

Toni Kallio

DRIVE INTERFACE STUDY

Sähkötekniikan koulutusohjelma

2014

DRIVE INTERFACE STUDY

Kallio, Toni
Satakunta's University of Applied Sciences
Training program for electrical engineering
May 2014
Instructor: Suvela Timo
Number of pages: 52
Annexes: 5

Keywords: module, contactor, standard, reliability

Purpose of this thesis was to carry out pre-study for drive interface module, which will be placed between the control system of the elevator and the drive that runs the hoisting motor. Second topic was planning of reliability tests and performing of preliminary and noise tests for contactors and contactors relays used in drive interface modules today and for contactors and contactor relays which are planned to be used in upcoming module. Thesis was made for R&D department of KONE Oyj placed in Hyvinkää Finland.

On thesis electrical and mechanical requirements for design of the new module were determined. Also first mock-up version of the module was built from which basis building of new detailed module prototype could be started.

For contactors reliability tests, test environment was planned and built to KONE reliability laboratory premises in Hyvinkää. Testing will be started during summer 2014. Preliminary and noise tests were performed also in KONE testing premises in Hyvinkää.

Purpose of contactor tests was to compare characteristics of contactors used in drive interface modules today and contactors planned to be used in upcoming module and to ensure reliability level of those contactors before implementing them to production.

Table of content

1	RECITAL	5
2	DESCRIPTION OF DRIVE INTERFACE MODULE.....	5
2.1	Regenerative drives.....	6
2.1.1	Variable speed drive system.....	6
2.1.2	Regeneration	7
2.2	Electrical Interface	8
2.3	Mechanical interface	9
2.4	Safety system	9
2.4.1	Difference between old and new safety systems	9
3	REQUIREMENTS FOR NEW MODULE	10
3.1	Recital	10
3.2	In general	10
3.3	Mechanical.....	11
3.4	Electrical	13
3.5	Contactors in drive interface module.....	14
3.5.1	Mechanically linked contacts	14
3.5.2	Mirror contacts	15
3.5.3	Utilization categories.....	16
3.5.4	Pick and drop voltages.....	17
3.6	Standard demands for main contactor.....	18
3.6.1	EN81-1	19
3.6.2	A17.1	21
4	VISION FOR NEW MODULE	21
4.1	Recital	21
4.2	IP classes.....	21
4.3	First mock-up content/visio	25
4.4	Changes to electrical functionality.....	28
5	CONTACTOR TESTS.....	28
5.1	Recital	28
5.2	Tests	29
5.3	Reliability test	30
5.4	Preliminary test	30
5.4.1	Coil characteristic test	31
5.4.2	Conclusions of coil characteristic measurements.....	34
5.4.3	Pick and drop out tests.....	35

5.4.4	Conclusions of pick and drop out tests.....	37
5.5	Noise tests	44
5.5.1	Contactors relays.....	46
5.5.2	Conclusions for contactor relays	46
5.5.3	DC contactors	47
5.5.4	Conclusions for DC contactors.....	48
6	ABBREVIATIONS.....	51
7	CONCLUSION	51
	BIBLIOGRAPHY	52

1 RECITAL

On developing elevator technology amount of programmable electrical systems with relation to traditional mechanical systems is increasing. In R&D design those changes need to be taken into account when creating new products under many regulations with difference by continents.

Tightened lead-times of projects have raised significance of pre-studies about products. Global differences in elevator concepts and in requirements due to standardization are important to know to complete projects design effectively. Reliability of components in environment of use must be ensured before taking products to markets.

Detailed requirement specification is essential before starting actual design. Accurate definition of the requirements ensures good quality, usability and reliability of the final product.

2 DESCRIPTION OF DRIVE INTERFACE MODULE

Drive interface module is a module between elevator drive and electrification including for example elevator motion controller, main contactor(s) and brake module(s) as a main parts. Drive interface module allows the usage of a generic variable speed drive by separating main parts from the drive system. /1/

Elevator concept, standard and code requirements and hoisting motor type are causing variation to the module design. Globally main standards for elevators are EN81 in Europe and Asia Pacific area and A17.1 in North America. These standards are having small differences for example related to braking control and dimensioning of main contactors(s). Common elevator concepts are machine room elevator and machine-room-less elevator which set different space requirements for the module. Hoisting motor size of a variable speed drive causes variation to the module design.

Main contactors size changes based on a current range of the drive. Brake module changes based on a hoisting motor type.

Different parts on elevator, for example drive system and electrification might be manufactured in different factories from where those parts are delivered to consolidation center. In consolidation center all elevator parts are compiled together and delivered to elevator installation site when required. So parts don't meet before final assembling on the site. This is also reason why parts in drive interface module are wanted to keep on a separate module.

2.1 Regenerative drives

Drive interface modules are used with regenerative variable speed drives. Drives are used with mid-range elevators KONE MonoSpace®, KONE MiniSpace™, KONE Transys™, KONE ReGenerate™. Also KONE ac-gearless modernization and EcoDisc® gearless machineries with various size alternatives are used with regenerative drives. /1/

2.1.1 Variable speed drive system

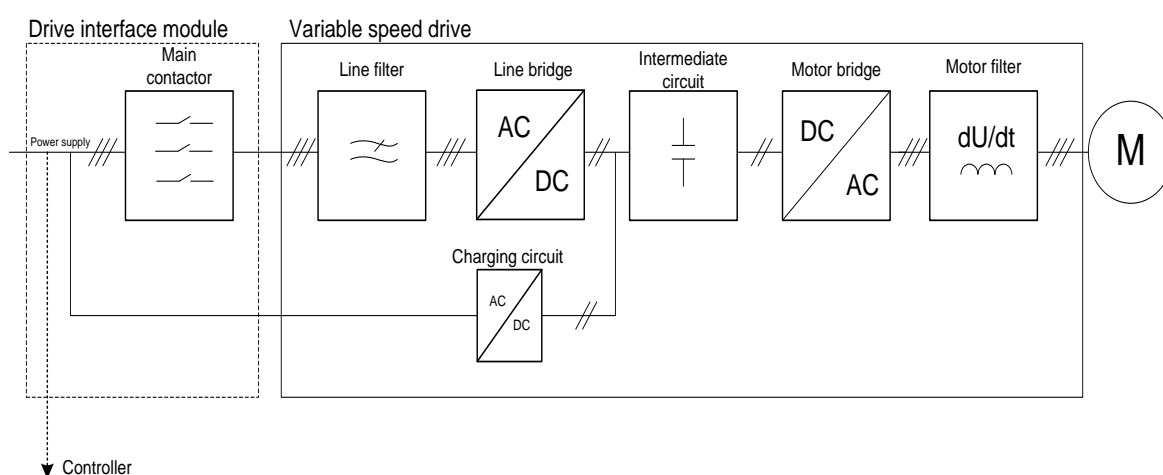


Figure 1 Regenerative, variable speed drive system structure

On elevators with machine room, drive is based in control cabinet together with control system and drive interface module. On machine room less elevators drive exist in elevators shaft attached to wall fixings. In variable speed drive system the main 3-phase AC power supply goes after drive interface module to power module's line filter which attenuates radio frequencies from power supply. Current flows through line bridge converter which converts it to 2-phase DC voltage. Power capacitors stores the DC voltage in intermediate circuit. When necessary, motor bridge inverter converts the capacitors stored DC voltage back to 3-phase AC voltage to drive the motor. Motor filter reduces rise velocity of voltage values from phase-to-phase voltage and cuts frequencies above switching frequency enabling suitable AC voltage to flow to the hoisting motor. Load from a load weighing device, speed and position feedback from motor encoder and other references from controller sets the dimensions for voltage and frequency supplied to the motor. /2/

2.1.2 Regeneration

To reach better energy efficiency, regenerative drives are designed to regenerate energy back to the mains network when motor functions as a generator. Motor functions as a generator when full car or car with heavy load runs down direction or empty car or car with light load runs to up direction, this is based on weight proportion of car and counterweight. Typically counterweights mass is 40-50% from the mass of elevator car. Part of regenerated energy is supplied to lightning and ventilation. Over 30 percent of total power can be recovered.

Electrically regeneration is based on offset of voltage and current when power flows between elevator and network. On regenerative, variable speed electric drive is active network inverter which allows current flow to both directions based on four quadrant use. Current controllers of inverter forces line currents on sine curve shape and to same phase than line voltages making $\cos \phi = 1$. In result of that no reactive power is transferred, all transferred power is active power.

DC voltage of drives intermediate circuit depends of how much power flows to circuit and how much power is flown off the circuit. DC voltage regulator of intermedi-

ate circuit keeps DC voltage constant by adjusting current rule of network inverter and keeping the power on balance. When active power flows to elevator, current and voltage of network are on same phase and when power flows to network current and voltage are on 180° offset.

2.2 Electrical Interface

Main parts of drive interface module are main contactor, motion control board, main contactor control board, brake control module, DC-link, charging circuit and optionally interface to motor hoisting fan. /1/

Motion control board receives values from load weighing device, motor thermistors and motors encoder and communicates with drive module through special dual channel network to set correct values for drive to control the movements of motor. Motion control board also gives speed information to the elevator control system (electrification). Present module uses contactors with DC coil. Main contactor control board is used to rectify voltage for the main contactor coil. Main contactor control board is designed for use with a specific contactor. Brake control module communicates with motion control board. Brake control module controls the open and close operation of the electromechanical brakes based on the control of the motion controller. Electromechanical brakes are picked with 200 VDC, after brakes have picked, voltage is reduced to half. Brake control board sends brake feedback information to motion control board which deliveries it forward to the drive module. Furthermore North American module also gives emergency brake feedback to control system for status of the brake. Difference on North American module against other is a result of different elevator standard which requires many alterations. Motor fan control module relay controls motor fan status by using information received from motion control board.

2.3 Mechanical interface

In machine-room-less elevator, hoisting motor and drive interface module are located in elevator shaft. Components of the drive interface module are located in own enclosure. In elevator with machine room, components of drive interface module are located in control cabinet in machine room.

Due the variation of the hoisting machine size and different power of brake control modules, changes to brake control module enclosure and therefore also to the mechanical design of the drive interface module are required. One of main purposes of this thesis is to clarify possibilities to decrease number of these module variants by fitting certain components in one mechanical interface to improve managing, installing, maintaining and modernization of drive interface modules.

2.4 Safety system

Safety system is built to ensure safety of users and maintenance people using the elevator. Safety system is connected to all safety contacts on elevator and it controls power supply of hoisting machine via main contactors by re-energizing power supply, if some of safety contacts are open. /3/

2.4.1 Difference between old and new safety systems

The biggest difference in safety system, when moving from old control system to new control system is usage of programmable electronics instead of relay logic in new control system. In old system, safety contacts which control the main contactors or auxiliary main contactors are connected in series creating a safety chain. On new system there is no real safety chain but safety circuit which consist main safety circuit PCB board and safety contacts. Main safety circuit PCB board reads shaft and machine room safety contacts directly and car safety contacts via special dual channel network. Main safety circuit PCB board uses safety contact and sensor information from shaft, machine room and car and controls main and brake contactors with main safety output. The benefit of programmable safety circuit is cost-efficient

implementing of different options and market area dependent differences by using the same hardware platform. /3/

3 REQUIREMENTS FOR NEW MODULE

3.1 Recital

This paragraph sets requirements for new upcoming drive interface module design starting in future. New module will be designed for new control system and its design follows general requirements of new control system. Due to the new safety circuit in new electrification, it is possible to remove some of the parts of existing drive interface module design. New control system is more space efficient which allows integration of new functionalities inside drive interface module. Some components will be removed from the module and otherwise some components will be added to the module.

As mentioned before, one of primary purposes of this study is to decrease amount of variants of drive interface module by harmonizing and simplifying functions of old modules and by finding similar electrical and mechanical structures to make installing, maintenance and manufacturing easier and more effective. One key requirement for the new module is to make installing and attachments to other systems smooth and quick. Detailed requirements are set to avoid changes needed in the future. On this paragraph demands for new module will be determined and on paragraph 4 vision for new drive interface module will be inspected.

