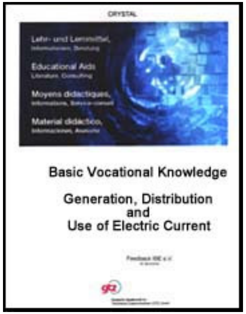
Basic Vocational Knowledge
Generation, Distribution
and
Use of Electric Current

8.4. Secondary protective elements

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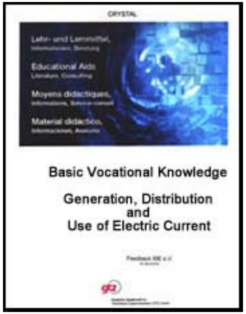

Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

Textbook for Vocational Training

**Institut fr berufliche Entwicklung e.V.
Berlin**

Original title:
“Berufliche Grundlagen - Erzeugung, Verteilung, Anwendung des elektrischen Stromes”

Author: Frank Ponemunski

Institut fr berufliche Entwicklung e.V.
Parkstraβe 23
13187 Berlin

Order No.: 91-34-0107/2

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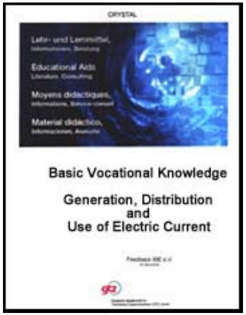

Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

8. Protective, control and supervisory systems as important additional equipment for power installations

8.1. General

Functions

Their protective, control and supervisory functions for electro-technical installations can be summarized as follows:

- **to guarantee stable supply of electric energy to the consumers,**
- **to ensure safe operation of the installation equipment throughout, from the supplier to the consumer of electric energy.**
- **to minimize damage caused by operational failures,**
- **to permit quick fault location and trouble shooting,**
- **to protect people against electric shocks.**

Disturbances

They are external effects on the normal operation of an electro-technical installation changing the specified technical/technological cycle of a process. They occur at an unforeseen time and with very different intensity. Their possible consequences can be taken into account and coped with in advance.

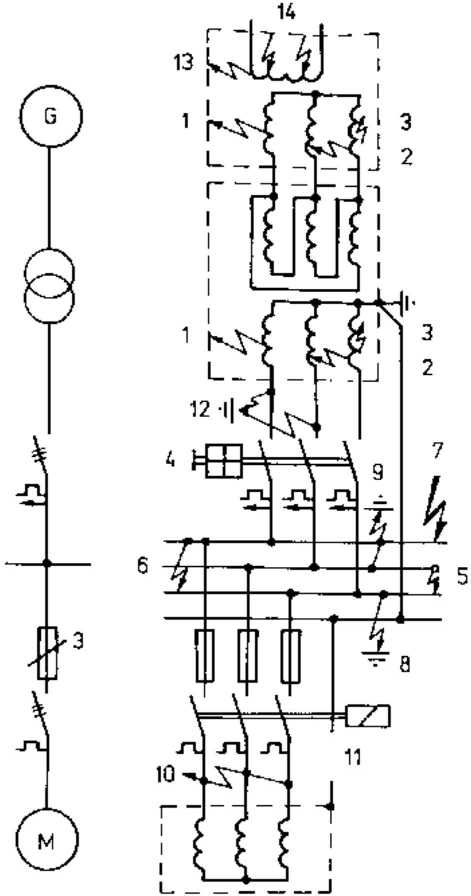

Figure 79. Possible disturbances in an electrical installation

1 earth-leakage fault of a winding,
2 winding-to-winding short circuit,
3 interturn short circuit,
4 operating error.
5 line-to-line fault,
6 three-phase short circuit,
7 atmospheric discharge,
8 earth-leakage fault,
9 line-to-line fault with earth connection,
10 three-phase short circuit with earth connection,
11 conductor break,
12 double earth fault,
13 earth-leakage fault of rotor,
14 double earth fault of rotor

Overloading and short circuit

- Causes

- **Load exceeding the rated values (P_n. I_n).**
- **Insulation damage in line or cable installations and electric machines.**

- Effects

- **Thermal stress**

The insulation gets unduly heated, it chars or burns.

- **Dynamic stress**

Switching devices, converters, current bars and the respective insulators are

mechanically destroyed.

Increased voltage (overvoltaqe)

- Causes

- **Switching operations.**
- **Atmospheric discharge.**
- **Increased voltage by capacitive mains effects.**

- Effects

- **Insulation breakdowns.**
- **Voltage spark-overs.**

(In both cases arcs are formed with consequent burning)

Operating and maintenance errors

- Causes

- **Human errors.**
- **Misunderstanding (wrong information).**
- **Lack of technical knowledge.**

- Effects

- **Impairment of human health.**
- **Destruction of parts of installations or of whole installations.**
- **Loss of production by faulty switching.**

Protection

This includes all electrotechnical measures which, in the event of faults, result in direct switching-off of parts of installations or of whole installations through acquisition and processing of disturbances as well as measures of bypassing and/or attenuation of disturbances. Protection also includes indication of disturbances to the operator.

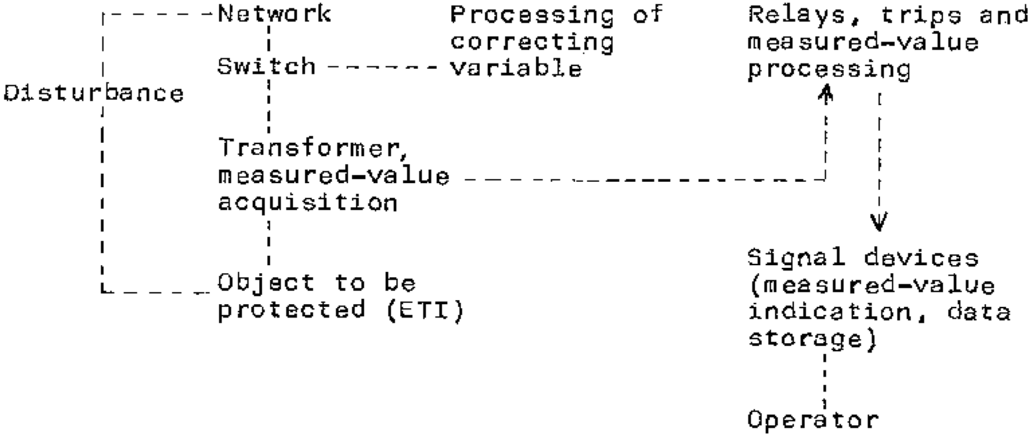

Table 26 Schematic of the protective system of an electrotechnical installation (ETI)

- Primary protection

The protective elements are directly included in the circuit to be protected. The fault current or fault voltage act directly on them.

Table 27 Primary protective elements

Elements	Application
Stranded earth conductors Protective spark gaps	Overvoltage protection

Voltage-limiting devices	
Valve-type arresters	
Relays	
Coils (reactors)	Overcurrent protection
Fuses	
Current-limiting circuit breakers	
Relays	

- Secondary protection

The protective device is connected with the circuit to be protected through current or voltage transformers. The switching actuator is not directly excited by the fault current or fault voltage but by their secondary quantities.

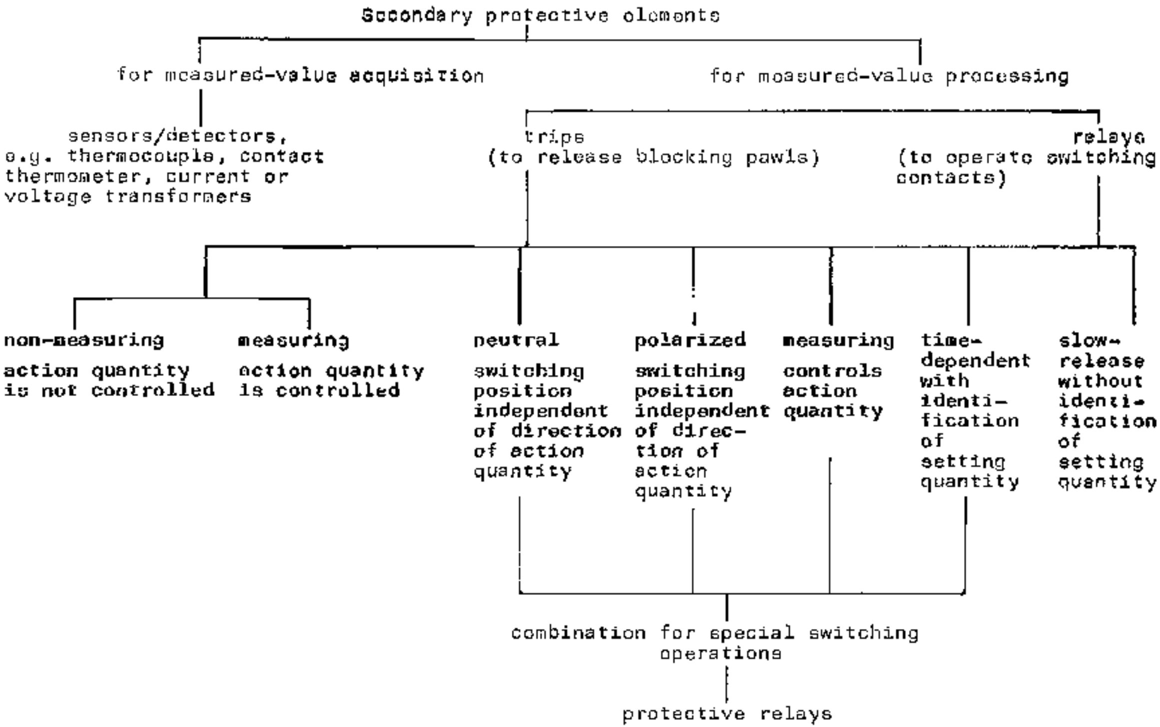

Table 28 Secondary protective elements

Supervision

Supervisory devices detect operating conditions and signal them to the operator using signal elements. Signals indicating disturbances can be acknowledged, i.e. switched off, after processing.

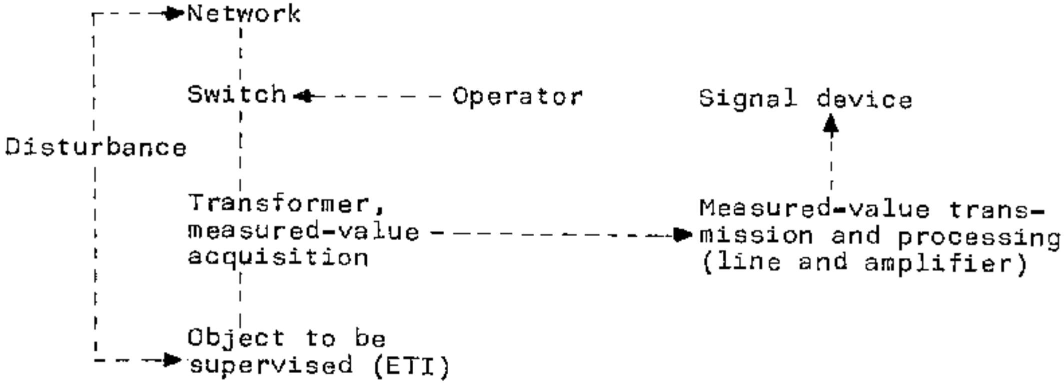

Table 29 Schematic of the supervisory system of an electro-technical installation (ETI)

Conditions supervised are, for example:

- load conditions in the network,
- temperature in boiler plants,
- filling levels in tanks,
- voltage in emergency power plants,
- line conditions (e.g. line interruptions).

8.2. Primary protective elements against overvoltage

<u>Stranded earth conductors and lightning arresters</u>

Their purpose is to render more difficult the development of overvoltage of uncontrollable amount and duration in the event of atmospheric discharge at overhead lines and in other electrical installations. One or more stranded conductors are run above the active conductors of overhead lines and conductively connected with the earthed poles.

Lightning protection for other electrical installations is provided by hot galvanized round bar steel installed at the highest point of the installations and conductively connected with the earth potential. These measures provide a certain shielding for the overhead lines and other electrical installations against atmospheric overvoltages. (The success percentage is about 33 % for overhead lines.) Stranded earth conductors and lightning arresters are used in all high-voltage overhead-line installations (seldom in medium-voltage installations, generally from 110 kV).

Protective spark gaps

Their purpose is to carry off dangerous overvoltages to near-earth places using electric field effects of overhead lines. They consist of electrically conductive arcing horn rings with short electrodes.

When an overvoltage caused by atmospheric discharge is applied to the insulator, the spark gap of the arrester strikes because of the electric field effect and carries off the overvoltage to the earth. The arcing horn rings are designed so as to carry the arc away from the insulator and let it burn out at a distance which is not dangerous. The protective spark gaps are used in all high-voltage overhead-line installations which are provided with automatic reclosing.

