SEINÄJOEN AMMATTIKORKEAKOULU
SEINÄJOKI UNIVERSITY OF APPLIED SCIENCES

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Energy efficient building automation project in a market property

Thesis
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Thesis abstract

Degree Programme: Bachelor of Engineering, Automation Engineering

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The thesis was conducted for Caverion Suomi Oy, focusing on the implementation of an energy-efficient building automation system for a retail store in Vaasa. The goal was to implement an automation system according to the client's and the designer's specifications.

The thesis examined the structure of building automation, cybersecurity, selected logic-controllers for the system, and the Caverion Drive property management system. The thesis was carried out for Caverion Suomi Oy, but the actual implementation was for Caverion's customer. The thesis project included planning, making wiring diagrams and equipment lists, programming, creating graphics, commissioning and testing.

As the result of the thesis project, an energy efficient automation system was developed for the property, enabling remote management and autonomous control of the building. The goals set by the client and the designer were thus achieved.

[1] Keywords: building automation, energy consumption, heating, heating system, ventilation systems,

SEINÄJOEN AMMATTIKORKEAKOULU

Opinnäytetyön tiivistelmä

Tutkinto-ohjelma: Insinööri (AMK), Automaatiotekniikka

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Tämä opinnäytetyö toteutettiin Caverion Suomi Oy:lle ja aiheena oli energia-tehokkaan rakennusautomaatiojärjestelmän toteutus myymälä-kohteeseen Vaasassa. Tavoitteena oli toteuttaa sekä asiakkaan että suunnittelijan näkemysten mukainen automaatiojärjestelmä.

Työssä tutkittiin rakennusautomaatiojärjestelmän rakennetta, kyberturvallisuutta, kohteeseen valittuja logiikoita sekä lyhyesti Caverion yrityksen Drive- kiinteistöhallintajärjestelmää. Opinnäytetyö toteutettiin Caverion Suomi Oy:lle, mutta itse toteutus tehtiin heidän asiakkaallensa. Työhön sisältyi suunnittelu, kytkentäkaaviot ja laitteistoluettelot, ohjelmointi, grafiikan luominen, kytkentä, käyttöönotto ja testaus.

Työn tuloksena syntyi energia-tehokas kiinteistön automaatiojärjestelmä, jolla voi etähallinnalla ja autonomisesti ohjata kiinteistöä. Sekä asiakkaan että suunnittelijan asettamiin tavoitteisiin siis päästiin.

[2] Asiasanat: energiankulutus, ilmanvaihtojärjestelmät, lämmitys, lämmitysjärjestelmä, rakennusautomaatio

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Terms and Abbreviations

VAK	Control centre.
I/O	Input/Output.
AI	Analog input.
DI	Digital input.
DO	Digital output.
AO	Analog output.
TCP/IP	Transmission control protocol/Internet protocol.
TK	Supply air machine.
CPU	Central processing unit. The heart of the computer which controls rest of the parts in the system.
Modbus	Modbus is a communication protocol developed by Modicon in 1979, used for communication between intelligent devices.
EIB	The predecessor communication protocol of KNX.
LON	LON refers to a data exchange method used with vertical data transmission which also enables free network topology.
KNX	A bus technology that allows devices to communicate without a central computer.
Setpoint	An input set by the user or automatically by the program.

1 INTRODUCTION

This thesis focuses on a building automation project. Addressing a need for an energy-efficient retail store in Vaasa. The thesis discusses building automation and cybersecurity in general, after which the project planning, implementation and deployment are handled in detail.

1.1 Aim of the thesis

The aim of this thesis is to design and implement a system that can independently control heating, ventilation and other separate points in the building's infrastructure, according to the end user's needs and that can defect and predict maintenance or failure situations. Achieving the desired and results requires programming, design, installation, interaction with other contractors, and understanding the customer needs.

1.2 Structure of the thesis

The first chapter is about giving the reader basic knowledge about the project and the objectives sought from the project. In the end of the first chapter, the company Caverion and the site where the project takes place is introduced. The second chapter explains briefly what building automation is and presents its three hierarchy levels. The third chapter discusses cybersecurity and its three categories, on the basis of which this paper will discuss in more detail the security classification of technical systems. In the fourth chapter the thesis explains how this project is designed to be energy efficient and what kind of savings could be expected in practice from the use of the planned methods. The fifth chapter discusses logic controllers in general, particularly focusing on the Distech's logic controllers selected for the project. Chapter six describes the development of the project property management solution. In the 7th chapter, the thesis discusses the creation of Excel sheets which generate necessary documents such as wiring diagrams and equipment lists. The chapter also covers the software aspects of the project and how they were created according to the designer's instructions, followed by delving into the graphics side. Last part of the chapter will go through installation and commissioning phases. The 8th chapter will summarize the thesis.

1.3 Caverion Suomi Oy

Caverion Suomi Oy is a Finnish company founded in the 1960s and specialising in technical building systems, (Caverion, n.d.-b). Caverion has experts specialised in design, installation and maintenance, enabling the company to bring forward the best solutions to improve energy efficiency, maintenance efficiency and reliability in the Caverions customers' needs in their technical entities. Caverion Suomi Oy is a sister company of Caverion. Caverion operates in 10 countries in Northern and Central Europe. Caverion Suomi Oy employs around 4000 employees and in total Caverion employs around 15 000 employees.

1.4 Site description

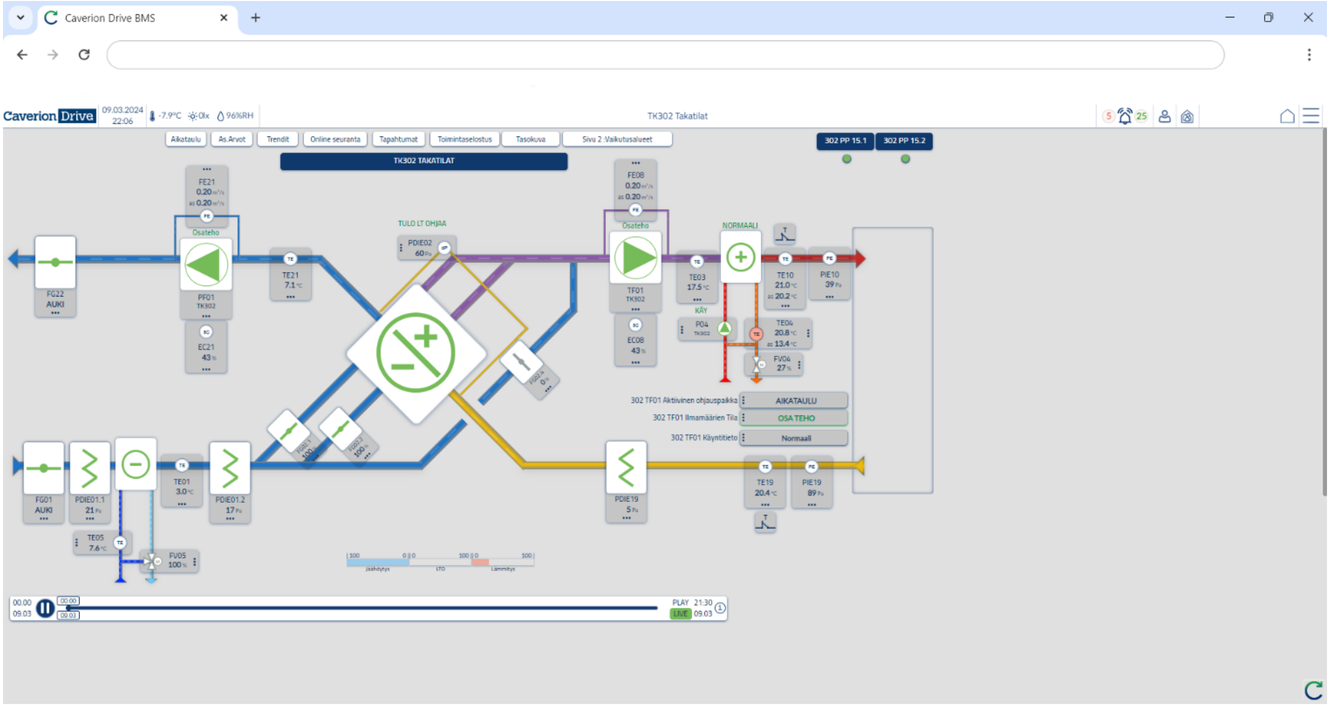
The project will be implemented in an average sized retail store. In total the project involves three large scale ventilation machines, three smaller exhaust air machines, one circulation air machine, a heat distribution circuit and numerous other control points, which should eventually be connected to the maintenance and monitoring site and the local access terminal provided by Caverion to the customer.

2 BUILDING AUTOMATION

Building automation generally consists of a system which generally involves monitoring, controlling, alarm points, and adjusting actuators based on measurement points (Räikkönen, 2001, p. 89-96). The aim is to achieve versatile functions that promote energy efficiency, controllability, and user friendliness. Traditional building automation typically consists of three levels.

2.1 Administrative level

Administrative level works as an interface between a user and an automation system. Simply put the interface often means PC-based monitoring, which can operate locally, but also remotely (Räikkönen, 2001, p. 94). For maintenance companies, as well as property owners the benefit of remote monitoring is centralised management. The interface allows the user to check reports and maintenance needs and to change setpoints, schedules and controlling points as needed. Communication from the lower levels to the administrative level usually happens through TCP-IP protocol, but in legacy systems fixed internet connections and SMS-connections are sometimes found to been implemented. Picture 1 demonstrates an example of administrative level.



Picture 1. Example of administrative level.

2.2 Automation level

Automation level is broken down into segments: CPU, I/O cards and programs that execute the process/system. This level works between administrative level and field level as a middle-man and processing unit. (Spangar et al, 2012, p. 94). Communication between the management level and the automation level usually takes place via TCP-IP protocol (Räikkönen, 2001, p. 94). Depending on the supplier, the product and the customer/designer, data can be transferred to the lower layers using different protocols, e.g. Modbus, EIB, Lon, KNX. Picture 2 demonstrates an example of automation level.

Picture 2. Example of automation level.

2.3 Field level

Field levels include sensors, actuators but also can include I/O cards (Räikkönen, 2001, p. 95). The primary purpose of the field level is to communicate the needed measurements and state information to the automation level and get back the needed control information in return. Picture 3 demonstrates an example of field level device. The device shown in the picture is a sensor.

Picture 3. Example of field level device.

3 CYBER SECURITY

Properties and businesses are currently digitising a significant amount of information concerning their operations and conditions (Rakennustieto, 2020, p. 2). Systems can contain important information about customers and employees on top of other building information. Technical systems, such as ventilation equipment, lighting, heating- and fire protection systems, can suffer considerably in the context of a data breach.

By reinforcing and enhancing the security of hardware, identification and access to control points the risk of cyber-attacks in building automation can be reduced (Rakennustieto, 2020, p. 2). The key word for preparing against cyber-attacks is awareness. Updating the systems and working with producers will take us towards a safer environment, but it is also important to practice beforehand how to react in these situations if preparations are not enough.

3.1 Digitalisation and digital security

Digitalisation enables, for example, savings in maintenance and energy costs. (Rakennustieto, 2020, p. 3). Based on sensor data, property managers and maintenance companies can intervene more effectively in maintenance or fault situations in the future, whereas in the past they had to rely on observations and maintenance schedules.