3.2 In general

New drive interface module will be designed compatible for both Monospace and Minispace elevators despite where drive interface module is planned to place, in control panel of Minispace elevator or inside an enclosure of drive interface module attached on elevator shaft wall on Monospace elevator. Compatible structure or struc-

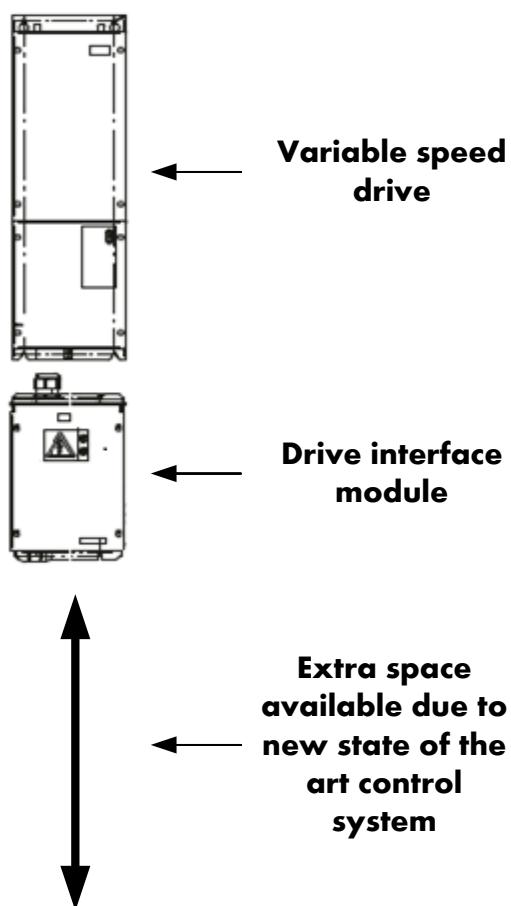
ture which differs less between Minispace and Monospace elevators would decrease level of designing and make maintaining of each product easier. New module will consist two different types of brake control module. One of the types is existing model which is already in production and another model is new one, which is under development but not in production yet. New module will not anymore support old brake control module. In European models there will be one brake module and in North American models two braking modules, which sets space reservation requirement for the enclosure layout. Drive interface module is attached to elevators control unit and to drive system on elevator site, so pre preparations will be done as complete as possible already on factory so modules installing on site would be fast and easy, which will effect also on total installation time. Short installation time is valuable asset on elevator market because of the tight building schedules for buildings. In addition to requirements, possibility to make module with black housing need to be kept on consideration during design, because on scenic (transparent) elevator shafts many clients wants to have shafts electrification parts on black so that they don't come up so striking from dark elevator shaft than housings with standard metallic color. For noise requirements of the new drive interface module, good target is that module does not exceed more than 45dB sound outside the housing in any situations. $\geq 45\text{dB}$ is a decent value so noise of module does not disturb users of the building outside elevator shaft.

3.3 Mechanical

Outer dimensioning of the new module will be based on the dimensions of variable speed drive. All the modules on elevator shaft will be designed to same outer dimensions to have uniform mechanical outlook. Because new, state of the art control system brings more space in the elevator shaft, it is possible to increase vertical length of drive interface module if needed. If length of the new module must be increased, measures of measurement equipment need to be taken into account so that no new measurement equipment needs to be built if not necessary. On Monospace elevator, North American module and module for European and Asia Pacific continents will be designed to the same housing, which will decrease level of mechanical design and make design more uniform globally. Object with new design is that drive interface

module could be installed individually on elevator shaft wall in enclosure or as it is without enclosure inside the control cabinet in Minispace elevator.

The lid of new module enclosure needs to be fixed so when opening the housing, lid does not loose from its attachments, for example hinge type lid. Also screws of lid and screws need to be loosed during service must be captive type so they can't drop to elevator shaft during installing and maintenance processes. New module must meet the demands for IP23 class when lid of the module enclosure is closed. Lid open IP class requirement is IPXXB, which means finger protection. For module enclosure, drilling template needs to be designed to ease wall attachment in shaft.



Picture 1 Arrangement of variable speed drive and drive interface module on elevator shaft.

3.4 Electrical

Table 1 Main parts of new Drive interface module

Main parts of new Drive interface module
Motion control board
Main contactor
Braking module
Circuit Breaker
interface connectors for control system
PE connectors
Fuse for intermediate charging circuit
Remote Main Switch components
Warning Stickers

In table above is shown main parts of new drive interface module. Main changes comparing to old module are bringing of remote main switch components inside drive interface module and removal of at least one of the auxiliary contactors and also main contactor control board. Function of remote main switch is to allow disconnection of the power supply remotely. For remote main switch, plug connection is required to ease the installation. Plug connection for remote main switch might cause challenges because circuit of protective earth shall not break even though plug is disconnected for example during maintenance service. Also whole module will be designed to have plug and play style connections so it is easy to connect to other devices. Other electrical demand is to make whole module with halogen free cables. Halogen free cables constitute less smoke than PVC cables in a case of fire. Also unlike halogen free cables, PVC cables constitute hydrochloric acid when they get mixed with water. Hydrochloric acid is harmful to building structures so for those reasons, halogen free cables will be more profitable in the long run. For emergency power supply connected below the module needs to have electrical and mechanical interface connection and interface need to be easy to connect between those devices. Every component is demanded to be easy to replace, which means that every compo-

ment must be able to remove and switch without need for removing of other components during maintenance process. Intension is to design internal wiring by using only one wire harness. Wire harness may have several variants depending on components inside the module. Multi-function wire harness will decrease the number of materials inside PDM structure and helps administration of material list.

3.5 Contactors in drive interface module

Contactors are components used to switch power circuits. In drive interface module contactor(s) are used to switch 400VAC mains supply on and off and further on the voltage supplied to the drive and hoisting motor of the elevator. In elevator these contactors are called as main contactors. Contactors or contactor relays are used to control power supply to the brake control module(s) and main contactor. Following paragraphs explain the meaning of mechanically linked contacts, mirror contacts, utilization categories and standard requirements for pick and drop voltages of contactors based on IEC standards.

3.5.1 Mechanically linked contacts

Auxiliary contacts in contactors or contactor relays used in drive interface modules have mechanically linked contacts. Mechanically linked contact means such a combination of make and brake contacts, where undefined number of make and brake contact element(s) are designed in such a way, that they cannot be in closed position simultaneously. /5/ (IEC 60947-5-1 2009, 84)

Requirements for mechanically linked contact elements are: While any of the make contact element(s) is closed, none of the brake contact element(s) shall be closed and while any of the brake contact element(s) is closed, none of the make contact element(s) shall be closed. Mechanically linked contacts need to be marked in control circuit device itself and/or in manufacturer's documentation. /5/ (IEC 60947-5-1 2009, 85)



IEC 1511/99

Picture 2 Symbol for device containing mechanically linked contacts (IEC 60947-5-1 2009, 85)

3.5.2 Mirror contacts

Mirror contact is normally closed (NC) auxiliary contact which cannot be in closed position simultaneously with the normally open (NO) main contact. So when any of main contacts of the contactor is closed, mirror contacts shall be open /8/ (IEC 60947-4-1 2009, 98). Mirror contacts are tested with artificially welded contacts. State of contact can be tested in two ways, with impulse voltage test or by measuring clearance of contact. Contact can be verified to be open if clearance is at least 0,5mm. Usually mirror contacts are mechanically linked so that normally closed auxiliary contact and normally open main contact state cannot be same. Main contactors used in drive interface modules have mirror contacts to reliably monitor the state of the main contacts. In spite of that, mirror contacts should not be considered as an only safety device.



IEC 2136/02

Picture 3 Mirror contact (IEC 60947-4-1 2009, 99)

3.5.3 Utilization categories

Utilization categories describe the intended application for a contactor. Categories define range of currents, voltages, power factor and selectivity for certain application. Utilization categories for ac and dc contactors defined by the standard are presented in table on next page. Any other type of utilization needs an agreement between manufacturer and user. Information given in the catalogue of manufacturer may constitute such an agreement. /8/ (IEC 60947-4-1 2009, 27)

Table 2 Standard utilization categories (IEC 60947-4-1 2009, 29)

Utilization category	Type of application
AC-1	Non-inductive or slightly inductive loads
AC-2	Slip ring motors: Starting and switching off
AC-3	Squirrel cage motors: Starting and switching off while motor is running
AC-4	Squirrel cage motors: Starting, plugging and inching
AC-5a	Switching of electric discharge lamps
AC-5b	Switching of incandescent lamps
AC-6a	Switching of transformers
AC-6b	Switching of capacitor blanks
AC-7a	Slightly inductive loads in household environment, like blenders etc.
AC-7a	Motor loads in house hold environment, like fans etc.
AC-8a	Hermetic refrigerant compressor motor control with manual resetting of overload releases
AC-8b	Hermetic refrigerant compressor motor control with automatic resetting of overload releases
DC-1	Non-inductive or slightly inductive loads
DC-3	Shunt motors: Starting, plugging and inching with dynamic breaking of dc motors
DC-5	Series motors: Starting, plugging and inching with dynamic breaking of dc motors
DC-6	Switching of incandescent lamps

3.5.4 Pick and drop voltages

IEC standard requires, that electromagnetic contactors shall close satisfactorily at any value between 85% to 110% of their rated control supply voltage. Where range is declared, 85% shall apply to the lower value and 110% to higher value. With ac contactors, the limits between which contactors shall drop out and open fully are 75% to 20% and with dc contactors 75% to 10% of their control supply voltage. Where a

range is declared, 20% or 10% shall apply to the higher and 75% to the lower value. /8/ (IEC 60947-4-1 2009, 39)

From limits explained above, could be seen that ranges for contactor pick and drop voltages are quite large. Voltage levels for pick and drop operations are good to know due to fact that range in IEC standard is rather wide. This knowledge is useful for example when dimensioning contactors in long control circuits. Pick and drop out voltages for contactor relays used in drive interface modules are studied as a part of preliminary tests made during this thesis.

3.6 Standard demands for main contactor

Drive interface module includes main contactor of elevator. This paragraph covers elevator safety standards for contactors set on EN81-1:1998 and A17.1/B44. EN81-1:1998 is standard for elevators in European and Asian Pacific markets and A17.1/B44 for elevators in North American markets.

New upcoming EN81-20 standard will be published by CEN in June 2014. EN81-1 and EN81-2 standards will still remain valid until June 2017 and in this thesis requirements of EN81-20 will not be covered. However, requirements of new standards need to be taken into account before implementing new drive interface module. /4/

3.6.1 EN81-1

Stopping of the machine and checking its stopped condition is explained in paragraph 12.7 in EN81-1:1998+A3:2009 part 1.

If motor is supplied directly from AC or DC mains, elevators motor supply shall be interrupted by two independent contactors. If the lift is stationary and one of the contactors has not opened the main contacts, further movement of the car shall be prevented at least at the next change in direction of motion. /6/ (EN81-1:1998+A3 2009, 75)

If AC or DC motor is supplied and controlled by static elements, one of the following methods shall be used. /6/

- a) Two independent contactors interrupting the currents of the motor. If whilst the lift is stationary, one of the contactors has not opened the main contacts, any further movement shall be prevented, at least at the next change in direction of motion. /6/ (EN81-1:1998+A3 2009,75)
- b) System consisting of
 1. A contactor interrupting the current at all poles. The coil of the contactor shall be released at least before each change in direction. If the contactor does not release, any further movement of the lift shall be prevented.
 2. A control device blocking the flow of energy in the static element is also needed.
 3. System needs also a monitoring device which verifies the blocking of the flow of energy each time the lift is stationary. /6/ (EN81-1:1998+A3 2009,76)

If, during a normal stopping period, the blocking of the flow of energy by the static elements is not effective, the monitoring device shall cause the contactor to release and any further movement of the lift shall be prevented. /6/ (EN81-1:1998+A3:2009, 76)

Requirements for contactors and contactor relays used in elevators are explained in paragraph 13.2 in EN81-1:1998+A3:2009. The main contactors, i.e those necessary to stop the machine as explained above, shall belong to the following categories as defined in EN60947-4-1. /6/ (EN81-1:1998+A3:2009, 79)

- a) AC-3 for contactors for AC motors.
- b) DC-3 for contactors for DC power.

These contactors shall, in addition allow 10% of starting operations to be made as inching. In upcoming EN81-20, inching doesn't need to be taken into account when using variable speed drive. /6/ (EN81-1:1998+A3:2009, 79)

If relay contactors are used to operate the main contactors as in currently used drive interface module, those relay contactors shall belong to the following categories as defined in EN60947-5-1.

- a) AC-15 for controlling AC electromagnets.
- b) DC-13 for controlling DC electromagnets.

On the measurement situations, if contactors and relay contactors refers requirements set above, it may be assumed that

- a) If one of the break contacts (normally closed) is closed, all the make contacts are open;
- b) If one of the make contacts (normally open) is closed, all the break contacts are open. /6/ (EN81-1:1998+A3:2009,79)

3.6.2 A17.1

In American standard requirements for main contactors are explained in a different way that in EN81-1. A17.1 requires for contactors that if springs are used to actuate the contactors to break the circuit to stop an elevator at the terminal landings, they shall be of the compression type. /7/ (ASME A17.1. 2007, 106)

Standard also requires, that if contactors are used to remove power independently from the driving machine motor, an electromechanical contactor shall be arranged to open each time the car stops or open at the latest each time the car reverses direction, except for re-leveling. Also it has been verified at each stop that there is no current flow exceeding normal leakage current through the other means. Power need to be removed also from the driving-machine brake. /7/ (ASME A17.1. 2007, 106-107)

4 VISION FOR NEW MODULE

4.1 Recital

In this paragraph forming of required IP class, content of first mock-up version of the new drive interface module and changes to electrical functionality of the module are presented.

4.2 IP classes

EN81-1 sets minimum IP class requirements for elevator enclosures. Some special lift types, for example firefighting lift requires higher IP protection. Plan is to make drive interface module uniform by its IP level so that additional covers are not required in this kind of cases. Testing for required IP class need to be performed thoroughly so that required IP class is guaranteed, because switching and modifying of enclosures because of incorrect IP class is expensive.

On paragraph 3.3, one requirement was that new module must meet the demands for IP23 class when lid of module enclosure is closed and demands for IPXXB, when lid is open. This paragraph will deal how those IP classes form, what are requirements for those classes in standard IEC60529 and how required IP classes will be tested. Also ideas how to manufacture module enclosure which accomplishes requirements for IP23 and IPXXB are proposed.

