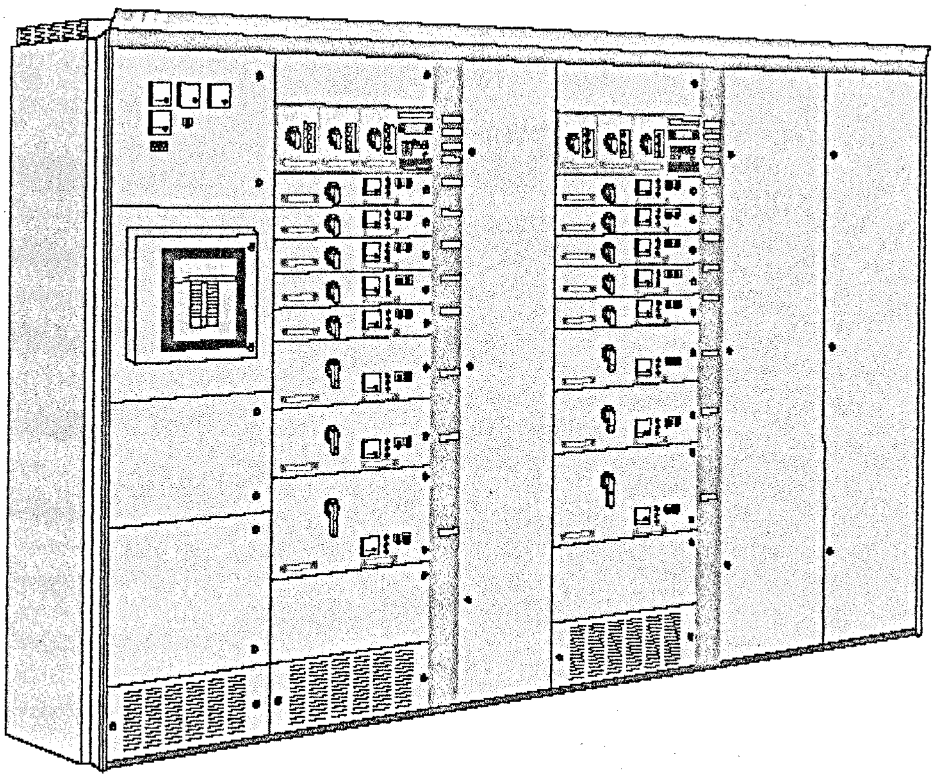
Development of the Power System Protection - Low Voltage Switchgear MNS



Final Report of the Project, Seminar or End of Course Work

Degree in Electrical and Computers Engineering

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Porto, 2006

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Operacional Ciência e Inovação 2010

Abstract

This is a final report of the Project, Seminar or End of Course Work made for the Department of Electrical and Computers Engineering of Porto University, performed at ABB Automation Products, Low Voltage Systems Business Unit in Wroclaw, Poland, during six months.

This internship consisted in the development of the Power System Protection Low Voltage Switchgear MNS. These systems are used for power distribution, motor power supply and to supply building services, with the aim of switching or protecting electrical equipment.

Depending on the purpose and application, they include equipment for switching, protecting, conversion, control, regulation, monitoring and measurement. Even though, because of the extremely varied applications and requirements, different enclosure designs and solutions can be produced.

In the beginning, special attention was given to the basics of power protection and its needs, following the training and inductions received in the company, in order to understand better the assembling of the switchgear. It was also done a description of the system and its included equipment with special focus on the circuit breaker as main switching device.

Finally, we end up with the mechanical and technical aspects developed in the assembling and erection of this system, namely the busbar system, distribution busbars and possible assembling configurations.

Acknowledgments

This internship was only possible due to the corribution of several people.

Firstly, I would like to thank the Manager of Lov Voltage Business Unit in ABB Wroclaw – Mr. Maciej Merek – for giving me this valuble opportunity.

I would like to express my gratitude to the engineering, production and project management teams for all help and advices given, specially my supervisor Mr. Janusz Wilczynski.

To Professor Cláudio Monteiro the availability ɔ accede to my request to be my supervisor.

I would like, as well, to thank my Parents and Agnieszka for all support given.

To POCI 2010 for the financial assistance.

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Introduction

1.1 Purpose

This report aims to give a deeper insight in fields like power protection systems and its devices, as well as several principles in the assembling and commissioning of a system with the complex characteristics of Switchgear, in an industrial and technological environment such as ABB.

Performing an internship of this nature, had as main goal the creation of a link between the wide university knowledge and a real work experience, receiving in this way the necessary tools and inductions to face the professional career with more realistic and accurate orientation.

1.2 Background

ABB has a leading position within power and automation technologies. The ABB Group operates in approximately 100 countries and has about 104 000 employees.

Its core business is organized into five divisions: Power Products, Power Systems, Automation Products, Process Automation and Robotics. Moreover, there is a downstream oil and gas business – ABB Lummus Global. The division of Automation Products has ten Business Units, and one of them is the Low Voltage Systems Unit where this internship is being performed. In the appendix is shown the ABB organization structure in Poland.

1.3 Reader Instructions

This report can be divided into two main parts. First, from the literature study and research made, we analyze the basics of power systems and power protection systems, as well as its most important devices and characteristics. References to power quality and common power disturbances are presented also in this part of the report.

The second part is directly connected with the work developed in the factory. For this reason, Low Voltage Switchgear is here described, followed by its main characteristics, applications and possible configurations and solutions. We finish with conclusions and personal reflections about this practical experience at ABB.

Chapter 2

General Introduction to Power Systems

2.1 Notion of Power System

Finding a definition of Power System can be a hard and long task due to the complexity of all systems, devices and notations needed to describe each parameter. Moreover, we would be moving out of the scope of this report. Nevertheless, a quick and simple answer is to say that it is a system that deals with electric power and energy, where power is the rate of change of energy. The relation between these two variables is shown in the following graphics:

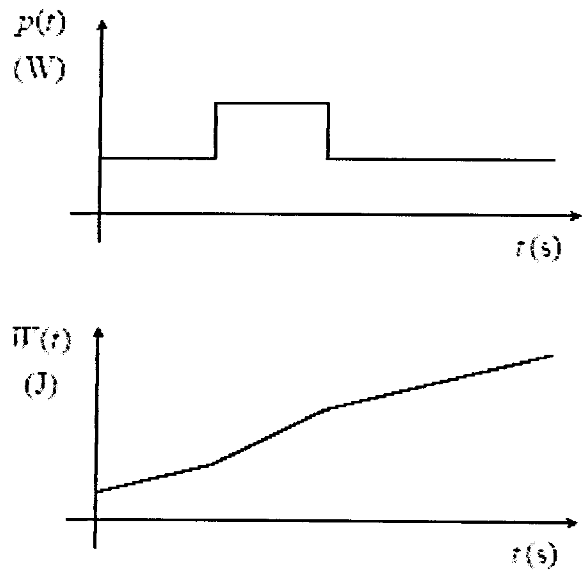


Figure 1 - Basic visualization of the electric power and energy waves.

The following description can be made:

- *p(t)* is the instantaneous power in Watt (W)

- *W(t)* represents the energy in Joules (J); however, in electric power systems energy is expressed in multiples of the unit Watt-hour (Wh).

- **What is the basis?**

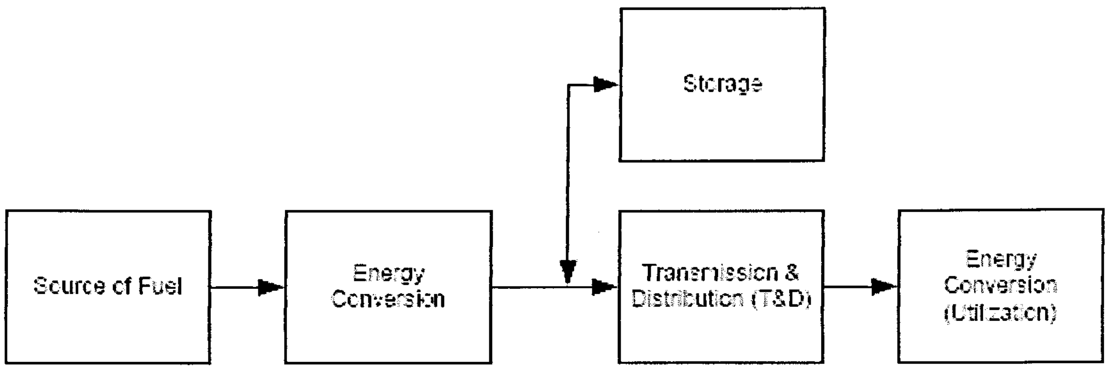


Figure 2 - Power system diagram.

- **Powers Systems examples**
  - Power stations
  - Power utilities
  - Power grid
  - Auxiliary power supplies
  - Emergency systems in hospitals and other critical infrastructures

- **The importance of Power Systems**
  - In a developed and modern society Power Systems are among the most important components of the infrastructures.
  - The economy and development of a country depends directly of the reliability and power quality of its electrical network in order to avoid, for instance, power outages or blackouts.
  - Power Systems are one of the most complex engineering systems. This theme comprises not only the field of science and engineering but also the area of economics.

2.2 Power Quality

Power is generated at a power plant. The most efficient way to transmit this voltage to customers is to increase the voltage. Transmission voltage levels vary, depending on distance and the load it must supply. Transmission voltages are typically 60kV and above. In some cases transmission voltages can be in what is called the extra high voltage range (EHV) of 300 kV and above. Once transmission voltage reaches a local substation it is stepped down, by means of a transformer, to a lower distribution voltage.

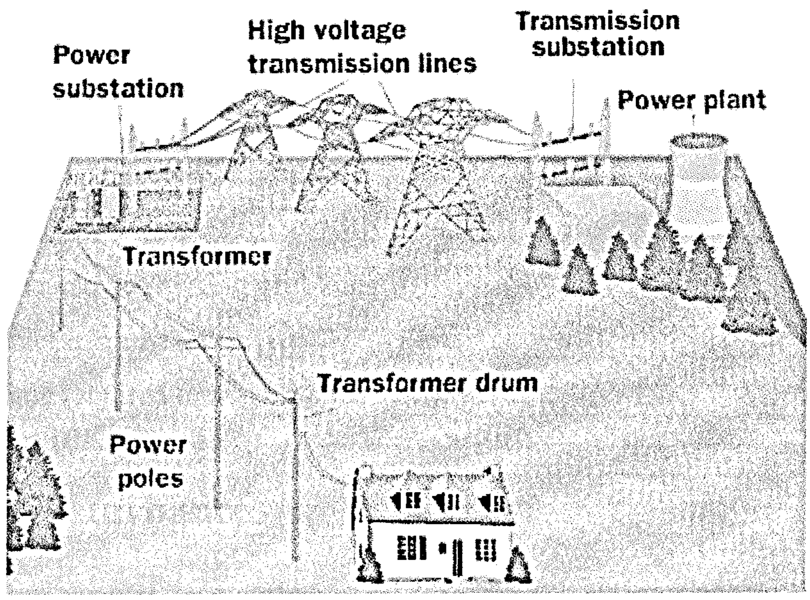


Figure 3 - Power Distribution Grid.

Power quality is a term commonly used nowadays. After power generation it is expected that power energizes all electrical equipment satisfactorily. Nevertheless, energy misapplication, misuse, or accident can unleash the frightening strengths of uncontrolled electrical power. Such uncontrolled release of electrical energy will probably result in damage to both life and material objects through electrical hazards.

This uncontrolled flow of electrical energy is generally the result of such misapplication, misuse or accident and manifests itself in the form of electrical fault currents either in intended or unintended electrical circuits or paths. For these reasons, power quality has practical implications for the devices and equipment but also for our business.

Changes in power quality are especially common in large industrial and commercial complexes and include increases and decreases in voltage, momentary power outages, and "noise" on the electrical system.

Voltage used in the home can be represented by a sine wave. Ideally a sine wave would be smooth and free of disturbances. However, even the best distribution systems are subject to changes in system voltage from time-to-time.

Consequences of weak power quality

Nowadays, electric and electronic devices have a high sensitivity, what makes them more vulnerable to power disturbances. Relatively to economical and logistical aspects we can show which kind of problems can occur in an industrial or business environment:

- Lost productivity due to inactive staff and equipment
- Lost orders, customers and profits
- Lost transactions
- Revenue and accounting problems
- Customer dissatisfaction
- Overtime required to make up for lost work time

2.3 Power Disturbances

We describe and define below what kind of power disturbances can exist in a power line:

- **Surge** – A rapid short-term increase in voltage. Since sensitive electronic devices require a constant voltage, surges stress delicate components and cause premature failure.
- **Spike** – An extremely high and nearly instantaneous increase in voltage with a very short duration measured in microseconds. Spikes are often caused by lightning or by events such as power coming back on after an outage.
- **Sag** – A rapid short-term decrease in voltage. A sag typically is caused by simultaneous high power demand of many electrical devices such as motors, compressors and so on. The effect of a sag is to "starve" electronic equipment of power causing unexpected crashes and lost or corrupted data. Sags also reduce the efficiency and life span of equipment such as electric motors.
- **Noise** – A disturbance in the smooth flow of electricity. Often technically referred to as electro-magnetic interference (EMI) or radio frequency interference (RFI). Harmonics are a special category of power line noise that causes distortions in electrical voltage. Noise can be caused by motors and electronic devices in the immediate vicinity or far away. Noise can affect performance of some equipment and introduce glitches and errors into software programs and data files.

- **Outage** – Total loss of power for some period of time. Outages are caused by excessive demands on the power system, lightning strikes and accidental damage to power lines. In addition to shutting down all types of electrical equipment, outages cause unexpected data loss.

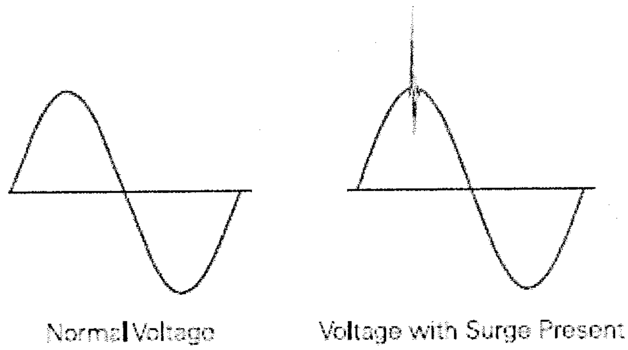


Figure 4 – Disturbance in form of surge on the sine wave.

Variation of Voltage

Voltage changes can range from small voltage fluctuations of short duration to a complete outage for an extended period of time. Undervoltage occurs when voltage decreases outside normal rated tolerance. An undervoltage is often referred to as a sag when the duration is two seconds or less. Undervoltages and sags can cause, for instance, a computer to crash and confuse a digital clock.

Overvoltages occur when voltage increases above normal rated tolerance. An overvoltage is referred to a swell when the disturbance lasts two seconds or less. Overvoltages and swells can upset sensitive electronic equipment, and cause damage in some cases.

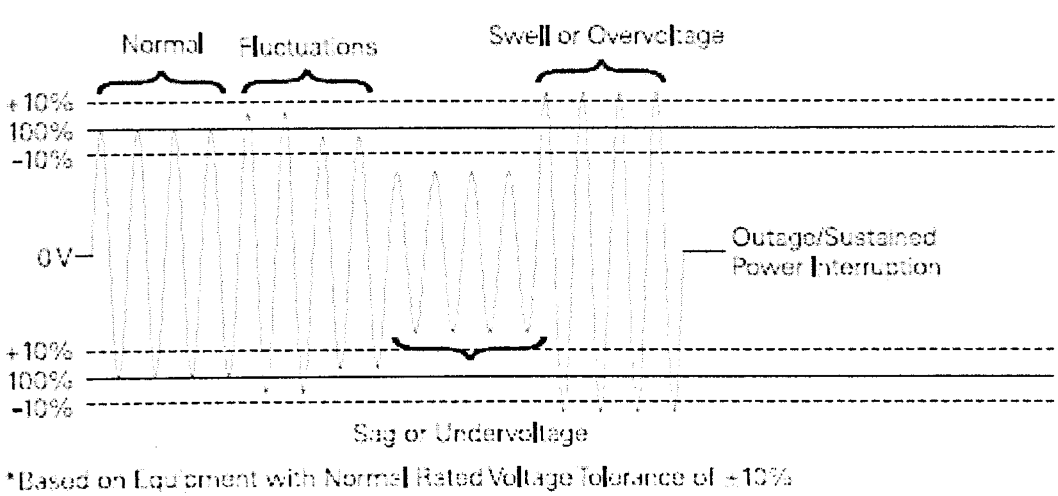


Figure 5 – Voltage variation.

2.4 Need for Current Protection

Current and Temperature

Heat is generated in a conductor when current is flowing. When a greater value of current is present, there is consequently an increase in the conductor's temperature.

Excess heat is damaging to electrical components and conductor insulation. For this reason conductors have a rated continuous current carrying capacity, or ampacity. Overcurrent protection devices, such as fuses, are used to protect conductors from excessive current flow.

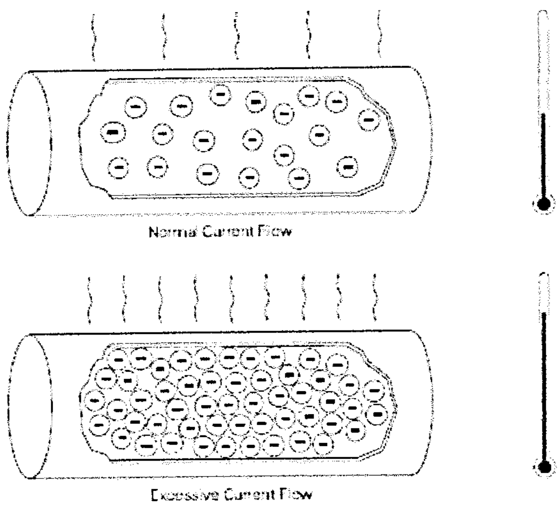


Figure 6 – Temperature in a current conductor

The term overcurrent is known as an excess of current. It can be defined as any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

Overload

An overload occurs when too many devices are operated on a single circuit, or when a piece of electrical equipment is made to work harder than it is designed to work. This situation can be originated by short circuit, by incorrect installation or by misuse.

Conductor Insulation

Every circuit requires some form of protection against overcurrent and the heat it produces. For example, high levels of heat to insulated wire can cause the insulation to break down and flake off, exposing the conductors.

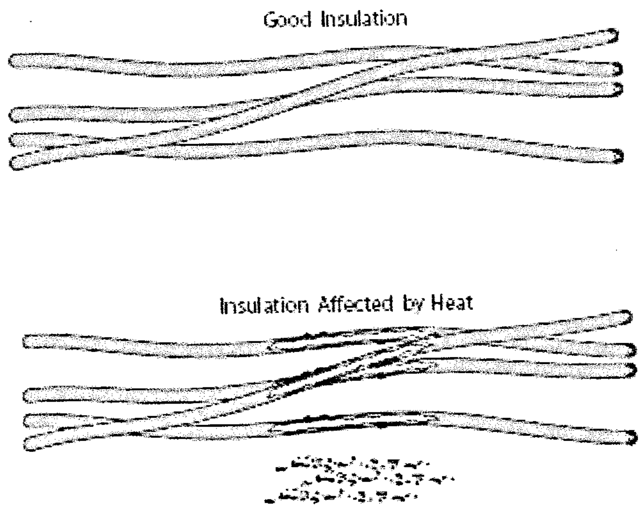


Figure 7 – Effects of heat in the insulation.

Short Circuits

Exposing conductors on an incorrect way leads to a short circuit and the circuit resistance is forced to drop to nearly zero. Because of this very low resistance, short circuit current can be thousands of times higher than normal operating current.

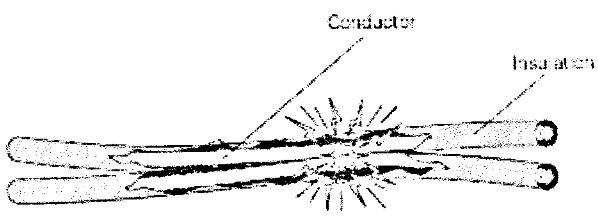


Figure 8 – Damaged insulation.

