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RECIRCULATION FILTER DESIGN FOR
WOOD PROCESSING FACTORIES
MSc thesis

The author applies for
the academic degree
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AUTHOR's DECLARATION

I declare that I have written this graduation thesis independently.
These materials have not been submitted for any academic degree.
All the works of other authors used in this thesis have been referenced

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FOREWORD

Graduation thesis topic was proposed by Hekotek AS electro-automation department manager. Topic was chosen in order to implement acquired knowledge for company purposes in which I currently work. Tackling the task I hope to achieve additional experience and knowledge to help with everyday tasks in current company position. Thesis was written in the company mentioned above with assistance from electro-automation department employee. Thesis is based on a new project using information and experience gathered in previous filter projects.
LIST OF ABBREVIATIONS

PLC     Programmable Logic Controller
ATEX    *ATmosphères EXPlosibles* - Two EU directives describing what equipment
        and work environment is allowed in an environment with an explosive atmosphere.
PL      Performance Level
PLr     Performance Level Required
SIL     Safety Integrity Level
MTFF\textsubscript{d} Mean Time to dangerous Failure of the components
DC      Diagnostic Coverage or Direct Current
CCF     Common Cause Failure
PFH\textsubscript{d} Probability of dangerous failure per hour
F       Frequency
P       Possibility
S       Severity
NO      Normally Open contacts
NC      Normally Closed contacts
HMI     Human Machine Interface
CPU     Central Processing Unit
U\textsubscript{n}  Power Supply
I\textsubscript{n}  Nominal Current
I\textsubscript{K}  Short-Circuit Protection
P\textsubscript{n}  Installed power
N       Neutral Conductor
PE      Protective Conductor
I/O     Inputs/Outputs
SM      Signal Modules
TON     Timer on delay
IP      Ingress Protection
1. **INTRODUCTION**

Project on which this thesis is based on is to design, manufacture, assemble and run recirculation filter for wood processing factory in Estonia. Client's problem is large amount of wood waste, dust and chips from wood processing and recirculation filter task is to gather and collect the waste while re-circulating air back to the factory. Thesis is concentrated on electrical and automation part of this filter with thesis author's focus in safety systems.

AS Hekotek is a mechanical engineering company founded in 1992; its main operations include design and production of woodworking technologies and facilities. The company was founded by Finnish specialists who had been for decades working in the field of wood processing. Due to their experience Hekotek has now grown into the largest manufacturer of sawmill and bio-energy sectors equipment in the Baltic region. Beside wood processing sector, Hekotek has also produced and delivered various installations and conveyors for other industrial sectors. [1]

For several years already the turnover of Hekotek exceeds the level of 30 million EUR. In spite of good results already achieved, we go further on the way of sustainable development.

Currently Hekotek employs over 110 people. Hekotek activities in the basic export markets are strongly supported by the local representatives. When producing our equipment we cooperate with several reliable materials sub-suppliers. The production plant has over 5000 m² of manufacturing and storage space; the whole plant area making up approximately 6 hectares. [1]

Hekotek produces and delivers equipment for most of the largest sawmills of the Baltic region, as well as to Finland, Sweden, Russia, Belarus, Poland and Germany. The furthest delivery destination for Hekotek has so far been Republic of South Africa, Argentina and Uruguay. [1]

Hekotek designs and produces equipment for collecting and cleaning the air containing sawdust and fine particles and reversing clean air back to production area. Our recirculation filters enable to optimize production area heating costs, as well as ensure cleaner working environment for enterprise workers. Filters consist of standard units for air volume from 10000 m³/h up to 120000 m³/h, enable to revert hot air fully or partially back to the production area. An example of a working filter is shown in figure 1.1. [1]
Currently in Estonia there are only few companies who sell and service aspiration systems for large wood processing factories, but all of them are out sourcing the whole system which gives our company advantage. Most of the solutions are similar everywhere, the difference comes in programming and experience. Compared to other Estonian competitors Hekotek has the flexibility to adjust to customer needs by having a design department and production plant for manufacturing new solutions or making changes to old ones according to customer feedback. In case customer wants to make some hardware changes we can quickly adjust automation system by reprogramming PLC (Programmable Logic Controller) via remote access.

All of the project schematics are designed in CADS Planner electric which is user-friendly and offers all the required tools at a reasonable price. Siemens TIA Portal was used for programming Siemens controllers. Both of software offer very good user support which is the one of the main reasons for its popularity.

First steps working on this thesis will be learning how recirculation works and how automation has been done in previous projects. There are a lot of European Union standards requirements this filter has to fill and some of those limit our choices for electrical and automation parts.

In current project 100% of the air is returned to the workshop with our 80000 m3/h recirculation filter. Wood processing particles like dust, chips or waste are transported by the exhaust fan in to the recirculation filter. Recirculation filter input lines have non-return flaps
for stopping particles traveling back. Input air is filtrated while traveling through filter bags and is directed in to the workshop. Maximum dust throughput is less than 0.2 mg/m³. All the wood processing particles are collected by the screw conveyor at the bottom of the recirculation filter and directed through rotary valve in to transfer line. Transfer pipeline sends particles into silo using transfer fan. Rotary valve allows 100% of the air to be recycled. Maximum processing particles are rated at 2500 kg/h or 20 m³/h. Silo fill level is possible to see in real-time through internet browser visual interface. Recirculation filter is designed to work with the entire workshop machines or separately. [2]

Recirculation filter and silo are controlled by Siemens S7-1200 controllers. Recirculation filter status is displayed touch screen displays located on electrical cabinet doors. On filter startup there is a sequence to launching. First transfer pipeline is activated, and then filter is starting with initial cleaning sequence for cleaning filter sections one by one according to program. At the same time exhaust fans are starting. Recirculation filter sections are constantly cleaned according to program and cleaning cycle rate and length is changeable manually or automatically. After wood processing operator should turn off the exhaust fan which should turn recirculation filter in to after cleaning mode. Recirculation filter sections will be cleaned according to program and then transfer system is turned off with a slight delay. Delay is required for getting all the wood processing particles out and removing any obstruction possibilities. All alarms can be programmed to be warning or stopping alarms, recirculation filter and silo are equipped with sound and light signals. When temperature rises to dangerous level (usually 70 °C) safety lock activates, fire hatch closes and recirculation filter stops. [2]
2. GROUNDWORK

Every recirculation filter project starts with customer, his wood processing machines and future needs on which whole aspiration system is calculated - filter size, aspiration piping, fan wattage and other components. Filter sizes are standardized by air filtration rate in cubic meters per hour. Transfer piping to silo is calculated according to filter size and wood particles separated. Every conveyor and rotary valve size has a rated volume feed rate on which they are chosen. Some of the wood processing factory output may peak higher than transfer piping is rated - in those cases rotary valve helps to smoothen filtrated wood particles flow.