IP class describes the degree of protection for enclosures of electrical devices. Figure below describes arrangement of IP code. /9/

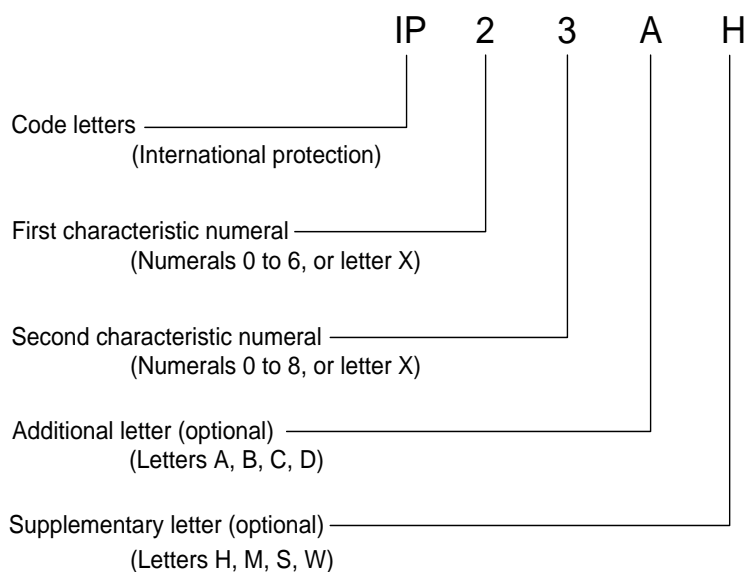


Figure 2 Arrangement of IP code

Where a characteristic numeral is not required to be specified, it shall be replaced by letter “X” (“XX” if both numerals are omitted). Additional letters and/or supplementary letters may be omitted without replacement. /9/ (IEC 60529 1989+A1:1999, 19)

On IP23, first characteristic numeral (2) means that enclosure is protected against access to hazardous parts with finger and against solid foreign objects with diameter of 12,5mm or more. Definition for number 2 is that the object probe with 12,5mm diameter shall not fully penetrate and jointed test finger with 12mm diameter and with 80mm length shall have adequate clearance from hazardous parts. Protection against access to hazardous parts with finger will be tested by inserting jointed test finger with 12mm diameter and 80mm length through any openings of the enclosure with $10N \pm 10\%$ force. Protection against solid foreign objects will be tested by push-

ing object probe with 12,5mm diameter against any openings of the enclosure with $30\text{N} \pm 10\%$ force. /9/

The second characteristic numeral indicates the degree of protection provided by enclosures with respect to harmful effects on the equipment due to the ingress of water /7/ (IEC 60529 1989+A1:1999, 27). Number 3 on second characteristic numeral indicates that enclosure is protected against spraying water. Definition to number 3 is that water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects. Protection against spraying water can be tested by using one of two different test devices. When using oscillating tube (see figure 4) tested enclosure is placed at the center point of semicircle. The tube is caused to oscillate through an angle of 120° , 60° on either side of the vertical. The time for one complete oscillation when tube oscillate 120° either side take about 4 seconds. Total test duration is 5 minutes. The oscillating tube is provided with spray holes over an arc of 60° either side of the center point. The support is not perforated. If for example tube radius is 1000mm, there are 41 open holes with 4mm diameter and total water flow is 2,9l/min. When using spray nozzle (see figure 5), test specimen is set to counterbalanced shield. Water pressure of spray nozzle is set between 50 to 150 kPa and kept in constant during test. The test duration is $1\text{min}/\text{m}^2$ of the calculated surface area of the enclosure. Minimum duration is 5 minutes. /9/

Lid open IP class demand for new drive interface module is IPXXB, additional letter B means that the enclosure is protected against hazardous parts with finger. Definition is that test finger with 12mm diameter and 80mm length shall have adequate clearance from hazardous parts. Degree of protection will be tested by pushing jointed test finger against any openings of the enclosure with force of $10\text{N} \pm 10\%$. If it partly or fully penetrates, it is placed in possible position, but in no case shall the stop face fully penetrate through the opening. Internal barriers are considered as enclosure. /9/

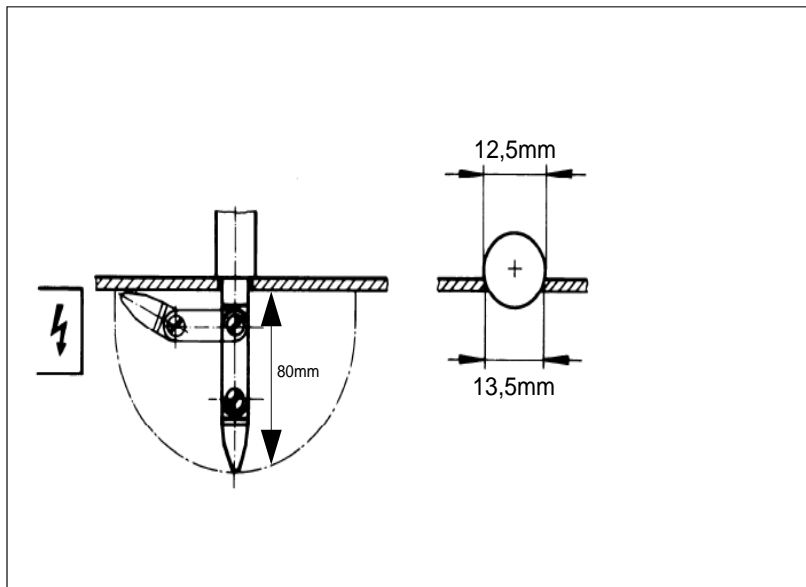


Figure 3 Jointed test finger and access probe (IEC 60529 1989+A1:1999, 76)

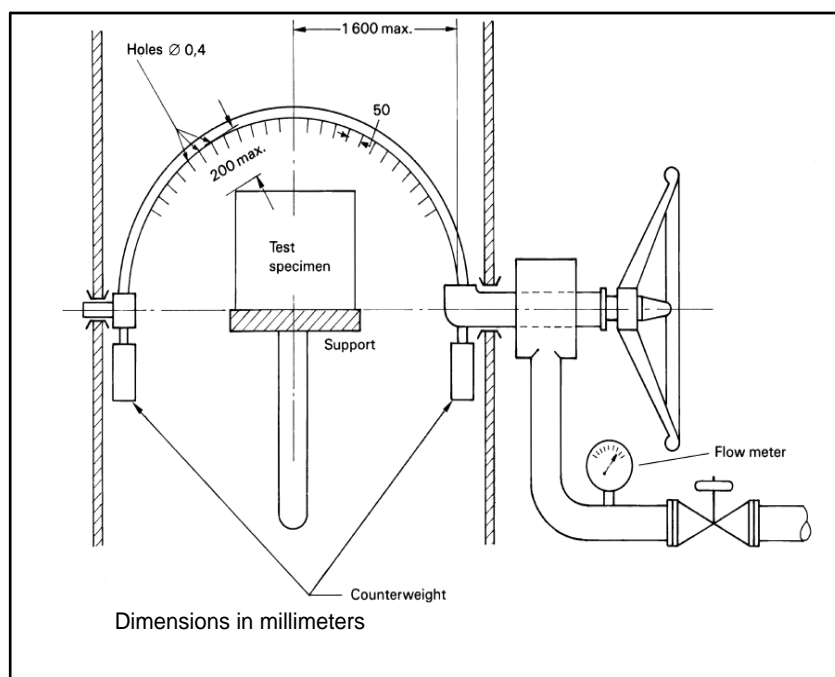


Figure 4 Oscillation tube (IEC 60529 1989+A1:1999, 69)

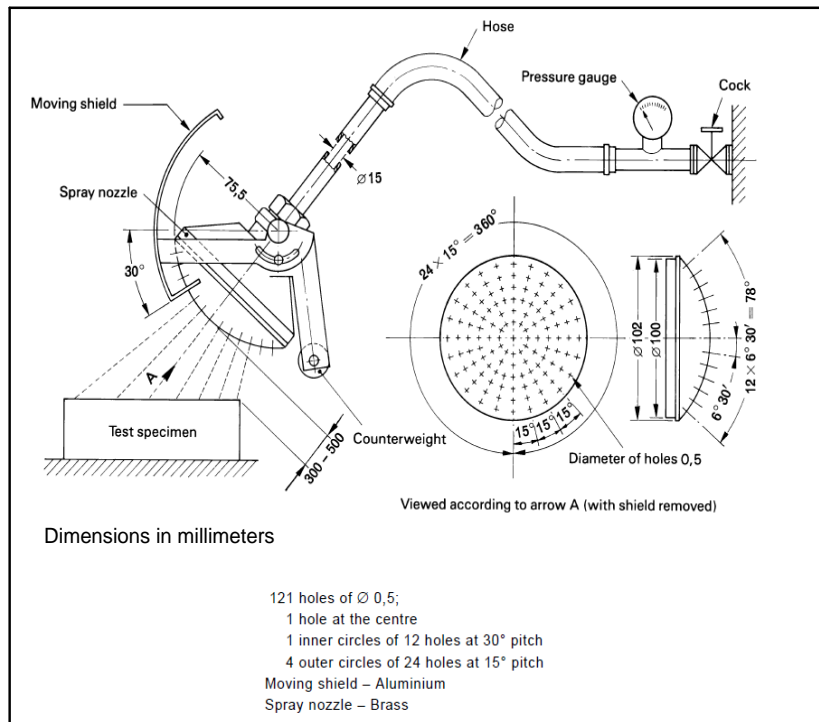


Figure 5 Spray nozzle (IEC 60529 1989+A1:1999, 70)

4.3 First mock-up content/visio

First mockup version was built to see the how thought ideas for new module work in practice and what difficulties may come up during manufacturing of the module. Mockup was built in KONE laboratory, first without wirings and after that including wires and lead- troughs. Enclosure follows width and depth of variable speed drive as demanded on paragraph 3. Height of module enclosure will rise from old module because of decreasing width, content of remote main switch components, increasing size of new brake module and requirement to fit American drive interface module and European and Asia Pacific module on the same enclosure.

To decrease the number of module variants like demanded on paragraph 3, all versions of new module will be installed on same module enclosure on Monospace elevator. Motion control board and brake module(s) will be installed on the base plate of the enclosure and other standard drive interface module components will be installed on separate bracket attached to the base plate. Also remote main switch components will be installed on own bracket.

Installing remote main switch components on own bracket and standard drive interface module components on own bracket will enable to manufacture complete brackets with different assembling of components depending on elevator type. This will for example enable using same bracket with different component configuration for elevators to American and European markets.

On Minispace elevator, module enclosure and remote main switch components are not needed, so only bracket with standard drive interface module components, motion control board and brake module(s) will be installed in control cabinet. Brackets will have rubbers in every corner underneath to decrease noise level when contactor operates and bracket vibrates against the base plate.

Finger protection (IPXXB) is implemented with plastic slide lid on remote main switch components and plexiglass on other components with current. Remote main switch components excluding the contactor are raised up from the bottom of the bracket so slide lid can be used to cover the components.

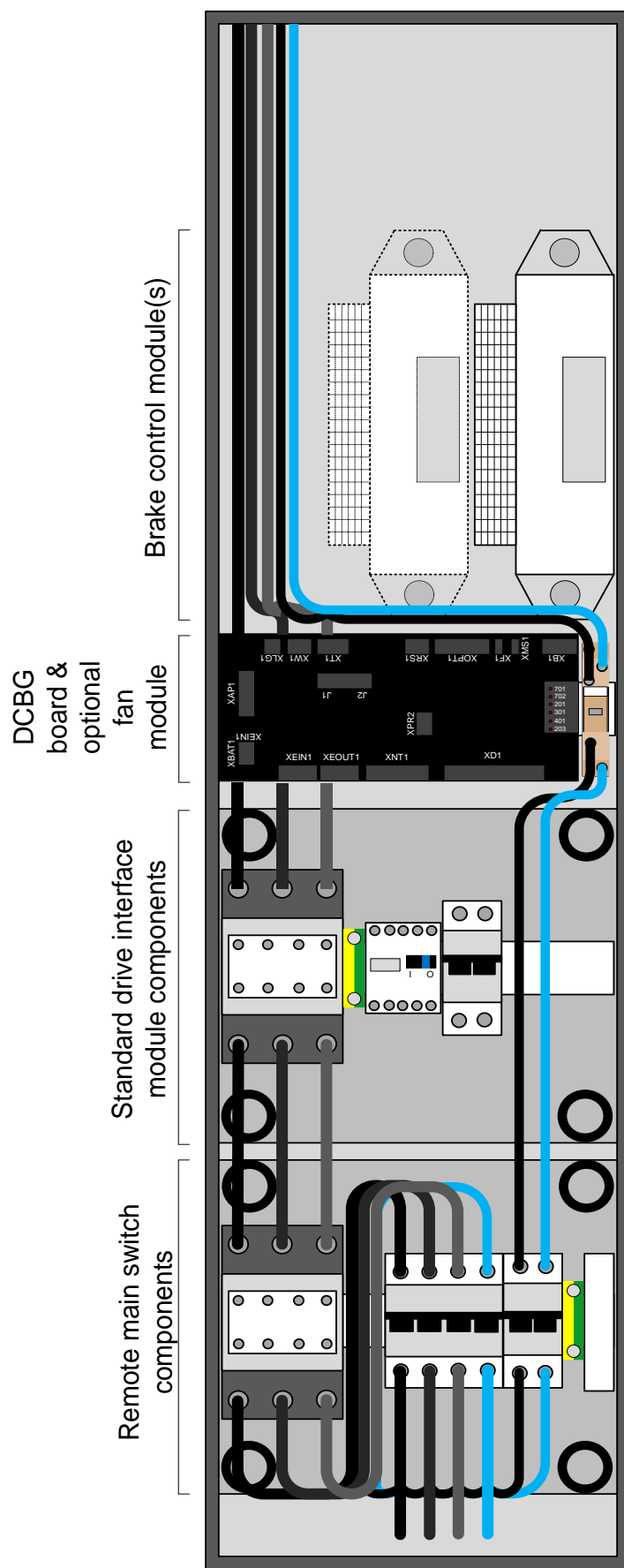


Figure 6 Drawing about first mockup version with supply cables to drive system and motor fan

4.4 Changes to electrical functionality

Electrically, biggest difference between present and new drive interface module will be bringing of remote main switch components inside drive interface module. 400VAC main supply will be supplied first through 4-pole circuit breaker and contactor of remote main switch before elevators main contactor, which controls the power supplied to drive module. 2-pole circuit breaker, also brought to the module for remote main switch, controls the flow of 1-phase 230VAC voltage supplied to central processing unit and main safety circuit of control system located in maintenance access panel.