As an example can be shown the following thought:

A 240 volt motor with 24 W (ohms) of resistance would normally draw 10 amperes of current.

$$I = \frac{E}{R}$$

$$I = \frac{240}{24}$$

$$I = 10A$$

During the appearance of a short circuit, resistance drops. For instance, if the above resistance dropped to 24 milliohms due to a short circuit, the current would increase to 10000 amperes.

$$I = \frac{240}{0.024}$$

$$I = 10000A$$

Short-Circuit Current in unprotected circuits

During the occurrence of a short circuit in an unprotected circuit, current will continue to flow until the circuit is damaged, or until the power is removed manually. The peak short-circuit current of the first cycle is the greatest and is referred to as **peak let-through current (IP)**. The electromagnetic force associated with this current can cause mechanical damage to electrical components.

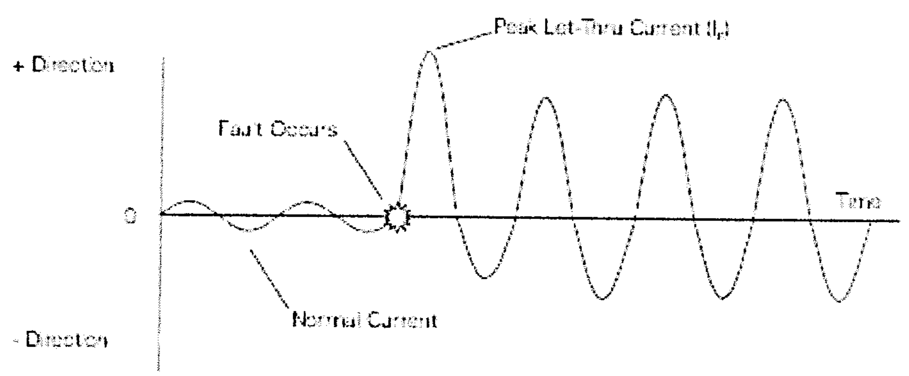


Figure 9 – Peak let-through current (IP) visualization.

The **maximum destructive energy let-through (I2t)** is a measure of the energy associated with this current. It is capable of producing enough heat to melt conductors.

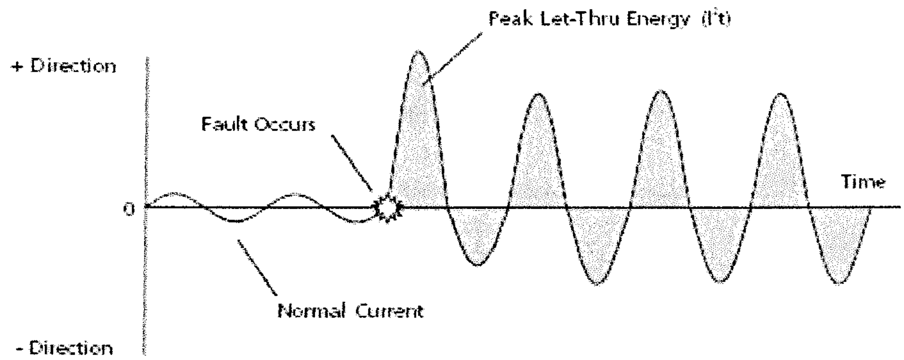


Figure 10 - Maximum destructive energy let-through (I2t) visualization.

Short-Circuit Current in Protected Electrical Circuits

If an adequate overcurrent protecting device is present, the circuit will be opened, protecting in this manner the devices of the peak let-through current (IP) and energy (I2t) effects.

A properly applied overcurrent protecting device will open the circuit quickly, limiting peak let-through current (IP) and energy (I2t).

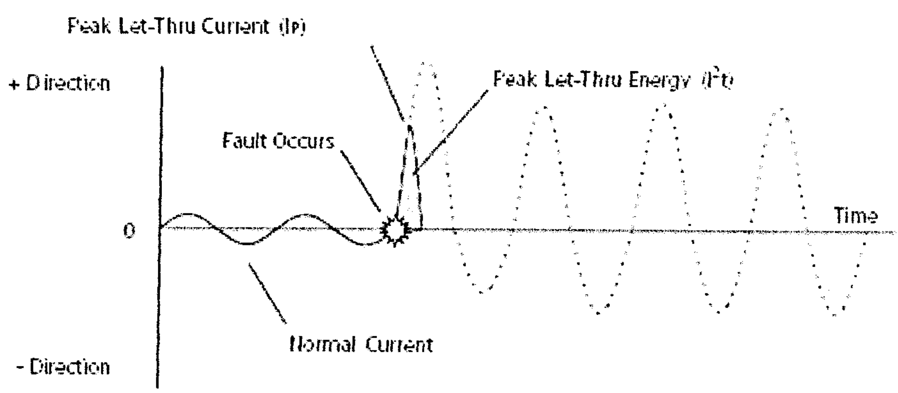


Figure 11 - Peak let-through current (IP) limited by a protective device.

Chapter 3

Power Systems Protection Background

As we have mentioned in the last chapter, the electric power system should be associated to an efficient and reliable protection system in order to ensure the safe and quick delivery of power to particular, commercial or industrial purposes.

In this part of the report, we are going to show the importance of power protection and its objectives, as well as describing its features and most important characteristics.

3.1 Basics for efficient protection

Typically, the situation that concerns more engineers and designers, relatively to electrical failure is the short circuit. Even though, there are also other anomalous operating conditions that demand special precaution.

In order to prevent electrical failure, the following aspects should be taken in account:

- Adequate insulation.
- Coordination between insulation strength and capabilities of lightning arresters.
- Application of overhead ground wires and low tower-footing resistance.
- Strong mechanical design in order to decrease the failures caused by animals contact.
- Adequate operation and maintenance practices.

In order to attenuate the effects of failure, the following features should be followed:

1. Aspects that mitigate the immediate effects of an electrical failure.
   - Project to restrict the magnitude of short-circuit current.
     - Limiting too large concentrations of generating capacity.
     - Employing current-limiting impedance.
   - Appropriate design in order resist to mechanical stresses and heating.

- Time-delay undervoltage devices on circuit breakers to prevent dropping loads during momentary voltage dips.
- Ground-fault neutralizers.

2. Quick disconnection of the faulty element
   - Protective relaying.
   - Circuit breakers with adequate interrupting capacity.
   - Fuses.

3. Mitigate the loss of the faulty element.
   - Alternate circuits.
   - Reserve generator and transformer capacity.
   - Automatic reclosing.

4. From the period of fault beginning until its removal, these are the features responsible for voltage and stability maintenance.
   - Automatic voltage regulation.
   - Stability characteristics of generators.

5. Observing the electiveness of the foregoing features.
   - Automatic oscillographs.
   - Efficient human observation and record keeping.

3.2 Protective Relaying

Protective relaying has as main function the fast removal from service of any element of a power system when it suffers a short circuit, or when it starts to operate in any abnormal condition. As support to relaying equipment there are circuit breakers which should be capable of disconnecting the faulty element when they are called to do so.

Normally, circuit breakers are located so that each generator, transformer, bus, transmission line, etc., can be completely disconnected from the rest of the system. These circuit breakers must have sufficient capacity so that they can carry momentarily the maximum short-circuit current that can flow through them, and then interrupt this current;

they must also withstand closing in on such a short circuit and then interrupting it according to certain prescribed standards.

In respect to fuses, theses elements are used where protective relays and circuit breakers are not economically justifiable.

Protective relaying should mitigate the effects of short circuits, and other special non-working conditions in motors and generators.

Other function of protective relaying is to provide indication of the location and type of failure. They furnish as well means for analyzing the effectiveness of the fault-prevention and mitigation features.

Principles of protective relaying

There are two types of protective relaying: primary relaying and back-up relaying.

Primary relaying is the first to act if some defective element of a power system is detected. In the other hand, back-up relaying is only provided in case of primary relaying failure or circuit breaker failure.

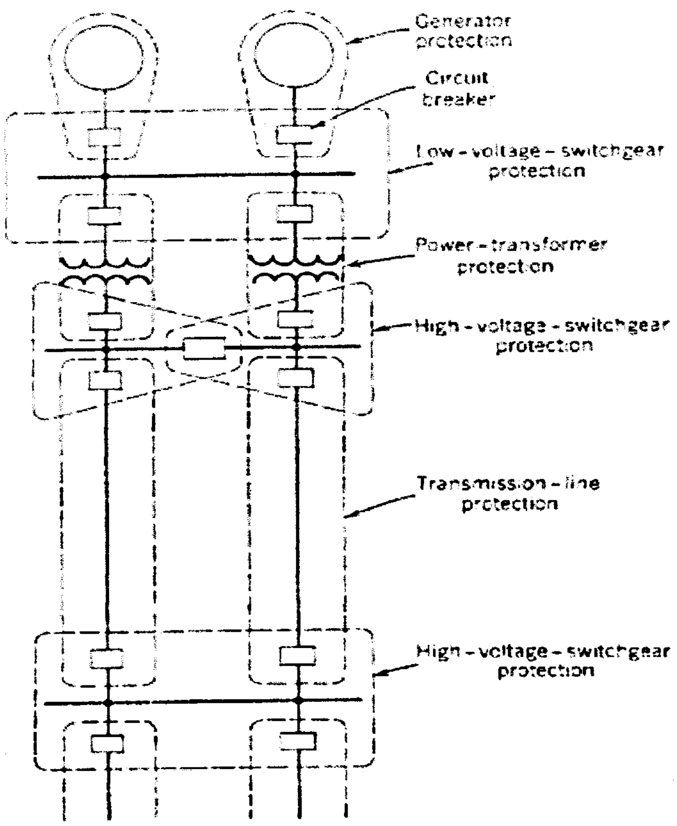


Figure 12 - Diagram of a part of an electrical power system illustrating primary relaying.

It is possible to observe that circuit breakers are located in the connections to each power element. This provision makes it possible to disconnect only a faulty element. Occasionally, a breaker between two adjacent elements may be omitted, in which event both elements must be disconnected for a failure in either one.

The second observation is that, without at this time knowing how it is accomplished, a separate zone of protection is established around each system element. The significance of this is that any failure occurring within a given zone will cause the “tripping” (i.e., opening) of all circuit breakers within that zone, and only those breakers. It will become evident that, for failures within the region where two adjacent protective zones overlap, more breakers will be tripped than the minimum necessary to disconnect the faulty element. But, if there were no overlap, a failure in a region between zones would not lie in either zone, and therefore no breakers would be tripped. The extent of the overlap is relatively small, and the probability of failure in this region is low; consequently, the tripping of too many breakers will be quite infrequent.

Finally, it will be observed that adjacent protective zones overlap around a circuit breaker. This is the preferred practice because, for failures anywhere except in the overlap region, the minimum number of circuit breakers need to be tripped. When it becomes desirable for economic or space-saving reasons to overlap on one side of a breaker, as is frequently true in metal-clad switchgear the relaying equipment of the zone that overlaps the breaker must be arranged to trip not only the breakers within its zone but also one or more breakers of the adjacent zone, in order to completely disconnect certain faults. This is illustrated in Figure 13, where it can be seen that, for a short circuit at X, the circuit breakers of zone B, including breaker C, will be tripped; but, since the short circuit is outside zone A, the relaying equipment of zone B must also trip certain breakers in zone A if that is necessary to interrupt the flow of short circuit current from zone A to the fault. This is not a disadvantage for a fault at X, but the same breakers in zone A will be tripped unnecessarily for other faults in zone B to the right of breaker C. Whether this unnecessary tripping is objectionable will depend on the particular application.

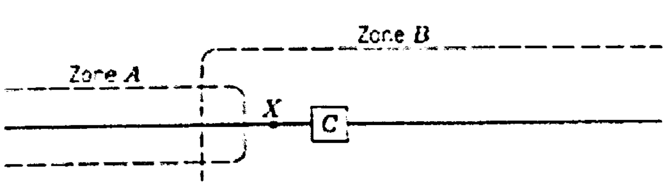


Figure 13 - Overlapping adjacent protective zones on one side of a circuit breaker.

Back-up relaying is used only for protection against short circuits. Because short circuits are the preponderant type of power failure, there are more opportunities for failure in short primary relaying. As we know that back-up relaying only acts when primary relaying fails, it is pertinent to know the main reasons of primary relaying failing:

1. Current or voltage supply to the relays.
2. DC tripping-voltage supply.
3. Protective relays.
4. Tripping circuit or breaker mechanism.
5. Circuit breaker.

It is highly desirable that back-up relaying be arranged so that anything that might cause primary relaying to fail will not also cause failure of back-up relaying. It will be evident that this requirement is completely satisfied only if the back-up relays are located so that they do not employ or control anything in common with the primary relays that are to be backed up. So far as possible, the practice is to locate the back-up relays at a different station.

In some cases, it is impossible to provide any back-up protection; in such cases, greater importance is given to maintenance. In fact, even with complete back-up relaying, there is still much to be gained by proper maintenance. When primary relaying fails, even though back-up relaying functions properly, the service will always suffer. In this way, the best practice to protect the power system is to provide a proper maintenance in the electric system.

3.3 Characteristics of Protective relaying

To accomplish the objectives of protective relaying, four criteria should be considered: speed, selectivity, sensitivity and reliability.

- **Speed** is defined as the high-speed tripping of all terminals of a faulted circuit to isolate the faulted electric system elements. This normally requires the application of a pilot relay scheme on transmission lines and high speed differential relaying on generators, buses and transformers.

While simultaneous tripping at all terminals is desirable, it is recognized, in the case of multi-terminal lines, that high-speed sequential tripping may be necessary to prevent imposing load limitations due to overly sensitive relay settings. Briefly, speed has the ability of minimize damage from current and maximize power transfer and stability.

- **Selectivity** is the ability of the protective relaying to trip the minimum circuits or equipment to isolate the fault. Coordination is required with the adjacent circuit protection including breaker failure, generator potential transformer fuses and station auxiliary protection.

- **Sensitivity** demands that the relays be capable of sensing minimum fault conditions without imposing limitations on circuit or equipment capabilities. The settings must be investigated to determine that they will perform correctly during transient power swings from which the system can recover.

- **Reliability** is a measure of the protective relaying system's certainty to trip when required (dependability) and not to trip falsely (security). Dependability should be based on a single contingency, such that the failure of any one component of equipment, e.g., relay, current transformer, breaker, communication channel, etc., will not result in failure to isolate the fault.

  Protection in depth (i.e., primary and back-up schemes) necessary to accomplish this must be designed so as not to compromise the security of the system.

Chapter 4

Low Voltage Switchgear

Switchgear is used to connect and disconnect electric power supplies and systems. It is a general term which covers the switching device and its combination with associated control, measuring, protective and regulating equipment, together with accessories, enclosures and supporting structures. [Warne, D. F., Newnes Electrical Engineer's Handbook]

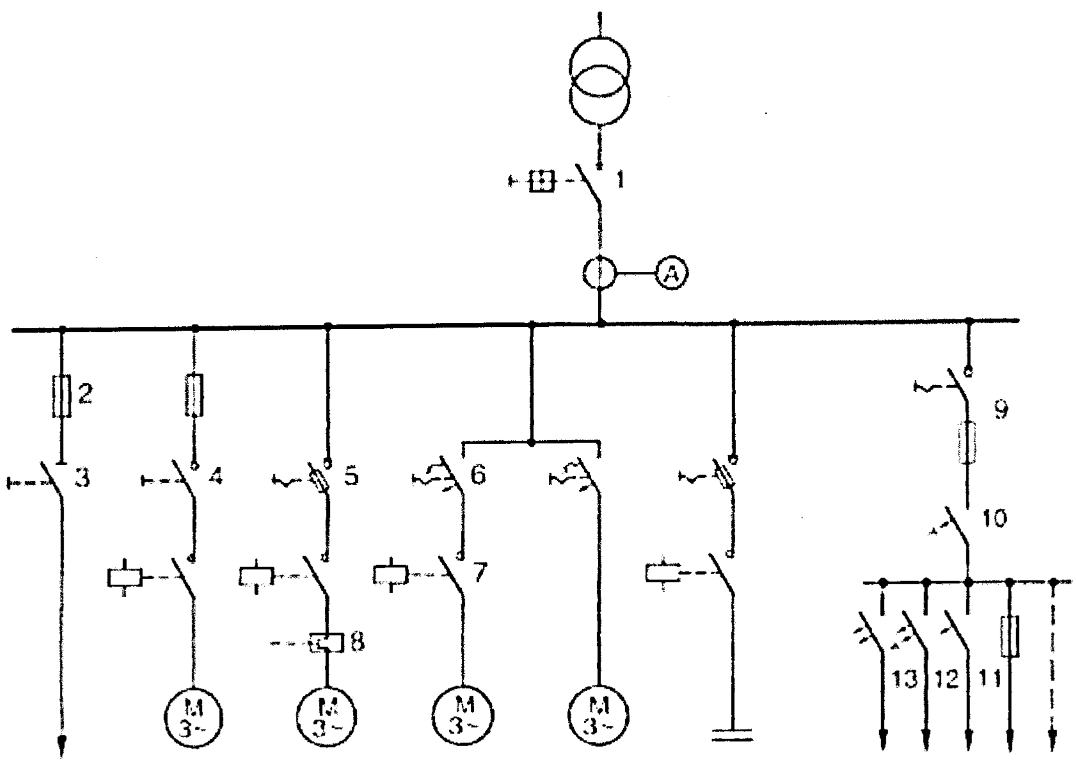


Figure 14 - Examples for use of low voltage switchgear:
1. Circuit-breaker general 2. Fuse 3. Disconnector 4. Loadbreak switch 5. Fused switch disconnector 6. Motor starter (motor protection switch) 7. Contactor 8, Overload relay 9. Switch disconnector with fuses 10. Residual current-operated circuitbreaker (RCCB) 11. Miniature circuit-breaker 12. Residual current-operated circuitbreaker with overcurrent tripping (RCBO) 13. Residual current-operated miniature circuit-breaker (RCD).

4.1 Functions of Low Voltage Switchgear

Low Voltage (LV) Switchgear is designed for switching and protection of electrical equipment. The selection of switchgear apparatus is based on the specific switching task: isolation, load switching, short-circuit current breaking, motor switching, protection against overcurrent and personnel hazard. Depending on the type, switchgear apparatus can be used for single or multiple switching tasks. Switching functions can be conducted also by a combination of several switchgear units. Figure 14 showed some applications for LV switchgear.

The main functions of switchgear are:

- Electrical protection
- Electrical isolation of sections of an installation
- Local or remote switching

Electrical protection at low voltage is (apart from fuses) normally incorporated in circuit breakers, in the form of thermal-magnetic devices and/or residual-current operated tripping devices. In addition to those functions shown in Table 1, other functions, namely:

- Over-voltage protection
- Under-voltage protection

are provided by specific devices - lightning and various other types of voltage-surge arrester, relays associated with contactors, remotely controlled circuit breakers, and with combined circuit breaker/isolators, etc.

Electrical protection against	Isolation	Control
• Overload currents • Short-circuit currents • Insulation Failure	• Isolation clearly indicated by an authorized fail-proof mechanical indicator • A gap or interposed insulating barrier between the open contacts, clearly visible	• Functional switching • Emergency switching • Emergency stopping • Switching off for mechanical maintenance

Table 1 – Basic functions of LV switchgear.

4.1.1 Electrical protection

Protection of electric motors

The goal is to limit or avoid the destructive or dangerous consequences of excessive (short-circuit) currents, or those due to overloading and insulation failure, and to separate the defective circuit from the rest of the installation.

A distinction is made between the protection of:

- The elements of the installation (cables, wires, switchgear…)
- Persons and animals
- Equipment and appliances supplied from the installation

Protection of circuits

- **Against overload**; a condition of excessive current being drawn from a healthy (unfaulted) installation
- **Against short-circuit currents** due to complete failure of insulation between conductors of different phases or (in TN systems) between a phase and neutral (or PE) conductor

Protection in these cases is provided either by fuses or circuit breaker, in the distribution board at the origin of the final circuit (i.e. the circuit to which the load is connected).

