Jogow Ahmednuor Abdi

MOTOR PROTECTION WITH REM 615

MACHINE TERMINAL

Technology and Communication

2011

FOREWORD

This thesis has been written for VAMK University of Applied Sciences. The test room of the equipment will be placed at the Technobotnia Research Center in Vaasa.

During this whole project, there were many people who supported and helped me. First of all I would like to thank Almighty Allah, who gave me strength to accomplish this task, my supervisor Olavi Mäkinen, Principal Lecturer, who gave me advice during making this thesis. Special thanks for my wife, Farhia Mohamed, my children Abdiaziiz and Iqra, and my mother who gave me indescribable
support.

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Sähkötekniikan koulutusohjelma

ABSTRACT

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The purpose of the thesis was to create written lecture handout for laboratory work, which includes instructions concerning the laboratory work and hardware protector for motor protection relay testing. This will help the students to understand the devices and to complete practical work during the laboratory exercises, and simulate educational equipment test situation based on the lecture handout.

The main objectives of this thesis were to determine REM615 educational equipment and design main diagram, circuit diagram etc. The planned hardware protector was commissioned with the PCM600 (Protection and control IED Manager) software and its WHMI (Web base human machine interface). After commissioning the documents and laboratory exercise was tested.

In this project ABB Oyj is a partner with VAMK University of Applied Sciences. ABB supplies the main components such as REM615 device and the software PCM600. The rest of the components, such as test simulator and the torque for the motor will be supplied by VAMK.

Keywords	REM615, PMC600

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Sähkötekniikan koulutusohjelma

TIIVISTELMÄ

Tekijä	Jogow Ahmednuor Abdi
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Tämä opinäytetyön tarkoituksena oli suunnitella REM615 releelle moottorin-suojausopetuslaitteisto ja laatia englanninkielinen opetusmoniste, jota käytetään REM615 laitteen opetusmonisteena laboratoriossa. Tämä auttaa oppilaita ymmär-tämään sekä laitteen toiminnan että käytännön työn ja suorittaa työn onnistuneesti laboratorion aikana.

Tämä opinäytetyön tavoitteena oli määritellä REM615 opetuslaitteiston kaavio ja suunnitella opetuslaitteiston kytkentä ja kaaviokuvat. Työssä määriteltiin opetus opetuslaitteistolla testattavat vikatilanteet pohjautuen ohjeeseen REM543 ja otet-tiin käyttöön PCM 600 ohjelmisto ja sen WHMI-versio kohdelaitteena REM615. Lopuksi laadittiin englanninkielinen työohje ja testattiin sen toimivuus rakennetul-la opetuslaitteistolla.

Opinnäytetyössä selvitettiin REM615 ja PCM600 yleiset ominaisuudet ja toimin-nallisuus käyttäen lähdemateriaalina REM615 käyttöohjeita. Laboratorioharjoi-tuksia asiakirjoja ei ole sisälly tähän asiakirjaan, vaan ne toimitetaan erikseen opettajalle käytettäväksi.

Asiasanat	REM615, PCM600

LIST OF TERMS AND ABBREVIATIONS

CT	Current transformer
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DT	Definite time
EFHPTOC	Non-directional earth-fault protection, high stage
EFIPTOC	Non-directional earth-fault protection, instantaneous stage
EFLPTOC	Non-directional earth-fault protection, low stage
EFxPTOC	Non-directional earth-fault protection
FLC	Full loaded current
GOOSE	Generic Object Oriented Substation Event
I_2	Negative phase sequence current
IDMT	Inverse definite minimum time
IE	Internet Explorer
IEC 60870-5-103	Communication standard for protective equipment; A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modelling
IED	Intelligent electronic device

JAMPTOC	Motor stall protection
LAN	Local area network
LHMI	Local human-machine interface
LOFLPTUC	Loss of load protection
MNSPTOC	Negative phase-sequence current protection
MPTTR	Three-phase thermal overload protection for motors
PCM 600	Protections and Control IED Manager
PEAK-TO-PEAK	The amplitude of a waveform between its maximum positive value and its maximum negative value
PHHPTOC	Three-phase non-directional overcurrent protection, high stage
PHIPTOC	Three-phase non-directional overcurrent protection, coinstantaneous stage
PHLPTOC	Three-phase non-directional overcurrent protection, low stage
PHxPTOC	Three-phase non-directional overcurrent protection
PREVPTOC	Phase reversal protection
RMS	Root-mean-square (value)
STTPMSU	Motor start-up supervision
TCP/IP	Transmission Control Protocol/Internet Protocol
VT	Voltage transformers
WAN	Wide area network

WHMI   Web human-machine interface

CONTENTS

1. INTRODUCTION

Relay Feeder Managers are being used worldwide in order to facilitate the automation of a substation. REM615 is an intelligent electronic device with all the electrical systems of protection, control and measurement. The main scope of this project is to create laboratory exercises based upon the use of REM615 Relay Feeder Managers and PCM600 engineering tool. In the laboratories, the ABBs sales engineers around the world and the of course upcoming students will learn the use of these devices practically.

A simple explanation will be included in the laboratory exercise on how to use the REM615 via the panel, PCM600 engineering tool or web-based human machine interface (WHMI), and also how to create project using the PCM600 engineering tool.

2. MOTOR PROTECTION

Electrical Power System protection is required for protection of both user and the system equipment itself from fault, so the electrical power system is not allowed to operate without any protection devices installed. A Power System fault is defined as undesirable condition that occurs in the power system. These undesirable conditions are such as short circuit, ground fault, over current and over voltage. With the increasing loads, voltages and short-circuit duty in distribution system, over current protection has become more important today.

Motors are a significant investment and often run critical processes. Motor protection relays are used to protect the windings in the stator from damage due to electrical faults and thermal overloads. Sufficient motor protection not only prevents motor damage, but also ensures optimal process efficiency and minimal interruption. Cost recovery for protection is achieved by extending the life of the motor, preventing motor rewinds and reducing downtime.

REM615 is one of the series product families of IEDs designed for protection, control and measurement and outgoing feeder for motor bay. The usage of REM615 and its related software will be explained in this document.

3. DRAWINGS FOR MOTOR TESTING CABINET

The electrical design was made using CADS electricity planning application which includes all the necessary features needed in electrical design.

The drawings were started from a scratch and were not easy, because the previous machine had not any documentation, which can be used as a base. We had to open the old REM543 box and see how it was wired, and the drawings were made based on that.

The face panel diagram was designed by using CADS software, it gives a clear picture of inside wiring and what connection to use in a various testings. The switches were made easy in various testings by turning the switch On/Off. Some of the connectors were not used in this project, but in the future it will be useful and it has been added just in case. The wiring diagram is made very clear it is also numbered and the connectors named for voltage or ampere and the size of resistance.
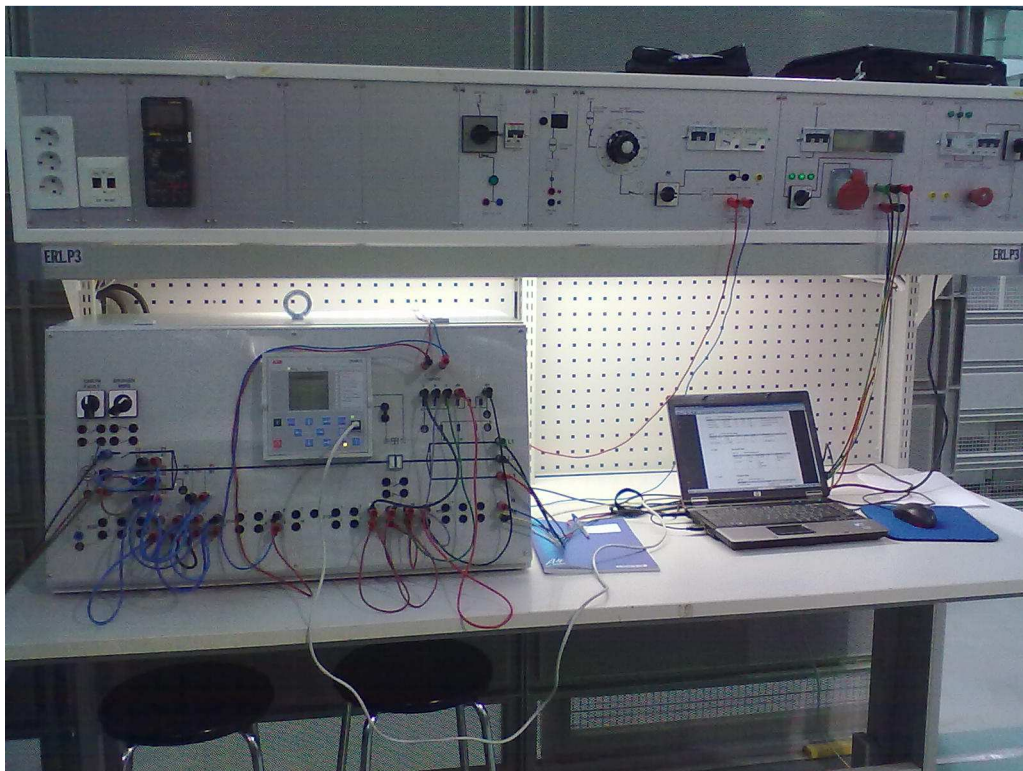

