately grounded and the three-phase load remains relatively balanced, the utilization of the TN-C-S system is still viable in construction site electricity. However, in scenarios where there are unbalanced three-phase loads present, coupled with the presence of a dedicated power transformer at the construction site, it becomes imperative to employ the TN-S power supply system. [4]

2.3.5 TN-S power supply system

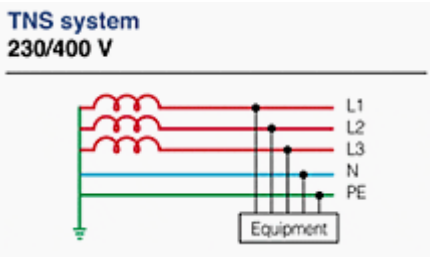


Figure 9 - TN-S System earthing [4]

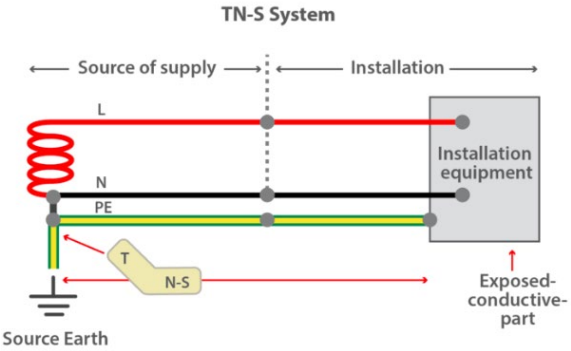


Figure 8 - TN-S System earthing [4]

The TN-S mode power supply system is a power supply system that strictly separates the working neutral N from the dedicated protection line PE. It is called the TN-S power supply system. The characteristics of the TN-S power supply system are as follows. [4]

- When the system is running normally, there is no current on the dedicated protection line, but there is unbalanced current on the working zero line. There is no voltage on the PE line to the ground, so the zero protection of the metal shell of the electrical equipment is connected to the special protection line PE, which is safe and reliable;

- The working neutral line is only used as a single-phase lighting load circuit;

- The special protection line PE is not allowed to break the line, nor can it enter the leakage switch;

- If the earth leakage protector is used on L line, the working zero line must not be grounded repeatedly, and the PE line has repeated grounding, but it does not pass through the earth leakage protector, so the leakage protector can also be installed on the TN-S system power supply L line;

- The TN-S power supply system is safe and reliable, suitable for low voltage power supply systems such as industrial and civil buildings. The TN-S power supply system must be used before the construction works begin.

2.3.6 TT power supply system

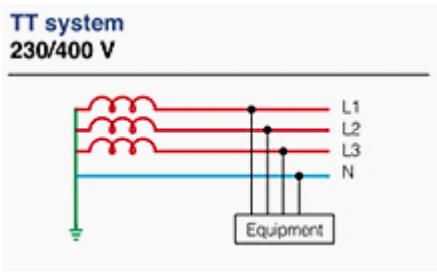


Figure 11 - TT System earthing [4]

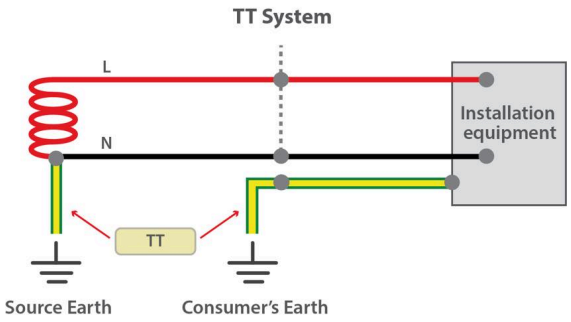


Figure 10 - TT System earthing [4]

The TT method refers to a protective system that directly grounds the metal housing of an electrical device, which is called a protective earthing system, also called a TT system. The first symbol T indicates that the neutral point of the power system is directly grounded; the second symbol T indicates that the conductive part of the load device that is not exposed to the live body is directly connected to the ground, regardless of how the system is grounded. All grounding of the load in the TT system is called protective grounding. The characteristics of this power supply system are as follows. [4]

- When the metal shell of the electrical equipment is charged (the phase line touches the shell or the equipment insulation is damaged and leaks), the grounding protection can greatly reduce the risk of electric shock. However, low-voltage circuit breakers (automatic switches) do not necessarily trip, causing the earth-leakage voltage of the leakage device to be higher than the safe voltage, which is a dangerous voltage;

- When the leakage current is relatively small, even a fuse may not be able to blow. Therefore, a leakage protector is also required for protection. Therefore, the TT system is difficult to popularize;

- The grounding device of the TT system consumes a lot of steel, and it is difficult to recycle, time, and materials.

At present, some construction units use the TT system. When the construction unit gets its power supply for temporary use of electricity, a special protection line is used to reduce the amount of steel used for the grounding device.
Separate the newly added special protection line PE line from the working zero line N, which is characterized by the following:

- There is no electrical connection between the common grounding line and the working neutral line;
- In the normal operation, the working zero line can have current, and the special protection line does not have current;
- The TT system is suitable for places where ground protection is very scattered.

2.3.7 IT power supply system

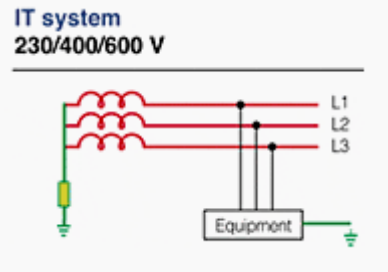


Figure 13 - IT System earthing [4]

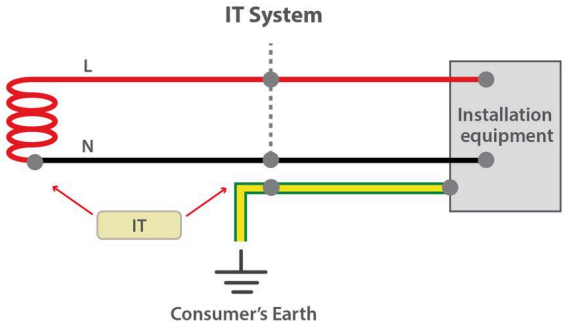


Figure 12- IT System earthing [4]

IT mode power supply system I indicates that the power supply side has no working ground or is grounded at high impedance. The second letter T indicates that the load side electrical equipment is grounded.

The IT mode power supply system has high reliability and good security when the power supply distance is not long. It is generally used in places where no blackouts are permitted, or places where strict continuous power supply is required, such as electric power steelmaking, operating rooms in large hospitals, and underground mines. The power supply conditions in underground mines are relatively poor and the cables are susceptible to moisture.

Using the IT-powered system, even if the neutral point of the power supply is not grounded, once the device is leaking, the relative ground leakage current is still small and will not damage the balance of the power supply voltage. Therefore, it is safer than the neutral grounding system of the power supply. However, if the power supply is used for a long distance, the distributed capacitance of the power supply line to the earth cannot be ignored. [4]

2.4 Material usage in control cabinets

In control cabinets, a variety of materials are utilized, with a predominant use of metals alongside specific types of plastics. Materials, such as steel, aluminum, or copper alloys, are commonly employed due to their excellent mechanical strength, conductivity, and durability. These metals provide a solid framework for supporting and securing components within the control cabinet.

Furthermore, plastics play a significant role in control cabinet construction. Certain types of plastics, such as polycarbonate or ABS (acrylonitrile butadiene styrene), are chosen for their electrical insulation properties, corrosion resistance, and lightweight nature. These plastics are often utilized for components like insulating barriers, terminal blocks, and covers, providing an added layer of electrical safety and protection.

The selection of materials in control cabinets is driven by the need for a robust and reliable infrastructure that withstands the operational requirements, environmental factors, and electrical demands. The use of metals and specific plastics ensures a balance between structural integrity, electrical insulation, and overall performance in the control cabinet assembly. Careful consideration is given to these materials to ensure compliance with the requirements of MSZ EN 61439 and to guarantee the safe and efficient functioning of the control cabinet system. [35][5]

For example, here's the material composition of a Schneider Electric PrismaSeT P modular frame (Schneider Electric ref. number: LVS08406)

Figure 15 - PrismaSeT P LVS08406 [5]

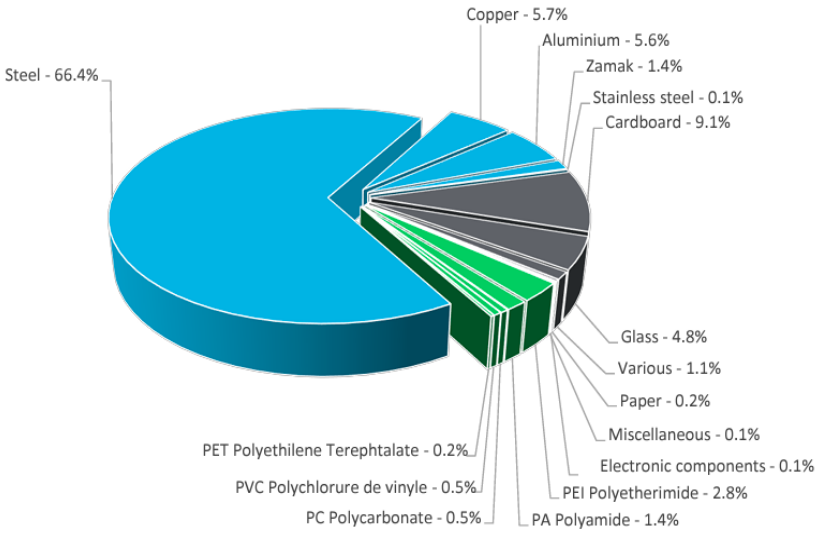


Figure 14 - Materials found in LVS08406 [5]

3. TECHNICAL OVERVIEW

3.1 Requirements of project

The focus of my thesis project entails the automation of processes within a hotel, and the control cabinets being discussed revolve around this particular objective. Owing to confidentiality considerations, certain project-specific details cannot be disclosed. However, it is worth noting that the control cabinet in focus plays a crucial role in automating ventilation-related processes within the hotel.

By automating the ventilation processes, the control cabinet optimizes energy efficiency, ensures adequate air quality, and provides a comfortable environment for guests and occupants. It may incorporate features such as air quality sensors, adjustable dampers or vents, variable speed drives, and intelligent control algorithms to achieve optimal ventilation performance.

While specific design details and functionality remain confidential, this control cabinet represents the integration of automation technology within the hotel environment, enhancing comfort, energy efficiency, and operational effectiveness in relation to ventilation systems.

When constructing the control cabinet, it is crucial to prioritize durability and longevity, ensuring its reliable operation over an extended period of 10-20 years. To achieve this goal, several key aspects should be considered:

- *Structural Integrity*: The control cabinet should be built with sturdy materials, such as robust metals or high-quality plastics, capable of withstanding environmental conditions, vibrations, and mechanical stress. Reinforced construction and proper fastening methods help ensure the cabinet's structural integrity throughout its intended lifespan;

- *Environmental Protection*: A control cabinet should provide adequate protection against environmental factors that may compromise its functionality. This includes shielding against dust, moisture, temperature fluctuations, and electromagnetic interference. Proper gasketing, sealing, and ventilation mechanisms should be employed to maintain optimal operating conditions;

- *Component Selection*: The choice of components within the control cabinet should be carefully considered to ensure their compatibility, reliability, and longevity. High-quality electrical components, such as relays, circuit breakers, and contactors, should be sourced from reputable manufacturers with a proven track record in durability and performance;

- *Adequate Cooling and Heat Dissipation*: To prevent excessive heat buildup that may compromise the cabinet's functionality, appropriate cooling measures should be implemented. This may involve the use of fans, cooling fins, or even air conditioning systems, depending on the heat dissipation requirements of the control cabinet;

- *Regular Maintenance and Inspection*: Even with a robust construction, regular maintenance and periodic inspections are necessary to identify and address potential issues in a timely manner. Routine checks, cleaning, and testing of components help ensure correct and precise functionality over the cabinet's lifespan.

By adhering to these considerations, the control cabinet can be built to be robust, reliable, and able to function correctly and precisely for the intended timeframe of 10-20 years. This ensures long-term operational efficiency, minimized downtime, and optimal performance in the control processes it governs.

3.2 Tools needed for project

To successfully complete the construction of the control cabinet, several tools are essential. This section shall provide an overview of some of the tools commonly required for this task, these being manufactured by Weidmüller.

3.2.1 Wire cutter

The KT8 wire cutter is a specialized tool used for cutting wires. The "KT8" designation refers to the specific size or model of the wire cutter. This tool is designed to provide efficient and precise wire cutting capabilities, ensuring clean and accurate cuts. There's also the option to use a battery operated wire cutter, which is only used on large diameter wires. [6]

Figure 16 - KT8 [6]

3.2.2 Wire stripping tools

The STRIPAX wire stripper is a convenient tool that enables users to strip wires quickly and consistently to the same length. It offers various adjustable features that enhance its usability and versatility. The tool incorporates a slider mechanism for wire diameter adjustment, allowing for effortless adaptation to different wire sizes. Additionally, it features a slider on the jaws that can be set to define the desired stripping length, ensuring all consecutive wires are stripped uniformly.

This is the basic STRIPAX, which is able to strip up to a 10 mm^2 wire. [7]

Figure 17 - STRIPAX [7]

And this is the STRIPAX 16. The reason that we use two types of stripping tools is that this type is able to strip wires up to 16 mm^2 reliably, while the basic STRIPAX is not designed for diameters upwards of 10 mm^2 and can be ruined when used above the maximum specified diameter. [8]

Figure 18 - STRIPAX 16 [8]

3.2.3 End ferrule crimping tools

To ensure a safe and dependable connection, the mentioned tools are utilized for crimping end ferrules onto the stripped wire ends. This process enhances the integrity and performance of the electrical connections within the control cabinet. Different types of crimping tools are employed based on the wire diameters and specific requirements. Additionally, for larger wire diameters above 50 mm², a battery-operated crimping tool is available, providing efficient and convenient crimping capabilities.

The selection and use of appropriate crimping tools are crucial for achieving secure and reliable connections. These tools are designed to apply the necessary pressure to create a strong bond between the wire and the end ferrule. This ensures proper electrical conductivity, reduces the risk of wire strand breakage, and minimizes the chances of loose connections or electrical faults.

The availability of multiple types of crimping tools allows for versatility in accommodating different wire sizes and ferrule types commonly found within the control cabinet. By using the appropriate tool designed for the specific wire diameter, operators can ensure consistent and accurate crimping results.

The most often used crimping tool is the PZ 10 SQR, which is suitable for up to 10 mm^2 wires. This specific tool crimps the end ferrules into a square shape. [9]

Figure 19 - PZ 10 SQR [9]

For larger diameter wires up to 16 mm^2, we utilize the PZ 16. This ensure that we can crimp larger than 10 mm^2 wire without damaging the former PZ 10 SQR. [10]

Figure 20 - PZ 16 [10]

For wire sizes even larger than 16 mm^2, we use the PZ 50, which allows us to crimp 25-35-50 mm^2 wires with ease. For even larger diameters, we must resort to the more expensive battery operated tool. [11]

Figure 21 - PZ 50 [11]

3.2.4 Insulated cable lug crimp tool

The CTI 6 crimp tool is specifically designed for crimping cable lugs. This specialized tool ensures reliable and secure connections by effectively crimping the cable lugs onto the wires. The designation "CTI 6" refers to the specific model or type of crimp tool used in this context. [12]

Figure 22 - CTI 6 [12]

3.2.5 Screwdriver and plier set

A set of screwdrivers and pliers are considered the fundamental and frequently utilized tools in our toolkit. These tools play crucial roles in various tasks and applications within our work.