Protection of persons

- Against insulation failures. According to the system of earthing for the installation (TN, TT or IT) the protection will be provided by fuses or circuit breakers, residual current devices, and/or permanent monitoring of the insulation resistance of the installation to earth

The protection of electric motors

- Against overheating, due, for example, to long term overloading, stalled rotor, single-phasing, etc. Thermal relays, specially designed to match the particular characteristics of motors are used. Such relays may, if required, also protect the motor-circuit cable against overload. Short-circuit protection is provided either by type aM fuses or by a circuit breaker from which the thermal (overload) protective element has been removed, or otherwise made inoperative.

4.1.2 Isolation

The aim of isolation is to separate a circuit or apparatus (such as a motor, etc.) from the remainder of a system which is energized, in order that personnel may carry out work on the isolated part in perfect safety.

In principle, all circuits of an LV installation shall have means to be isolated. In practice, in order to maintain an optimum continuity of service, it is preferred to provide a means of isolation at the origin of each circuit.

An isolating device must fulfil the following requirements:

- All poles of a circuit, including the neutral (except where the neutral is a PEN conductor) must open.
- It must be provided with a locking system in open position with a key (e.g. by means of a padlock) in order to avoid an unauthorized reclosure by inadvertence
- It must comply with a recognized national or international standard concerning clearance between contacts, creepage distances, overvoltage withstand capability, etc.: Other requirements apply:
- Verification that the contacts of the isolating device are, in fact, open.

The verification may be:

- Either visual, where the device is suitably designed to allow the contacts to be seen (some national standards impose this condition for an isolating device located at the origin of a LV installation supplied directly from a HV/LV transformer)
- Or mechanical, by means of an indicator solidly welded to the operating shaft of the device. In this case the construction of the device must be such that, in the eventuality that the contacts become welded together in the closed position, the indicator cannot possibly indicate that it is in the open position
- Leakage currents. With the isolating device open, leakage currents between the open contacts of each phase must not exceed:

- 0.5 mA for a new device
- 6.0 mA at the end of its useful life

- Voltage-surge withstand capability, across open contacts. The isolating device, when open must withstand a 1.2/50 μs impulse, having a peak value of 6, 8 or 12 kV according to its service voltage.

4.1.3 Switchgear control

"Control" signifies any facility for safely modifying a load-carrying power system at all levels of an installation. The operation of switchgear is an important part of power-system control.

Functional control

This control relates to all switching operations in normal service conditions for energizing or de-energizing a part of a system or installation, or an individual piece of equipment, item of plant, etc.

Switchgear intended for such duty must be installed at least:

- At the origin of any installation
- At the final load circuit or circuits (one switch may control several loads)

Marking (of the circuits being controlled) must be clear and unambiguous.

In order to provide the maximum flexibility and continuity of operation, particularly where the switching device also constitutes the protection (e.g. a circuit breaker or switch-fuse) it is preferable to include a switch at each level of distribution, i.e. on each outgoing way of all distribution and subdistribution boards.

The technique may be:

- Either manual (by means of an operating lever on the switch) or
- Electric, by push-button on the switch or at a remote location (load-shedding and reconnection, for example)

These switches operate instantaneously (i.e. with no deliberate delay), and those that provide protection are invariably omni-polar.

The main circuit breaker for the entire installation, as well as any circuit breakers used for change-over (from one source to another) must be omni-polar units.

Emergency switching - emergency stop

An emergency switching is intended to de-energize a live circuit which is, or could become, dangerous (electric shock or fire). An emergency stop is intended to halt a movement which has become dangerous. In the two cases:

- The emergency control device or its means of operation (local or at remote location(s)) such as a large red mushroom-headed emergency-stop pushbutton must be recognizable and readily accessible, in proximity to any position at which danger could arise or be seen
- A single action must result in a complete switching-off of all live conductors
- A "break glass" emergency switching initiation device is authorized, but in unmanned installations the re-energizing of the circuit can only be achieved by means of a key held by an authorized person

It should be noted that in certain cases, an emergency system of braking, may require that the auxiliary supply to the braking-system circuits be maintained until final stoppage of the machinery.

4.2 Elementary switching devices

Disconnector (or isolator)

This switch is a manually-operated, lockable, two-position device (open/closed) which provides safe isolation of a circuit when locked in the open position. A disconnector is not designed to make or to break current and no rated values for these functions are given in standards. It must, however, be capable of withstanding the passage of short-circuit currents and is assigned a rated short-time withstand capability, generally for 1 second, unless otherwise agreed between user and manufacturer. This capability is normally more than adequate for longer periods of (lower-valued) operational overcurrents, such as those of motor-starting. Standardized mechanical-endurance, overvoltage, and leakage-current tests, must also be satisfied.

Load-breaking switch

This control switch is generally operated manually (but is sometimes provided with electrical tripping for operator convenience) and is a non-automatic two-position device (open/closed). It is used to close and open loaded circuits under normal unfaulted circuit conditions. It does not consequently provide any protection for the circuit it controls. We can define:

- The frequency of switch operation (600 close/open cycles per hour maximum)
- Mechanical and electrical endurance (generally less than that of a contactor)
- Current making and breaking ratings for normal and infrequent situations

When closing a switch to energize a circuit there is always the possibility that an unsuspected short circuit exists on the circuit. For this reason, load-break switches are assigned a fault-current making rating, i.e. successful closure against the electrodynamic forces of short-circuit current is assured. Such switches are commonly referred to as "fault-make load-break" switches. Upstream protective devices are relied upon to clear the short-circuit fault.

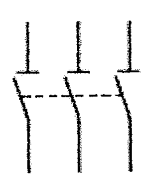


Figure 15 - Symbol for a disconnector (or isolator).

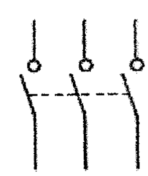


Figure 16 – Symbol for a load-breaking switch.

Remote control switch

This device is extensively used in the control of lighting circuits where the depression of a pushbutton (at a remote control position) will open an already-closed switch or close an opened switch in a bistable sequence.

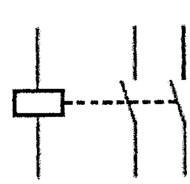


Figure 17 - Symbol for a bistable remote control switch.

Typical applications are:

- Two-way switching on stairways of large buildings
- Stage-lighting schemes
- Factory illumination, etc.

Auxiliary devices are available to provide:

- Remote indication of its state at any instant
- Time-delay functions
- Maintained-contact features

Contactor

Contactors are remote-control switching devices with restoring force, which are actuated and held by their actuator. They are primarily intended for high-switching frequency for switching currents with equipment in a healthy state, including operational overload. Contactors are suitable for isolation to a limited extent only, and they must be protected against short circuit by upstream protection equipment.

Apart from the electromagnetic actuation most often used, there are also contactors with pneumatic or electropneumatic actuation.

Contactors are fitted with current-dependent protection devices to prevent thermal overload of motors. For protection against motor overload or in the event of external conductor failure, e.g. line break or blowing of only one fuse, the overload relays are set to the rated current of the motor. Modern overload relays have a temperature compensation facility to prevent interference from varying ambient temperatures affecting the trip times of the bimetallic contacts. They also have a phase failure protection; manual or automatic reset can be selected.

Protection must be actuated without problem within the voltage limits of 85 % and 110 % – with control current flowing.

When sending commands over long control lines, the contactor may not react to the command on closing because of excessive voltage drop (AC and DC actuation) or on breaking because of the excessive capacitance on the line. A voltage drop of max. 5 % is permissible for calculating the length of the control line.

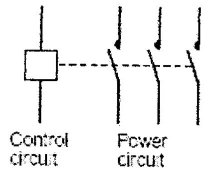


Figure 18 - Symbol for a contactor.

Discontactor

A contactor equipped with a thermal-type relay for protection against overloading defines a "discontactor". Discontactors are used extensively for remote push-button control of lighting circuits, etc., and may also be considered as an essential element in a motor controller.

The discontactor is not the equivalent of a circuit breaker, since its short-circuit current breaking capability is limited to 8 or 10 In. For short-circuit protection therefore, it is necessary to include either fuses or a circuit breaker in series with, and upstream of, the discontactor contacts.

Fuses

Fuses are protection devices that open a current circuit by the melting of one or more fusible elements and break the current if it exceeds a specific value for a specific period. Low-voltage fuses are classified by their operating classes and designs.

The first letters identifies the breaking range:
g – General purpose fuses can continuously conduct currents up to their rated current and can disconnect currents from the smallest fusing current to the rated breaking capacity.
a – Back-up fuses can continuously conduct currents up to their rated current and can disconnect only currents above a specific multiple of their rated current.

The second letter identifies the application; this letter determines the time-current characteristic.
G – for general application
M – for the protection of motor current circuits and switchgear
R – for protection of semiconductor components

Tr – transformer protection

B – mine substation protection

D – fuse links with delay (North American practice)

N – fuse links without delay (North American practice)

Standards define two classes of fuse:

- Those intended for **domestic installations**, manufactured in the form of a cartridge for rated currents up to 100 A and designated type gG.
- Those for **industrial use**, with cartridge types designated gG (general use); and gM and aM (for motor-circuits).

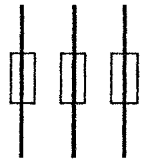


Figure 19 - Symbol for fuses.

The main differences between domestic and industrial fuses are the nominal voltage and current levels (which require much larger physical dimensions) and their fault current breaking capabilities. Type gG fuse-links are often used for the protection of motor circuits, which is possible when their characteristics are capable of withstanding the motor-starting current without deterioration.

A more recent development has been the adoption of a fuse-type gM for motor protection, designed to cover starting, and short-circuit conditions. At the present time the aM fuse in combination with a thermal overload relay is more-widely used.

A gM fuse-link, which has a dual rating, is characterized by two current values. The first value In denotes both the rated current of the fuse-link and the rated current of the fuseholder; the second value Ich denotes the time-current characteristic of the fuse-link as defined by the gates. These two ratings are separated by a letter which defines the applications.

Fusing zones - conventional currents

The conditions of fusing (melting) of a fuse are defined by standards, according to their class.

Class gG fuses

These fuses provide protection against overloads and short-circuits. Conventional non-fusing and fusing currents are standardized, as shown in Figure 20:

- The conventional non-fusing current Inf is the value of current that the fusible element can carry for a specified time without melting.
- The conventional fusing current If (= I2 in Figure 20) is the value of current which will cause melting of the fusible element before the expiration of the specified time.

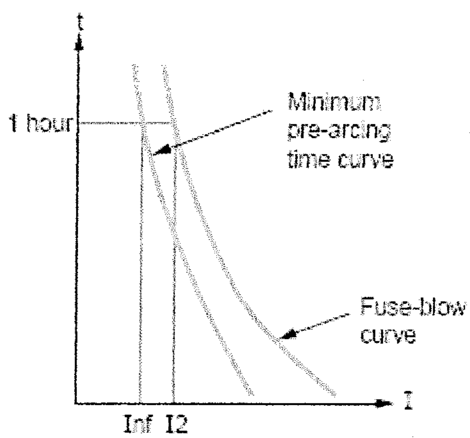


Figure 20 – Graphic of the zones of fusing and non-fusing for gG and gM fuses.

Class aM (motor) fuses

These fuses afford protection against short-circuit currents only and must necessarily be associated with other switchgear (such as discontactors or circuit breakers) in order to ensure overload protection < 4 In. They are not therefore autonomous. Since aM fuses are not intended to protect against low values of overload current, no levels of conventional non-fusing and fusing currents are fixed.

The characteristic curves for testing these fuses are given for values of fault current exceeding approximately 4 In (see Figure 21), and fuses tested to standard requirements must give operating curves which fall within the shaded area.

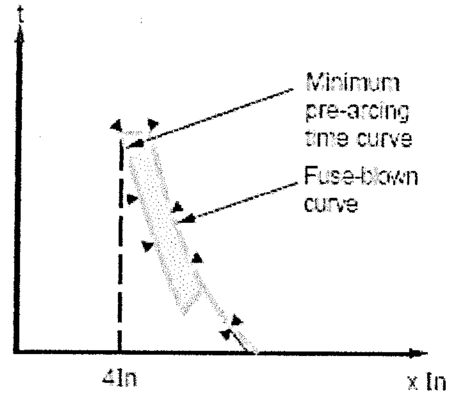


Figure 21 – Graphic of the zones of fusing for type aM fuses.

4.3 Combined switchgear elements

In general, single units of switchgear do not fulfil all the requirements of the three basic functions: Protection, control and isolation.

Where the installation of a circuit breaker is not appropriate (notably where the switching rate is high, over extended periods) combinations of units specifically designed for such a performance are employed. The most commonly-used combinations are described below.

Switch and fuse combinations

Two cases are distinguished:

- The type in which the operation of one or more fuses causes the switch to open. This is achieved by the use of fuses fitted with striker pins, and a system of switch tripping springs and toggle mechanisms (see Figure 22)

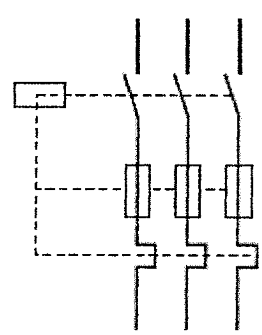


Figure 22 - Symbol for an automatic tripping switch-fuse.

- The type in which a non-automatic switch is associated with a set of fuses in a common enclosure.

In some situations, the terms “switch-fuse” and “fuse-switch” have specific meanings:

- A switch-fuse comprises a switch (generally 2 breaks per pole) on the upstream side of three fixed fuse-bases, into which the fuse carriers are inserted.

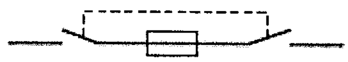


Figure 23 - Symbol for a non-automatic fuse-switch.

- A fuse-switch consists of three switch blades each constituting a double-break per phase.

These blades are not continuous throughout their length, but each has a gap in the centre which is bridged by the fuse cartridge. Some designs have only a single break per phase.

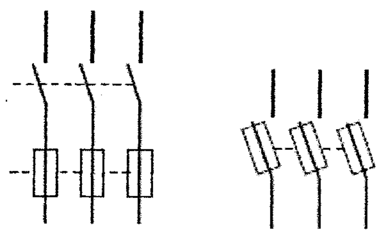


Figure 24 - Symbol for a non-automatic switch-fuse.

The current range for these devices is limited to 100 A maximum at 400 V 3-phase, while their principal use is in domestic and similar installations. To avoid confusion between the first group (i.e. automatic tripping) and the second group, the term “switch-fuse” should be qualified by the adjectives “automatic” or “non-automatic”.

Fuse – disconnector + discontactor

Fuse - switch-disconnector + discontactor

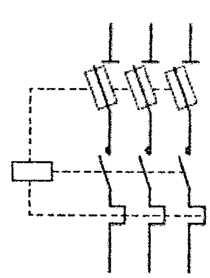


Figure 25 - Symbol for a fuse disconnector + discontactor.

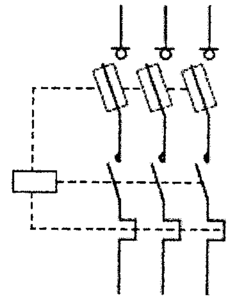


Figure 26 - Symbol for a fuse-switch disconnector + discontactor.

As previously mentioned, a discontactor does not provide protection against shortcircuit faults. It is necessary, therefore, to add fuses (generally of type aM) to perform this function. The combination is used mainly for motor control circuits, where the disconnector or switch-disconnector allows safe operations such as:

- The changing of fuse links (with the circuit isolated)
- Work on the circuit downstream of the discontactor (risk of remote closure of the discontactor)

The fuse-disconnector must be interlocked with the discontactor such that no opening or closing manoeuvre of the fuse disconnector is possible unless the discontactor is open, since the fuse disconnector has no load-switching capability.

A fuse-switch-disconnector (evidently) requires no interlocking.

The switch must be of class AC22 or AC23 if the circuit supplies a motor.

Circuit-breaker + contactor

Circuit-breaker + discontactor

These combinations are used in remotely controlled distribution systems in which the rate of switching is high, or for control and protection of a circuit supplying motors.

4.4 Switchgear selection

ABB is actually using software for the optimal selection of switchgear. The circuits are considered one at a time and a list is drawn up of the required protection functions and exploitation of the installation.

In this way, a number of switchgear combinations are studied and compared with each other against relevant criteria, with the aim of achieving:

- Satisfactory performance
- Compatibility among the individual items; from the rated current In to the fault-level rating Icu
- Compatibility with upstream switchgear or taking into account its contribution
- Conformity with all regulations and specifications concerning safe and reliable circuit performance

It is worth to say that we have been using the ABB Quotation and Engineering software PRODAT 5.20 in order to simulate and select different switchgear solutions to serve as support to the production team.

4.5 Circuit breaker

The circuit breaker is the only device of switchgear capable of simultaneously satisfying all the basic functions necessary in an electrical installation.

Moreover, it can, by means of auxiliary units, provide a wide range of other functions, for example: indication (on-off - tripped on fault), undervoltage tripping, remote control, etc. These features make a circuit-breaker the basic unit of switchgear for any electrical installation.

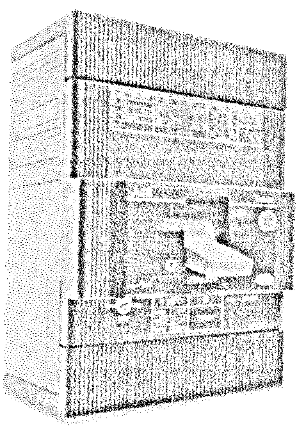


Figure 27 – Circuit breaker Tmax ABB Sace used in the LV switchgear system.

Main functions

Figure 28 shows schematically the main parts of a LV circuit breaker and its four essential functions:

- The circuit-breaking components, comprising the fixed and moving contacts and the arc-dividing chamber
- The latching mechanism which becomes unlatched by the tripping device on detection of abnormal current conditions. This mechanism is also linked to the operation handle of the breaker.
- A trip-mechanism actuating device:

  - Either: a thermal-magnetic device, in which a thermally-operated bi-metal strip detects an overload condition, while an electromagnetic striker pin operates at current levels reached in short-circuit conditions, or

  - An electronic relay operated from current transformers, one of which is installed on each phase
- A space allocated to the several types of terminal currently used for the main power circuit conductors

Domestic circuit breakers perform the basic functions of:

- Isolation
- Protection against overcurrent

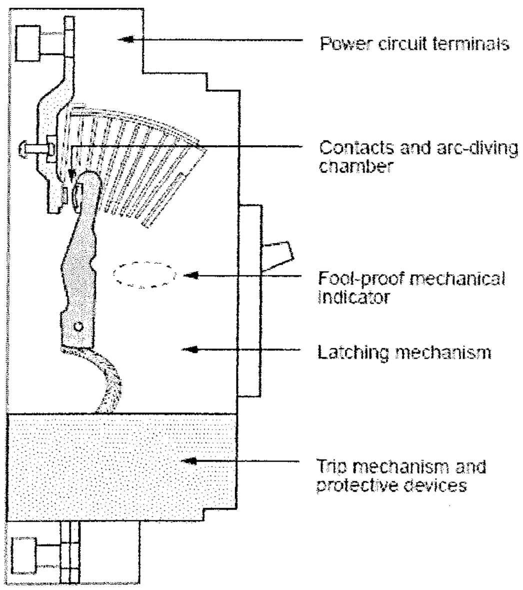


Figure 28 - Main parts of a circuit breaker.

Some models can be adapted to provide sensitive detection (30 mA) of earthleakage current with CB tripping, by the addition of a modular block, while other models (RCBOs and CBRs) have this residual current feature incorporated as shown in Figure 30.

Apart from the above-mentioned functions further features can be associated with the basic circuit breaker by means of additional modules.