Figure 1. Relay REM615 commissioning with motor testing cabinet

This picture was taken during commissioning the hardware. The hardware connected to the main supply through resistance to the load. The laptop is connected to the hardware using a RJ-45 cable and the parameters of the hardware were controlled and configured using the PCM600 software.
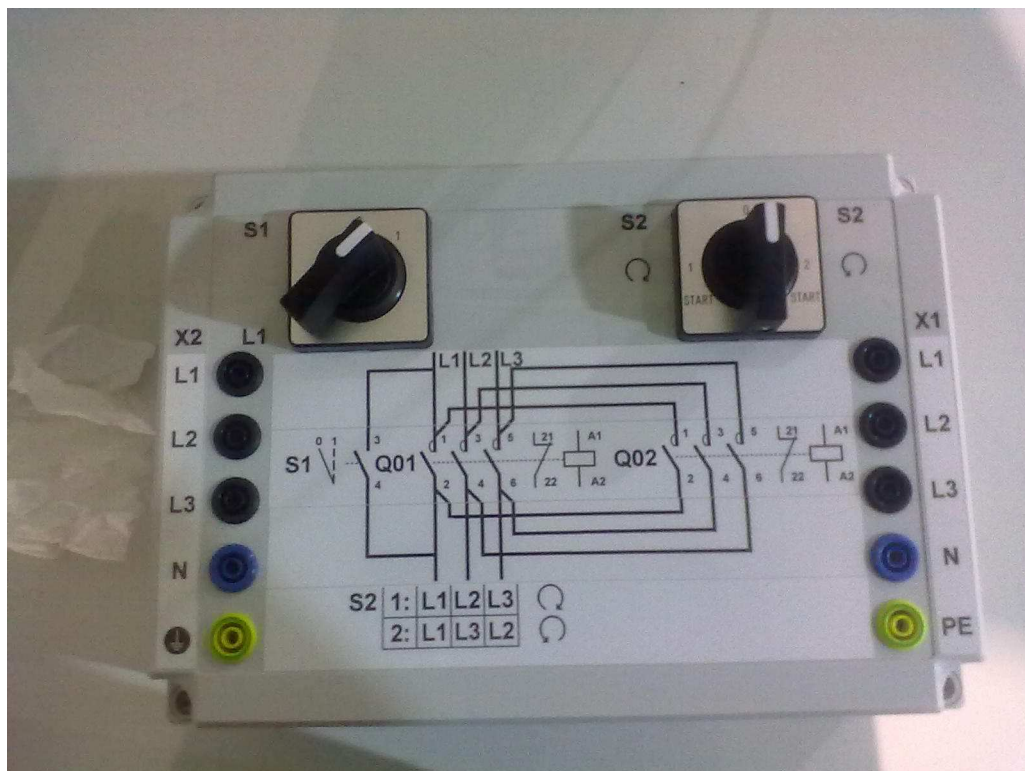

Figure 2. Motor reversing switch

The reversing switch changes the motor direction while the motor is running. The motor reversing switch has many connectors which are used when it is connecting. The motor reversing switch is connected between the motor and relay protection system. This motor reversing switch was designed especially for PREVPTOC1 function test.

4. REM615

REM615 is a product family of IEDs designed for the protection, control, measurement and supervision of asynchronous motors in manufacturing and process industry. Typically REM615 is used with circuit-breaker or contactor controlled HV motors, and contactor controlled medium sized and large LV motors in a variety of drives. REM615 is available in three standard configurations including all the basic motor protection functions, voltage protection functions and power and energy measurements.

Figure 3. REM 615 HARDWARE /1/

REM615 is very smart with feature draw-out-type design with a variety of mounting methods, compact size and ease of use. REM615 offers control of one circuit breaker with dedicated push-buttons for opening and closing.

An individual user account with role-based access control protects the IED from unauthorized access. It has four access levels: viewer, operator, engineer and

administrator. It can be used from the front-panel user interface, Web browser based user interface and PCM600 software. Passwords are programmable by the administrator.

The control position of the IED can be changed with the R/L button. In local position primary equipment, such as circuit breakers or disconnectors, can be controlled via the LHMI. In remote position, control operations are possible only from a higher level that is from a control center. The R/L button is pressed for two seconds in order to activate the interference remote or local control. The control position cannot be simultaneously local and remote but it can be disabled when neither of the positions is active.

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. With push-buttons you can give open or close commands to one primary object, for example, a circuit breaker, disconnector or switch. The pushbuttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

4.1.   Communication, Standards and Protocol

The IED supports a range of communication protocols including IEC 61850, IEC 60870-5-103, Modbus and DNP3. Operational information and controls are available through these protocols.

IEC 61850 is a standard for the design of electrical substation automation. The IEC 61850 communication effectuation supports all monitoring and control functions. Additionally, parameter setting and disturbance file records can be accessed using the IEC 61850 protocol. Disturbance files are available to any Ethernet-based application in the standard COMTRADE format.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The IED can be connected to Ethernet based communication systems via the RJ-45 connector. */2/*

4.2.   Web HMI

Web-based Human Machine Interfaces (WHMI) represents the next step in the evolving functionality of digital displays. The evolution of Web-based HMI has allowed real-time information from automation systems to be accessible to anyone in the corporation using technologies such as Internet Explorer 7.0 or later. According to ABB, the username and the password of the web user interface are: Username: ADMINISTRATOR Password: remote0004

When the web-browser based user interface is used, the IED can be accessed either locally or remotely using a web browser (IE 7.0 or later). Locally you can connect your laptop to the IED via the front communication port and remotely over LAN/WAN.

For security reasons, the web browser based user interface is disabled by default. The interface can be enabled with the PCM600 tool or from the front panel user interface. The functionality of the interface can be limited to read-only access by means of PCM600.
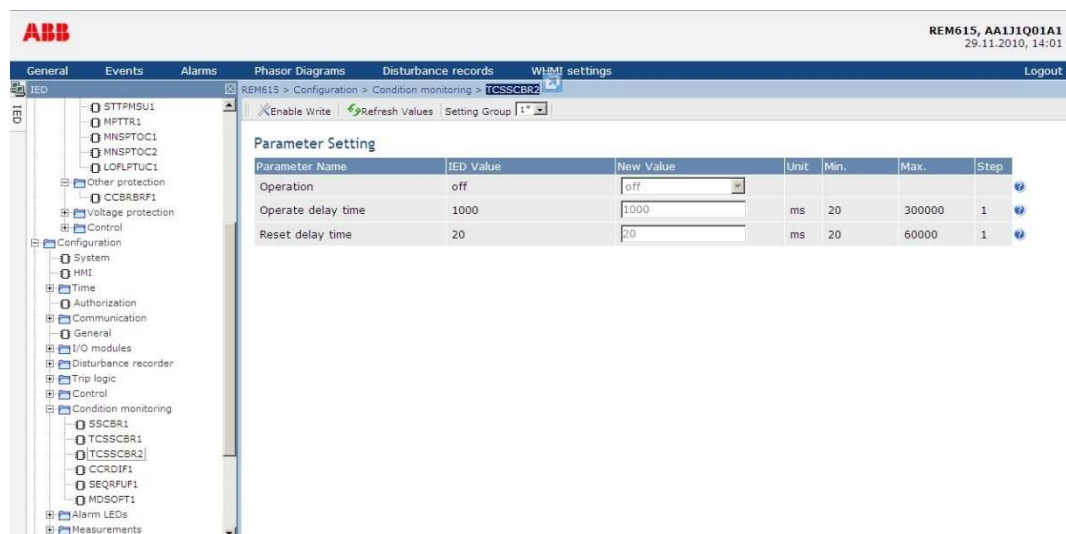
Figure 4. WHMI menus

The menu tree structure on the WHMI is almost identical to the one on the LHMI. Use the menu bar to access different views.

The General view shows the IED version and status. The Events view contains a list of events produced by the application configuration. The Alarms view shows the status of alarm LEDs. The Phasor diagrams view shows phasor diagrams. The Disturbance records view shows the list of disturbance records. The WHMI settings view contains user settings for the client that is the web browser. WHMI settings include, for example, the client-specific setting for the WHMI language.

5. PROTECTION AND CONTROL IED MANAGER (PCM600)

This chapter introduces briefly in general the main software in which the laboratory exercises are based on. Protection and control IED manager (PCM600) offers all necessary functionality to work throughout all stages of the IED life cycle

5.1. Properties of PCM600

Protection and Control IED manager (PCM 600) is an easy-to-handle tool for configuration, parameter setting, disturbance handling and monitoring of protection relays, terminals and IEDs. The management tool fully complies with the IEC 61850 standard, which simplifies engineering and enables information exchange with other IEC 61850 compliant devices. Table 2 shows the supported functions in a different variation.

Table 1. Supported functions /3/

Function	PCM600	PCM600 Engineering Pro
Parameter setting	•	•
Signal configuration (signal matrix tool) [1]	•	•
Signal monitoring	•	•
Disturbance recorder handling	•	•
Disturbance record analysis	•	•
Event viewing [2]	•	•
IEC 61850 communication configuration, GOOSE	-	•
Modbus® communication configuration	•	•
DNP3 communication configuration	•	•
IEC 60870-5-103 communication configuration	•	•
Saving of settings as templates in the tool	•	•
User management	•	•

1) Supported only in 615 series IEDs
2) Not supported in 615 series IEDs, 610 series relays or SPACOM series relays

PCM600 is available in two variants: PCM600 and PCM600 Engineering Pro. The PCM600 Engineering Pro variant offers, in addition to the functionality of PCM600, IEC 61850 peer-to-peer (GOOSE) communication configuration.