Screwdrivers provide the necessary means for installing, tightening, or removing screws and fasteners. With a variety of sizes and types, including flathead and Phillips head screwdrivers, they accommodate different screw heads and ensure proper engagement for secure fastening.

Pliers, on the other hand, offer versatility in gripping, bending, cutting, and holding various materials and components. This includes handling wires, nuts, bolts, and other small objects. Pliers often come in different forms, such as combination pliers, needle-nose pliers, or locking pliers, each designed to fulfill specific functions.

The combination of screwdrivers and pliers provides a solid foundation for many essential tasks, such as assembly, disassembly, connection, or adjustment. These tools are indispensable in electrical work, general maintenance, repairs, and a wide range of applications across different industries and professions. [13][14]

Figure 24 - Screwdriver set [13]

Figure 23 - Set of pliers [14]

3.2.6 Hilti SFE 2-A12

Investing in a high-quality hand drill can greatly improve the efficiency and productivity of any project. A good hand drill enables users to work faster and more effectively by providing a faster method to tightening bolts and screws. By ensuring that you have a dependable and well-designed hand drill, you can save time and effort in your projects while achieving better results. For this reason, we use Hilti hand drills, which are kept in high regard for their quality and being reliable. [15]

Figure 25 - Hilti SFE 2-A12 [15]

This particular type of Hilti hand drill also comes with four interchangeable heads for either drilling or tightening a fastener in a hard to reach location, or a quick-change head that utilizes a ball bearing to keep screwdriver bits in place.

3.2.7 Heat gun

When utilizing uninsulated cable lugs in a control cabinet, there are two important considerations: touch protection and visual aesthetics.
Firstly, for touch protection, it is necessary to insulate the uninsulated cable lugs. This is crucial to prevent accidental contact with live electrical components and enhance safety. By insulating the cable lugs, the risk of electrical shock or injury is significantly reduced, ensuring a safer working environment.

Secondly, insulating the cable lugs also contributes to the visual appearance of the control cabinet. Insulation not only provides a more professional and cleaner look but also helps organize the wiring and maintain a neat and organized cabinet layout.

Shrink tubes are utilized to ensure proper insulation of these cable lugs. A heat gun is employed to shrink the rubber material of the tubes, securely enclosing the cable lugs with an insulating layer. [16]

Figure 26 - Einhell heat gun [16]

3.3 Tools required for final testing

Once the control cabinet is fully assembled and wired according to the plans, a technician performs a comprehensive final check. This involves testing the outputs of the control cabinet to identify any potential errors that may have arisen during the assembly or wiring process. The purpose of this final check is to ensure that the control cabinet is functioning correctly, and all connections are properly established. By conducting thorough testing, any issues or mistakes can be detected and rectified before the control cabinet is put into operation, helping to ensure its reliability and performance.

I will discuss the final testing further in another section, but some specific tools are required to properly test the control cabinet.

3.3.1 VT Digi Pro

The two-pole voltage tester serves two primary purposes: checking voltage levels and determining phase sequence.
Firstly, it is used to check voltage levels. By connecting the tester to the electrical circuit, it allows technicians to measure the voltage present at a specific point. This helps ensure that the voltage is within the expected range, verifying the proper functioning of the electrical system. [17]

Secondly, the two-pole voltage tester helps determine the phase sequence. Phase sequence refers to the order in which the phases of a three-phase power system are arranged. With the tester, technicians can identify the correct sequence of the phases, which is essential for the proper operation of various electrical equipment and systems.

Figure 27 - VT DIGI PRO [17]

4. OVERVIEW OF DRAWING

In this section, the intention is to give an overview and demonstrate the general logic of the drawing used for the construction and wiring of the control cabinet.

As mentioned before, specific details such as the location, name of the project, customer, as well as the individuals and company involved in the design of the control cabinet cannot be shared due to privacy obligations.

4.1.1 Datasheet

In the first few pages of the drawing, this datasheet is provided as an explanation of some of the names used and their meaning. This includes information about the terminals, potentials, wire color notations, and also inside terminals, which are only utilized inside the control cabinet, and don't connect to any outside wires or cables. [18][35]

Potentials :

ST : Control voltage AC 230V
STN : Control voltage-N AC 230V
G : Control voltage AC 24V
GN : Control voltage-N AC 24V
j : Control voltage DC 24V
n : Control voltage-N DC 24V

Terminals :

-X0 = Power supply 400/230V AC
-X1 = Main circuit 400/230V AC
-X2 = Control voltage 230V AC
-X3 = Low voltage 24V DC
-X4 = Low voltage 24V AC
-XT4 = DDC Analog inputs / outputs
-XT5 = DDC Digital inputs (pot. free)
-XT6 = Bus
-XT9 = External voltage
-XFAS = Fire alarm signal max. 24V AC/DC

Colour notations :

Main circuit 400/230V AC	:	black	(BK)
Main circuit (N)	:	light blue	(LBU)
Earth (PE)	:	green-yellow	(GNYE)
Control voltage 230V AC	:	Red / Blue	(RD / BU)
Control voltage 24V AC	:	Brown / Grey	(BN / GY)
Control voltage 24V DC	:	Violet / White	(VT / WH)
External voltage	:	orange	(OG)
DDC / PLC Analóg bemenet	:	Yellow / Grey	(YE / GY)
DDC / PLC Analóg kimenet	:	Green	(GN)

Internal terminals :

-XLBEL = Lighting, socket, ventilation 230V AC
-X230VAC = Control circuits 230V AC
-X24VAC = Low voltage 24V AC
-X24VDC = Low voltage 24V DC

Figure 28 - Datasheet [18]

4.1.2 Table of equipment identification

This table refers to other equipment and switchboards that this control cabinet will have a connection point for. [18]

Szerkezetazonosító lista / Table of equipment identification

Teljes megnevezés / Equipment:		Teljes megnevezés / Description:
=HMU8SCC1		Füstmentesítés gépészeti elosztó / Smoke exhaust swb.
+TART		Tartalomjegyzék
+Kábellista		Kábellista
+Anyagjegyzék		Anyagjegyzék
+Összesített anyagjegyzék		Összesített anyagjegyzék
+SSA		Kapcsolószekrény átnézeti rajz
+F1		1. mező / Field 1.
+F2		2. mező / Field 2.
+MULPH1		Füstmentes lépcsőház 1. / Overpressure staircase 1.
+MULPH2		Füstmentes lépcsőház 2. / Overpressure staircase 2.
+WATRFM		Átrium hő- és füstelvezetés / Atrium heat- and smoke extraction
+MUKFM1		Emeleti zárt közlekedők hő- és füstelvezetés / Upstairs floors corridors heat- and smoke extraction
+MUKFM2		Emeleti zárt közlekedők hő- és füstelvezetés / Upstairs floors corridors heat- and smoke extraction
+MUKFM7		7. emeleti zárt közlekedők hő- és füstelvezetés / 7th floor corridors heat- and smoke extraction

Figure 29 - Table of equipment [18]

4.1.3 Table of contents

Of course, there is a table of contents that make up the first 40 pages of this drawing, this includes an extensive list of materials which consists of every component used in

Tartalomjegyzék / Table of contents

==ET =HMU8SCC1 +TART		Tartalomjegyzék
	1	Előlap / Cover sheet
	1a	Jelölésrendszer magyarázata Notation comments
	1b	Jelölésrendszer magyarázata Notation comments
	2	Tartalomjegyzék : ==ET=HMU8SCC1+TART/1 - ==ET=HMU8SCC1+Anyagjegyzék/9
	2.a	Tartalomjegyzék : ==ET=HMU8SCC1+Anyagjegyzék/10 - ==ET=HMU8SCC1+Anyagjegyzék/37
	2.b	Tartalomjegyzék : ==ET=HMU8SCC1+Anyagjegyzék/38 - ==ET=HMU8SCC1+F1/34
	2.c	Tartalomjegyzék : ==ET=HMU8SCC1+F1/35 - ==ET=HMU8SCC1+F1/101
	2.d	Tartalomjegyzék : ==ET=HMU8SCC1+F1/102 - ==ET=HMU8SCC1+F2/202
	2.e	Tartalomjegyzék : ==ET=HMU8SCC1+F2/203 - ==ET=HMU8SCC1+F2/236
	2.f	Tartalomjegyzék : ==ET=HMU8SCC1+F2/237 - ==ET=HMU8SCC1+F2/267
	2.g	Tartalomjegyzék : ==ET=HMU8SCC1+F2/268 - ==ET=HMU8SCC1+F2/341
	2.h	Tartalomjegyzék : ==ET=HMU8SCC1+F2/342 - ==ET=HMU8SCC1+F2/383
	3	Módosításjegyzék / Modification list
	4	Table of equipment identification Szerkezetazonosító lista
==ET =HMU8SCC1 +Kábellista		Kábellista
	1	Kábeljegyzék List of cables
	2	Kábeljegyzék List of cables
	3	Kábeljegyzék List of cables
==ET =HMU8SCC1 +Anyagjegyzék		Anyagjegyzék
	1	Anyagjegyzék List of materials
	2	Anyagjegyzék List of materials
	3	Anyagjegyzék List of materials
	4	Anyagjegyzék List of materials
	5	Anyagjegyzék List of materials
	6	Anyagjegyzék List of materials
	7	Anyagjegyzék List of materials
	8	Anyagjegyzék List of materials
	9	Anyagjegyzék List of materials

Figure 30 - Table of contents [18]

the control cabinet, and also a list of cables going in and out of the control cabinet. Since it is such an extensive list, I will only include a few screenshots of this section.

==ET =HMU8SCC1 +F1	1. mező / Field 1.
10	Kiemelt betáplálás / Power supply
11	Világítás, dugalj, szellőzés, fűtés / Lighting, socket 230V AC, ventilation, heating
12	Fázisfigyelés / Phase monitoring
13	Túlfeszültség levezető / Surge protection
14	Vezérlő feszültség 230V AC / Control voltage 230V AC
15	Vezérlő feszültség 24V AC / Control voltage 24V AC
16	Vezérlő feszültség 24V DC / Control voltage 24V DC
17	Vezérlő feszültség 24V DC / Control voltage 24V DC
18	Lámpa próba / Lamp test
19	Mező leágazás, tartalék leágazások / Field branch, Reserve branches
30	+MULPH1-S Lépcsőház helyi indítás jelzésadók Staircase local switches
31	+MULPH1-FU1 Lépcsőház befúvó ventilátor frekvenciaváltó Staircase supply fan VFD
32	+MULPH1-FU1 Lépcsőház befúvó ventilátor frekvenciaváltó Staircase supply fan VFD
33	+MULPH1-FU1 Lépcsőház befúvó ventilátor frekvenciaváltó Staircase supply fan VFD
34	+MULPH1-FCST11 Füstcsappantyú - Füstmentes lph. Smoke damper - Staircase

Figure 31 - Table of contents 2 [18]

As mentioned, the cable overview section provides comprehensive information about all the cables utilized in the control cabinet. It includes details such as the cable names, their originating point, destination, diameter, function, and the corresponding page number where they can be found in the drawing.

This section serves as a reference, enabling easy identification and tracking of each cable's specifications and location within the control cabinet. By providing this detailed overview, it facilitates efficient installation, troubleshooting, and maintenance of the control cabinet's wiring system.[18]

Kábellista / Cable overview

Kábeltípus / Cable type	Tervjel / Cable designation	honnan / from	hová / to	erek / wire	keresztmettsz. cross sect.	Funkciószöveg / Function text	Lap / Page
NHXH-J E90/FE180	W+F1-X1/+MULPH1-FU1	+F1-X1	+MULPH1-FU1	4	4	Befúvó ventilátor frekvenciaváltó Supply fan VFD	+F1/32.1
	W+F1-X1/+MULPH1-V2	+F1-X1	+MULPH1-V2	3	2,5	Légpótló ventilátor Air-supply fan	+F1/41.1
	W+F1-X1/+MULPH2-FU1	+F1-X1	+MULPH2-52FU1	4	4	Befúvó ventilátor frekvenciaváltó Supply fan VFD	+F1/52.1
	W+F1-X1/+MULPH2-V2	+F1-X1	+MULPH2-V2	3	2,5	Légpótló ventilátor Air-supply fan	+F1/61.1
	W+F1-X1/+WATRFM-V4	+F1-X1	+WATRFM-V4	4	6	Füstelszívó ventilátor Smoke exhaust fan	+F1/72.1
	W+F1-X1/+WATRFM-V4D	+F1-X1	+WATRFM-V4	4	6	Füstelszívó ventilátor Smoke exhaust fan	+F1/72.2
	W+F1-X2/+MULPH1-ZTL1	+F1-X2	+MULPH1-ZTL1	5	1,5	Túlnyomás levezető zsalu Overpressure release damper	+F1/38.1
	W+F1-X2/+MULPH2-ZTL1	+F1-X2	+MULPH2-ZTL1	5	1,5	Túlnyomás levezető zsalu Overpressure release damper	+F1/58.1
JB-H(St)H E90/FE180	W+F1-X3/+MULPH1-SD1	+F1-X3	+MULPH1-SD1	2x2	0,8	Füstérzékelő Smoke detector	+F1/36.1
	W+F1-X3/+MULPH1-SD2	+F1-X3	+MULPH1-SD2	2x2	0,8	Füstérzékelő Smoke detector	+F1/37.1
	W+F1-X3/+MULPH2-SD1	+F1-X3	+MULPH2-SD1	2x2	0,8	Füstérzékelő Smoke detector	+F1/56.1
	W+F1-X3/+MULPH2-SD2	+F1-X3	+MULPH2-SD2	2x2	0,8	Füstérzékelő Smoke detector	+F1/57.1
NHXH-J E90/FE180	W+F1-X4/+MULPH1-FCST11	+F1-X4	+MULPH1-FCST11	7	1,5	Füstcsappantyú Smoke damper	+F1/34.1
	W+F1-X4/+MULPH1-FCST12	+F1-X4	+MULPH1-FCST12	7	1,5	Füstcsappantyú Smoke damper	+F1/35.1
JB-H(St)H E90/FE180	W+F1-X4/+MULPH1-S	+F1-X4	+MULPH1-SP3;+MULPH1-S7	2x2	0,8	Lépcsőház - P3 szint helyi indítás jelzésadó Staircase local switch	+F1/30.1
NHXH-J E90/FE180	W+F1-X4/+MULPH1-Z2	+F1-X4	+MULPH1-Z2	7	1,5	Frisslevegő zsalu Fresh-air damper	+F1/42.1
	W+F1-X4/+MULPH2-FCST11	+F1-X4	+MULPH2-FCST11	7	1,5	Füstcsappantyú Smoke damper	+F1/54.1
	W+F1-X4/+MULPH2-FCST12	+F1-X4	+MULPH2-FCST12	7	1,5	Füstcsappantyú Smoke damper	+F1/55.1
JB-H(St)H E90/FE180	W+F1-X4/+MULPH2-S	+F1-X4	+MULPH2-SP3;+MULPH2-S7	2x2	0,8	Lépcsőház - P3 szint helyi indítás jelzésadó Staircase local switch	+F1/50.1
NHXH-J E90/FE180	W+F1-X4/+MULPH2-Z2	+F1-X4	+MULPH2-Z2	7	1,5	Frisslevegő zsalu Fresh-air damper	+F1/62.1

Figure 32 - Cable list [18]

And here's a portion of the extensive bill of materials, listing every component used, their designation, their type, manufacturer and also the part number.