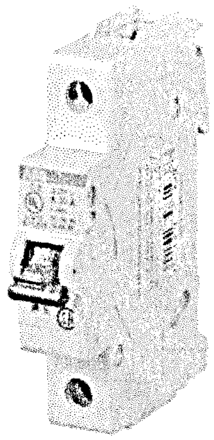


Figure 29 - Domestic-type miniature circuit breaker providing overcurrent protection and circuit isolation features.

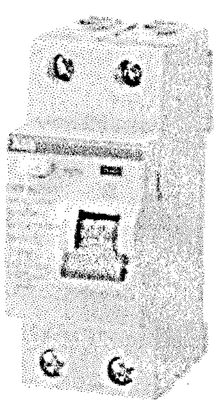


Figure 30 - Domestic-type circuit breaker with incorporated protection against electric shocks.

Fundamental characteristics of a circuit breaker

Circuit breakers must be capable of making, conducting and switching off currents under operational conditions and under specified extraordinary conditions up to the point of short circuit, making the current, conducting it for a specified period and interrupting it. Circuit breakers with overload and short-circuit instantaneous tripping are used for operational switching and overcurrent protection of operational equipment and system parts with low switching frequency. Circuit breakers without overcurrent releases, but with open-circuit shunt release (0,1 to 1,1 Un), are used in meshed systems as "network protectors" to prevent reverse voltages.

Circuit breakers are supplied with dependent or independent manual or power actuation or with a stored-energy mechanism. The circuit breaker is opened by manual actuation, electrical actuation by motor or electromagnet, load current, overcurrent, undervoltage, reverse power or reverse current tripping.

Preferred values of the rated control voltage are listed in the following table:

U_s											
DC voltage						AC single-phase voltage					
24	48	110	125	220	250	24	48	110	127	220	230

Table 2 - Preferred values of the rated supply voltage of control devices and auxiliary circuits.

The major classification criteria of circuit breakers are:

– by utilization categories

A: without short-time grading of delay tripping for selectivity under short-circuit conditions

B: with intended short-time delay of short-circuit tripping (adjustable or nonadjustable)

– by type of arc extinction medium

Air, vacuum, gas

– by design

compact design or „moulded case" type,

open design or „air-break" type

– by installation type

fixed,

draw-out

– by type of arc extinction

current-limiting circuit breaker,

non-current-limiting circuit breaker

"Moulded case" circuit breakers consist of an insulation case that contains the components of the breaker. This type of breaker is designed for rated currents up to about 3200 A.

"Open type circuit breakers" or also "air-break circuit breakers" do not have a compact insulation case. They are designed for rated currents up to 6300 A.

Non-current-limiting circuit breakers extinguish the arc at the natural alternating current zero crossing. The conducting paths are so dimensioned that they can conduct the full short-circuit current thermally. All downstream system components are also thermally and dynamically loaded with the unlimited peak short-circuit current.

Current limiting circuit breakers interrupt the short-circuit current before it reaches the peak value of the first half-cycle. The peak short-circuit current is limited to a value (cutoff current I_D) that significantly reduces the thermal and dynamic stress on the downstream components. Figures 31 and 32 show the energy-limiting and current-limiting characteristics of a current-limiting circuit-breaker.

Current-limiting circuit breakers, like fuses, are particularly suitable for short-circuit protection of switchgear with lower switching capacity (back-up protection).

Rated short-circuit currents:

Rated-operating short-circuit current I_{CS}

Test duty: O – t – CO – t – CO

Rated-limiting short-circuit current I_{CU}

Test duty: O – t – CO

O = open; CO = close-open; t = dead time between operations (3 min)

Utilization category A % of I_{cu}	Utilization category B % of I_{cu}
25	–
50	50
75	75
100	100

Table 3 - Recommended percentage values for I_{CS} based on I_{CU}.

Short-circuit-breaking capacity I (rms value in kA)	Power factor	Minimum value for n $n = \frac{\text{Short-circuit-making capacity}}{\text{Short-circuit-breaking capacity}}$
4.5 < I ≤ 6	0.7	1.5
6 < I ≤ 10	0.5	1.7
10 < I ≤ 20	0.3	2.0
20 < I ≤ 50	0.25	2.1
50 < I	0.2	2.2

Table 4 – Ratio *n* between short-circuit-making and -breaking capacity and associated power factor (with alternating current circuit breakers).

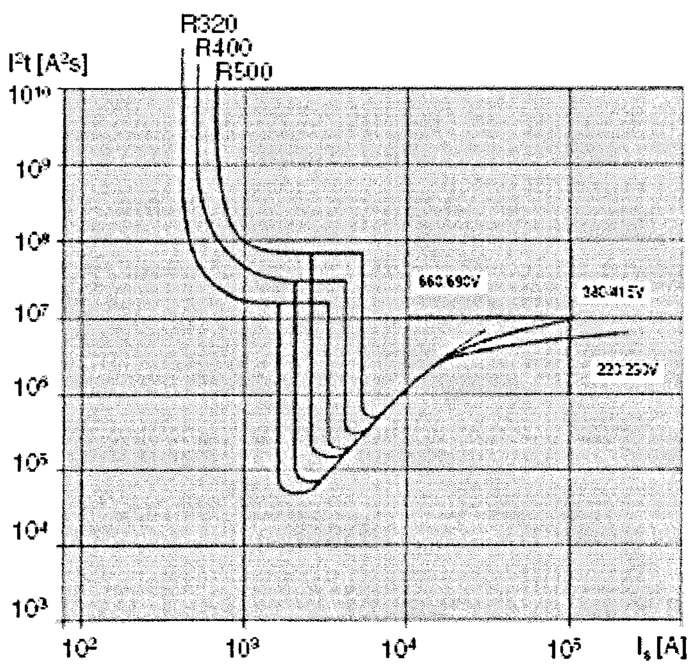


Figure 31 - Limitation of let-through power I2•t by a current-limiting circuit breaker for In= 630 A with various tripping settings (R 320 to R 500).

I_s = short-circuit current, prospective r.m.s. values

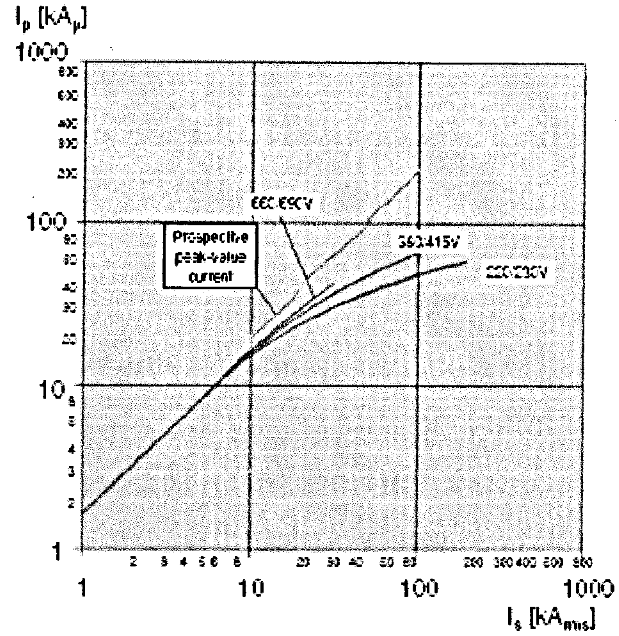


Figure 32 - Limitation of the short-circuit current by a current-limiting circuit breaker for In= 630 A with various service voltages.

Ip = let-through current, peak current values

Is = short-circuit current, prospective r.m.s. values

4.6 Motor Starter

The motor starter is the term for the combination of all devices required for starting and stopping a motor in connection with appropriate overload protection.

Compact, manually operated motor starters, also referred to as motor protection switches, are suitable for switching short-circuit currents if they meet the conditions for circuit-breakers.

Motor starters can be actuated manually, electromagnetically, by motor, pneumatically and electropneumatically. They are suited for operation with open-circuit shunt releases, undervoltage relays or undervoltage tripping releases, delayed overload relays, instantaneous overcurrent relays and other relays or releases.

The rated normal current of a motor starter is dependent on the rated operating voltage, the rated frequency, the rated operating duty, the utilization category and the type of housing.

Chapter 5

Assembling MNS - Practical Experience

5.1 Introduction

This part of the report goes through the technical and mechanical aspects developed in the assembling and erection of the Low Voltage Switchgear MNS.

Due to this fact, we describe here the issues that concern to the choice of the electrical and mechanical equipment as well as the solutions used by ABB in the construction of this system. Because of the extremely varied applications and requirement combinations, this description has special emphasis mainly in the work developed in the factory field during our time in the company, inserted in the ABB production and workshop teams.

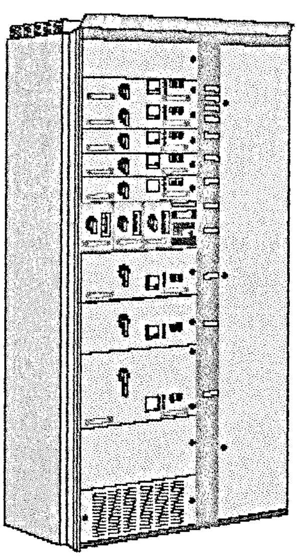


Figure 33 - Apparatus cubicle W/R.

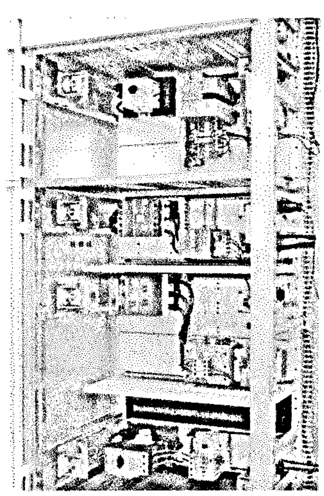
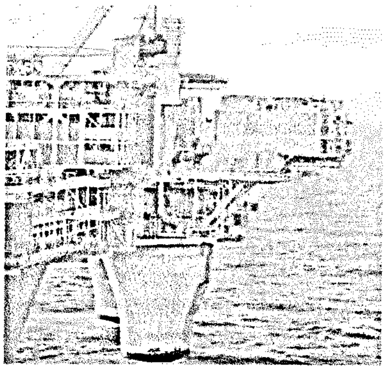


Figure 34 – Cubicle equipped with protective devices, control system and cables.

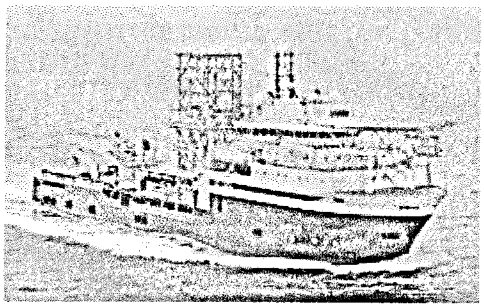
5.2 Technical aspects

Fields of application

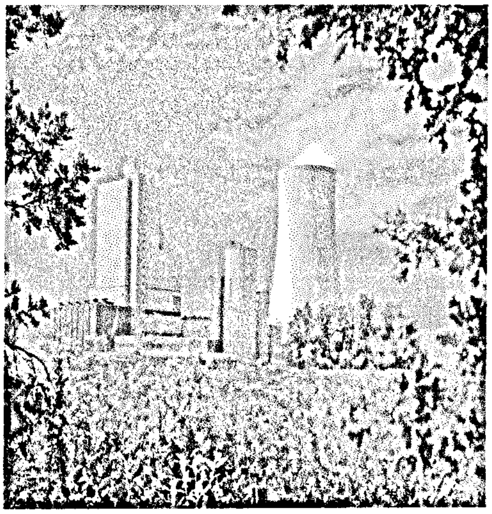
The MNS system is used in the fields connected with the generation, distribution and use of electrical energy. For this reason we can see this system being used as:



- Motor current supply of Motor Control Centres
- Main and sub-distribution boards for energy
- Electronic cabinets for open and closed-loop control purposes
- in buildings for other than dwelling purposes
- in power plants
- in oil refineries
- on off-shore drilling platforms
- on ships
- in utility companies
- in production facilities
- in sewage management



Nevertheless, typically LV Switchgear is installed in:



- **Industrial Plants** — for power and lighting networks and feeders, power generation and other auxiliaries, and to provide power for machine tools and material handling equipment drivers.

- **Utility and Co-generation Facilities** — for motor control centers to protect and distribute power to electrical devices such as blowers, compressors, fans, pumps, and motors.

- **Commercial and Residential Buildings** — for protection and distribution of power for lighting, elevators, air conditioning, blowers, fans, motors, and pumps.

Characteristics

Many special features and control functions can be included in a switchgear assembly so that a complete engineered product designed and tested for the specific application, can be supplied to the customer ready for quick and easy installation.

Due to the consistent application of the modular principle both in electrical and mechanical design, MNS System allows the preferential selection of the structural design, interior arrangement as well as degree of protection in conformity with the environmental and operating needs. The kind of material used in the MNS System minimizes in a short period of time electric arcs effects. Several tests prove that the effects of the striking accidental arcs were limited to their places of occurrence and the operation of neighbouring withdrawable modules was not affected. After cleaning, the withdrawable module compartments were fully operative again, mechanically interlocked withdrawable modules remained firmly within the cubicle and even in isolating position, none of the substance indicators located in front of the cubicle were ignited.

We present below some of the most important features and skills that the MNS System can grant:

- Economic energy distribution in the cubicles
- Back-to-back arrangement
- Compact, space-saving design
- Easy project and detail engineering through standardized components
- Comprehensive range of standardized types
- Various design levels depending on operating and environmental conditions
- Easy combination of the different equipment systems, such as fixed and withdrawable modules, in a single cubicle
- Arc-proof design possible (standard design with fixed module design)
- Earthquake-, vibration- and shock-proof design possible
- Easy assembly without any special tools
- High operational reliability and availability
- Optimum personal protection
- Largely maintenance-free
- Easy conversion and retrofit

Operating and environmental conditions

MNS type switchgear can be installed in closed locations for electrical equipment and other operating facilities in accordance with their degree of protection (up to IP 54).

Ambient temperature

Short-time maximum value + 40 °C
Maximum mean value over a 24-hour period + 35 °C
Minimum value - 5 °C
An adoption to other ambient temperatures is possible under consideration of the reduction factors.

Atmospheric conditions

Normal climatic service conditions to IEC 439-1, EN 60439, VDE 0660 part 500.
Relative humidity 50 % at 40 °C.
It must be ensured that indoor conditions are maintained for the place of installation.
Moisture condensation on the switchgear components must be prevented by suitable measures such as heating and/or ventilation.

The system is designed to operate in demanding conditions

- in earthquake-prone áreas
- in tropical areas
- in offshore switchboards
- in shipbuilding
- in shelters

The standard version of the MNS system has been tested and approved under the supervision of German Lloyds and Lloyd's Register of Shipping for use in shipbuilding. The switchgear installations are vibration-proof for a frequency range between 5 and 100 Hz.

All technical information is showed in the table below. Here it is possible to verify the responsible entities for the certification of the system, as well as the electrical and mechanical characteristics.

FEUP
Universidade do Porto
Faculdade de Engenharia

ABB

Technical data

Standards		Type-tested switchgear assemblies (TTA)*	IEC 439-1, CEI 439-1, EN 60 439, DIN VDE 0660 part 500, BS5486, UTE 63-412
Test certificates		Germanischer Lloyd, Hamburg (shipping) ASTA, Great-Britain (resist. to accidental arcs acc. to IEC 1641 and IEC 298. Federal Ministry for Regional Planning, Building and Urban Development, Bonn (shelters) DLR German Research Institute for Aerospace e. V. Jülich, Earthquake Test for Security Areas in Nuclear Power Stations	
Electrical data	Rated voltages	Rated insulation voltage U_i	1000 V 3~, 1500 V- **
		Rated operating voltage U_e	690 V 3~, 750 V-
		Rated impulse withstand voltage U_{imp}	8 kV
		Overvoltage category	III
		Degree of pollution	3
		Rated frequency	up to 60 Hz
	Rated currents	**Busbars:**	
		Rated current I_e	up to 6300 A
		Rated peak withstand current I_{pk}	up to 250 kA
		Rated short-time withstand current I_{cw}	up to 100 kA
		Distribution bars:	
		Rated current I_e	up to 2000 A
		Rated peak withstand current I_{pk}	up to 165 kA
		Rated short-time withstand current I_{cw}	up to 86 kA
Mechanical character-istics	Dimensions	Cubicles and frames	DIN 41488
		Recommended height	**2200** mm
		Recommended width	400, **600**, 800, **1000**, 1200 mm
		Recommended depth	400, **600**, 800, 1000, 1200 mm
		Basic grid size	E = 25 mm acc. to DIN 43660
		Hinged frame for accomodation of electronic subracks	DIN 41494, sheet 1, ASA C 83.9
	Surface protection	Frame	Alu-zinc coated
		Internal subdivision	Alu-zinc-coated
		Transverse section	Galvanized
		Enclosure	Paint finish RAL 7035, light-grey
	Degrees of protection	According to IEC 529 or VDE 0470 part 1	IP 00 up to IP 54
	Plastic components	Halogen-free, self-extinguishing, flame retardant, CFC-free	DIN VDE 0304 part 3
	Internal subdivision	Device compartment - device compartment Busbar compartment - cable compartment Busbar compartment - device compartment Device compartment - cable compartment Compartment bottom plates	
Extras	Paint finish	Enclosure	Special colours (standard RAL 7035)
	Busbar system	Busbars	Insulated (standard is bare)
	Special qualification	Test certificates	see test certificates listed above

* Definition TTA: Switchgear assembly corresponding, to a large degree, with the original type or system of switchgear assembly type-tested in accordance with these standards.

** Depending on the electrical equipment

Table 5 – Characteristics of the standard version of MNS system.

5.3 Mechanical design

During the realization of a MNS project high importance is given to the mechanical disposition of the equipment and devices that are included in the switchgear. This part of the report describes how the material is mounted, arranged and the types of construction that are technically possible to assembly.

Frame

The basic elements of the frame are C-sections with holes at 25 mm intervals according to DIN 43660. All frame parts are secured maintenance-free with tapping screws or ESLOK-saved screws. Based on the basic grid size of 25 mm frames can be constructed for the various cubicle types without any special tools.

Single or multicubicle switchgear assemblies for front or front and rear operations are possible.

Enclosure

Different designs are possible to assembly, depending on the enclosure required. An open design with a protective rod as barrier on the front side, optionally with rear and side panels, a panel design (front IP 30), and a totally enclosed cubicle with IP 54, with the following front side options:

- single equipment compartment door
- double equipment compartment door
- equipment and cable compartment door
- module doors and/or withdrawable module covers and cable compartment door
- hinged frame

The hinged frame is designed to accommodate electronic subracks and instrument plates (may also be used as equipment frame). The mounting area of the hinged frame can be covered with an additional door with or without a window.

The bottom side of the cubicle can be provided with floor plates. With the aid of flanged plates, cable ducts can be provided to suit all requirements.

Doors and cladding can be provided with one or more ventilating louvers, roof plates can be completely ventilated (valid for IP 40 and IP 41).

Switchgear cubicles in withdrawable design are always totally enclosed.

Internal subdivision

A frame structure is selected which can be subdivided into the following compartments (functional areas), depending on the requirements:

- equipment compartment
- busbar compartment
- cable compartment

The equipment compartment holds the equipment modules; the busbar compartment contains the busbars and distribution bars; the cable compartment accommodates the incoming and outgoing cables (optionally from above and from below) and the wiring required for connecting the modules as well as the supporting devices (cable mounting rails, cable connection parts, parallel connections, wiring ducts, etc.).

The functional compartments of a cubicle as well as the cubicles themselves can be separated by partitions. Horizontal partitions with or without ventilating louvers can also be inserted between the modules.

Internal subdivision reduces the effect of arc faults outside their point of origin to a minimum.