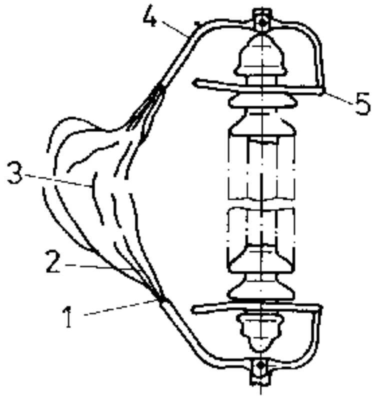

Figure 80. Arc horn and arc course - 1 arc foot, 2 arc stem, 3 arc centre, 4 arc horn, 5 open ring

Valve-type arresters

Multiple protective spark gaps with bleeder resistors, voltage and earthing connections in porcelain casing with an additional external protective spark gap. Resistor plates are placed on upon the other with very small distances.

Between two adjacent plates there is a glow discharge at about 350 V and a spark-over at 500 V. When an overvoltage is applied, the auxiliary spark gap is bridged by an electric arc. The downstream voltage-depending resistors limit the quantity of charge, a mains voltage collapse is thus prevented.

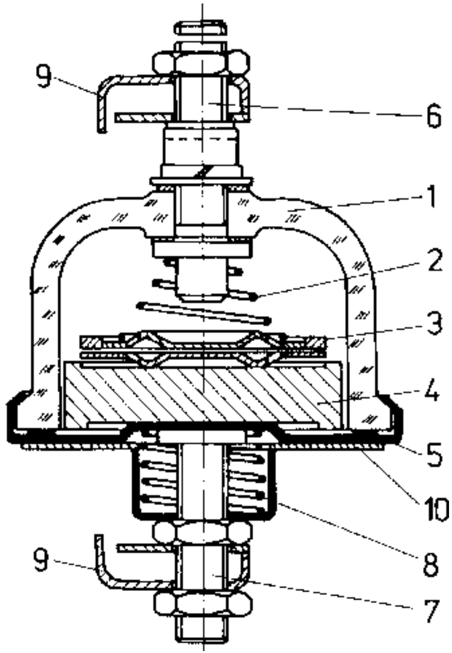

Figure 81. Construction of a valve-type arrester - 1 glass casing, 2 spring, 3 spark gap with distance and centring facilities, 4 resistance plate, 5 flanged cap, 6 voltage connection, 7 earth connection, 8 mains isolator, 9 connection clamp, 10 0-ring seal

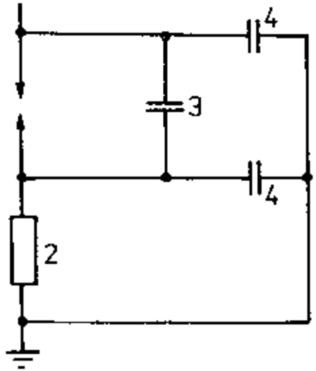

Figure 82. Equivalent circuit of a valve-type arrester - 1 spark-gap, 2 load resistance, 3 spark-gap capacitance, 4 earth capacitance

Use

- **as D.C. voltage arrester,**
- **as A.C. voltage arrester for networks of all voltage levels,**
- **for all switching and distributing plants at the overhead-line inlet,**
- **for junctions, overhead line - cable,**
- **for all cables of more than 12 m length.**

<u>Expulsion-type arresters</u>

Spark-gap with insulating conduit, voltage and earthing connections. The striking (arcing) depends on the level of voltage and on the distance between the electrodes. The arcing in the event of overvoltage vaporizes organic insulating material of the insulating conduit. The gas pressure produced escapes through the so-called exhaust electrode, the arc is quenched. The voltage collapse that follows is eliminated by automatic reclosing.

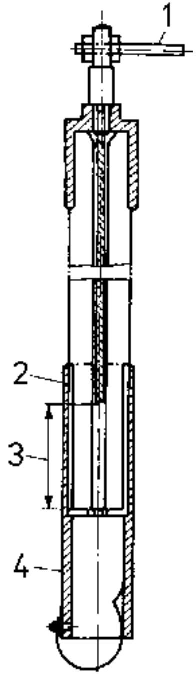

Figure 83. Construction of an expulsion-type arrester - 1 voltage connection, 2 insulating conduit, 3 quenching gap, 4 exhaust electrode

Use as A.C. voltage arrester in medium-voltage installations.

8.3. Primary protective elements against overcurrent

Current-limiting coil

It attenuates excessive short circuits by its inductive reactance and thus helps to protect the electrotechnical installation against the effects of high currents. It consists of a coil with a large conductor cross section. The coil has no iron core and is mounted in procelain, concrete or hard wood. If a very high short circuit is flowing in the current path, a widely straying magnetic field is created in the turns. Current-limiting ceils are mainly installed in the busbar branches of medium-voltage plants.

Fuses

Fuses are switching devices for automatic opening (breaking) of circuits by interrupting a current path by fusing of the conductor.

- Principle of operation

The fusing conductor in the fuse link is the weakest point in the circuit. In the event of overload or short circuit the fusing conductor is interrupted by the Joule hoat.

- Breaking factor

The various electrotechnical installations require different breaking factors for overcurrents or short circuits. This is achieved by time lag of fusing of the fusing conductor.

Table 30 Coordination of breaking factors and types of current protection

Type of current protection	Breaking factor k	
	in consumers' installations	in cable and overhead-line networks up to (inclusive) service box and fuse in the rising mains

Fuses up to 30 A/time-lag and up to 63 A/instantaneous	3.5	2.5
from 63 A/time-lag	5	
Protective switches or relays with undelayed (less than 0.5) release,e.g. short-circuit instantaneous trips	1.25 (breaking curre = k x setting current short circuit trip)	
Protective switches or relays with delayed I:) (from 0.5 s) release,e.g. thermal trips, time-lag magnetic trips	k as given above trips since protective switches or relays with delayed release must be used only in connection with fuses or undelayed trips	
Automatic cut-outs up to 25 A. 380 V, except domestic cut-outs	3.5	2.5
Domestic automatic cut-outs up to 25 A, 380 V	2.5	
	It is to be made sure that fuses and automatic cut-outs cannot be mixed up.	

- Time lag

Low-voltage fuse links

- **time-lag fuse links**
- **instantaneous fuse links**
- **time-lag instantaneous fuse links**
- **high-speed fuse links**

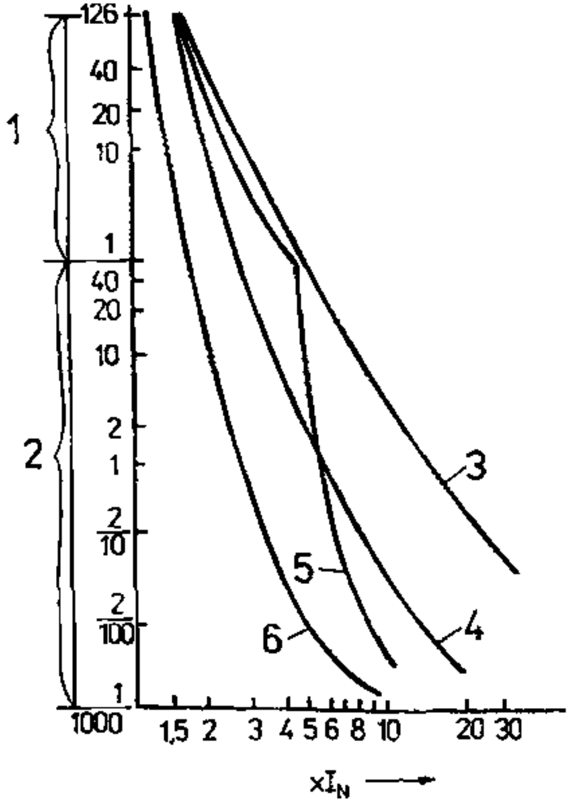

Figure 84. Switch-off delay characteristic of fuses - 1 minutes' range, 2 seconds' range, 3 time-lag fuses, 4 instantaneous fuses, 5 time-lag instantaneous fuses, 6 high-speed fuses

- Use

- **Time-lag fuse links are used where, for technological reasons, high currents flow for a short time but do not have detrimental effects for the lines (motor-starting currents).**

- **Instantaneous and high-speed fuse links are used to protect lines and equipment where little overcur- rent has detrimental effects.**

Note:

When automatic cut-outs, bimetallic and instantaneous trips are used, another breaking factor k is to be taken into account,

- Types

- **D fuses (Diazed fuses - diametral two-step Edison screw)**

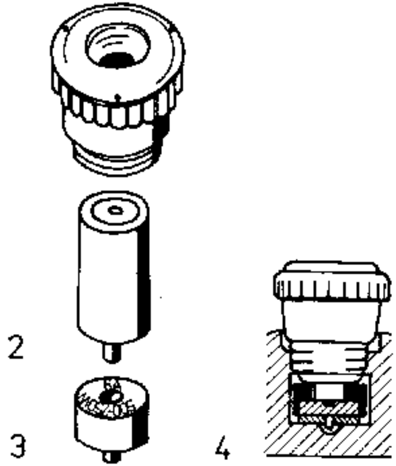

Figure 85. Construction of a screwed-type fuse - 1 fuse carrier, 2 fuse link (cylindrical), 3 gauge piece, 4 assembly in the fuse socket 1

Use:

Wiring installations, control systems, protection of lines, cables, machines and equipment. Rated current:

2 to 200 A depending on the screw type (E 16 to E 33 and R 1.1/4” to R 2”).

- **NH fuses (low-voltage HBC fuses)**

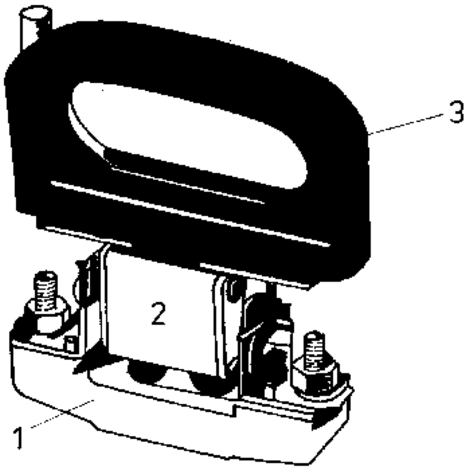

Figure 86. NH fuse (low-voltage HBC fuse) - 1 fuse base. 2 fuse link, 3 fuse link replacement handle

Use:

Wiring installations, control systems, protection of lines and cables in bigger distributing plants.

Rated current:

6 to 630 A, depending on the size (00 to 3).

- **HH fuses (high-voltage HBC fuses).**

Overcurrent protection in medium-voltage installations (local networks, industrial plants), particularly as short-circuit system in connection with on-load disconnecting switches.

<u>Current -limiting measures</u>

- Creation of sub-networks (sub-systems)

The system impedances (Z.) are increased. This contributes to the attenuation of the short-circuit current and provides the possibility of partial disconnection.

- Increase of the resistance (Z) in the transformer section in the event of short circuit by direct transformer/reactance interconnection.

<u>Current-limiting circuit breakers (e.g. automatic cut-outs)</u>

Thermal and electromagnetic primary trips in the current path interrupt the excessive current by tripping of circuit breakers. Automatic cut-outs have a thermal overcurrent trip and an electromagnetic instantaneous trip. The two types of separate tripping mechanisms guarantee excellent protection against over-current (heat) and short circuit for the downstream electrotech-nical installation.

Rated current: 6 to 25 A.

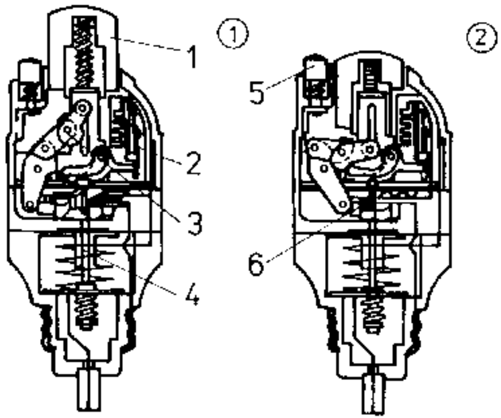

Figure 87. Automatic cut-out (screw-in type) - (1) off-position, (2) on-position - 1 switch-on button, 2 thermal trip. 3 toggle, 4 electromagnetic trip, 5 switch-off button, 6 switching contacts

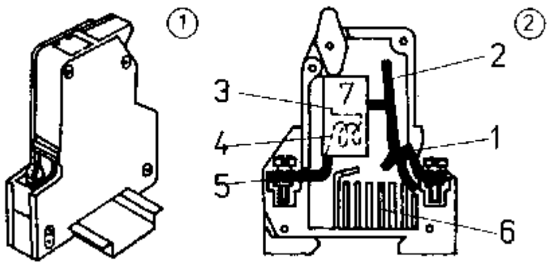

Figure 88. Automatic cut-out (built-in type) - (1) mounted on supporting rail, (2) schematic construction - 1 pole terminal, 2 switching contact, 3 bimetal, 4 tripping

impulse, 5 outgoing terminal, 6 deion chamber, 7 switching mechanism

8.4. Secondary protective elements

Current transformers

They work to the principle of a secondary short-circuited transformer.

Standard primary values
between 5 A and 30 kA.
Standard secondary values
between 1 and 5 A.