PCM600 provides the functionality required for commissioning, operation, monitoring and engineering of IEDs. PCM600 uses ABB's IED-specific connectivity packages, which ensures that appropriate IED basic data are being used in the tool. The connectivity package is a collection of software and information related to a specific protection and control terminal providing system products and tools to connect and interact with the IED.

Using the project explorer of PCM600 the user is able to create a plant structure with substations, voltage levels, bays and IEDs. A new plant structure can also be created by use of IED templates. This enables the re-use of existing IED configurations. IEDs, bays, voltage levels or a whole substation can be copied and pasted in the plant structure.

Additionally, PCM 600 features a powerful IED import-export and copy-paste functionalities which allow you to efficiently reuse existing IEDs, bays, voltage levels or substations.
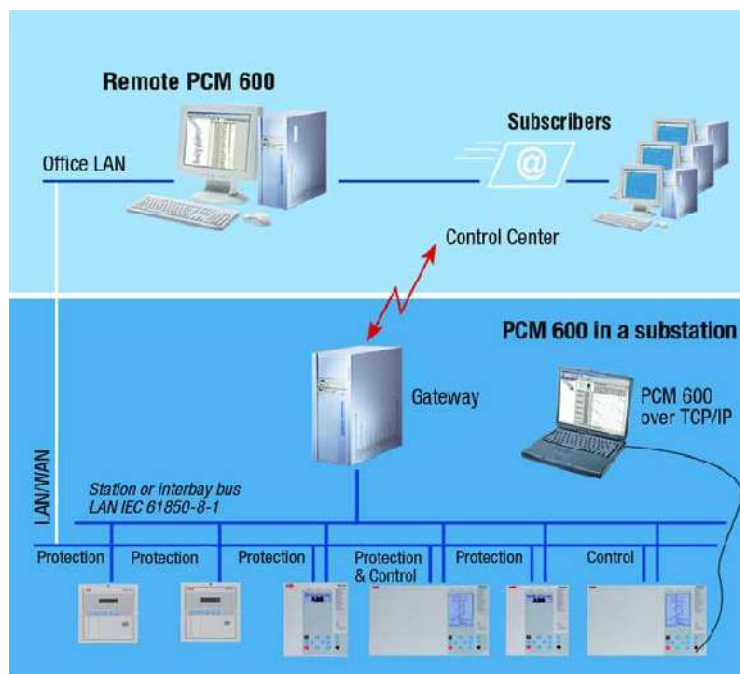

Figure 5. PCM 600 architecture */4/*

With the individual tool components, you can perform different tasks and functions and control the whole substation. PCM600 can operate with many different topologies depending on customer needs.

PCM 600 scans and retrieves disturbance information for automatic report file generation. Automatic reporting allows relay engineers to concentrate on disturbance analysis instead of manually collecting data. PCM600 offers improved data transfer between the IEDs and the PC.

The IEDs can be accessed remotely using the TCP/IP protocol via a local area network (LAN) and standard Ethernet cables, a secured wide area network (WAN), a secured wireless network (WLAN) or, locally, using the IEDs' front communication port.

5.2. Signal Matrix

The graphical signal matrix of PCM600 allows the user to efficiently connect CTs, VTs, binary input and output signals to the configuration. The configuration can also be changed from here. The tool can also be used for connecting the LEDs on the IED as well as for connection of the GOOSE signals between the IEDs.

5.3.   Signal Monitoring

Figure 6. Signal Monitoring viewer

The signal monitoring function provides the user with online information about the measured values and displays the status of binary input and output signals. Moreover, PCM600 facilitates commissioning and testing of physical connections by allowing the user to activate both analog and binary signals via the signal monitoring tool

5.4.   Parameters Setting

The parameter setting tool of PCM600 allows the user to view and set IED parameters locally or remotely. The settings can be uploaded from the IED to PCM600 or downloaded from PCM600 to the IED while the IED is in service.

Figure 7. Parameter setting tool view

The parameter setting function can be used in two different modes. The normal mode allows the IED protection engineer to quickly view and change the most commonly used parameters, whereas the advanced mode unveils all parameters that can be set.

PCM600 further offers a filtering function allowing the user to view all IED parameters or the parameters related to a specific function block. In addition, the user can choose to only view parameters that have been changed or parameters with values deviating from the IED's setting.

After changing the desired parameters the Filtering functionality of PCM 600 allows you to compare them easily with the uploaded settings. This way you can ensure that the intended settings have been modified and that the values are correct before the new IED settings are downloaded. This also reduces the time needed for commissioning and maintenance. PCM 600 permits the restoring of verified default settings to the IED anytime after the IED has been taken into operation.

5.5.   Event Viewer

The event viewer of PCM600 enables the user to view the IEDs' sequence of events information including timestamps. The event log facilitates detailed post-fault analyses of faults and disturbances.

5.6.   Disturbance Handling

PCM600 offers efficient handling and monitoring of disturbance records from the IEDs. The disturbance files stored in the standard COMTRADE format allows the user to view the disturbance record using the included Wavewin ABB software or any available disturbance analyzer software, which supports the COMTRADE format.

6. PROTECTION FUNCTIONS

This chapter will give an introduction to the main protection functions, which are used in this laboratory work. It is important to understand the protection functionality before using it, and this chapter will give a full explanation.

6.1. Motor Start Up Supervision (STTPMSU)

The motor startup supervision function STTPMSU is designed for protection against excessive starting time and locked rotor conditions of the motor during starting. For good and reliable operation of motor, the thermal stress during the motor starting is maintained within the allowed limits. The starting of motor is supervised by monitoring the TRMS magnitude of all the phase currents or by monitoring the status of the circuit breaker connected to the motor.

During the startup period of the motor, STTPMSU calculates the integral of I_2t value. If the calculated value exceeds the set value, the operate signal is activated. The motor startup supervision has the provision to check the locked rotor condition of the motor using the speed switch, which means checking if the rotor is able to rotate or not. This feature operates after a predefined operating time.

STTPMSU also protects the motor from an excessive number of start-ups. Upon exceeding the specified number of start-ups within certain duration, STTPMSU blocks further starts. The restart of the motor is also inhibited after each start and continues to be inhibited for a set duration. When the lock of start of motor is enabled, STTPMSU gives the time remaining until the restart of the motor. This time can be seen at the parameter settings. /1/
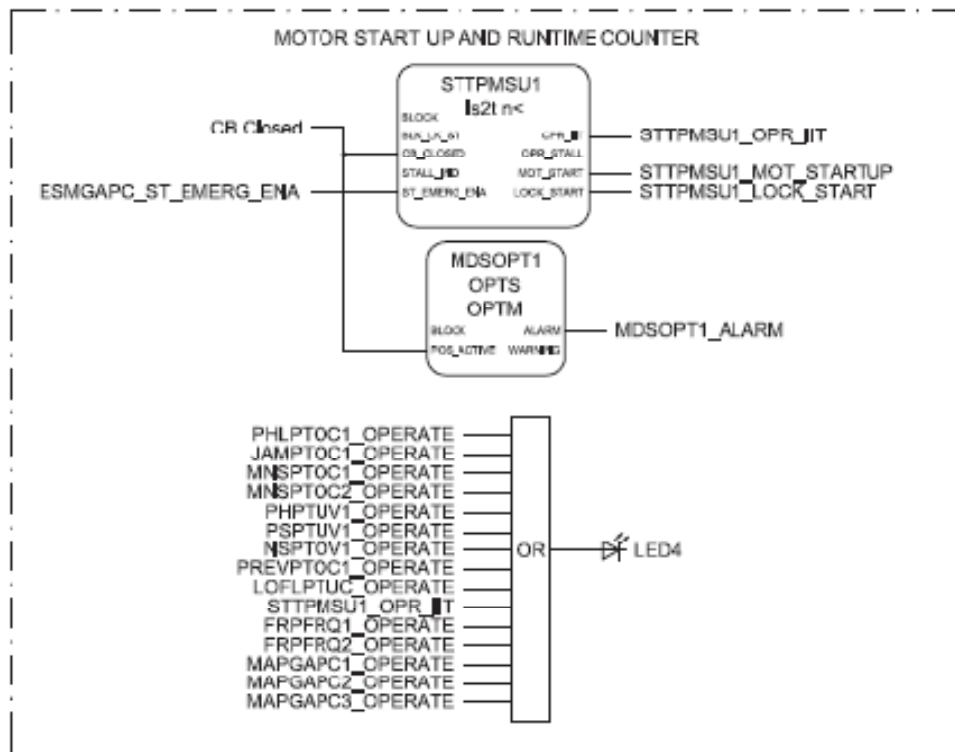
Figure 8. Motor startup supervision /4/

With the motor startup supervision function (STTPMSU1) the starting of the
motor is supervised by monitoring three-phase currents or the status of the
energizing circuit breaker of the motor.