Digital security can be divided into three categories.

Cybersecurity. Cybersecurity aims to secure the functions of society as threats to functions of the community and health- and safety of individuals (Rakennustieto, 2020, p. 3). Speaking about building automation cybersecurity aims to prevent situations where a data breach can cause economic damage, for example in heating systems, ventilation systems, energy consumption or security systems.

Data protection. Data protection ensures that individuals' data or the data of companies are processed and treated securely and fairly (Rakennustieto, 2020, p. 3). Data protection legislation defines how personal data must be processed.

Information security. Information security refers to the availability of data and the protection of confidentiality (Rakennustieto, 2020, p. 3). If personal or private information would be leaked to wrong and unwanted parties it could, in the worst case, obligate the source of the leaked information to pay a penalty or even compensation to the injured party. In the case of building automation, targets may include control rooms, project plans or project security during implementation.

3.2 Technical building security levels

There are four levels of technical building protection (Rakennustieto, 2020, p. 5). These levels seek to facilitate the classification of systems and the definition of objectives. Understanding the level of security required can provide peace of mind for users and customers. For many customers safe and reliable operations are top priorities.

3.2.1 DT1 – Low risk

To achieve this this level of security, in addition to regulations, simple measures are required, such as clear instructions for exceptional situations and disturbances (Rakennustieto, 2020, p. 7). User identification and the management of access rights for company platforms, as well as data transmission must be encrypted.

This level is appropriate for situations where a breach causes minimal damage to operations, reputation, facilities, equipment and the economy of a company (Rakennustieto, 2020, p. 7). In short, the data breach is limited to a low level of disruption caused by the breach.

3.2.2 DT2 – Moderate risk

The necessary safety practices at this level include on top of the prior levels of security (Rakennustieto, 2020, p. 7). Clear guidelines and procedures for emergency and incident recovery. The company uses staff supervision to control the physical and topological connectivity of the systems.

DT2 is appropriate for companies where data breach can cause damage, but its impact will only affect a limited area (Rakennustieto, 2020, p. 7). The information leaked in the breach is internal company information. The finances of the company will not be seriously affected, workers will not be seriously injured and need to take only a couple of days of sick leave.

There is no more than a noted/recorded value of the incident and the property, or its functions have only been slightly affected.

3.2.3 DT3 – High risk

The DT3 level includes the security methods of the above levels, but in an enhanced form (Rakennustieto, 2020, p. 7). Protection and control are addressed through structural and technical safety measures. In addition to guidance and organization, training will also be provided on recovery from the event. Software has been used to improve data transfer, encryption and access rights.

DT3 is used when the maximum expected damage in the event of a data breach is: If one or all of the following experiences significant loss, damage, leakage or inoperability: company reputation, equipment, security operations, confidential documents (Rakennustieto, 2020, p. 7). As at the national level, an act of damage or an employee’s sick leave of several days.

3.2.4 DT4 - Critical risk

DT4 includes the above levels (Rakennustieto, 2020, p. 7). In addition to these, protection and control are managed with special protection solutions, recovery from an incident is regularly practiced and it has been made possible to switch the important equipment to manual control.

The maximum effects of a breach expected cause serious harm to the business, finances and property or a national threat (Rakennustieto, 2020, p. 7). A cyber-attack on critical company or customer documents. Can cause multiple days of sick leave or even fatalities. Requires action from senior management.

3.3 The cyber security policy of Caverion

The cyber security of Caverion is implemented according to the ISO 27001 standard, which requires the company to manage the integrity and security of the information flow through guidelines, management and risk management measures (Caverion, internal memo, 2023).

The solution of the company is based on a three-server setup, enabling 99.9% availability (Caverion, internal memo, 2023). In case of a server failure, virtual machines boot automatically from another server. The physical servers are under a 24/7 maintenance contract with a 4-hour response time. Network connections are continuously monitored, with a 24/7 response to incidents. Virtual machines are also backed up once a day to another disk system for added resilience. The systems of Caverion include the necessary steps to meet the requirements of the DT4 security level.

4 ENERGY SAVING SOLUTIONS

The cost of energy is rising day by day, and although devices and buildings are gradually becoming more energy efficient in heating and cooling, there is still a need for improvement in energy consumption. Smart building solutions enable the recovery and utilization of thermal energy from cooling systems for the heating needs of the property (Caverion, n.d,-c). With current systems, achieving 60-70% savings over the entire systems lifecycle compared to traditional systems is not wishful thinking.

The property's heating and cooling solution

In the design of the geothermal loop, it is important to consider the energy needs of the facility (Energiatehokaskoti, n.d). Generally investing in a geothermal loop is a profitable decision because they are cost effective and durable. The principle of operation for a loop is to transfer heat into the ground during the cooling season and extract heat from the ground during the heating season. Type of soil at the site also matters. The greatest benefit is obtained from the soil with high moisture content. For example, in clayey terrain, the liquid content on is at least 40%, whereas sandy soil, the same value can be 4%.

Our system utilizes three loops. Cooling coils have been installed into the ventilation for cooling purposes. Figure 1 demonstrates a cooling coil (Granlund, internal document, 2023).

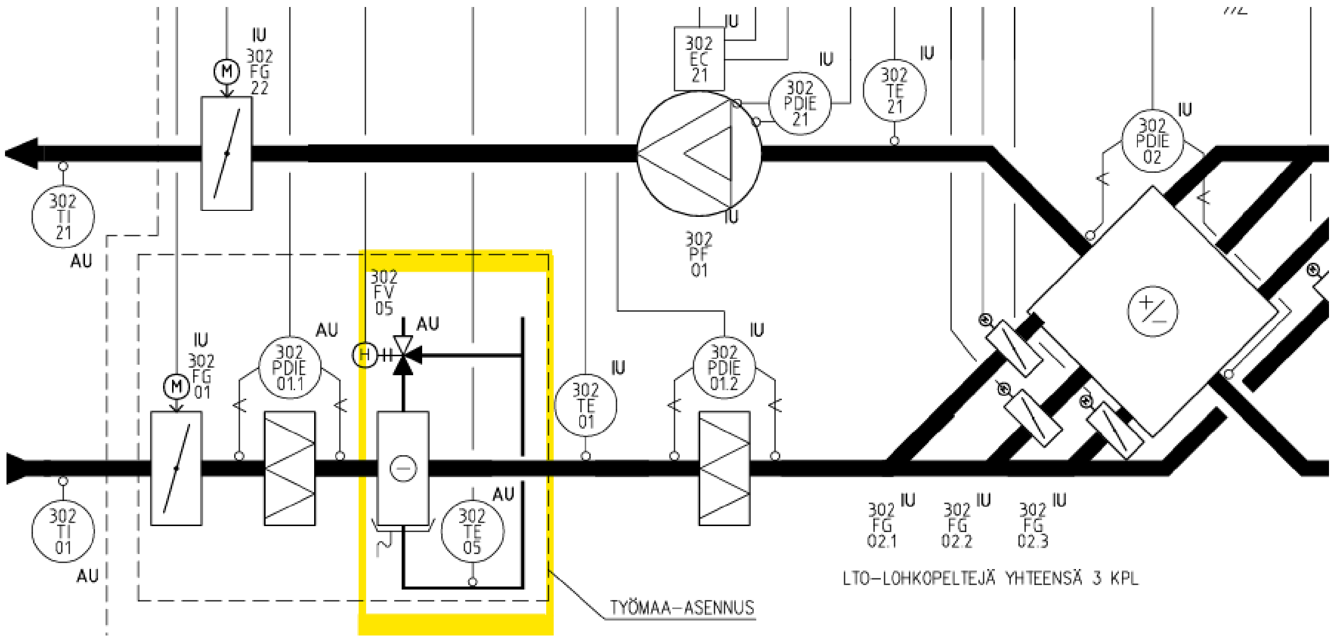
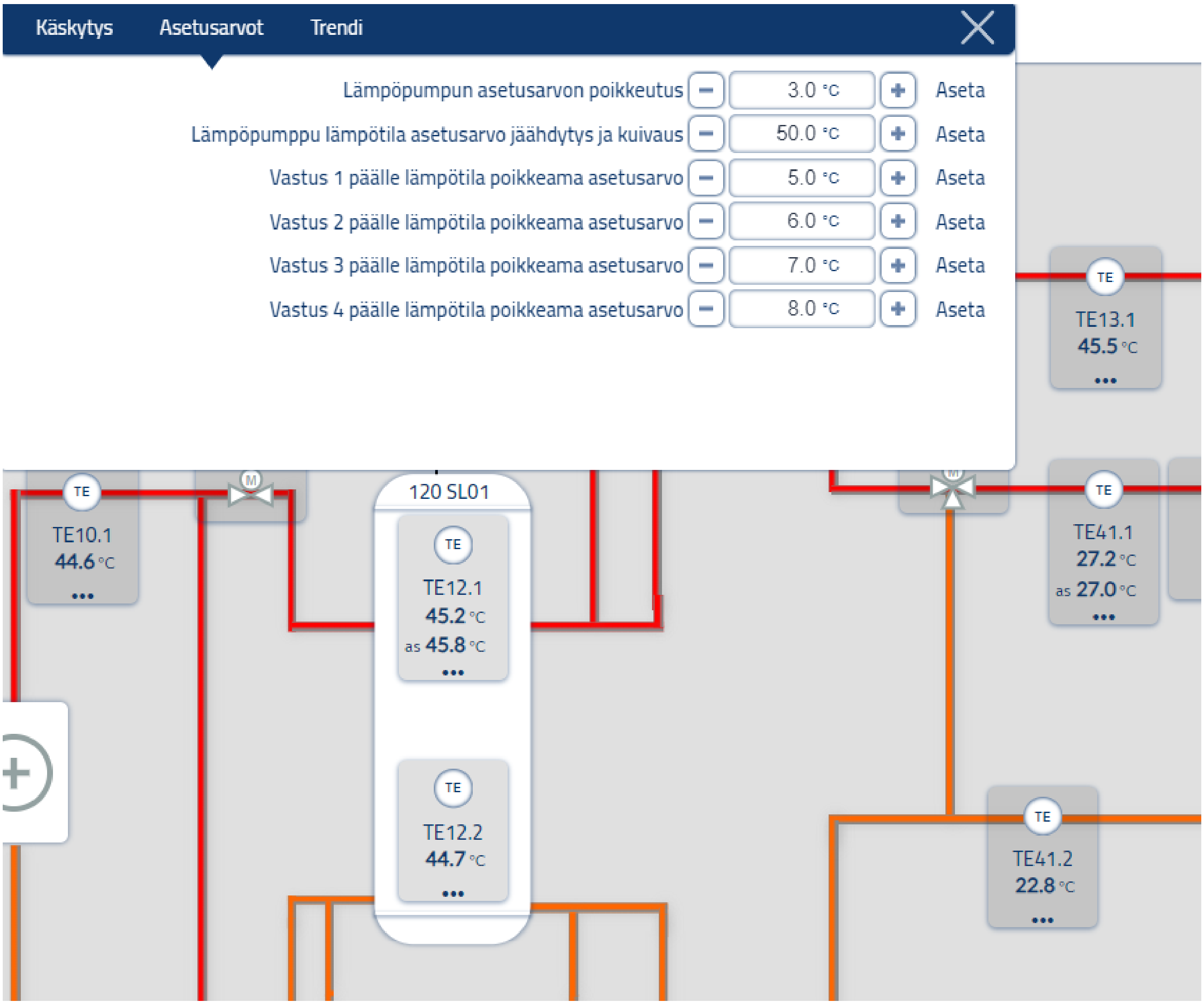


Figure 1. Cooling coil (Granlund, internal document, 2023).