Alkatrészjegyzék / Bill of materials

Tervjel / Device designation Elhelyezés / Position	db / pcs. ME	Megnevezés / Designation	Típus szám / Type	Gyártó / Manufact.	Cikkszám / Part number Funkciószöveg / Function text
=HMU8SCC1+++F1 -11S1 +-ET+HMU8SCC1+F1/11.3	1	Türpositionsschalter 1S+1Ö, 0.6m, orange Ajtókontaktus 1Z+1NY, 0.6m, narancs		RIT RIT	RIT.SZ 4315.520 Ajtó kapcsoló Door contact
=HMU8SCC1+++F1 -18S1 +-ET+HMU8SCC1+F1/18.1	1 Darab	Választókapcsoló, karos fogantyú, 1-0-2, 60°, visszaálló	ZB4-B	SE SE	SE.ZB4BJ5 Lámpa próba/Lamp test
=HMU8SCC1+++F1 -18S1 +-ET+HMU8SCC1+F1/18.1	1	Rögzítő gyűrű, ZB4 kapcsolóhoz	ZB	SE SE	SE.ZB4BZ009 Lámpa próba/Lamp test
=HMU8SCC1+++F1 -18S1 +-ET+HMU8SCC1+F1/18.1	2	Érintkező blokk 1Z		SE SE	SE.ZBE101 Lámpa próba/Lamp test
=HMU8SCC1+++F1 -31S1 +-ET+HMU8SCC1+F1/31.1	1 Darab	Kulcsos választókapcsoló, kulcs "0"-ban távolítható el, 1-0-2, 45°	ZB4-B	SE SE	SE.ZB4BG3
=HMU8SCC1+++F1 -31S1 +-ET+HMU8SCC1+F1/31.1	4	Érintkező blokk 1Z		SE SE	SE.ZBE101
=HMU8SCC1+++F1 -31S1 +-ET+HMU8SCC1+F1/31.1	1	Rögzítő gyűrű, ZB4 kapcsolóhoz	ZB	SE SE	SE.ZB4BZ009
=HMU8SCC1+++F1 -40S1 +-ET+HMU8SCC1+F1/40.1	1 Darab	Kulcsos választókapcsoló, kulcs "0"-ban távolítható el, 1-0-2, 45°	ZB4-B	SE SE	SE.ZB4BG3
=HMU8SCC1+++F1 -40S1 +-ET+HMU8SCC1+F1/40.1	4	Érintkező blokk 1Z		SE SE	SE.ZBE101
=HMU8SCC1+++F1 -40S1 +-ET+HMU8SCC1+F1/40.1	1	Rögzítő gyűrű, ZB4 kapcsolóhoz	ZB	SE SE	SE.ZB4BZ009
=HMU8SCC1+++F1 -51S1 +-ET+HMU8SCC1+F1/51.1	1 Darab	Kulcsos választókapcsoló, kulcs "0"-ban távolítható el, 1-0-2, 45°	ZB4-B	SE SE	SE.ZB4BG3
=HMU8SCC1+++F1 -51S1 +-ET+HMU8SCC1+F1/51.1	4	Érintkező blokk 1Z		SE SE	SE.ZBE101
=HMU8SCC1+++F1 -51S1 +-ET+HMU8SCC1+F1/51.1	1	Rögzítő gyűrű, ZB4 kapcsolóhoz	ZB	SE SE	SE.ZB4BZ009
=HMU8SCC1+++F1 -60S1 +-ET+HMU8SCC1+F1/60.1	1 Darab	Kulcsos választókapcsoló, kulcs "0"-ban távolítható el, 1-0-2, 45°	ZB4-B	SE SE	SE.ZB4BG3
=HMU8SCC1+++F1 -60S1 +-ET+HMU8SCC1+F1/60.1	4	Érintkező blokk 1Z		SE SE	SE.ZBE101
=HMU8SCC1+++F1 -60S1 +-ET+HMU8SCC1+F1/60.1	1	Rögzítő gyűrű, ZB4 kapcsolóhoz	ZB	SE SE	SE.ZB4BZ009
=HMU8SCC1+++F1 -70S1 +-ET+HMU8SCC1+F1/70.1	1 Darab	Kulcsos választókapcsoló, kulcs "0"-ban távolítható el, 1-0-2, 45°	ZB4-B	SE SE	SE.ZB4BG3
=HMU8SCC1+++F1 -70S1 +-ET+HMU8SCC1+F1/70.1	4	Érintkező blokk 1Z		SE SE	SE.ZBE101

Figure 33 - Bill of materials [18]

4.1.4 External view of the control cabinet

This specific control cabinet consists of two separate switchboards that are initially fastened together during the final testing phase. This allows for comprehensive testing of the entire control system as a unified unit before installation.

Once the control cabinet has completed the final testing and validation process, it is permanently installed together at the designated location. This permanent joining ensures a secure and stable configuration, ensuring the reliability and performance of the control cabinet once it is put into operation.

By initially fastening and later permanently joining the switchboards, it enables easier transportation, followed by a solid and secure installation at the intended location for optimal functionality. [18]

The external view of the two switchboards assembled together:

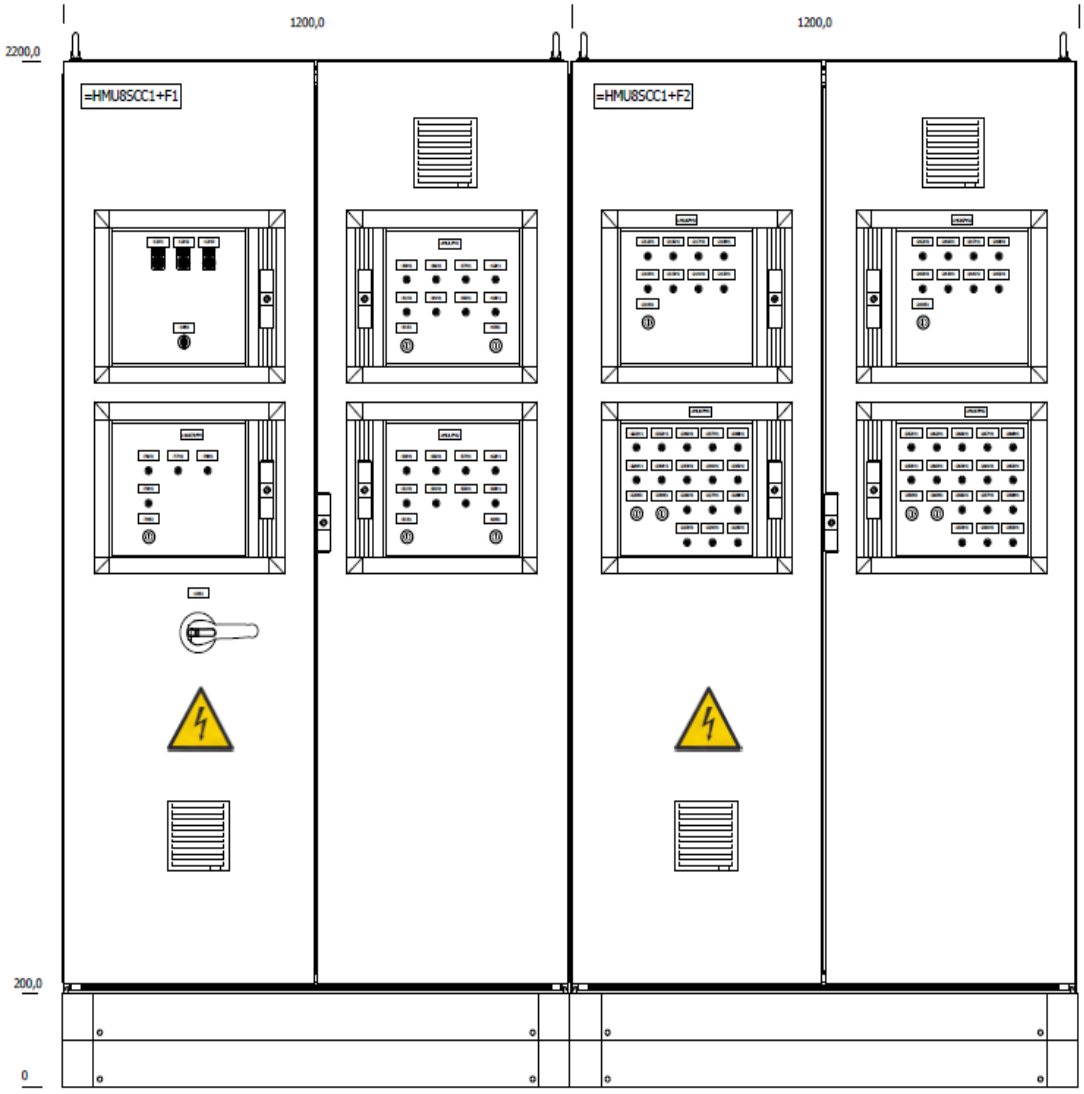


Figure 34 - External view of the control cabinet [18]

The switchboard on the left side, named HMU8SCC+F1 is the first field, and the second named HMU8SCC+F2 is the second field. *From this point forward I will be referring to each field as F1 and F2.*

4.1.5 Approximate layout of switchboards

The section provides an approximate layout of the switchboards, as indicated by the title. While it is not obligatory to adhere strictly to this layout, certain adjustments may be necessary as per the customer's modification requirements.

Fortunately, the drawing was meticulously planned by the designer, resulting in a well-thought-out configuration. Consequently, no changes were required during the construction of the control cabinet.

The careful planning and accurate depiction in the drawing helped streamline the construction process and ensured that the control cabinet was built according to the intended design. [18][35]

Layout of F1:

F1 is going to be receiving the main power cable that supplies power to the whole control cabinet. This can be seen on the lower left side of the layout where the designer has put the main fuse and main power switch of the control cabinet.

Next to them on the right side is the two outgoing connection terminals, consisting of Weidmuller manufactured terminals that can be installed onto DIN rails.

In the bottom of the layout the neutral and protective earth rails can be found, and below them are the two transformers for the 24 V and 230 V AC power that is used in the control circuits.

The rest of the layout consists of relays, magnetic switches, contactors and so on.

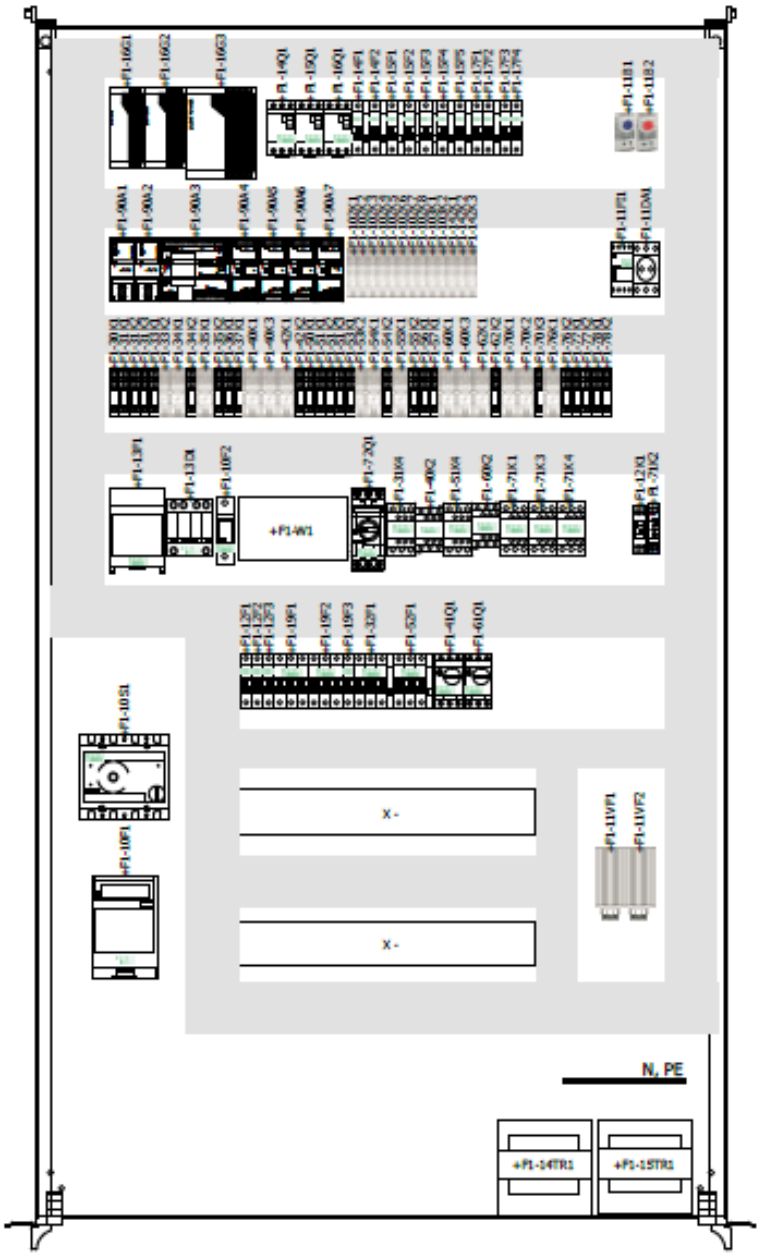


Figure 35 - Layout of F1 [18]

Layout of F2:

The bottom of the layout is similar to F1, consisting of the neutral and protective earth rails at the very bottom, and two outgoing connection terminals.

Within the control cabinet, compartment F2 plays a crucial role as it accommodates the majority of the relays and the Siemens Programmable Logic Controller necessary for the automation processes. It serves as a dedicated space for these components, providing a centralized location for efficient control and automation operations within the control system.