Other distinctions for new module are removing of another auxiliary contactor and main contactor control board when moving to new electrification system. In old drive interface module, main function of main contactor control board was to rectify AC voltage to DC voltage so that it is possible to use DC contactors as a main contactor. Reason to use DC contactors as a main contactor is more silent noise level than with same size AC contactor. Series resistors function in main contactor control board is to decrease the pick and drop force of contactor and from that way to decrease noise level. Board's effect on noise level of contactors to be used in new module will be defined in noise tests. Purpose for new module is to remove DC rectifying from module and still achieve demanded noise level measured from outside of the module. Difference between absorbing level of AC and DC contactors will be balanced by using the most silent AC contactors and by improving the sealing of module enclosure to achieve better absorption.

5 CONTACTOR TESTS

5.1 Recital

By managing reliability tests for contactors on laboratory, reliability level of new contactors will be inspected and possibility of using new contactors reliable will be

ensured. Also possibilities to use cheaper contactors without decreasing level of reliability will be explored on those tests. Noise tests for contactors will be managed as a noise reference test. On reference tests, noise level of each contactor will be inspected and comparison of noise characteristics will be made. Noise characteristics of drive interface module are important because module usually exists on top of elevator shaft close of buildings top floor apartments, so noise harm of elevator must be minimized.

5.2 Tests

On a part of this study is planning of reliability tests which will be performed for contactors used in drive interface modules. Siemens is about to update its SIRIUS 3RT1 series to new Siemens SIRIUS RT2 series. Purpose of these tests is to ensure at least same reliability level for new contactors as contactors in use today. On tests Chint NC8 series contactors and Siemens China contactors will be tested also to check the reliability level of these contactors and contactor relays. Tests for contactors used with low range elevator drive are also planned to be tested, but those tests need different kind of test environment because of PCB connected contactors. Contactors reliability will be analyzed as a life cycle cost to avoid using of contactors with smaller purchasing price but higher life cycle cost in a cause of using contactors with lower reliability level. Lower reliability level of contactors will cause more service actions during maintenance process and in consequence may add life cycle cost even though a purchasing price would be smaller.

Before actual reliability tests preliminary tests will be performed to check coil characteristics of contactors and to get reference results for analyzes to be done after tests. Preliminary tests include for example coil characteristic and contactor pick and drop out tests.

Tests will be arranged in KONE reliability laboratory in Hyvinkää. Test bench for reliability tests will be built already during this study and testing will start during summer 2014. Preliminary test results and noise test results will be published with this study.

5.3 Reliability test

In reliability tests, one test bench will include ten contactors and one test environment three test benches. Various test environments will be built so all contactors used in drive adapter modules could be tested, but at first tests will contain only one test environment, which will be used as a model for other test environments. Contactors of each test bench are coupled so that every other operates with current and every other without current. Time cycle has programmed in to the Siemens logic system so that after each of the contactors in one test bench has operated, time cycle will return in to starting point, cycle will loop during whole test (see annex 1). Operation times will be adjusted depending of power of the contactors. Every test bench will have resistive and inductive loads to make contactors fail faster during tests. Tests will be continued as long as every contactor have been failed to determine the lifetime of each contactor type.

In measurements current and voltage values in a different points of the circuit will be observed to notify the wearing out of contactor contacts by calculating the changes in contact and coil resistances. In first test case ambient temperature will be normal room temperature and also humidity will be normal room humidity. Test case with higher ambient temperature and humidity will also be considered later. Circuit diagram of contactor test equipment and measuring points are shown in annex 2.

5.4 Preliminary test

Preliminary tests for contactor relays are performed before reliability test. On preliminary tests coil characteristics and pick and drop out voltages will be determined. Test results will be used together with reliability test results to compare characteristics of each contactor type and to analyze reasons for worn out of the contactors and contactor relays.

5.4.1 Coil characteristic test

Purpose of coil characteristic test was to check and compare coil characteristics of Siemens RT1 series, Siemens RT2 series, Chint NC8 series and Schneider contactor relays.

Tested contactor relays:

- Siemens 3RH1131-1AP00
- Siemens 3RH2131-1AP00
- Chint NC8-09M01
- Schneider LC7-0901M7
- Schneider LP1K090085MD
- Schneider LP1K12015M

Tests for Siemens 3RH1131-1AP00 and Schneider contactor relays have been performed by KONE senior specialist on April 2013. Test environment for Siemens 3RH2131-1AP00 and Chint NC8-09M01 was built as similar as possible to get comparable results with old measurements. Tests were performed in KONE reliability laboratory.

Measured values:

- Supply voltage (U_s)
- Voltage over test circuit potentiometer (U_R)
- Voltage over contactor coil (U_{coil})
- Contactor coil current (I_{coil})
- Ambient temperature (T_A)
- active power (fundamental frequency, 50 Hz) (P_{L1_H1})
- reactive power (fundamental frequency, 50 Hz) (Q_{L1_H1})
- apparent power (fundamental frequency, 50 Hz) (S_{L1_H1})
- displacement power factor ($\cos_phi_{L1_H1}$)
- active power (P_{L1})
- reactive power (Q_{L1})
- apparent power (S_{L1})
- power factor (PF_{L1})
- load impedance (fundamental frequency, 50 Hz) (Z_{L1_H1})
- load impedance (Z_{L1})

Calculated values:

- coil resistance in ambient temperature (fundamental frequency, 50 Hz) (R)
- coil reactance in ambient temperature (fundamental frequency, 50 Hz) (XL)
- coil inductance in ambient temperature (L)

Coil resistance, coil reactance and coil inductance in ambient temperature was calculated by using following equations.

$$R = Z_{L1_H1} \cdot \cos_{\phi_{L1_H1}}$$

$$X_L = Z_{L1_H1} \cdot \sin(\phi_{L1_H1})$$

$$L = \frac{X_L}{2 \cdot \pi \cdot 50}$$

Ten contactors from each contactor type were tested. Siemens contactors were tested first separately and then by coupling two contactors in parallel. Schneider contactors were tested only on separate. Results were monitored by using DEWETRON 2600 measuring device and Dewesoft software.

Tests for Siemens RT1 and RT2 series and Schneider contactor relays were performed by using RC circuit with a contactor relay as a filter. Chint has not designed RC circuit for contactor relays, only varistor to block over voltages. For that reason Siemens RH2131-1AP00 were tested also without RC circuit to get reference results with Chint and also with Schneider and RT1 series contactors. Chint was also tested with varistor to see if it effects to coil characteristics.

Schneider LC7-K0901M7 has a DC coil, supply voltage for the contactor is 50Hz AC but there is a diode bridge inside the contactor and therefore real coil voltage is full wave rectified DC. For that reason coil reactance and inductance are not determined with this contactor relay. However, coil resistance is measured by using DC supply voltage for the tests. There is a voltage drop over the diodes but it is so small (~2x0,5V) that it can be ignored. Schneider LP1K090085MD and LP1K12015M contactors are also DC contactors, but there is no internal rectifier, however the situation is same than with LC7-K0901M7. LP1K090085MD and LP1K12015M are PCB connectable contactors, so CO-16 board was used to attach contactors in test circuit.



Picture 4 DEWE-2600 measuring device



Picture 5 0,5Ω shunt for current measurement

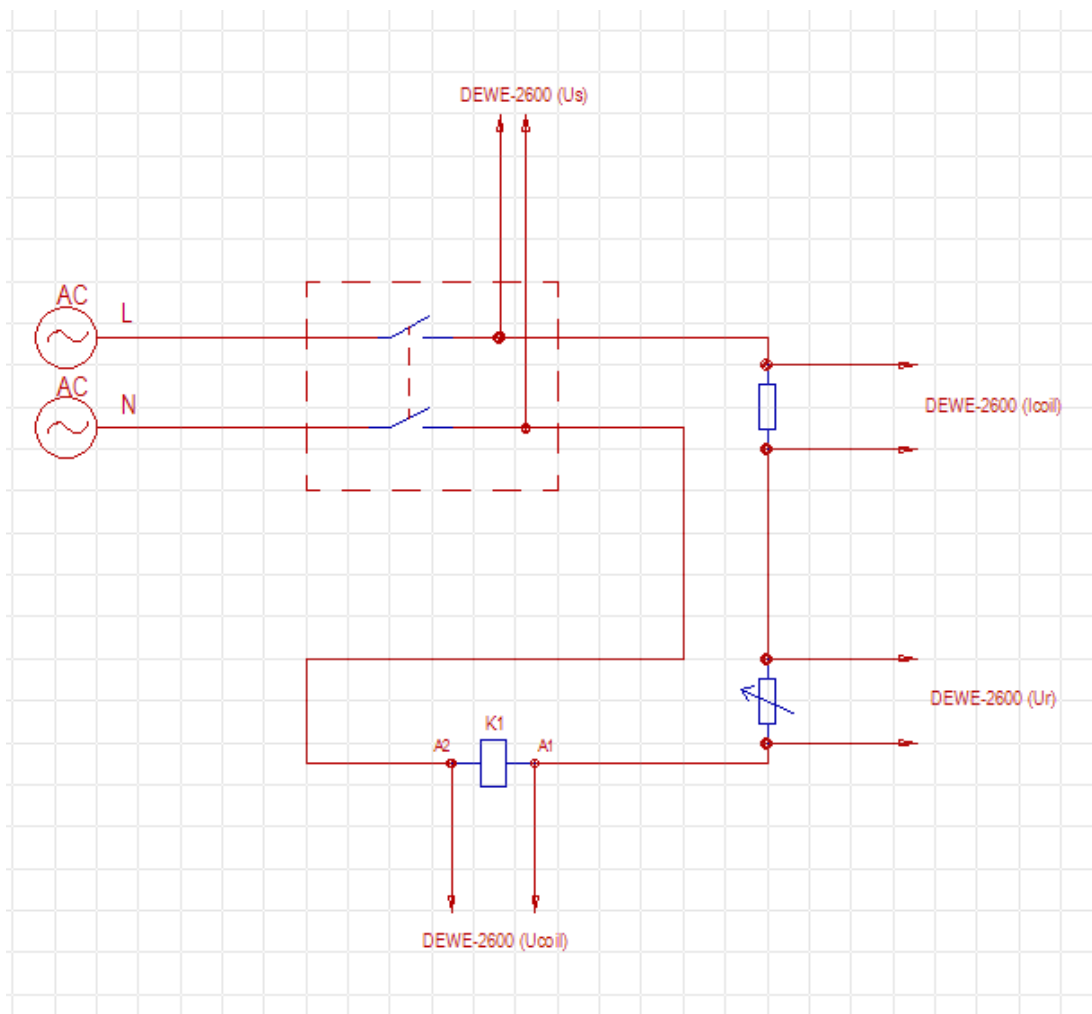


Figure 7 Circuit diagram from measuring equipment

5.4.2 Conclusions of coil characteristic measurements

Compared contactor relays:

- Siemens 3RH1131-1AP00
- Siemens 3RH2131-1AP00
- Schneider LC7-0901M7
- Chint NC8-09M01

PCB connectable contactor relays, Schneider LP1K090085MD and LP1K12015MD are not comparable with other tested relays, so those have been left outside of comparison. Chint NC8-09M01 is comparable only with Siemens 3RH2131-1AP00 because those are only contactor relays measured without RC circuits.

Between Siemens contactors, most significant differences were measured on power factor, average difference 0,12, on coil resistance, average difference 1372 Ω , on coil reactance, average difference 362 Ω and on load impedance, average difference 373 Ω . Big difference in power factor effects also in to the big difference in coil resistance.