4.1 Condensate energy used in heating network.

The target property is heated using condensate energy obtained from the refrigeration units in the shore. The refrigeration units generate heat during operations, which is then transferred to the heating network through a heat exchanger. The heating network produces heat for the ventilation network, floor heating network, frost prevention network, and domestic hot water. In traditional systems and larger properties, district heating is commonly solely or in conjunction with condensate heating. However, this property generates heat using condensate, geothermal energy, heat pumps, and electric resistors in water tanks. If the temperature of water after condensate heat exchange and geothermal energy is not warm enough, the heat pump further heats the water to the require temperature. If that is still insufficient, the resistors in the tanks are activated one by one to achieve the necessary temperature. Picture 4 demonstrates the heating steps on the graphics page.



Picture 4. Water heater steps on the graphics.

4.2 Ventilation systems heating and cooling.

Utilizing the heat from exhaust air through heat recovery can reduce heating energy consumption by 30-40% (Tom Allen Senera, n.d.). the projects ventilation units utilize heat generated by the heating network but also incorporate their own HR (Heat recovery) systems. The ventilation unit can either recirculate exhaust air as supply air using a bypass damper or transfer heat directly, either through a heat exchange or a radiator.

In cooling, our site utilizes the geothermal loops and ventilation machines have a programmatically built night ventilation, which, as needed and under special conditions, cool the building during the summer.

4.3 Investment payback

In this section the calculations are made to show how long it will take to recoup the investment compared to district heating by investing in a setup like this. This does not consider the cooling benefits obtained from the ground loop which are used in the ventilation machines for cooling purposes.

A district heating package for a site like this would cost an estimated 75 000–80 000€, considering connection fees, the district heating package, control system, and labour. A system which is installed to this site cost approximately 140 000€, considering drilling the geothermal holes, heat pump, fluids, controls and labour.

To calculate the energy consumption, it is important to consider the size of the property. In this case the target has 1845 square meters which is multiplied based on the assumption of consumption of 120kWh per square metre, which comes to 221 400 kWh.

Prices of district heating depend on the area and the energy producer. This site locates in Vaasa where the current prices stand at 63€ per megawatt (Vaasan sähkö, n.d.). With ground heat megawatt price standing at 20€ per megawatt. The yearly price for heating would be with district heating 13 948€ and ground heat comes to 4 428€.

Taking into account also the maintenance fees of both systems since for the ground heating system maintenance will be more expensive as there is more controlled points and devices in use as in the district heating solution. The maintenance estimate for ground heat over ten years are 15 000–20 000€ and the estimate for district heating at 10 000€.

Estimated recoup for the system is round 7 years taking to account the maintenance, higher investment and prices to obtain the needed energy. The calculations show that, the recoup period is not at the most favourable side, as typically, the payback period ranges from 3 to 5 years. Nevertheless, the calculations did not include the benefits of the cooling from the collection pipes, or the heating generated from the heat recovery of the ventilation machines. Installing a system like this will also increase the property value and give out a greener image of the property.

5 PROGRAMMABLE LOGIC CONTROLLER

Programmable logic controllers are usually a smaller processor unit than a household computer which are used to control real-time automation processes. The reason for them becoming more and more used is that one controller can replace multiple control blocks and relays which were used back in the day for controlling an automated system.

Distech programmable logics. Distech is one of numerous logic manufacturers. Distech has a wide range of programmable logics but in our case, we had three reasonable options of which we chose two. Distech controllers are widely used in our company for their reliability and availability.

When choosing logic, different things must be taken into considering, for example: processing ability, the number of I/O points, compatibility with needed data transfer protocols, how well-known the programming language is and expansions possibilities that may be needed in the future. (Distech, n.d.).

In addition to programming logic, Distech also has many other parts necessary for building a system for our customers' requirements such as field interfaces, sensors and additional cards for relays and data transmission (Distech, n.d.).

5.1 Distech controller: ECY-S1000-48

Picture 5 displays Distech controller ECY-S1000-48. Distech controller ECY-S1000-48 is a CPU capable of supporting maximum of 10 Modbus devices and it has the capability of supporting up to 320 I/O points and up to 20 I/O modules (Distech, 2023b). It supports BACnet MS/TP, Modbus RTU and Modbus TCP. With extension modules it can support more than one communication protocol or trunk. For the first VAK this controller has more than enough power to run our program and the devices behind it. The first VAK has been designed to control the heat distribution circuit and the controls for lights and defrosting. Picture 6 displays Distech extension module.

Picture 5. Distech controller ECY-S1000-48.

Picture 6. Distech extension module.

5.2 Distech controller ECY-APEX

For the second VAK our project needed more power as the second VAK had to control three bigger ventilation machines and a lot of smaller controlling points, so ECY-APEX was selected (Distech, 2023a). The APEX controller supports up to 320[4] I/O points and up to 20 I/O modules. As the ECY-S1000-48 controller the APEX controller supports also BACnet, Modbus RTU and Modbus TCP communication protocols. APEX controller will support up to 96[3] Modbus devices. Picture 7 displays Distech ECY-Apex controller.

Picture 7. Distech ECY-Apex controller.

6 CAVERION DRIVE

In the future, property management is the key to more energy efficient and sustainable property solutions (Caverion, n.d,-c). Caverion Drive is a platform that includes programming libraries, protocol support, secure solution-based cybersecurity, measurement and trend analytics with reporting which enables a greener system by utilizing emission and price data provided by the energy supplier. Drive enables easy integration into various devices and systems with its extensive protocol support, including energy a space management, security solutions, access controls, and property controls. Figure 2 demonstrates Caverion Drive operation.

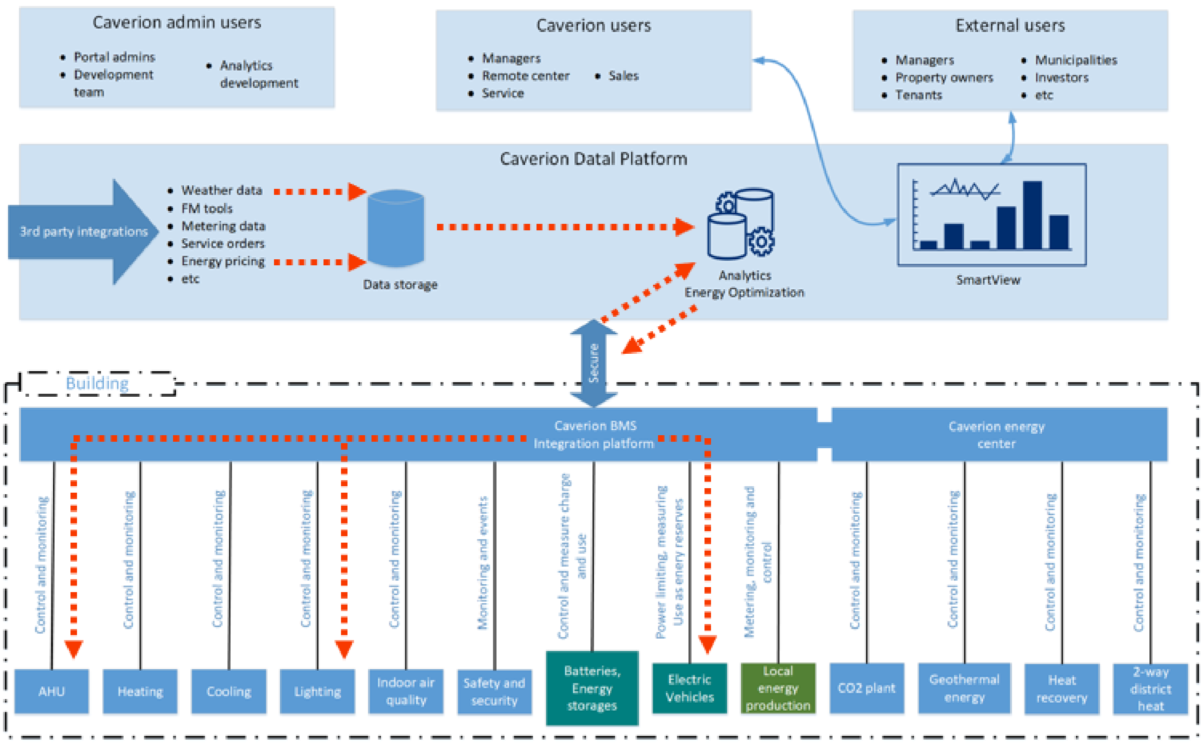


Figure 2. Caverion Drive.

7 PROJECT PROGRESS

7.1 Point- and cable design.

The programming task initiated by creating a point list in Excel. This list serves as the foundation for generating points in the GFX – program, cable routing plans, connection diagrams, device list, and the control panel (VAK) layout. This phase is crucial groundwork for all future work, as errors left in the foundation could lead to significant additional work in both programming and graphics creation.

Caverion has created an excel template that tremendously facilitates our work in the scenarios mentioned above. Next section will be a overview of it.

Point index - The actual point on the I/O card.

Point name - Which is used in the programming stage and the graphics.

Units - In which the program and the graphics page will show value of the point.

Description - Which lets the user know in detail which sensor/actuator that point holds.

Signal type - Signal types can be resisting signal, 0-10V, a digital signal, 0-20mA and 4-20mA.

Scale - From where to where the sensor measures. In the case it’s from 0 Celsius to 100 Celsius.

Modbus register – Using the wrong Modbus register, the program will not display or produce the correct/desired value to the user.

Notify class - is where we choose the importance of the alarm.

High limit - is the set limit for which if the value of the sensor goes above the alarm sets.

Low limit - is the set limit for which if the value of the sensor lower above the alarm sets.

Deadband - is the range which an input can varied before the alarm set on/off.

Once this selection has been filled with using the building automation plans, we can move on to choosing the device and the cable. First field form the left is the device for this point, and this will be used in generating the device list. Fifth form the right is the cable needed for the connection and the number of wires in the cable needed which will be useful in generating the cable routing plans and connection diagrams. Tables 1, 2 and 3 illustrate the Excel sheet used in this project.

Table 1. I/O points on Excel sheet.