Recirculation filter is always placed outside for fire safety reasons but as close to factory as possible to decrease the cost of materials for piping and wiring but also to minimize pressure loss due to long piping.

2.1. Main Design

Our standard filter is designed to comply is EVS-EN 12779:2015 „Safety of woodworking machines – Chip and dust extraction systems with fixed installation – Safety related performances and safety requirements“. [7]

Filter consist standard modules (sections) and is built to be installed outside. The filter is supported on strong steel base-frame. Base-frame is fastened to foundation. Maintenance platform, ladders and safety gates are attached to base-frame. The dust and chips from wood processing are transported using pneumatic flow from devices to the filter.

Filtering elements are needle bunched woven polyester bags (16 bags in one section). The cleaned air is returned to manufacturing building or into atmosphere. Service doors, safety gate and other critical components are monitored using sensors for safety reasons. Filter consists of service doors, service platform, summer/winter valves, screw conveyer, air return channel and sub frame as seen on figure 2.3. [6]

Recirculation filter summer/winter hatches are used for directing recalculated air in to atmosphere during summer to stop recirculation filter from heating factory air and directing already heated air back in to the factory during winter.

The recirculation filter is designed in accordance to ATEX 94/9/C Directive. All electric devices are placed outside the risk zone. The devices in the risk zone (screw conveyor and rotary valve) work at low speed and are not an ignition source. The moving parts of transport ventilators are placed farther from the filter. The control hatch at the lower part of the filter and service doors at the upper part of filter are equipped with special fastenings and
weatherproof contacts and act as explosion hatches the same time. The service platform is restricted with gates that stop the filter in case of opening. Additionally the transfer route can be equipped with spark detector and extinguisher. [6]

The explosion relief doors are a protective system for re-circulating modular filter unit (zone 20 inside), relieving by their opening pressure $p_{\text{red, max}}$ from inside area of the filter unit with combustible dust class $k_{\text{st, max}}$. The doors open with the value of their static opening pressure $p_{\text{stat}}$. Thereby explosion pressure is reduced to the value which is lower than the allowable pressure resistance of the protected modular filter unit. The series of modular filter unit with the explosion door for explosion venting located at the cell of the dirty section and also at the cell of the clean section fulfill this condition till the values $p_{\text{red, max}} = 30 kPa$, $p_{\text{stat, max}} = 1,9 kPa$ and $k_{\text{st, max}} = 20 MPa m s^{-1}$. [6]

Figure 2.3 Hekotek Recirculation filter construction [6]
2.2. ATEX

ATEX is mainly two European directives controlling explosive atmosphere:
• The Directive 94/9/EC covers equipment and protective systems intended for use in potentially explosive atmospheres (ATEX). The Directive defines the minimum technical requirements and conformity assessment procedures, to be applied before equipment is placed on the EU market. [5]
• The ATEX 'Workplace' Directive 1999/92/EC deals with the minimum requirements for improving the level of health and safety protection of workers potentially at risk from explosive atmospheres. [5]

Explosive atmospheres can be caused by flammable gases, mists or vapors or by combustible dusts. If there is enough of the substance, mixed with air, then all it needs is a source of ignition to cause an explosion. Explosions can cause loss of life and serious injuries as well as significant damage. Preventing releases of dangerous substances, which can create explosive atmospheres, and preventing sources of ignition are two widely used ways of reducing the risk. Using the correct equipment can help greatly in this. An explosive atmosphere is defined as a mixture of dangerous substances with air, under atmospheric conditions, in the form of gases, vapors, mist or dust in which, after ignition has occurred, combustion spreads to the entire unburned mixture. Atmospheric conditions are commonly referred to as ambient temperatures and pressures. That is to say temperatures of –20°C to 40°C and pressures of 0.8 to 1.1 bar. [5]

To ensure the safety the work process has to be organized in accordance with Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. [6]

2.3. Market analysis

As noted in introduction there are many manufactures in wood waste and chips recirculation filters market segment. We took a look at few competitor filter systems in 80000m³/h range for comparison shown in table 2.1.
As seen in table 2.1 there isn’t much difference between different competitors if 80 000m³/h filter is required. It's hard for others to compete in Estonian market with us because of lesser cost of manufacturing, logistics and better local customer support. Nestro's intermediate filter with shakers is shown in figure 2.2. The main design stays the same and competitors also use rotary valve. Shaking cleaning method may have few advantages depending on wood processing type and surrounding environment but also includes more moving parts and complex design.

![Figure 2.2 Nestro Intermediate filter with shakers](image)

**2.4. Current project design**

As seen in figure 2.1 current project has five aspiration pipelines for collecting wood waste from processing machines and transfer piping to first silo. In total there are two silos, one for loading wood waste on to a trailer and second for feeding boiler system. Both silos are connected so operator can choose what to do with the wood processing waste. It can be burned for heat during winter or loaded on to trailer and stored somewhere during summer. As mentioned in introduction current project 100% of the air is returned to the workshop with
our 80000 m3/h recirculation filter and both the filter and the silo are controlled with Siemens S7-1200 controllers and status displayed with HMI as requested by client.

Figure 2.1 Current project recirculation filter layout with two silos [2]

Main components from layout (figure 2.1):

010 - filter (includes screw conveyor and rotary feeder);
020 - regeneration fans;
030 - rotary feeder;
040 - return piping;
060, 070, 080 & 090 - exhaust fans;
110 - electrical switchboard for filter;
120, 130, 140, 150 & 160 - exhaust piping;
170, 250 - transfer piping;
180, 260 - transfer fan;
190, 270 - silos;
210, 290 - cyclones;
310, 320 - transfer screw conveyors;
330 - electrical switchboard for silo.
2.5. Thesis task

Our task is to design safety and alarm circuits for recirculation while the main part is done by electro-automation department employee and then implement our part in to the final PLC program. Task includes choosing components, writing HMI manual, electrical switchboard inspection and on site startup. Before choosing components we gather knowledge about safety of machinery, do a risk assessment and check components compliance to EN ISO 13849 standard and ATEX directives. Electrical circuits design was done using CADS Planner electric and PLC programming using Siemens TIA Portal as mentioned in introduction.
3. SAFETY OF MACHINERY

Safety of machinery is regulated by EN ISO 13849 which divides in two parts - first defining general design principles and second describing validation. EN ISO 13849 is the new replacement for EN 954-1 standard which was used till 31.12.2011. Designers can also use EN 62061 instead of EN ISO 13849 for designing safety functions in protection system in order to provide sufficient reliability. EN 62061 defines the structures slightly differently. [9][10][11]

Difference between EN ISO 13849 and EN 62061:

- EN ISO 13849 uses PL (Performance Level) which is a technology-neutral concept that can be used for electrical, mechanical, pneumatic and hydraulic safety solutions;
- EN 62061 uses SIL (Safety Integrity Level) that can only be used for electrical, electronic or programmable safety solutions.