Schneider LC7-0901M7 has a dc coil, so power factor, coil resistance and coil reactance were not measured or calculated. On load impedance difference between Schneider and Siemens 3RH1131-1AP00 was on average 1863 Ω and between Schneider and Siemens 3RH2131-1AP00 2227 Ω .

When comparing Siemens 3RH2131-1AP00 and Chint NC8-09M01, could be noticed that coil characteristics were quite similar. Power factor and load impedance were almost at the same level and in coil resistance and reactance differences were much smaller than for example between Siemens contactors. Difference between coil resistances was on average 227 Ω and between coil reactance on average 65 Ω . Measurements also showed, that SR8-A RV250 varistor had no effect to coil characteristics of Chint contactor relay.

The most remarkable difference on test was power factor between Siemens contactor relays. Effect of difference in power factor will be inspected on reliability tests. Other differences on coil characteristics between contactor relays were rather small on these measurements. On reliability tests, differences between contact materials, coil windings and so on will be really noticed when relays will be loaded and contacts start to wear out. Results from coil characteristic measurements are shown on annex 3.

5.4.3 Pick and drop out tests

Test equipment for pick and drop out test was same than with coil characteristic tests. Only difference was AC power source, which was added to monitor exact time for pick and drop operation by supplying 10VAC current to one of the NC contacts of

the contactor relay to see when contact actually opens or closes by watching a graph from measuring device. Pick and drop out tests for Siemens RT1 series contactor relays and Schneider contactor relays were also already performed by KONE senior specialist on April 2013 and now same test were made to Siemens RT2 series contactor relays and to Chint NC8-09M01 contactor relays.

Coil voltage for pick and drop operations were defined by adjusting resistance of the circuit with potentiometer as long as contactor status changes. With Siemens RT1 series and Schneider contactor relays, 100K Ω potentiometer have been used instead of 50K Ω potentiometer used in test equipment with Siemens RT2 series and Chint. Measured values were recorded from time just before NC contact closes or opens. Exact time was determined from diagrams of DEWE-2600 measuring device.

Like on coil characteristic test, on pick and drop out tests Siemens and Chint contactor relays were tested first on separate and then by coupling two relays in parallel to see effect of parallel connection. Schneider contactor relays were tested only separate.

Tested contactor relays:

- Siemens RH1131-1AP00
- Siemens RH2131-1AP00
- Chint NC8-09M01
- Schneider LC7-0901M7
- Schneider LP1K090085MD
- Schneider LP1K12015M

Measured values on drop out test:

- Supply voltage (U_s)
- Voltage over test circuit potentiometer (U_R)
- Voltage over contactor coil (U_{coil})
- Contactor coil current (I_{coil})
- Ambient temperature (T_A)

Measured values on pick up test:

- Supply voltage (U_s)
- Voltage over test circuit potentiometer (U_R)

- Voltage over contactor coil (U_{coil})
- Contactor coil current (I_{coil})
- Ambient temperature (T_A)
- Active power (P_{L1})
- power factor (PF_{L1})



Picture 6 LPS-301 power supply for observing of contactor status

5.4.4 Conclusions of pick and drop out tests

On these conclusions, all DIN rail attachable contactors are compared with each other because of a small effect of RC circuit or varistor with Siemens 3RH2131-1AP00 and Chint NC8-09M01 contactor relays.

Compared contactor relays:

- Siemens 3RH1131-1AP00
- Siemens 3RH2131-1AP00
- Schneider LC7-0901M7
- Chint NC8-09M01

Comparing measurement result and by watching diagrams drawn from those result, could be seen that Siemens and Chint drops with most high coil voltage, most low coil voltage on drop operations was with Siemens 3RH1131-1AP00. In coil current on drop operation, big differences were not noticed. RC circuits suppressing effect could still be proved. Figures 8 and 9 show charts drawn from drop out test measurement results.

On pick up test, coil voltage on pick operation was clearly much bigger with Siemens 3RH1131-1AP00 than with other tested contactor relays, which were on quite same range. Coil current was as for much smaller with Schneider LC7-0901M7 due to the dc coil. Also Siemens RT1 series contactors picked with a bit smaller coil current than Siemens RT2 series or Chint contactors. Charts from pick up test measurement result are shown on figures 10 and 11.

Test results show that differences on coil voltage in pick and drop operations are quite big. Some of the differences may still result from inaccuracy on time when measurement was recorded. From diagram of DEWE software, recorded measurement results could be monitored between quite big gap and due to very high rise/decrease on voltage just before operation, recorded result can differ much. Effects of this phenomenon could be decreased by adding number of measurements when average value equalizes the differences.

Also one noticeable thing in pick and drop out tests were that one of the tested 3RH2131-1AP00 contactor relays did not operated at all during test operation with single connection. With parallel connection contactor in question operated normally. Contactor will go to further investigations to see the reason for problem.

In pick up test, coil current ascends step by step before pick operation, when circuit resistance is adjusted by hand with potentiometer. Just before contactor picks, it goes to buzz state and coil current is very high. Range of this buzzing voltage is important to determine for contactors, because if due to some error, coil voltage goes and stays in this buzz range, it breaks easily because of high current in contactor coil. Examples of contactors pick operation in figures 12, 14 and 16.

In drop out test, coil current drops near zero when circuit resistance is raised with potentiometer. When contactor drops, current rises a bit and stays on that level, examples in figures 13, 15 and 17.

In figures from pick and drop out operations, blue curve is contactor status, red curve is coil current and green curve is coil voltage.