Point Index	Point Name	Units	Description	Point Type UI 12	DI 8	A 7	DO 4	Signal Type	Scale	Part Number	Detail	Rev	Modbus register
Point Index	Point Name	Units	Description	UI 15	DI 5	O 7	DO 4	Signal Type	Scale	Part Number	Detail	Rev	Modbus register
UI 201	302.RetWaterTemp	°C	302 TE04 Paluuvesi lämpötila	X				0-10V	0/100				
UI 202	302.SupAirFlrPresDiff01	Pa	302 PDIE01.1 Tuloilmasuodatin paine-ero	X				0-10V	0/500				
UI 203	302.ExhAirFlrPresDiff	Pa	302 PDIE19 Poistoilmasuodatin paine-ero	X				0-10V	0/500				
UI 204	302.HrAirPresDiff	Pa	302 PDIE02 Lämmöntalteenotto paine-ero	X				0-10V	0/500				
UI 205													
UI 206	302.SupAirPres	Pa	302 PIE10 Tuloilma paine	X				0-10V	0/1000				
UI 207	302.ExhAirPres	Pa	302 PIE19 Poistoilma paine	X				0-10V	0/1000				
UI 208	302.SupAirFanPresDiff	Pa	302 PDIE08 Tuloilmapuhallin paine-ero	X				0-10V	0/1000				
UI 209	302.ExhAirFanPresDiff	Pa	302 PDIE21 Poistoilmapuhallin paine-ero	X				0-10V	0/1000				
UI 210	302.SupAirTemp	°C	302 TE10 Tuloilma lämpötila	X				10K Type II					
UI 211	302.ExhAirTemp	°C	302 TE19 Poistoilma lämpötila	X				10K Type II					
UI 212	302.SupAirHrTemp	°C	302 TE03 Tuloilma lämpötila LTO:n jälkeen	X				10K Type II					
UI 213	302.ExhAirHrTemp	°C	302 TE21 Poistoilma lämpötila LTO:n jälkeen	X				10K Type II					
UI 214	302.NetwTempRetCv	°C	302 TE05 Esilämmityksen paluuveden lämpötila	X				10K Type II					
UI 215	302.SupAirFlrPresDiff02	Pa	302 PDIE01.2 Tuloilmasuodatin paine-ero	X				0-10V	0/500				
UI 216	302.SupAirCvTemp	°C	302 TE01 Tuloilma lämpötila jäähd.jälkeen	X				10K Type II					
Sheet													
DI217	302.FrostProtectAlm	HÄLYTYS/OK	302 TZA04 Jäätymisvaara hälytys		X			Digital					
DI218	302.SupAirFanSt	KÄY/SEIS	302 TF01 Tuloilmapuhallin tilatieto		X			Digital					
DI219													
DI220	302.ExhAirFanSt	KÄY/SEIS	302 PF01 Poistoilmapuhallin tilatieto		X			Digital					
DI221													
DI222	302.HeatPumpAlm	HÄLYTYS/OK	302 P04 Lämmityspumppu hälytys		X			Digital					
DI223	302.HeatPumpSt	KÄY/SEIS	302 P04 Lämmityspumppu tilatieto		X			Digital					
DI224													
DI225													
DI226													
DI227													
DI228													
DI229													
DI230													
DI231													
DI232													
Sheet													
MRE201			MRE2.1 Relay modul							MRE	24VAC		
DO233	302.SupAirFanCmd	PÄÄLLÄ/POIS	302 TF01 Tuloilmapuhallin ohjaus				X	Digital			MRE2.1.1		1
DO234	302.ExhAirFanCmd	PÄÄLLÄ/POIS	302 PF01 Poistoilmapuhallin ohjaus				X	Digital			MRE2.1.2		2
DO235	302.SupAirDamper	AUKI/KIINNI	302 FG01 Tuloilmapeltimoottori				X	Digital			MRE2.1.3		3
DO236	302.ExhAirDamper	AUKI/KIINNI	302 FG22 Poistoilmapeltimoottori				X	Digital			MRE2.1.4		4

Table 2. I/O points on Excel sheet.

Display I/O-couplings	Notify class	High Limit/Alarm value /feedback point	Low Limit/ Deviation limits	Deadband	Update	Device	Sapcode	Platetype
	2	65	9	3		Produal, TEV PT1000	FIA3811503	FieldDevicePlate
	3	250	None	20		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	3	270	None	20		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	2	AlarmSetpoint	20/None	10		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	None	None	None	None				
	2	AlarmSetpoint	20/-20	5		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	2	AlarmSetpoint	20/-20	5		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	None	None	None	None		Produal, IML	FIA4231010	FieldDevicePlate
	None	None	None	None		Produal, IML	FIA4231010	FieldDevicePlate
	2	AlarmSetpoint	5/-5	1		Produal, TEK NTC 10	FIA3006001	FieldDevicePlate
	2	25	15	2		Produal, TEK NTC 10	FIA3006001	FieldDevicePlate
	None	None	None	None		Produal, TEKA NTC_10 50CM	FIA3021001	FieldDevicePlate
	None	None	None	None		Produal, TEK NTC 10	FIA3006001	FieldDevicePlate
	None	None	None	None		Produal, TEK NTC 10	FIA3006001	FieldDevicePlate
	3	220	20/-20	5		Produal, PEL 2500_N	FIA4206006	FieldDevicePlate
	None	None	None	None		Produal, TEHR NTC 10	FIA3001001	FieldDevicePlate
	1	None	None	None		Produal, JVA 24	FIA3811001	
	1	FalseAlarm	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	2	None	None	None				
	1	FalseAlarm	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None				
	None	None	None	None		Mariachi Oy, KORTTIMRE_1RELAYMOD	FIA2533001	
	2	218	None	None				
	2	220	None	None				
	None	None	None	None		Belimo, SF24A	FIA5001205	FieldDevicePlate
	None	None	None	None		Belimo, SF24A	FIA5001205	FieldDevicePlate

Table 3. Cable design Excel sheet.

Produal, TEV PT1000	FIA3811503	FieldDevicePlate		Switch_Nomak12x7p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	7ar	7va		
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE01.1 N	1ar		2ar	2va
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE19 N	1ar		2ar	2va
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE02 N	1ar		2ar	2va
				Spare_MIO52	Reservation_v3							
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PIE10 N	1ar		2ar	2va
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PIE19 N	1ar		2ar	2va
Produal, IML	FIA4231010	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE08 N	1ar		2ar	2va
Produal, IML	FIA4231010	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE21 N	1ar		2ar	2va
Produal, TEK NTC 10	FIA3006001	FieldDevicePlate		Switch_Nomak12x1p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	1ar	1va		
Produal, TEK NTC 10	FIA3006001	FieldDevicePlate		Switch_Nomak12x2p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	2ar	2va		
Produal, TEKA NTC_10 50CM	FIA3021001	FieldDevicePlate		Switch_Nomak12x3p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	3ar	3va		
Produal, TEK NTC 10	FIA3006001	FieldDevicePlate		Switch_Nomak12x4p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	4ar	4va		
Produal, TEK NTC 10	FIA3006001	FieldDevicePlate		Produal_fielddev_2wire_Nomak2x	Produal_fielddev_2wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 C1	1ar	1va		
Produal, PEL 2500_N	FIA4206006	FieldDevicePlate		Produal_fielddev_3wire_Nomak2x	Produal_fielddev_3wire_v3	NOMAK 2x2x0.5+0.5	L709683	302 PDIE01.2 N	1ar		2ar	2va
Produal, TEHR NTC 10	FIA3001001	FieldDevicePlate		Switch_Nomak12x6p	Switch_v3	NOMAK 12x2x0.5+0.5	L403377	302 C1	6ar	6va		
Produal, JVA 24	FIA3811001			Produal_jva24_alm_InterlockExt	Produal_jva24_alm_v3	Internal Wiring	CAV001	302 TZA04 I				
				Switch_Jamak4x1p	Switch_v3	JAMAK 4x(2+1)x0.5	L263869	302 TF01 J	1pu	1ri		
				Spare_MIO52	Reservation_v3							
				Switch_Jamak4x1p	Switch_v3	JAMAK 4x(2+1)x0.5	L263869	302 PF01 J	1pu	1ri		
				Spare_MIO52	Reservation_v3							
				Switch_Nomak2x1p	Switch_v3	NOMAK 2x2x0.5+0.5	L709683	302 P04 N	1ar	1va		
				Switch_Nomak2x2p	Switch_v3	NOMAK 2x2x0.5+0.5	L709683	302 P04 N	2ar	2va		
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							
				Spare_MIO52	Reservation_v3							

7.2 PROGRAMMING

Ventilation machine TK302

Distech uses the EC-gfxProgram programming platform. The platform uses function block programming (FBD) which is familiar for many programmers.

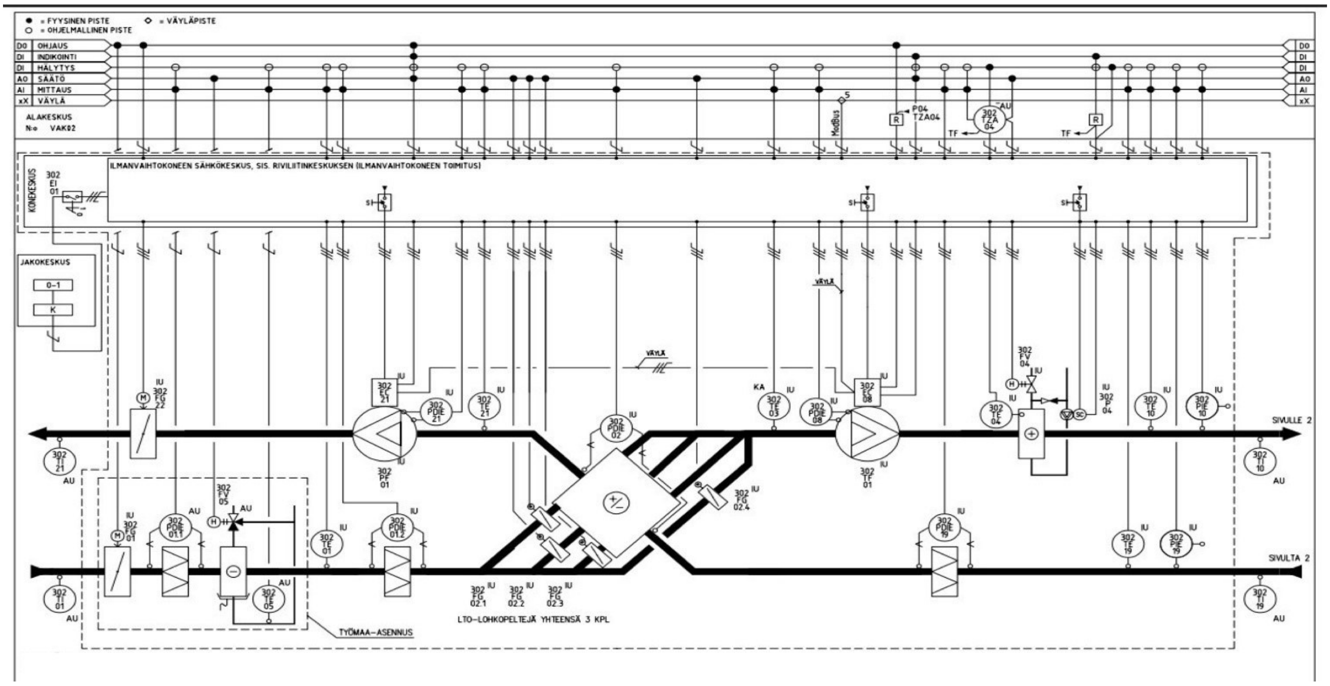


Figure 3. Technical drawing for TK302 (Granlund, internal document, 2023).

Figure 3 demonstrates control circuit for ventilation machine TK302 (Granlund, internal document, 2023). In the programming of the ventilation unit, it is crucial to ensure the functionality of necessary interlocks from the perspective of device shutdown and recovery. Traditional interlocks include emergency shutdown of ventilation, ventilation system fault alarm, exhaust fan operation allowed only when supply fan is running, heat pump status, and freeze hazard alarm. These measures are in place to preserve the integrity of the unit, for instance, in an event of a fire, ensuring the machine shuts down autonomously.