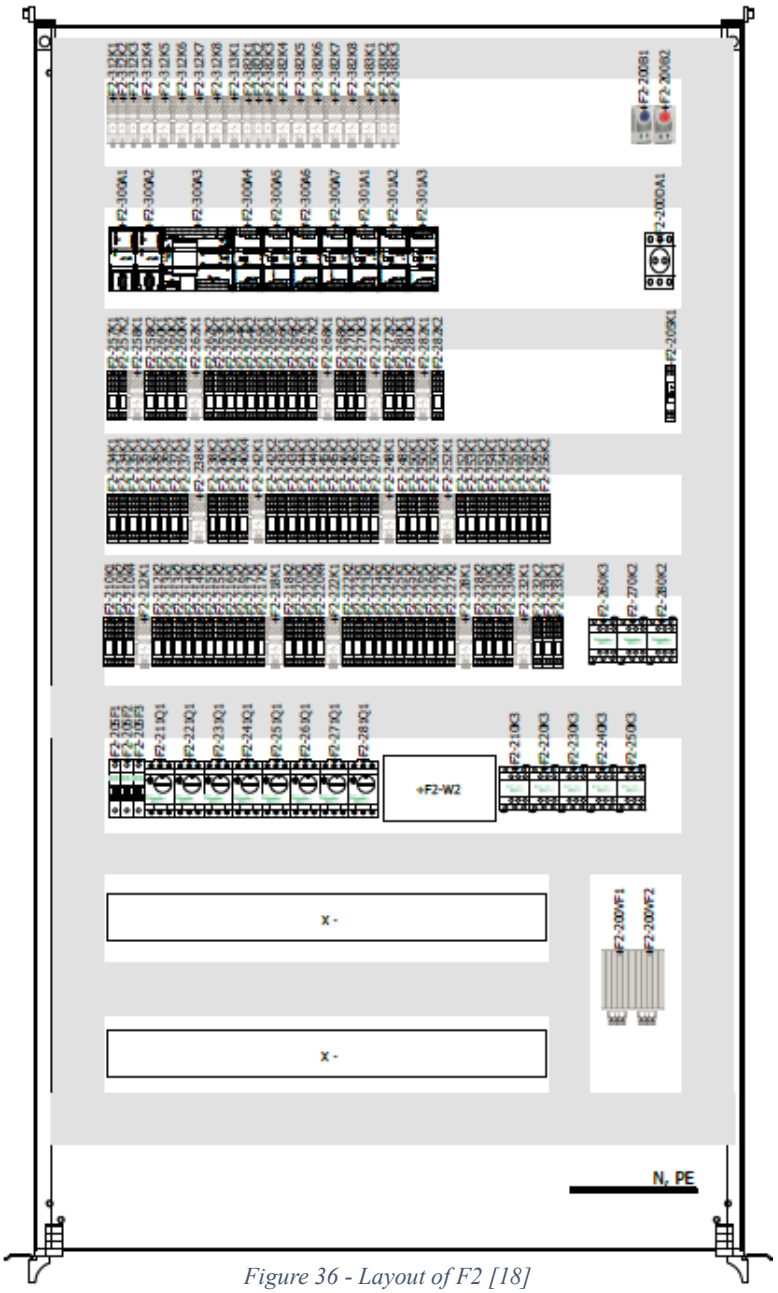


Figure 36 - Layout of F2 [18]

Both compartments F1 and F2 in the control cabinet are equipped with internal heating elements, fans, and temperature sensors. These components work together to maintain the control cabinet at an optimal operating temperature.

The internal heating elements serve the purpose of heating the cabinet when necessary, preventing humidity and condensation that could potentially affect the sensitive components inside. The fans facilitate the circulation of air within the cabinet, ensuring proper ventilation and heat dissipation. Additionally, temperature sensors monitor the internal temperature to provide feedback and facilitate automatic temperature control.

By incorporating these heating elements, fans, and temperature sensors in both compartments, the control cabinet can effectively regulate its temperature, creating a suitable environment for the reliable operation of the enclosed equipment and ensuring optimal performance.

4.1.6 Input power

The first page of the circuit drawing represents the initial stages of the power flow within the control cabinet. It illustrates the input power being supplied through a power cable and connected to various components.

The power from the incoming cable is first directed to the main fuse, which serves as a protective device. From there, it is connected to the main switch, allowing for manual control of the power supply to the control cabinet.

Subsequently, the power is directed to a power distribution box located inside the control cabinet. This distribution box serves as a central point for branching the power to different sections and components within the cabinet.[18]

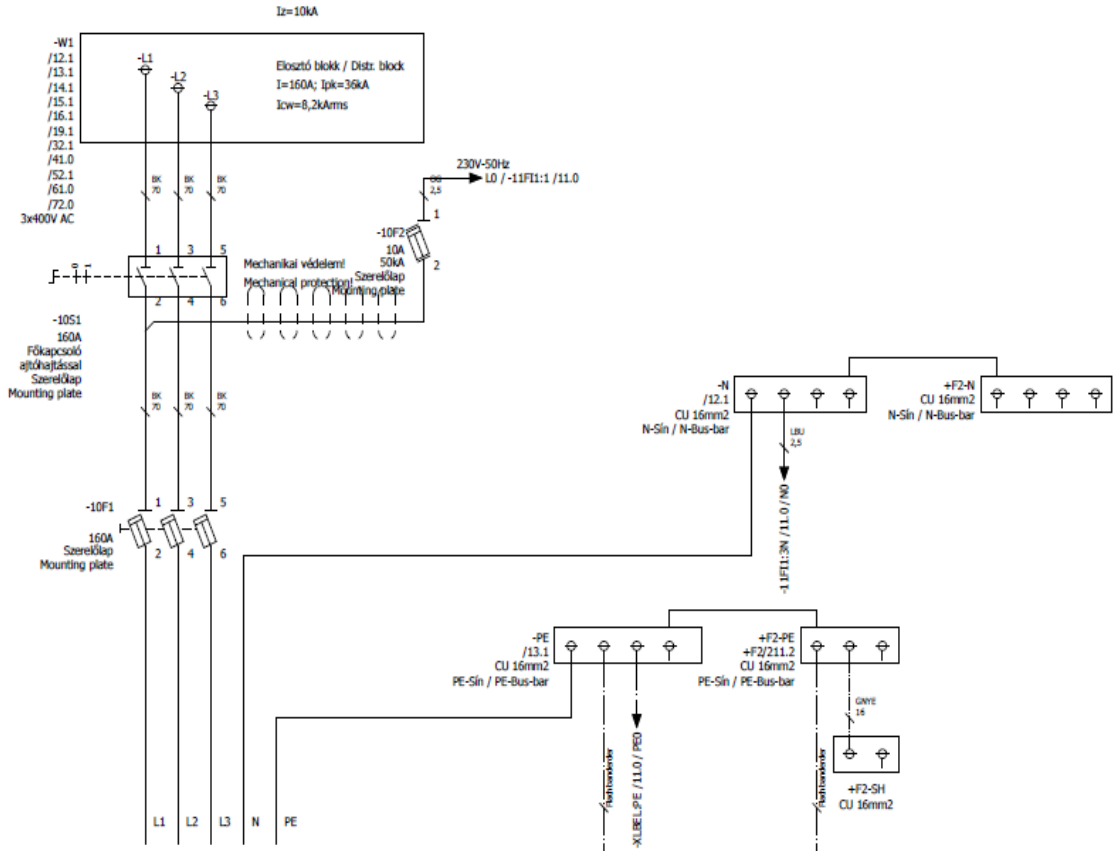


Figure 37 – Wiring diagram of input power [18]

The power supply cable's neutral and protective earth is directly connected to the neutral and protective earth rails inside the control cabinet.

4.1.7 Internal heating, cooling, light source, and service outlet

This is the schematics for the power directed to the internal heating and cooling components, as well as the internal lighting and service outlet. The power required for these components are first connected to an internal connection terminal, and then from there connected to the respective components.
This is done so maintenance, or in the case of a component malfunctioning, replacement components can be easily wired to and from the connection terminals, instead of having to disassemble multiple parts of the control cabinet.

As it can be seen on the schematics, for both the heating and cooling, the internal temperature sensors are directly controlling the heating element and the cooling fan.[18]

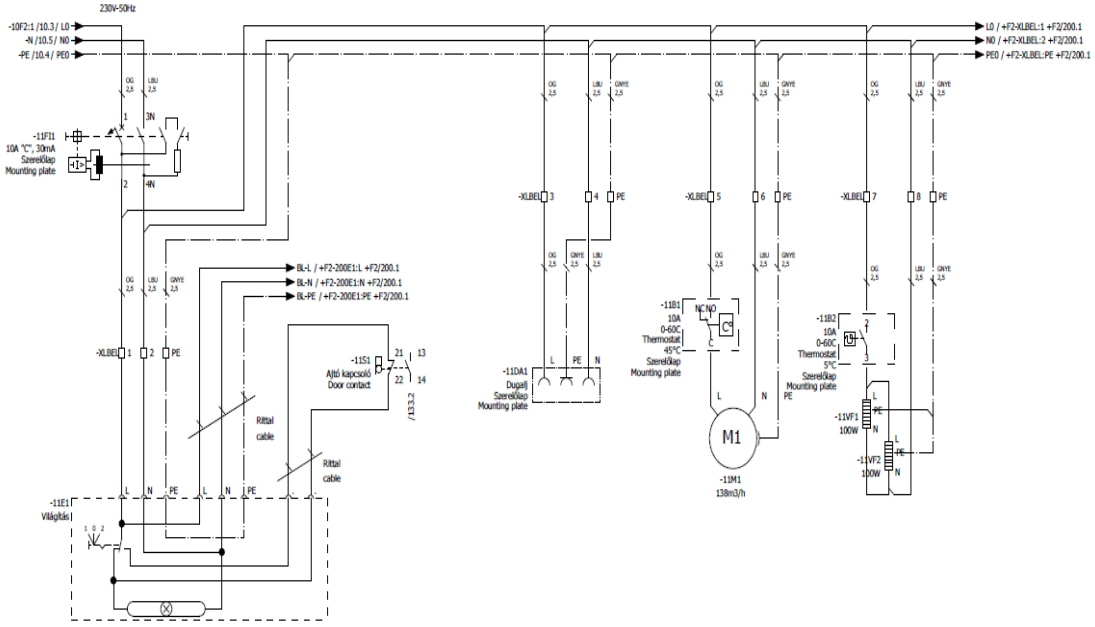
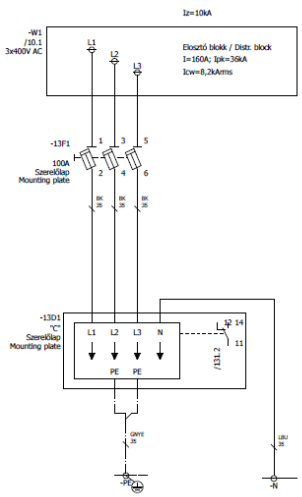


Figure 38 - Wiring diagram of internal heating, cooling and lighting [18]

4.1.8 Surge protection



Surge protection is a crucial component that has been implemented in this electrical system. By incorporating surge protection measures, the system is safeguarded against voltage spikes or surges that can occur due to various factors such as lightning strikes, power grid fluctuations, or equipment malfunctions.

Surge protection devices are designed to redirect or limit excessive electrical energy, diverting it away from sensitive components and preventing potential damage. The inclusion of surge protection in the system helps to ensure the safety

Figure 39 - Wiring diagram of surge protection [18]

and longevity of the equipment by minimizing the risk of voltage surges and their harmful effects.
By integrating surge protection as an integral part of the electrical system, potential risks associated with electrical surges are effectively mitigated, enhancing the overall reliability and protection of the system. [18]

4.1.9 Transformer circuits

Two transformer circuits are present, and each circuit is safeguarded by circuit breakers to protect against short circuit faults.

The first transformer is a 400/230 V 400 VA transformer, responsible for providing 230 V AC power to the 230 V AC relays.

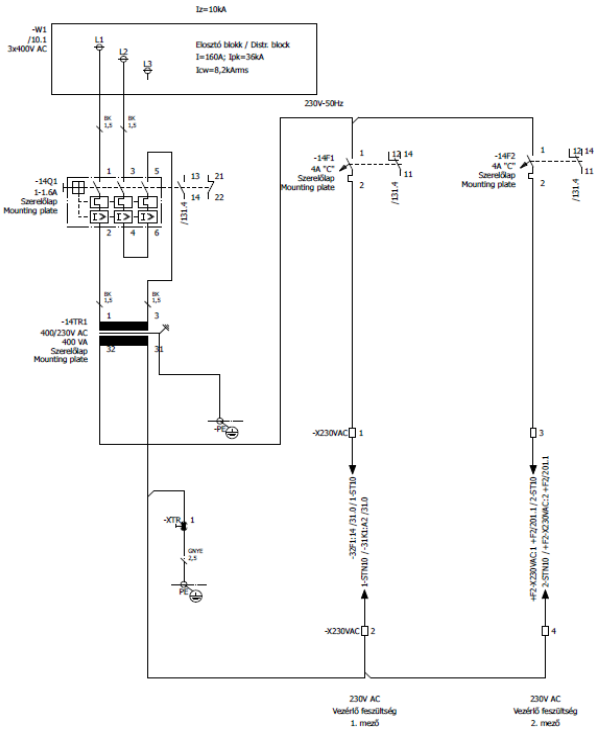


Figure 40 - Wiring diagram of 400/230 V AC transformer [18]

The second one being a 230/24 V 630 VA transformer, providing the necessary 24 V AC power for the 24 V AC relays.

Both transformer outputs are first routed through circuit breakers for additional protection, and also the neutral point of the transformer is protected by a fuse to earth.
[18]

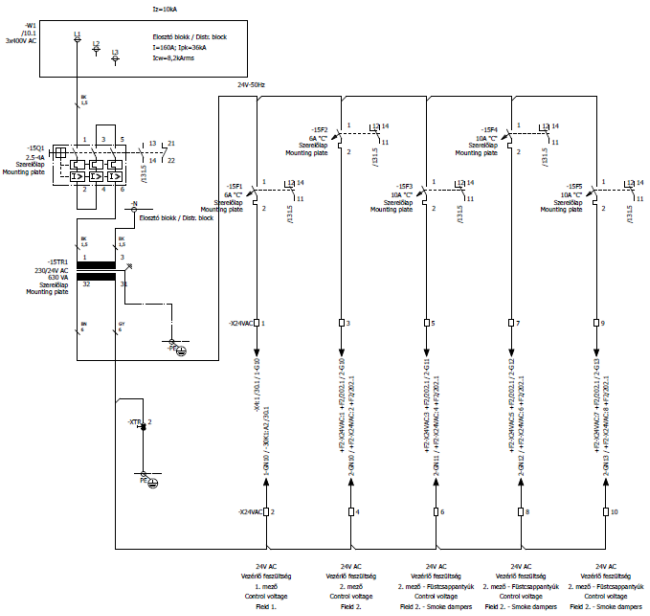


Figure 41 - Wiring diagram of 230/24 V AC transformer [18]

4.1.10 LED test circuit

To facilitate easy testing of the LEDs used as indicators of normal function or error presence, a lamp test circuit is incorporated into the control cabinet. This circuit includes a diode block with a power input controlled by a switch, as well as 10 lamp outputs that are connected to each LED power circuit.

By activating the switch, power is provided to the lamp outputs, allowing the LEDs to be powered outside of normal operation. This setup enables convenient testing of all the LEDs to verify their functionality and to ensure that they are properly indicating normal operation or the presence of any errors.

The lamp test circuit provides a practical means to validate the LEDs' performance and quickly assess the overall status of the control cabinet, enhancing troubleshooting and maintenance procedures.