Class accuracy 0.1, 0.2, 0.5, 1, 3, 5 P, 10 P.
Rated impedance between 0.04 and 2.4.

Voltage transformers

They work to the principle of a secondary open-circuited transformer.

Standard primary values

between 100 V and $\frac{400\,\mathrm{Kv}}{\sqrt{3}}$

Standard secondary values

$$100\mathrm{V}, \frac{100\,\mathrm{V},}{\sqrt{3}} \frac{2 \times 100\,\mathrm{v}}{\sqrt{3}}, \frac{2\,\mathrm{x}\,200\,\mathrm{v}}{\sqrt{3}}$$

Class accuracy 0.1, 0.2, 0.5, 1, 3. 3 P. 6 P.

Relays

Relays are devices which are influenced by a change of the action quantity in the driving system and actuate electrical switching elements.

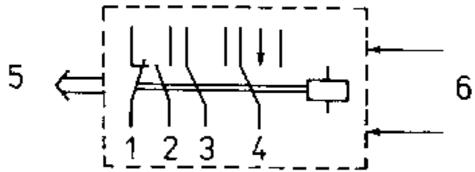

Figure 89. Relay with its contact types (contact element types) - 1 break contact, 2 make contact, 3 change-over contact, 4 wiping contact, 5 correcting variable, 6 measurable variables

Examples of relay types:

- Undervoltage and overvoltage relays

These relays are suitable for undelayed tripping of switches in the event of mains voltage drop or failure or for undelayed tripping of switches in the event of overvoltage, respectively.

- Overcurrent relays

These relays are designed for undelayed tripping of switches in the event of overcurrents caused by overload or short circuits. The response is indicated by optical signals.

- Overcurrent time-lag relays

These relays serve for current-controlled supervison of motors (low voltage and high

voltage) and transformers to protect them against overload and short circuit.

- Magnetic overcurrent relays

Magnetic overcurrent time-lag relays to protect consumers of low-voltage installations against overload. They are mainly used in ship installations. They are self-contained units and work in connection with low-voltage circuit breakers.

- Time-lag relays

Short-time time-lag relays can be used for any delayed switching operations in control engineering where a short, adjustable time delay is required. In connection with overcurrent or undervoltage relays, they can be used for delayed tripping of switches.

Precision time-lag relays feature a high accuracy of time. In connection with single-, two- or three-contact overcurrent and undervoltage relays, they can be used to build up time-lag protective devices.

FI protective switches

Fault-current circuit breakers or the fault-current protective device, respectively, supervise inductively with a current transformer the sum of ingoing and outgoing currents of the installation to be protected.

Signal elements (examples)

- Signal relays

Signal relays serve to indicate disturbances (voltage failure) and operating conditions (on, off, full, empty).

- Acknowledging switches

Acknowledging switches serve to indicate and supervise the switch position in mimic diagrams and illuminated circuit diagrams of electrotechnical installations and to indicate faults by optical or sound signals or as control switches, e.g. for the control of switches indicating the switch position at the same time.

- Acknowledging control switches

Acknowledging control switches are used in switching plants to control power circuit breakers and disconnectors as well as to indicate and supervise their switch position in mimic diagrams.

<u>Questions for recapitulation and testing</u>

1. What does the collective term “protective, control and supervisory systems” cover in particular?
2. What are current-limiting measures?
3. What are the principles of working of current and voltage transformers?

<u>Answers to the questions for recapitulation and testing</u>

2.1. Brown coal, hard coal. nuclear power, water power, heat of the earth.

2.2. Reasonable illumination expenditure, adaptation of the power of motors to the machines to be driven, use of modern technologies, taking into account, peak-load periods.

3.1. Water power stations, thermal power stations, climatolo-gical power stations.

3.2. Unused electric energy is stored in the form of water in an upper reservoir. When the energy is needed, the stored water is drained off into the lower reservoir through turbines generating electric energy which is immediately available.

4.1. Networks for power supply to smaller areas, such as towns, parts of towns, industrial plants, etc. The transmission voltages range from to 30 kV.

4.2. One or two feeding points.

4.3. Clear identification of the network conditions for the purposeful selection of adequate protective measures against electric shocks.

4.4. It is decisive for the thickness of the insulation, for the distance between non-insulated conductors and for the qual-itiy of the insulating material.

4.5 It is important for the type of material (Al. AlCu, Cu), the size of the cross section, type and extent of cooling.

4.6. It is an electrotechnical installation including accessories, the main purpose of which is to distribute electric energy to several outgoing lines.

4.7. Use of expansion joints and slide supports.

4.8. Conductor, insulating cover, sheathing.

4.8. Conductor, insulating cover, belt, sheathing, inner protective covering, armouring, outer protective covering.

4.10. Versatility, interchangeability, high packaging density for various fields of application.

4.11. Indoor switching plants, sheet steel-enclosed low-voltage distributing plants, standard box systems, outdoor switching and distributing cabinets, switchgear cubicles (cells), substations, transformer stations.

4.12. They open (break) and close (make) current paths.

4.13. Porcelain, thermoset plastic material, hard paper, cast resin.

4.14. To avoid damage to the conductor and insulator caused by improper transportation, storage, laying or fixing.

4.15. Cable protecting caps must be completely filled with sand so as to avoid cavities between the cable and the cap.

4.16. To reliably conduct current from one conduction to another one and to avoid or minimize transition resistances.

5.1. According to the type of building, such as residential buildings, industrial buildings, social buildings, agricultural buildings, medical buildings, special installations.

5.2. Standardized, prefabricated installation parts which are normally suitable for repeated use. Basically there are current bar systems and cable and line systems.

5.3. Pressing technique. The working tools are expensive but the connections produced are equal to welded joints.

6.1. Wide variety of consumers, e.g. with respect to size, type of operation, operation at the same time, degree of utilization, type of current, voltage level, frequency.

7.1. Visual inspection of all component parts, A.C. voltage testing and/or lightning-stroke

voltage testing of the insulating property, insulation testing.

7.2. Hand generator or electronic insulation measuring device.

7.3. For new installations: 10 $\frac{k\Omega}{V}$

For old installations: 1 $\frac{k\Omega}{V}$

For installations of 100 V or less: 100 Ωm

8.1. Installations guaranteeing stable supply of electric energy and safe operation from the supplier to the consumer of electric energy, quick fault location and trouble shooting and protecting people against electric shocks as well as minimizing damage caused by operational failures.

8.2. Creation of sub-systems and increase of the resistance of the system impedances.

8.3. Current transformers: principle of a secondary short-circuited transformer. Voltage transformers: principle of a secondary open-circuited transformer.

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Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

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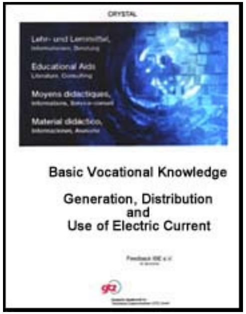

Preface

The present textbook is based on the rich experience of FRG vocational training and intended for trainees in the field of electrical engineering.

In the form of a compendium, it contains the necessary basic knowledge to understand the fundamentals of the of electric current in heavy-current electrical engineering. Related aspects of information electronics are mentioned additionally only wherever it is absolutely necessary for technical reasons. Installation (plant) engineering is only dealt with in the low-voltage range of up to 1 kV.

- generation,
- distribution and

- use

Subjects discussed in great detail in other IBE textbooks, such as “Electrical Installation,” “Electrical Machines” and “Switch-gear”. are only presented in a brief and concise way here. For better understanding of the technical knowledge contained in this textbook, it is necessary to have basic knowledge of natural sciences and electrical engineering. The author tried to explain the subject-matter in a clearly arranged and easy-to-understand manner. Comprehensive illustrations and relevant tables as well as descriptive and comprehensible wording shall help the trainees to conceive the problems dealt with.

Considering the inseparability of theory and practice throughout. the textbook can be used by the trainees to acquire knowledge of electrical engineering in the training process, both in theoretical and practical vocational training. Questions for recapitulation and testing, concentrating on the main points of the relevant subjects, shall help the trainees to examine their knowledge.

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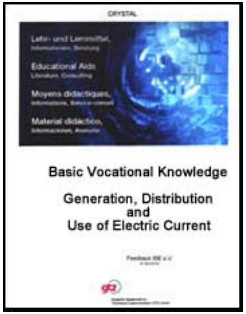


1. Introduction

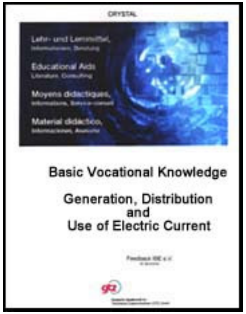
Electric current is generated, distributed and used in a closed system, normally called electrical installation (or plant). Physical effects make it necessary to subdivide the electrical installation into two subsystems:

Power unit (or electric energy equipment)

It is exclusively used for the generation, transformation, storage, transmission, distribution and use of electric energy and comprises an energy unit with the equipment to serve the afore-mentioned purpose and an information unit to guarantee the control and protection of the installation.

Secondary unit (or information equipment)

It is used for the generation, acquisition, transmission, processing and output of information (control and protection of the electrical installation) and comprises an energy unit to supply the necessary energy and an information unit with the respective equipment to serve the afore-mentioned purpose of the installation.



2. General remarks on the demand for electric energy and on the natural resources available

The demand for electric energy depends on the level of development of a country in view

of its economy and the technologies used.

Inexpensive production methods, energy transmission with a minimum of losses and the use of waste produced for useful purposes are ecologically beneficial because of optimum utilization of the natural resources.

Nowadays intensive work is being done in an endeavour to reduce the losses in the process of transformation, transmission and use of energy.

In these days, the thesis that the demand for energy increases proportionally with the increase in production and standard of living of the people of a country is a controversial international issue. The losses can be avoided to a large extent by: use of new production technologies, optimum dimensioning of the equipment and reasonable illumination intensity. The point of emphasis is on rational use of energy. This shall be illustrated by a few examples:

<u>Measures of rational use of energy</u>

Basis of comparison: energy intensity energy Intensity,

$$\text{energy intensity}\ \frac{\text{consumption of energy}}{\text{goods production}}$$

The aim should be:

Reduction of the energy intensity by exact indicators of power economy (energy plan) which makes it possible to find out and eliminate sources of losses, particularly of key losses.

The energy plan is an important instrument of management.

- Industry

- **Reasonable illumination expenditure conforming to standards with rational use of energy.**
- **Adaptation of the power of motors to the machines' capacity and disconnection of idle motors from the power supply system.**
- **Use of modern technologies.**
- **Shifting of the use of energy-intensive machines to periods outside the peak-load periods.**

- Households

- **Reduction of consumption of energy during peak-load periods.**
- **Avoidance of unnecessary energy consumption.**
- **Use of modern, highly efficient forms of space heating (electrical storage heaters).**
- **Illumination of rooms according to illumination engineering aspects.**

The natural resources of electric energy - in the order of priority with respect to their use and utilization - are:

- brown coal (lignite)
- hard coal
- nuclear power
- water power

- heat of the earth

Questions for recapitulation and testing

1. What are the natural resources for the generation of electric energy?
2. What measures are conducive to rational use of energy?

