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Automatization of a grain dryer

Thesis

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Thesis abstract

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The purpose of this thesis was to modernize a grain dryer control system designed in the 1970s. A new grain dryer control system was designed because the old system was functionally uncertain and fault diagnosis was difficult.

In the thesis it was found out how the current grain dryer works, a logic control was designed, and electrical pictures, wiring diagrams, images and center for the logic were drawn. The implementation of the plan was postponed and it will be done within two years after the completion of this thesis.

Keywords: automation, PLC-logic, electrical planning

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Tämän opinnäytetyön tarkoitus oli modernisoida 1970-luvulla suunniteltu viljakuivurin ohjauskeskus. Viljakuivurin ohjaus haluttiin suunnitella uudestaan, koska vanha järjestelmä oli toiminnaltaan epävarma ja vikadiagnostiikka vaikeaa. Työssä selvitettiin nykyisen viljakuivurin toiminta, suunniteltiin viljakuivurille logiikkaohjaus, piirrettiin sähkökuvat, kytkentäkuvat ja keskuskuvat sekä luotiin logiikalle ohjelma. Suunnitelman toteutus jäi myöhempään ajankohtaan ja se toteutunee kahden vuoden sisällä opinnäytetyön valmistumisesta.

Avainsanat: automaatio, PLC-logiikka, sähkösuunnittelu

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USED TERMS AND ABBREVIATIONS

Start-Delta switch	Motor switch that decreases motor's starting current to delta by accelerating motor with a star- connection
Threshing	Collecting grain from the field
PLC	Programmable Logic Controller

1 INTRODUCTION

Grain drying season is a very short period of time, which takes only a few weeks per year, but it has a great impact on the whole farm's profitability. Problems with the dryer are usually noticed at the beginning of the drying period, when the grain drying starts. Depending on the quality of the problem repairing may take a long time and drying is carried out with the dryers of other farms, which may be expensive. For this reason, the dryer's functionality should be secured by using the latest technology.

This thesis was written for a small farm, which needed dryer's electrical renovation. The dryer's problem has been reliability and the control system's old age. The dryer is used to dry the farm's own grain, but also the neighboring farm's grain, so reliability should be guaranteed. The dryer has been upgraded in the recent years from outside, imported two new silos have been moved next to dryer building and the heating system has been modernized. The next update for the dryer is the modernizing of the electric and control systems.

2 THEORY OF GRAIN DRYING

Finland has a long tradition of grain production. The grain has been a multi-commodity, it has been a source of food for humans and animals and in the middle ages it served as currency when paying taxes. Threshing was made by hand, first cropped with a sickle shaft to sheaves and then the sheaves were taken into drying barns to be dried. Grain sheaves were set on the rods high near the ceiling and then it was started to heat the barn. The barn was getting warmer and filled with smoke, drying and disinfecting grains so that they would preserve. Heating the barn was risky because flammable dry sheaves ignite easily and the barn burns as well as the next winter's food with it. After drying the grains were separated from the sheaves, for example the threshed rye sheaves were beaten to the wall so that the grains fell to the floor next to the wall. The grains were then separated from the chaff by throwing grain from one wall to the other where only the grain flew to the wall on the other side of the room and chaff and other debris fell during the fly into the middle of the room. Another common way to separate the sheaves and grain was to hack the sheaves with a two-piece stick called "varsta" which lead to same result. Seeds were sorted for sowing and grinding, straws were fed to the animals or used as mattress' stuffing. People's quality of life depended on harvests. Sometimes there were good years when there was enough food for the winter whereas sometimes the food ran out. (Näri 1987.)

In the 1800s threshing machinery was getting common. The grain threshing cage was a cage with new features, like suitable working height, and instead of using the two-piece stick they began to use smaller and lighter stick. Another new invention was a horse powered grain cleaning system called "Viskuri" where the grains were cleaned with the fan and sieve. Viskuri was Finland's most common agricultural machine in the early 1900s. (Savolainen & Niemi & Tiilikainen 2015.)

Along with the development the drying room changed to a drying cabinet and in the 1930's a heat-proof cabinet was placed into the drying cabinet's ceiling where the cabinet's heated air went through the sheaves into the sky. This warm air flow was a more efficient way to dry sheaves than passive heating. (Näri 1987.)

The modern grain drying system was created in the late 1930s when the drying silo was built from stacked wooden boxes and the furnace heated hot air passed through drying the grain. They used a grain elevator to circulate grain from the grain hopper to the top of the silo. The new overpressure grain dryer type was supposed to be a fireproof invention, but in reality the fires were still a common problem. (Näri 1987.)

2.1 NATURAL AIR AND WARM AIR DRYERS

In Finland 80% of grain dryers are warm air grain dryers. They are based on externally heated warm air which is sucked or blown through the heat exchangers, whereby warm air binds the grain moisture. After that the cool, humid air is directed out of the dryer. In the warm air dryer the air usually circulates in the dryer so that grain germination and characteristics as food will not suffer. If the grain doesn't circulate, hot air flow burns the grain and the grain cannot be used anymore as seeds or food. The most common fuel in these dryers is oil. (Posio 2013, Suomi et al 2003.)

In the natural air dryer grain is dried with unheated air. This method is slower than the warm air drying and drying grain in Finland with this method in the usually humid autumn may take a long time, because cool air doesn't bind as much moisture from the grain as the warm air does. The natural air dryer's expenses are much smaller than in the warm air dryer because the grain doesn't have to move during the drying process and the fuel is not consumed for heating. Natural air dryers are often used during the warm days of late summer and also as pre-dryer before the warm air dryer. This way the warm air drying time is reduced and fuel saved. The benefit of natural air dryer is also that the threshed grain doesn't decay in this dryer as easily as in the cart when waiting for proper drying. (Suomi et al 2003, Hautala & Jokiniemi & Ahokas 2013.)

2.2 VACUUM AND OVER PRESSURE DRYERS

In over pressure grain dryer heated air mass is blown through the grain. This method is the most common, but it has the disadvantage of dustiness. Over pressure drying

technology is now increasing being replaced with vacuum drying because of better efficiency and profitability. (Suomi et al 2003.)

In a vacuum dryer heated air is drawn through heat exchangers by centrifugal fan. Because the air is drawn through the grain, drying is almost free of dust. Vacuuming the grain also removes mold spores from the grain. Warm under-pressured air absorbs more moisture than over-pressurized air. The manufacturers of vacuum dryers often allow to use a constantly higher drying temperature than with over-pressured dryers because drying facilities are free of dust and vacuum reduces the risk of fire. Increasing the drying air temperature from 70 degrees to 100 degrees reduces fuel consumption by 10-15% and because of that the vacuum dryer is a better choice for new drying facilities. (Seppänen 2000, Suomi et al 2003.)

2.3 THE MEANING OF GRAIN DRYING

Grain has to be dry to ensure long-term storage of grain and to maintain the characteristics of grain. The two main factors in the grain's preservation are the storage temperature and grain moisture percentage. Grain has to be dried to a moisture content of about 14 percent to prevent mold spores to evolve and to prevent decay, while retaining the grain germination characteristics when it is used as a seed. 14 percent moisture is also used as a moisture limit in trade because wetter grain is a great risk of decaying in the long-term storages (Figure 1.). Drying under 14 percent is unnecessary because the grain drying requires a lot of energy, the benefits achieved are very small and germination of seed grain gets worse. (Suomi et al 2003, Ahokas & Jokiniemi 2015.)

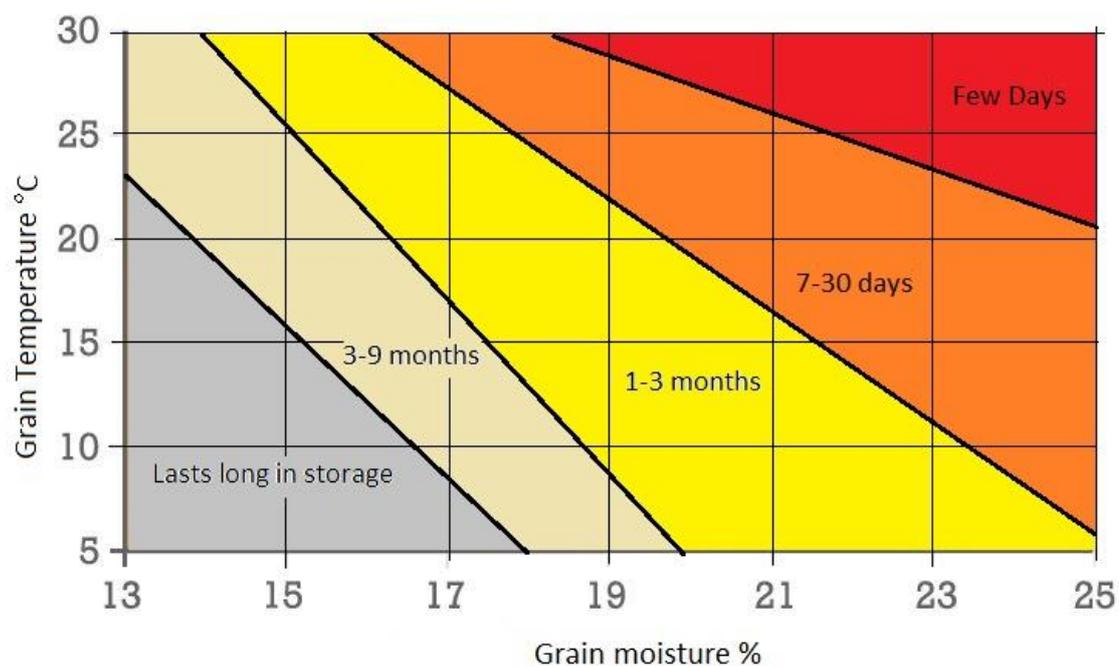


Figure 1. Grain moisture and temperature effects when stored (Ahokas et al 2015.)

3 THE FARM'S GRAIN DRYER

This farm uses the old Antti-Teollisuus's in the 1970s made 170 hectoliter Aitta-Jaakko- dryer. To current location the dryer (Figure 2.) has been moved in 1998 and two metal-sheet silos has been added to the dryer complex increasing the total storage capacity by 360 cubic meters while the dryer's dumping hopper capacity is 20 cubic meters. The dryer facility was bought from to the current owner in 2007 and in the same year the old heater was replaced to a new Antti-Teollisuus's A330 oven. Later two smaller silos were added to the dryer complex with total volume of 72 cubic meters. The Control Center is Maansähkö Oy's 1970s designed original control unit, which operates with clocks and relays. The problem with the old center is that the fault occurs the diagnostic is very difficult for the lack of information and components age.