Since we have no preferences set by the customer and use mechanical safety solutions as well as electrical we chose to use EN ISO 13849 which uses PL. PL is measure of reliability of a safety system and is divided into five levels (a-e). PL level e gives best reliability and is equivalent to that required at the highest level on risk. [9]

To calculate system PL level following requirements must be met [9]:

- Knowing the system's structure;
- Knowing MTFF\textsubscript{d} (Mean Time to dangerous Failure of the component);
- Knowing the system's DC (Diagnostic Coverage);
- Protecting the system against a failure that knocks out both channels (CCF);
- Protecting the system from systematic errors built into the design;
- Following rules to ensure software can be developed and validated correctly.

The five PL levels (a-e) correspond to certain ranges of PFH\textsubscript{d} (probability of dangerous failure per hour) values, in calculation PFH\textsubscript{d} provides more accurate results because PL is a simplification. To minimize calculation error ABB products have pre-calculated PFH\textsubscript{d} values and ABB offers a freeware calculation application. [9]

Anyone who builds or modifies a machine is required to perform risk assessment for the machine design and also include an assessment of all the work operations that need to be performed. A risk assessment begins with determining the scope of the machine. This includes the space that the machine and its operators need for all of its intended applications, and all operational stages throughout the machine’s life cycle. Risk assessment is made according to figure 3.1. [9]
All risk sources must then be identified for all work operations throughout the machine’s life cycle. Risk estimation is made for each risk source, i.e. indication of the degree of risk. According to EN ISO 13849-1 the risk is estimated using three factors: injury severity (S, severity), frequency of exposure to the risk (F, frequency) and the possibility you have of avoiding or limiting the injury (P, possibility). For each factor two options are given. Boundary between the two options is not specified in the standard but is commonly interpreted: [9][10][11]

S1 - bruises, abrasions, puncture wounds and minor crushing injuries;
S2 - skeletal injuries, amputations and death;
F1 - less frequently than every two weeks;
F2 - more often than every two weeks;
P1 - slow machine movements, plenty of space, low power;
P2 - quick machine movements, crowded, high power.

Risk estimation scheme is shown in figure 3.2 [9]
For recirculation filter based on previous risk analysis we estimate severity of injury to be serious, exposure to hazard less often and possibility of avoiding hazard to scarcely possible leaving us with performance level $PL_{r} = d$.

ABB RT9 24DC (product ID 2TLA010029R0000) universal safety relays are used in safety circuits which falls into safety category 3, $PL_d$ (because we're using dual channel two normally open contacts). This means our safety relay category fits our needs perfectly. In order to achieve category 4 there is need to have two channels that can cut the power to the machine individually so incase of dual channel NO contacts would need to wire ABB RT9 relay for use for dual channel on normally open and on normally closed contacts which would result safety cat 4, $PL_e$. In current case individual failures do not result in any loss of safety function. ABB RT 9 relay maximum $PFH_d$ is rated at $9.55E-09$. [9]

ABB CEPY1-2001 emergency button has two NC (normally closed) contacts that allow it to fit safety category 3, if one of the contacts fail it will still be able to stop the recirculation filter. Figure 3.3 shows relationship between categories.[9]
According to risk analysis and switchboard location in addition to emergency stop button located at switchboard we add additional emergency stop buttons near recirculation filter where there is easy access. Near every electrical motor we have safety switch for making maintenance safer.

All maintenance hatches have magnetic sensors to detect hatch opening so that filter cannot be started while filter bags are visually checked. Magnetic sensors SMS02 are used in this project, they have normally open and normally closed contacts and are suitable with ISO 13849-1 category 4. [10]

Alarm sirens and indication lights are built in to notify factory workers as soon as possible, all alarms are logged into PLC and recirculation filter cannot be started without high level alarms.

### 3.1. The choice of components

Main factor for choosing component manufacturer is prior experience in reliability, durability and client specifications from the contract. Our electrical switchboard subcontractor is using ABB components which is why we use it in our circuit diagrams and have great experience so far. Siemens programmable logic controller (PLC) and human machine interface (HMI) is used for controlling filter process if not stated otherwise in the contract. Component parameters are chosen by application. In current project main component for automation is Siemens S7 1200 controller defined by contract, before starting with schematics all information should be gathered from project leader and project layout. When main layout drawing is confirmed we can start calculating short circuit currents, voltage drop and calculated power. To keep project budget down all cables are manually selected and ordered to calculated length. Cable type depends on number of signals and voltage drop.
Siemens S7 1200 (seen in figure 3.4) is a basic controller for compact automation systems, we're using controller with CPU1214C which has 24 integrated input/outputs and can be expanded by one signal board, eight signal modules and three communication modules. Siemens S7 1200 controller with CPU1214C has six fast counters (three with max 100 kHz and three with max 30 kHz). CPU1214C is the midrange option for our controller, it has the most integrated input/outputs without any unneeded options, of course 24 integrated inputs/outputs is not enough for this project and expansion modules have to be used. Controller used in recirculation filter program is chosen DC/DC/DC which means the controller supply voltage is DC (Direct Current), inputs are DC and outputs are DC. [8]

![Siemens S7 1200 controller](image)

Figure 3.4 Siemens S7 1200 controller [8]

ABB offers various safety relays like JSB series, BT series and RT series. The JSB series consist of specialized safety relays for e.g. two hand devices with dual channel synchronization. The BT series consist of safety relays designed to connect safety devices, such as emergency stops, directly in the voltage supply circuit to the relay. Despite a compact width of 22.5 mm the relays are very powerful. These relays can also be used as expansion relays for Pluto to increase the number of outputs. The RT series consists of universal relays that have the most common functions used in safety situations. These safety relays can supervise both your safety devices and the internal safety of your machinery. In addition you can select the safety level required for each installation. We've chosen RT series for our application. Three relay models are available with the main difference in output type and count. ABB RT9 safety relay with 2 NO (normally open) relay outputs is best fit for our needs, it can be configured for dual channel input and both channels are monitored for correct
operation before resetting (configuration seen in figure 3.5). When configured to use dual channel with two normally opened contacts, both input contacts (s14 and S34 in figure 3.5) must be closed before relay output is activated. If one of the input contacts opens the output contacts will open. A manual reset requires reset input to be closed and opened before activating safety relay outputs. [9]