When the emergency start request is activated by ESMCAPC1 and STTPMSU1 is
in lockout state, which inhibits motor starting, the lockout is deactivated and
emergency starting is available. /4/

7. Three-phase Non-Directional Overcurrent Protection (PHxPTOC)

Three-phase overcurrent protections PHxPTOC is used as one-phase, two-phase
or three-phase non-directional overcurrent and short-circuit protection for feeders.
The function starts when the current exceeds the set limit. The operate time
characteristics for low stage PHLPTOC and high stage PHHPTOC can be selected
to be either definite time (DT) or inverse definite minimum time (IDMT).
The instantaneous stage PHIPTOC always operates with the DT characteristic. In
the DT mode, the function operates after a predefined operation time and reset

when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.
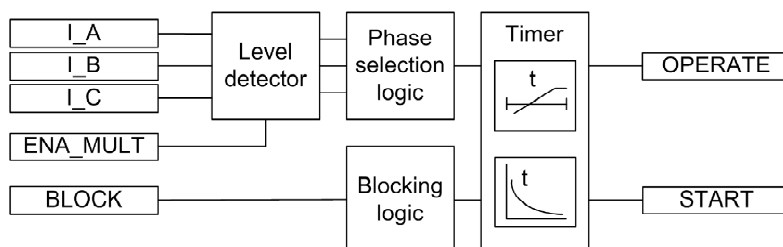

Figure 9. functional module diagrams. I_A, I_B and I_C represent phase currents /1/

The measured phase currents are compared phase-wise with the set Start value. If the measured value exceeds the set Start value, the level detector reports the exceeding of the value to the phase selection logic. If the ENA_MULT input is active, the start value setting is multiplied by the Start value Mult Setting.

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the Number of start phases setting, the phase selection logic activates the timer module.

The timer activates the START output. Depending on the value of the Operating curve types setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of Operate delay time in the DT mode or the maximum value defined by the inverse time curve, the OPERATE output is activated.

There are three operation modes in the blocking functionality. The BLOCK input can be controlled by a binary input, a horizontal communication input or an

internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting Blocking mode. */1/*

Figure 10. Overcurrent protection */4/*

Two overcurrent stages are offered for overcurrent and short-circuit protection. The motor jam protection function (JAMPTOC1) is blocked by the motor startup protection function. PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the short-circuit protection. */4/*

7.1. Phase Reversal Protection (PREVPTOC)

The phase-reversal protection PREVPTOC is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase sequence current I_2 of the motor.

PREVPTOC starts and operates when I_2 exceeds the set limit. PREVPTOC operates on definite time (DT) characteristics. PREVPTOC is based on the calculated I_2, and the function detects too high I_2 values during the motor startup.

The excessive I2 values are caused by incorrectly connected phases, which in turn makes the motor rotate in the opposite direction.
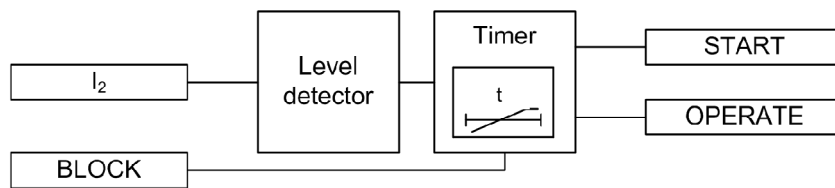

Figure 11. Functional module diagram of PREVTOC */1/*

The level detector compares the negative phase-sequence current to the set Start value. If the I_2 value exceeds the set Start value, the level detector sends an enable signal to the timer module.

The timer activates the START output. When the operation timer has reached the set Operate delay time value, the OPERATE output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value of 200 ms, the operate timer resets and the START output is deactivated. */1/*

7.2. Negative Phase-sequence Current Protection (MNSPTOC)

The unbalance protection based on negative-phase-sequence current function (MNSPTOC) protects electric motors from phase unbalance. A small voltage unbalance can produce a large negative-sequence current flow in the motor.

Negative phase-sequence current protection detects the large negative-sequence current and disconnects the motor.
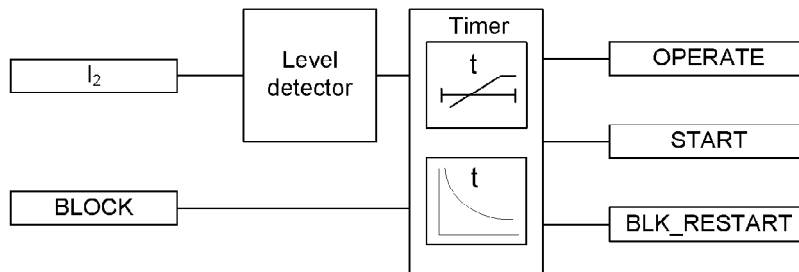

Figure 12. Functional module diagram of MNSPTOC /1/

The calculated negative-sequence current is compared to the Start value setting. If the measured value exceeds the Start value setting, the function activates the timer module.

The timer activates the START output. Depending on the value of the set Operating curve type, the time characteristics are according to DT or IDMT. When the operation timer has reached the value set by Operate delay time in the DT mode or the maximum value defined by the inverse time curve, the OPERATE output is activated. */1/*
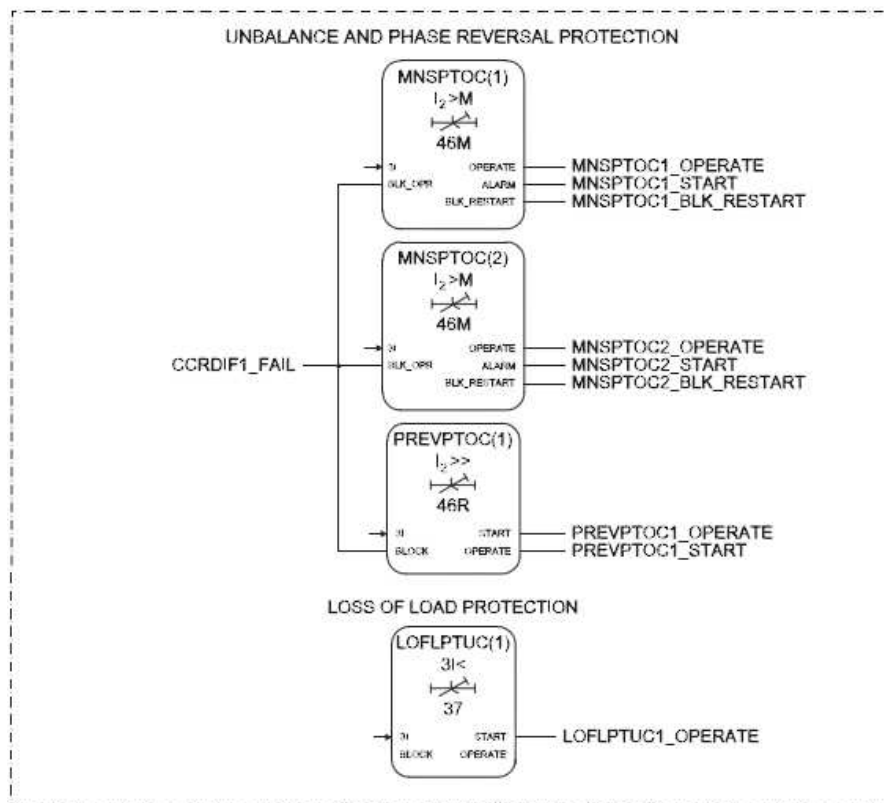
Figure 13. Phase unbalance protection /4/

Two negative-sequence overcurrent stages MNSPTOC1 and MNSPTOC2 are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The negative-sequence protection and phase reversal protection are blocked if the current circuit supervision detects failure of CCRDIF1_FAIL. /4/

7.3. Loss of Load Protection (LOFLPTUC)

The loss of load protection LOFLPTUC is used to detect a sudden load loss which is considered as a fault condition. The loss of load protection starts when the current is less than the set limit. It operates with the definite time (DT) characteris-

tics, which means that the function operates after a predefined operate time and resets when the fault current disappears.
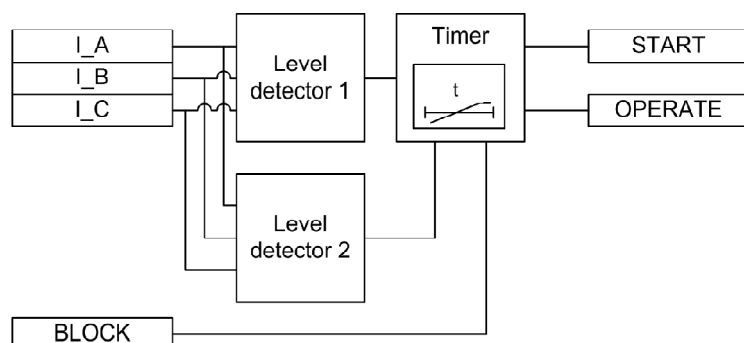

Figure 14. Functional module diagram of LOFLPTUC */1/*

The level detector 1 compares the phase currents RMS value to the set Start value high setting. If all the phase current values are less than the set Start value high value, the loss of load condition is detected and an enable signal is sent to the timer. This signal is disabled after one or several phase currents have exceeded the set Start value high value of the element.

Level detector 2 is a low-current detection module, which monitors the de-energized condition of the motor. It compares the phase currents RMS value to the set Start value low setting. If any of the phase current values is less than the set Start value low, a signal is sent to block the operation of the timer.