Figure 2. Farm's dryer

Antti-Teollisuus's A330 heater is located at the rear of the dryer in a separate room so dust doesn't interfere with its operation. Heater in connection with 7.5kW fan and Oilon Oy's KP-26 H-II 2-flame burner. Clearing of the silos is done with three

conveyors, one them transfers the grain from the small silo to the dumping hopper where the elevator moves it into the dryer. Another small silo is cleared by second conveyor to the larger silos' conveyor and from there to elevator. Cleaning of the large silos are done with conveyor under the large silos. Smaller silos are filled up by changing the position of the 3-way distributor above the grain dryer complex and filling up the large silos is done by changing the distributor and with the conveyor above the silos. Using the conveyor above silos is necessary, because the roof is too low for right inclination angle and we have to use external power. Small silos' conveyors are Jussi-Tuote's M150 and bigger silos' conveyors are Sami 140-models.

3.1 GRAIN DRYING PRINCIPLE

Before the start of the drying dryer must be filled with grain. Grain is dumped to the dumping hopper. The hopper is designed so that grain will drain into cavity where the elevator is to elevate grain on top of the whole grain dryer complex on which the grain drain through the 3-way distributor into the dryer. When the dryer is full the hopper scuttle is closed and drying can be started.

This dryer's type is over-pressured warm air dryer. The fan draws outside air into the dryer and blows it through the heater. The burner sucks the fuel from the outside tank to the burner and the burner is regulated by its own operations trying to keep the dryer going at a constant temperature of 80 degrees. Air enters the dryer from side of the heat exchangers. There the air passes through the channels of the heat exchangers to the other side absorbing moisture from the grain. The other side of the heat exchangers cooled moist air is conducted out of the dryer. Grain dryer circulates the grain in dryer so that grain goes through the dryer once in hour. When the grain is dry enough, the burner is turned off and grain circulates in dryer few hours. When grain and oven have cooled down whole process shuts down. The grain is then unloaded from the dryer with elevator to 3-way distributor where the storage is selected by changing the distributors location.

3.2 FILLING THE DRYER

When the dryer needs to be filled, elevator and pre-cleaner buttons are pushed from the old center's control panel (Figure 3.) and the dumping hoppers scuttle needs to be opened. Grain is dumped into the hopper, where the elevator carries grain to the 3-way distributor. When the dryer is full the grain drain from the overfilling protection scuttle back to the dumping hopper along the pipe. Then the dumping hopper's scuttle need to be closed and elevator's and pre-cleaner's buttons must be turned off. Motors shutdown reduced motors' current peaks to the overall power grid when the actual drying starts.



Figure 3. Old control center

First appropriate drying time for the fan's clock need to be set. The cooling time needs to be taken account when determining the fan's operating time. Then the burner's operating time is set and it's normally few hours shorter than the fan's operating time. Then the star-delta switch (Figure 4.) is set to the middle position and the motor starts accelerating. Switch has to be kept manually in this position for a few seconds and after that turned to the final position. Reason for this kind of starting method is that the starting current is reduced to almost half of motor's normal starting current where using only on/off- switch gives too big current peak and burns the fuses.

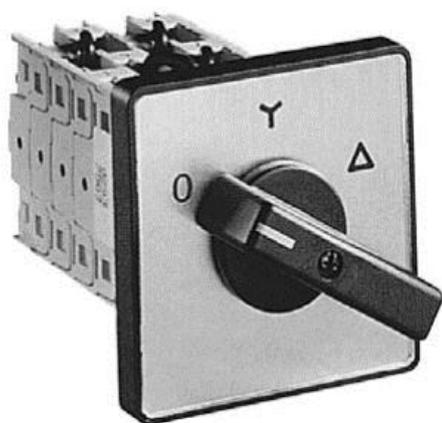


Figure 4. Star-Delta Switch

Next step is to start engines alternately from their own buttons in the following order: pre-cleaner, elevator, floor cleaner and feeder. When the feeder is switched on the grain runs slowly through feeder rollers to the bottom of the dryer where the elevator is lifting grain up again. Actual drying happens in the middle of the dryer where the wider side profiles are located. The feeder rotates at a constant speed and grain circulation speed is dependent on the size of the grain. The elevator guard follows elevator's speed and gives an alarm when the elevator is running too fast or too slow. When the burner clock's time runs out, dryer start cooling the system. Dryer cool down for about two hours and when the fan clock runs out of time, all motors are turned off except the elevator that goes off with a small delay to prevent clogging.

3.3 CURRENT SYSTEM'S PROBLEMS

When the control panel was designed in the 1970s it has been made to work with that time's hardware. Over the decades, the center has been added some equipment and made some own modifications, after all, no one knows what is really happening in terminals and the color-coded wires can't be trusted. Center's bulbs are no longer working and the fan may turn off during cooling without any reason. There is no wiring diagram of the center and if a problem occurs the diagnostics is very hard.

The feeder works all the time with the same speed so the grain circulation speed is fully dependent of the grain type. Air humidity sensor needs to be calibrated from time to time and the amount of air to the fan needs to be regulated mechanically with scuttle when the outside temperature is too low. To these problems we are going to find a solution when new center's designing begins.

4 NEW CONTROL CENTER

Customer's wish was to get the automatic programs for filling and drying. To dryer's own silo the ultrasonic sensor will be installed, which recognizes the grain surface to the right height, then stops filling and start drying. While operating the dryer should monitor the exhaust air's temperature and to initiate the automatic cooling when the temperature is high enough. After cooling, the dryer should shut down itself to the standby mode. The old humidity sensor will be replaced by a temperature sensor.

Fan's sudden shutdown problem was also important thing to pay attention to. If the fan goes off while the heater is still hot shortens the heaters operating-life considerably and in the worst case, melt the entire oven to unusable condition. The electricity distribution grid shutdowns and errors should also be taken noticed when designing the program for the new system.

Constant-speed feeder was wanted to be speed-controlled device so that the circulation time can be adjusted to specific grain type. The frequency converter was the obvious solution for this problem. The frequency converter is going to be placed inside the center and the potentiometer will be set to the center's door. From there the speed of the feeder can be changed without opening the center's door.

The fan is controlled in the old system with star-delta switch. This switch was decided to replace with a soft starter, because the frequency converter is quite expensive because the size of the motor and fan speed don't needed to be changed. Soft starter limits the starting current to desired value and start the engine without the high current peaks to the electrical distribution grid and the user doesn't need to manually start the motor which enables auto-startup from the logic.

The current manually-operated hopper shutter was decided to replace with manually tuned, but the logic triggered model. The idea was that the above the shutter flange is mounted about 20 kg of weight and the gravity force closes the shutter. Above the shutter is installed the pulley and vertically moving pedal and pressing the pedal the shutter will open. The pedal is locked down using an electromagnet under the pedal, which can be controlled with 24VDC. Normally, the magnet should be turned on and when the shutter is desired to close by the program the magnet is turned off and the

flange is released to close the shutter. Near the mechanism will also be installed a manual button, which also releases the pedal manually from the magnet. Under the pedal and next to magnet will be installed an inductive sensor which gives pedal's status information to the logic. This shutter mechanism cost about 150 euros, when real hopper shutters like linear motors and spindle motors cost 500 euros to 1000 euros so the savings are significant.

4.1 COMPONENT SELECTION

In this chapter example component selection has been made. It's not necessary to use exactly these components, but the specifications should be the same. The selected components are found from these websites: <https://www.elfaelektroniikka.fi> and http://www.finnparttia.fi/kuvat/fp_hinnasto.pdf. The main criteria for the chosen components were the price and ability to prevent dust.

4.1.1 LOGIC CONTROL

The old control system is almost manual, operated by buttons and timers. When the new center was started to design, became very quickly clear that the new center would be a logic-controlled entity. Programmable logic controllers (PLCs) are designed for small or medium-sized enterprises to control and replace the clocks and timers, so that unnecessary hardware can be lopped off from the control center. The logic controls advantages are graphical and easy to use interface, versatility, connectivity and functions of a real-time monitoring so changing and improving functions is quick and easy. The sensors can be connected directly to the logic to give real time information about the state of process so the intelligent automatic system can be built.

When the device manufacturer was started to choose the first criterion was the price. Programmable logic prices start at around 100 euros and the most expensive PLCs costs few thousands euros. For the dryer control a smaller logic would be fine and it can be extended to the required size with extension modules. After searching and comparison Siemens's LOGO! - small logic controller (Figure 5.) was the best choice

for this use. The logic of the basic version includes eight digital inputs and four digital outputs, the device has a small digital display, four programmable buttons and Ethernet- interface in the stock version that makes possible to remote access and control via the Internet. The LOGO! - Logic costs only little bit over hundred euros and offered the same features as several hundred euros more expensive models. Because of the large number of inputs is going to be needed in the system so the basic version is not going to be enough and we have to buy several extension modules.



Figure 5. Siemens LOGO! 8 Press picture

The greatest amount of inputs to one LOGO! - logic is 24 digital inputs and eight analog inputs. Similarly, the maximum number of digital outputs is 20 and eight analog outputs. To control the dryer system it was calculated the needed of 24 digital inputs, three analog inputs and 15 digital outputs, so it was necessary to expand the basic version with two DM16- additional modules which gave 16 digital inputs and outputs and with two AM2- modules, which increased number of analog input to four. From analog modules one was chosen to support the PT100 and PT1000 – standard, which are intended for monitoring the temperature and the other module with 0-10V or 4-20mA for normal analog signal detection. All modules operated with 24VDC for safer handling and lower risk of fire. Module outputs was chosen to work with transistor technology, because their intended light use. Transistor Technology's benefits are longer life expectation, single cable functionality and faster action compared to relay systems. (Siemens 2015a, Siemens 2015b.)

4.1.2 SENSOR SELECTION

Sensor selection was influenced by dryer's dustiness and the price. Temperature sensors were selected SS45-300 type sensors with operating range of -45 degrees to 180 degrees. Temperature sensors needed to be PT100- standard type sensors, so that they fitted directly to one of the analog modules and easy to configure from the program. The sensors were placed in the supply air pipe before the drier and the air pipe after the dryer. The drier silo's surface monitoring was designed to be done with an ultrasonic sensor, because dustiness of the space and the serviceability ruled out all other sensor types. The sensor was selected to be UA 30 C 35 PK- type sensor having an operating distance of 250mm - 3500mm and the sensor gives 0 - 10V feedback signal linearly with the surface depending on the height. This analog signal fitted directly to one of the analog modules as planned. To 3-way distributor's and the hopper's status sensors were chosen to be four E2A-M12KN08-WP-B1 2M- inductive sensors with an operating voltage of 10-32VDC, M12 mounting and equipped with a two-meter cable. The sensors' detecting distance was 8mm.