![Figure 3.5. ABB RT9 dual channel 2 NO wiring [9]](image)

Emergency stop buttons are chosen from ABB product line. For mounting outdoors and indoors we've chosen ABB CEPY1-2001 emergency button which has IP66 enclosure rating (dust tight and protected against powerful jets of water). This safety switch uses two normally closed contacts so if one of the contacts fail while emergency stop button is activated a relay will not activate. Safety switch is seen in figure 3.6. [16]

Sensors - to ensure safety of machinery service doors and safety gate are monitored. After previous experience with optical sensors in our company we had problems with optical sensors in price point where we currently use magnetic sensors. For magnetic sensors our supplier offers Carlo Gavazzi magnetic sensors with two models, SMS-01 and SMS-02. These sensors only difference is in operating distance as seen in figure 3.7, we're using SMS02 model just because it is not always possible to mount sensors and magnets within 10mm range in our application. [13]

![Figure 3.7. Carlo Gavazzi magnetic sensors specification [13]](image)

For silos we're using full detector from UWT. Model RN4001 sensor is has a rotating plastic housing with rope extension for vertical installation and adjustable sensitivity (technical data

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figure 3.8). If the rotation stops the recirculation filter is stopped and alarm signal is sent to operator. RN4001 sensor has ATEX II certificate which means it's intended for use in explosive atmosphere and category II stands for use in surface industries. Detector housing is rated dust tight and protected against low pressure water. [14]

![Figure 3.8 UWT RN 4001 technical data](image)

Silo filling level is measured with UWT Nivobob 3200 series sensor, this is done in order to give operator information and empty silo before its full and recirculation filter is stopped. This sensor from UWT has also ATEX II certificate and is housing enclosure rating is IP66. Technical data is shown in figure 3.9. [14]
Screw conveyor below recirculation filter has a bearing housing in direct contact with wood waste so in order to meet ATEX regulations we have a PT100 temperature sensor inserted in bearing housing for monitoring. If temperature reaches higher than 70°C the recirculation filter is shut down. PT100 technical data is shown in figure 3.10. [15]
4. SAFETY CIRCUIT DESIGN

Safety circuit is designed according to Safety of Machinery standard ISO 13849 and Equipment Safety Act. Components are chosen based of chapter 3 and 3.1. Electrical installation data is shown below in Table 4.1 and Table 4.2. [10]

Table 4.1 Electrical installation data for switchboard 1025EK1

<table>
<thead>
<tr>
<th>Power supply</th>
<th>$U_n=400/230V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Current</td>
<td>$I_n=380A$</td>
</tr>
<tr>
<td>Short-Circuit protection</td>
<td>$I_k=10kA$ (calculated short-circuit current $\sim 8.3kA$)</td>
</tr>
<tr>
<td>Installed power</td>
<td>$P_n=190kW$ ($\cos \phi =0.82$)</td>
</tr>
<tr>
<td>System</td>
<td>TN - S (not directly earthed)</td>
</tr>
</tbody>
</table>

Table 4.2 Electrical installation data for switchboard 1025EK2

<table>
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<tr>
<th>Power supply</th>
<th>$U_n=400/230V$</th>
</tr>
</thead>
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<tr>
<td>Nominal Current</td>
<td>$I_n=63A$</td>
</tr>
<tr>
<td>Short-Circuit protection</td>
<td>$I_k=10kA$ (calculated short-circuit current $\sim 1.6kA$)</td>
</tr>
<tr>
<td>Installed power</td>
<td>$P_n=32kW$ ($\cos \phi =0.82$)</td>
</tr>
<tr>
<td>System</td>
<td>TN - S (not directly earthed)</td>
</tr>
</tbody>
</table>

Power supply is specified in client contract and is according to EVS-EN 60038:2012. Nominal current $I_n$ is calculated with adding together electrical motors nominal current seen in table 4.3. 1025EK1 is the main switchboard for whole filter, silo switchboard 1025EK2 is connected through switchboard EK1025EK1 so that for nominal current only electrical motors 9-17 are included in calculation.

Short-circuit protection $I_k$ can be calculated using information gathered from client (main power cable type, length and installation, transformer apparent power, fuse type and location), to avoid human errors we're using software "Lühisvoolud" to calculate as seen in figure 4.1 and figure 4.2. Short-circuit current calculation has two objectives - determination of the maximum possible short-circuit currents helps to check wiring and apparatus short-circuit withstand capability and determination of the minimally possible short-circuit currents helps to check safety components effectiveness. For the first object 3-phase short-circuit current is calculated in the closest point to provide the highest current, the second objective short-circuit is calculated for single phase at the end of the line to get the lowest current. Symmetrical three-phase simplified short-circuit current can be calculated with formula 4.1. [17]
\[ i = \sqrt{2} I_p \sin \left( \omega t - \frac{\pi}{2} \right) + \sqrt{2} I'' e^{-\frac{t}{\tau}} = i_p + i_a \]  

(4.1)

where \( i_p \) - short-circuit periodic component current value,
\( i_a \) - short-circuit aperiodic component current value,
\( I_n \) - short-circuit periodic component effective value,
\( I'' \) - short-circuit periodic component initial effective value,
\( \tau \) - circuit electromagnetic time constant,
\( t \) - time.

Short circuit calculated is lower than 10kA so our switchboard subcontractor uses components to withstand minimum of 10kA short-circuit by default. 10kA short-circuit components are more widely used and lowers the switchboard cost than using a 5kA short-circuit switchboard for instance. Installation power \( P_n \) can be calculated adding together power specification from
electrical appliances data sheets, efficiency factor is also specified in electrical appliances data sheet. Darker rows in table 4.3 show appliances that are used in switchboard 1025EK2.

Table 4.3 Electrical appliances data [18] [19]