The freeze hazard alarm protects the heating coil from freezing, which is one crucial component of the ventilation unit. In the program, this is addressed by setting a setpoints for the TE05 measurement point (Granlund, internal document, 2023). When the temperature falls below a certain threshold, the ventilation unit is directed to operate on minimum speed, and if it drops even further, the unit is commanded to stop. The program also adjusts the valve FV04 to modulate the return water temperature towards the setpoint by closing the valve for indoor loop if the temperature is too high and fully opening it again when the temperature has dropped too low.

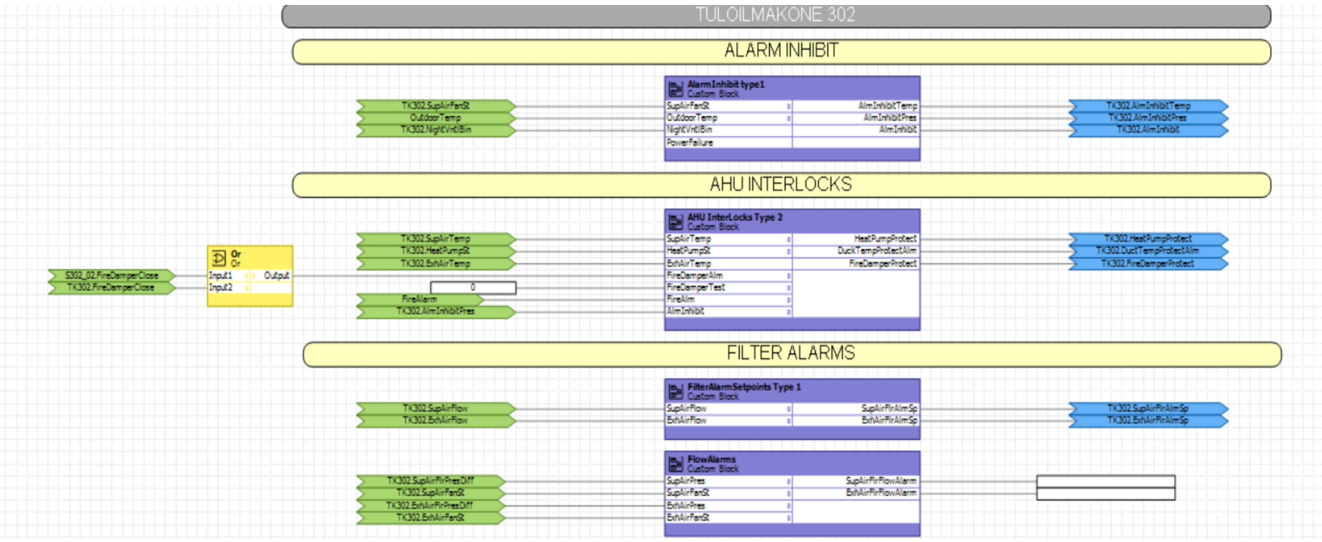
Operation of the unit

Temperature control: The program directs the unit to achieve the setpoint temperature at the TE10 measurement point for supply air (Granlund, internal document, 2023). This is achieved by controlling a series of components, including the heating coil, heat recovery, and preheating coil.

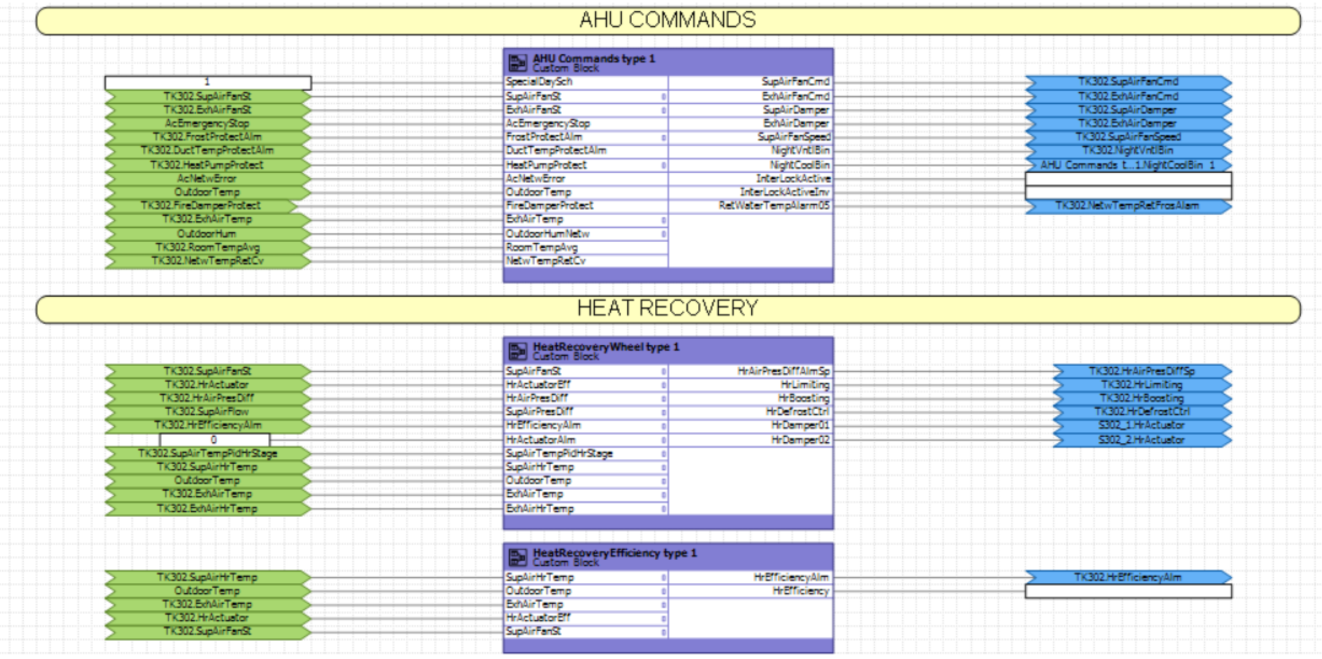
Air volume: The regulation of air volume is based on the pressure differences between exhaust and supply air, from which a setpoint is calculated (Granlund, internal document, 2023). The program adjusts the rotation speeds of TF01 and PF01 to maintain the airflow of the fans at the setpoint.

Fire dampers: When the fire dampers close, the ventilation unit is directed to shut down (Granlund, internal document, 2023). Every six months, the ventilation unit is manually set to standby as the dampers are tested leaving a note to control room of the testing. The control room issues a reminder if more than 6 months have passed since the last test.

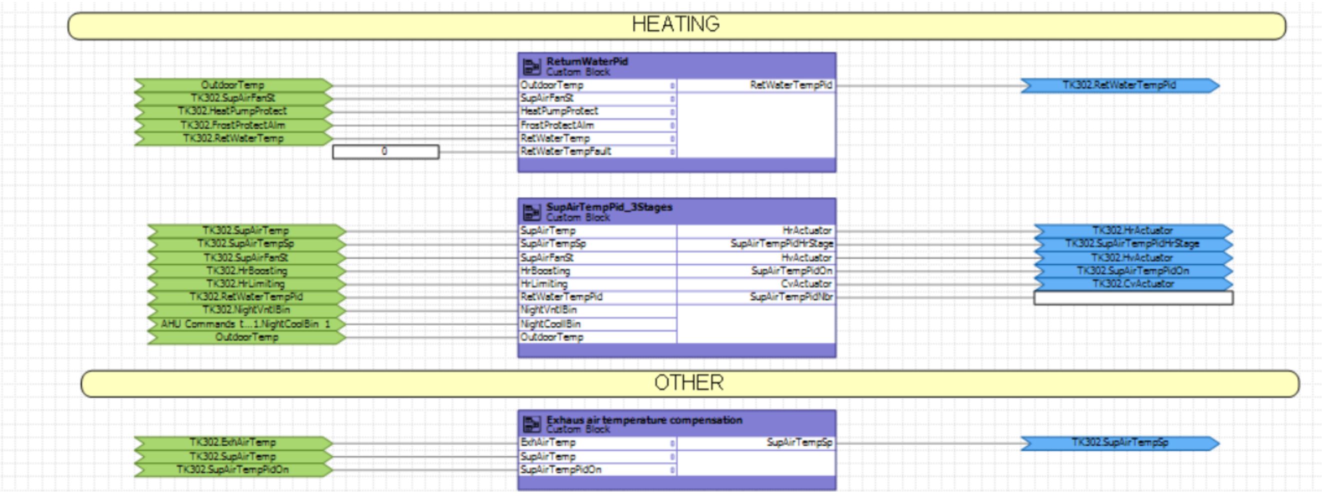
Precautions and alarms: If the pressure difference measurement PDIE02 reaches the frost limit, the program controls the heat recovery dampers to open and close to thaw the dampers (Granlund, internal document, 2023). The program also aims to maintain the desired temperature setpoint at TE03 by controlling the damper’s operation. Filter pressure differentials are monitored, and if the pressure increases too much, it triggers a filter guard alarm in the system. Pictures 8, 9, 10 and 11 illustrate the ventilation machine TK302 program.



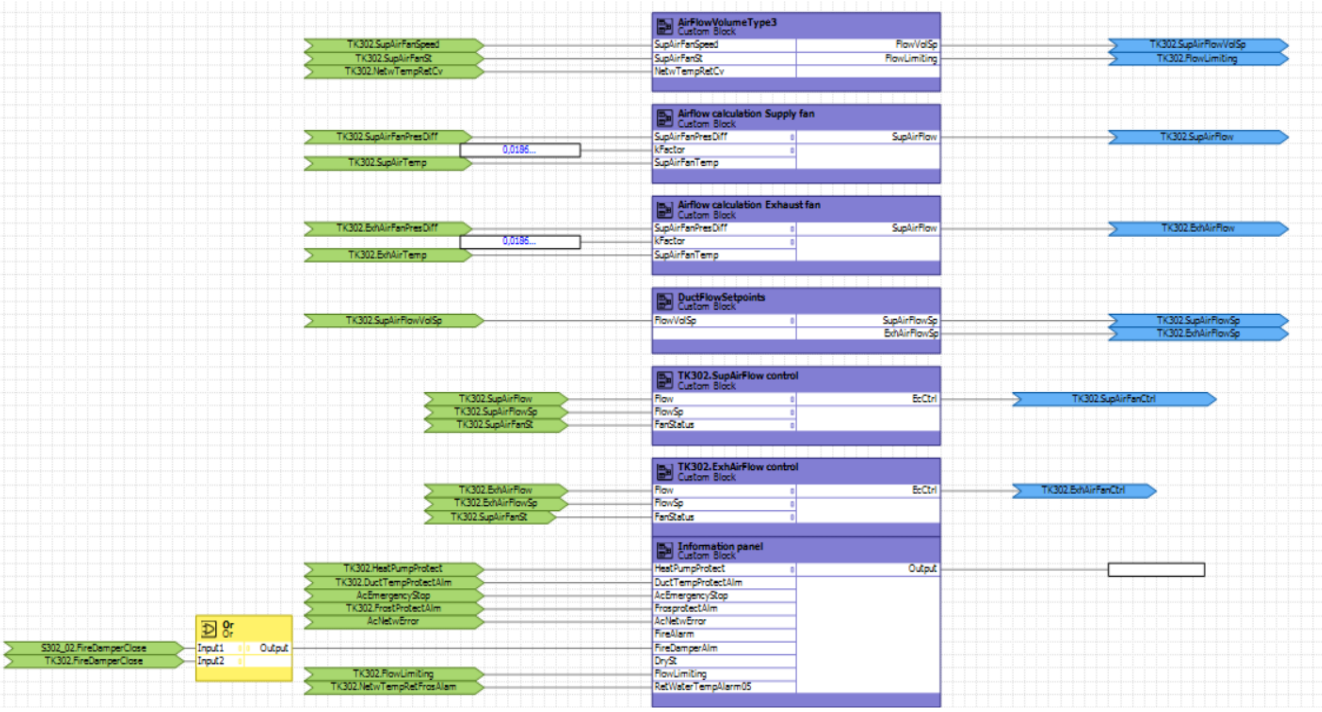
Picture 8. TK302 Program part 1.