4.1.3 MOTOR PROTECTION SWITCHES

Motor protection switches are used commonly in the 1- and 3-phase motors direct starting and stopping, short-circuit protection as well as the engine overload control. As a starter motor protection switch is used only in the individual household and agricultural equipment, such as cutters and water pumps. In industry motor protection switch and contactor combinations are very often used together, because the combination's controllability. If a fault occurs, where short-circuit protection and overload protection is triggered, the fault must be acknowledged from the button on top of the motor protection, before operations can continue. Motor protection switches were selected according to engine power (Table 1.).

Table 1. Motor Protection Switch selection

Motor	Current	Motor protection switch		
		Model	Control area	Aux. Contact
Precleaner	4,7A	SMS 6,3	4-6,3A	SMS APU
Fan	15,2 A	SMS 16	10-16A	SMS APU
Elevator	7A	SMS 10	6,3-10A	SMS APU
Floor Cleaner	2A	SMS 2,5	1,6-2,5A	SMS APU
Feeder	1,2A	SMS 1,6	1-1,6A	SMS APU
Burner	2,5A	SMS 4	2,5-4A	SMS APU
L. silos up conv.	4,8A	SMS 6,3	4-6,3A	SMS APU
L.silos low conv.	4,8A	SMS 6,3	4-6,3A	SMS APU
A-silo conv.	4,8A	SMS 6,3	4-6,3A	SMS APU
B-silo conv.	4,8A	SMS 6,3	4-6,3A	SMS APU

Each motor protection switch was added to the SMS APU auxiliary contact (1 NC- and 1 NO- contact), from where the error signal can be imported to the logic. (Mäkinen & Kallio 2004)

4.1.4 DC POWER SUPPLY AND ELECTRICAL MAGNET

For the 24VDC control circuit one Mean Well's DRP-240-24 Power Supply was selected. Power supplier's input voltage is 230VAC and output is 24VDC for the coil control, sensors and the logic. Power supply efficiency is between 72-89%, maximum current 10A and there is an integrated short-circuit, overload, over-temperature and surge protection. To protect the power supply one ABB S201-B16-circuit breaker was chosen to cut off the current peaks over 16A. For the Center's main switch one ABB OT25 was chosen and it also works as the main fuse.

For the dumping hopper's shutter's electrical magnet Kuhnke HT-D40-F-24V100%-model magnet was selected, with a holding strength of 400 N and the power of 6 watts. Magnet runs with 24 VDC and is controlled either manually by pressing the button in the center's door or by the changeover switch which is activated by the PLC.

4.1.5 CONTACTORS

Contactors were selected (Table 2.) according to the power of the motor and the coil voltage was 24VDC. All contactors were chosen from the Siemens Sirius- series and they are normally open- type contactors. All the motors' contactors were selected to be similar except for the fan's contactor. This is important because in case of a fault the contactors can be tested with each other and they are interchangeable (Figure 6.). The burner does not need a contactor to the center, because it has its own contactor in the control circuit and the feeder is controlled by the frequency converter.



Figure 6. Siemens Sirius Contactor 3RT20151BB41 Press picture

Table 2. Contactor selection

Motor	Power	Contactor Model	Switching power
Precleaner	2,2kW	Siemens Sirius 3RT20151BB41	3kW/400V
Fan	7,5kW	Siemens Sirius 3RT20181BB41	7,5kW/400V
Elevator	3kW	Siemens Sirius 3RT20151BB41	3kW/400V
Floor Cleaner	0,75kW	Siemens Sirius 3RT20151BB41	3kW/400V
L. silos up conv.	2,2kW	Siemens Sirius 3RT20151BB41	3kW/400V
L.silos low conv.	2,2kW	Siemens Sirius 3RT20151BB41	3kW/400V
A-silo conv.	2,2kW	Siemens Sirius 3RT20151BB41	3kW/400V
B-silo conv.	2,2kW	Siemens Sirius 3RT20151BB41	3kW/400V

In addition one Murr Miro 52005 changeover switch was chosen to control the magnet of the dumping hopper's shutter.

4.1.6 SOFT STARTER AND FREQUENCY CONVERTER

As the fan's soft starter was chosen the Siemens Sirius- series 3RW3018-1BB04-model soft starter. Starter's acceleration time is from 0 to 20 seconds, power is 7.5kW / 400V and max current is 17.6A. The starter will be adjusted so that the starting current will not exceed 10A.

The feeder's frequency controller was selected from the Yaskawa V1000- series TM 0.25 V- model (Figure 7). Since the feeder motor is only 0.25kW, frequency converter with 1-phase power supply was selected to use, which was about half cheaper than the equivalent three-phase power supply. For frequency converter zero, phase and earth will be delivered but the frequency converter outputs 3-phase power to the motor. Frequency converter will be set to the center next to the contactors and to the center's door is fitted with a potentiometer for the speed control.



Figure 7. Yaskawa V1000 frequency converter

The frequency converter's power supply comes through the EMC-filter to meet the standard EN61800-3. EMC-filter removes interfering frequencies to supply network which comes from the frequency converter. Inside the frequency converter a current throttle will be installed to stabilize the DC circuit's supply changes and it's

mandatory for less than 1 kW frequency converters to meet the standard EN61000-3-2 requirements. The cable between the frequency converter and the feeder motor has to be shielded against outside magnetic disturbance. (Yaskawa 2015, Hedman 2009.)

5 ELECTRICAL PLANNING

Old electrical plan was the base for the new plan. There was no longer a proper drawings of the old electrical plan so lot of research was done to find out how the current system works. Using the logic for the system control made electrical planning easier, because all the functions was made with the program and not with relays, timers and clocks. Now all physical program functions were transferred to the logic, the electrical design pays attention to the motors power supply and control circuit connections.



Figure 8. Power Supply

After the main fuses the DC power supply supplies the logic's operating voltage and the inputs voltage (Figure 8.). The circuit breaker is installed next to the DC power supply to protect it. The power supply contains a built-in short circuit and overload protectors for the 24VDC circuit.

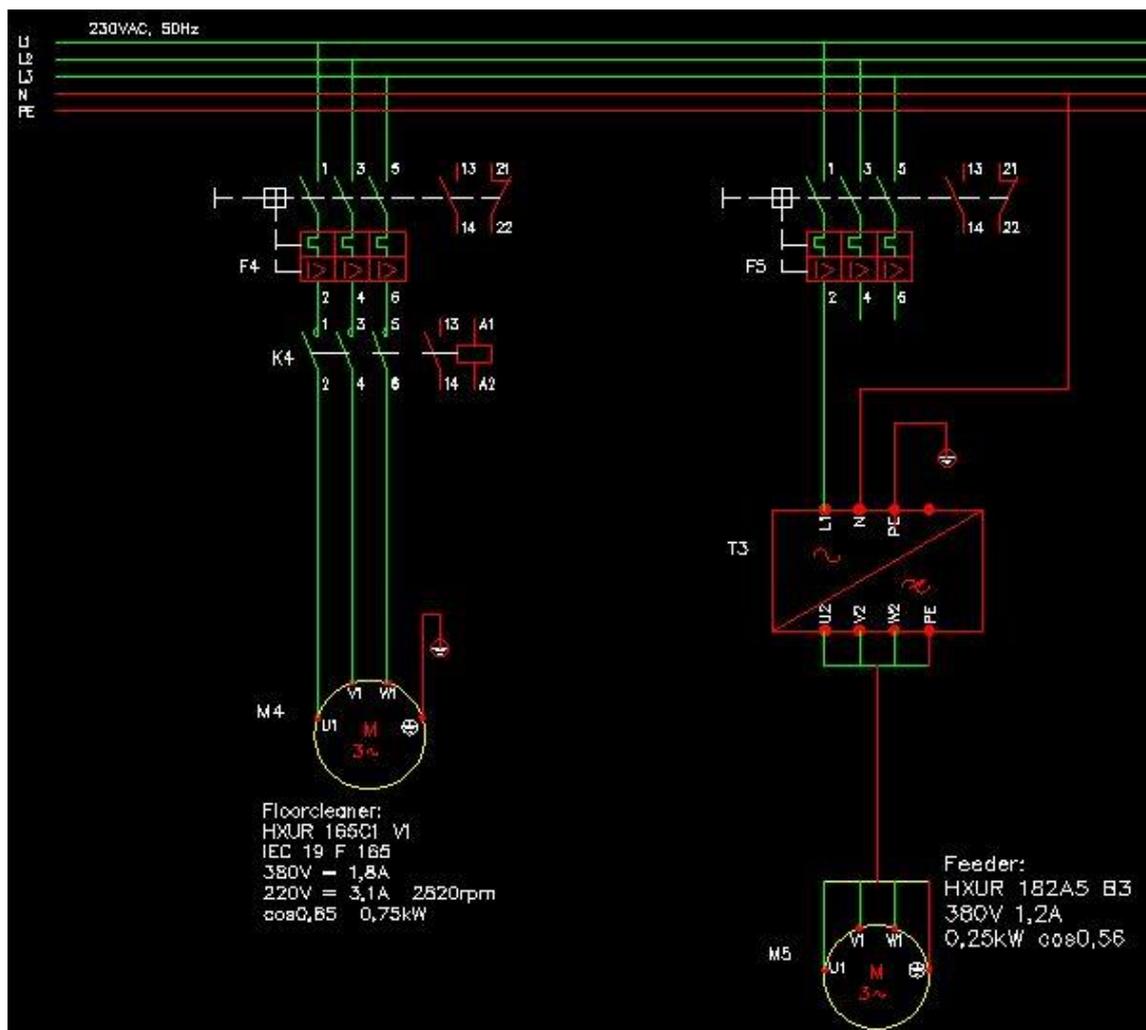


Figure 9. Power supply for the motors

The motor protection switches were placed for each motor (Figure 9.). Auxiliary switches were set for each motor protection switch. State information from the auxiliary contact is imported separately with own input ports to logic. Contactors were then added after motor protection switches, which are controlled by the state signal from the logic to contactor's coil. Because the feeder's frequency converter adjusts motor's state it doesn't need a contactor. (Mäkinen et al 2004.)

6 PLC-PROGRAM

Without the program the new control system is completely useless. All the dryer's functions are designed to work through the logic and play a big role in the success of the entire project. In the old control system all the dryer's functions were mechanical and small delays between operations were carried out either by the user, timers or clocks.

The program's starting point was reliability and safety. Most attention was paid to the operation of the fan. The fan must can't go off during the drying and even it does go off (for example, due to power supply failure), fan will start up again. The program determined that if the supply air temperature is above 55 degrees, the fan stays on / goes on without a separate command. The basic functions wanted to keep simple and clear, so the program was designed with two kind of running options: manual and automatic program.

6.1 MANUAL PROGRAM

Manual program's benefit is its clarity, each button makes always a certain function. Manual program is used if the automatic program takes place problems occur in automatic program during the grain drying period, when the dryer must work. Person performing the manual program should be aware of the dryer's functions, because the manual control allows the dryer to clog the dryer and in worst case, the whole grain batch of pollution or burn the dryer. Due to this risk the dryer is more likely used in automatic program, which sets limits that reduces the risks. Automatic and manual program selection is done by turning the Auto/Manual switch. If the switch is set to zero, manual program is selected and the automatic programs will not turn on from the key combinations.