<table>
<thead>
<tr>
<th>No.</th>
<th>Motor application</th>
<th>$P_n$ (kW)</th>
<th>$I_n$ (A)</th>
<th>Cosf</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Filter screw conveyor</td>
<td>2,2</td>
<td>4,6</td>
<td>0,80</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Regeneration fans</td>
<td>2,2</td>
<td>5,0</td>
<td>0,79</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Rotary valve</td>
<td>1,1</td>
<td>2,5</td>
<td>0,79</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Exhaust fan 1</td>
<td>37,0</td>
<td>67,0</td>
<td>0,85</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Exhaust fan 2</td>
<td>30,0</td>
<td>54,5</td>
<td>0,85</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Exhaust fan 3</td>
<td>22,0</td>
<td>41,5</td>
<td>0,85</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Exhaust fan 4</td>
<td>11,0</td>
<td>21,0</td>
<td>0,85</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Transfer fan 1</td>
<td>11,0</td>
<td>21,0</td>
<td>0,85</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Silo 1</td>
<td>4,0</td>
<td>8,0</td>
<td>0,82</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Rotary valve between cyclone and silo 1</td>
<td>0,8</td>
<td>1,7</td>
<td>0,79</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Rotary valve for transfer piping</td>
<td>0,8</td>
<td>1,7</td>
<td>0,79</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Store bunker</td>
<td>3,0</td>
<td>6,2</td>
<td>0,81</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Transfer fan 2</td>
<td>11,0</td>
<td>21,0</td>
<td>0,85</td>
<td>1</td>
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<tr>
<td>14</td>
<td>Silo 2</td>
<td>4,0</td>
<td>8,0</td>
<td>0,82</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Rotary valve between cyclone and silo 2</td>
<td>0,8</td>
<td>2,1</td>
<td>0,65</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Transfer screw conveyor to heater</td>
<td>2,2</td>
<td>4,6</td>
<td>0,80</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>Transfer screw conveyor for unloading</td>
<td>4,0</td>
<td>8,0</td>
<td>0,82</td>
<td>1</td>
</tr>
</tbody>
</table>

Earthling system info is given by client. TN-S system is widely used in Europe and has neutral conductor (N) and protective conductor (PE) separated as seen in figure 4.3. [12]

![Figure 4.3 TN-S System](image)
Switchboard is designed in metal enclose with IP54 protection level (IP68 for control switches and signal laps). Switchboard is installed vertically to the wall with only one service side. Door is lockable without a handle and power-coated in RAL 7032. All the cable entries are from above. All the conductors have to be numbered yellow or black by the terminal point connection number and 20% of spare space is required for future installations.

4.1. Switchboard 1025EK1 and 1025EK2 safety circuits

Appendix A.1 switchboard 1025EK1 circuit page 2, the safety circuit part begins at switchboard where the filter is controlled. On Switchboard door there is an indication light for emergency, emergency stop button with twist release and emergency reset button to the far right (figure 4.4).

![Figure 4.4 Appendix A.1 switchboard 1025EK1 circuit page 2](image)

Appendix A.1 switchboard 1025EK1 circuit page 5 and 6, emergency stop buttons have two NC contacts, one of the contacts is in serial connection with the safety relay port S14 and when activated ABB RT9 safety relay removes all power from the control circuit. Second contact from each emergency stop button goes in to input module so we can monitor which button was pressed. Input E0.1 monitors if contactor is activated. Secondary safety function is controlling last three controller modules on with connection 5/18:B (figure 4.5).

![Figure 4.5 Appendix A.1 switchboard 1025EK1 circuit page 5](image)
Appendix A.1 switchboard 1025EK1 circuit page 7, emergency reset button is connected to input module and emergency LED (light-emitting diode) is connected to output module. Process is controlled by PLC program and in normal working conditions the LED is turned off (figure 4.6).

Figure 4.6 Appendix A.1 switchboard 1025EK1 circuit page 7

Appendix A.1 switchboard 1025EK1 circuit page 8 and 9, SMS-02 magnetic sensors are in serial connection through a junction box and used as an input to the controller module. In this case just one of the magnetic sensors is needed to be triggered for shutting down the whole recirculation filter.

Appendix A.1 switchboard 1025EK1 circuit page 10, 21, 22, 28 and 29 for controlling the gear motor a regular module is used because gear motor feedback is monitored with contactor. Motor protection switch and safety switch are connected to the input module. Output module controls gear motor via PLC program (figure 4.7).
Appendix A.1 switchboard 1025EK1 circuit page 10

Motor protection switch is connected to the input module. Safety relay is not used, motor feedback is monitored with contactor (figure 4.8).

Appendix A.1 switchboard 1025EK1 circuit page 11-20, motor protection switch is connected to the input module. Safety relay is not used, motor feedback is monitored with contactor (figure 4.8).

Appendix A.1 switchboard 1025EK1 circuit page 23-27, electronic softstarter wiring diagram for our transfer pipeline fan. If safety switch 120Q1 is turned on then PLC gets information from input E5.5. Turning on motor protection switch sends signal to relay 120K4. Relay 120K4 NO contact closes and sends power to contactor 120KM1 and power to electronic softstarter 120U1. This only powers up the softstarter, in order for it to start transfer pipeline
fan 120K3 and 120KM1 need to be activated. Activation signal to relay 120K3 is sent via program from PLC output Q13.5
Appendix A.1 switchboard 1025EK1 circuit page 33, fire hatch NC contacts are connected to input module.
Appendix A.1 switchboard 1025EK1 circuit page 34, screw conveyor bearing housing temperature is monitored using PT100 sensor. Sensor resistance rises with temperature, this information is transferred through analog module extender to plc analog input and is later converted into degrees (figure 4.9).

Figure 4.9 Appendix A.1 switchboard 1025EK1 circuit page 34
Appendix A.1 switchboard 1025EK1 circuit page 37, PLC output controls relays K444 and K445 that activate the blinker and the siren (figure 4.10).

Figure 4.10 Appendix A.1 switchboard 1025EK1 circuit page 37
Appendix A.2 switchboard 1025EK2 circuit page 17, silo full detector pendulum shaft stops turning when wood waste reaches it, sends info to PLC input E1.4 and stops the recirculation filter. Silo level control sends pin down, calculates the fill percentage and sends information to PLC via input E1.5 (figure 4.11).

Figure 4.11 Appendix A.2 switchboard 1025EK2 circuit page 17
5. PROGRAMMING PLC

If electrical schemes are ready and all the information is marked up we can start the plc programming part. Our task was to add safety circuits and alarms to the program.

First we have to check:

- How many alarms we need to describe
- What types of alarms we need to describe
- How many safety circuits inputs do we have

After that we set up I/O (inputs/outputs). Then we can start writing a data block for reading information. We gather all the information in to the data block and give each input a memory address which is used to make programming easier (figure 5.1). Memory bits are used in together as words (in Siemens PLC data types 1 word is made up of 16 bits) this saves up programming time.

![Figure 5.1 mdef datablock](image)

When data blocks are ready and alarm inputs have assigned to each memory address we can start using them in program. We add alarms to HMI (Human Machine Interface) alarms table. Memory addresses are classified and each memory address is given an alarm text (for example exhaust fan 1 engine safety switch is triggered) shown in figure 5.2.
Finally alarm screen is created where recirculation filter operators can read and reset alarms for this we need to create a platform that reads alarm memory statuses from data blocks shown in figure 5.3 and alarms classification in figure 5.4. Alarms are saved with description of the alarm and alarm time.
Main safety logic is shown in figure 5.5 where we can see that in order to start the filter (set motor control bit M5.0) all the safety switches and motor protection switches must be activated and none of the emergency stop buttons, service doors, fire alarms or screw conveyor bearing temperature bit is set. After one of these conditions fails filter start bit is reset through negation logic.