Picture 9. TK302 Program part 2.



Picture 10. TK302 Program part 3.



Picture 11. TK302 Program part 4.

Room controllers

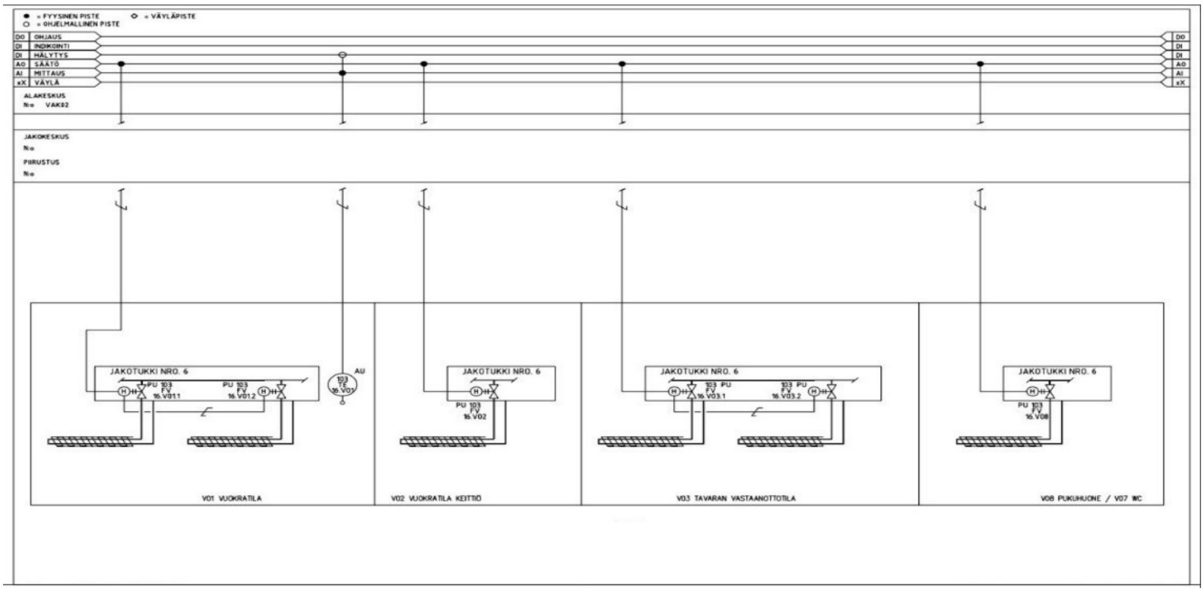
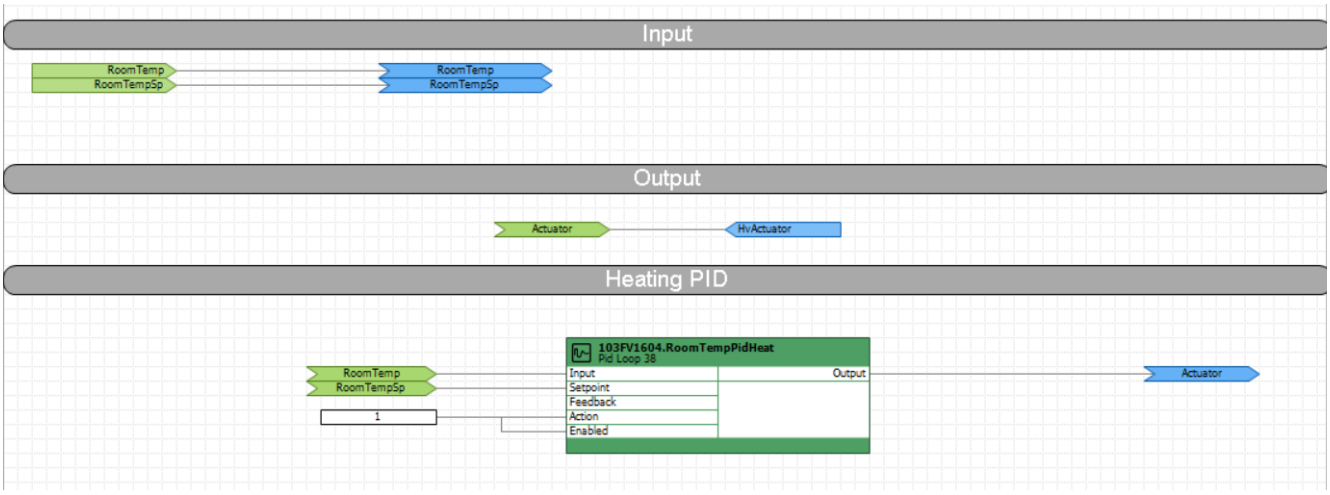


Figure 4. Technical drawing for room controllers (Granlund, internal document, 2023).

Figure 4 demonstrates control circuit for room controllers (Granlund, internal document, 2023). Programming the room controllers started with going through the desires set by the client and designer. In our case the instructions were simple. Program should keep the room temperature at a user-set setpoint by controlling the operation of the circuit-specific valve actuator and to provide an upper and lower temperature limit alarm to the building automation system.

The valve actuator can be controlled in degrees from 0º to 100º by sending the actuator a voltage message from 0 Volts to 10 Volts. With programming in mind. Creating an adjustment message is not difficult when using a proportional-integral-derivative controller more known as a PID controller.

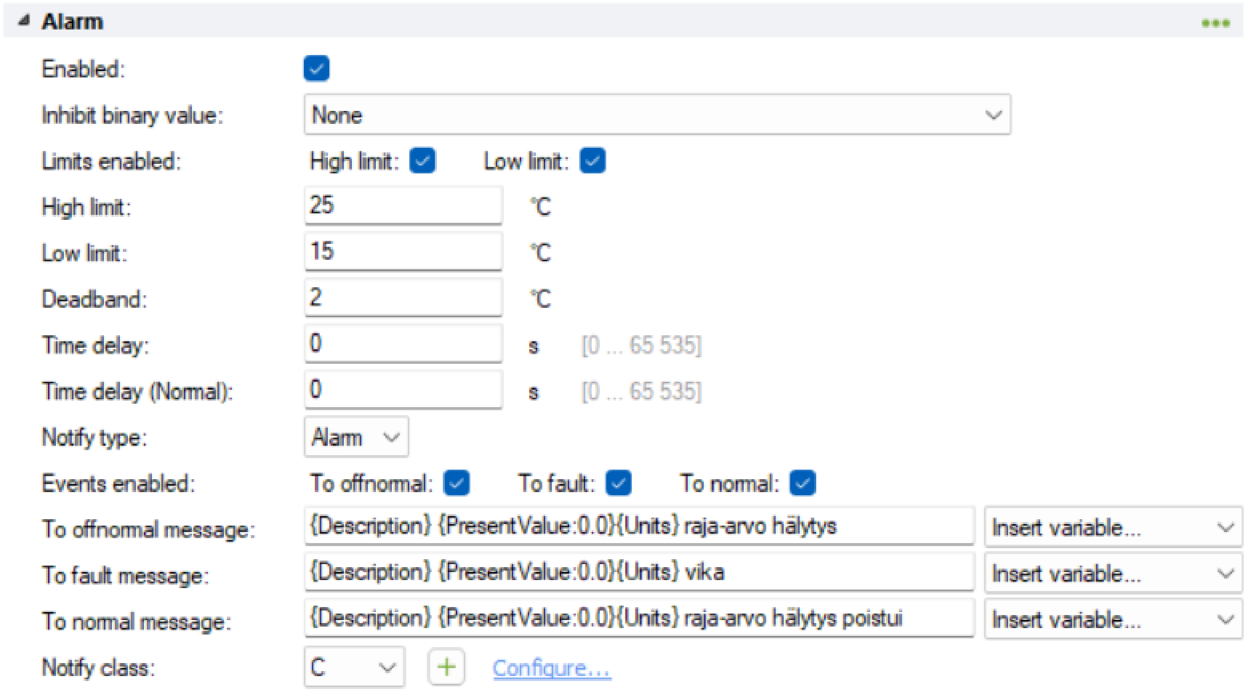
In this case the PID controller gives out an output which it has calculated from the input and setpoint to control the valves position. Pictures 12 shows a PID controller used by one of the room controllers.



Picture 12. Room controller PID.

- Input: The temperature that controls the desired actuator.
- Setpoint: The wanted temperature for the space.
- Enable: Authorises the block to operate.
- Output: The calculated output message from the input messages.