The timer activates the START output. When the operation timer has reached the set Operate delay time value, the OPERATE output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value of 200 ms, the operate timer resets and the START output is deactivated. */1/*

7.4. Three-phase Thermal Overload Protection for Motors (MPTTR)

The three-phase thermal overload protection function MPTTR detects short- and long term overloads under varying load conditions. The motor thermal overload protection function MPTTR protects the electric motors from overheating. MPTTR models the thermal behavior of motor on the basis of the measured load current and disconnects the motor when the thermal content reaches 100 percent. The thermal overload conditions are the most often encountered abnormal conditions in industrial motor applications. The thermal overload conditions are typically the result of an abnormal rise in the motor running current, which produces an increase in the thermal dissipation of the motor and temperature or reduces cooling. MPTTR prevents an electric motor from drawing excessive current and overheating, which causes the premature insulation failures of the windings and, in worst cases, burning out of the motors.

MPTTR is intended to limit the motor thermal level to predetermined values during the abnormal motor operating conditions. This prevents a premature motor insulation failure. The abnormal conditions result in overheating and include overload, stalling, failure to start, high ambient temperature, restricted motor ventilation, reduced speed operation, frequent starting or jogging, high or low line voltage or frequency, mechanical failure of the driven load, improper installation and unbalanced line voltage or single phasing. */1/*
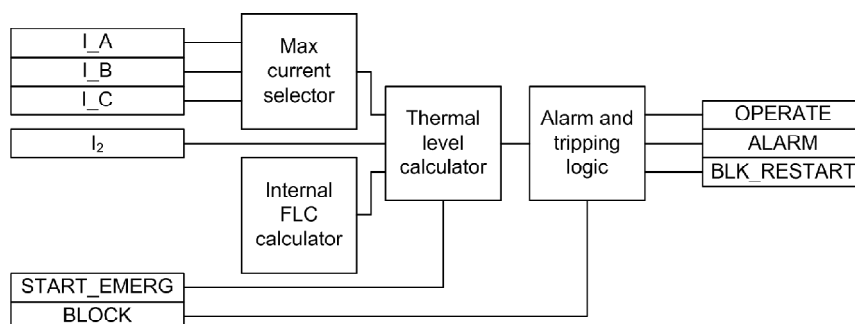

Figure 15. Functional module diagram of MPTTR */1/*

The maximum current selector selects the highest phase current and reports it to the thermal level calculator. The FLC of the motor is defined by the manufacturer at an ambient temperature of 40°C the calculation of an internal FLC is based on the ambient temperature shown in the Table 2. The environment temperature mode setting decides whether the thermal level calculations are based on FLC or internal FLC.

The thermal level calculator module calculates the thermal load considering the TRMS and negative sequence currents. The heating up of the motor is determined by the square value of the load current. However, in case of unbalanced phase currents, the negative sequence current also causes additional heating. By deploying a protection based on both current components, abnormal heating of the motor is avoided. The thermal load is calculated based on different situations or operations and it also depends on phase current level.

The alarm and tripping logic generates alarm, restart inhibits and tripping signals. When the thermal level exceeds the set value of the Alarm thermal value setting, the ALARM output is activated.

Table 2. Modification of internal FL /1/

Ambient Temperature T_{amb}	Internal FLC
<20°C	FLC x 1.09
20 to <40°C	FLC x (1.18 - T_{amb} x 0.09/20)
40°C	FLC
>40 to 65°C	FLC x (1 –[(T_{amb} -40)/100])
>65°C	FLC x 0.75

7.5.   Non-directional Earth-fault Protection (EFxPTOC)

The earth-fault function EFxPTOC is used as non-directional earth-fault protection for feeders. The function starts and operates when the residual current exceeds the set limit.

The operate time characteristic for low stage EFLPTOC and high stage EFHPTOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage EFIPTOC always operates with the DT characteristic. In the DT mode, the function operates after a predefined operation time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.
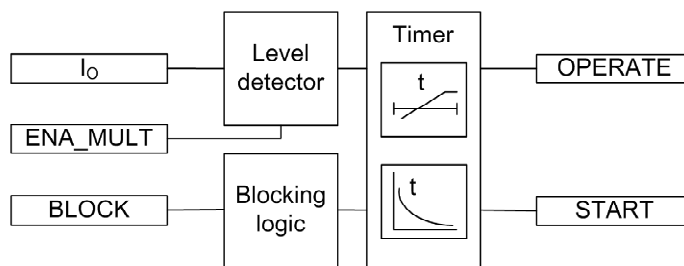

Figure 16. Functional module diagram of the EFxPTOC /1/

The measured residual current is compared with the set Start value. If the measured value exceeds the set Start value, the level detector sends an enable-signal to the timer module. If the ENA_MULT input is active, the Start value setting is multiplied by the Start values Mult Setting.

The timer activates the START output. When the operation timer has reached the set Operate delay time value, the OPERATE output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value of 200 ms, the operate timer resets and the START output is deactivated. */1/*
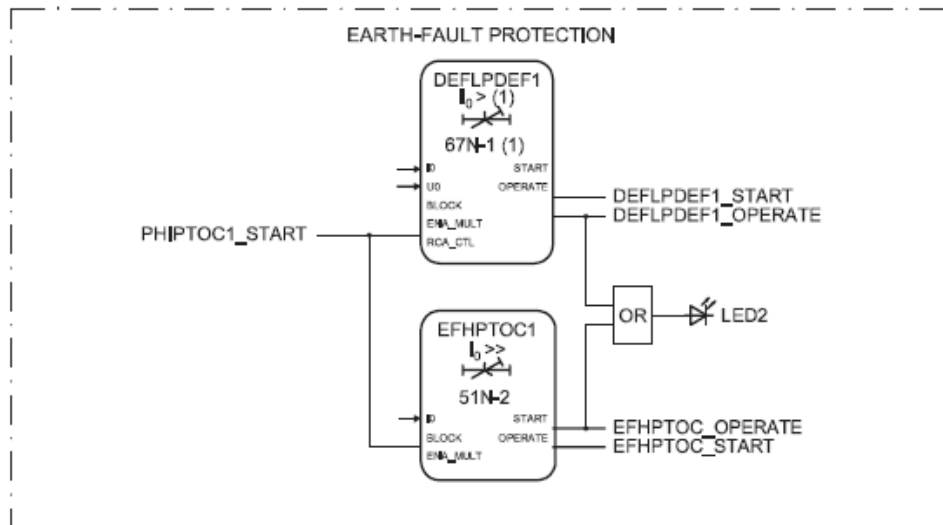
Figure 17. Non-directional earth-fault protection */4/*

One and the two stage non-directional earth-fault protection (EFHPTOC1) is offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing. In addition, there is a directional protection stage (DEFLPDEF1) which can be also used as a low stage non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor startup.

The earth- fault protection is blocked when the short circuit protection (PHIPTOC1) is started. The operation of the earth-fault protection functions is connected to alarm LED 2. */4/*

8. HANDOUT

The main focus of this exercise is to study the motor protection with the REM 615 multipurpose relay and familiarize the usage of the REM_ series terminal in a normal and fault situation of the protected application.

The participants will familiarize themselves with protection functions by setting up a predefined motor protection application and testing the functionality of the application by creating various operating conditions for the motor and electrical faults to the motor feeder.

In this exercise a fault simulation console will be used. The REM 615 protection and control terminal has been mounted to the console. The console allows the user to create electrical fault situations into the motor feeder. The mechanical load of the motor is simulated by the means of the motor test bench where the counter torque is adjustable.

8.1.   Commissioning

When commissioning any kind of electronic, some problems will arise that have to be solved. In order to see that the relay works we had to load it, so we used resistance instead of motor, and started the relay. The machine started and worked for view seconds. The problem that was encountered at this stage was soon fixed.

Now we had to access the configuration and change it if it need be, but first we had to communicate with the device via pc using Ethernet connection cable RJ-45 from front panel. After configuring the relay using PCM600, web HMI or the local panel, it is very important to check the configurations if the parameters works properly or not. To test the configurations we have used a view test, such as broken wire, non-directional earth-fault. Based on these tests we were able to see the best suitable parameters for the each testing.

8.2. Testing

 The idea of making test is to see how the protection function works during testing. The protection function system is to isolate the fault in the shortest time possible. Once fault occurs, the isolation part takes place by disconnecting the circuit at the fault section. All protection functions will act automatically when fault occurs.

Each protection function was set suitable parameters using a relay configuration tool or manually, after view tests were done.

The IED has the capacity to store the records of four latest fault events. The records enable the user to analyze the four most recent power system events. Each fault record (FLTMSTA) is marked with an up-counting fault number. Slot fault record 1 always contains the newest record, and fault record 4 the oldest. The time stamp is taken from the beginning of the fault.