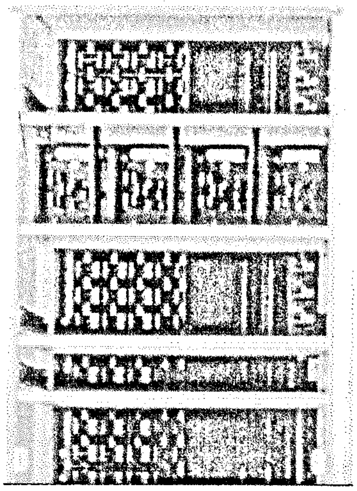
Busbar system

The busbar system is installed in the cubicle before delivery and includes horizontal main busbar system including neutral and protective busbars; vertical busbars.

The **horizontal busbars** are situated, either at the top or at the bottom, in a segregated area at the rear of the cubicle to prevent accidental contact. The busbars in adjacent cubicles are interconnected at site after the cubicles have been fixed to the foundation. This arrangement facilitates easy extension of an already existing switchgear.

The **vertical busbars** are protected to degree of protection IP20. The apparatus units are connected to the busbars with plug-in contacts. The vertical busbar system is available with 3 or 4 poles and in two versions:

- metal enclosed
- insulated enclosed



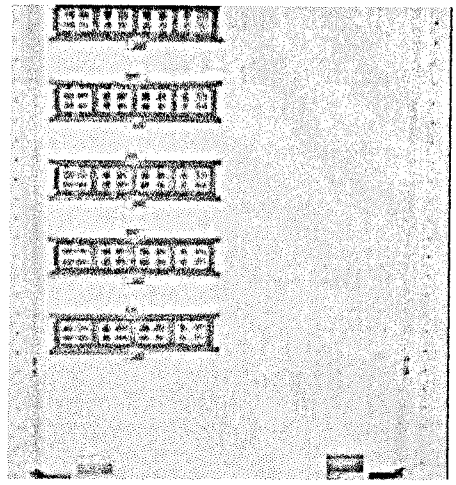


Figure 35-Insulated enclosed vertical busbar system Figure 36-Metal enclosed vertical busbar system.

Barriers

The switchgear cubicles are fitted with barriers:

- in front of horizontal busbar system
- between units
- between units and cable compartment
- in front of vertical busbars
- between apparatus and busbars.

The material in the barriers will not produce poisonous gases if affected by arcing.

Protective and neutral conductor bars

It is possible equip the MNS system with a 4- or 5 conductor bar system. Apart from busbars and distribution bars, the 4-conductor system includes a protective neutral bar (PEN). The 5-conductor system has an additional neutral conductor bar (PE + N).

The protective/neutral conductor bar is mounted horizontally directly to the frame in the lower section of the equipment compartment and cable compartment, if necessary. Parallel to this, the neutral bar is mounted on insulators. The lengths of the bars correspond to the transport units of the cubicle. The protective/neutral connecting bar is arranged vertically in the cable compartment. Parallel to this, the neutral connecting bar is mounted on insulators. The bar lengths are matched to the height of the cubicle. All PE, N and PEN busbars and connecting bars are perforated according to a grid system which permits the bars to be mounted in the cubicle and the outgoing cables and wiring to be connected as required.

Protective conductors with cross-sections up to 35 mm2 can be directly connected to the terminal carriers of the standard fixed modules as well as to the withdrawable module condapter for 8E/4 and 8E/2 modules.

Wiring ducts, cable mounting equipment

A control cable duct is located in the upper cubicle section for installing the electrical equipment necessary for the supply of the auxiliary circuits within on cubicle and for accommodating the cross-links within one shipping unit or switchgear system. The front of this wiring duct is equipped with a mounting rail for installing electrical equipment of the snap-mounted type, e. g. control voltage MCBs. For accommodating the connecting lines within cubicles or switchgear systems, additional vertical wiring ducts and mounting sections for cable installations are also available.

Spaces or spare modules between individual modules are protected by covers. In fixed-mounted and withdrawable design, the control cable duct in the upper, and the PEN busbar in the lower section of the cubicle are protected by a module door or front cover. The lower front cover contains ventilation louvers.

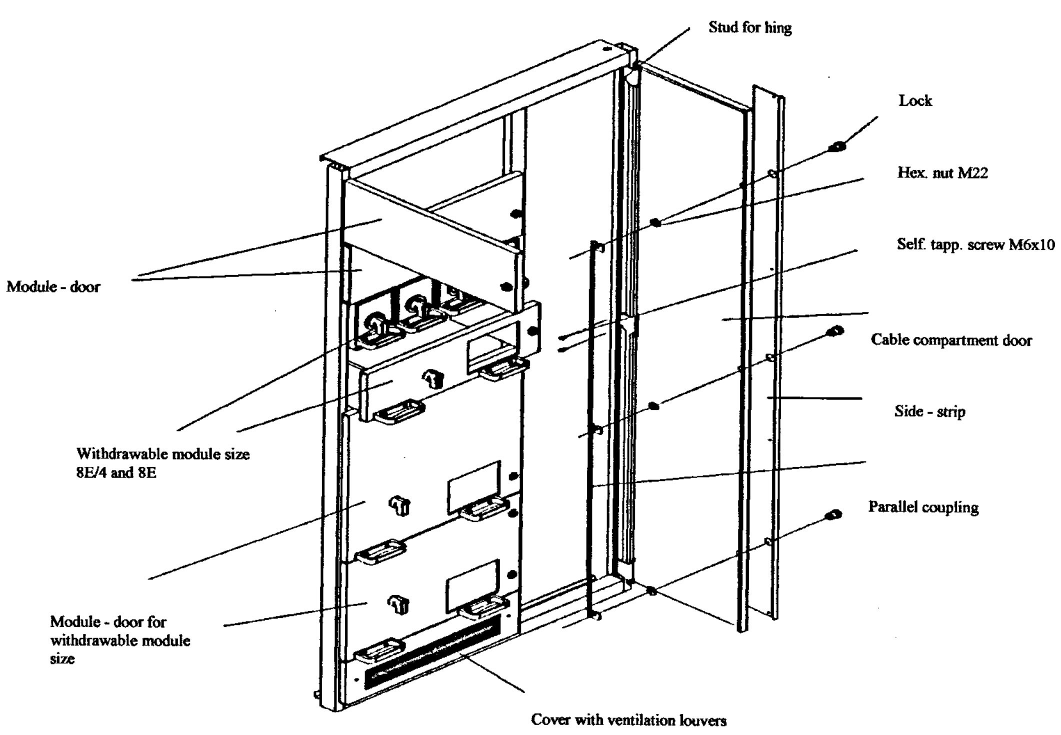


Figure 37- Front mounted equipment

5.4 Functional units in the form of modules

The standardized subdivision of a section into various functional compartments, i.e. equipment compartment, busbar compartment and cable terminal compartment, offers advantages not just for design but also in operation, maintenance, change and also safety.

The basic design of a section with the configuration of the busbars and the distribution busbars for supplying power to fixed, removable or withdrawable parts is shown in Figure 36. A particular advantage of the MNS system is the configuration of the busbars at the rear of the section (in contrast to the formerly common configuration above in the section). It offers supplementary safety for personnel in the event of an accidental arc on the busbar, provides space for two busbar systems if required, enables an advantageous back-to-back configuration with only one busbar system and allows cables to be fed in through cable racks from above.

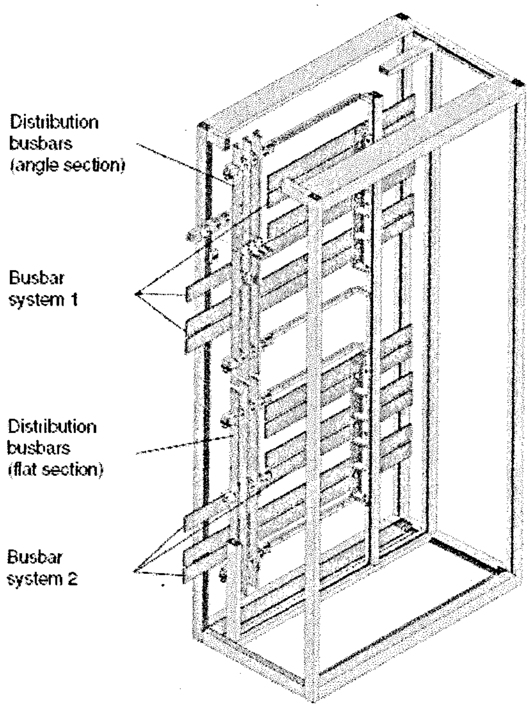


Figure 38 - MNS switchgear system, busbar systems and distribution busbars.

The configuration of the function wall with the access openings for the plug-in contacts is shown in Figure 39. The function wall of the MNS system, as the most important internal subdivision, provides the electric shock protection (IP20) and the arc barrier between equipment compartment and busbar compartment. This is achieved with formdesign features only without automatically actuated protective shutters.

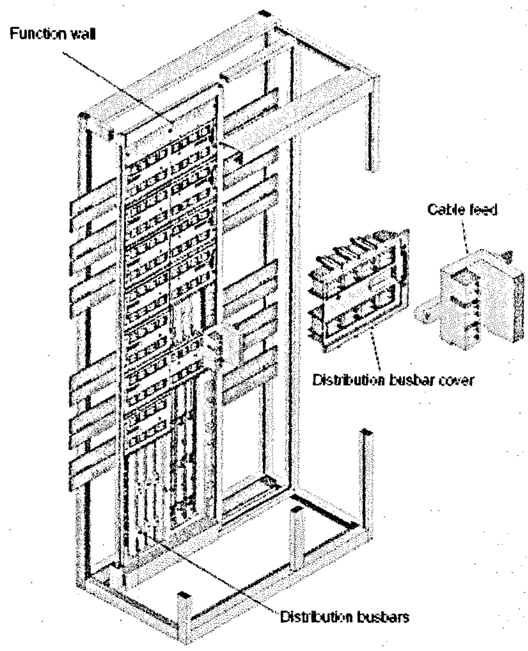
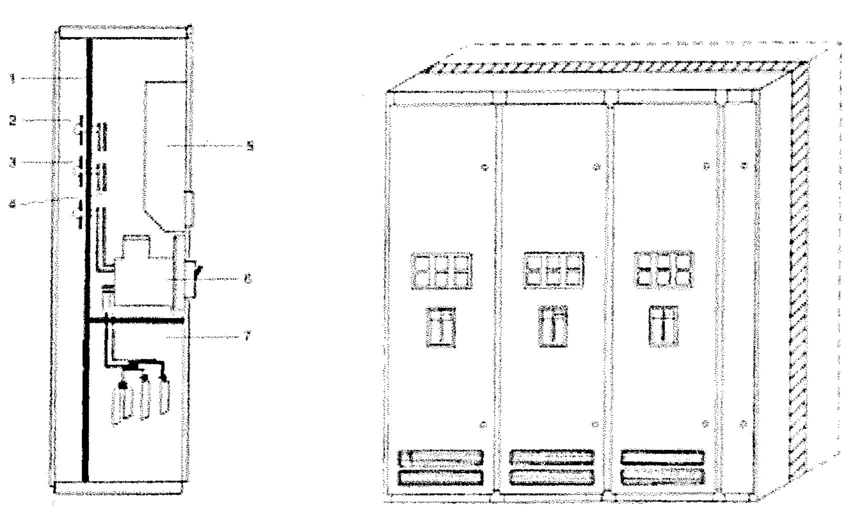
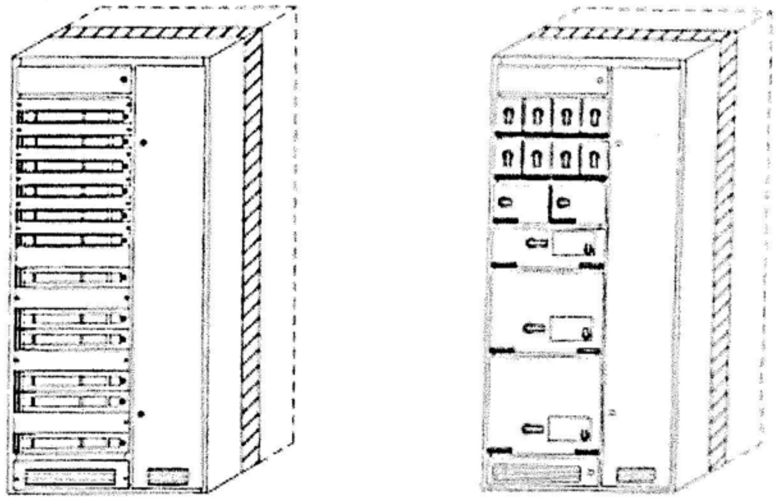


Figure 39 - MNS switchgear system configuration of function wall.

Fixed and withdrawable parts basically have plug-in contacts as busbar-side terminals. In fixed parts the equipment is arranged two-dimensionally on the functional units, while it has a three-dimensional design in withdrawable parts with maximum usage of the cabinet depth. With a majority of smaller modules (<7.5 kW), the demands on switch cabinet volume are around 40 % less with the withdrawable part design. The withdrawable part sizes are adjusted to one another to enable small and large modules to be economically combined in one bay. Later changes of the components can be made without accessing the bay function wall. Reliable mechanical and electrical interlocking of the switchgear prevents operating errors when moving the withdrawable parts.



a b



c d

Description of switch positions:

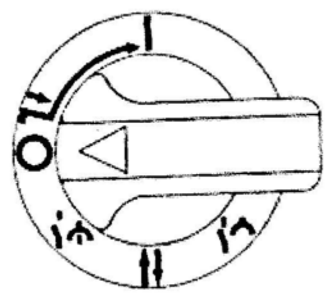
I = operating position, main switch on, withdrawable part cannot be moved.

O = main switch off, control voltage circuit open, withdrawable part cannot be moved.

= test position, main switch off, control voltage circuit closed, withdrawable part cannot be moved.

= position for moving the withdrawable part, main and control voltage circuit open.

= isolated position, withdrawable part withdrawn by 30 mm (to stop), main and control contact open, withdrawable part mechanically locked.



e

Figure 40 - Bay types of the MNS System.

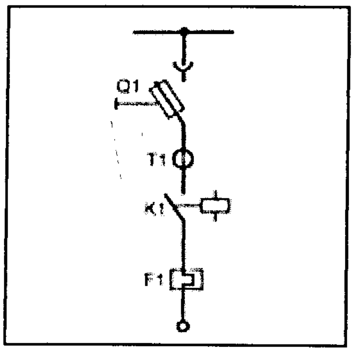
a) and b) cutaway view and view of MNS sections with circuit-breakers 1 arc partition, 2 busbar compartment, 3 primary busbar, 4 distribution busbar, 5 instrument recess, 6 circuit-breaker and 7 cable terminal compartment.

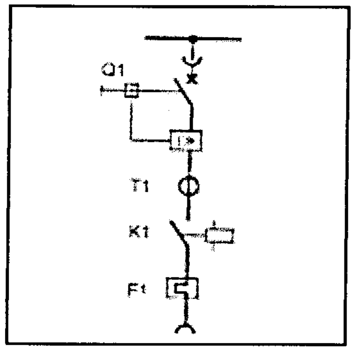
c) MNS section with power output modules in strip form.

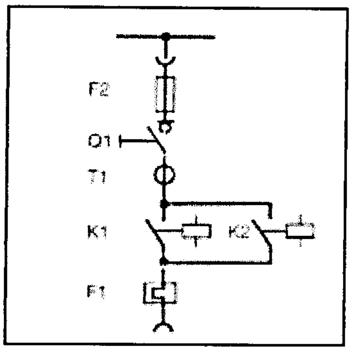
d) MNS section with withdrawable units.

e) Control switch for withdrawable unit.

The circuit diagrams of typical motor starters, which can be obtained as fixed or withdrawable parts, are shown in Figure 41. MNS assemblies can be supplied as arcresistant, shock-resistant, vibration-resistant and earthquake-resistant as required for specific quality demands.







a b c

Figure 41 – Examples of standard modules with circuit diagrams for motor starter:

a) with fuse switch-disconnector and thermal relay (fixed-part technique).

b) with circuit-breaker and thermal relay (withdrawable-part design).

c) with load-break switch, fuse, thermal relay and reversing (withdrawable-part design).

5.5 Standardized terms

The following configurations are among those standardized as units of switchgear assemblies:

– *Section:* unit of a switchgear assembly between two sequential vertical limit levels.

– *Sub-section:* unit of a switchgear assembly between two horizontal limit levels positioned one above the other in a section.

– *Compartment:* section or sub-section that is fully enclosed, except for the openings required for connections, control or ventilation.

– *Functional unit:* part of a switchgear assembly with all electrical and mechanical components required to meet the same function.

– *Fixed part:* a rack of equipment assembled and wired on a common support for fixed installation.

Note: cannot be removed under voltage, even if the rack is designed to be inserted on the supply side.

– *Removable part:* unit that can be removed from the switchgear assembly and replaced as a whole, even when the current circuit to which it is connected is live.

– *Withdrawable part:* removable part that can be placed in a position where an isolating distance is open while it is still mechanically connected to the switchgear assembly.

– *Type tests:* type tests are used to confirm compliance with requirements specified in the standards. Type tests are conducted on an example of a switchgear assembly or on those parts of switchgear assemblies that are repeatedly manufactured in the same or similar type. The tests is conducted or commissioned by the manufacturer. The testing laboratory prepares a test certificate.

– *Routine testing:* routine testing is used to detect any material and manufacturing defects. Routine testing is conducted on every new switchgear assembly after assembly or on every transport unit. A second round of routine testing at the set-up area is not required.

5.6 Modules with Direct Connections to the Main Busbar System

Air circuit breaker and moulded-case circuit breaker rated 630 A and higher are connected directly to the busbars. Withdrawable switches are furnished with an additional plug-in unit as intermediate link to the busbars.

Cubicle structure

Included in all incoming feeder, outgoing feeder and bus coupler cubicles is one switching device. These devices may be fixed-mounted switch disconnectors, fixed-mounted or withdrawable circuit-breakers in open or moulded-case design. This type of cubicles is subdivided into equipment and busbar compartments, their size (H x W x D) is 2200 mm x 400 ... 1200 mm x 600 mm., depending on the size of the switchgear used. Cubicles with open-type circuit breakers up to 2000 A can be built in narrow design (W = 400 mm).
It is possible to interconnect cubicles to form shipping units with a maximum width of 3000 mm.

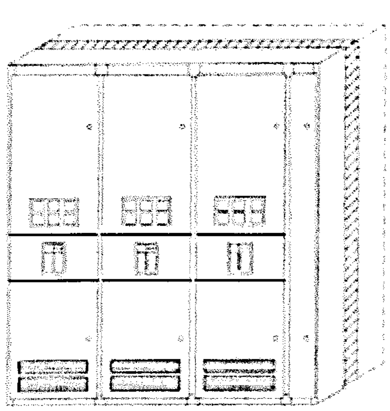


Figure 42 - Switchgear cubicle for energy distribution with 3 equipment compartments for circuit breakers, with busbar compartment and busbar connection compartment.

Switching devices

As standard switching devices there are switch-disconnectors up to 3150 A, moulded-case circuit-breakers up to 1600 A and open-type circuit-breakers up to 5000 A. Relatively to withdrawable versions, these types include a fixed-mounted cassette with disconnecting contacts.

Auxiliary contacts, lock and key interlocks, offering a broad range of possible applications are available for circuit-breakers, electronic, microprocessor-controlled overcurrent releases, shunt, undervoltage and closing releases as well as motor drives. The mechanical accessories of the cubicles include a measuring recess with a fold-out instrument panel and shock hazard protection covers. The doors have suitable openings for operation from outside. Current measurement and measuring voltage supply are available as electrical accessories. Switch-disconnectors for 1000 A or more, moulded-case circuit-breakers for 630 A or more, and open-type circuit-breakers are directly connected to the busbars. Busbars or cables (up to 12 parallel cables) can be connected at the incoming and outgoing sides.

Connection is made directly in the equipment compartment from above or below, however, cable connection from above is limited to 1600 A.

Standard modules

Switch disconnector (OETL)

Rated current A	Rated short-circuit breaking capacity at 400 V~, cos φ = 0,95 A	Equipment compartment Width 3-pole mm	Width 4-pole mm	Depth mm
1250	2500	600	800	400
1600	2500	600	800	400
2500	4800	600	800	400
3150	4800	600	800	400

Table 6 – Switch-disconnector characteristics.