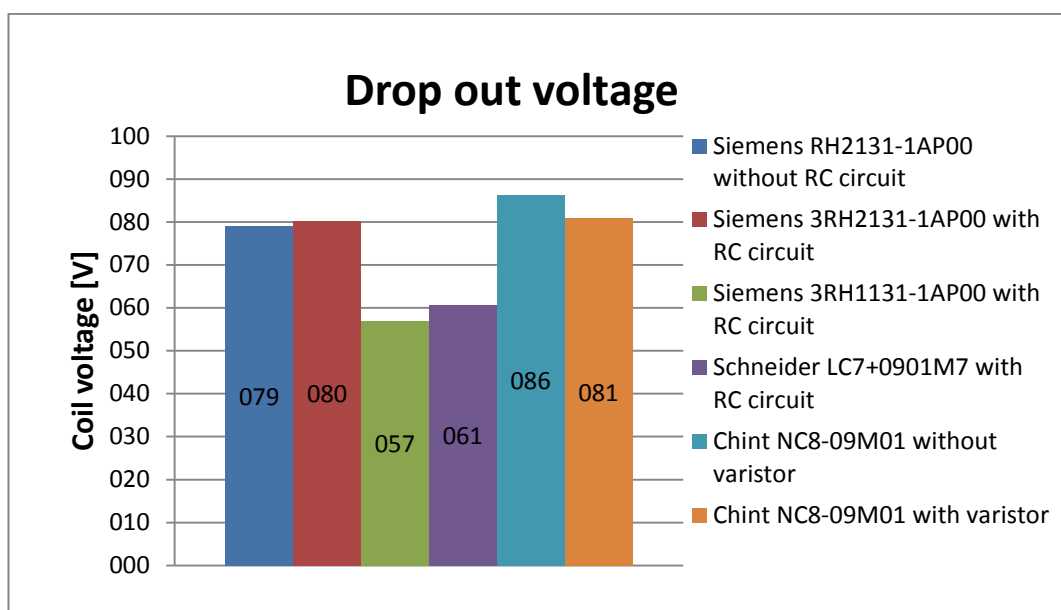


Figure 8 Coil voltages on drop out test

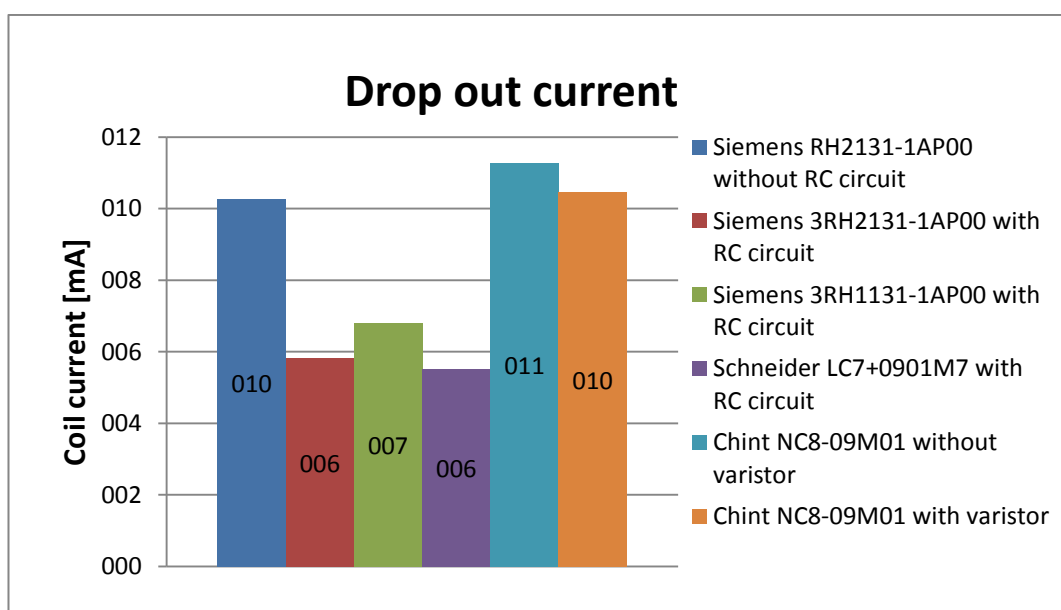


Figure 9 Coil current on drop out test

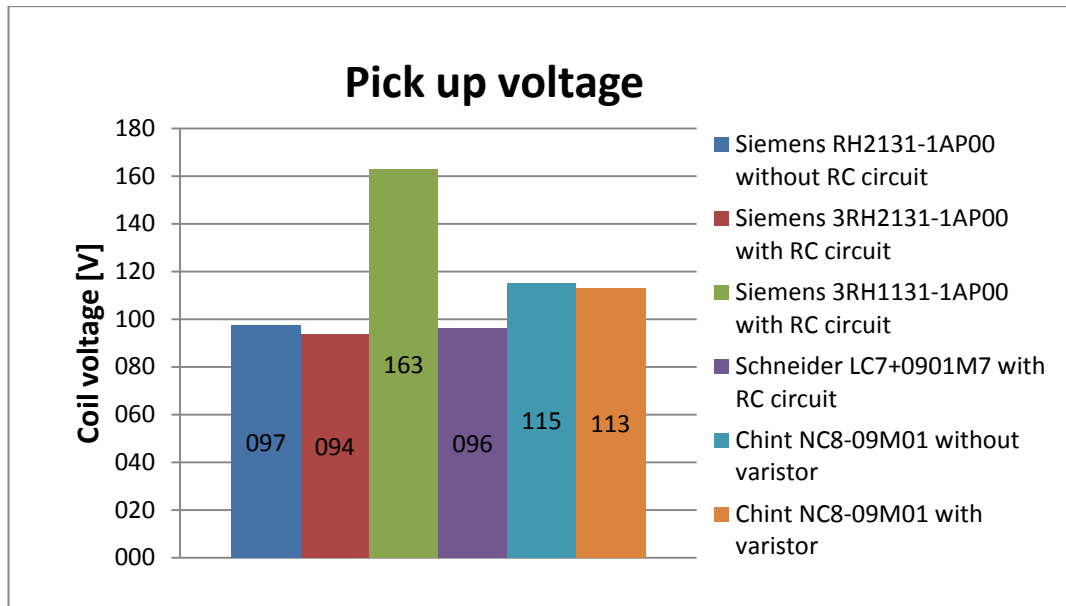


Figure 10 Coil voltages on pick up test

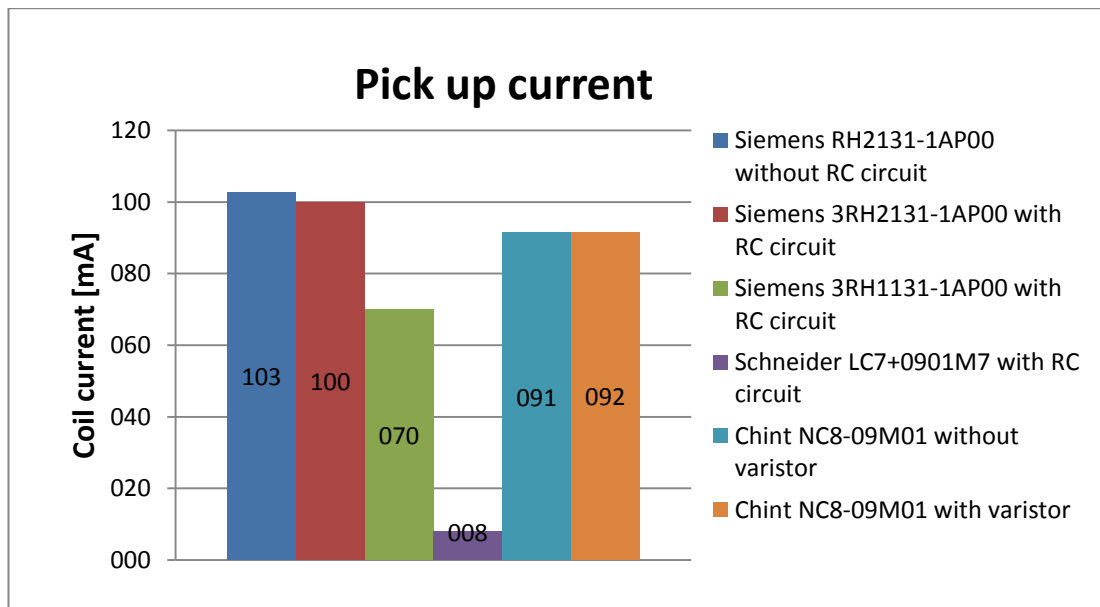


Figure 11 Coil currents on pick up test

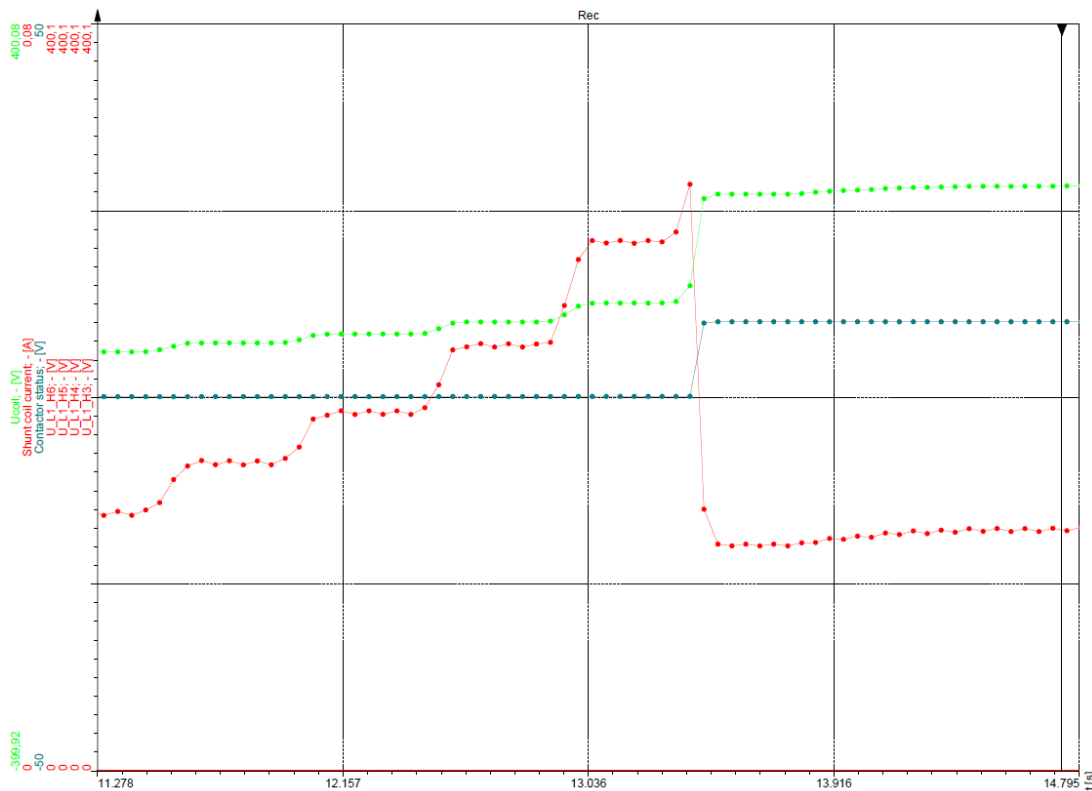


Figure 12 Pick-up test diagram, Chint NC8-09M01 with SR-8 A250 varistor

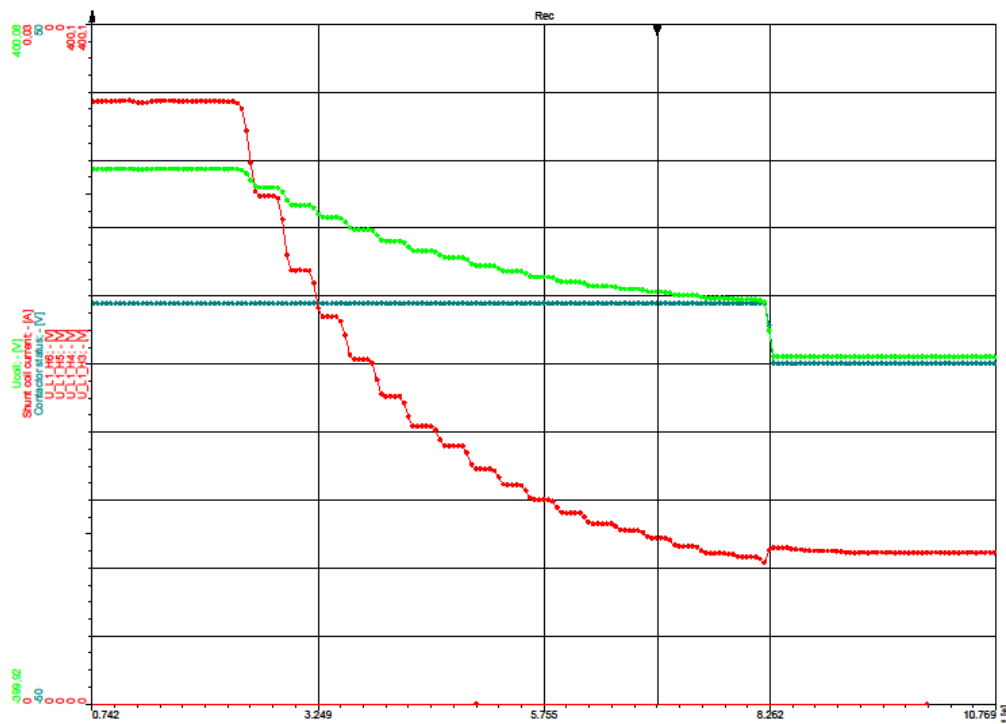


Figure 13 Drop out test diagram, Chint NC8-09M01 with SR-8 A250 varistor

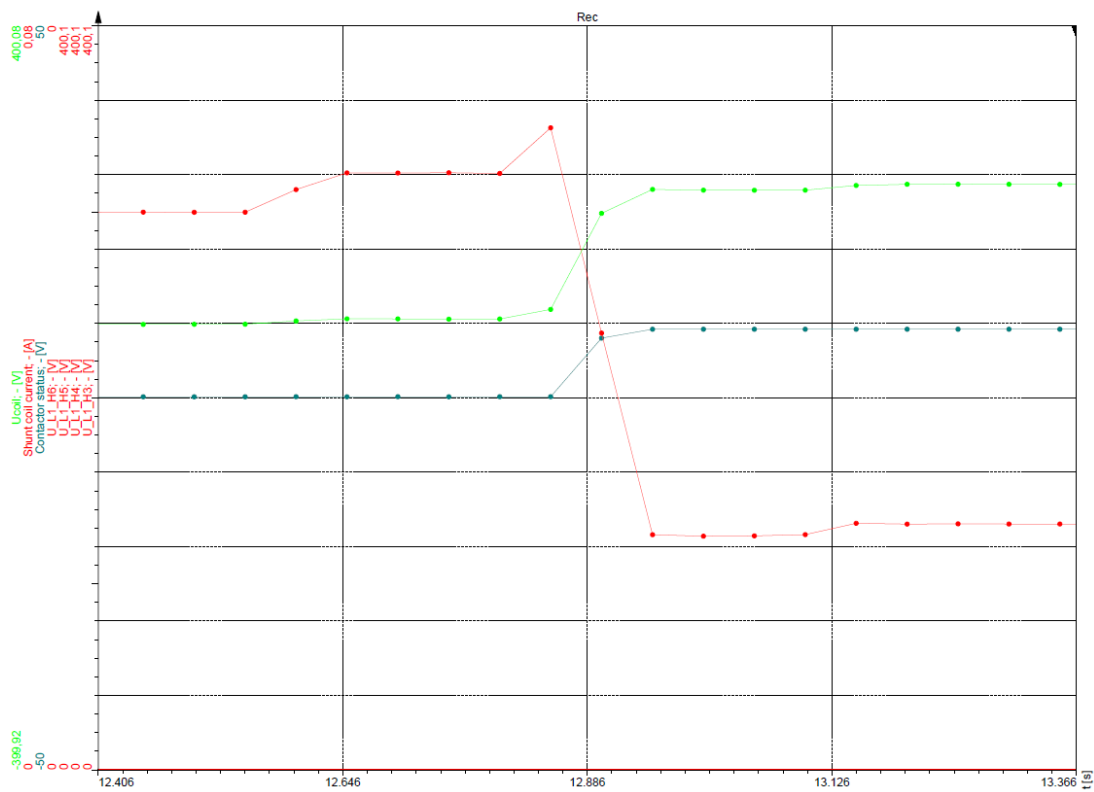


Figure 14 Pick-up test diagram, Siemens RH2131-1AP00

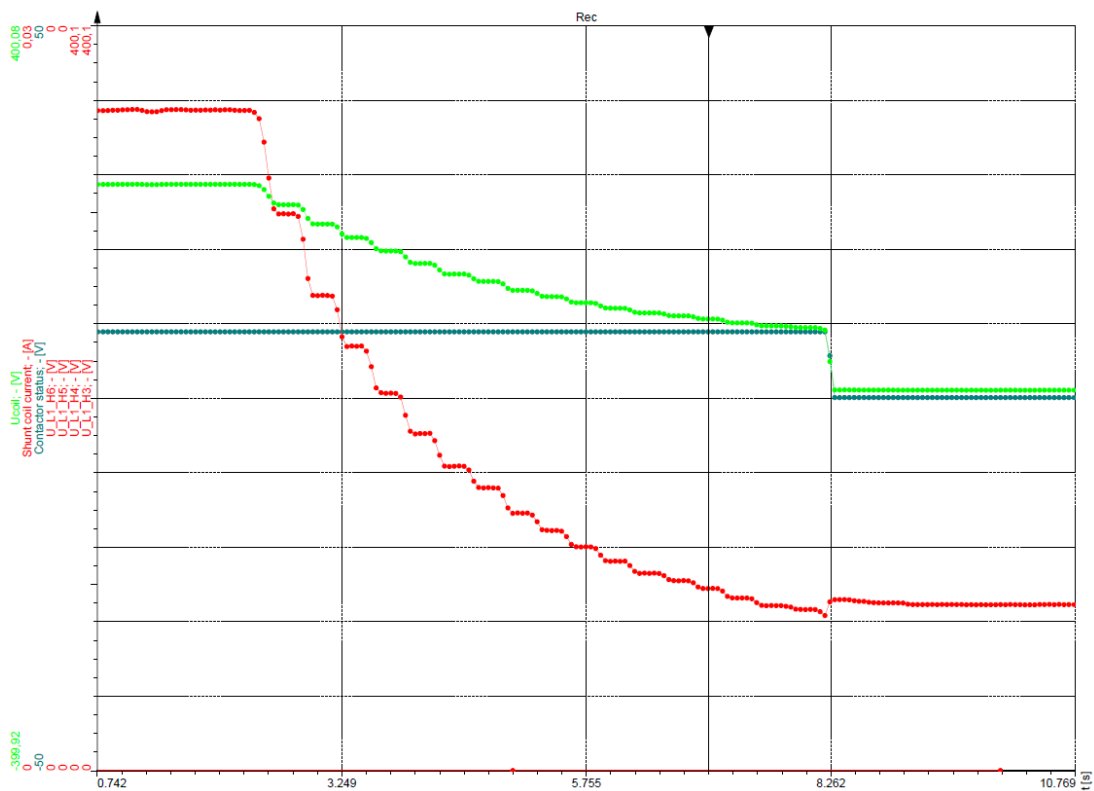


Figure 15 Drop out test diagram, Siemens RH2131-1AP00

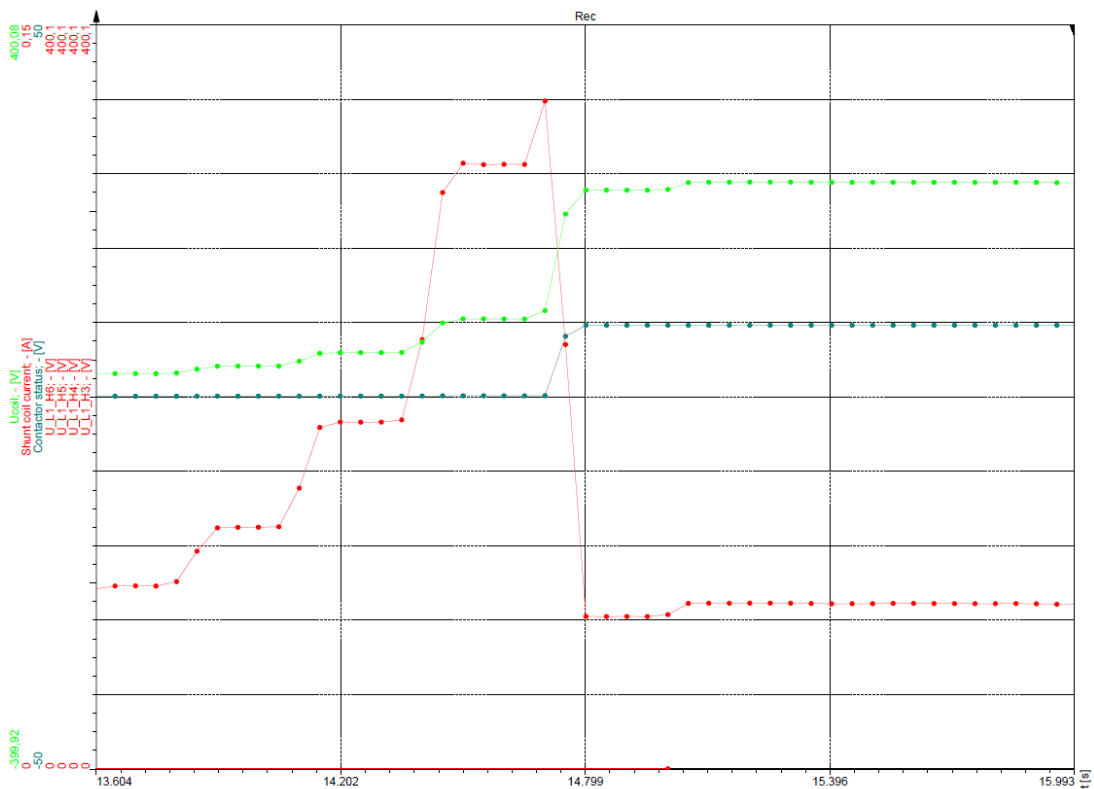


Figure 16 Pick-up test diagram, two Siemens RH2131-1AP00 contactors with 3RT2916-1CD00 RC circuits, parallel connection