REM615 > Alarms

Alarms

Description	Value
Alarm LEDs LED 1	○
Alarm LEDs LED 2	○
Alarm LEDs LED 3	○
Alarm LEDs LED 4	○
Alarm LEDs LED 5	○
Alarm LEDs LED 6	○
Alarm LEDs LED 7	○
Alarm LEDs LED 8	●
Alarm LEDs LED 9	●
Alarm LEDs LED 10	○
Alarm LEDs LED 11	○

LED	Default usage
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Voltage protection operated
4	Negative-sequence overcurrent or phase discontinuity protection operated
5	Thermal overload protection operated
6	Circuit-breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit-breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

Figure 18. Alarm leds meaning in alarm view

Table 3. Parameters of the motor and information of the measurement circuit

Parameter	Value	Parameter	Value
Motor code	MT 100 LA	I_{L1} CT ratio	10 A / 1A
P_N	2,2 kW	I_{L2} CT ratio	10 A / 1A
n_N	1430 1/min	I_{L3} CT ratio	10 A / 1A
U_N	400 V	I_0 CT ratio	10 A / 1A
I_N	5,2 A	U_{12} VT ratio	400 V / 100V
Cos Ø	0,76	U_{23} VT ratio	400 V / 100V
I_{ST}/I_N	5,5	U_{31} VT ratio	400 V / 100V

Current (I0,CT): 1					
Current (I0,CT)					
Secondary current		1A			
Primary current		10,0	A	1,0	6000,0
Amplitude corr.		1,000		0,900	1,100
Voltage (3U,VT): 1					
Voltage (3U,VT)					
Primary voltage		0,400	kV	0,001	440,000
Secondary voltage		100V			
VT connection		Delta			
Amplitude corr. A		1,000		0,900	1,100
Amplitude corr. B		1,000		0,900	1,100
Amplitude corr. C		1,000		0,900	1,100

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Voltage (U0,VT): 1					
Voltage (U0,VT)					
Secondary voltage		100V			
Primary voltage		0,230	kV	0,001	440,000
Amplitude corr.		1,000		0,900	1,100
Current (3I,CT): 1					
Current (3I,CT)					
Secondary current		1A			
Primary current		10,0	A	1,0	6000,0
Amplitude corr. A		1,000		0,900	1,100
Amplitude corr. B		1,000		0,900	1,100
Amplitude corr. C		1,000		0,900	1,100

Figure 19. The parameters of the voltage and current transformer of the measurement circuit

7.2.1 Testing of the PREVPTOC Functional Block

The phase-reversal protection is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase sequence current I_2 of the motor.

The PREVPTOC starts and operates when I_2 exceeds the set limit. The excessive I_2 values are caused by incorrectly connected phases, which in turn makes the motor rotate in the opposite direction.
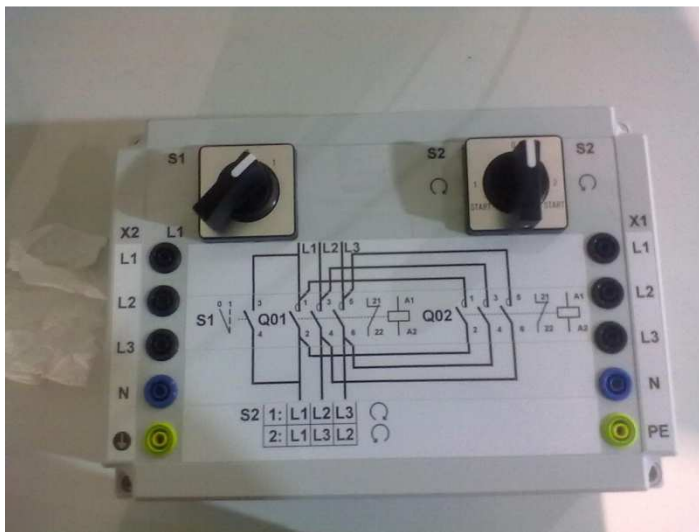
Figure 20. Motor reversing switch

The motor reversing switch was designed especially for this testing. The reversing switch changes the motor direction while the motor is running. The motor reversing switch has many connectors which are used when it is connecting. The motor reversing switch is connected between the motor and relay protection system.

Figure 21. Settings of PREVPTOC function block and fault recorded data

Before starting the test these parameter settings must be done. As is can be seen from the picture the start value is 0.3 x I$_N$, and the operate delay time is 400 ms. After setting the parameters, the test is ready to be done.

As the above picture is seen how phase-reversal protection works. The function starts operates after 385 ms. As soon as the motor starts protection function starts with it, after that relay sees that the motor rotation changes and the function sends alarm and warning at the same time and it disconnects the motor.
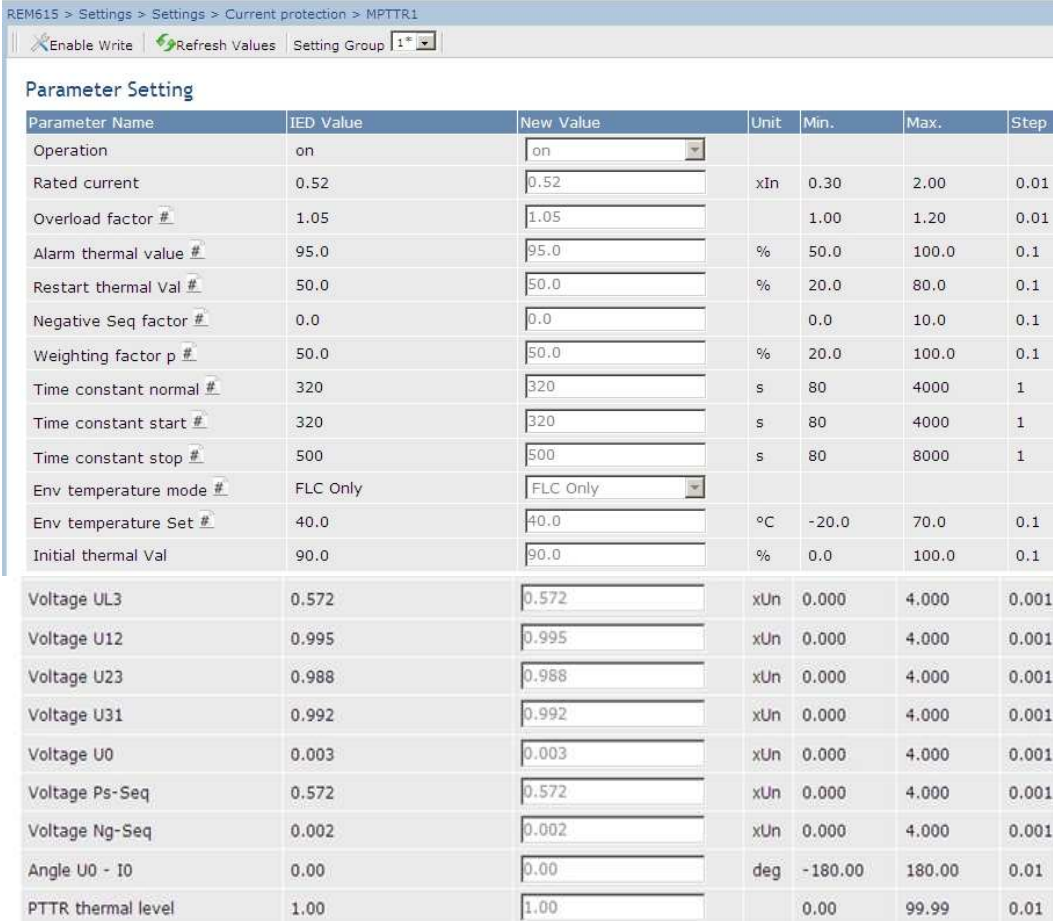
7.2.2 Testing of the MPTTR1 Functional Block

The motor thermal overload protection function MPTTR protects the electric motors from overheating. MPTTR models the thermal behavior of motor on the basis of the measured load current and disconnects the motor when the thermal content

reaches 100 percent.

This prevents a premature motor insulation failure. The thermal load is calculated using the true RMS value and negative sequence value of the currents.

With a relay configuration tool or manually, make the following settings to the function parameter.

REM615 > Settings > Settings > Current protection > MPTTR1

✗Enable Write | ↻Refresh Values | Setting Group 1* ▾

Parameter Setting

Parameter Name	IED Value	New Value	Unit	Min.	Max.	Step
Operation	on	on ▾				
Rated current	0.52	0.52	xIn	0.30	2.00	0.01
Overload factor #	1.05	1.05		1.00	1.20	0.01
Alarm thermal value #	95.0	95.0	%	50.0	100.0	0.1
Restart thermal Val #	50.0	50.0	%	20.0	80.0	0.1
Negative Seq factor #	0.0	0.0		0.0	10.0	0.1
Weighting factor p #	50.0	50.0	%	20.0	100.0	0.1
Time constant normal #	320	320	s	80	4000	1
Time constant start #	320	320	s	80	4000	1
Time constant stop #	500	500	s	80	8000	1
Env temperature mode #	FLC Only	FLC Only ▾				
Env temperature Set #	40.0	40.0	°C	-20.0	70.0	0.1
Initial thermal Val	90.0	90.0	%	0.0	100.0	0.1
Voltage UL3	0.572	0.572	xUn	0.000	4.000	0.001
Voltage U12	0.995	0.995	xUn	0.000	4.000	0.001
Voltage U23	0.988	0.988	xUn	0.000	4.000	0.001
Voltage U31	0.992	0.992	xUn	0.000	4.000	0.001
Voltage U0	0.003	0.003	xUn	0.000	4.000	0.001
Voltage Ps-Seq	0.572	0.572	xUn	0.000	4.000	0.001
Voltage Ng-Seq	0.002	0.002	xUn	0.000	4.000	0.001
Angle U0 - I0	0.00	0.00	deg	-180.00	180.00	0.01
PTTR thermal level	1.00	1.00		0.00	99.99	0.01

Figure 22. Settings of PREVPTOC function block and fault recorded data

The thermal level has reached the limit which is 100 degrees, and function block acted as it should be. The above picture PTTR thermal's value is 100 because of the parameters settings was set 1.00 instead of 100.