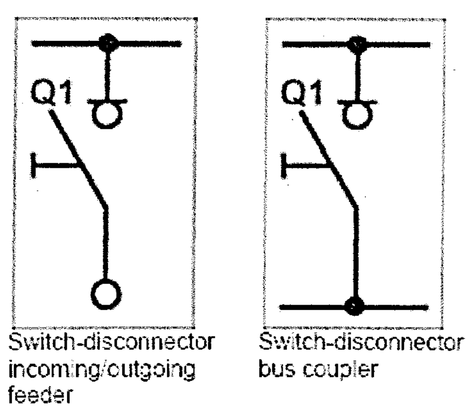
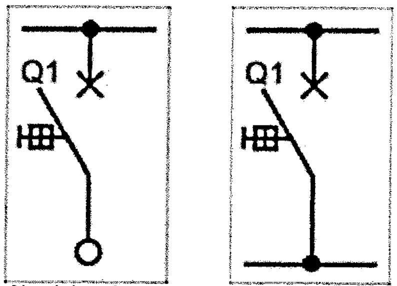


Figure 43 – Circuit diagrams for switch-disconnector.

Moulded case circuit breaker (ISOMAX S)

Rated current A	Rated short-circuit breaking capacity at 400 V ~, cos φ = 0.3/0.25 kA	Equipment compartment Width 3-pole mm	 Width 4-pole mm	 Depth mm
630	50 up to 80	400, 600	600	400, 600, 800
800	50 up to 80	400, 600	600	400, 600, 800
1250	55 up to 80	400, 600	600	400, 600, 800
1600	55 up to 80	400, 600	600	400, 600, 800

Table 7– Moulded case circuit-breaker characteristics.



Circuit-breaker incoming/outgoing feeder, fixed

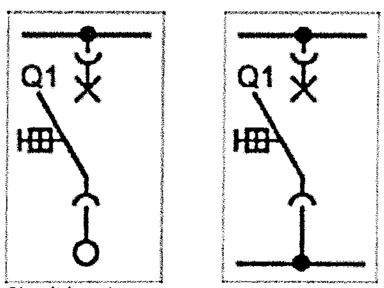
Circuit-breaker bus coupler, fixed

Figure 44 – Circuit diagrams for moulded case circuit breaker.

Open type circuit breaker (Emax E)

Rated current A		Rated short-circuit breaking capacity at 400 V ~, cos φ = 0,3/0.25 kA	Equipment compartment Width 3-pole mm	 Width 4-pole mm	 Depth mm
800 1250 1600 2000	E 1 and E 2	36 up to 130	400	600	600
2500 3200	E 3	65 up to 130	600	800	600
4000	E 4	75 up to 100	800	800	600
5000 6300	E 6	100 up to 120	1000	1200	600

Table 8 – Open type circuit-breaker characteristics.



Circuit-breaker incoming/outgoing feeder, withdrawable

Circuit-breaker bus coupler, withdrawable

Figure 45 - Circuit diagrams for open type circuit breaker.

5.7 Modules with Connections to the Vertical Busbar System

Cubicle structure

Incorporated in the MNS system, components belonging to one functional group are assembled to form a simple mechanical and electrical module. Power and control modules are available.

Cubicles for plug-in, removable and withdrawable-mounted modules are divided into equipment, cable and busbar compartments. Their size (H x W x D) is 2200 mm x 800 / 1000 mm x400 ... 600 mm.

Distribution bars

The main goal of distribution bars is to provide the connection between the busbars and the modules. They are arranged vertically in the busbar compartment. Distribution bars are single busbars with a rectangular cross-section of 50 x 5 [mm] or an angular cross-section 50 x 30 x 5 [mm] designed for plug-in connections. The distribution bars are made copper (Cu).

A maximum of two three-or four-pole distribution bar systems can be installed in a switchgear cubicle. The busbars can be arranged over the entire cubicle height, or over partial heights, or can be interrupted (e. g. for couplers).

5.7.1 Fixed-Technique

Fixed-modules (motor starters up to 450 kW and feeders up to 800 A) are connected to the distribution bars by means of fixed bolt connections. The connections are realised by using power cables or fixed bars. The degree of protection is IP 20 against the distribution bars and IP 30 against the cable compartment. Basic parts for fixed modules consist of assembly plate, side walls (left and right), bushing side walls for outgoing compartment bottom plate, which separates the modules from each other.

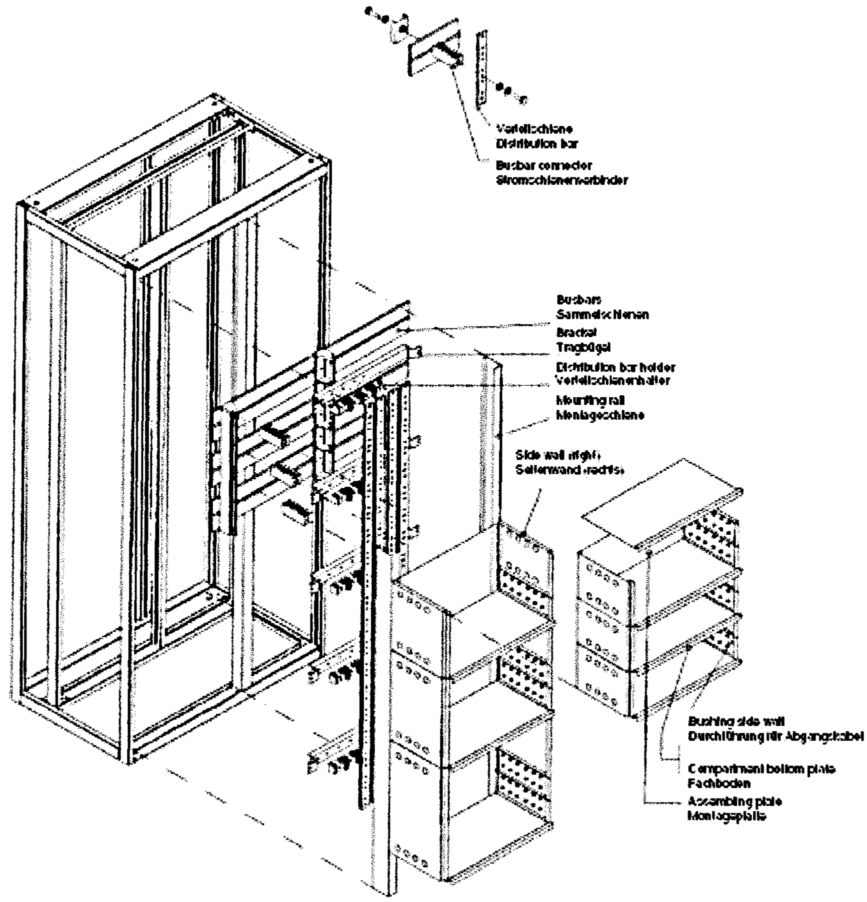


Figure 46 – Cubicle with fixed technique.

Energy distribution, fused 3- und 4-pole (OESA)

Rated current		Module dimensions		
		Height	Width	Depth
A		E = 25 mm	B1 mm	T1 mm
63 up to 160		8	600	400
250 up to 400		12, 16*)	600	400
630 up to 800		24	600	400

*) Height of module for 4-pole construction

Energy distribution, fuseless 3- und 4-pole (ISOMAX S)

Rated current	Rated short-circuit capacity	Module dimensions		
		Height	Width	Depth
A	kA	E = 25 mm	B1 mm	T1 mm
32 up to 250	35, 65	8, 12*)	600	400
320 up to 400	35, 65	12	600	400
630 up to 800	35, 65	16	600	400

*) Height of module for 4-pole construction

Table 9 - Fixed technique characteristics.

5.7.2 Plug-In-Technique

Using plug-in contacts, plug-in, disconnectable and railable modules (up to 630 A) are connected to the distribution bars.
The LV HRC load break switch type SR constitutes a type of plug-in module. The complete unit is mounted directly on the frame and connected through its own contact elements to the distribution bars.

The plug-in module technology basically consists of supporting plates made of sheet steel with an alu-zinc coating.
Modules of any size may be built in a 25mm grid up to a height of 1800 mm (standard) which comprise one or several supporting plates. The equipment compartment width of standard modules is 600 mm. The modules are fastened directly to the MNS frame using tapping screws secured with a screw cage. If necessary, supporting plates are provided with cut-outs for contact units which serve for contact with the distribution bars. When installed without a multi-function separator, the empty slots will be covered. On the outgoing side of the modules, the connections are made via terminals or directly to the switchgear units.

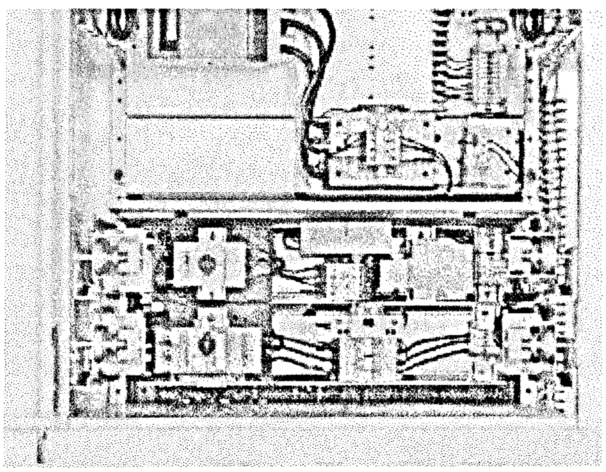


Figure 47 – Plug-in modules as motor starters.

Strip-type energy modules

The SR series comprises strip-type equipment for load-breaking and fuse protection to be installed in MNS switchgear systems. The completely assembled unit is installed horizontally in the switchgear cubicle with an equipment compartment 600 mm wide and 200 or 400 mm deep. the vertical space requirements is 2E, 4E or 8E (1E = 25 mm), depending on the equipment size.

The unit fronts are equipped with plastic covers or doors hinged on the left-hand side with degree of protection IP 41. The outgoing cable connection is made with brackets or cable terminals.

The switch-disconnector is equipped with a spring-assisted mechanism, and the switching speed does not depend on the operation speed of the switch disconnector handle at the front. The switching state can be observed from outside through a transparent front cover and by the position of the handle. An interlocking device between the switch-disconnector and the front cover prevents the cover from being opened when the switch is closed.

With switch type SR-E, the load-breaking element is located in the fuse access section, with switch type SR-M it is found on both sides of the fuses so that the fuses can only be replaced when the switch is open.

The following additional components may be fitted:

- 1 current transformer (integrated into strip)
- 3 current transformer (only with 400 mm equipment compartment depth)
- 1 ammeter 48 x 48 (integrated into strip)
- plug-in connections for fuse monitoring
- plug-in connections for signalling the switch position

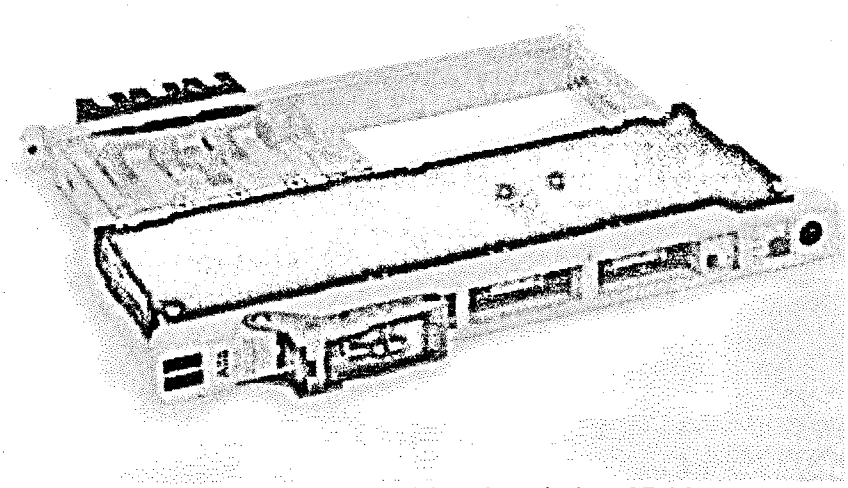


Figure 48 - Fused load-break switches SR00.

Plug-In modules

The basic elements are supporting plates and mounting rails made of an aluminium alloy. The vertical rail serves as a fastening element for securing the module to the frame. By combining supporting plates and mounting rails, modules of any desired height can be realized. The Plug-In-mounted modules can be combined with front modules for indicating, measuring, signalling and operating equipment.

Modular construction offers major advantages for the user:

- Compact design
- Easy replacement of complete functional units by means of plug-in connection at the primary side
- Easy, time-saving maintenance and testing
- Adaptability to changed service conditions
- Large cable compartments for easy connection of cables
- Automatic contacting (without screws) by means of plug-in contact units up to a rated current of 630 A
- Suitable for 690 V AC and 750 V DC
- Factory-assembled supply to IEC 439-1 and VDE 0660 part 500, type tested

With standardized components and assemblies, Plug-In-mounted units (modules) can be produced in accordance with the customer's specification. The modules are installed horizontally at the module frame in the equipment compartment of an MNS cubicle 600 mm wide and are connected to the distribution bars with the help of contact units (plug-in connection). Outgoing cables and feeders are connected to terminals. Wiring ducts can be mounted between the mounting rails. The module height depends on the equipment and the rated power.

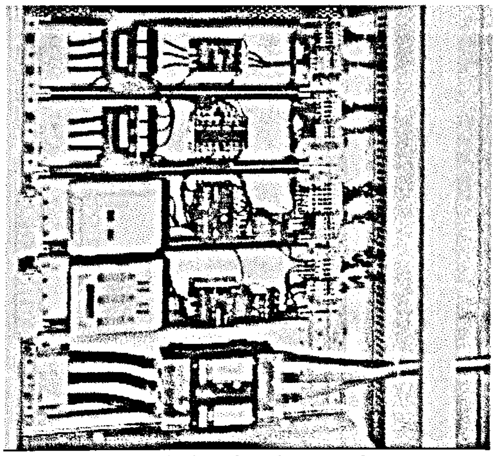


Figure 49 - Plug-In modules in the equipment compartment.

When modules are replaced, retrofitted, or a module extension is carried out (e. g. subsequent installation in spare modules), the cubicle must be disconnected from the mains.

The basic design of the standard fixed-mounted modules comprises the equipment carrier, the contact units to be connected to distribution bars, and terminals for incoming cables.

Depending on the application, the components are installed in various combinations:

- Switch-disconnectors (with and without fuse monitoring)
- Energy distribution, fuse based (SLP)
- Load break switch (OETL)
- Moulded case circuit breaker (MCCB)
- Fuse based motor starter, with thermo relay or INSUM
- Fuseless motor starter, with thermo relay or INSUM
- Reactive power compensation

Removable-Modules

The removable modules have plug-in connections to the incoming supply from the distribution bar system, whereas the outgoing cables are connected permanently direct to the apparatus terminals. The auxiliary circuits are connected via multi-pole plug-in contact units. The main switch is operated by the operating handle on the module door which is also used for the mechanical interlocking.

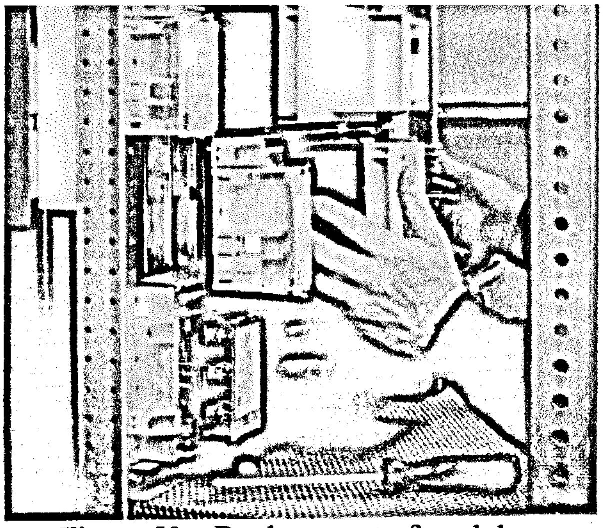


Figure 50 – Replacement of modules.

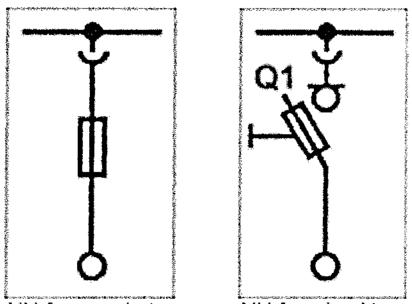
Standard modules for energy distribution

- **Strip-Type fuse switch disconnector (SR)**

Type		SR-B	SR-E	SR-L	SR-M	SR-S	SR-U	Overall height/mm
Rated voltage	V	690	690	500	690	690	500	
Rated current	A	160 250 400 630	160[1] 250[1] 400[1] 630[1]	160 - - -	160 250 400 630	- - 400 630	160 250 400 630	50, 100[*] 100, 150[*] 200, 300[*] 200, 300[*]
Short-circuit making current	kA	50	50	50	50	50	-	
Dyn. short-circuit strength	kA	-	100	100	100	100	100	
Utilization category		AC22	AC21	AC21	AC23	AC23	AC20	

[1] SR-E-are also available at this overall heigth/mm
[*] Module height for 4-pole type

Table 10 – Characteristics for Strip-Type fuse switch disconnector (SR).



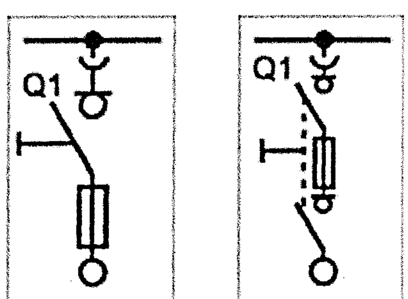
NH-fuse socket SR-U
NH-fuse load break switch SR-L

Figure 51 – Circuit diagrams for Strip-Type fuse switch disconnector (SR).

- **Fuse based (SLP)**

Rated current	Rated breaking capacity Utilization category AC22 bei 690 V~	Module dimensions Height	Width	Depth
			B1	T1
A	A	E = 25 mm	mm	mm
125	800	7;9	600	400

Table 11 – Characteristics for fuse based (SLP) type.



Load break switch with NH-fuses SR-E
Load break switch with NH-fuses, double break SR-M

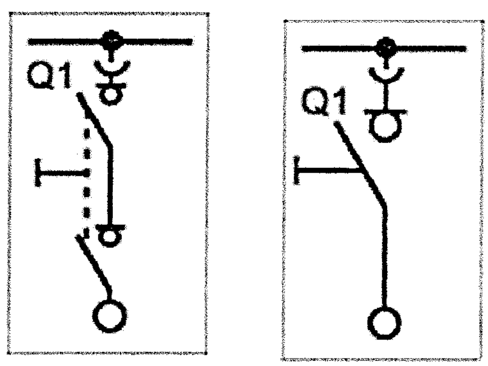
Figure 52 – Circuit diagrams for fuse based (SLP) type.

- **Switch disconnector (OETL)**

Rated current A	Making capacity kA	Rated operating current Utilization category AC21 bei 400 - 690 V~ A	Module dimensions Height E = 25 mm	Width B1 mm	Depth T1 mm
200	35	200	11, 13*)	600	400
250	35	250	11, 13*)	600	400
315	35	315	11, 13*)	600	400
400	65	500	15, 17*)	600	400
630	80	630	17, 19*)	600	400

*) Module height for 4-pole type

Table 12 - Characteristics for switch disconnector (OETL) type.



Load break with double break SR-B **Load break switch OETL**

Figure 53 – Circuit diagrams for switch disconnector (OETL) type.