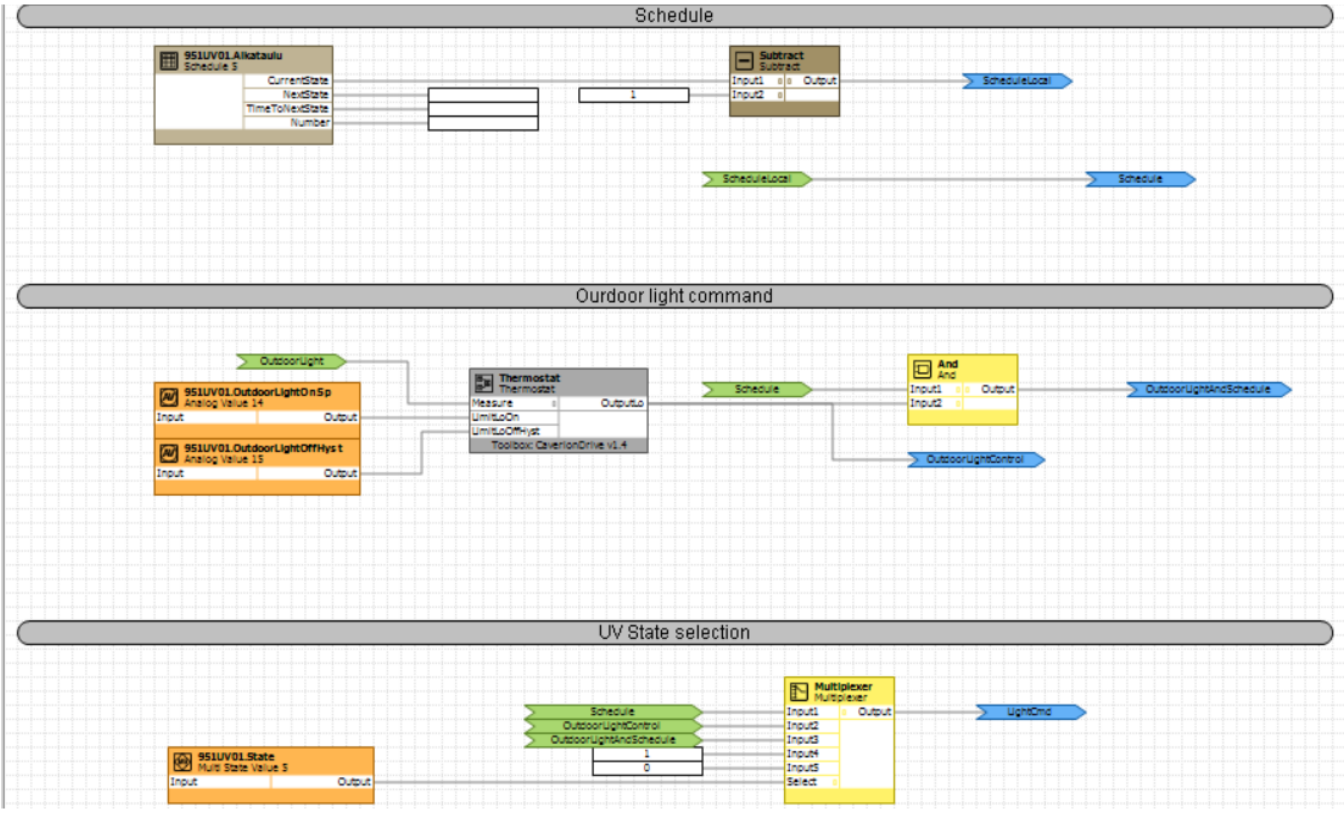
Distech program platform lets the lower and higher alarm limits to be set straight into the variables. Deadband prevents toggling with the alarm by requiring the input to drop below or rise above the threshold by the amount of the deadband before the alarm turns off or on. Notify class specifies the priority of an alarm in the variable. Picture 13 demonstrates alarm setpoints of the room thermostat.



Picture 13. Alarm setpoints of the room thermostat.

Lights

The lighting controls operate by a schedule, control buttons and a light sensor. The light sensor measures the ambient light outside, which the program reads, and when the outdoor light drops below a certain point, the outdoor lights turn on. Pictures 14 demonstrates Program of outdoor lights.

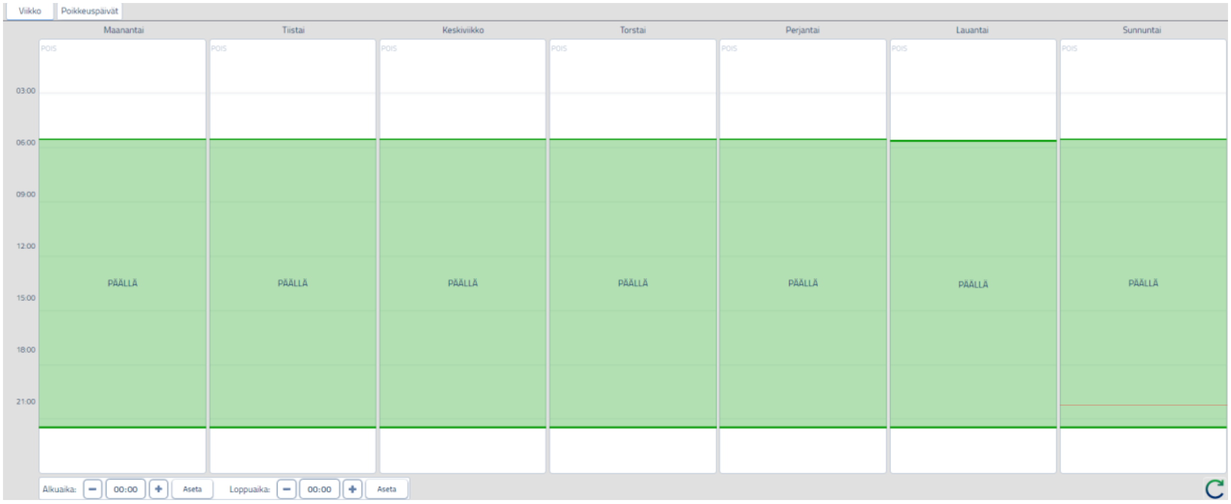


Picture 14. Program of outdoor lights.

The program controls outdoor lighting based on the schedule and light sensor. The ambient light value is inputted into the control block, where the threshold value for turning the lights on is set. When the measured value from the sensor falls below the set value, the control blocks output turns on. The control block also includes hysteresis, which enables smoother operation of the output. Without hysteresis, the lights might flicker on and off when the value from the sensor hovers around the threshold value of activation.

From the interface (Picture 15), the user can choose whether they want to control to be based on the sensor, schedule or both. Picture 16 depicts the schedule of outdoor lights.

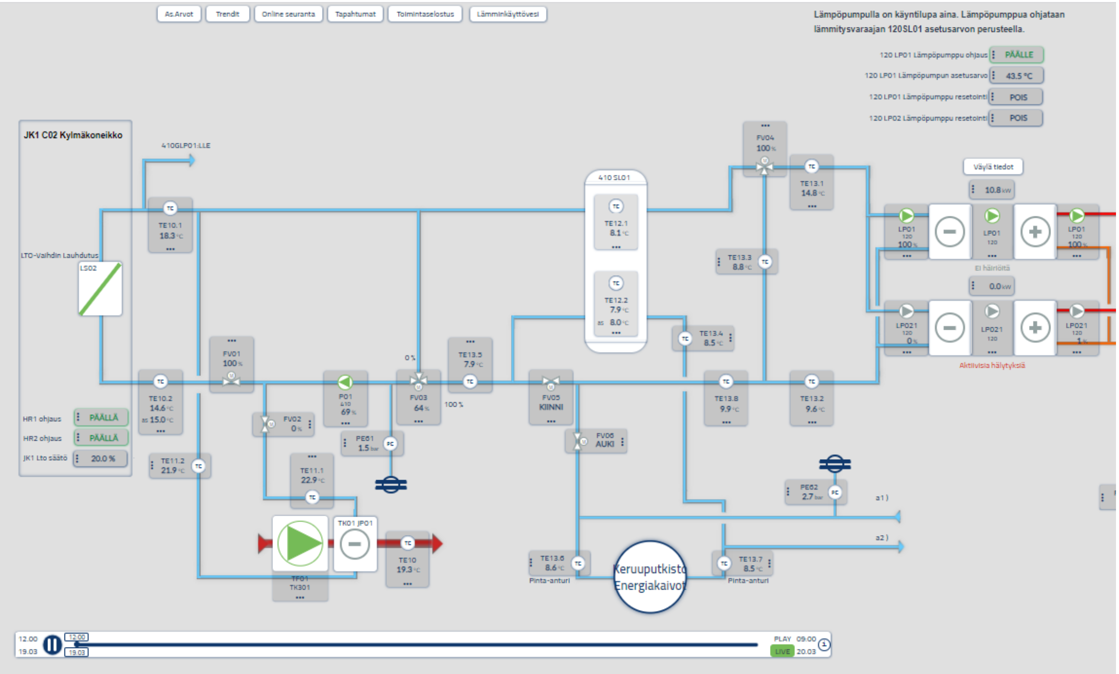
Picture 15. Outdoor lighting graphics.



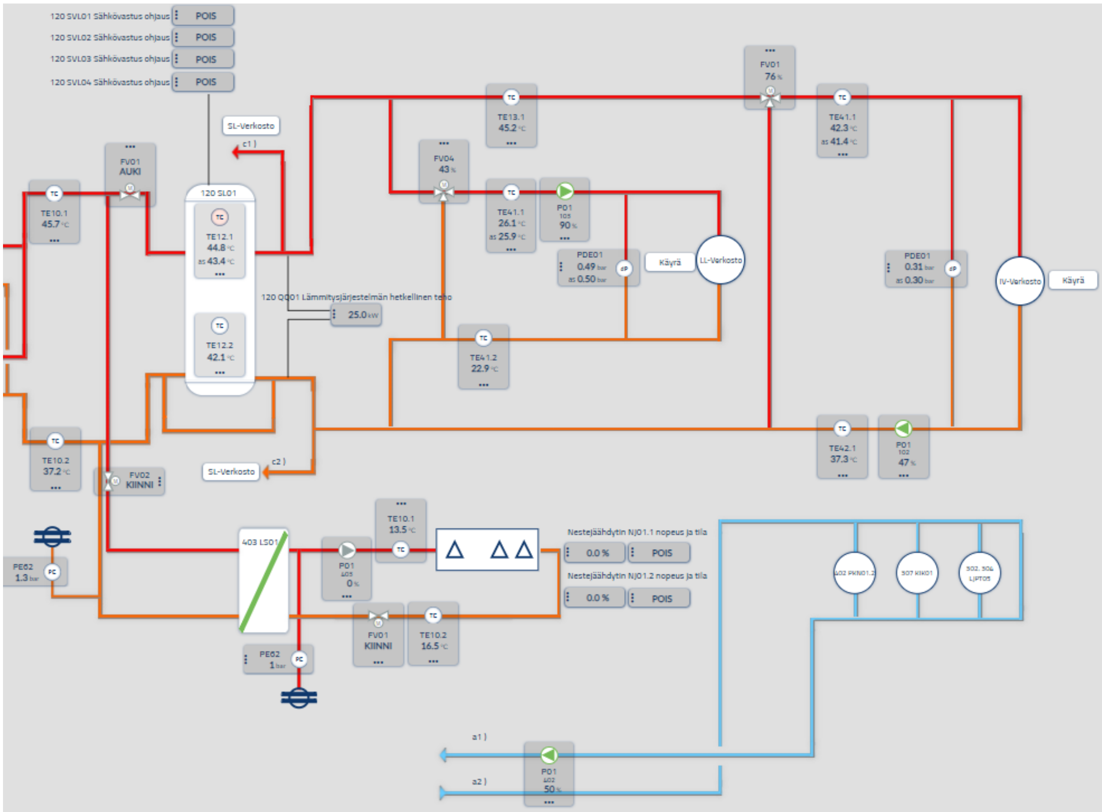
Picture 16. Schedule of outdoor lights.

Heating and cooling system.

The heating system operates through a combination of a condensers, electric resistors, and heat pump combined with collection pipes (geothermal loops). Primarily, heat is generated with the loops combined with the heat pump and condensing the heat from commercial refrigeration systems back into the property’s needs. If the collection pipes heat pump and condensers are insufficient to meet the required heat output, the electric resistors in the water tanks activate progressively to ensure the necessary heat is produced. The program controls the circulation and output of heat through valves, pumps, and resistors. Additionally, excess heat is dissipated from the property’s roof. In winter the heat extracted is replaced by pumping back the cool liquid into the ground loops, which can be utilized in the summer by pumping it back for use in air handling units. Pictures 17 and 18 illustrate the heating and cooling circuit.