7.2.3. Testing of the EFHPTOC1 Functional Block

The earth-fault function EFxPTOC is used as non-directional earth-fault protection for feeders.

EFxPTOC is designed for protection and clearance of earth faults in distribution and sub-transmission networks where the neutral point is isolated or earthed.

The function starts and operates when the residual current exceeds the set limit.

REM615 > Settings > Settings > Current protection > EFHPTOC1

Enable Write | Refresh Values | Setting Group 1*

Parameter Setting

Parameter Name	IED Value	New Value	Unit	Min.	Max.	Step
Operation	off	off				
Start value #	0.10	0.10	xIn	0.10	40.00	0.01
Start value Mult #	1.0	1.0		0.8	10.0	0.1
Time multiplier #	1.00	1.00		0.05	15.00	0.05
Operate delay time #	100	100	ms	40	200000	10
Minimum operate time	20	20	ms	20	60000	1
Reset delay time	20	20	ms	0	60000	1
Operating curve type #	IEC Def. Time	IEC Def. Time				
Type of reset curve #	Immediate	Immediate				
Measurement mode	DFT	DFT				
Curve parameter A	28.2000	28.2000		0.0086	120.0000	0.0001
Curve parameter B	0.1217	0.1217		0.0000	0.7120	0.0001
Curve parameter C	2.00	2.00		0.02	2.00	0.01
Curve parameter D	29.10	29.10		0.46	30.00	0.01
Curve parameter E	1.0	1.0		0.0	1.0	0.1
PTTR thermal level	0.00	0.00				0.00
PHLPTOC1 duration	0.00	0.00	%			0.00
PHIPTOC1 duration	0.00	0.00	%			0.00
EFHPTOC1 duration	100.00	100.00	%			0.00
DEFLPDEF1 duration	0.00	0.00	%			0.00

Figure 23. Settings of PREVPTOC function block and fault recorded data

This picture was taken after test was done, and it can be seen from the picture that the function tripped immediately after the fault occurs and disconnects the motor from the supply.

9. CONCLUSIONS

The main purpose of this thesis was to research and create written lecture handout for laboratory work, which includes instructions concerning the laboratory exercises and hardware protector for motor protection relay testing. This will help the students to understand the devices and the practical work to be accomplished during the laboratory and to simulate educational equipment test situation based on the lecture handout.

In this thesis the functionalities of relay protection were studied and its features which could be used in this laboratory work. At first the work was started by studying the old relay protection system and then on that basis the new relay was drawn in block diagrams. The installation of relay protection was made from drawn diagrams and then it was commissioned and tested.
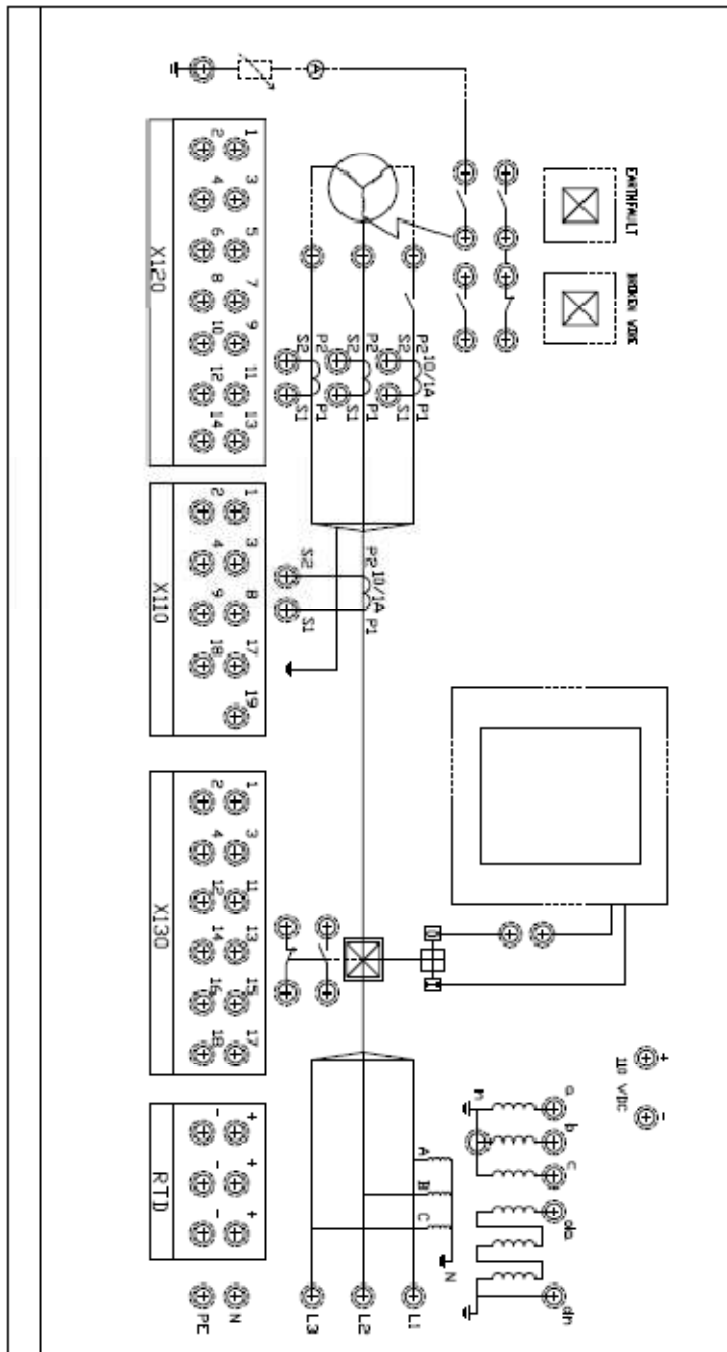
The direct beneficiaries of this research are the upcoming students, who will use the created laboratory work to further their knowledge regarding the power automation features. In addition to that, this research is also beneficial to the concerned teachers who will use it in their subjects.
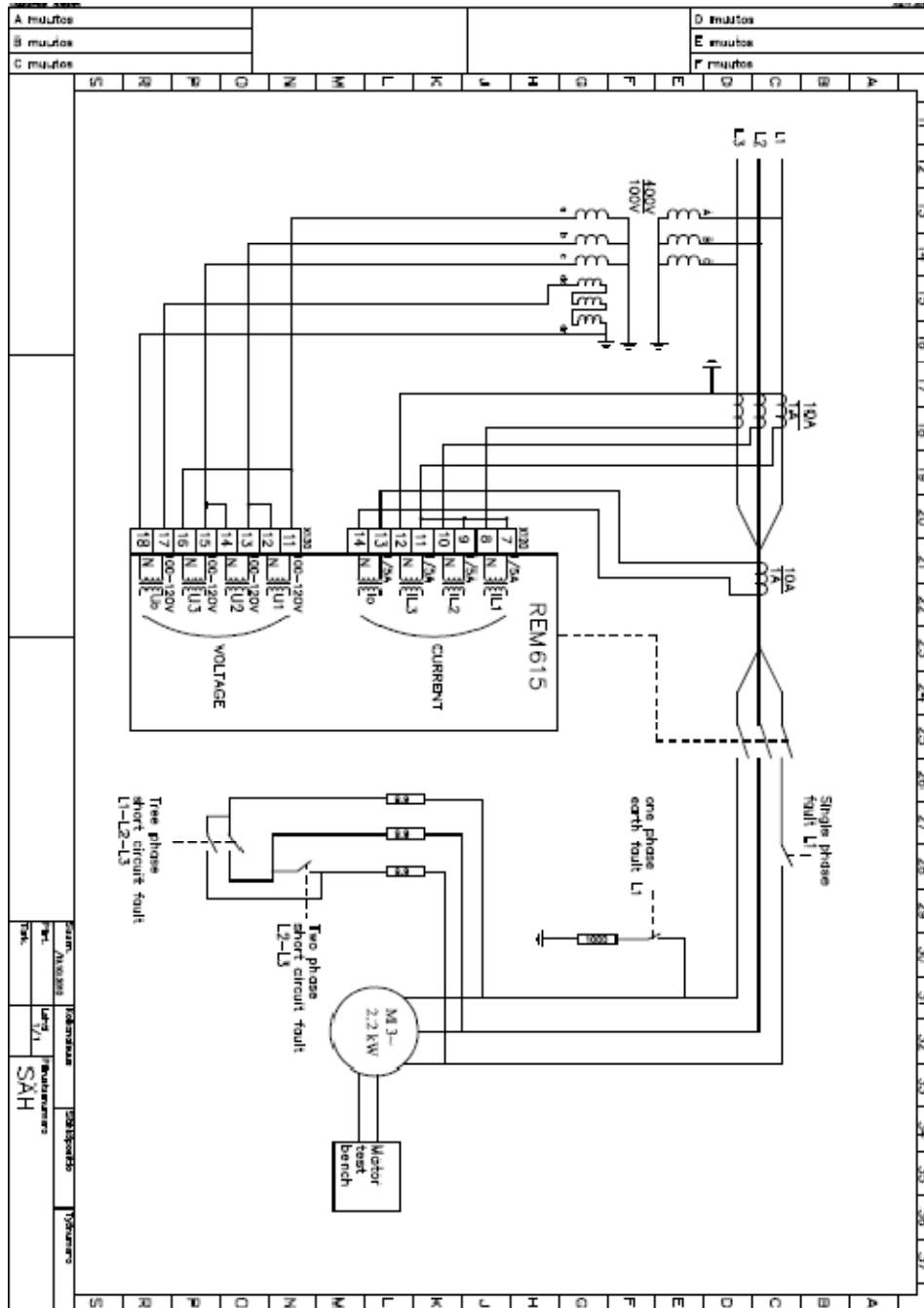
REFERENCES