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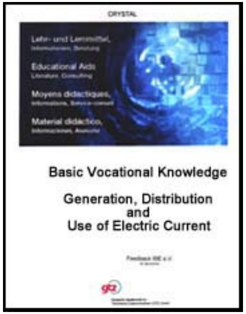


Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

3. Ways of generation of electric energy

A high percentage of electric energy is generated by coal power stations. In the years to come, the capacity of power stations will be increased to 2000 MW and more by installing power-station units of higher capacity (200 MW and more). One unit consists of the steam generator and turbine including the necessary parts and facilities of the

installation. One power station normally comprises several power-station units. Advantages of higher generator capacity with stable power consumption are:

- **less consumption of material for the power-station unit,**
- **higher efficiency factors,**
- **lower specific costs for generator and turbine,**
- **lower investment costs for the power plant,**
- **less personnel for operation and maintenance.**

Disadvantages of bigger generators are:

- **longer starting and run-down times,**
- **longer times required for stopping in slack periods,**
- **not suitable for peak-load power stations.**

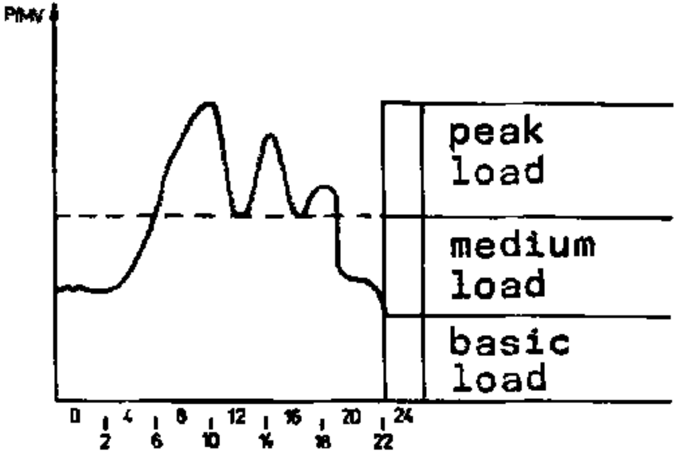
Types of power stations

- Water (hydroelectric) power stations (storage power stations, pumped storage power stations, run-of-river power stations)

- Climatological power stations (tidal power stations, solar power stations, wind driven power stations, geothermal power stations)

- Thermal power stations (gas turbine power stations, steam power stations, nuclear power stations, diesel power stations, magnetohydrodynamic (MHD) generators)

Share of power station types in the generation of electric energy



<u>Table 1</u> Distribution of the daily load on the types of power stations on the network

industrial power stations, pumped storage power stations, diesel and gas turbine power stations
industrial power stations
thermal power stations, storage power stations thermal power stations, nuclear power stations, run-of-river power stations

3.1. Water power stations

<u>Storage power station</u>

The potential energy of water is stored in artificial lakes (reservoirs)

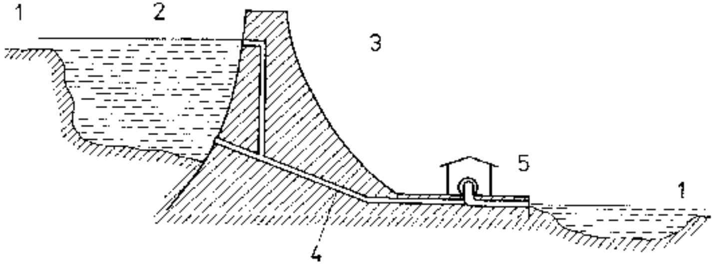


Figure 1. Schematic representation of a storage power station 1 river, 2 artificial lake, 3 hydrodam wall, 4 bleeding line, 5 power plant (power house)

<u>Pumped storage power station</u> (pump-fed power station)

Water flowing from an upper reservoir into a lower reservoir is utilized for power generation to meet the demand during peak-load periods. In slack (low-load) periods the generator works as pumping motor pumping the water into the upper reservoir.

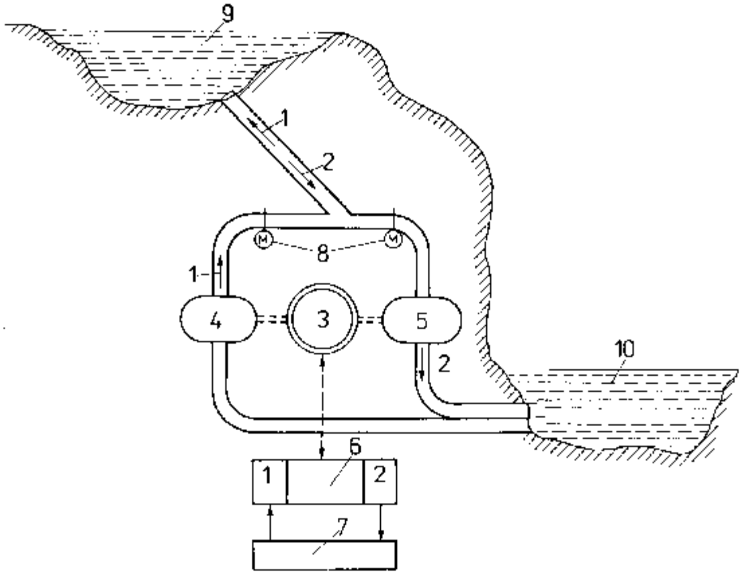


Figure 2. Schematic representation of a pumped storage power station - 1 pumping mode (electric energy is taken from the public power system - generator works as pumping motor), 2 generator mode (electric energy is delivered to the public power system), 3 generator, 4 pump, 5 turbine, 6 electric energy, 7 public power system, 8 gate, 9 upper reservoir, 10 lower reservoir

Run-of-river power station

Water flowing in a river bed is directly utilized to drive water turbines.

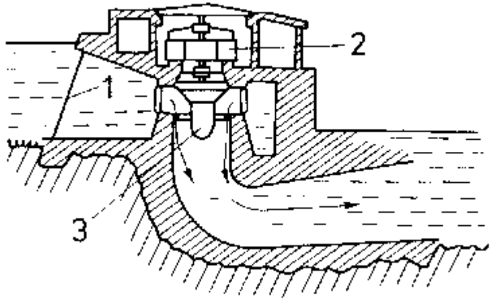


Figure 3. Schematic representation of a run-of-river power station - 1 screen, 2 generator, 3 runner

3.2. Climatological power stations

Climatological power stations include tidal power stations, solar power stations, wind (driven) power stations and geothermal power stations.

3.3. Thermal power stations

<u>Gas turbine power station</u>

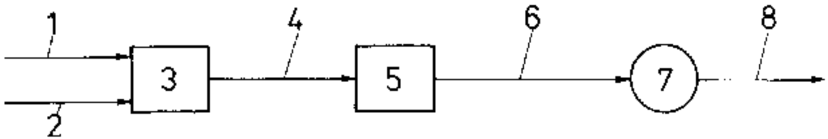


Figure 4. Functional diagram of a gas turbine power station - 1 compressed air, 2 combustible gas, 3 combustion chamber, 4 mechanical energy in the form of combustion gases (flow), 5 gas turbine, 6 mechanical energy in the form of rotation, 7 generator, 8

electric energy

Steam power station

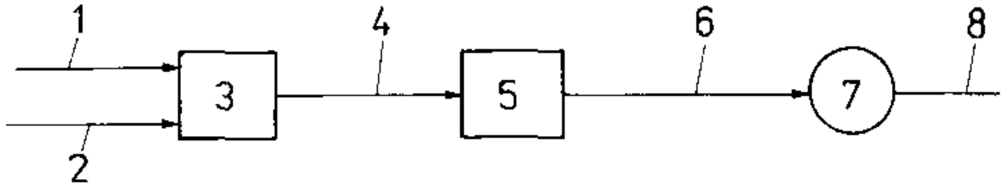


Figure 5. Functional diagram of a steam power station - 1 air, 2 fuel, 3 steam generator, 4 mechanical energy in the form of steam (flow), 5 steam turbine, 6 mechanical energy in the form of rotation, 7 generator, 8 electric energy

Nuclear power station

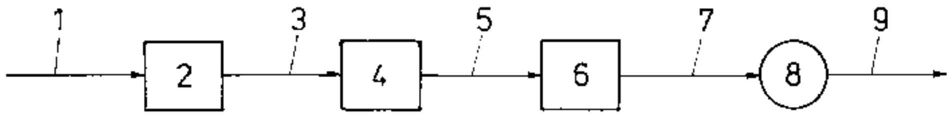


Figure 6. Functional diagram of a nuclear power station - 1 fissionable material, 2 nuclear reactor, 3 thermal energy in the form of coolant, 4 heat exchanger, 5 mechanical energy in the form of steam (flow), 6 steam turbine, 7 mechanical energy in the form of rotation, 8 generator, 9 electric energy

Questions for recapitulation and testing

1. What are the main types of power stations?
2. What is the principle of working of a pumped storage power station?

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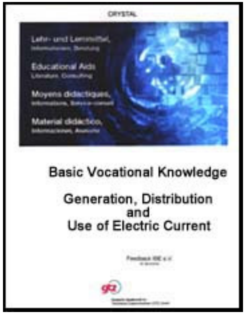


Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

4. Power transmission and distribution in power supply systems

Electric power system

The whole of electrotechnical installations and networks including all necessary additional devices for the generation, transmission and use of electric power within one regional unit,

Electrotechnical installation (or plant)

The whole of equipment required for proper functioning of the complete technological unit.

Electrotechnical network (or electric mains)

A system of interconnected electric lines of the same rated voltage for the transmission and distribution of electric power.

4.1. Types of networks

Supergrids (extra-high voltage systems)
(transmission function)
for power supply to larger areas with transmission voltages of 110 kV, 220 kV and 380 kV.

Medium-voltage systems
(distribution function) for power supply to smaller areas (towns, parts of towns, industrial plants, etc.) with transmission voltages of 1 to 30 kV.

Low-voltage systems (supply function) for power supply to the majority of consumers (electric household appliances and motors of low and medium capacity) with transmission voltages of up to 1 kV.

Open systems
have a single feeding point.

Closed systems
have two feeding points which makes the network more fail-safe.

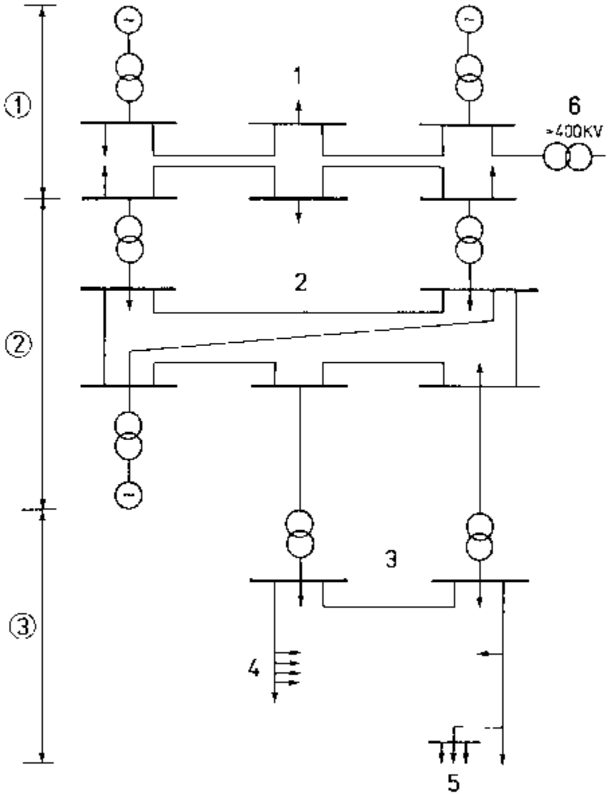


Figure 7. Various types of networks as integral parts of the electric power transmission system - (1) supergrids (extra-high voltage systems (2) medium-voltage system (3) low-voltage systems - 1 mesh-operated network, 2 medium-voltage ring-operated network, 3 low-voltage distribution network (closed), 4 open network (multiple lump-loading), 5 star network, 6 feeding

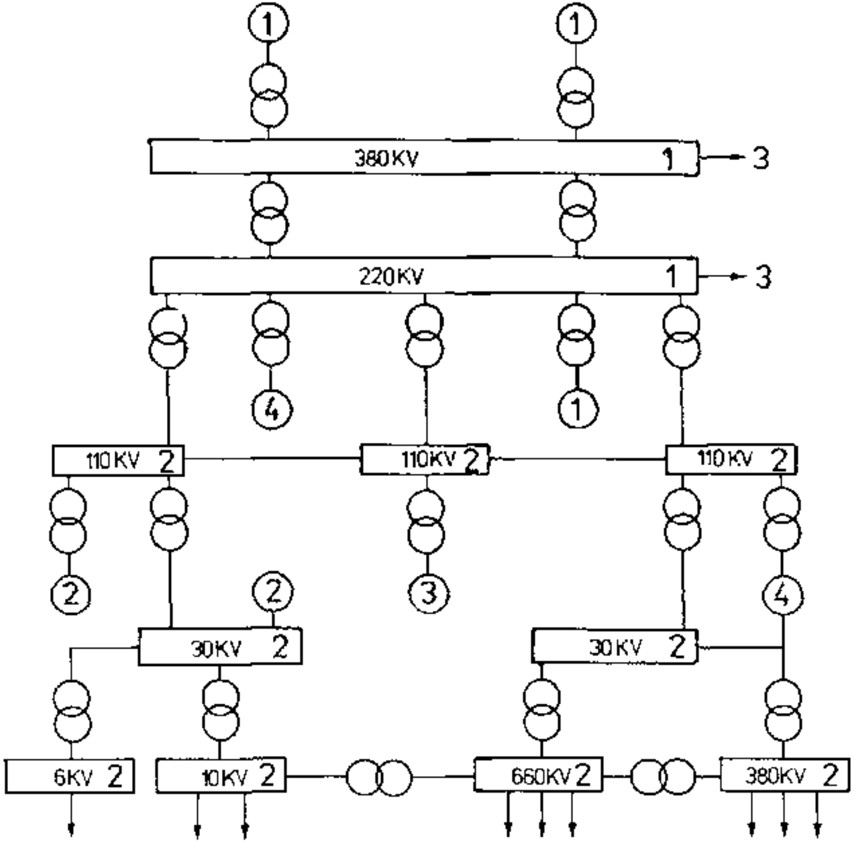
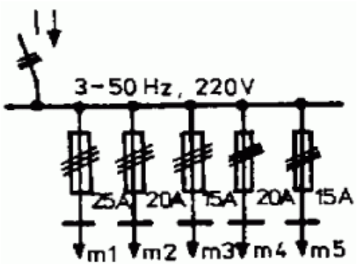
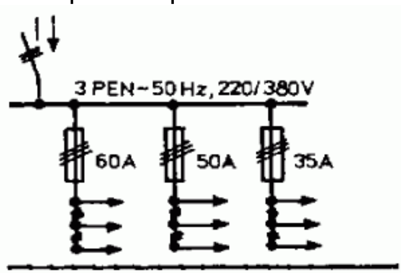
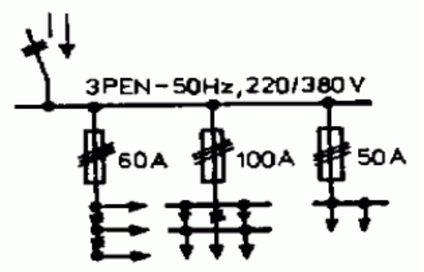
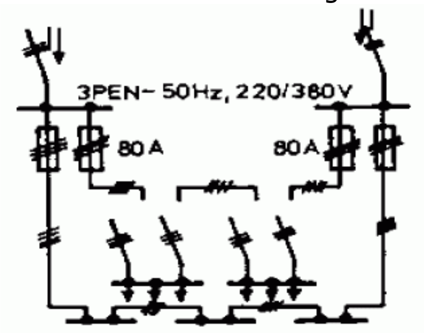
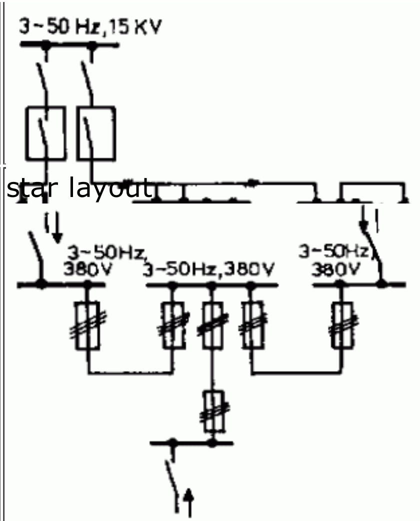
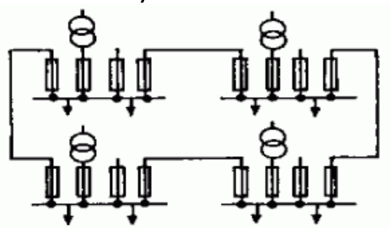