For safety reasons a little timer on delay is added into the control logic (figure 5.6).

Safety reset button SB01 as seen from switchboard 1025EK1 circuit (Figure 4.6) input E0.5 is marked I0.5 in TIA Portal, as we can when triggered it activates output Q0.0 and Q0.2 that resets RT9 relays on 1025EK1 circuit page 6 and page 8 because both of these RT9 relays require manual reset before its outputs can be activated after emergency. Also reset button sets memory bit M5.1 so that the system knows reset was pressed (figure 5.7).
Input I0.0 (E0.0) and I0.1 (E0.1) from switchboard 1025EK1 circuit page 6 shows if emergency stop safety relay outputs are activated. This emergency stop safety relay outputs operate PLC last three control modules (Figure 4.5) and maintenance hatches safety relay input. Since both of these outputs are switched simultaneously, if one of the emergency stop buttons is pressed or anything else happens these outputs are switched off and memory bit M211.5 will be set and emergency stop will be activated (figure 5.8).

Maintenance hatch safety relay RT9 that is controlled by magnetic position sensors and when one of the hatches is open safety relay contact Y14 which is internally closed to 0 V when RT9 is not reset and memory bit M211.6 will be set. Memory bit M211.6 will set its contact to keep memory bit activated until reset button is pressed. Y14 is internally closed to +24V when relay is reset (figure 5.9).

When first fire hatch temperature sensor reads high temperature that may lead to explosion (+70°C) the hatch closes, and sends info to input I0.7 that sets alarm bit which needs to be reset before restarting the filter (figure 5.10)
Converting temperature is done by measuring temperature with the PT100 sensor which has output range from converting current from 4 to 20 mA. Analog input for controller is used with a range from 0 to 27648 that is converted to a temperature in Celsius, if temperature exceeds allowed temperature (from the manual) for screw bearing a memory bit M212.3 will activate and keep it activated until reset (figure 5.11).

Motor controlling is done with a little sub program, in the alarms block are all the alarms listed and if any of them are active then no signal is going to motors control block and none of the motors will be turned on (figure 5.12).

A large proportion of the programming can be written in user blocks that can be used for many motors just by specifying block inputs and outputs. For example motor error blocks that wait for some time (set in TON) for the contactor feedback after motor has been powered on.
to see if it starts. When no feedback from contactor is received an error is set and depending on filter component the whole system may be stopped (figure 5.13).

Figure 5.13 User block for motor feedback in TIA Portal
6. SWITCHBOARD INSPECTION

After the whole circuit for recirculation filter is designed and inspected by department manager it's sent to subcontractors with components to be assembled. After subcontractor finished assembling switchboard it will be inspected by our electro-automation department workers. Switchboard inspection is divided in several parts:

- **Visual inspection** - checking that every component is according to designed circuit, all fuses and circuit breakers match calculated value, wiring is straight and all covers are in place.
- **Short-circuit inspection** - whole circuit is inspected with a tester, all circuit breakers are inspected in both positions
- **Power up** - after short-circuit inspection switchboard is turned on.
- **PLC and SM communication** - to save time on working site programs are loaded, settings configured and communication established.
- **Circuit inspection with simulating filter work process** - after our entire program is loaded and communication working we should test it by simulating various switches and sensors to check if our program is working as it should.

After finishing these inspection points the final adjustment to the program will be made on working site, inspection prior to sending switchboard to working site can save a lot of time and gives time to make last minute changes if some problems are found.
7. **ON SITE STARTUP**

Preparations begin with feedback from installation crew 2-3 days ahead. We got to make sure all the required components and installation materials are on site and everything is set up before heading out. Since most equipment manuals are in English there are always few problems installing new type of sensors so installation crew has to be on site on the day of startup to eliminate any installation mistakes made or make quick changes.

If everything is ready and installation crew is waiting we head out with the required tools. Everything starts with visual inspection of installation:

- checking if installation is according to layout;
- checking if there are any cables, sensors or buttons need to be relocated;
- checking cables (correct cross-section and marking).

After visual inspection we must check for short circuit just in case (during the transport or installation a lot can happen). Startup begins with checking if the motors are working and rotate in the correct direction. The hardest is to check if regeneration fan rotates in the correct direction because of its location, the only way is to climb up and check near the return pipe. If regeneration fan rotates in the wrong direction filter bags will quickly become clogged. After all the motors are working and rotating in the correct direction the installation crew can be sent home, this gives an advantage to listen every motor one by one checking for various problems like bad bearing.

When we load the ready program we have to make some minor network changes depending on local network and even after that there are almost every time some changes need to be made. First we check if every motor can be started from touch screen panel and if it turns in the correct direction. Second we setup an algorithm based on clients request with changeable variables for later adjustments. After all of the programming project leader inspects if everything is working according to clients request and if he's satisfied hands it over to the client.

Final stage is filter operators training according to user manual. If everything works and training is complete then our job is one.
8. USER MANUAL

8.1. General overview

Control modes - There are two options for controlling main recirculation filter apparatus
- Manual mode - apparatus works independently from others;
- Automatic mode - apparatus works along with others according to PLC program.

Emergency stop - Emergency stop buttons are located on switchboard door and near working components. If emergency stop button is activated the filter will stop.

In order to re-start recirculation filter after emergency stop users needs to:
- Find the reason why emergency stop was activated, and deactivate emergency stop button if problem is eliminated;
- Press emergency reset button;
- Turn on one of the waste exhaust fans (any waste exhaust fan).

Emergency stop button is only for emergency use!

Safety switch - electric motors that use safety switch can be disconnected from power source if required. Safety switches are not intended for switching appliance on/off in normal operating state. Safety switches are only for use when devices are turned off from the operating panel or when an emergency situation requires it.

All safety requirements must be followed during equipment maintenance, unauthorized personnel operations must be prevented. During maintenance and repairs recirculation filter must be stopped from the operation panel and corresponding device safety switch must be switched to position "0" and locked in position with a padlock. Repairing devices that do not have a safety switch recirculation filter must be stopped from the operation panel and switchboard main switch must be switched to position "0" and locked in position with a padlock.

Switching devices on-off can be done from operating panel. Restoring power does not automatically activate recirculation filter. Alarms can be reset by pressing "Häire reset" button on switchboard door or by operating panel. During alarms blinker is turned on indicating an alarm and it stays on while situation is active.
8.2. Recirculation filter working principles

When recirculation filter is turned off and no alarms are active the filter can be started by pressing "Puruventilaator start" button on switchboard door.