- **Moulded case circuit breaker**

Switch Type	Rated current A	Rated breaking capacity bei 400 V~ kA	bei cos φ =	Module dimensions Height E = 25 mm	Width B1 mm	Depth T1 mm
Motor protecting switch	11	10	-	5; 9	600	400
Current limitor	32	50	0.5	5; 9	600	400
	63	50	0.5	5; 9	600	400
	125	170	0.25	9; 11	600	400
	200	200	0.2	9; 11	600	400
	320	200	0.2	9; 13	600	400
	500	200	0.2	13	600	400
	630	200	0.2	13	600	400
Zero-point circuit breaker	125	65 / 85	0,3; 0,25	7; 11	600	400
	160	35 - 100	0.25	9; 11	600	400
	250	35 - 100	0.25	9; 11	600	400
	400	35 - 100	0.25	15	600	400
	630	65 - 100	0.25	15	600	400

Table 13 – Characteristics for moulded case circuit breaker type.

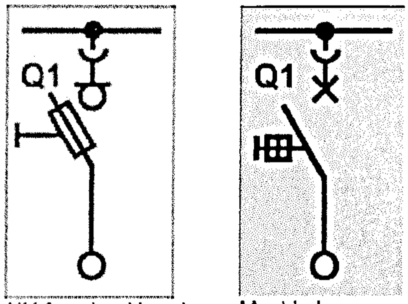


Figure 54 – Circuit diagram for moulded case circuit breaker type.

5.7.3 Withdrawable-Technique

Cubicle structure

Components belonging to one functional group are assembled to form a single mechanical and electrical module. Power and control modules are available as withdrawable types.

For size 8E/4 four modules and for size 8E/2 two modules are arranged horizontally at a width of 600 mm. The height of theses modules is 8E = 200 mm. Withdrawable modules size 4E, 8E, 12E, 16E, 20E and 24E require the entire equipment compartment width of 600 mm per module. The size designation also specifies the vertical space requirement in E.

The withdrawable modules can be withdrawn when connected to mains. Type tests have proven 100 withdrawal/insertion cycles. Conversion of the withdrawable module compartments is possible without any danger without disconnecting the neighbouring modules.

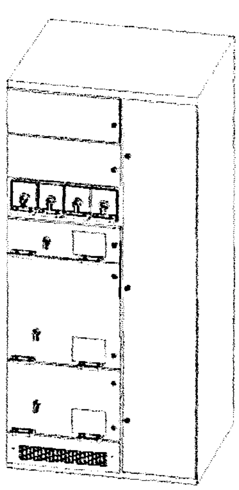


Figure 55 - Switchgear cubicle for withdrawable modules with equipment, cable and busbar compartments.

Multi-function separator

For switchgear cubicles in withdrawable design, or in combines fixed-mounted and withdrawable design, one-pole distribution bars (angular section 50 x 30 x 5 [mm]) are embedded into the multi-function separator made of insulating material and protected by distribution bar covers. Shock hazard protection (IP 20) with respect to the entire busbar system is thus ensured without a shutter. As with open installation, a max. of two busbar systems can be installed (also in sections). The multi-function separator is resistant to accidental arcs and thus constitutes a partition between the equipment compartment and the busbar compartment.

Compartments size 8E/4 and 8E/2

Compartments size 8E/4 and 8E/2 consist of a compartment bottom plate, a module condaptor, guide rails and front posts. The module condaptor provides the connection of the power and control circuit with the distribution bar, the module and the cable compartment. The withdrawable module condaptor is designed for a current up to 125 A and can hold 2 modules size 8E/2 up to 63 A or 4 modules size 8E/4 up to 45 A. It comprises a 20-pole control connector for each module size 8E/4 and one or two 20-pole control connectors for each module size 8E/2.

The connections between the incoming and outgoing side are arranged inside the withdrawable module condaptor and are protected against accidental arcs.

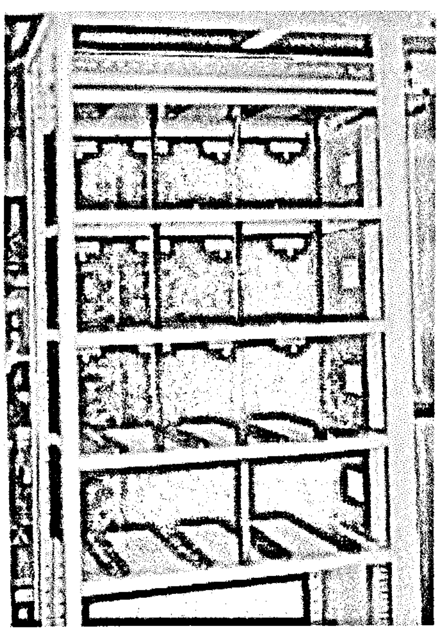


Figure 56 - Withdrawable module compartments size 8E/4 and 8E/2.

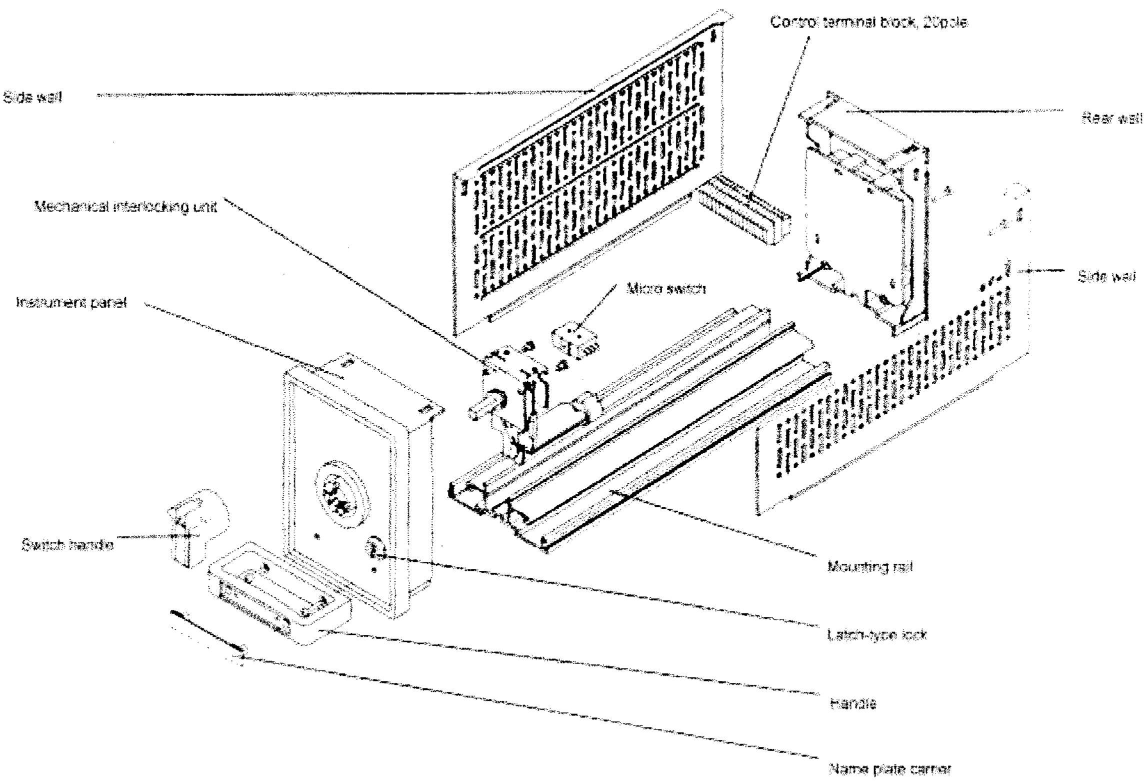


Figure 57 - Empty withdrawable unit size 8E/4 (without electrical equipment).

Compartments size 4E...24 E

Compartments size 8E ... 24E consist of a compartment bottom plate, guide rails and a sheet metal side wall with the outgoing control connector. Withdrawable module feeder connection to the distribution bars in the multi-function separator is made by means of one-pole segregated contact units. Outgoing power cables are connected via cable connectors (main circuit), control cable connections are established via 16 or 32-pole by the 4E-Module for 16 or 20-pole control connectors (auxiliary circuits). The power cable connectors are fastened to the multifunction separator.

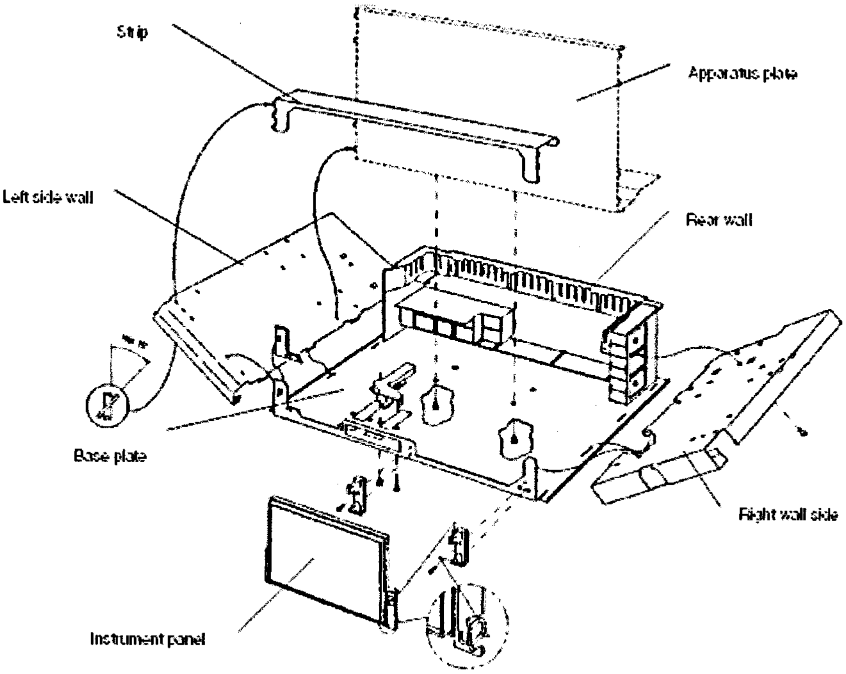


Figure 58 - Empty withdrawable unit > 4E (without electrical equipment).

Cable and wiring connections

At one side of the withdrawable modules, in the cable compartment, there are cable connection elements and terminal blocks for connecting outgoing cables and wires and interconnecting the modules.

The incoming and outgoing cables and wires are mounted to cable mounting rails located at the right-hand side of the cable compartment.

The power terminals are located in the rear area, the control terminals are arranged in front of them, turned by 45°.

The control terminals provide for cable connection in screw-on or plug-in technique or with the Termipoint method. The power terminals on the withdrawable module condaptors up to 63A are additionally equipped with PE terminals.

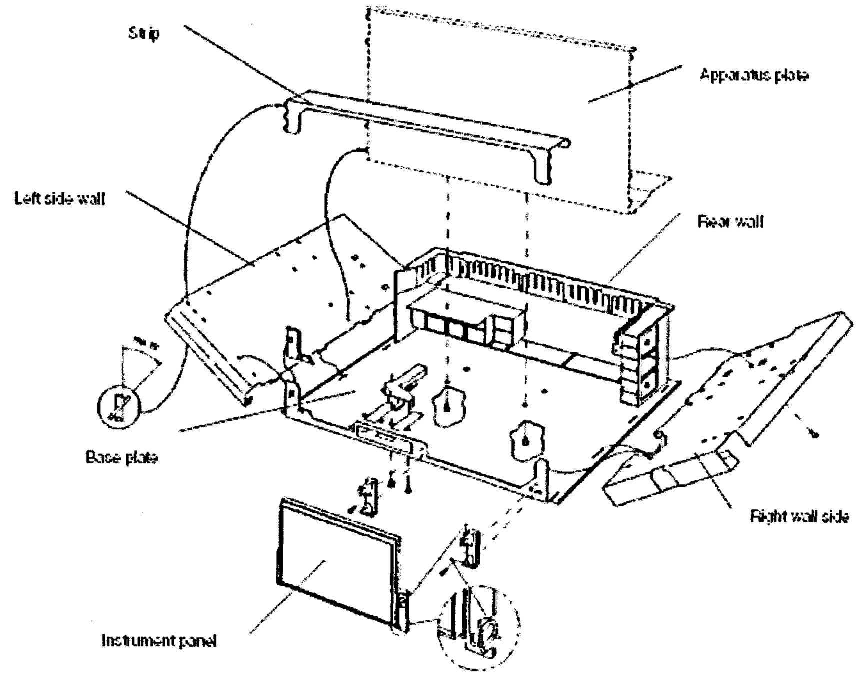


Figure 58 - Empty withdrawable unit > 4E (without electrical equipment).

Cable and wiring connections

At one side of the withdrawable modules, in the cable compartment, there are cable connection elements and terminal blocks for connecting outgoing cables and wires and interconnecting the modules.

The incoming and outgoing cables and wires are mounted to cable mounting rails located at the right-hand side of the cable compartment.

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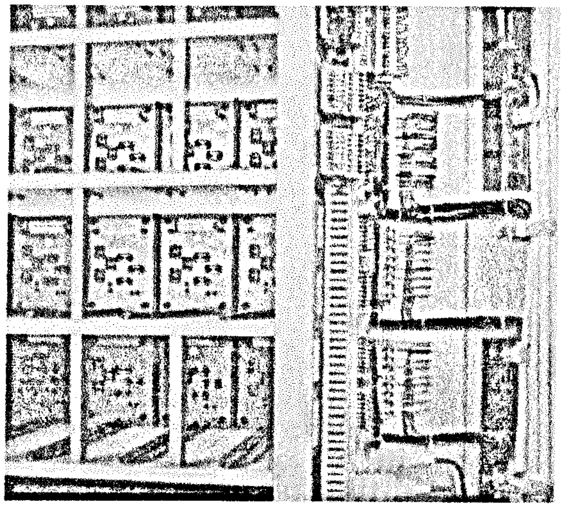

Figure 59 - Cable and wiring connections in a switchgear cubicle with withdrawable modules.

Withdrawable modules

Standardized withdrawable modules:

- Energy distribution by means of switch disconnector or moulded-case circuit-breaker
- Motor starter with fuses
- Motor starter without fuses
- Motor starter with INSUM® and fuses
- Motor starter with INSUM® without fuses

Possible sizes: 8E/4, 8E/2, 4E, 8E, 12E, 16E, 20E und 24E (1 E = 25 mm)

Withdrawable module size 8E/4 and 8E/2

Withdrawable modules size 8E/4 and 8E/2 consist of the instrument panel and side panels made of insulating material, the rear wall with integrated cable connections, and a 20-pole control connector as well as one or two profile sections for mounting snap-mounted components. If required, the withdrawable module size 8E/2 can be equipped with two 20-pole control connectors.

The instrument panel has preformed knockouts for mounting measuring, operating and indicating instruments.

The main switchgear (normally a fused motor switch or circuit-breaker) is operated by means of the operating handle located at the instrument panel, which is also used for the electrical as well as the mechanical interlocking function. A micro-switch with 1 make and 1 break contacts is provided for electrical interlocking.

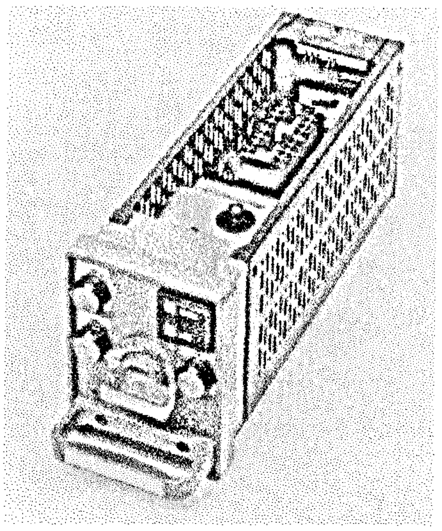

Figure 60 - Withdrawable module size 8E/4.

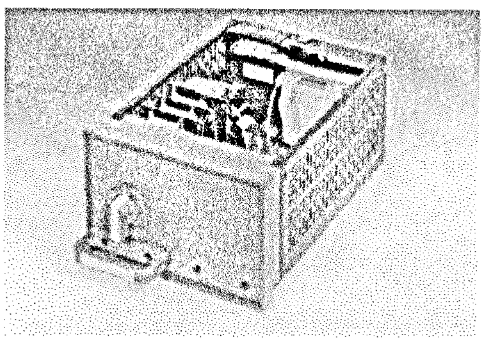

Figure 61 - Withdrawable module size 8E/2.

Withdrawable modules size 4E, 8E, 12E, 16E, 20E and 24E

In respect to withdrawable modules size 4E up to size 24E, these modules consist of an instrument panel and a rear wall made of insulating material, and a front cover and side panels made of sheet steel, as well as mounting channels.

The hinged front cover offers the advantage of easy accessibility of the built-in components (e. g. for replacing fuses) from the front side without withdrawing the module. Opening the front cover in operating or test, is possible only with a tool (screwdriver, doublebit lock), in isolating position it is possible by doublebit lock. The front cover is provided with a cut-out for an instrument panel. This panel remains in position when the front cover is opened. It is designed with preformed knockouts for mounting measuring, operating and indicating instruments and carries a switch handle by which the electrical (micro-switch with 1 NO and 1 NC contacts) and mechanical interlocks can be operated.

5.8 Control systems for low voltage switchgear assemblies

Today's automated, advanced designs for operation of low voltage systems for power distribution, supply of power for motors and connection to the controls of higher-order control systems require control components based on microprocessors even for low-voltage switchgear installations.

ABB supplies the INSUM system as such a control system. The versatile protection and control functions of every single motor starter are controlled by Motor Control Units (MCU) in the INSUM system. The operator at the switchgear assembly can access and read out measured values on a simple menu-controlled operation and display device (Human Machine Interface HMI) to control up to 128 MCUs, i.e. motors.

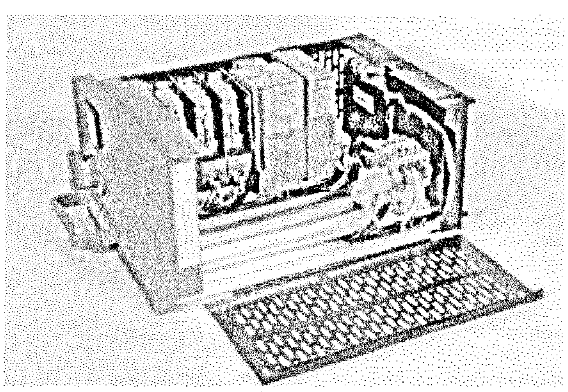

Figure 62 - Withdrawable module size 8E/2 with INSUM.

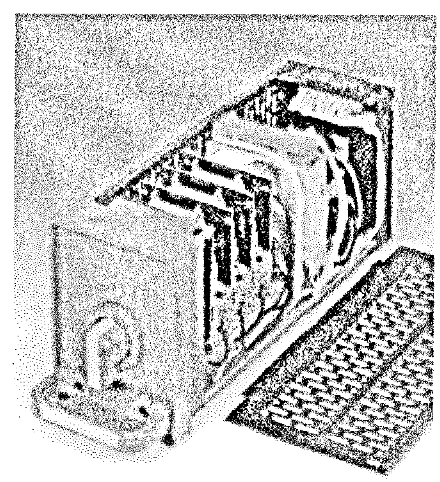

Figure 63 - Withdrawable module size 8E/4 with INSUM.

INSUM offers the following functions, which can be used as required:

Protection tasks such as:

– overload protection/automatic restart
– low-load indicator
– off-load protection
– blocking protection
– phase failure monitoring
– autoreclosure blocking
– safety interlocking

– thermal overload protection by thermistor

– loss of supply monitoring/sequential starting of motors after voltage recovery

– earth-fault detector

– cyclic bus monitoring/fault protection

Control functions:

– control of the motor starter/circuit-breaker via the MMI, the local control panel, with the integrated INSUM OS monitor workstation or the higher-order process control system

– test function

Measured and metered value recording, such as:

– phase currents

– voltages

– power outputs

– earth-fault current

– switching cycle counter

– operating hours

Signalling functions:

– status messages and signals

– warning and fault messages in plain text in the local language

Communications functions:

– use of the LON open intersection bus (Local Operating Network)

– direct integration into ABB ADVANT OCS process control system and Freelance 2000 using LON

– protocol converters (gateways) such as for PROFIBUS DP, MODBUS RTU or ETHERNET TCP/IP are available for serial connection to all PLT systems of other manufacturers.