Figure 8. Example of interconnected national networks - 1 transmission levels, 2 distribution levels, 3 international networks, - (1) power station, (2) heat-generating station, (3) industrial power station, (4) pumped storage power station

Table 2 **Open and closed systems (networks)**

Type and circuit		**Advantages and disadvantages**	**Examples of application**
Open systems with	end-loaded lines  	simple circuit, clear arrangement, very simple protective system, very easy planning, good utilization, low costs, poor operational reliability, poor voltage maintenance, high losses	small industrial plants and local networks of small extent
	multiple lump-loaded lines  		

	branched lump-loaded lines		lighting installations
			
Closed systems with	lines with double feeding 	simple circuit	local networks for long-distance settlements, extended factory halls
Closed system of	ring layout	clear arrangement	factory plants, medium-voltage distribution networks,

			higher-level supergrids
	star layout 	better voltage maintenance, less losses, easy planning, better operational reliability, poor utilization, acceptable costs, sophisticated protective system	low-voltage distribution networks in big industrial plants
	meshed layout 	very good operational reliability, very good voltage maintenance, low losses, very good utilization, less simple circuit, less clear arrangement, very sophisticated protective system, less easy planning, acceptable costs	local networks for bigger and large towns, low-voltage networks for big companies

4.2. International networks

The designation of networks and conductors is internationally coded to IEC 445.

The code letters used have the following meaning:

T terre (French) (earth)
I insulation
N neutral wire
C combined
S separated
P protection
E earth

<u>TN-networks</u>

Networks where one point of the network, i.e. one point of the service circuit, is directly earthed (T) and the casings of the equipment or installations are electrically connected with such point through a protective conductor (N). They apply the protective measures of connection to neutral or protective earthing with fault current return through metallic conductors (water pipes, cable sheathings).

- TN-C-network
PEN protective conductor with function of neutral wire.

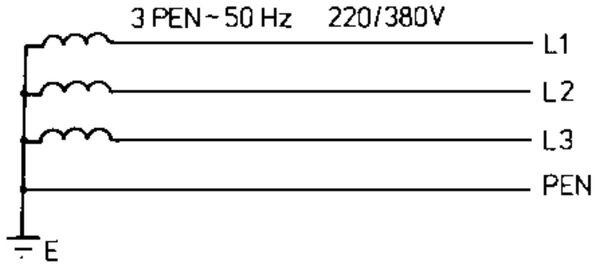


Figure 9. TN-C-network

- TN-S-network
PE protective conductor carrying no operating current.

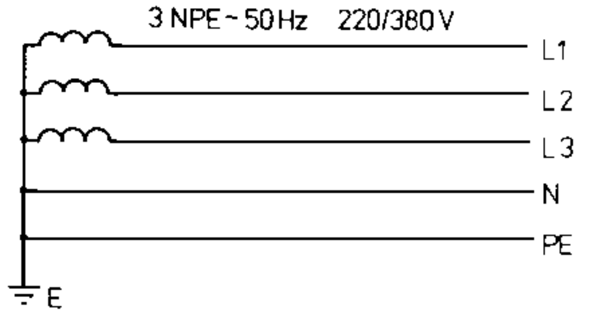


Figure 10. TN-S-network

- TN-C-S-network
PE protective conductor carrying no operating current.

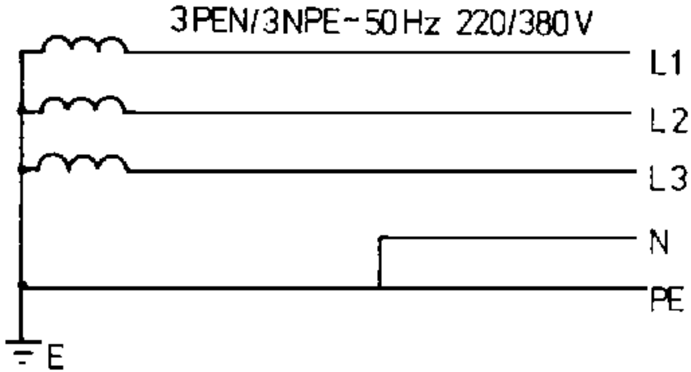


Figure 11. TN-C-S-network

TT-networks

Networks where one point of the network is directly earthed (1) and the casings of the equipment or installations, irrespective of the existence of any neutral wire, are connected with earth leads which are not electrically connected to the earthed network point (T). Such networks, which are internationally called TT-networks, apply protective earthing (single earthing) using FI or FU protective circuits.

TT-network

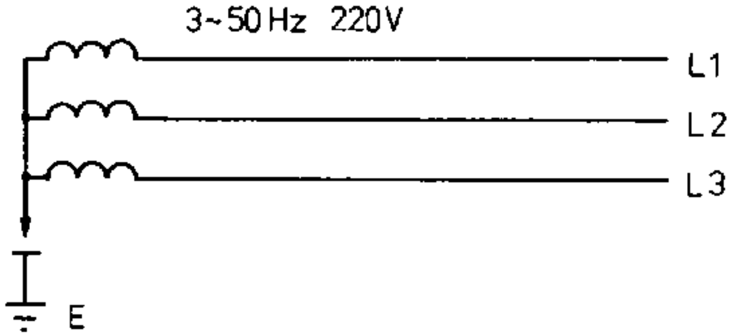


Figure 12. TT-network

IT-networks

Networks where no point of the network is directly earthed (I) but the casings of the equipment or installations are directly earthed (T). Such networks apply the protective conductor system, protective earthing, FI and FU protective circuits.

IT-network

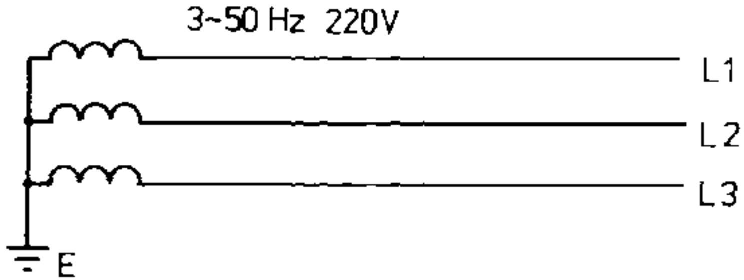


Figure 13. IT-network

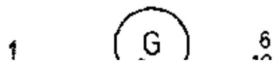
4.3. Common voltage levels in the flow of electric energy

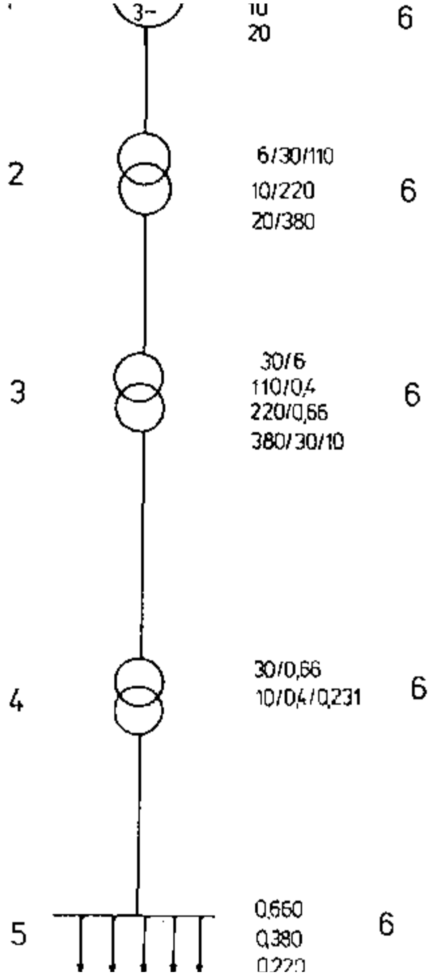
4.3.1. The importance of the voltage

The amount of voltage is decisive for the thickness of the insulation material (wire insulation) or the size of the distance of active conductors between each other and the earth. Economically this means the use of expensive or less expensive insulation material and, with respect to overhead lines, additionally occupation of ecologically important land. High-voltage overhead lines also involve overhead construction problems. Depending on the climatic zones, loads due to wind and ice, for example, are material-intensive design factors.

4.3.2. Voltage levels of the elec-trotechnical networks

The variety of the individual levels shall be demonstrated by means of an example of an installation





10
20
6
2
6/30/110
10/220
20/380
6
3
30/6
110/0,4
220/0,66
380/30/10
6
4
30/0,66
10/0,4/0,231
6
5
0,660
0,380
0,220
6

Figure 14. Example of possible voltage levels - 1 generator, 2 generator transformer, 3 substation transformer, 4 distribution transformer, 5 consumers, 6 voltages in kV

To enable efficient transmission of high powers over large distance, the transmission voltages have become higher and higher in the course of technological development.

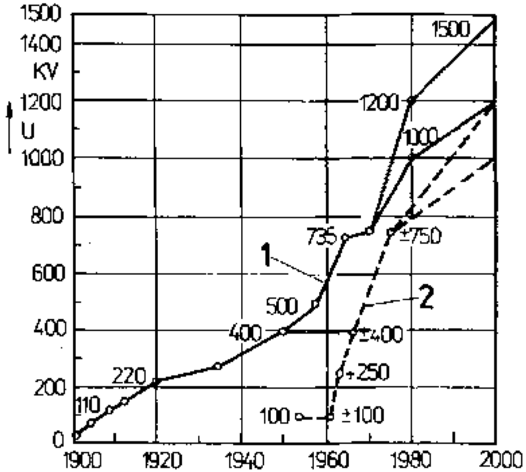


Figure 15. Development of transmission voltages worldwide - 1 high-voltage three-phase transmission, 2 high-voltage D.C. transmission

4.4. The importance of the electric current as dimensioning criterion for all transmission elements

Having dealt with the effects of the voltage on the physical dimensions of all electrotechnical transmission elements, we now consider the effects of the electric

current:

There are three objective factors of influence on the dimensioning.

4.4.1. Operating current

The operating current is important for normal operation which may be of continuous, short-time or intermittent type.

Continuous operation

Continuous operation means uninterrupted loading of all transmission elements by current of almost constant intensity which, depending on the current density, results in heating of the active conductors. That means that all materials and auxiliary materials (insulation) as well as components, which are in direct contact with the active conductor, absorb heat. The consequences are expansion and aging effects on busbars, metal-clad cables, wire insulations etc.

Short-time operation/intermittent operation

Short-time operation/intermittent operation mean that, after periods of heating, all transmission elements undergo periods of cooling. This may be aimed at maximum thermal peak-load on the one hand or at thermal load below the limit load on the other hand. It depends on the components to be used.

4.4.2. Short-circuit current

Faults normally involve extreme loads for all components, depending on the design of the installation in terms of protection:

- Instantaneous short-circuit current

The so-called instantaneous or asymmetric short-circuit current involves high electrodynamic loads for the installation parts immediately on its occurence. The intensive magnetic fields generated as a consequence of such current can physically destroy busbar installations, current transformer heads (insulator-type transformer), switching devices etc. Conductor elements of overhead lines may also be affected.