6.2 AUTOMATIC DRYER FILLING PROGRAM

Automatic dryer filling can be turned on when the dryer is empty (Figure 10.). Filling program is started by selecting the Auto/Manual switch to "1", pressing the elevator's button on, directing 3-way distributor to dryer and pressing the dumping hopper's shutter's pedal to the floor. With these functions automatic filling program is selected and the program starts when the Start button is pressed.

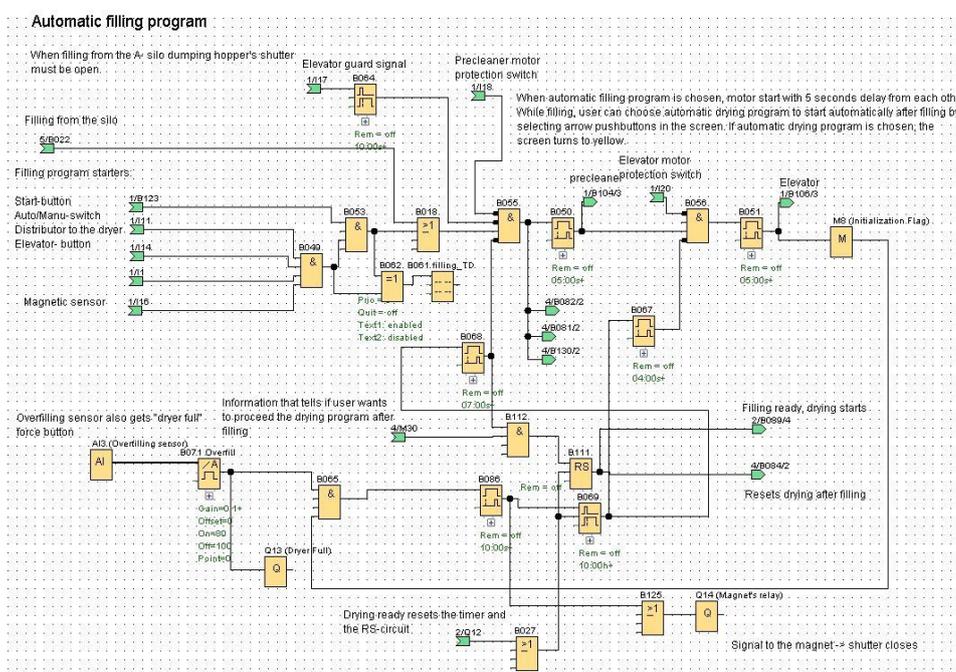


Figure 10. Automatic filling program

Dryer launches the pre-cleaner after five-second delay and then the elevator also with five second delay. The dryer starts to fill. User can monitor the filling progress from the logic's display in the center's door. When the dryer is full (according to the ultrasonic sensor's parameters), the program closes the drying hopper's shutter and turn off the motors with five-second delay from each other. This filling program has filled the dryer with grain. The filling program also has an ability to launch the automatic drying after filling by selecting the center's screen (Figure 11.). To activate this

function, press the arrow keys during the filling program, first right-pointing arrow key once and then press the up arrow key and the display will change to yellow. When the display is yellow automatic drying program starts automatically after the dryer is filled with grain. Pressing the right arrow key, the user can examine also the vertical filling diagram. Pressing once more to right-pointing arrow user is back on the main page.

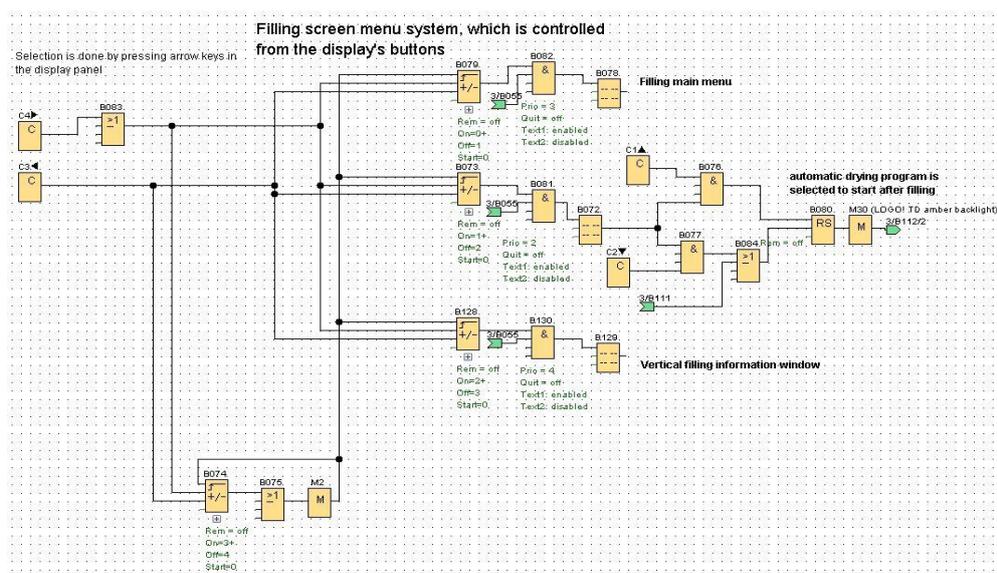


Figure 11. Automatic filling's screen menu system

If the dryer is not full, the program will not stop filling. If the user wants to dry less than full batch of grain, program can be forced to stop the filling by keeping "dryer full forcing signal" - button down for 10 seconds and after that the dryer stops filling.

6.2.1 AUTOMATIC DRYER PROGRAM

Automatic drying is activated by either from the filling program's display menu or with its button combination: Auto/Manual switch must be in position "1", fan's button pressed and 3-way distributor to the dryer (Figure 12.). Finally, automatic drying is activated by pressing the Start button.

Dryer to start the motors in order of size from largest to smallest with five-second delay from each other. At first, the fan starts up, then the pre-cleaner, elevator, floor

cleaner, feeder, and the last one is burner. Once the burner goes on the hour calculators goes on and leave the center's display show "Drying: ON" when the drying is active. If the elevator slows down significantly during the drying process, the elevator guard cuts the power from the feeder after 10 seconds of incorrect rotation speed when the elevator gets time to extract a potential clog. When the elevator works normally again, the feeder will continue to operate. Also, the burner stops operating at any fault situation during the drying, because the grain does not circulate in the dryer if the feeder is not running. This function prevents grain from heating too much.

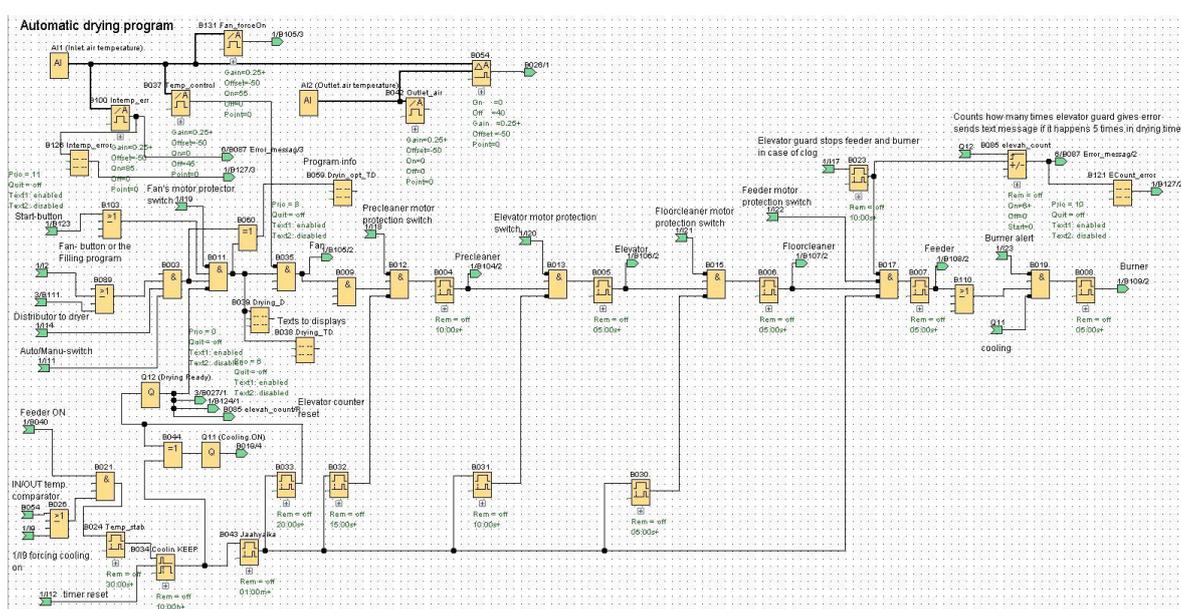


Figure 12. Automatic drying program

When the dryer's outlet air temperature and the inlet air temperature reaches a small enough difference to each other, the program finds the grain to be dry enough. When the difference between temperatures will have remained small enough for more than 30 seconds, the program will start cooling. Cooling program turns off the burner and continue grain circulation in the dryer normally. Cooling lasts as long as in the automatic program's timer's B043 parameters is set and when the time is up the program shuts down the motors one at a time in the reverse-launched order with five second delay from each other. When all the motors are off, the program will put on "Drying ready"- lamp to center's door. If the temperature-difference related cooling sometimes does not work, the cooling is started manually by holding

"Large silos upper conveyor" - button on for 30 seconds, which bypasses the temperature comparator and forces the program to start cooling.

6.2.2 DRYER GRAIN EVACUATION PROGRAM

When the grain is dried, it's stored to one of the storage silos. Dryer's evacuation program is selected when Auto/Manual switch set to "1" and the elevator button is pressed (Figure 13.). The user selects the silo by turning the 3-way distributor manually to the right storage and then pressing the Start button. If the user moves the distributor to large silos, automatic program switches the large silos' upper conveyor on above the silos, the launches the elevator and the feeder. User turns off the evacuation program by pressing the elevator button off.