– parameter setting and event logging with trending function with INSUM OS PC control station, monitor workstation or laptop.

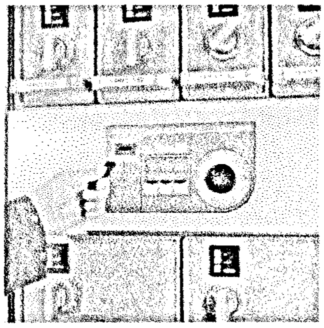

Figure 64 - Front view of withdrawable modules size 8E/4 and 8E/2 with INSUM.

Chapter 6

Conclusions and Personal Reflections

We presented, in this report, theoretical and practical principles as well as the different stages in the assembling and erection of a protection system like Switchgear MNS.

Our special emphasis went to the characterization and assembling description of modules, also to the construction of the mechanical parts of cubicles and their compartments, which was the stage that we were more involved with, during the participation in the production and workshop teams.

To understand better our pathway during these six months inside ABB, we explain below the main phases that were attended in a form of a work plan:

- **Engineering Team (45 days)**

Familiarization and study of the main protective devices included in the ABB Switchgear as well as its understanding; Study and training in project analysis and material selection and order; Participation in a three-member-team responsible for the execution of the *MNS Service Manual - Erection, Commissioning, Operation and Maintenance* in the English-Russian version; Workshop in Health and Safety at Work.

- **Production/Workshop teams (45 days)**

Project analysing; Material selection; Assembling of modules - mounting circuit breakers, contactors, switches, instrument panel, control system, etc. in the mounting rail and base plate of the module. Connection of feeders, cables and wires following the requirements of specific project; Mounting of busbars and distribution bars; Commissioning and testing of modules for later mounting in cubicles.

- **Project Management team (90 days)**

Brief training pointing the aims and functions of the project management department; ABB SACE training (two days) focused in the circuit breaker Emax; Using ABB Quotation and Engineering software PRODAT 5.20 with the objective of simulating switchgear standard solutions to serve as support to the production team.

In respect to what was exposed, we feel safe to say that we have developed several skills in this internship.

We understood how to develop a device in an industrial and rigorous environment from the design until its testing and we learned real production and manufacturing techniques.

Due to our passage through the Engineering, Production/Workshop and Project Management departments, we received many inductions and know-how, not only technical but also social and ethical.

Moreover, we have been given the opportunity to deal, beyond Polish citizens, with people from France, Denmark, Norway and Italy, which enriched our profile and broadened future perspectives.

Having as basis what was said, we conclude that the realization of this internship was the right choice to start, in the best way, our career of electrical engineer.

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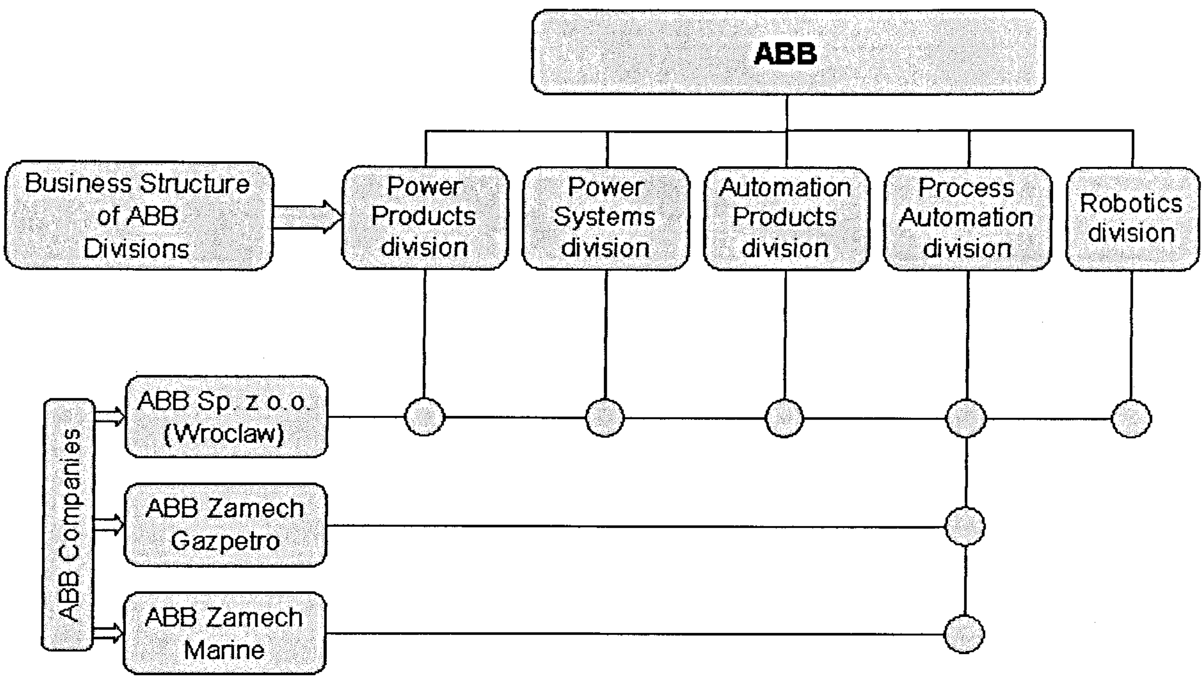
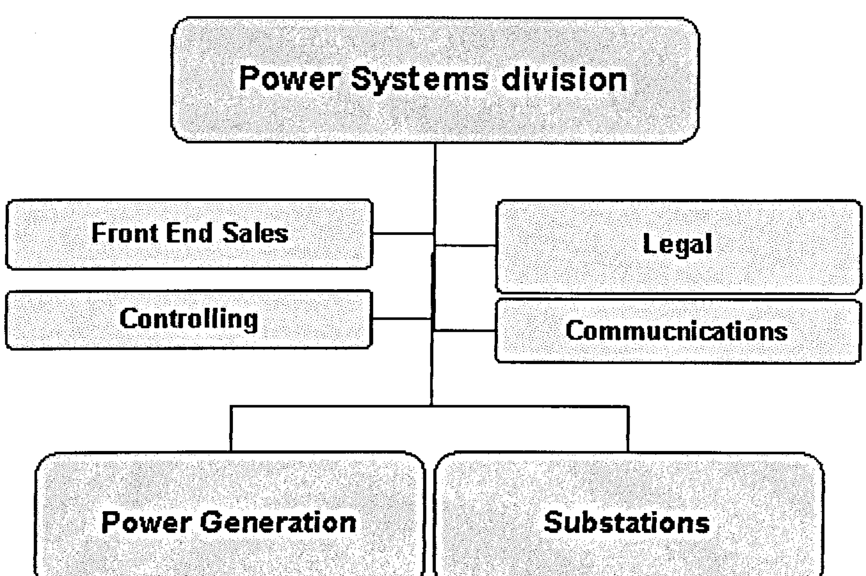
ABB Intranet.

Appendix A

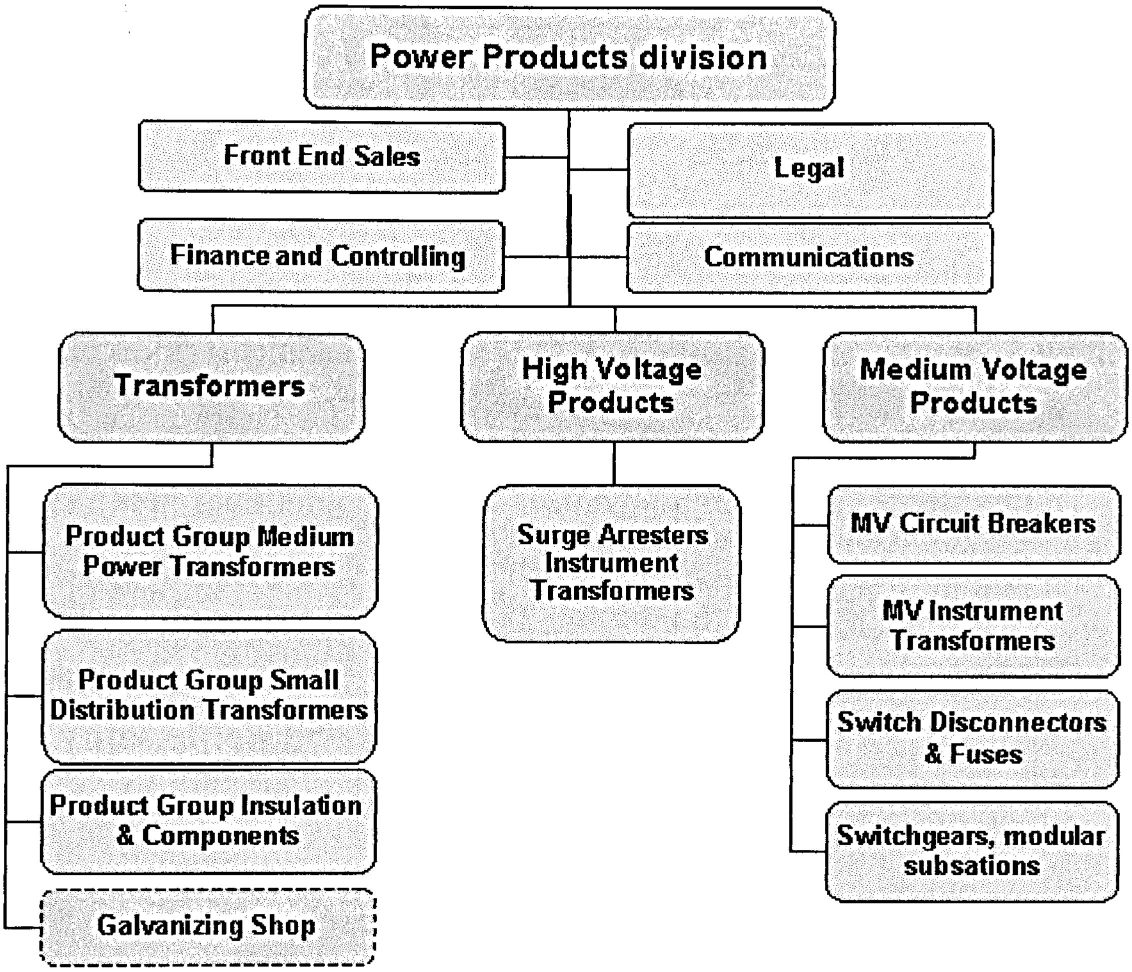
- **ABB Organization in Poland**



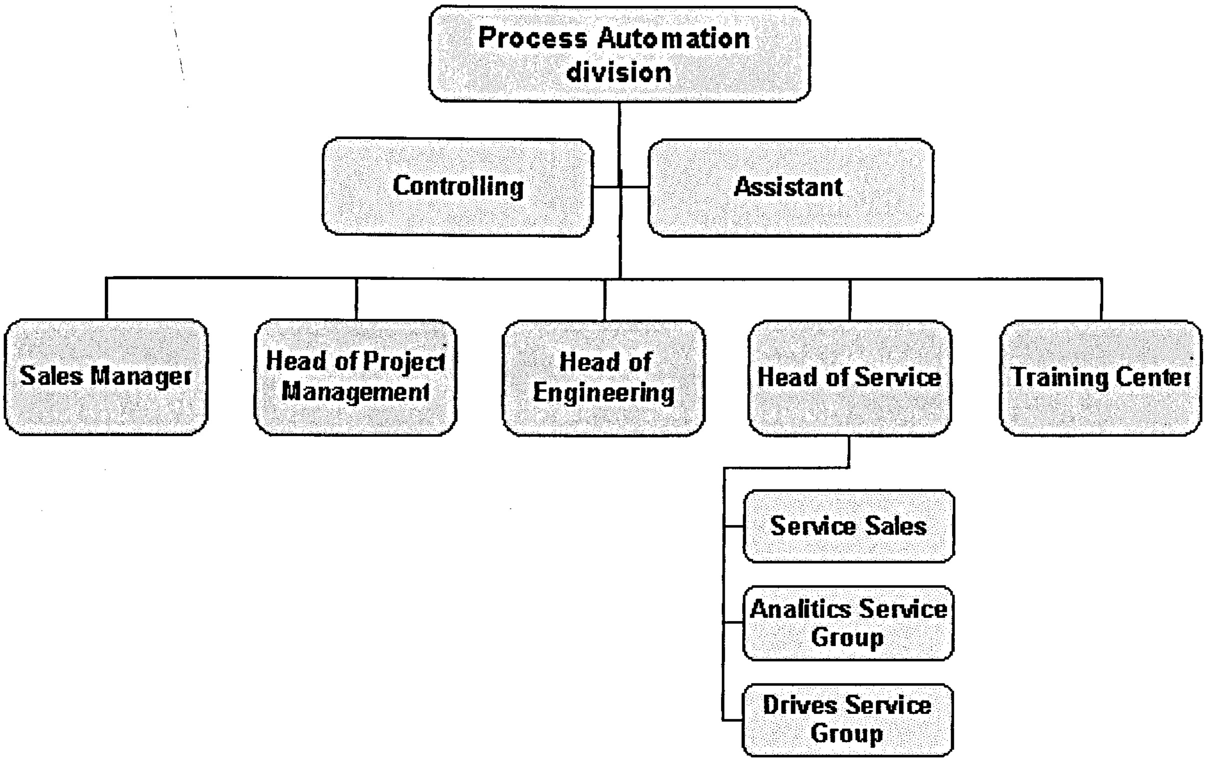
- **Power Systems division Organization**



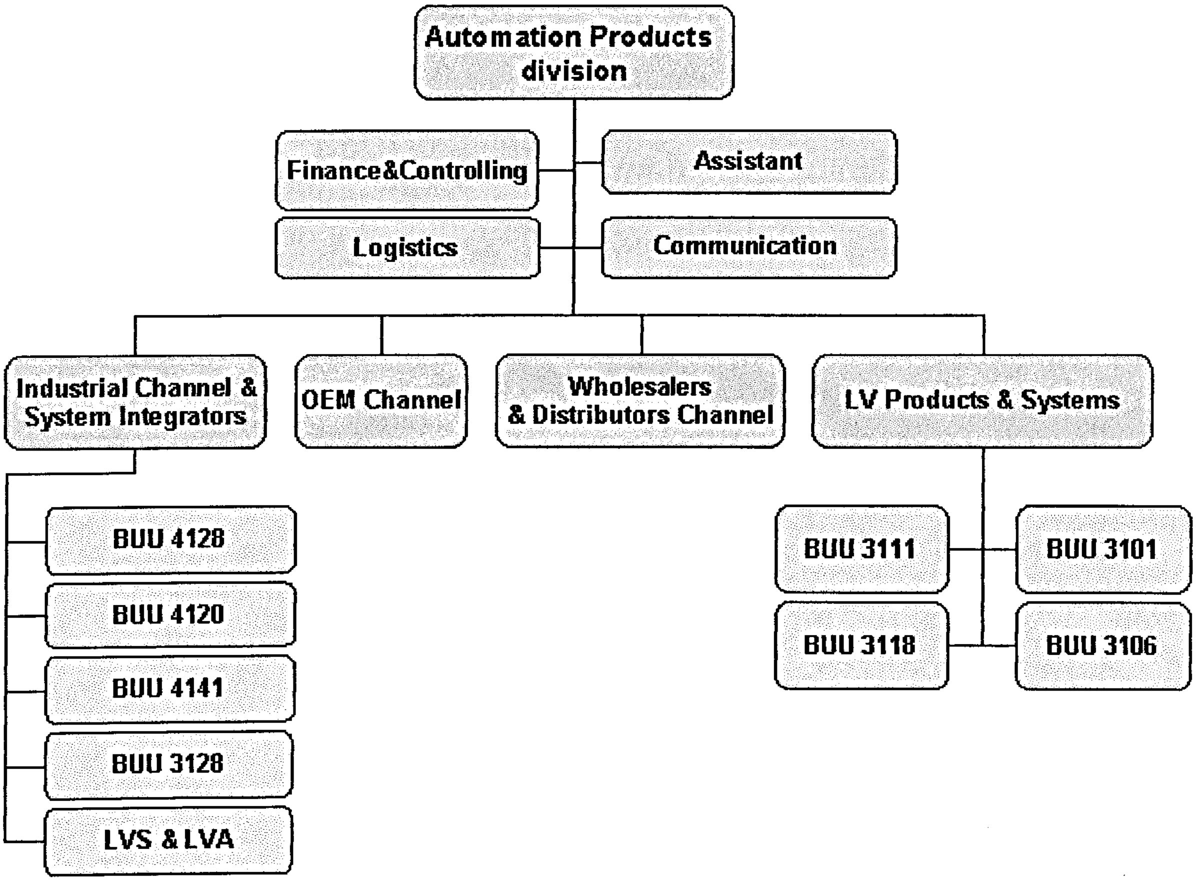
- **Power Products division Organization**



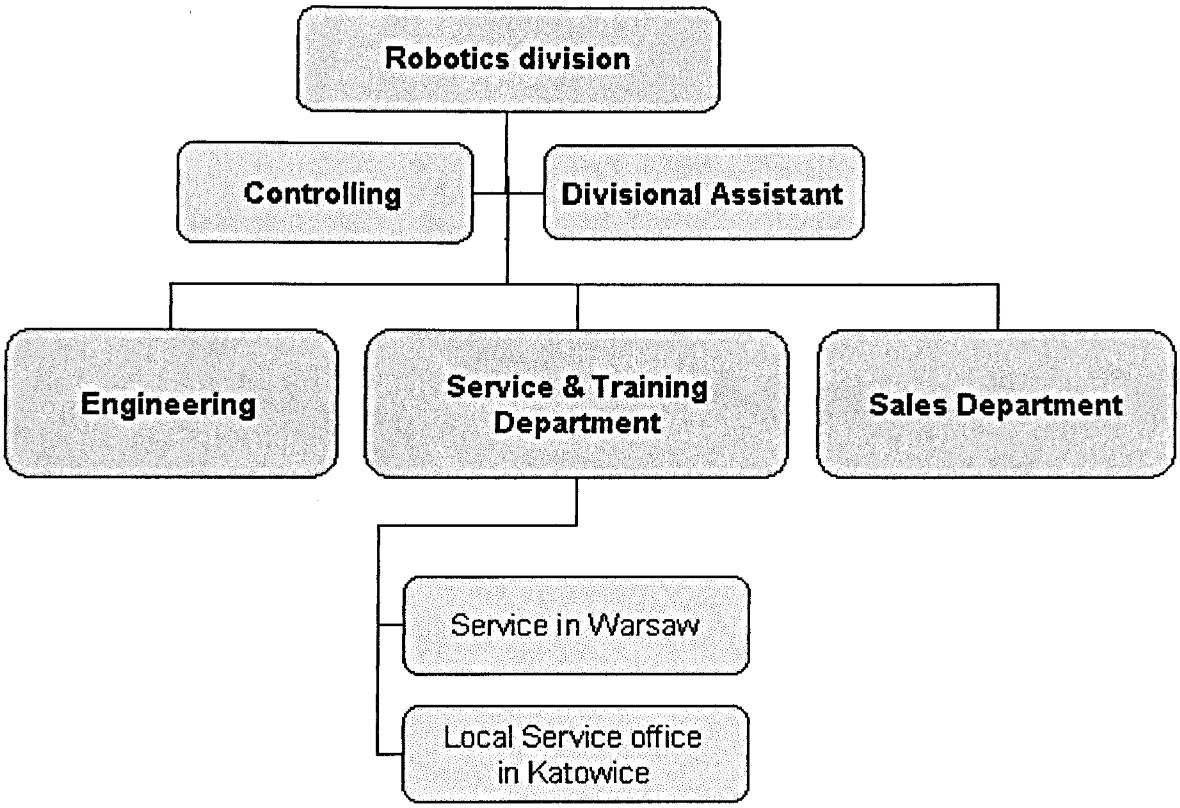
- **Process Automation division Organization**



- **Automation Products division Organization**



▪ Robotics division Organization



▪ ABB Factory in Wroclaw