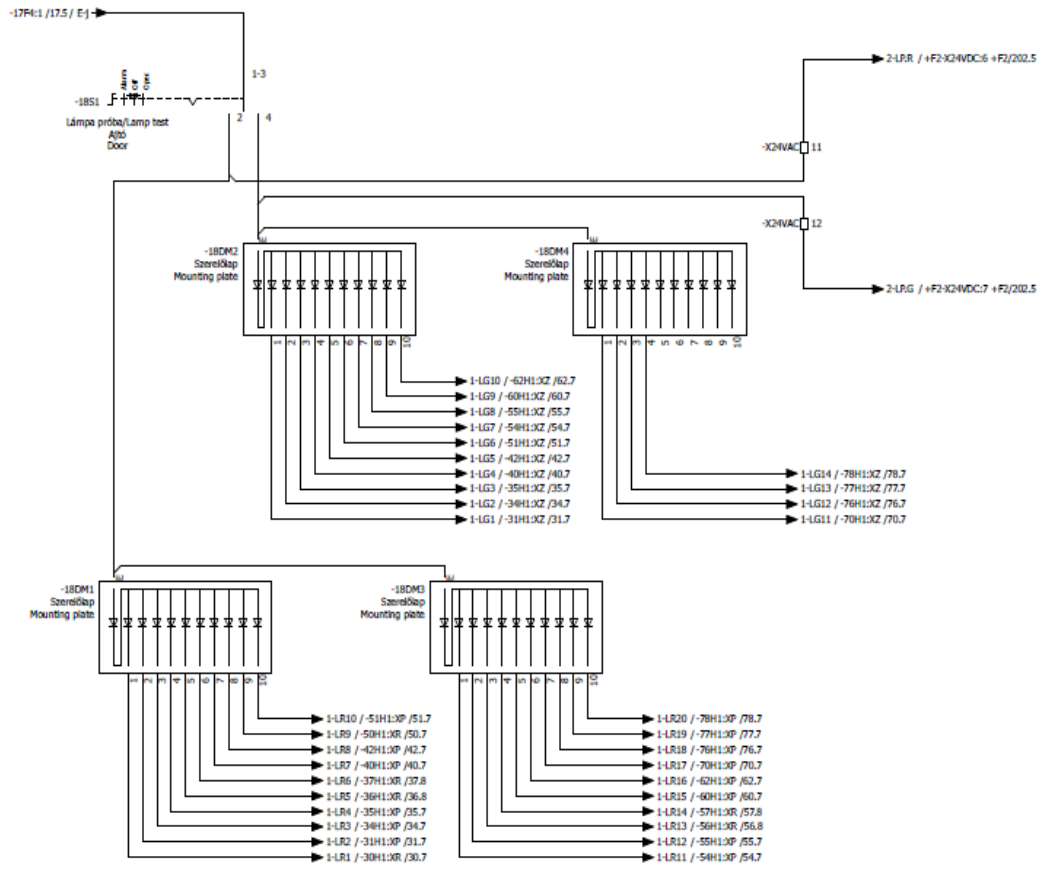


Figure 42 - Wiring diagram of LED test circuit [18]

4.1.11 Excerpt of the control logic

In this instance, a staircase supply fan's controller (Variable frequency drive) is being controlled either in manual mode or in automatic mode. In manual mode, a switch requiring a key has to be operated, while in automatic mode the control cabinet's PLC control the power to the VFD.

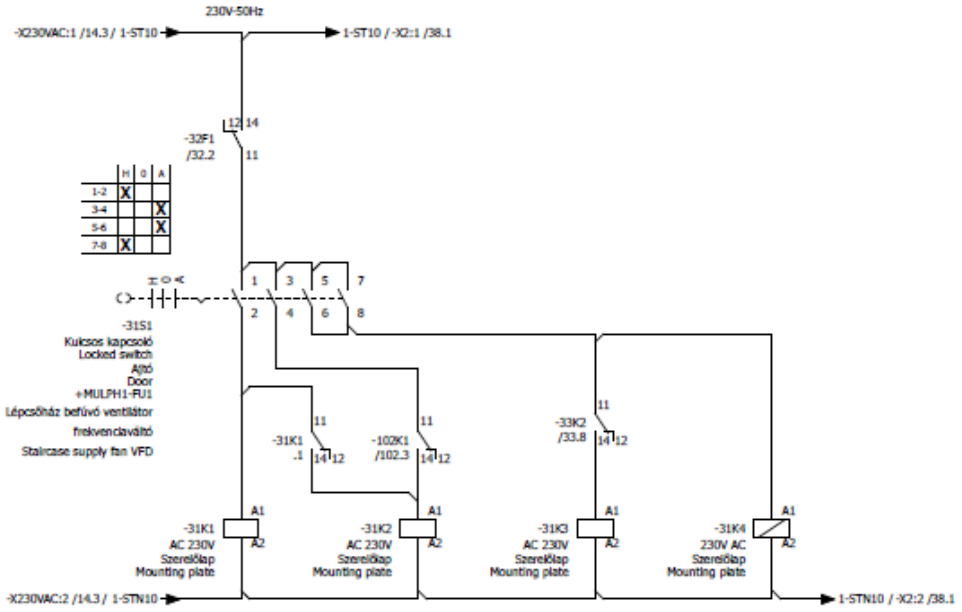


Figure 43 - Wiring diagram of switch 31S1 [18]

When the switch powers the connected relays, and all prerequisite relays have switched, the relays 31K1 to 31K4 are controlling the VFD that runs the fan, as seen in the next figure.

Of course, we only have to wire up until terminal X1's 7,8,9 points, since from there a cable is connected which takes the signal to the outside controller.

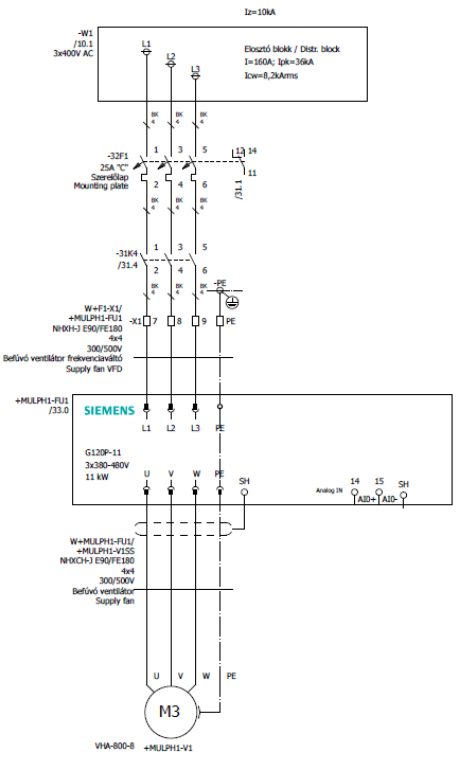
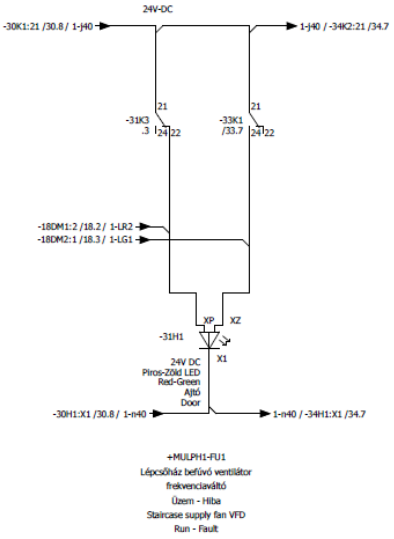


Figure 44 - Wiring diagram of the output controlled by 31K4 [18]

Figure 45 - Wiring diagram of indicator LED 31H1 [18]

And here we can see how the LED's are controlled via the same relays controlled by the switch, and also how the lamp test circuit gets connected to the LED's.



The provided figures illustrate the responsibilities of the Programmable Logic Controller located in compartment F1 of the control cabinet.

The diagram focuses on detailing the specific functions and tasks that the PLC is responsible for within the control system. It provides a visual representation of the inputs, outputs, and logic implemented in the PLC, showcasing its role in controlling and monitoring various aspects of the system.

By referencing this diagram, technicians and operators can gain a comprehensive understanding of the PLC's responsibilities and what it interacts with in the control cabinet. This visualization aids in troubleshooting, maintenance, and further development of the control system.

Digital input side:

Figure 46 - Digital inputs of the PLC in F1 [18]

Digital output side:

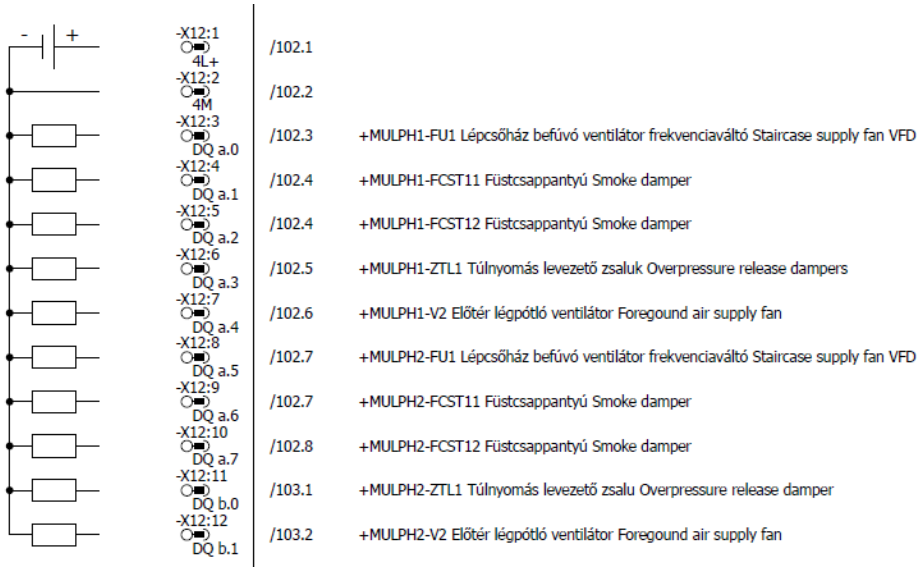


Figure 47 - Digital outputs of the PLC in F1 [18]

The various inputs and outputs to the PLC's digital input and output pins are initially managed and controlled by relays. These relays act as control devices, allowing or interrupting the flow of electrical current to different components or circuits.

In addition to their primary control function, relays often serve as indicators, signaling the operation status or the presence of errors. Through their switching actions, relays can activate indicators such as LEDs or sound alarms to provide visual or audible feedback to operators or technicians.

By utilizing relays in the control system, it becomes possible to manipulate and monitor the different inputs and outputs effectively, ensuring proper operation and enabling the detection of any errors or malfunctions that may occur during system operation.[18]

Here’s an excerpt of the digital output side of the wiring:

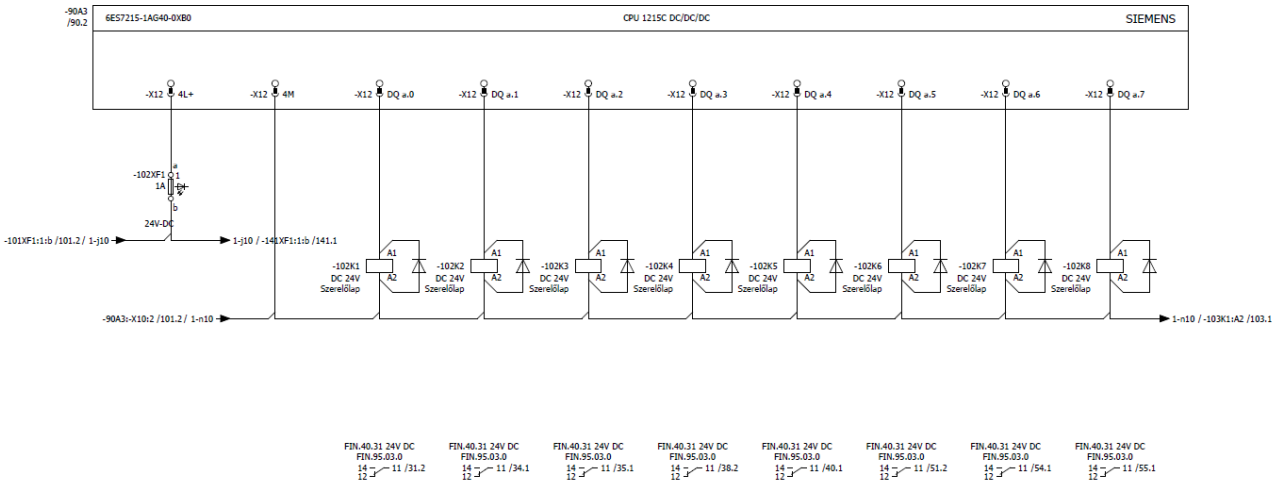


Figure 48 - Wiring diagram of the digital output side of the PLC in F1 [18]

And of the input side:

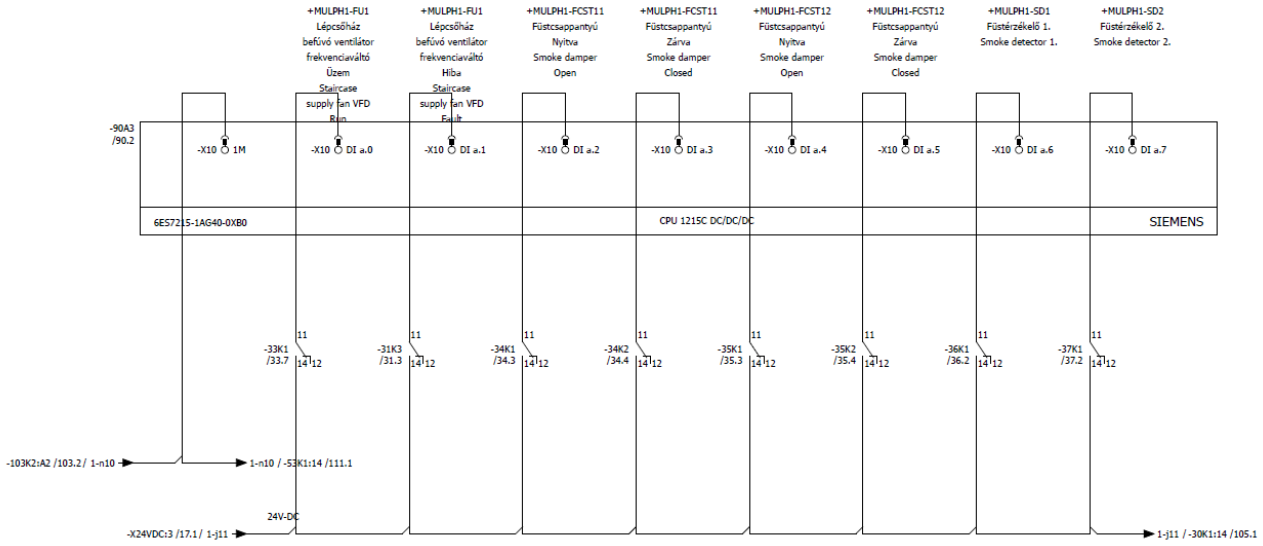


Figure 49- Wiring diagram of the digital input side of the PLC in F1 [18]

5. COMPONENTS USED

The construction of this control cabinet involved the integration of various components sourced from different manufacturers. While listing all components may not be feasible, I will highlight the most essential ones in this section.