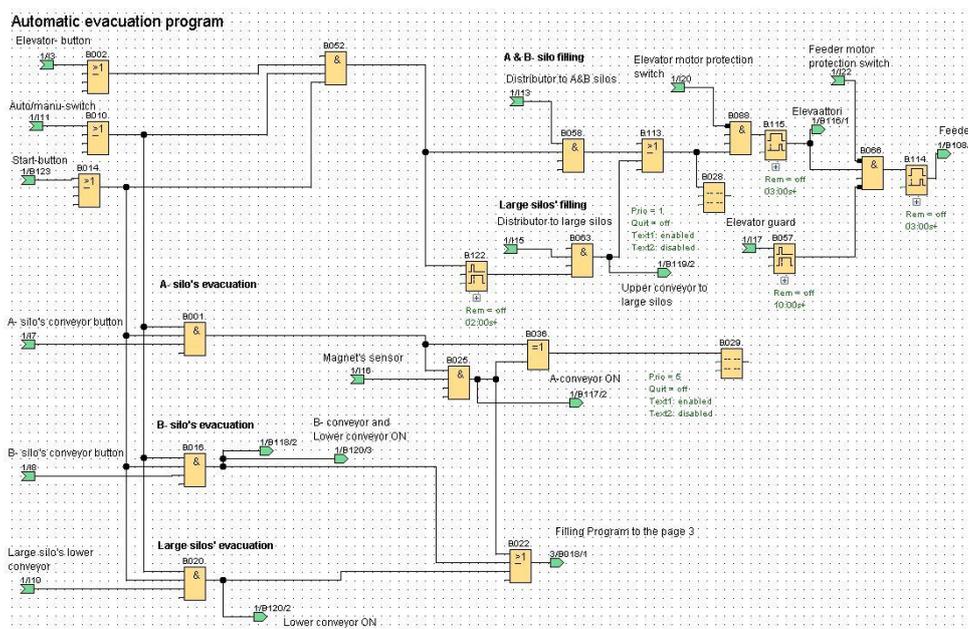


Figure 13. Automatic evacuation program

6.2.3 STORAGE SILOS' EVACUATION PROGRAM

This program allows the evacuation of the silos to another silo, to trailer or to the dryer. The program does not watch for the target location, so user must be careful that grain will not go into a wrong place. Target location is chosen by turning the 3-way distributor to desired position. Automatic storage silo evacuation program is

chosen when the Auto/Manual switch is in the "1" - position and right storage silo's button is pressed which we want to evacuate. Then the Start button is pressed and the program starts to evacuate grain. The user must also remember to open specific silo shutter so the grain comes out from the silo to conveyor.

When evacuating the A-silo the user must also remember to press the dumping hopper's pedal because A-silo's conveyor transfers grain from the silo to the dumping hopper. In B-silo's evacuation B-silo conveyor and large silos' lower conveyor are activated, so that the grain gets to elevator. In large silos' evacuation only large silos' lower conveyor is activated. Each evacuation program is performed through the dryer's own filling program and evacuation is stopped by pressing the desired silo's button off. The user must remember to take care that the silo and conveyors will be empty before the program is shut down to action.

6.3 DATA GATHERING AND ERROR CONTROL

The program has a built-in data collection the function and it's called the "Data log" – block (Figure 14.). The block can be defined as the values from the program that user want to collect and Data log stores the desired information on the logics memory card in regular intervals. This program was set to collect information about the inlet air and outlet air temperatures, as well as from the elevator guard's fault counter.

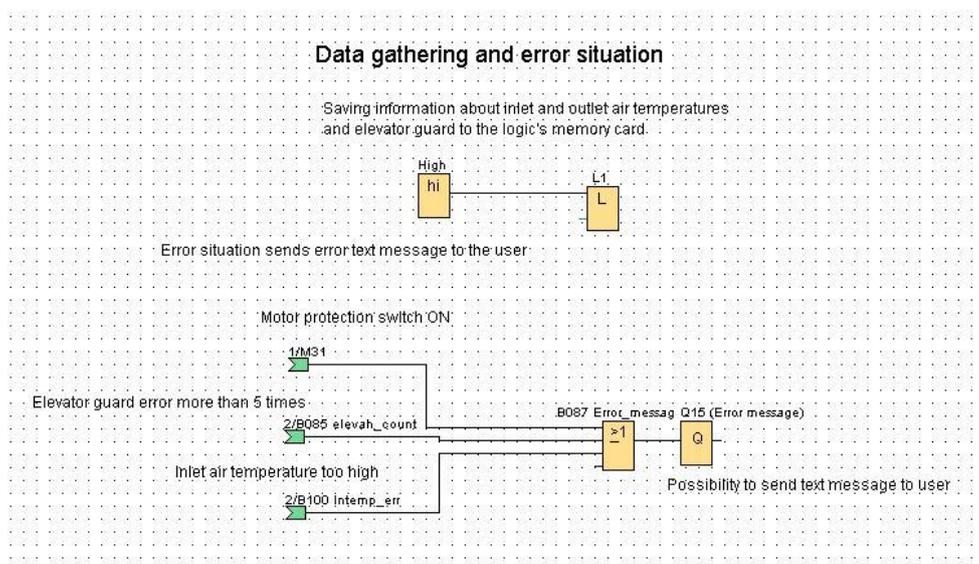


Figure 14. Data log and error message

When fault occurs the program activates logic's Q15- output to external GSM transmitter, which sends error text message to the user. These faults are motor protection switch's triggering, more than five times coupled elevator guard's fault signal and if the supply air temperature gets too high. For each fault logic also gives a message to logics display, where is said the name of the fault and the display changes its color to red.

7 CENTER PLANNING

The new control center was planned to be built in the same place where the existing center locates (Figure 15.). The center's design should take into account dustiness, required space for components and device placement. The main switch of the center is installed inside the center and the arm handle for the switch was installed to the center's door for disconnecting the center from the electrical supply grid. The layout of the center was designed to signal the propagation direction from top to bottom so that it would be easier to follow the cables inside the center. In the middle of the center's door there was placed the logic's display and above the display located the lamps. Below the display panel were the switches and controls. The size of the center was designed to be 750x1250x320mm.



Figure 15. Center's and Center's door layout

8 REMOTE ACCESS

8.1 ABOUT REMOTE ACCESS AND CONTROL

Remote access allows the monitoring and use of the logic over the internet. In the new series of LOGO! 8- PLC the remote access is a built-in feature in all models (Figure 16.). The PLC is connected to the internet using the Ethernet bus on which each logic has been given the IP-address so that it can be accessed from another device which is connected to the internet. The connection to the device is secure and password protected.



Figure 16. LOGO! Web Server press pictures

Remote Access Configuration begins with setting the IP-address to the logic. The logic is connected to the computer's RJ45-connector via an Ethernet-cable. Then the user opens the LOGO! Soft Comfort- program and looks for "tools" -menu, "select hardware" - option and clicks it. When the window opens the user moves to the "Online Settings" -tab and finds the device. When the logic has been found the user creates the IP-address for the device. After this the user moves to "User profile settings", from which the user selects the settings according to the picture on the logic and creates a password. The logic program's "Message text" –text blocks in the "Message Destination" should be selected to "Web server" so that when the

center's screen text changes it changes also on the Web Server's monitor at the same time. Now the logic can be exported to its place and can be contacted by writing to the logic IP-address to the Internet browser's address field, enter the logic's password and begin monitoring. (Siemens 2015a.)

With Web Server-feature can be done real time monitoring from the logic's display panel about what is happening, make simple changes to the program over the display panel and monitor the status of the inputs and outputs. Web Server feature can also be used on mobile devices and user can also make own user interface, where the user can define what values wants to follow or the program's inputs user wants to set. (Siemens 2015a.)

8.2 REMOTE ACCES FOR THE DRYER

The biggest problem in this case is that there is no actual internet connection to the dryer. Logic requires a solid network for the corresponding Ethernet-port connector. For this purpose only is not clever to create physical access to the Internet, but we decided to use cheaper and simple way to create connection to internet by using router, which supports the USB interface installed 3G receiver. 3G receiver will add phone operator's SIM-card and from the router's RJ45-port we create the connection for the logic by using CAT-cable. 3G-receiver and the router is placed to its own dust protected case and located to the dryer's upper platform for the best possible signal.

9 SUMMARY

The aim of this thesis was to design a new grain dryer control system and it was accomplished successfully. In the beginning the problem was to find out how the current system works, because there were no proper electrical pictures of the old system. Therefore a brand new system had to be created. The LOGO! from Siemens seemed to be the best option, but in the end of the project it was necessary to eliminate some functions and make compromises. LOGO! should still be the cheapest logic option and its expandability in the future is possible by purchasing a second main module and connecting both logics together into a single entity. Logic programming with LOGO! Soft Comfort- program was surprisingly easy and simple.

The main problems of electrical planning were with the practice. Some solutions may look like a good idea on paper but in reality the idea may not work. In the end of the project the drawings were viable.

Although some may think that this kind of project does not require more than some new device and management, project surprised with its scope. In particular, the logic program was difficult to get to work in a secure and reliable way. Ultimately, the project was a viable entity and it will be used in the future when the dryer control is going to be renewed.

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APPENDICES

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APPENDIX 2. CENTER LAYOUT - DOORPANEL