- Sustained short-circuit current

The sustained short-circuit current occuring after the instantaneous short-circuit current has several times the intensity of the operating current and, with a time lag after the short- circuit, results in heavy or extreme heating of all components in the fault circuit. Mostly such current destroys the installation parts unless this is prevented by adequate protective measures.

4.4.3. Environment

The thermal effects of the environment are important for the dimensioning of the installation with respect to the cross sections of the transmission elements and to the protective elements to be used. High ambient temperatures physically call for larger cross sections and low ambient temperatures permit smaller cross sections than normally specified for the operating current. Mutual heating is taken into account in installation engineering by providing for adequate distances of busbars, stranded conductors, lines and cables between each other and between components and for air circulation.

4.5. Common technical terms in the field of transmission and distribution

Outdoor plant/installation
Installation exposed to weather conditions without protection (see outdoor).

Open-type plant/installation
Installation with equipment not fully protected against accidental contact.

Outdoor(s)
Limited area in the open air featuring the same temperature and air humidity according to the local climate.

Assembly unit
A combination of several components or devices forming a functional unit.

Component
A single part that can only work in connection with other components.

Subassembly/module
Locally combined group of components which can function independently. Subassembly (in the context of a project) is a self-contained part of a plant/installation as defined from shipping and installation aspects.

Modular component/module
A component which, because of its specific modular design, can be assembled with other similar modular components into a consistent whole.

(Component) part
A constructionally and electrically self-contained member of a part of an installation.

Enclosed
Equipment and plants/installations which are protected against environmental influences.

Protected outdoor installation/plant
Outdoor installation which is protected against rainfall up to an angle of incidence of 30

degrees to the perpendicular.

Main distribution (system)
First distribution system after power feeding.

Information unit
The information unit of an installation or section or part of an installation comprises its locally functionally combined equipment for the generation, transmission, processing and reception of information, even though this is implemented according to the rules of heavy-current engineering.

Indoor installation/plant
Installation inside rooms or buildings.

Indoor(s)
Room in buildings which is free from effects of weather conditions

Mesh network
Closed network system consisting of crossing lines which are interconnected and fused at the crossing points. The crossing points are called "nodal points", the closed sections between the nodal points a "mesh" and each part of the line "mesh line".

Nodal point of a network
A point in the electric energy distribution system where more than two circuits (lines) can be interconnected.

Potential equalization
Electrically conductive connection between electrically inactive parts, such as water, gas and heater pipes, steel structures, metallic cable sheathings, foundation earth leads and protective conductors. This measure prevents a potential difference (voltage) between

such parts.

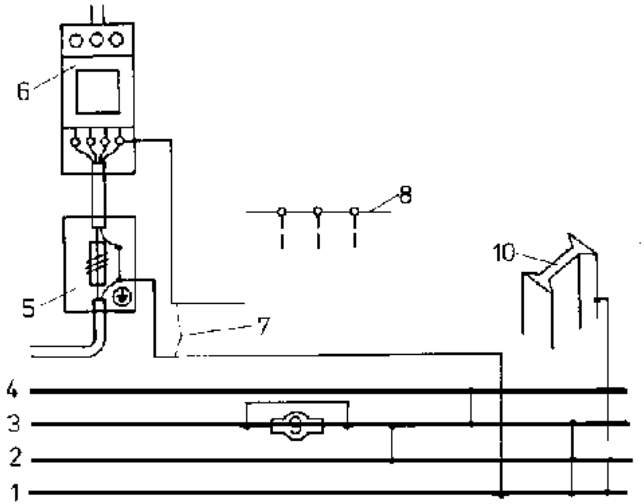


Figure 16. Example of central potential equalization - 1 foundation earthing electrode, 2 heating tube system, 3 drinking water pipe, 4 gas distribution pipe, 5 house connection box, 6 customer's meter. 7 potential equalization line (connection point optional), 8 potential equalization bar (if necessary), 9 water meter (conductively bridged, if the meter is built into a metallic pipe system), 10 structural design

Primary system

It serves the purpose of directly distributing the electric energy and includes all components directly involved in the transmission of electric energy.

(Main) busbar

A conductor - bar or rope - to which several conductors or lines are connected.

Busbar section

A portion of busbars or busbar systems.
Each section comprises only one part of the switchboard sections.

Busbar system

Busbars with connected switchboard sections.

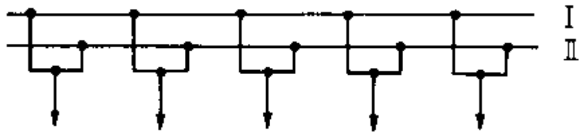


Figure 17. Double busbar system - I system 1, II system 2

Busbar coupling

Conductive connection between busbar sections.

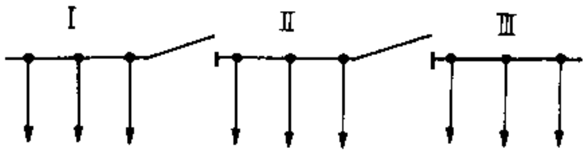


Figure 18. Longitudinal busbar coupling - I, II, III busbar sections

Switching plant

Distribution system with switching devices which make it possible to electrically connect and disconnect the outgoing main lines with/from the busbar.

Switchboard section
Local combination of the elements belonging to one branch.

Secondary system
It includes all facilities which are necessary for the protection, control, monitoring, measuring and metering but are not directly involved in the transmission of electric energy,

Station
Room or part of a building housing one or more electrotechnical installations or parts of installations and their service facilities for the purpose of distribution and conversion of electric energy.

Conversion
Change of the nominal value of physical quantities which are characteristic of the form of electric energy. Conversion includes transformation, frequency changing, rectification and inversion.

Subsidiary distributing system
Distribution system following the main distribution system.

Distribution plant
Electrotechnical installation including accessories, such as actuators, transformers, measuring devices etc., the main purpose of which is to distribute electric energy to several outgoing lines.

Cubicle (cell)
is a construction of suitable material which stands on the floor and has a degree of protection at least at one side but not at all sides.

4.6. Lines and cables as transmission and distribution elements

4.6.1. Basic terms

Lines

They serve the purpose of transmission and distribution of electric energy in general and of power supply and information trans-mision of any kind in particular. They are produced as bare (plain) and insulated types.

Cables

They have the same functions of energy transmission and distribution. Their particular construction permits their laying in the media air, soil and water under various external and internal conditions (mechanical, chemical, physical and electrotechnical).

System earthing and protective earthing wires

They include all conductors which carry off the electric energy to the earth in the event of fault. They have the potential of the earth. Since they have to be in direct contact with the soil, they are not insulated but have a high degree of protection against corrosion.

Types of laying

- Fixed laying
is a type of laying where the lines cannot change their position after installation (fixed with clips etc.)

- Movable laying
is a type of laying allowing the line to be frequently moved to another place (relocation of the equipment connected).

Line resistances

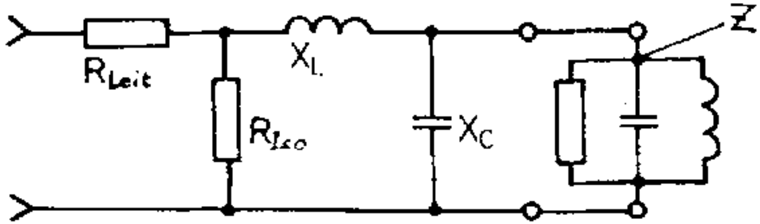


Figure 19. Equivalent connection diagram of a line - R_{Leit}. line resistance, R_{Iso} insulation resistance, X_L inductive reactance (inductance), X_C capacitative reactacne (capacitance), Z consumer

- Ohmic line resistance R_{Leit}

It depends on the length, material, cross section and temperature:

$$R = \frac{\rho \times 1}{A}; R = R_{20}(1 + \alpha \Delta \vartheta)$$

The conductor cross-section is to be selected so as not to exceed the admissible voltage and conduction loss:

$$U_V < 1.5\%, P_V \approx 4 \text{ to } 8\%$$

$$R_{Leit} \approx 0.0015 \text{ to } 0.01 \Omega/km$$

- Insulation resistance R_{Iso}

It depends on the type of insulation, A general rule for cables and lines is $R_{Iso} \approx 1K\Omega/V$

The insulation resistance is reduced by dirty surfaces, cracks in the insulation material, increasing tensional load and aging.

- Inductive reactance (inductance) X_L

It depends on the line inductance and on the frequency:

$$X_L = \omega \times L; \omega > 0.$$

The inductance per conductor depends on the length of the line "l", the conductor distance "a" and the conductor radius "r". It is calculated as follows:

$$L = l \times (4.61 \ \lg\frac{a}{r} + 0.4)10^{-4}$$

L	1	a	r
H	km	mm	mm

If it is a line with return line, the total inductance of the line is to be calculated using 2.1 for the length. Because of the small conductor distance "a" of cables, the inductive reactance of cables is considerably lower than that of overhead lines.

Examples:

$$\text{Overhead line } L \approx 1 mH/km, \quad X_L \approx 0.3\,\Omega/km$$

$$\text{Cable } L \approx 0.1 mH/km \qquad X_L \approx 0.03\,\Omega/km$$

- Capacitive reactance (capacitance) X_C

Capacitive charges occur between conductor and conductor and between conductor and earth.

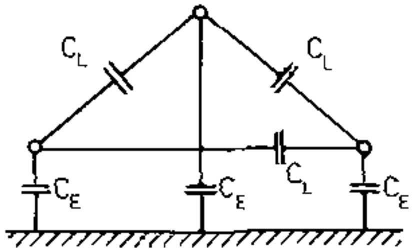


Figure 20. Equivalent connection diagram of the capacitances of - a three-phase overhead line, C_L conductor-conductor capacitance, C_E conductor-earth capacitance

The mutual capacitance of a three-phase overhead line is calculated as follows:

$C_B = C_E + 3\ C_L$
C_B = mutual capacitance
C_E = conductor-earth capacitance
C_L = conductor-conductor capacitance

Charge current of the three-phase line

$$I_C = \frac{U}{\sqrt{3}} \omega \times C_B$$

The admissible values of capacitance and reactance are

- for overhead lines $C_B \approx 12 nF/km$, $X_C \approx 215 k\Omega/km$

- for cables $C_B \approx 400 nF/km$, $X_C \approx 8.4 k\Omega/km$

Table 3 Influence of circuit elements on the behaviour of lines with respect to different types of voltage and current

Elements	Low voltage	Medium and high voltage	Direct current	Three-phase current
Line resistance	heating U_V, P_V	heating U_V, P_V	heating U_V, P_V	heating U_V , P_V
Insulation resistance	insulation and corona losses are low	insulation and corona losses increase with increasing voltage, therefore from 110 1<V bundle conductors for overhead lines	low corona losses	insulation between several conductors to be considered, e.g. in multi-conductor cables
Line inductance	self-inductance effects in the event of switching operations, little inductive phase shift since short line length	self-inductance effects in the event of load variations, inductive phase shift increases with increasing line length	self-inductance effects only when switching on and off	with 2 three-phase systems and operating currents flowing in opposite directions the self-inductance effects are compensated
Line capacitance	low	medium to high	capacitance increases with	line capacitance depends on distance between each of the three conductors,

			increasing line length and voltage	on the insulation and screening

4.6.2. Lines for heavy-current installations

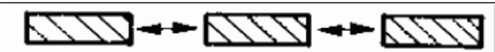
Bare (plain) lines

Bare lines are non-insulated conductors installed on insulating bodies (insulators), outside the area of contact on poles, behind protective grids or inside casings. As earth leads, bare lines are layed in the soil and in the area of contact.

- Bars (rails)

Solid, non-insulated conductors which, because of their shape or cross section, are highly resistant to deformation. They may be marked by colour codes.

Table 4 **Bar (rail) sections and section moduli**

No. Section	Position of conductor bars to each other	Section moduli
1 flat		high compared to 2
2 flat		low compared to 1
3 tubular		very high compared to 4
4 round		low compared to 3 and 1

		
5 channel		very high compared to 1 to 4

The bars are connected by welded or screwed connections.

They are held by line carriers on porcelain insulators or without carriers on thermoset plastic insulators or in hard paper fans.

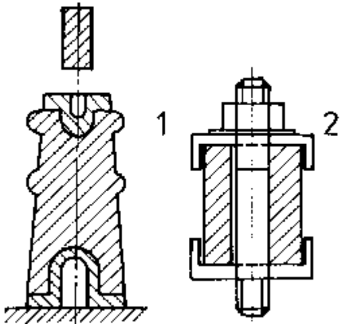
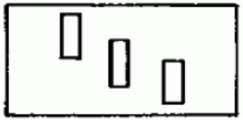


Figure 21. Pin-type (rigid-type) insulator - 1 support, 2 bar carrier for two busbars (laid on edge)

<u>Table 5</u> Hard paper boards for fixing of busbards

Designation	**Construction**	**Comments**
Hard paper fan		easy mounting

		
Hard paper fan with end strip		better hold compared to simple fan
Hard paper board with recesses		to be used where high bending stresses may occur (short circuit)

- Busbars

Busbars are bars or ropes to which several conductors or lines for current supply or derivation are connected. They are selected according to the current load (thermal load) from tables. Painted busbars can resist higher loads because the paint enables better dissipation of heat. The admissible D.C. load is higher than the A.C. load. Due to the skin effect of A.C. the cross section is not fully utilized. Therefore, pipe sections etc. are used in high-voltage installations. In order to avoid the accumulated temperature (ambient temperature V.. plus conductor temperature V,) to be exceeded, the admissible load current is to be reduced (load reduction) in the event of a higher ambient temperature. This can also be influenced by the way of laying.