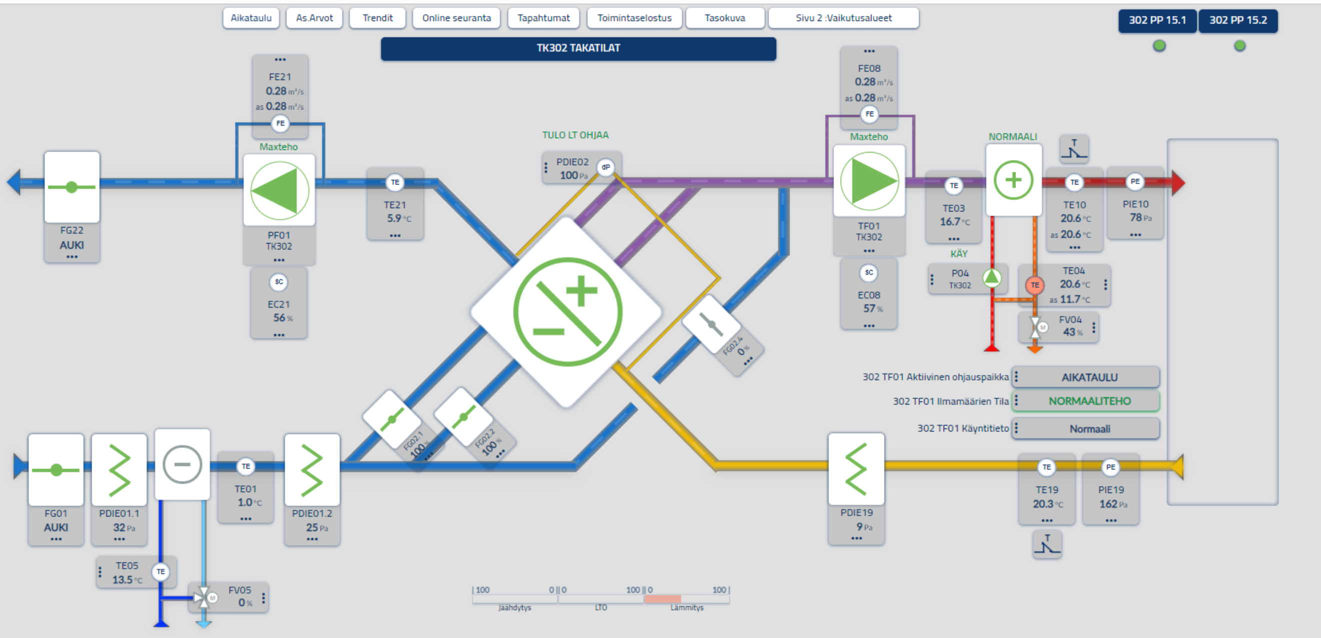
Picture 17. Graphics of the heating system part 1.



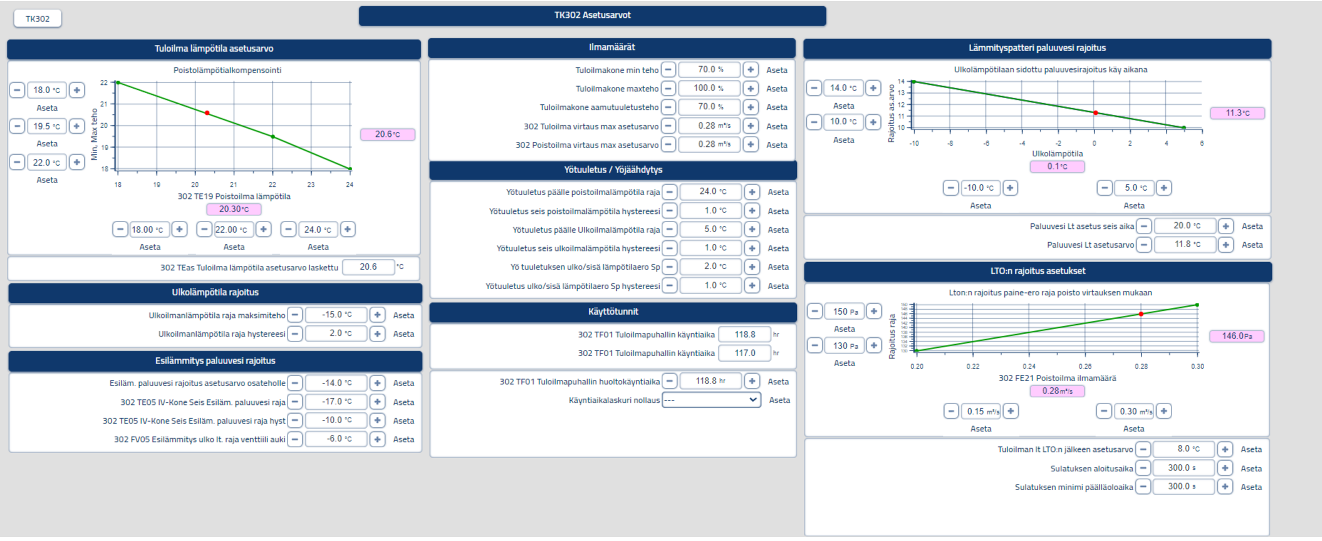
Picture 18. Graphics of the heating system part 2.

7.3 Grafting graphics

The process of drawing graphics began with review of the design plans, enabling an understanding of graphic page requirements. The graphics themselves were created using the Envysion-program. The program comes with its own libraries containing ready-made symbols. However, Caverion also has its own libraries that include the necessary symbols and drawings. Traditionally, graphics depict controls of actuators, status information, measurement points, and control points. The example picture below will give you a good understanding of finished graphics page. As you can see the page can also include buttons which opens a different page for example on the ventilation machine below there is schedules, setpoint list, trends, online tracking, events, operation description, floorplans, effected areas, and fire damper states. Pictures 19, 20, 21 and 22 represent the entirety of the graphics for ventilation machine TT302.

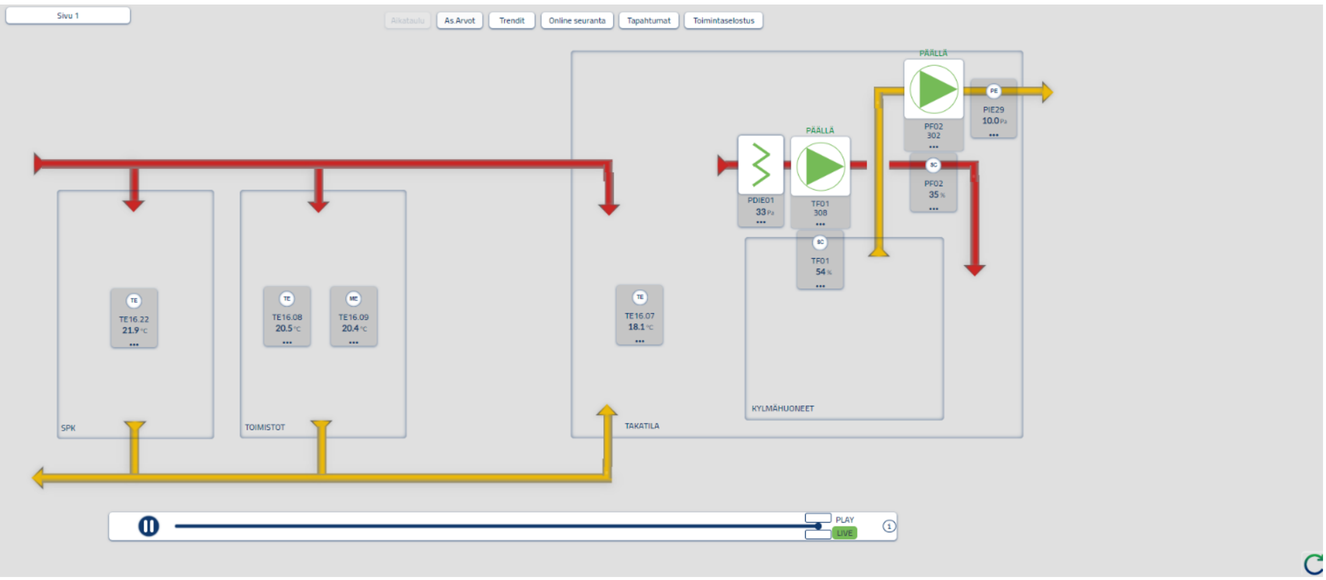


Picture 19. TK302 Graphic page ventilation machine.



Picture 20. TK302 Graphic page setpoint list.

Picture 21. TK302 Graphic page schedule.



Picture 22. TK302 Graphic page affected areas.

7.4 Installation and commissioning

Pre-site arrival and installation

Chapter 7.1 briefly covered cable routing plans and connection diagrams generated with Excel. These are crucial at the start of a construction site, when the electricians (in this case, a separate company) commence cable installation. Generally, after the cable routing plans have been generated, electricians can work independently. However, some sensor and actuator locations may require clarification, and on-site visits for adjustment. Following the cable routing plans, the next step involves ordering the devices and sensors. Once the ordered equipment has arrived on site, the automation installer proceeds to make the necessary connections using the wiring diagram.

Launching the program and software

Once the installation and connections are complete, it is time for the software designer and commissioning engineer to arrive at the construction site. Changes are typically expected both at the software and graphic fronts. On site, the location of the equipment in the graphical representation will be refined and any changes identified. From the software perspective, testing reveals if there are any deficiencies or need for alterations. An important example in this context is the speed controls of the overhead fans. The original software controlled the three speeds by sending notifications for each speed separately, even though the fans require full speed notifications for all lower speeds simultaneously. The software is simulated before arriving at the construction site using invented measurement results and setpoints.

This simulation creates real-life scenarios in the system, and it can be verified that the program functions as required.

Handover of the project

After verifying the functionality of installations, software, and devices, the system is monitored, and the client inspects the site and receives controls of the system. At the same time, the client is trained in the skills necessary for system maintenance and operation to ensure ease of controls for the client. Software and graphic designer are tasked with creating a user-friendly control panel where the purpose of setting setpoint values and labelling the control buttons are clear to the end user.

8 CONCLUSION

The goal of the thesis project was to implement a functional building automation system for a site, leaving the customer with a solution that operates autonomously, maintain the infrastructure of the property as desired and anticipate and report maintenance as they arise.

As a result, the customer got a solution that met their needs, thus the set goal was achieved. Caverion offers a service guarantee on site for two years, which allows Caverion to monitor the project and address needs should they arise.

Initially, the thesis project presented a challenge for me, despite my experience as an electrician and studies of Automation Engineering. Even though my previous work experience and current education did not directly prepare me for the task, they helped me to understand many aspects, such as troubleshooting programming challenges and creating wiring diagrams and equipment lists.

Programming was undoubtedly the most challenging part for me, even though I was already familiar with the Function Block diagram (FBD) programming language. Many functions were designed for devices to operate simultaneously or to override each other based on the importance of the function. Caverion provided a programming library with pre-made blocks for various systems, but often these blocks needed customization for the specific site. However, the most challenging part was understanding the designer’s intentions for the functions and translating them into a functional code.

Nevertheless, the thesis project was diverse and challenging. As the work progressed, I was able to study the subject extensively, which led to a significant learning experience involving building automation and the operation of related sensors and actuators. I believe that the experience gained from this project will enhance my skills and readiness for future tasks and projects.

The outlook for energy-efficient buildings is evolving rapidly. I believe that there will be significant development in building management in the future, thanks to AI programming and the use of sustainable and renewable energy sources in building infrastructure.

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