During recirculation filter startup following conditions must be met:

- emergency stop switches are deactivated;
- all explosion hatches are closed;
- all fire hatches are closed;
- all maintenance hatches are closed.

Startup is blocked if one of these conditions is not met, if during recirculation filter working one of these conditions fail the filter will be stopped, blinker and siren will be turned on and problem will be displayed on operating panel.

To start filtration system one of the exhaust fans should be started, this activates transfer fans. Transfer fans have some time to empty transfer piping before rotary feeders are activated. Rotary feeders have also some time to empty before screw conveyor activates. Screw conveyors empties filter from settled particles. After filter cleanup exhaust fans are starting and filter is ready for use. During startup green indicator lamp "Filter Sisselülitatud" is blinking. After the cleaning process green indicator will stay on.

Regeneration fans launching conditions:

- transfer fans are working;
- rotary feeders are working;
- screw conveyor is working.

Regeneration fans cleaning cycle:

- Initial cleaning - after recirculation filter startup when wood waste is properly working an initial cleaning will start. Initial cleaning lasts 90 seconds during which all regeneration fans are sequentially activated. Regeneration fan is activated for two seconds, there is two seconds pause and next regeneration fan is activated for two seconds.
- Normal operation cycle - while recirculation filter is working regeneration fans are activated after every three minutes during 57 seconds. Sequentially all regeneration fans are activated for two seconds, with two seconds pause before next fan is activated (similarly to initial cleaning cycle).
- Cleaning after shut down phase one - starts when filter is stopped. Phase one lasts for five minutes during which all the regeneration fans are sequentially activated for 2 seconds, with four seconds pause before next fan is activated.
• Cleaning after shut down phase two - starts after phase one. Phase two lasts for five minutes during which all the regeneration fans are sequentially activated for 4 seconds, with four seconds pause before next fan is activated.

Exhaust fan launching conditions:
• transfer fans are working;
• rotary feeders are working;
• screw conveyor is working;
• recirculation filter is working.

Exhaust fan can be manually started with the following green start button and stopped with a red stop button.

Exhaust fan is stopped if
• critical recirculation filter error occurs;
• power loss.

Filter is stopped if none of the transfer fans are working for a set period of time (time can be adjusted from operating panel). Transfer piping system is stopped only after shut down cleaning phase one and two are done.

Recirculation filter is stopped immediately if:
• critical recirculation filter error occurs;
• power loss.

8.3. Using operating panel

Operating panel (figure 8.1) is used for:
• displaying system alerts;
• displaying devices status;
• devices configuration (restricted access);
• system parameters configuration.
### Figure 8.1 Operating panel

**Recirculation filter controls**

<table>
<thead>
<tr>
<th>Button</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Home screen</td>
</tr>
<tr>
<td>F2</td>
<td>Summer/winter valves</td>
</tr>
<tr>
<td>F3</td>
<td>Devices and functions selecting</td>
</tr>
<tr>
<td>F4</td>
<td>Alarms</td>
</tr>
<tr>
<td>F5</td>
<td>HMI Panel settings</td>
</tr>
<tr>
<td>F6</td>
<td>Selecting devices and functions</td>
</tr>
<tr>
<td>F7</td>
<td>Selecting devices and functions</td>
</tr>
<tr>
<td>F8</td>
<td>Other settings</td>
</tr>
<tr>
<td></td>
<td>Previous tab</td>
</tr>
<tr>
<td></td>
<td>Next tab</td>
</tr>
<tr>
<td>FILTER</td>
<td>Filter home screen</td>
</tr>
<tr>
<td>Tapasipuhke Idapid</td>
<td>Summer/winter valves manual control</td>
</tr>
<tr>
<td>KÄSITSE JUHTEMINE</td>
<td>Manual control of filter motors for maintenance or manual filter startup</td>
</tr>
<tr>
<td>ALARMID</td>
<td>Alarms</td>
</tr>
</tbody>
</table>
8.4. Manual control of filter motors

Manual control is shown in figure 8.1, "ON" button activates motor in manual mode and the button starts to flash, "OFF" turns manual mode off and setting lets user configure timer parameters. "Tööaeg" configures for how long the motor will be turned on, "Seismise aeg" configures time how long motor will wait after start command to turn the motor on and "Tagasiside aeg" configures how long the program will wait for the motor feedback after giving start command.

![Figure 8.2 Filter motors manual control in HMI](image)

8.5. Filter settings

Filter settings are divided into four main categories (figure 8.2):
- Filter cleaning settings
- HMI panel settings
- Time settings
- Other settings
Figure 8.3 Filter settings control in HMI
Filter control is based on timers so filter cleaning settings lets user configure time for startup cleaning cycle, working cycle and shutdown cycle including time between cycles, regeneration filter working time and pause time, screw conveyor time (figure 8.3).

Figure 8.4 Filter cleaning settings control in HMI
A HMI panel setting has two functions, panel cleaning and calibration. Panel cleaning disables touch screen for 30 seconds for user to clean HMI panel which is essential in wood processing factories. Screen calibration calibrates automatically with no further user input required (figure 8.4).
Figure 8.4 HMI settings

Time settings give user option to set local time which is later useful for checking alarm times. Other settings (figure 8.5):

- Filter shutdown timer - time after last fan has been switched off.
- Screw conveyor bearing maximum temperature - sets temperature maximum temperature after which filter is shut down (fire hazard)
- Siren maximum time
- Blinker maximum time

Figure 8.5 Other settings in HMI
8.6. Alarms

All alarms and warnings are displayed in HMI alarms screen (figure 5.3). "Aktiivsed häired" shows all active alarms that have not been reset. If alarms stay in active window after alarm reset then it means alarm is still active. "Häirete ajalugu" shows history of alarms, history can be cleared with "delete" button.
SUMMARY

Information gathered from previous recirculation filters helped to achieve the required task. Using requirements specified by client in contract we designed and programmed safety and alarms portion of the filter control system starting from risk estimation. Risk estimation was done to choose components to fit required category for safety of machinery which is controlled by EN ISO 13849 standard and our performance level was estimated at "d". Components were chosen according to required safety of machinery standard performance level, ATEX certification and IP rating. Safety relays were used in critical electrical circuit control parts to ensure safety performance level. Electrical circuit safety and alarms part was designed according to task, inspected and later tested on site to ensure everything was working the way it should be.

PLC programming part was later added to main program successfully whiteout any complications. HMI panel gives filter operator feedback on filter working process and if any emergency stop or safety switches are pressed filter operator can see from HMI panel where, what and when it happened. As with every program we have made a simple user manual with visual aid.