Please note that the following list represents a selection of critical components, and it may not encompass every single component used in the control cabinet:

5.1.1 Enclosure of control cabinet

The control cabinet is enclosed within Rittal's VX25 enclosure, which was specifically chosen by the designers. This enclosure offers IP55 protection, ensuring a high level of protection for the components housed inside. The IP55 rating indicates that the enclosure provides dust resistance and protection against water jets from any direction, safeguarding the sensitive components from environmental factors.

Additionally, the VX25 enclosure is known for its robust and sturdy construction. It is designed to withstand demanding industrial environments, providing durability and reliability for the control cabinet. The sturdy construction of the enclosure helps protect the internal components from external impacts, ensuring their longevity and overall operational integrity.

By selecting Rittal's VX25 enclosure, the designers have prioritized both the protection and physical robustness of the control cabinet, ensuring a secure and reliable housing solution for the enclosed components.[19]

Figure 50 - Rittal VX25 enclosure [19]

5.1.2 Main switch

The chosen main switch for the control cabinet is Schneider Electric's Compact line INS160. Schneider Electric is a renowned manufacturer in the electrical industry, known for producing high-quality and reliable components.

The INS160 from the Compact line is specifically selected for its suitability in this application. It provides the required switching capabilities and electrical specifications necessary for effectively controlling the power flow within the control cabinet.

As a part of the Compact line, it is designed to offer compactness while maintaining optimal performance.

The selection of Schneider Electric's INS160 main switch demonstrates the designer's confidence in its performance, durability, and compatibility with the control cabinet. [20]

Figure 51 - Compact INS 160 [20]

5.1.3 Main fuse

The chosen main fuse for the control cabinet is the ISFT160, which is also manufactured by Schneider Electric. The ISFT160 serves as a crucial component in providing the first line of protection for the control cabinet.

As a fuse body, the ISFT160 safely houses the main fuse, which is designed to interrupt and protect the electrical circuit in the event of overcurrent or short circuit faults. It acts as a critical safeguard, preventing excessive current from damaging the components of the control cabinet.

By selecting the ISFT160 from Schneider Electric, the designer ensures reliable and effective protection for the control cabinet. This choice reflects the importance placed on the safety and integrity of the electrical system, guarding against potential electrical faults, and minimizing the risk of damage or malfunctions. [21]

Figure 52 - ISFT 160 [21]

5.1.4 Circuit breakers

The chosen circuit breakers for the control cabinet are Schneider Electric's ACTI9 IC60N line. These circuit breakers offer reliable and efficient protection against overcurrent and short circuits in the electrical system.

The ACTI9 IC60N line of circuit breakers provides a range of options with varying fault current ratings. This allows the designer to select the appropriate circuit breaker based on the specific current requirements of the control cabinet. By choosing circuit breakers rated for different fault currents, the control cabinet's electrical system can be effectively safeguarded and protected from potential faults.

Schneider Electric's ACTI9 IC60N line circuit breakers are trusted for their quality, performance, and versatility. With their ability to handle different fault currents, they ensure optimal protection for the control cabinet, minimizing the risk of electrical damage and ensuring the safety and reliability of the system. [22]

Figure 53 - IC60N Circuit breaker [22]

5.1.5 Magnetic switches

Schneider Electric's TeSyS magnetic switches were chosen for the control cabinet's magnetic switch requirements. These magnetic switches offer the capability to switch higher currents and are designed to have a longer life cycle.
The TeSyS magnetic switches from Schneider Electric are specifically designed to handle higher current loads, making them suitable for applications that require robust switching capabilities. Their ability to handle higher currents ensures efficient and reliable operation within the control cabinet.

Furthermore, these magnetic switches are engineered for a longer life cycle, meaning they are designed to withstand repeated switching over an extended period. This durability enhances the longevity and reliability of the magnetic switches, contributing to the overall performance and operational efficiency of the control cabinet.

These magnetic switches are responsible for switching the power to outgoing cables, which later connect to fans or mechanical apparatuses controlling the air ducts. [23]

Figure 54 - LC1D25 TeSyS magnetic switch [23]

5.1.6 Transformers

Two transformers have been specifically chosen for supplying control power to the relays and the PLCs within the control cabinet.

These transformers play a critical role in the electrical system by converting the input voltage to the required voltage levels for the relays and the PLCs. They ensure that the control components receive the appropriate power supply to operate effectively.

The selection of two transformers suggests that there may be a division of power supply within the control cabinet, catering to the different voltage requirements of the relays and the PLCs. This can help ensure optimized performance and enhance the overall system efficiency. [24][25]

For the 230 V side, the Schneider Electric Phaseo ABL6 TS40U was chosen.

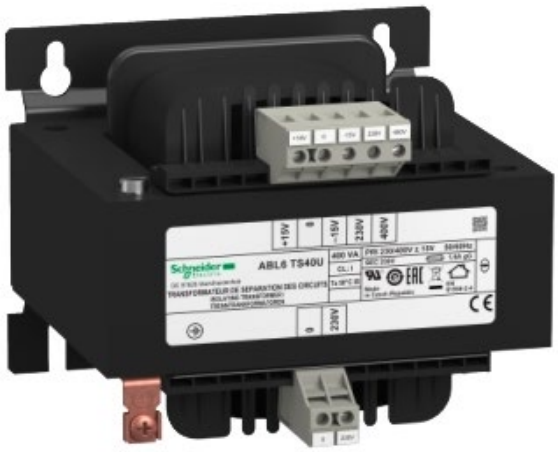


Figure 55 - Phaseo ABL6 TS40U transformer [24]

And for the 24 V side, the Phaseo AB6L TS63B was utilized.

Figure 56 - Phaseo ABL6 TS63B transformer [25]

5.1.7 Relays

Weidmuller's relays have been selected as an integral part of the control cabinet due to their reliability and cost-effectiveness. These relays play a crucial role in automation, logic, and controlling the outgoing power through the magnetic switches.
Weidmuller is recognized for producing reliable and high-quality relays that meet the requirements of various industrial applications. Their relays are known for their durability, ensuring consistent and dependable operation within the control cabinet.

Additionally, the reasonable pricing of Weidmuller's relays makes them an attractive choice for this application. The combination of reliability and cost-effectiveness makes Weidmuller's relays a suitable option to fulfill the automation and control needs of the cabinet. [26]

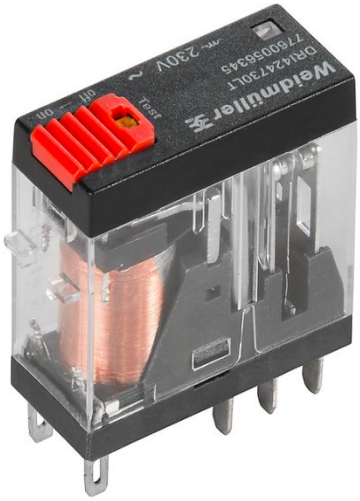


Figure 57 - DRI424524LT relay [26]

5.1.8 Surge protection

The ABB 2CTB803973R1600 surge protection device has been chosen for its compatibility with the control cabinet's surge protection requirements. This particular device from ABB offers a combination of reliability and cost-effectiveness.

Surge protection is essential in safeguarding the electrical system from transient overvoltages caused by voltage spikes or surges. The selection of the ABB 2CTB803973R1600 surge protection device implies that it fulfills the criteria for reliable surge protection and meets the necessary standards for the control cabinet application. [27]

Figure 58 - 2CTB803973R1600 surge protector [27]

5.1.9 Programmable Logic Controller (PLC)

The Siemens SIMATIC S7-1200 PLC has been selected as the primary Programmable Logic Controller for this project. The SIMATIC S7-1200 is a widely used and highly regarded PLC model offered by Siemens.
As the main PLC, the SIMATIC S7-1200 offers advanced functionality and features that are well-suited for the specific requirements of the project. It is designed to provide reliable control, communication, and automation capabilities for various industrial applications.

Siemens is known for its expertise and innovation in the field of automation, and the SIMATIC S7-1200 PLC is a testament to their commitment to delivering robust and efficient control solutions. The choice of this PLC signifies the confidence placed in Siemens' technology and the suitability of the SIMATIC S7-1200 for the intended purpose of the project.
By utilizing the Siemens SIMATIC S7-1200 PLC, the project benefits from a proven and established solution that offers flexibility, scalability, and reliable performance in managing the control and automation aspects of the system.

Of course, it is worthy to note that for this project, several additional boards have been added to the PLC, for their digital input and output pins. [28]

Figure 59 - S7-1200 PLC [28]

5.1.10 Connection terminals

The Weidmuller WDU connection terminal line has been implemented for all internal and external connection points within the control cabinet. These connection terminals are versatile and available in various sizes to accommodate a wide range of wires and cables.[29]
Weidmuller's WDU connection terminals are trusted for their reliability and have a long-standing presence in the industry. Their durability and proven track record make them a reliable choice for establishing secure and stable connections within the control cabinet.

Figure 60 - WDU 2.5 connection terminal [29]

5.1.11 Switches

For all the switches, Schneider Electric's Harmony ZB4 line has been used, for their reliability, ease of installation and wiring.[30][31][32]
Multiple parts are required for a complete switch, the first one being the body of the switch.

As seen in the figure below

Figure 61 - Switch body [30]

A switch mechanism is then installed onto the front of the switch body

Figure 62 - Switch mechanism [31]

And finally, the switch contacts can then be installed onto the back of the switch body.

Figure 63 - Switch contacts [32]

6. FINISHED CONTROL CABINET

I will be showing the fully assembled and wired control cabinet with pictures in this section and will give a short explanation as to what can be seen on each picture.

6.1.1 External view of control cabinet

Here we can see the external view of F1 and F2 of the control cabinet, fully assembled and ready for testing.

Figure 64 - External view of F1 [33]

Figure 65 - External view of F2 [33]

On the doors of the control cabinet, several extra enclosures can be seen. These serve a purpose to protect the switches and indicator LEDs that are installed onto the doors themselves. These extra enclosures can only be opened with a key, and are also IP55

protected, so no unauthorized personnel or outside element can damage the switches and LEDs. Also, the intake fans and exhaust port's grills can be seen on the doors.

Here's an inside view of these extra enclosures:

Figure 66 - Internal view of extra enclosure installed on the door of F1 [33]

6.1.2 HMU8SCC1 + F1 – inside view of the first field

Here's a compete view of the inside of F1:

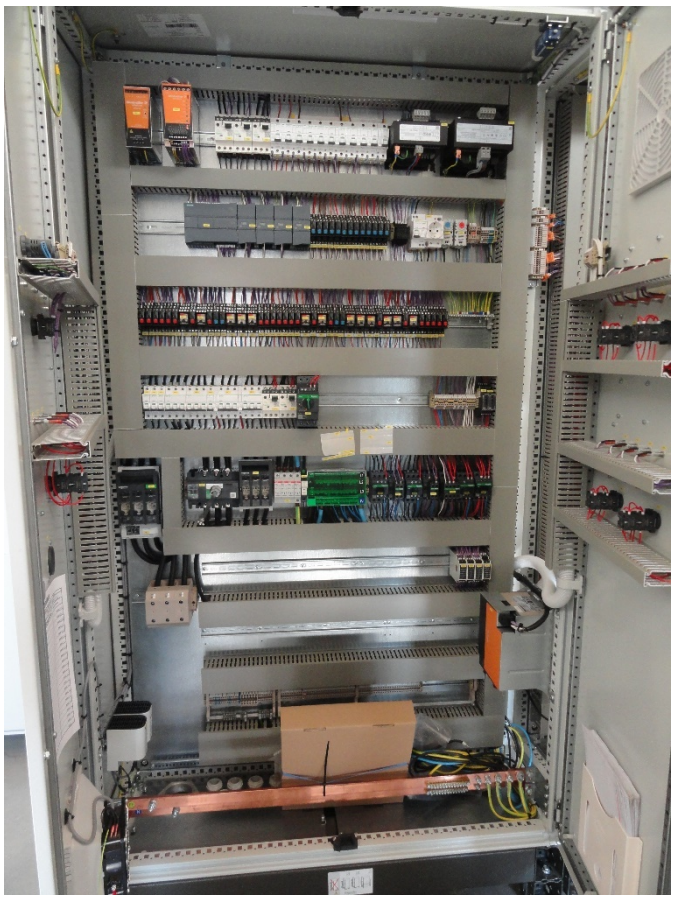


Figure 67 - Internal view of F1[33]

As discussed in the drawing's layout section, on the bottom left side is the main power supply cable's connection point, just above is the main fuse and to the right of it is the main switch, which is connected mechanically to the switch on the door.

Something that differs from the original layout is that the transformers can be seen on the top right side of the switchboard, rather than the bottom right side. This was an operational decision discussed and made by our team. The reason for this is that the neutral and protective earth rails would have been too close to the transformers,
and would have been a short circuit hazard otherwise.[18][33]

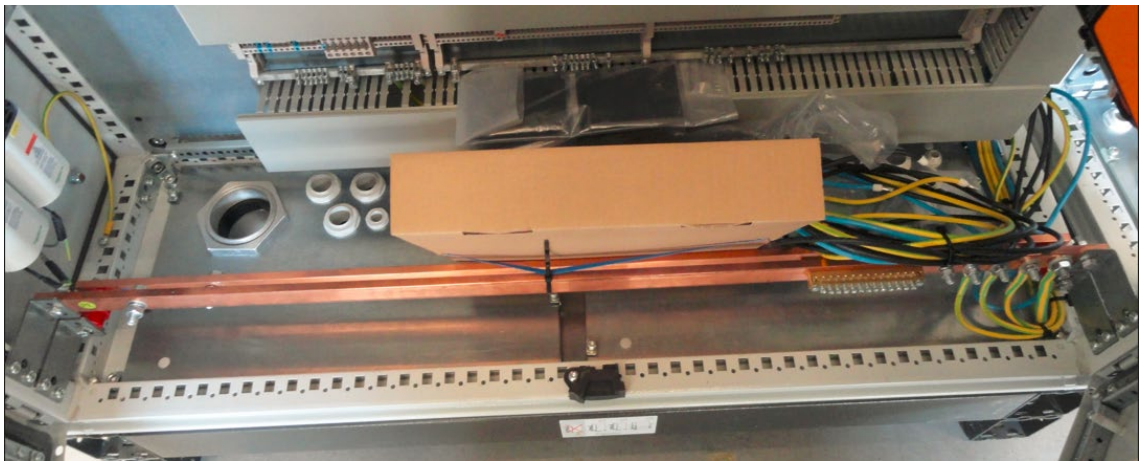


Figure 68 - Neutral and earth rails installed in the bottom of F1 [33]

Decisions like this are often discussed and made on the fly while assembling the control cabinet. Of course, this decision was relayed and confirmed by the customer first.

In the middle of the switchboard the PLC and relays can be seen.