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APPENDIX 4. MOTORS 1-3

APPENDIX 5. MOTORS 4-6

APPENDIX 6. CONVEYORS

APPENDIX 7. CONVEYOR

APPENDIX 8. LOGIC POWER SUPPLY

APPENDIX 9. INPUTS 1

APPENDIX 10. INPUTS 2

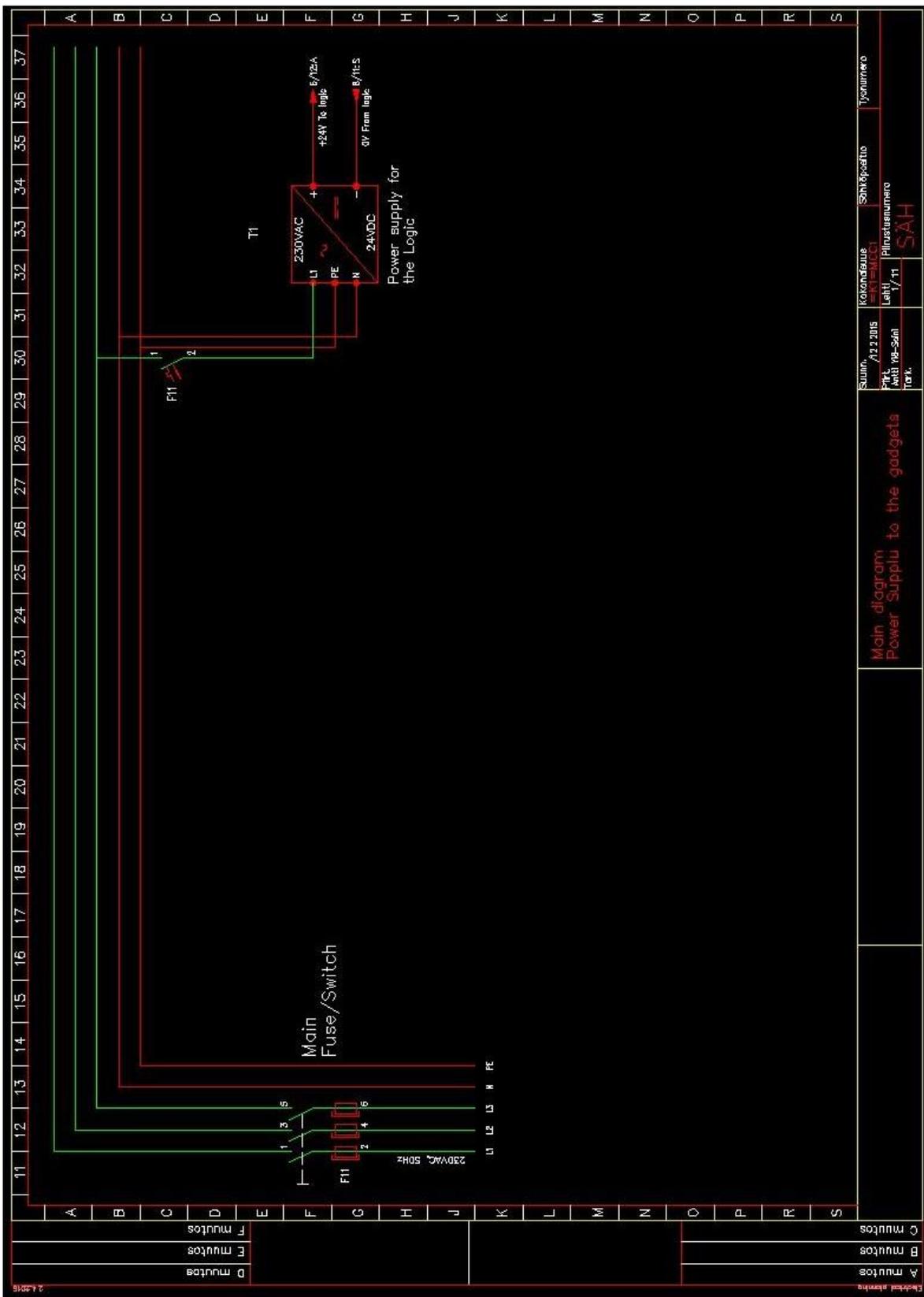
APPENDIX 11. OUTPUTS

APPENDIX 12. ERROR LAMPS

APPENDIX 13. FREQUENCY CONVERTER

APPENDIX 14. PART LIST

APPENDIX 3. POWER SUPPLY

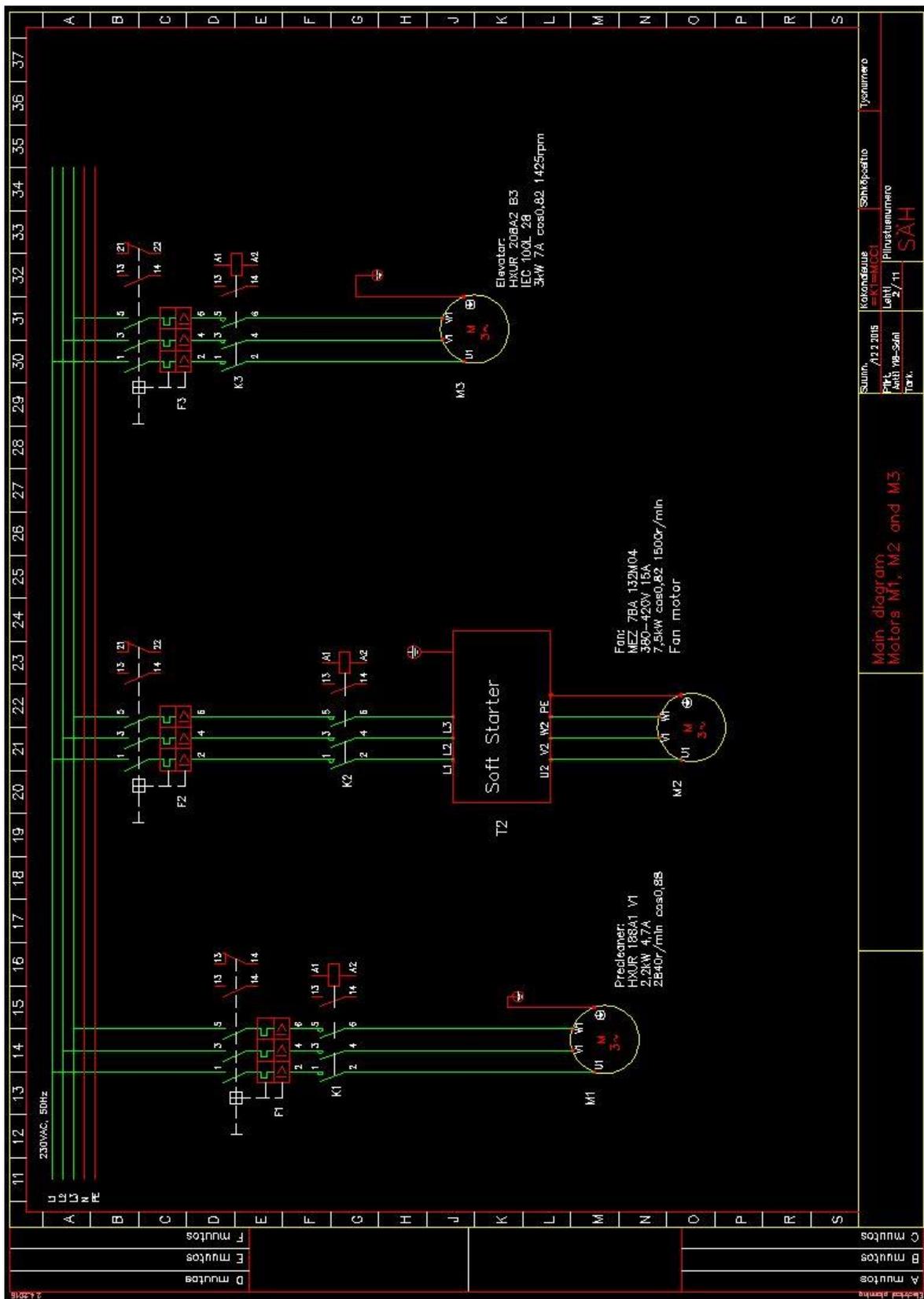


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B müttes				
C müttes				

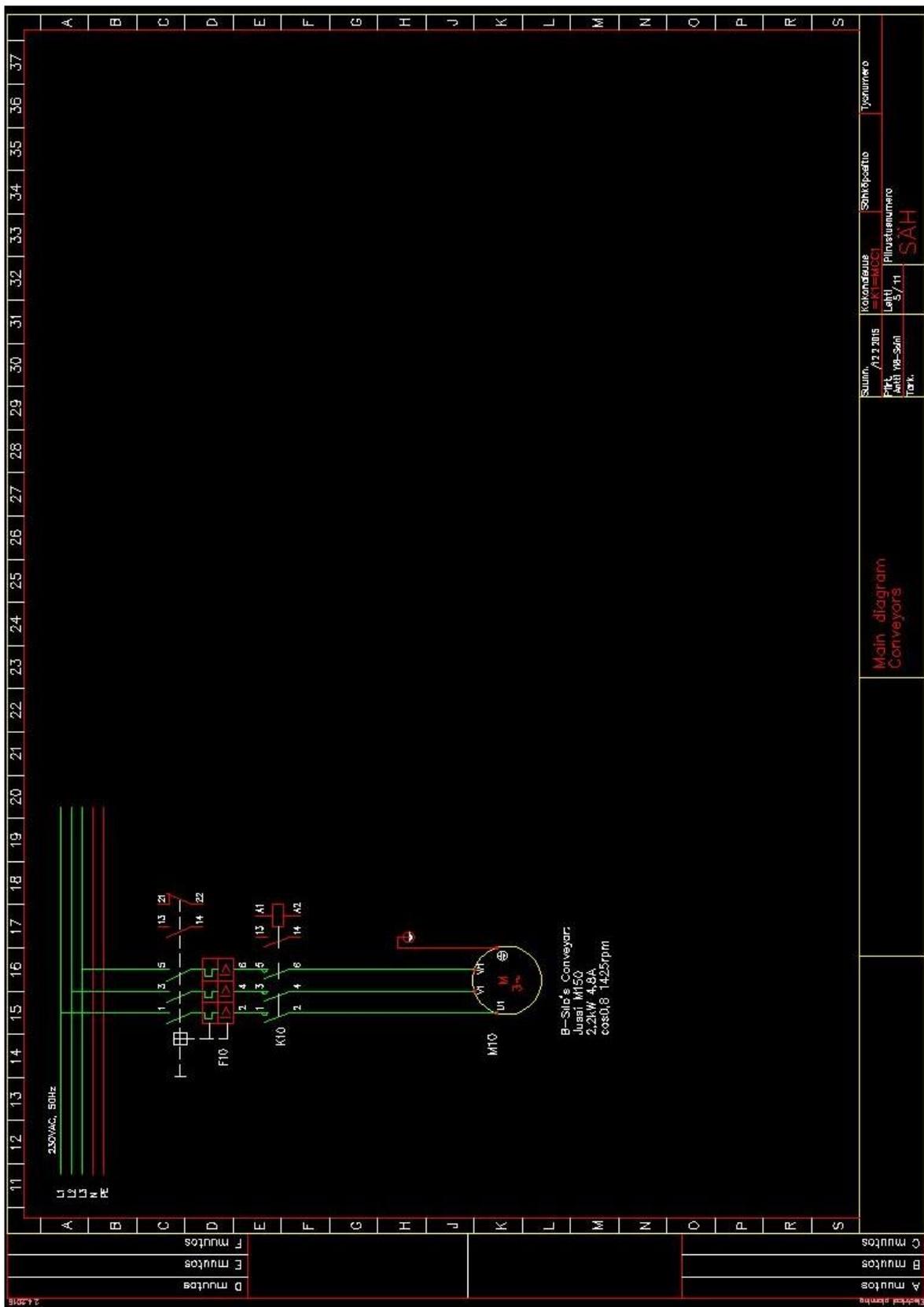
Main diagram
Power Supply to the gadgets

Şirket Adı	Şirket No	Şirket Adı	Şirket No
Şirket Adı	Şirket No	Şirket Adı	Şirket No