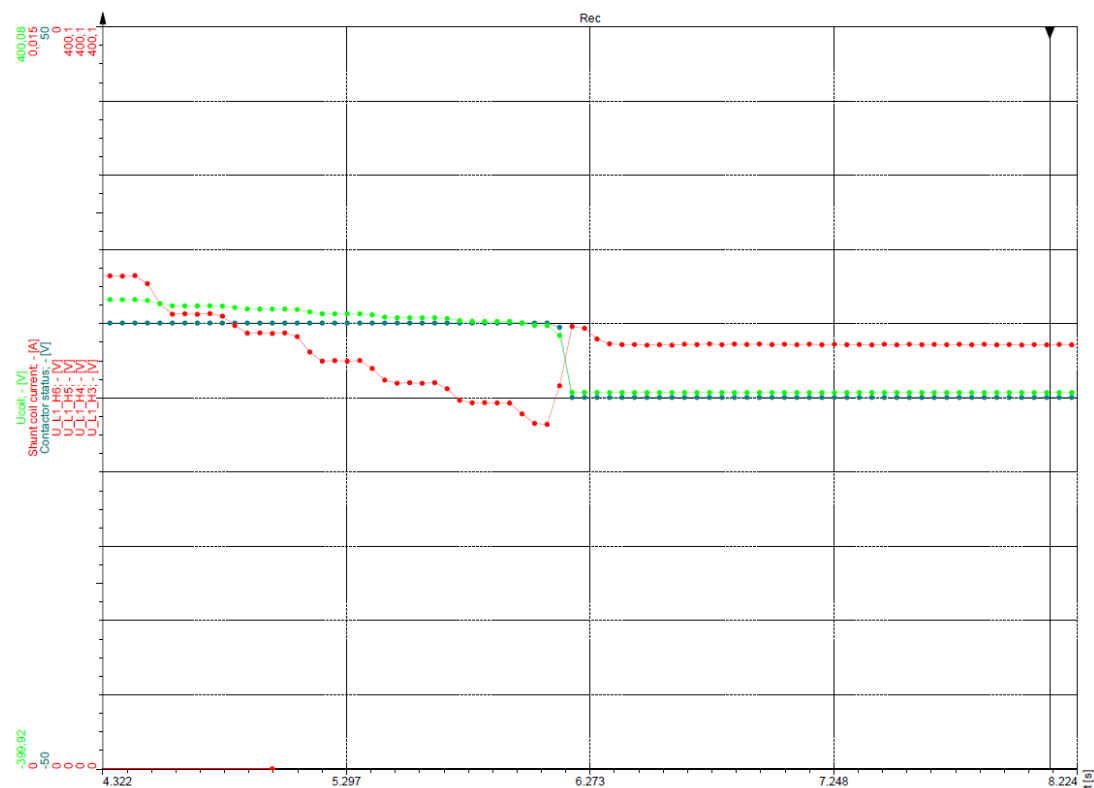


Figure 17 Drop out test diagram, two Siemens RH2131-1AP00 contactors with 3RT2916-1CD00 RC circuits, parallel connection

5.5 Noise tests

Noise tests were managed in KONE SW-Laboratory in Hyvinkää. Tests were made in silent room, where noises from outside of the room were minimized. Test were made as a noise reference test, so measured noise differences between contactors are more important conclusions than exact sound values.

Used equipment:

- ONO SOKKI LA-5111 Sound level meter
- Test platform for contactor
- Switch for operating the contactor

Tested contactors/contactor relays:

- Siemens 3RH2131-1AP00
- Siemens 3RH1131-1AP00
- Chint NC8-09M01
- Siemens RT2026-1BP40
- Siemens RT1026-1BP40
- Chint NC8-18/Z

Measuring points:

1. Noise level meter set to 1m distance from front side of the contactor at the same level with the contactor vertically and horizontally.
2. Noise level meter set to 1m distance from right side of the contactor at the same level with the contactor vertically and horizontally.

Performing of tests:

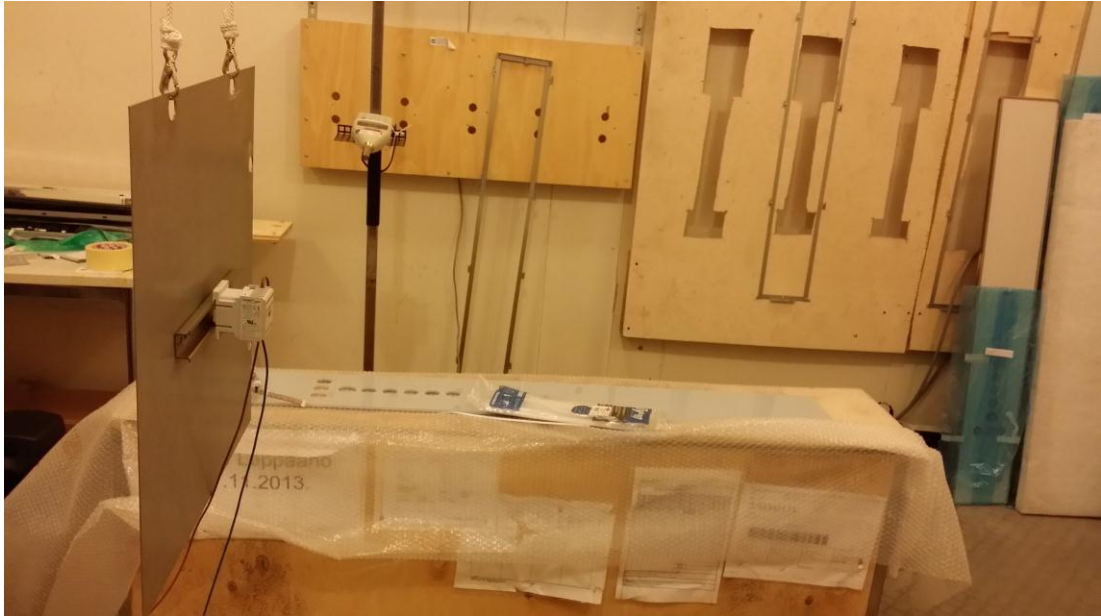
Tests were performed by measuring peak noise value [dB] with noise level meter on contactor pick and drop operations. Contactors were attached to test platform one by one. Test platform was hanging freely on the air attached to strings hanging from test room roof. Contactor operation was controlled by separate switch. Ten pick and ten drop operation values for each contactor were measured from each measuring point. Five different contactors from each contactor type were tested.



Picture 2 ONO SOKKI LA-511 sound level meter



Picture 3 Sound measurement from front side



Picture 4 Sound measurement from right side

5.5.1 Contactor relays

On test for contactor relays, Siemens RT1 series and Schneider contactor relays were tested along with Chint and new Siemens RT2 series.

Tested contactor relays:

- Siemens 3RH2131-1AP00
- Siemens 3RH1131-1AP00
- Chint NC8-09M01

5.5.2 Conclusions for contactor relays

On results of measurements and on scatters drawn from those measurement values, main conclusion is that Chint NC8-09M01 was generally more silent than Siemens 3RH2131-1AP00 and Siemens 3RH1131-1AP00 in all measurements. Differences were a bit smaller measured from right side of the contactor, especially contactor drop noise. With Chint NC8-09M01 contactor, dispersion in noise level were much bigger than with Siemens 3RH2131-1AP00, especially with a noise of pick operation, but still peak noise were louder with Siemens contactor relays. Smallest differ-

ence was noticed with the noise of drop operation measured from right side of the contactor. Also difference on pick operation noise was smaller measured from right side of the contactor than from front side of the contactor. From these results conclusion that Siemens contactor relays are closer of noise level of Chint NC8-09M01, when measuring point is on side of contactor relay can be drawn. In addition, noteworthy notice was that Chint NC8-09M01 kept buzz which was notable on human ear when relay were dropped. With Siemens 3RH2131-1AP00 and 3RH1131-1AP00 this phenomenon was not noticeable.

5.5.3 DC contactors

Noise tests for 230VDC contactors were performed by using main contactor control board (MCCB2) to rectify 230VAC network voltage to 230VDC voltage. On drive interface module used today, main contactor control board is used to rectify the voltage from AC to DC, because former test results have shown DC contactors to be more silent than same size AC contactors. Main contactor control board has resistors which adjusts the drop force of contactor to make the noise of drop operation more silent. Tests were performed with resistors connected on main contactor control board and also without resistors by over connecting the resistors before testing to see the effect of the resistors. Target for new module is to remove main contactor control board and still to get required noise level by using AC contactors.

Tested contactors:

- Siemens 3RT2026-1BP40
- Siemens 3RT1026-1BP40
- Chint NC8-18/Z

5.5.4 Conclusions for DC contactors

On results of measurements and on scatters drawn from those measurement values, could be noticed, that Chint NC8-18/Z contactor is clearly the most silent comparing to Siemens contactors on pick operation, measured from both directions, when main contactor control board resistors were used. On a comparison of Siemens RT1 and RT2 series, RT2 series contactors were a bit more silent, but differences were not remarkable. Because of arrangement of contactor coil inside the contactor, noise level measured from front is a bit bigger than measured from right side.

When main contactor control board resistors were over connected, Chint was averagely still the most silent contactor on pick operation measured from front side, difference was anyway clearly smaller than with the resistors. Measured from right side, Chint and Siemens RT2 series contactors were averagely on same noise level and Siemens RT1 series contactors bit louder. On this measurement point, Chint has surprisingly big differences between different contactors, because on other measurement points, differences between contactors were quite same with all contactor types.

On drop operation, as opposed to pick operation, Chint was the loudest tested contactor with quite big gap to Siemens contactors measured from both directions. Effect of main contactor control board resistors were smaller on drop operation than on pick operation, still with resistors noise level were a bit smaller with Siemens RT2 and Chint contactors. With Siemens RT1 series contactors, difference was not detected. On Siemens RT1 and RT2 comparison, RT1 series contactor was a bit more silent than contactor of RT2 series.

With an overview to calculations made of measurements, on average, Siemens RT2 series contactors were the most silent contactor with tiny gap to Siemens RT1 contactors. Anyway, by watching peak noises, the loudest noises were measured with Siemens RT1 series contactors and the most silent contactor was Chint. Figures on next pages show the diagrams from results.