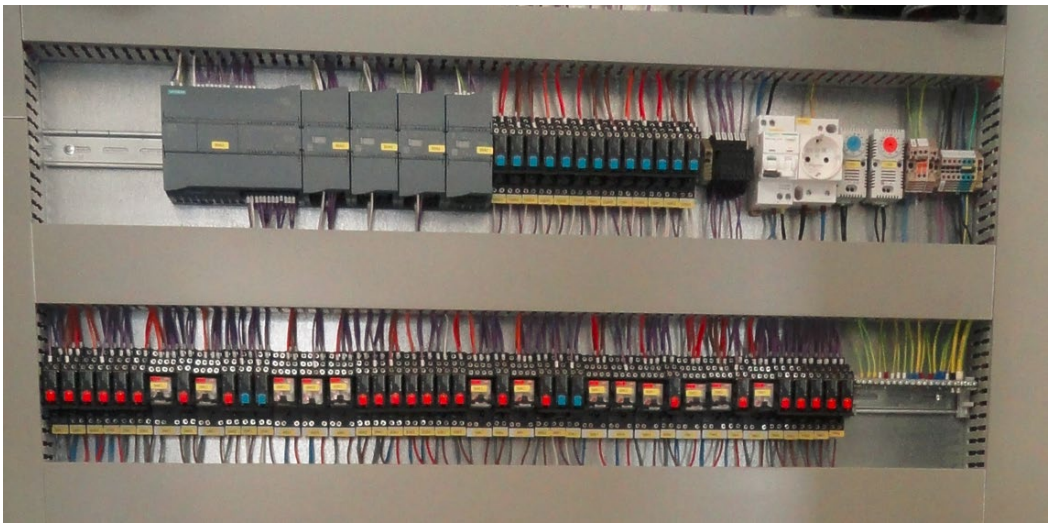


Figure 69 - The PLC and relays in the middle of the switchboard F1 [33]

Below them, the connection terminals can be seen, that are used for connecting wires and cables coming from the outside.
These cables are secured via cable glands found at the bottom of the control cabinet.

Figure 70 - Connection terminal in the bottom of F1 [33]

On the next figure, the internal connection terminals can be seen, and as discussed before, are only used for connections between the two fields.

These connections include some signal wires for both 24 and 230 V AC.

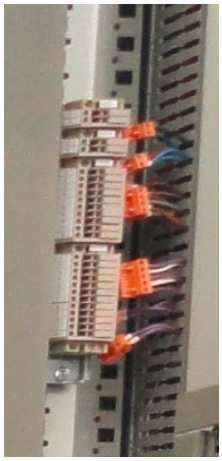


Figure 71 - Internal connection terminals [33]

Here we can see the service outlet, it's corresponding Residual Current Circuit Breaker (RCCB) the two thermostats that are responsible for the heating and cooling of the control cabinet and next to them are the connection points of the internal lighting. The internal lighting itself is controlled by a mechanical switch with normally open contacts. When the control cabinet's doors are opened, the switch switches on the internal light. [18][33]

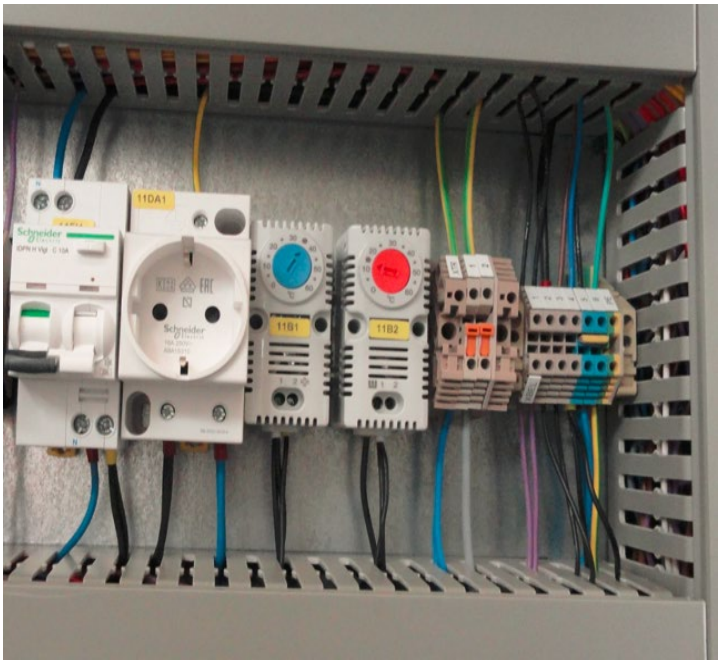


Figure 72 - Service outlet, the two temperature sensors and the connection points for the internal light [33]

Here's a picture of the switch and the light.

Figure 73 - The internal light and the switch that controls it [33]

On both doors the back side of the switches can be seen, with the indicator LEDs above them, as such:

Figure 74 – Left side door of F1 [33]

Figure 75 - Right side door of F1 [33]

6.1.3 HMU8SCC1 + F2 – inside view of the second field

Here's a picture of the internal view of F2, or the second field of the control cabinet.

It's basically identical to F1, but what differs from it is the fact that this field is filled with the relays responsible for most of the automation and logic, and also a second PLC.

On the left side door of F2 there are more switches and indicator LEDs and also an exhaust port.

From the top row down on the switchboard we can see a row of 24 V AC relays, then the PLC,
then come 2 rows of 230 V AC relays, finishing with a row of magnetic switches and then two rows of connection terminals.
[18][33]

Figure 76 - Internal view of F2 [33]

Here's a picture of the top row, on the left side of the picture are the aforementioned 24 V AC relays, and on the right side of the picture are the temperature sensor controlling the heating and cooling of F2.

At the top is the light and the switch controlling it.

Figure 77 - Internal light and the first row from the top in F2 [33]

Here’s a closer look at the diode blocks that are responsible for the LED test circuit.

Figure 78 - Diode block responsible for LED test circuit in F2 [33]

And here’s a closer look at the connection terminals responsible for connecting the cables that are connected from the outside, secured by cable glands.

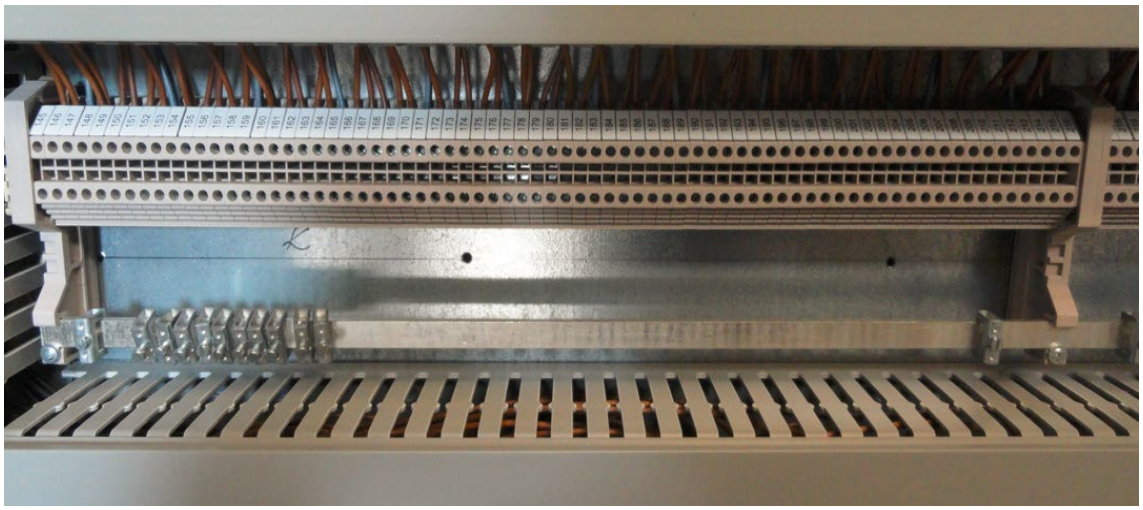


Figure 79 - Connection terminals in F2 [33]

Here are the aforementioned cable glands.

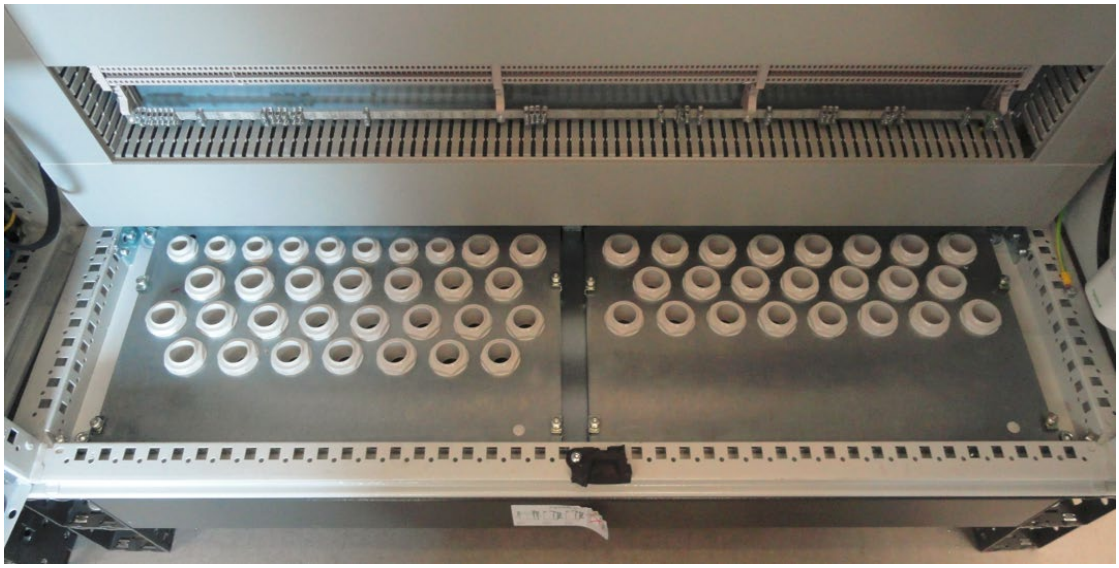


Figure 80 - Cable glands installed in the bottom panel of F2's enclosure [33]

And finally, here is the heating element and the cooling fan responsible for keeping optimal operating temperatures inside the control cabinet.

Figure 81 - Heating elements installed in the side of the control cabinet, and the cooling fan installed on the door of F2 [33]

7. FINAL QUALITY CONTROL CHECK

The final quality control check is conducted after the completion of assembly and wiring processes in the control cabinet. It follows a standard protocol where the person responsible for the final quality control check is different from the individual who performed the assembly and wiring tasks.

This segregation of responsibilities serves multiple purposes. Firstly, it ensures that the final quality control check is carried out by someone who possesses the necessary specialized qualifications. This helps guarantee that the control cabinet meets the required quality standards and specifications.

Secondly, having a different person perform the final quality control check minimizes the potential for oversight or bias. By having a fresh set of eyes examining the control cabinet, any errors or discrepancies introduced during the assembly and wiring process are more likely to be detected. This approach aims to enhance the overall accuracy and reliability of the control cabinet.

Implementing such a protocol recognizes that errors can occur unintentionally and that even the assembler may overlook certain mistakes. By involving a separate individual for the quality control check, any oversights or errors made during the assembly and wiring process are more likely to be identified and rectified, ensuring a high-quality final product.

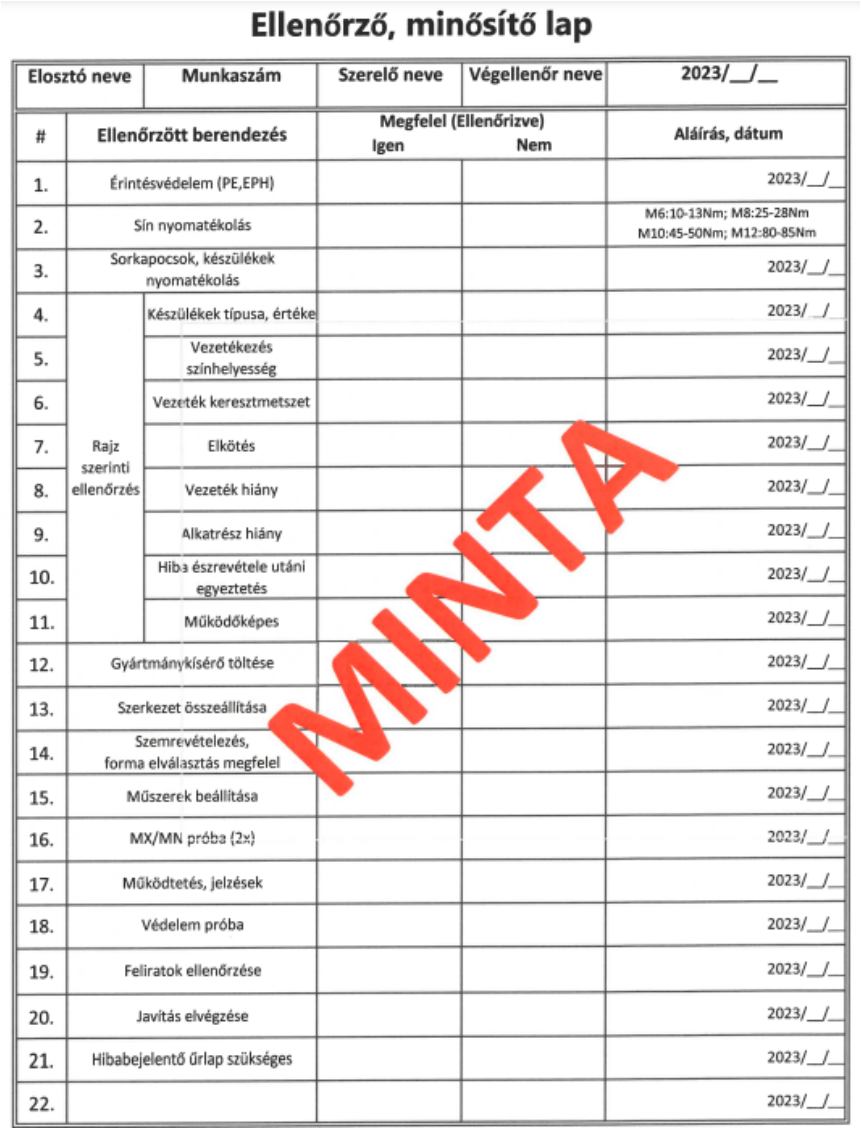
The final quality control process is facilitated through the use of a document that lists all the points to be checked. This document serves as a comprehensive checklist, outlining specific criteria and requirements that need to be reviewed and verified during the quality control inspection.

By documenting the points of the final quality check, it ensures that each aspect of the control cabinet's assembly and wiring undergoes thorough examination and validation. This approach helps maintain consistency and ensures that no critical step or element is overlooked during the inspection.

The document provides clear instructions and for the person responsible for conducting the final quality control check, enabling them to systematically assess each point and compare it against the specified standards. This structured approach is essential in maintaining the quality and reliability of the control cabinet.

The use of a documented checklist streamlines and formalizes the quality control process, enhancing efficiency and reducing the chances of errors or omissions. It also provides a record of the inspection, facilitating traceability and accountability in case of any discrepancies or issues identified during the final quality control check. [34]

Since this document was only available in Hungarian, I will translate each point and give some insight on what it entails.