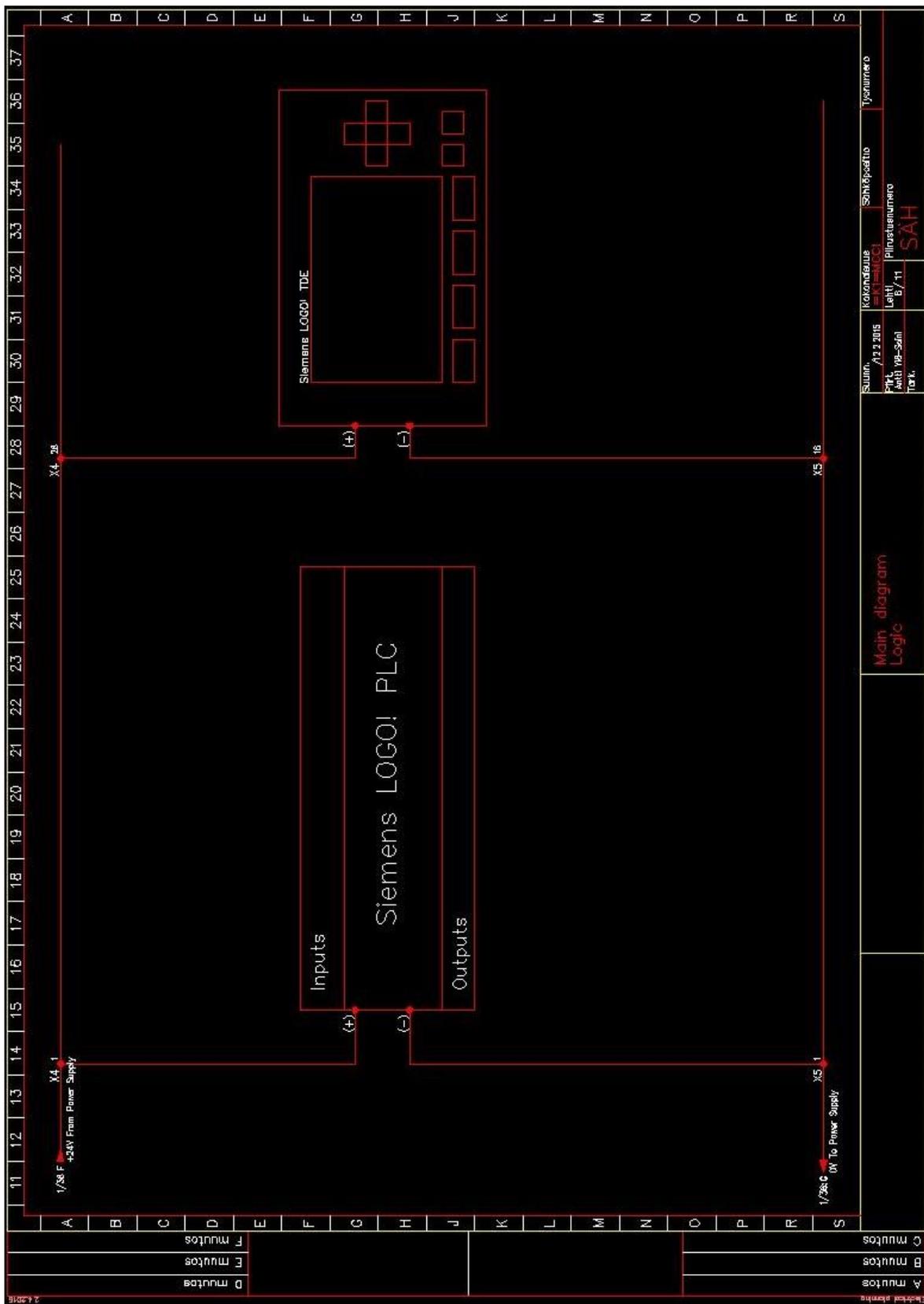
APPENDIX 4. MOTORS 1-3



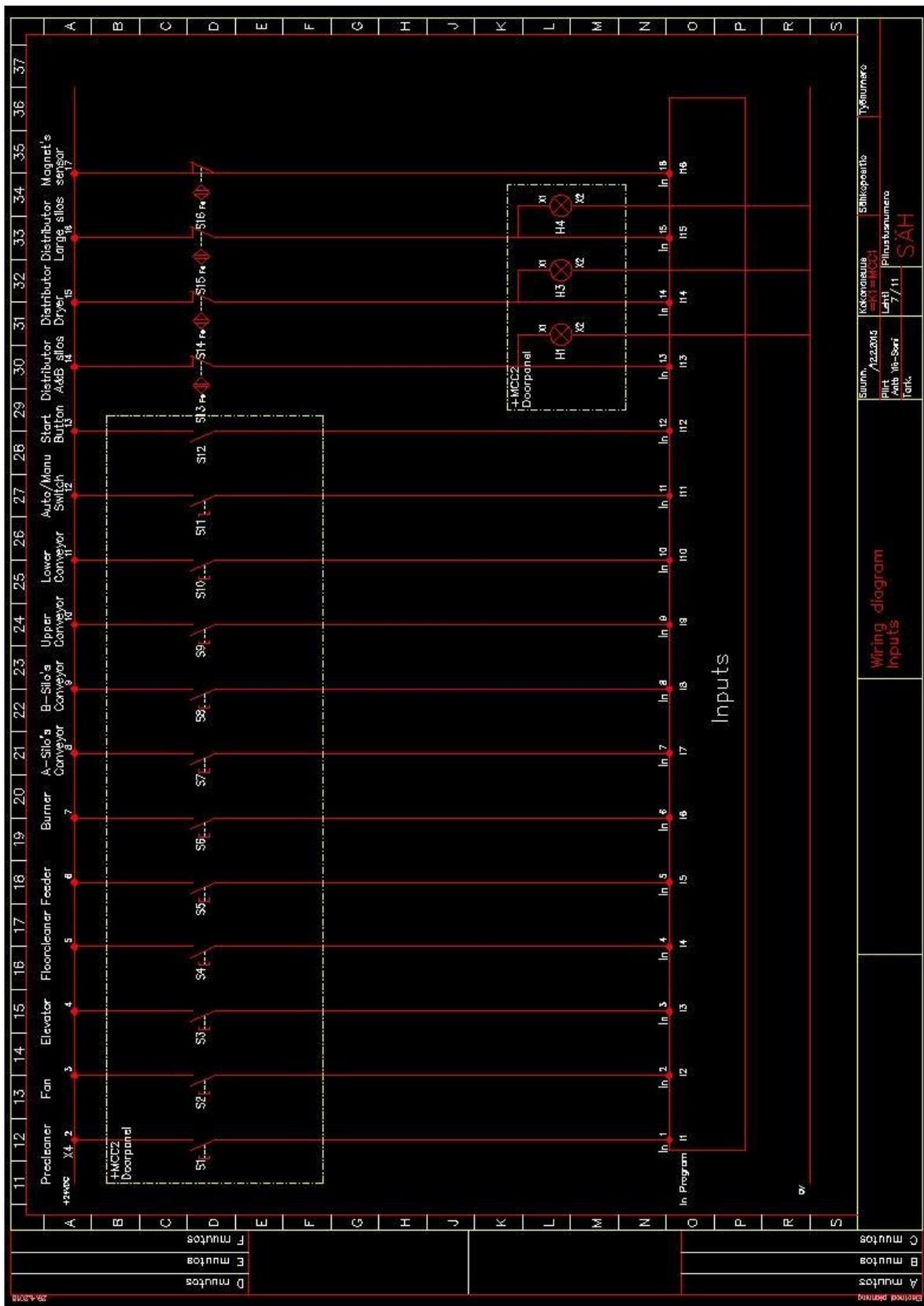
APPENDIX 7. CONVEYOR



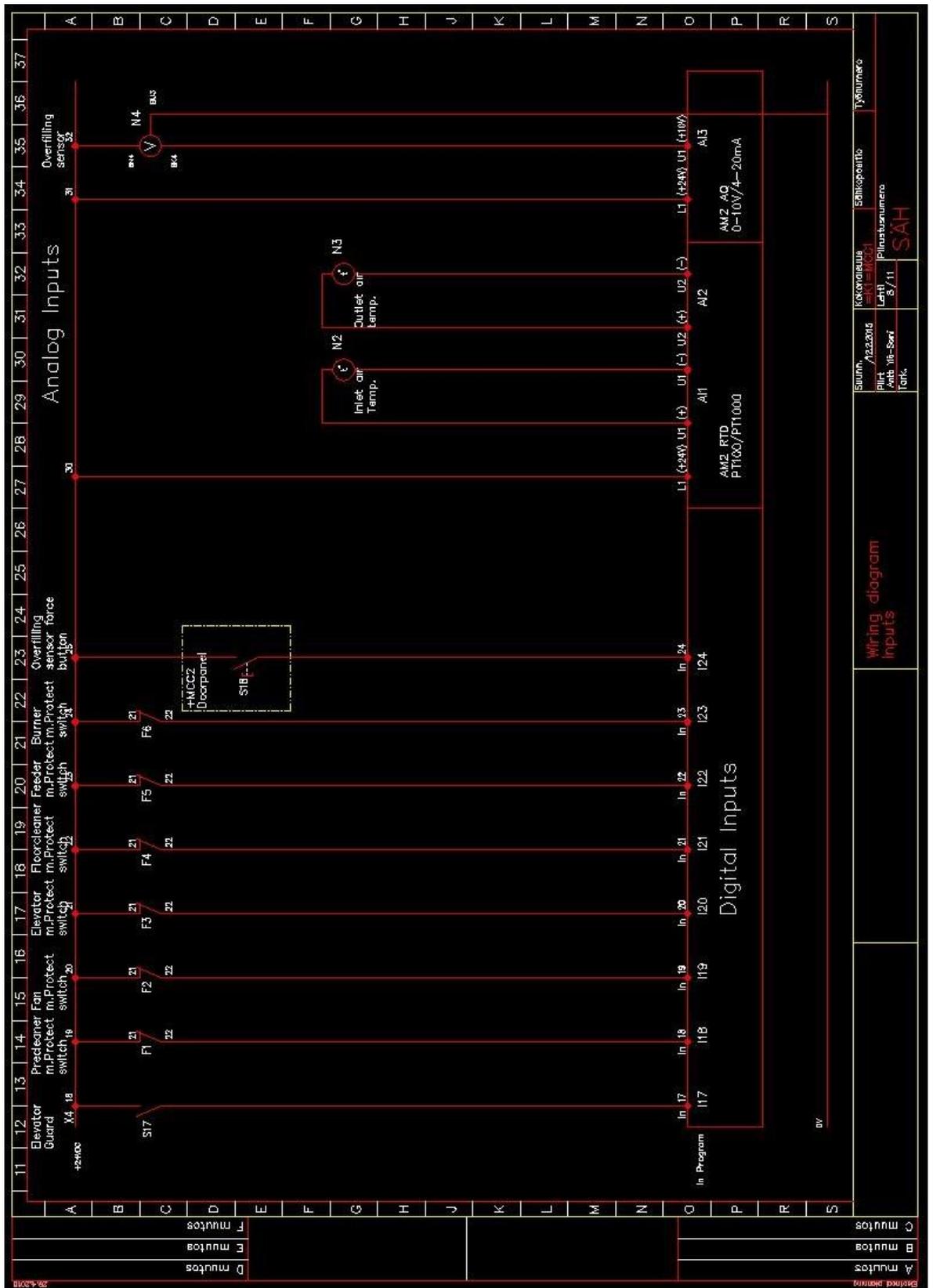
APPENDIX 8. LOGIC POWER SUPPLY



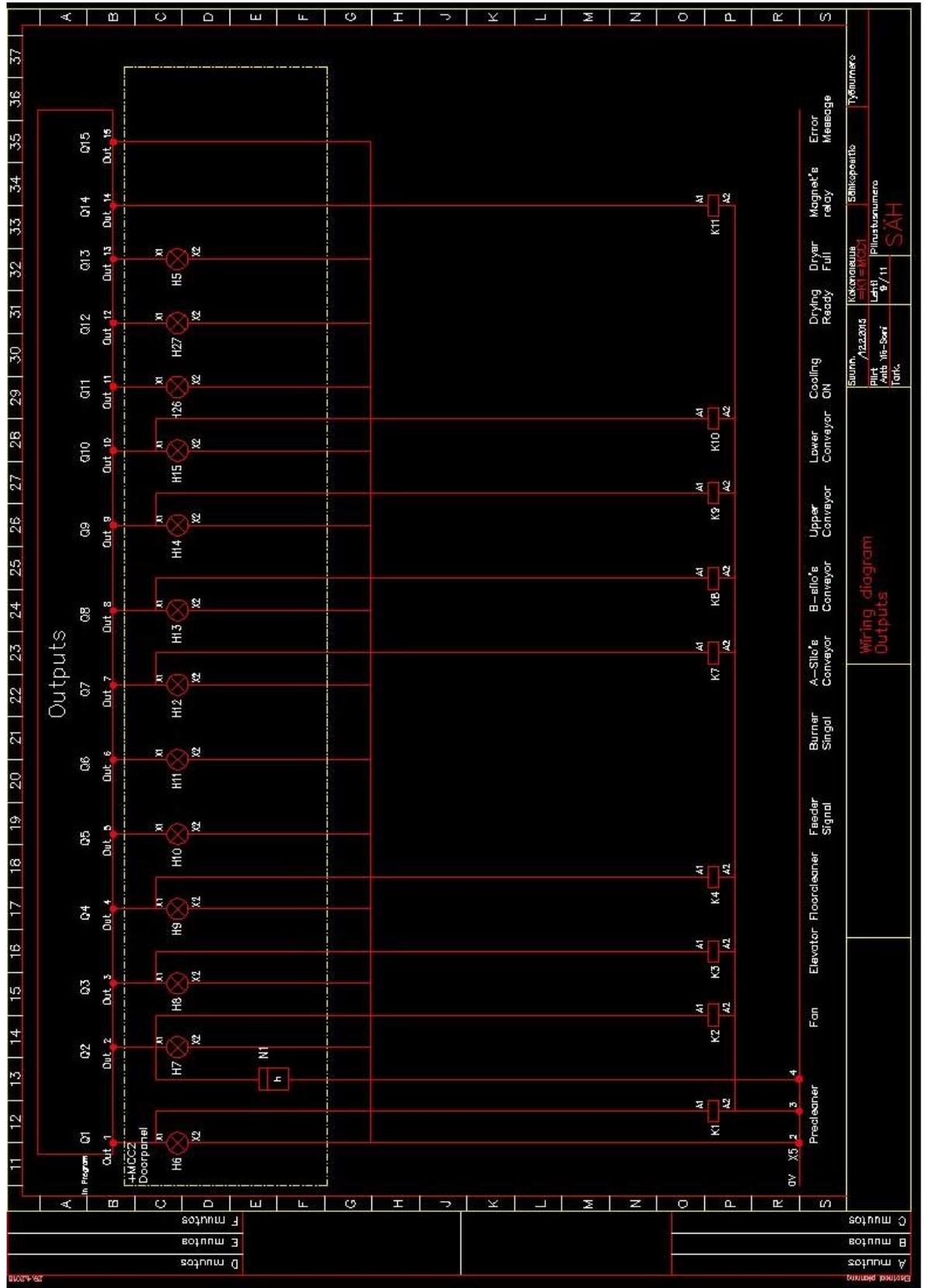
APPENDIX 9. INPUTS 1



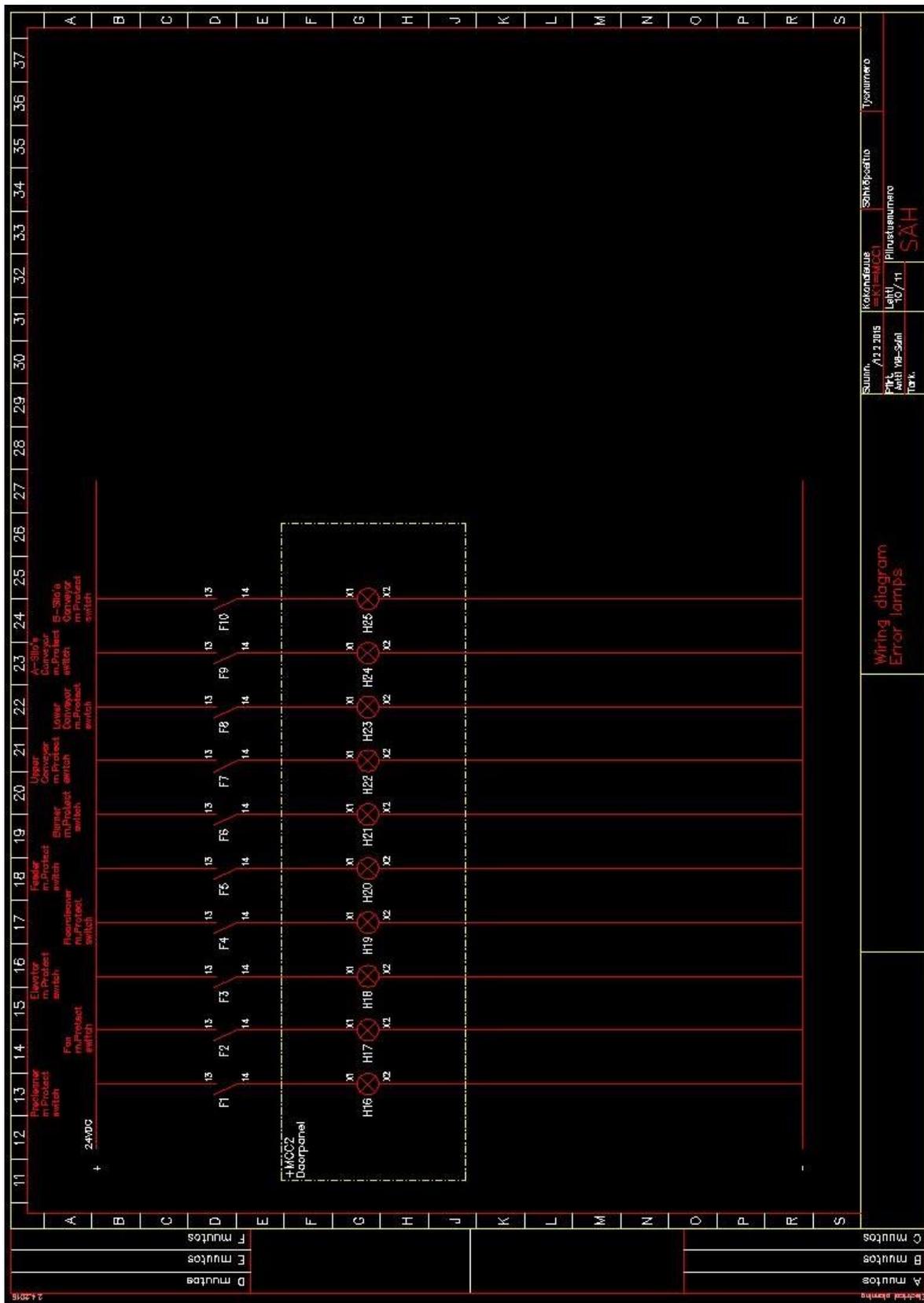
APPENDIX 10. INPUTS 2



APPENDIX 11. OUTPUTS



APPENDIX 12. ERROR LAMPS



APPENDIX 14. PART LIST

Part list

Number	Part name	Part type number	Sign	Quantity
1	Siemens LOGO! 8 PLC	6ED1052-1CC01-0BA8		1
2	Siemens LOGO! DM16	6ED1055-1CB10-0BA2		2
3	Siemens LOGO! AM2 RTD	6ED1055-1MD00-0BA2		1
4	Siemens LOGO! AM2 AQ	6ED1055-1MM00-0BA2		1
5	Siemens LOGO! TD Text Display	6ED1055-4MH00-0BA		1
6	Carlo Gavazzi UA-30PNP35AV Ultrasonic sensor	UA30CAD35PKTI	N4	1
7	GUENTHER SS45-300 Temp. Sensors	72-11301002-0300.0045.SS	N2,N3	2
8	OMRON Inductive sensor	E2A-M12KN08-WP-B1-2M	S13,S14,S15,S16	4
9	GE SMS 1.6 Motor Protection Switch	SMS 1.6	F5	1
10	GE SMS 2.5 Motor Protection Switch	SMS 2.5	F4	1
11	GE SMS 4 Motor Protection Switch	SMS 4	F6	1