<u>Table 6</u> Cooling at flat section

Way of laying	Use	Cooling
On edge, horizontal	busbar current bar outlet	good
On edge, vertical	busbar	good
Flat, horizontal	current bar	very bad

Flat, vertical	outlet	good

Load because of temperature changes results in displacement of the busbars. Such temperature difference, which may be caused by varying heating effect of the current (alternating load) and by varying ambient temperature of busbars, results in change of length. Busbars are, therefore, fixed in line carriers which permit sliding and/or expansion joints are included in the course of the line. The slide supports and expansion joints make the expansion forces ineffective.

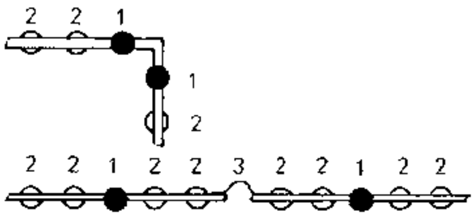


Figure 22. Diagram of busbar laying - 1 rigid support, 2 slide support, 3 expansion joint

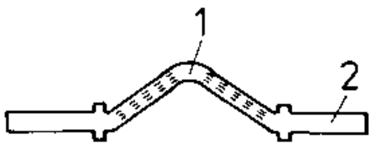


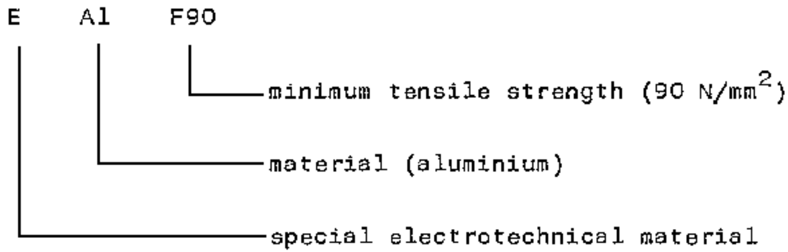
Figure 23. Expansion joint - 1 expandable portion of a multitude of thin strips, 2 connection piece

Loads by heavy currents, such as in the event of short circuit, generate a heavy magnetic field around the conductor. Heavy forces may occur between the fields. Their effect depends on the instantaneous short-circuit current, supporting point distance, conductor section, type of laying and conductor distance.

- Current bars

Current bars are rigid conductors for the transmission of electric energy to portable devices through current collectors. They are used as series line in low-voltage and high-voltage installations. The main materials are half-hard rolled copper or aluminium.

Example:



Figure

- Earth leads

Earth leads are bare conductors lying in the soil with a firm an conductive connection with the soil.

The main materials for protective earthing and system earthing lines are:

- **hot galvanized or copper clad strip steel or round steel with a minimum cross section of 50 mm,**
- **aluminium sections or rope with a minimum section of 35 mm,**
- **copper sections or rope with a minimum cross section of 16 mm,**
- **steel rope with a cross section of 120 mm ²**

Table 7 Customary minimum cross sections of earth leads

Type of earth lead	Semi-finished products	Minimum cross sections/dimensions	Customary size
Strip earth conductors	strip steel	100 mm² min. thickness: 3 mm	30 mm x 4 mm 40 mm x 5 mm
	round steel	diameter: 10 mm	diameter: 10 mm, 12 mm, 13 mm
Earth rods	mild steel tube angular steel or other similar sectional or round steel	diameter: 24 mm min. wall thickness: 3 mm 40 mm x 40 mm x 4 mm	diameter: 33.5 mm (1”) diameter: 60 mm (2”) 40 mm x 40 mm x 4 mm

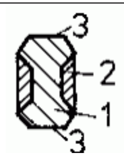
Earth leads are interconnected by screwed, clamped and welded connections.

- Contact lines.

Contact lines are used for electromobiles with and without longitudinal carriers including safety stop cables. Conductors of sectional rails in workshops, on ceilings, under bridges, in tunnels and passages are also belonging to the contact lines.

Table 8 Contact lines, types and use

Designation	Material	Type of section	Purpose of use
Steel-copper	Contact line		No high resistance to wear, suitable for subsidiary

contact line	with steel core and copper sheathing		routes with normal traffic and low speeds 1 copper sheathing 2 steel core 3 groove for fixing purposes
Copper contact wire	Solid copper section	as above but without steel core	Ri 80, Ri 100, Ri 120. use for standard-gauge railways
Steel contact line	All-steel contact line		For replacement purposes only, for short routes with little traffic
0 Steel current bar (rail)	Sectional steel rail with aluminium reinforcement		High resistance to wear, suitable for city or underground railway routes as feeder bar beside the track (only when provided with its own track bed - self-contained facilities) 1 steel rail section 2 aluminium subsequently or additionally added to enlarge the cross section 3 pick-up sides
Flat-section type	Copper or bronze		For small contact wires, crane tracks, conveyor equipment
Round-section type	Copper or copperbase alloys, bronze etc.		For crane equipment, conveyor equipment

- Overhead lines

These are open-type lines installed overhead in the open air with span lengths of normally more than 20m.

In order to place overhead lines out of reach of man and to ensure freedom of motion for vehicles of any kind, poles are required for overhead lines. Overhead lines of up to 1000 V, for example, are fixed on pin-type insulators or shackle insulators. Cap-and-pin insulators or long-rod insulators are used for rated voltages of more than 1000 V.

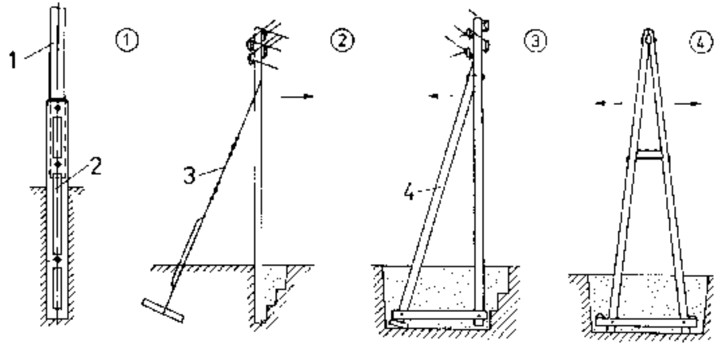


Figure 24. Types of poles - (1) supporting pole (straight-line pole), e.g. wooden pole with reinforced concrete pole footing, (2) angle pole, e.g. wooden pole with anchor, (3) angle pole, e.g. wooden pole with tie, (4) terminal pole, e.g. wooden A-pole (anchor and terminal pole) 1 wooden pole, 2 reinforced concrete footing, 3 anchor, 4 tie

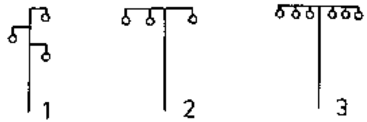


Figure 25. Pole head types - 1 use in the voltage range 0.4 to 6 kV as wooden pole or reinforced concrete pole, 2 use in the voltage range 6 to 20 kV as concrete pole (the central conductor is alternatingly run at the right-hand and left-hand side of the pole), 3 use for voltages of more than 20 kV up to about 220 kV as lattice steel pole

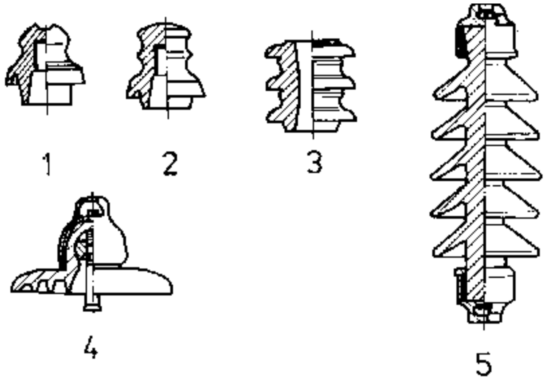


Figure 26. Insulators - 1, 2 pin-type (rigid-type) insulators, 3 shackle insulator, 4 cap-and-pin insulator, 5 long-rod insulator

- Open-type lines

Open-type lines include, for example, short connection lines in the area of buildings (over courtyards, between workshop halls etc.).

- Stranded conductors

Stranded conductors are multi-wire conductors which are movable because of their flexible construction.

- Earthing wires

Earthing wires are used to protect voltage-carrying conductors against direct lightning stroke or to carry off to the soil over-voltage of atmospheric or other origin and consequently to avoid or reduce step and contact voltages on poles and scaffoldings.

Marking of bare lines

Table 9 Identification colour codes for power transmission lines

Type of current	Conductor	Colour code
D.C.	L+	red
	L-	blue
	M	light-blue
Three-phase current	L 1	yellow
	L 2	green
	L 3	violet
	N	light-blue
A.C.	L 1	yellow
	L 2	violet

Table 10 Identification colour codes for protective earthing and system earthing lines

Type of earthing	Colour code
Protective earth	black
System earth	white with black cross-stripes
Joined protective earth and system earth	from the point of joining: black with white cross-stripes

Table 11 Identification colour codes for earthing lines from the conductor to the earth

Type of current	Conductor	Main colour	Identification colour additional colour as cross-stripes

Direct current	L+	black	red
	L-		blue
	M		white
Three-phase current	L 1		yellow
	L 2		green
	L 3		violet
	N, PE		white
	PEN		
Single-phase A.C. to IEC	L 1	black	yellow
	L 2		green
for raiIway facilities	L 1		yellow
	L 3		violet
Two-phase A.C.	L 1		yellow
	L 2		green

Insulated lines

- Construction

Insulated lines consist of a single insulated conductor or of multiple conductors insulated from each other and are provided with protection against impairment of the electric function. Normally they are not allowed for laying in soil and water.

- **Conductor**

Material: aluminium or copper, Type of conductor: single-wire, multi-wire or poly-wire,

fine-wire or extra-fine wire.

Shape of cross section: round.

• Insulating
cover consisting of rubber, plastic material, glass silk or artificial silk.

• Sheathing
consisting of rubber or plastic material.

- Wire marking

The insulating covers of multi-wire lines are marked with a colour code for safety reasons and for quicker working.

• Protective conductor

Colour code of protective conductor: green-yellow,

The green-yellow wire may only be used as protective conductor or auxiliary earthing wire.

• • Multi-wire lines are produced with or without protective conductor

• • With flat lines, the wire with the relevant colour code is to be used as protective conductor.

• • Wire marking

<u>Table 12</u> Wire marking

Number of wires	Lines with protective conductor	Lines without protective conductor
1	gnge	b1
	b1	sw or br
	sw or br	
2	gnge sw (only for fixed laying)	b1 sw or br
3	gnge b1 sw or br	b1 sw br
4	gnge b1 sw br	b1 sw br sw
5	gnge b1 sw br sw	

Gnge	green-yellow	br	brown
b1	blue	sw	black

- Abbreviations

All countries are aiming at standardized abbreviations for marking and identification. The following markings are an example:

- **Group markings**

A wire line
D triple line

F	flat line (ribbon conductor)
Fr	overhead line (wire or rope)
H	hose line
I	installation line (wiring line)
Kr	motorcar supply line

L tubular lamp line
N heavy-current line
P testing and measuring line rubber-sheathed line for mines
R X-ray line
S special line
Sch welding line
T trailing line
TS trailing line, multi-wire
TM trailing line, single-wire
W heater line
Z twin line
Z ignition line

- **Constructional elements**

C shield of metallic wires or conductive layer
CE like C, but around each wire
G insulating cover or sheathing of elastic material (rubber)
2G insulating cover or sheathing of silicone rubber
GS insulating cover, protective cover or fibre core of glass silk
St control wire (St) shield of metal foil
T carrying member
TX textile fibre core
U outer braiding
supervisory wire
Y insulating cover or sheathing of PVC

2Y insulating cover of polyethylene

- **Additionally marked porperties of the line**

fl flat
h increased electric strength
k increased resistance to cold
1 specially light-resisting
oil-resisting
u oil-resisting and non-inflammable
s increased wall thickness
t increased heat resistance
u non-inflammable

- **Additionally marked properties af the conductor**

b poly-wire
e single-wire
f fine-wire
m multi-wire
m/v multi-wire/compressed
vz tin-plated
w helical
z increased tensile strength

- **Colour code abbreviations**

b1	blue
br	brown
dgn	dark-green
el	ivory
ge	yellow
gn	green
gnge	green-yellow
gr	grey
nf	natural-coloured
sw	black
ws	white

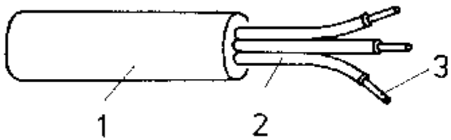


Figure 27. Insulated line - 1 sheathing, 2 insulating cover, 3 conductor

Designation	Abbreviation
Identification for heavy-current engineering	N
Group marking	
Marking of the construction elements and additionally marked properties of the line. (Only the construction elements necessary for marking the difference between the products are given in the order from inside to outside)	
For lines with green-yellow protective conductor the letter "J" is to be added For lines without protective conductor the letter "O" is to be added	
Number of wires multiplied by conductor cross section in square millimetres. The number "1" is to be marked only if the line is also available as multi-wire standard line.	
Additionally marked properties of the conductor.	
Material of conductor: aluminium (The material is not to be marked in the case of copper)	Al
Marking of the rated voltage if there are different standard voltages for the line	
Abbreviation of colour code (is not necessary for lines with black rubber sheathing or for lines available in one colour design only)	
Number of standard	

Table 13 Composition of abbreviations

- Insulated power lines for fixed laying - examples

- **Lighting line**

Abbreviation: NLZYF 2 x 0.5 - ws - (Un = 300/300 V). Fine-wire Cu-conductor, plastic

(PVC) insulating covers. Both wires are in parallel. Preferential colour: white. Application: in and at lamps with fixed laying. For dry and sometimes damp rooms, in and at lamps.