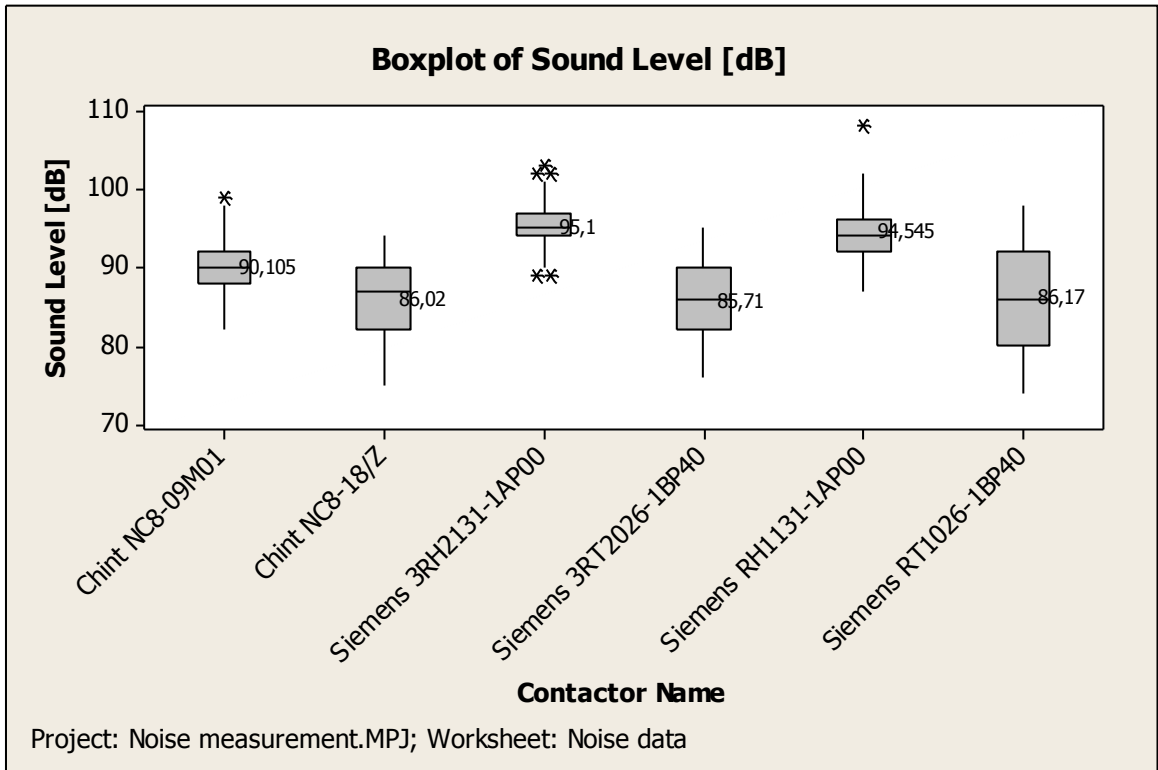


Figure 18 Boxplot of sound level

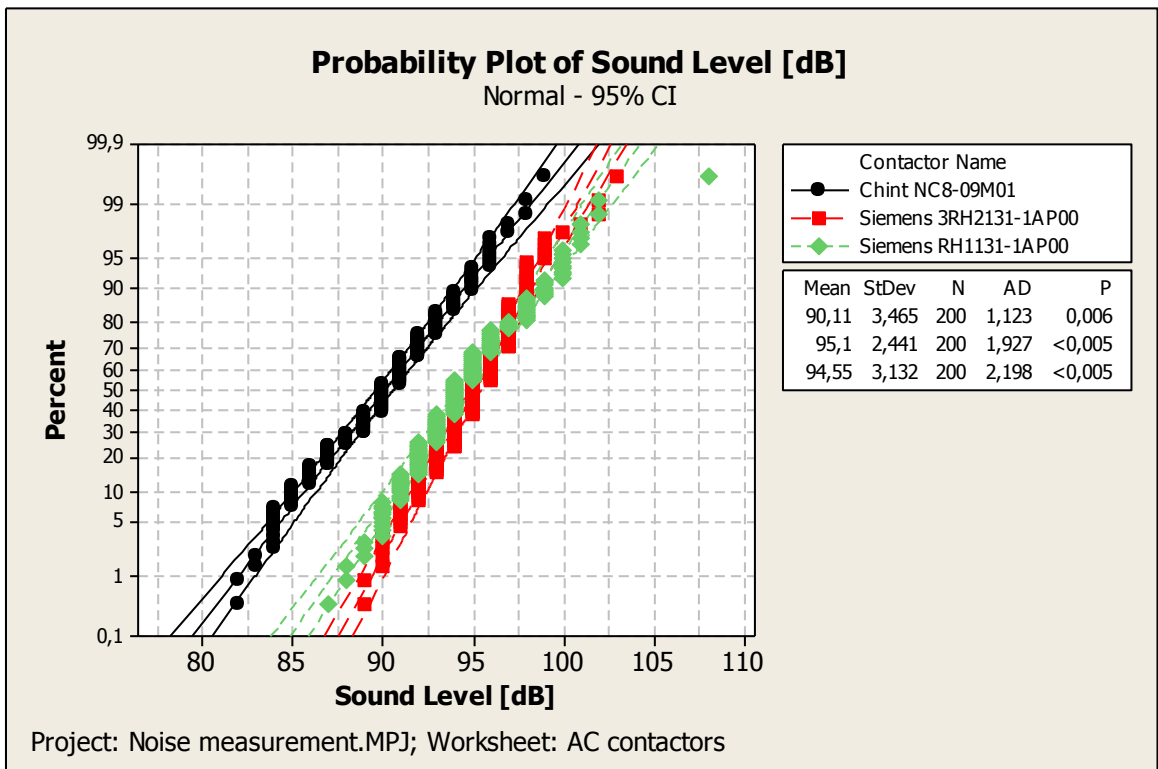


Figure 19 Probability Plot of Sound Level for contactor relays

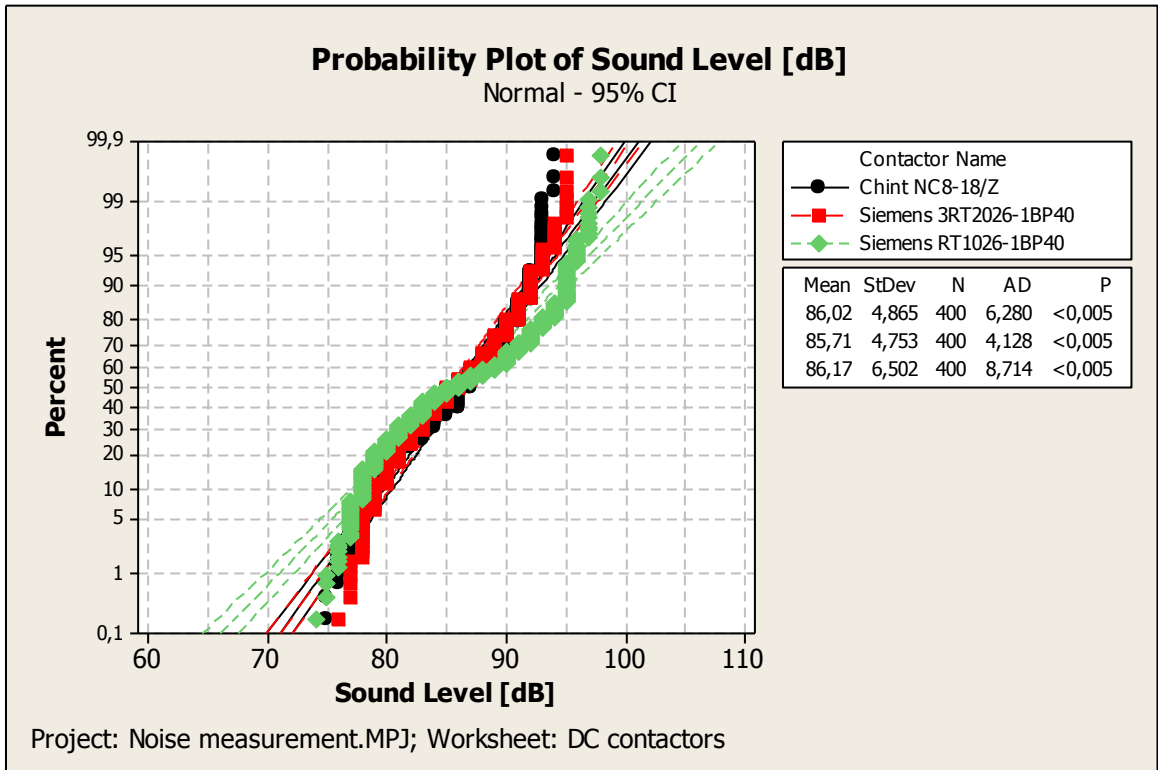


Figure 20 Probability Plot of Sound Level for DC contactors

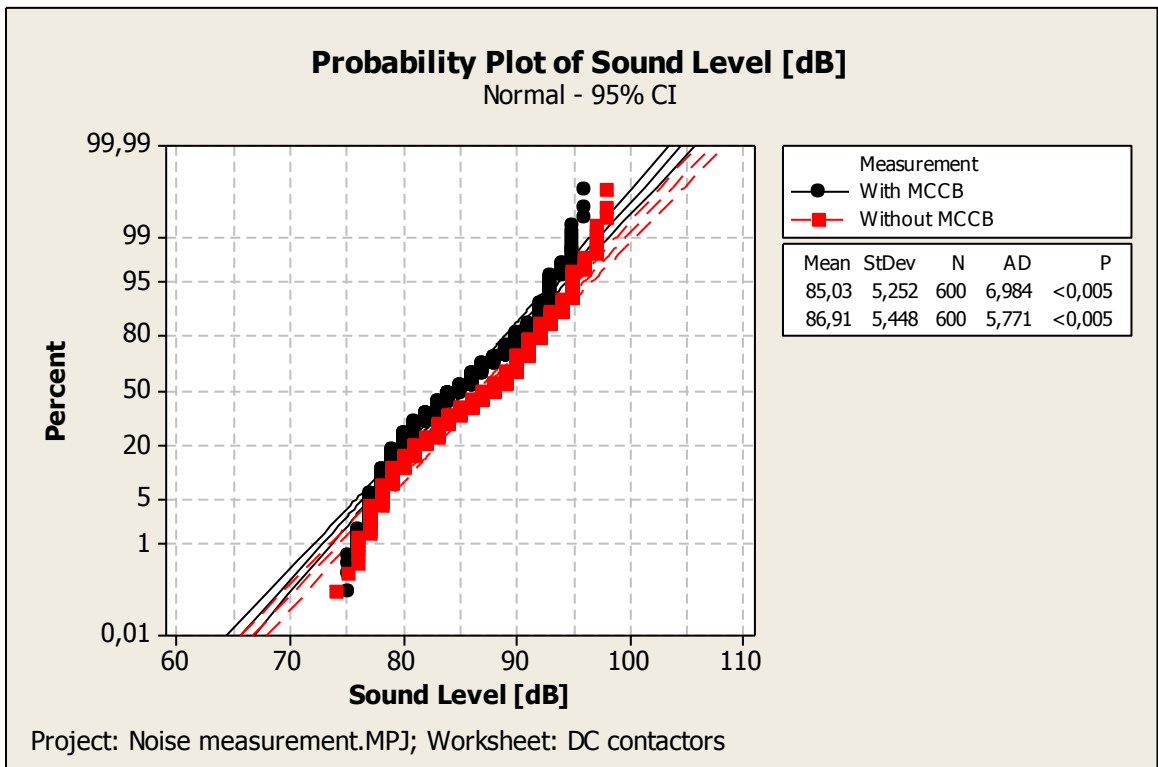


Figure 21 Probability Plot of Sound Level for DC contactors, comparison with and without main contactor control board

6 ABBREVIATIONS

Abbreviation:	Definition:
Minispace	Elevator with machine room
Monospace	Machine room less elevator

7 CONCLUSION

This thesis will work as a base for designing of new drive interface module starting in future by a named designing team. Requirements presented in this thesis will be noticed during design process and by observing those requirements new globally uniform module which differs as less as possible in spite of target country will be built. Next stage after first mock-up is first detailed prototype of the module which will be tested with real elevator simulator.

In original plans for this thesis was to have some tentative test result also from contactors reliability tests. Unfortunately, because of a lack of resources and measuring equipment, tests with planned contactor test environment will be started only during summer 2014 so any test results are not available yet. Tests will continue as long as every contactor type in production is tested and reliability level of each contactor type is inspected. Based from the results and analyses got from these tests, decisions about possible contactor types in production in future will be made. Noise tests, coil characteristic tests and pick and drop out tests will continue also after this thesis depending for availability of measuring devices and contactors to be tested.

For guiding of this thesis I would like to thank Senior Specialist Juha-Matti Aitamurto and all other personnel in KONE R&D department who have guided me with information for this thesis.

BIBLIOGRAPHY

- 1/1 Variable speed drive product description. *Internal document of KONE OY*
- 2/2 Variable speed drive system training material. *Internal document of KONE OY*
- 3/3 Introduction for new electrification system. *Internal document of KONE OY*
- 4/4 www pages of lift instituut solutions. *Referred 5.5.2014*
<http://www.liftinstituutsolutions.com>
- 5/5 IEC 60947-5-1. *Low-voltage switchgear and control gear. Part 5-1. Control circuit devices and switching elements – Electromechanical control circuit devices. 2009. International Electrotechnical commission IEC*
- 6/6 EN81-1:1998+A3. *Safety rules for construction and installation of lifts. Part1: Electric lifts. 2009. European committee for standardization CEN*
- 7/7 ASME A17.1. *Safety code for elevators and escalators. 2007. The American society of mechanical engineers*
- 8/8 IEC 60947-4-1. *Low-voltage switchgear and control gear. Part 4-1. Contactors and motor starters – Electromechanical contactors and motor starters. 2009. International Electrotechnical commission IEC*
- 9/9 IEC 60529 1989+A1:1999. *Degrees of protection provided by enclosures (IP code). 2002. International Electrotechnical commission IEC*
- 10/10 Test of LCE safety chain under external influences. *Internal document of KONE OY*

LIST OF ANNEXES

- | | |
|---------|--|
| Annex 1 | Time cycle for contactor reliability tests |
| Annex 2 | Circuit diagram and measuring points of contactors reliability tests |
| Annex 3 | Coil characteristic test results |
| Annex 4 | Contactors drop out test results |
| Annex 5 | Contactors pick up test results |