Ellenőrző, minősítő lap

Elosztó neve		Munkaszám	Szerelő neve	Végellenőr neve	2023/__/__
#	Ellenőrzött berendezés		Megfelel (Ellenőrizve) Igen	Nem	Aláírás, dátum
1.	Érintésvédelem (PE,EPH)				2023/__/__
2.	Sín nyomatékolás				M6:10-13Nm; M8:25-28Nm M10:45-50Nm; M12:80-85Nm
3.	Sorkapocsok, készülékek nyomatékolás				2023/__/__
4.	Rajz szerinti ellenőrzés	Készülékek típusa, értéke			2023/__/__
5.		Vezetékezés színhelyesség			2023/__/__
6.		Vezeték keresztmetszet			2023/__/__
7.		Elkötés			2023/__/__
8.		Vezeték hiány			2023/__/__
9.		Alkatrész hiány			2023/__/__
10.		Hiba észrevétele utáni egyeztetés			2023/__/__
11.		Működőképes			2023/__/__
12.	Gyártmánykísérő töltése				2023/__/__
13.	Szerkezet összeállítása				2023/__/__
14.	Szemrevételezés, forma elválasztás megfelel				2023/__/__
15.	Műszerek beállítása				2023/__/__
16.	MX/MN próba (2x)				2023/__/__
17.	Működtetés, jelzések				2023/__/__
18.	Védelem próba				2023/__/__
19.	Feliratok ellenőrzése				2023/__/__
20.	Javítás elvégzése				2023/__/__
21.	Hibabejelentő űrlap szükséges				2023/__/__
22.					2023/__/__

MINTA

Figure 82 - Document need for final quality control [34]

At the top of the document five separate parts have to be filled out manually. Going from left to right in order:

- Name of control cabinet;
- Project number (used to track projects company wide);
- Name of the person who assembled the control cabinet;
- Name of the person performing the final quality check;
- Date.

The next step is the checklist, where the person conducting the final check marks whether the control cabinet has passed or failed the inspection for each specific point. Following the marking, the person needs to provide a signature and date to authenticate the completion of the inspection.

1. Érintésvédelem (PE, EPH) – Touch protection (PE, EPH) - Refers to the proper earthing of each body panel consisting of metal, that needs to be properly grounded for touch protection.

2. Sín nyomatékolás – Rail torquing - Refers to checking the torque on every fastener connected to either the neutral or earth rails.

3. Sorkapcsok, készülékek nyomatékolása – Component and connection terminal torquing - this point is the same as the point before, only this time it refers to the torque values in every component and connection point. Components always specify a torque value that needs to be met, either in their documentation or online.

Points 4. through 11. are done via the supplied drawing for each control cabinet.

4. Készülékek típusa, értéke – Components type, value – The person doing the final check has to check that all components installed in the control cabinet are the same ones specified in the drawing, and also check their values.

5. Vezeték színhelyesség – Wire colour – Refers to checking the wire colours used in the control cabinet. The wire colours can be compared to the ones specified in the drawing, if it differs from our company wide colour chart.

6. Vezeték keresztmetszet – Wire diameter – Refers to checking all the wire diameters compared to the specified current in the drawing, and the wire diameter chart.

7. Elkötés – Wiring error – Refers to any wiring errors made while wiring.

8. Vezeték hiány – Missing wires – Refers to any missing wires that can be seen.

9. Alkatrész hiány – Missing component – Refers to any missing components that can be seen.

10. Hiba észrevétele utáni egyeztetés – Coordination after recognizing error – This point refers to the coordination done by the person responsible for the final check. This entails talking to the person who assembled the control cabinet and talking through any errors.

11. Működőképes – Operational – Refers to the fact that either the control cabinet is operational or not.

12. Gyártmánykísérő töltése – Manufacturing record – The manufacturing record is a separate document mandatory for each control cabinet assembled. This point refers to it being properly written.

13. Szerkezet összeállítása – Assembly of enclosure – Refers to the correct assembly of the control cabinet enclosure.

14. Szemrevételezés – Visual inspection – Refers to any errors recognizable by a visual inspection.

15. Műszerek beállítása – Instrument calibration – Refers to calibrating the instruments in the control cabinet, if there are any present.

16. MX/MN Próba (2x) – MX/MN Check (2x) – If any switches have an MX/MN extra contactors installed in them, then the person has to check their functionality.

17. Működtetés, jelzések – Operation, indicators/signals – Checking all the control signals and indicators (such as LEDs), if there are any present.

18. Védelem próba – Protection check – All components that serve as protection such as circuit breakers, RCCB-s and such have to be checked for functionality.

19. Feliratok ellenőrzése – Sign check – Any signs on the doors of the control cabinet have to be checked.

20. Javítás elvégzése – Performing repairs – Any errors found during final quality check have to be corrected and repaired.

21. Hibabejelentő űrlap szükséges – Fault reporting form is required – A fault reporting form is a separate document, on which any errors are written, and once corrected have to be signed and dated.

8. SUMMARY

I hope my thesis work offers a detailed exploration of various aspects related to the construction and quality control of a control cabinet. It begins with an introduction and an extensive literature overview that encompasses wire sizes, wire coloring, power supply and earthing methods, as well as materials used in control cabinets.

The literature overview section provides insights into wire sizes, focusing on current standards governing wire sizing. It also delves into wire sizing specifications specific to the thesis work, highlighting the importance of selecting appropriate wire sizes to meet the control cabinet's requirements effectively.

Similarly, the discussion on wire coloring explores current standards regarding wire colors and how they are applied in electrical systems. It further presents the wire coloring scheme adopted within the thesis work, showcasing practical examples of wire coloring in the context of the control cabinet.

Moving on, the document delves into power supply and earthing methods, emphasizing the significance of proper earthing in electrical systems. It covers the meaning and implication of letters I, T, N, C, and S, and provides detailed explanations of power supply systems such as TN-C, TN-C-S, TN-S, TT, and IT. This segment offers valuable insights into the different power supply configurations and highlights the importance of selecting appropriate methods based on specific project requirements.

An overview of the materials used in control cabinets further enriches the document. It highlights the considerations and best practices when selecting materials for components such as enclosures, main switches, fuses, circuit breakers, magnetic switches, transformers, relays, and Programmable Logic Controllers (PLCs). This section acts as a guide to ensure the selection of reliable and suitable materials for building robust control cabinets.

The technical overview section provides a deep dive into the requirements of the project and outlines the tools needed for successful execution. Various tools and equipment such as wire cutters, wire stripping tools, crimping tools, screwdrivers, pliers are discussed in detail. Additionally, specific tools required for final testing are highlighted, emphasizing the importance of thorough quality control.

An overview of the drawing highlights essential elements including the datasheet, equipment identification table, table of contents, external view of the control cabinet, approximate layout of switchboards, input power, internal heating, cooling, light sources, service outlets, surge protection, transformer circuits, LED test circuit, and an excerpt of the control logic. This section provides an insightful glimpse into the control cabinet's overall design and functionality.

The document concludes with a discussion on the building process of the control cabinet, outlining the necessary steps to ensure proper assembly and adherence to specifications. Additionally, it emphasizes the importance of conducting a final quality control check to verify the integrity and compliance of the completed control cabinet.

In conclusion, my thesis work comprehensively covered the considerations necessary for the successful construction, thorough inspection, and ongoing maintenance of a reliable and safe control cabinet. Adherence to stringent standards, involvement of specialized personnel, utilization of appropriate tools, and meticulous documentation at each step ensures exceptional performance, regulatory compliance, and long-lasting operation in diverse industrial applications.

9. LIST OF REFERENCES

[1]
IEC 61439-1 Annex. Table H.1
International Electrotechnical Commission – IEC61439:1:2011 – 2023.11.04.

[2]
Gordiusz 95 Zrt. - Wire size chart
Kábelméret táblázat áramerősség szerint – Gordiusz 95 Zrt. – 2023.11.11.

[3]
Gordiusz 95 Zrt. - Wire colour chart
Kábelszín táblázat használat szerint – Gordiusz 95 Zrt. – 2023.11.11.

[4]
https://electrical-engineering-portal.com/erection-procedures-of-earthing-arrangements-tnc-tn-s-tnc-s-and-tt
Erection of earthing arrangements (TNC, TN-s, TNC-S, TT) – Edvard Csavanyi – 2023.11.04

[5]
https://www.se.com/hu/hu/product/LVS08406/v%C3%A1zszerkezet-w650mm-d400mm/
LVS08406 – Schneider Electric – 2023.11.05.

[6]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=6C7431CF0D2A97EBACD1A630860BA91E?productId=(%5b9002650000%5d)&page=Product
KT 8 – Weidmuller – 2023.11.05.

[7]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=917045818D98F65C891A2B51D9613373?productId=(%5b9005000000%5d)&page=Product
STRIPAX – Weidmuller – 2023.11.05.

[8]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=917045818D98F65C891A2B51D9613373?productId=(%5b9005610000%5d)&page=Product
STRIPAX 16 – Weidmuller – 2023.11.05.

[9]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=0BAB76837B9CF746DEEF1CDB7EAF68E6?productId=(%5b1445080000%5d)&page=Product
PZ10SQR – Weidmuller – 2023.11.05.

[10]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=0BAB76837B9CF746DEEF1CDB7EAF68E6?productId=(%5b9012600000%5d)&page=Product
PZ16 – Weidmuller – 2023.11.05.

[11]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=0BAB76837B9CF746DEEF1CDB7EAF68E6?productId=(%5b9006450000%5d)&page=Product
PZ50 – Weidmuller – 2023.11.05.

[12]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=F2700F3B81FDCB82A88C18FB555C817A?productId=(%5b9006120000%5d)&page=Product
CTI6 – Weidmuller - 2023.11.05.

[13]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=F2C99D3FCCE44458C8C925C75BDC90CD?productId=(%5bproduct13540127676662%5d)&page=Product
SD SET S2.5-5.5/PH1/2 – Weidmuller – 2023.11.05.

[14]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=F2C99D3FCCE44458C8C925C75BDC90CD?productId=(%5b9203710000%5d)&page=Product
ZANGEN SET 1 – Weidmuller – 2023.11.16.

[15]
https://www.hilti.hu/c/CLS_CORDLESS_TOOLS_7123/CLS_CORDLESS_DRILL_SCREW_7123/CLS_CORDLESS_DRILL_7123/r11102216
SFE 2-A12 TÖBBFEJES FÚRÓ/CSAVARBEHAJTÓ GÉP – Hilti – 2023.11.16.

[16]
https://www.obi.hu/holegfuvok/einhell-th-ha-2000-1-forro-levegos-pisztoly/p/4036208
Einhell TH-HA 2000/1 forró levegős pisztoly – OBI – 2023.11.05.

[17]
https://catalog.weidmueller.com/procat/Product.jsp;jsessionid=463E834E653BFAD641C6A65849E5F08D?productId=(%5b9918870000%5d)&page=Product
VT DIGI PRO – Weidmuller – 2023.11.05.

[18]
DHB_HMU8SCC1_R00 – PDF of the control cabinet drawing
DHB_HMU8SCC1_R00 – Gordiusz 95 Zrt. – 2023.11.11.

[19]
https://www.rittal.com/hu-hu/products/PG0002SCHRANK1/PG0026SCHRANK1/PGRP21063SCHRANK1/PRO70035?variantId=8204000
VX25 – Rittal – 2023.11.14.

[20]
https://www.se.com/hu/hu/product/28912/interpact-ins160-3p/
Interpact INS160 – Schneider Electric – 2023.11.14.

[21]
https://www.se.com/hu/hu/product/LV480802/isft160-olvad%C3%B3biztos%C3%ADt%C3%B3s-szakaszol%C3%B3kapcsol%C3%B3-25-95mm/
ISFT160 – Schneider Electric – 2023.11.15.

[22]
https://www.se.com/hu/hu/product/A9F04116/acti9-ic60n-kismegszak%C3%ADt%C3%B3-1p-c-16a/
ACTI9 IC60N 1P C16 A – Schneider Electric – 2023.11.14.

[23]
https://www.se.com/hu/hu/product/LC1D25P7/ac-m%C3%A1gneskapcsol%C3%B3-11kw-25a-400v-ac3-csavaros-csatlakoz%C3%A1s-1z+1ny/
LC1D25P7 – Schneider Electric – 2023.11.18.

[24]
https://www.se.com/hu/hu/product/ABL6TS40U/phaseo-abl6-transzform%C3%A1tor-1f2f-230400-230vac-400va/
ABL6TS40U – Schneider Electric – 11.14.

[25]
https://www.se.com/hu/hu/product/ABL6TS63B/phaseo-abl6-transzform%C3%A1tor-1f2f-230400-24vac-630va/
ABL6TS63B – Schneider Electric – 11.13.

[26]
https://catalog.weidmueller.com/catalog/Start.do;jsessionid=BF7FE825139A5504A526B3310D63D78A?groupId=(%22group25088637874506%22)&ObjectID=7760056343&page=Product

[27]
https://www.plc-city.com/shop/en/abb-building-bld20-bld20b-bld20b20/abb-2ctb803973r1600-nfs.html?SubmitCurrency=1&id_currency=19&feed_country=HU&gad_source=1
2CTB803973R1600 ABB OVR T2-T3 3N – PLC City – 2023.11.15.

[28]
https://www.siemens.com/global/en/products/automation/systems/industrial/plc/s7-1200.html
S7-1200 – Siemens – 2023.11.15.

[29]
https://catalog.weidmueller.com/catalog/Start.do;jsessionid=2EC0E52CB330720E8B9680359E3696DE?groupId=(%22group12912449404439%22)&ObjectID=1020000000&page=Product
WDU 2.5 – Weidmuller – 11.17.

[30]
https://www.se.com/hu/hu/product/ZB4BZ009/harmony-f%C3%A9m-r%C3%B6gz%C3%ADt%C5%91aljzat/
ZB4Z009 – Schneider Electric – 2023.11.18.

[31]
https://www.se.com/hu/hu/product/ZB4BG3/harmony-f%C3%A9m-v%C3%A1laszt%C3%B3kapcsol%C3%B3-fej-%C3%B822-455-kulcsos-k%C3%B6z%C3%A9ps%C5%91-poz%C3%ADci%C3%B3ban-kivehet%C5%91-3-%C3%A1ll%C3%A1s%C3%BA/
ZB4G3 – Schneider Electric – 2023.11.19.

[32]
https://www.se.com/hu/hu/product/ZBE101/harmony-xb4-xb5-%C3%A9rintkez%C5%91-blokk-1no-csavaros-csatlakoz%C3%B3/?%3Frange=632-harmony-xb4&parent-subcategory-id=89188&filter=business-1-ipari-automatiz%C3%A1l%C3%A1s-%C3%A9s-vez%C3%A9rl%C3%A9s&selectedNodeId=12106255474
ZBE101 – Schneider Electric – 2023.11.19

[33]
Gordiusz 95 Zrt. – Pictures of HMU8SCC1
Gordiusz 95 Zrt. – 2023.11.11.

[34]
Gordiusz 95 Zrt. – Inspection, certification sheet
Ellenőrző, minősítő lap – Gordisuz 95 Zrt. – 2023.11.11.

[35]
SOMORJAI LAJOS - A kisfeszültségű kapcsoló- és vezérlőberenezések új szabványai, Presentation,MEE Szabványodítási Bizottság
Somorjai Lajos – 2023.12.01.