/1/   REM615 SERIES TECHNICAL MANUAL

           RE_615_tech_756887_ENb. ABB

/2/   Motor Protection and Control REM615 Product Guide

           REM615_pg_756890_ENb

/3/   PCM600 20 SP2 Product Guide_756448_Enc ABB

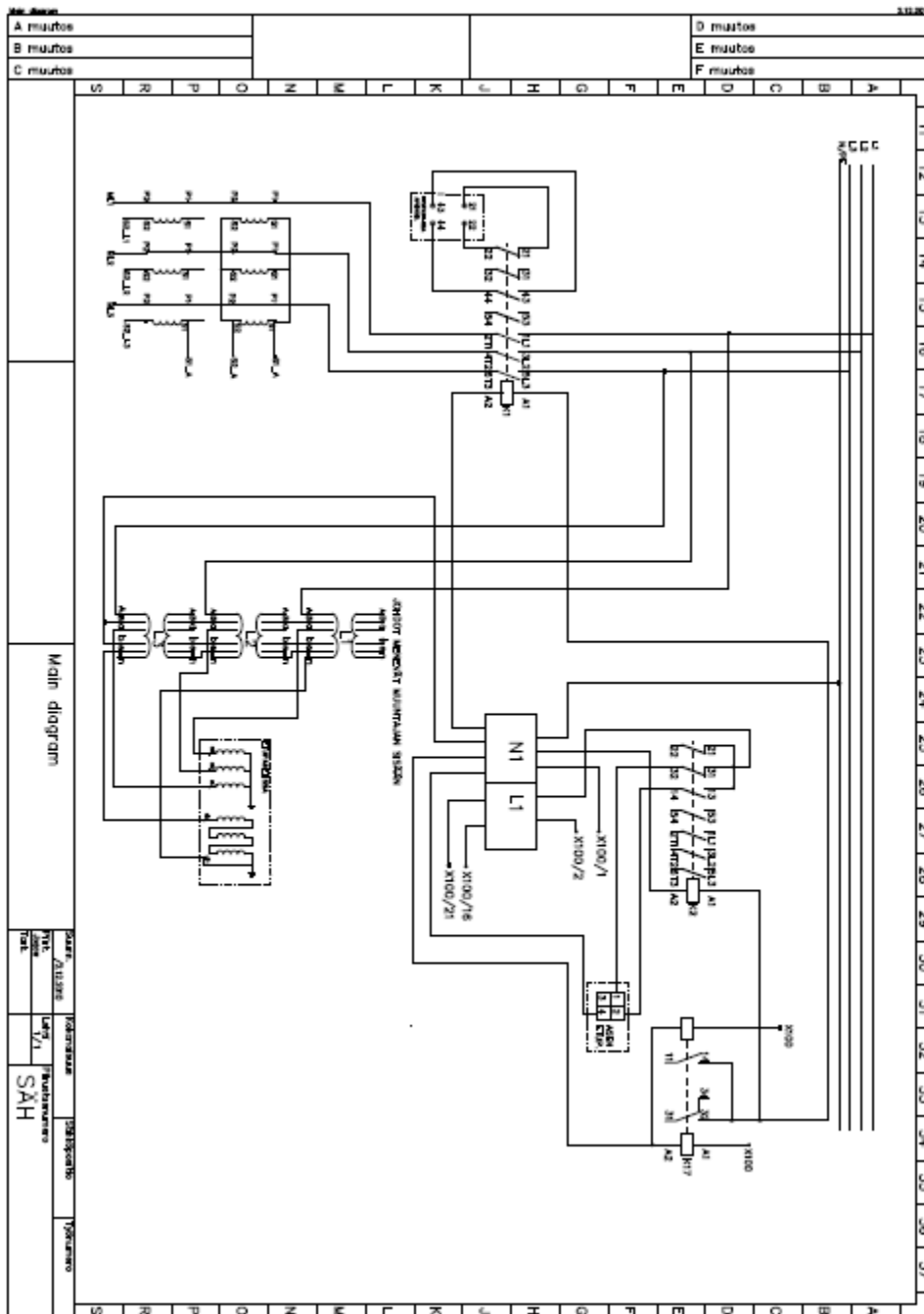/4/   Application Manual REM615_appl_756885_ENc   ABB

APPENDICES

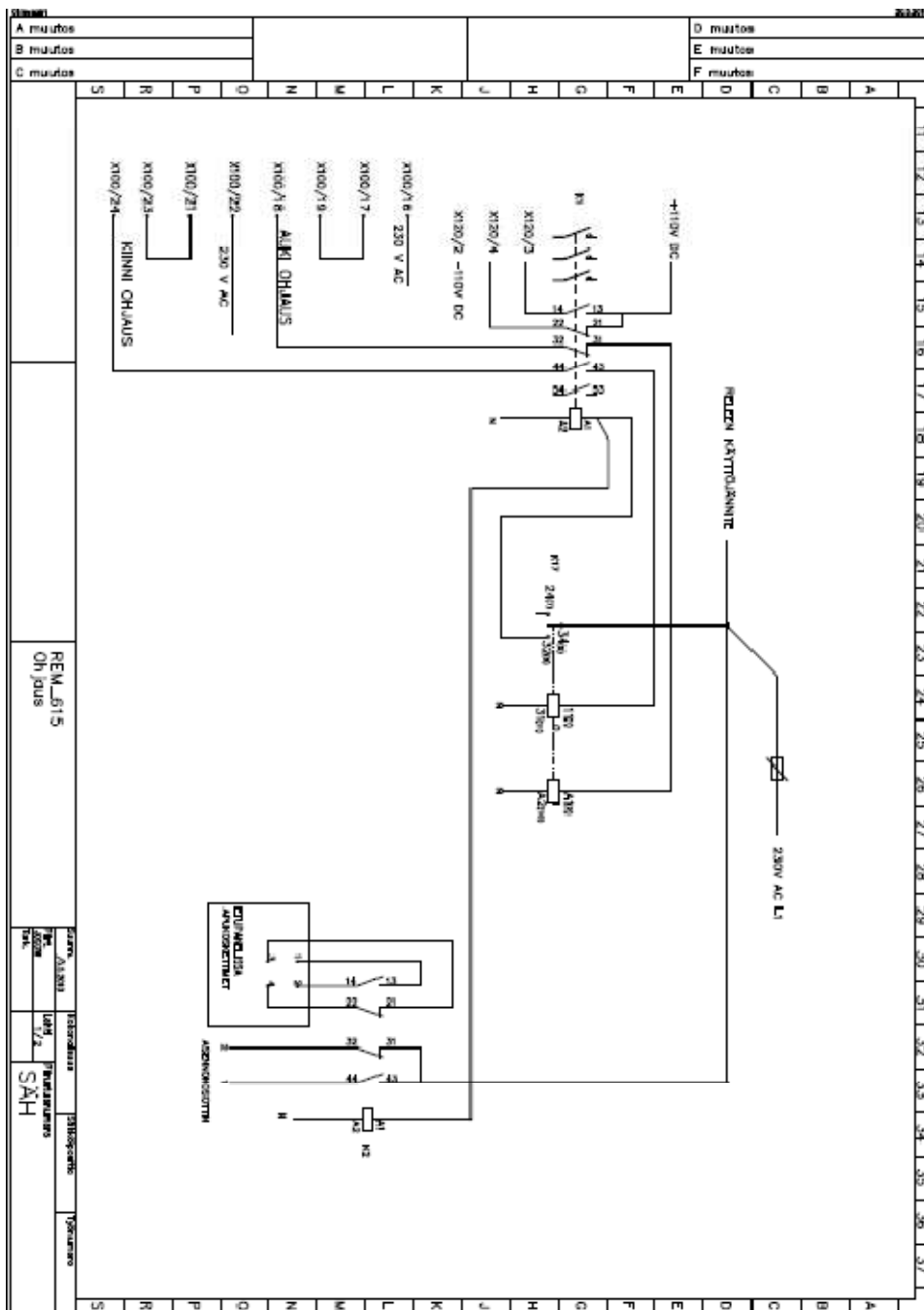## Appendix 1 FACE_PANEL DIAGRAM

Appendix 2 CONNETION DIAGRAM

Appendix 3 MAIN DIAGRAM

Appendix 4 CONTROL DIAGRAM

Appendix 5 DIRECT CHANGER DIAGRAM

Direct changer diagram