12	GE SMS 6.3 Motor Protection Switch	SMS 6.3	F1,F7,F8,F9,F10	5
13	GE SMS 10 Motor Protection Switch	SMS 10	F3	1
14	GE SMS 16 Motor Protection Switch	SMS16	F2	1
15	GE SMS APU Auxiliary contact	SMS APU		10
16	Mean Well Power supply	DRP-240-24	T1	1
17	ABB Circuit breaker	S201-B16	F12	1
18	ABB Disconnect Switch/ Main Switch	OT25F	F11	1
19	Siemens Sirius 3kW Contactor	3RT20151BB41	K1,K3,K4,K7,K8,K9,K10	7
20	Siemens Sirius 7,5kW Contactor	3RT20181BB41	K2	1
21	Murr Miro Changeover switch	52005	K11	1
22	Siemens Sirius Soft Starter	3RW3018-1BB04	T2	1
23	Yaskawa V1000 Frequency Converter	TM0.25V	T3	1
24	EMC Filter	EMC 0.4V	T4	1
25	Kuhnke Electric magnet	HT-D40-F-24V100%		1
26	Potentiometer	POTE 1		1
27	Alternating pushbutton to doorpanel			10
28	Momentary pushbutton to doorpanel			3
29	Indicator light to doorpanel			27
30	Hour meter		N1	1
31	"0/1-Switch" for Automatic/manual-switch			1
32	Fibox 750x1250x320 Enclosure	CAB PX 7512532-2DT		1
33	Weidmüller Terminal Block	WDU 2,5N	X4,X5	60
34	40mm Cable duct			3m