In conclusion recirculation filter was working according to contract and client was satisfied with the end result. Topic helped to implement acquired knowledge for company purposes and tacking the task gave additional experience and knowledge to help with everyday tasks is current company position and future projects.
KOKKUVÕTE

Antud projekt valmis vastavalt kliendi poolsetele nõudele, millest selles töös käsitleti turvaahelate ja häirete osa elektriskeemides ja nende integreerimises kontrolleri lõpp programmi.

Vastavalt standardile EN ISO 13849 hindasime antud seadme riskitasemeks "d". Vastavalt riski tasemele valisime turvaahela komponendid ning nende ühendusviisid (RT9 turvareele puhul). Komponentide valikut jälgisime ka ATEX direktiividele vastavust, ilmastikukindlust ja meie põhiliste tarnijate tootevalikut.

Elektriskeemide projekteerimise osas arvestasime kliendi poolt tarnitavate komponentidega. elektrikilbi tellimisel valmistati see majanduslikel põhjustel suuremale lühisvoolule kui arvutuslikult vaja kontrollides samal kaitse rakendumist.

PLC lõppprogrammi alarmide ja turvaahelate integreerimisel probleeme ei esinenud. Filtri operaatorile visuaalse tagasiside jaoks on kliendi poolt nõutud HMI paneele, millest on võimalik jälgida lisaks erinevatele mootorite seisunditele ja häirete tabelile näiteks ka tigukonveeri laagri temperatuuri reaalajas. Häirete tabelis kuvatakse hetkel aktiivseid olevaid häireid (mida pole lähtestatud) ja ka häirete ajalugu, igal häirel on juures ka häire tekkimise aeg. Filtri paneeli kasutamiseks on koostatud ka kasutusjuhend ja kõik filtri operaatorid koolitatakse välja antud kasutusjuhendi põhjal filtriga töötama.

Kokkuvõtteks võib öelda, et seatud eesmärgid said täidetud ja klient on rahul. Antud töö käigus sai rakendatud omandatud teadmisi, saades juurde vajalike kogemusi ka edaspidisteks projektideks.
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APPENDICES

Appendix 1. Electrical switchboard 1025EK1.
Appendix 2. Electrical switchboard 1025EK2
Appendix 3. PLC Program
Appendix 4. Electrical switchboard
Appendix 5. Controls on switchboard door
Appendix 6. Filter after installation
Appendix 1 Electrical Switchboard 1025EK1

7 Telljupa poolt tennitavad seadmed
5 Pehmekiviiti
   Kontroller, paneel ,lisamoodulid
   Safety relay RT9  2tk

8 1025EK1 juurde kuuluvad jaonised:
   1025EK1

9 Selgitus:
   Address 3 numbrit: 1025EK1/3/4
      l. kardinaal( jaonise ülemine rikk)
      l. pare
   Address 2 numbrit: 3/4
      l. kardinaal( jaonise ülemine rikk)
      l. pare
   Address 1 numbrit: 1
      l. kardinaal( jaonise ülemine rikk)
      l. pare

6 Määrused
   Kõik jätta ruumi 20% üles toimetada jaonite küünlite väljalõikumine (relaede, kaitsevastuvad, kontaktorite jne väljalõikumine)
   Iga kiemel on ligi 20% ruumi võimalus. Teist poolt isoleerida jätta samuti 20% ruumi.
   → sellistel tähendustel on võimalik leida lõikusid võimalikud kiimed muutumise osas.
   Kõik kiimendid tuleb uuesti siirdada võimalikult sisseloodetavate kordade vahel.
   Kõik kiemelid on peatud ja ka oksiditud kõrvalt kiimed.
   Kõik kiemelit on peatud ja oksiditud.
   Kõik kiemelit on peatud ja oksiditud.
   Samuti peab olla kiimedid ti kes on kaatri võttes edaspidi muudetud.

5 Signaaliparaatri
   Kontrolleride ja pealejäävaid jaonite jaonite parameetritest.

4 Tõhusus
   1. Gliisasseadet jätmet
   2. Tõhusad jaonised

3 Koesüsteemise taotlus
   1. Välischeid
   2. Selleks
   3. Saadakse

2 Elektroonikatööstus
   1.1 Nõunik
   1.2 Nõunik
   1.3 Vastupihade läbi
   1.4 Mõõdetavad alad
   1.5 Juriidilist väärtus

1 Elektrotööstuse andmed
   Vm = 300 V
   Ia = 150 V
   B = 10 kA
   P = 150 kW (o.e. 0,82)

Hekotek OÜ
Peetri Puit 04
80000m3/h

Tehniline ülesanne

Projekt nr. 09-01 09-33 09-34
Mikser nr. 1025EK1 1035
Vajamine 1/49

1025EK1
Re-gasification ventilaator 7
Positsioon 020.07
80000 m³/h

Regeneratsiooni ventilaator 7
1025EK1
Appendix 2 Electrical Switchboard 1025EK2

7 Tellija poolt tarvitavad seadmed

- Controller, panel lisamoodulid
- Safety relay RT9 1tk

8 1025EK2 juurde kuuluvad joonised:

1025EK2

9 Sisulisad

Address 1 number
1025EK2/3/4

3 kohtlised osad

1.1 Nõngaküps
1.2 Nõngaküps
1.3 Lõikuvõime läbisaha
1.4 Lõikuvõime läbisaha
1.5 Juhtliiku dütseem

2. Ehituskliud endmed

2.1 Hankese tall
2.2 Kolnaasrõd
2.3 Polüpositsioon Sondłe
2.4 Kerimislae Sondłe
2.5 Dekolux
2.6 Lõikuvõime läbisaha
2.7 Pinnisrõd

3. Koostikenduste teostus

3.1 Tall
3.2 Lõikuvõime läbisaha
3.3 Pinnisrõd

4. Töötledus

4.1 Juhtliiku dütseem
4.2 Lõikuvõime läbisaha

5. Signaalparameeter

104032

6. Nõukodu

7. Tellija poolt tarvitavad seadmed

- Controller, panel lisamoodulid
- Safety relay RT9 1tk

8 1025EK2 juurde kuuluvad joonised:

1025EK2

9 Sisulisad

Address 3 numbrit
1025EK2/3/4

3/4

Address 2 numbrit

4

9.1 Mõned

1. Tall
2. Lõikuvõime läbisaha
3. Pinnisrõd
4. Signaalparameeter

10. Nõukodu

11. Tellija poolt tarvitavad seadmed

- Controller, panel lisamoodulid
- Safety relay RT9 1tk
90
Appendix 3. PLC Program

PLC Program is presented on Compact Disc.
Appendix 4. Electrical switchboard
Appendix 5. Controls on switchboard door
Appendix 6. Filter after installation