- **Plastic-insulated line**

Abbreviation: NAYY-J 2 x 2.5 re - 1 kV - (Un =1 kV). Single-wire, round Al-conductor, plastic (PVC) insulating covers and sheathing with green-yellow wire. Universally applicable in all media for wiring and control purposes.

- **Plastic-insulated wire line**

Abbreviation: NY b 10 - bl - (U_n = 300/300 V). Poly-wire Cu-conductor, plastic (PVC) insulating cover, wire line for protected laying (wiring). For installations, in and at machines, in cases of vibrations and frequent bending stress, in dry and sometimes damp rooms.

<u>Table 14</u> Places of installation and examples of applications of insulated power lines for fixed laying

Type of line	Abbreviation	Rated 3) voltage	Application 2) Place of installation								Examples of applications
-	-	kV	1	2	3	4	5	6	7	8	--
Lighting line	NLZYF	0.3/0.3	x	-	-	-	-	-	-	-	in and at lamps
Tubular lamp line	NL2YY	7.5/7.6	x	-	-	-	-	-	-	-	advertisement illumination,
	NL2YCY	7.5/7.5	x	x	-	-	x	x	x	x	particularly outdoors
Rubber-											

sheathed line											
	NIAGGu	0.45/0.45	x	x	-	-	-	-	-	x	for illumination purposes
Silicone rubber-sheathed line	N2G	1 1)	x	-	-	-	-	-	-	x	in lamps, in and at thermic
	N2Gf										appliances, in hot rooms
Installation lines	NIAZY	0.3/0.3	x	-	-	-	x	-	-	-	flush with intermediate ceiling installation
	NIDAY	0.3/0.3	x	-	-	-	x	-	-	-	buried in bulk walls and ceilings and with underfloor and intermediate ceiling installation
Plastic-insulated cable	NYYD NYY	1	x	x	x	x	x	x	x	x	universally applicable for wiring and control purposes
	NAYYd										
	NAYY										
Plastic-sheathed line	NIYYf1	0.3/0.5	x	x	-	-	x	x	x	x	for wiring and control purposes
	NIAYYf1										
	NILAYYf1										
Plastic-insulated wire line	NY	0.3/0.3	x	-	-	-	-	-	-	-	for installations, in and at machines, in cases of vibrations or frequent bending stress
	NYb										
	NAY										

	N2AY									
Special-purpose	NSYb	0.6/1	x	-	-	-	-	-	-	-	for ships, rail vehicles
plastic-insulated	NSYf										
wire line											
Rubber-insulated	NGUb	0.6/1	x	-	-	-	-	-	-	-	rail vehicles
wire line		1.8/3									
		3.6/6									
	NGUf	0.6/1									
		1.2/2									
special-purpose	NSGGfu	1.8/3	x	x	-	-	-	x	x	-	rail vehicles
rubber-insulated	NSGCGfu	and									
wire line	NSGCGfuk	3.6/6									

Explanations of the figures

1)
up to 1.5 square millimetres rated voltage 300/500 V
from 2.5 square millimetres rated voltage 450/750 V

2)
1 dry and sometimes damp rooms

2 damp or wet rooms or outdoors
3 in soil
4 in water
5 flush or buried
6 on the surface, on trays and supporting brackets
7 on wood, cardboard, particle board or fibreboan
8 when there is a possibility of direct contact of the line

3) Rated voltage indicated as conductor-earth voltage/conductor-conductor voltage

- Insulated power lines for portable equipment - examples

- **Triple line**

Abbreviation: NDY 3 x 0.75 - gr - (Un = 300/300 V). Fine-wire Cu-conductor, plastic (PVC) insulating cover. The three wires are in parallel. Colour: grey. For light portable devices (kitchen appliances, radio and TV sets), no thermic appliances and no extension line, in dry and sometimes damp rooms and when there is a possibility of direct contact of the line.

- **Light plastic hose line**

Abbreviation: NHYY1 3 x 0.75 - gr - (Un = 300/300 V). Fine-wire Cu-conductor, plastic (PVC) insulating covers and sheathing. Colour of sheathing: grey. For office machines, vacuum cleaners, refrigerators, in dry and sometimes damp rooms and when there is a possibility of direct contact of the line.

- **Medium shielded plastic hose line Abbreviation: NHYYCY 3 x 1 - gr - (Un = 300/500 V). Fine-wire Cu-conductor, plastic (PVC) insulating covers, inner and outer sheathing. Shield of Cu-wire mesh. Colour of sheathing: grey. For medium mechanical stress, extension**

lines, shielding electric fields, for control purposes, in dry and wet rooms, in the open air, in water, on wood, cardboard, particle board and fibreboard and when there is a possibility of direct contact of the line.

Table 15 Places of installation and examples of applications of insulated power lines for portable equipment

Type of line	Abbreviation	Rated voltage	Application Place of installation								Examples of applications
-	-	kV	1	2	3	4	5	6	7	8	-
Twin line											light portable devices,
Triple line	NZY	0.3/0.3	x	-	-	-	-	-	-	x	no thermic appliances and extension lines
Plastic hose lines: especially light light	NDY	0.3/0.3	x	-	-	-	-	-	-	x	
	NHYY11	0.3/0.3	x	-	-	-	-	-	-	x	
	NHYY1	0.3/0.3	x	-	-	-	-	-	-	x	office machines, vacuum
	NHYY1f1										cleaners, refrigerators
medium	NHYY	0.3/0.5	x	x	-	x	-	-	x	x	for medium mechanical stress, extension lines
medium shielded	NHYYCY	0.3/0.5	x	x	-	x	-	-	x	x	like NHYY, shielding of electrical fields, for control purposes
with supporting facilities	NHT2YY	0.3/0.5	x	x	-	-	-	x	x	x	for high tensile stresses, such as
with supporting	NHT2YCY	0.3/0.5	x	x				x	x	x	elevators/lifts

with supporting facilities and shielded	NHT2YCY	0.3/0.5	x	x	-	-	-	x	x	x	elevators/lifts
Rubber hose lines: with textile braiding	NHGGU1	0.3/0.3	x	-	-	-	-	-	-	x	light thermic appliances, electrothermic appliances, extension lines
light	NHGG1	0.3/0.5	x	-	-	-	-	-	-	x	for medium mechanical stresses, workshop devices, tools, also outdoors, agricultural imple ments
Rubber hose lines: heavy							1)				
	NSH	0.6/1	x	x	-	x	-	x	x	x	for higher mechanical stresses,
	NSHu										construction machinery, heavy
	NSHuk										workshop equipment
	NSHCk						1)				
heavy with sup porting facili ties	NSHT	0.45/0.75	x	x	-	x	-	x	x	x	for high tensile stress (control purposes in shafts and on hoist ing gears)
	NSHTu										
Rubber hose lines for mines							1)				for underground mines, in pits
	N<u>Q</u>	0.6/1	x	x	-	x	-	x	x	x	with firedamp and explosion hazards
with supervisory conductor	NQ	0.45/0.75	x	x	-	x	-	x	x	x	like NQ but with supervisory
Welding line	NSCHGu	0.12/0.2	x	x	-	-	-	x	-	x	interconnection line between transformer and electrode holder

Trailing line							1)				
single-wire	NTM	1.8/3	x	x	-	x	-	x	x	x	for high mechanical stress, con
	NTMu	3.6/6									nection of high-voltage motors
	NTMCu	12/20									and power supply installations
	NTMCuk	18/30					1)				(peak-load stations)
four-wire	NTSCEu	3.6/6	x	x	-	x	-	x	x	x	as above, power supply for big
		6/10									equipment (excavators and
	NTSCEuk	12/20									conveyor bridges in open-cast
		18/30									lignite mines)

1) except in mining, on building sites and for portable equipment

- Fabricated power lines - examples

These are industrial, standard lines with integral connectors.

- **Mains connection lines**

- • **Abbreviation: A1-2-32/7 - gr -**

Mains connection line (A1) with integral coupler plug, two-pin, 2.5 A (also called

European plug) for appliances of protection class II. Line: NZY 2 x 0.75 mm, length 2 m, dismantling length 32 mm, insulation-stripping length 7 mm. Colour: grey.

Application: mains connection of electrical appliances of up to I = 2.5 A. Not allowed in the open air and in wet rooms.

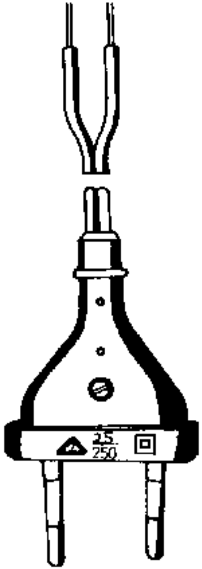


Figure 28. Mains connection line with integral coupler plus 2.5 A

- • **Abbreviation: EHI-4-63/7 - sw -**

Mains connection line (EHI) with integral safety plug, 10/16 A, of plastic material and with increased degree of protection for appliances of protection class I. Line: NMH 3x1 mm^2, length 4 m. dismantling length 64 mm, insulation-stripping length 7 mm.

Colour: black. Application: mains connection of electrical appliances of up to In = 16 A.

Allowed in the open air and in wet rooms.

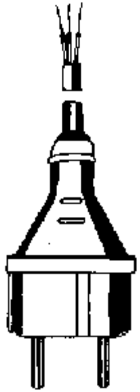


Figure 29. Mains connection line with integral safety plug 10/16 A

- **Interconnection lines**

Abbreviation: 22-1, 6-3-32/7 - sw -Interconnection line (Z2) with integral appliance lead-in of type 3 at one end. Line length: 1.6 m. Dismantling length 32 mm. Insulation-stripping length 7 mm. Colour: black. Application: interconnection line with fixed connection at both ends.

Figure 30. Interconnection line with fixed connection at both ends - 1 with integral appliance lead-in, 2 with outer braiding

- Not allowed laying of insulated lines

Type of line		Laying is not allowed in soil or un-accessible routes outside of buildings	in liquid media	in damp or wet rooms or outdoors	in flush or buried installations	on the surface, on trays, supporting brackets, hooks	in concrete ducts, concrete or clay conduits	on wood, cardboard, particle boards or fibre boards	when there is the possibility of direct contact of the line
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Plastic, special plastic or rubber-insulated line, special rubber-insulated wire line without sheathing, silicone rubber-sheathed line, glass silk-insulated wire line, plastic or silicone rubber-insulated connecting wire or stranded wire		x	x	x	x	x	x	x	x
Special rubber-insulated wire line with sheathing	unshielded	x	x	-	x	-	x	-	x
	shielded	x	x	-	x	-	x	-	x
Installation line		x	x	x	-	x	x	x	x
Flat plastic-sheathed line, telecom. sheathed line		x	x	-	-	-	-	-	-
Tubular lamp line	unshielded	x	x	x	x	x	x	x	x
	shielded								
Flat rubber-sheathed line (illumination line)		x	x	-	x	x	x	-	-

Heater line	unshielded	x	x	x	-	x	x	x	x
	shielded	-	x	-	-	x	-	x	-
Twin and triple line, especially light plastic hose line, flat light plastic hose line, rubber hose line with textile braiding		x	x	x	x	x	x	x	-
Round light plastic hose line, light rubber hose line, telecom. plastic hose line		x	x	x	x	x	x	x	-
Medium plastic hose line		x	x	-	x	x		-	-
Medium rubber hose line, telec. rubber hose line		x	x	-	x	x	x	-	-
Silicone rubber hose line		x	x	-	x	-	x	x	-
Plastic hose line with supporting facilities		x	x	-	x	-	-	-	-
Heavy rubber hose line, rubber hose line for mines, trailing lines		x	x	-	x	-	-	-	-
Welding line		x	x	-	x	-	-	x	-
High-voltage X-ray line	with plastic sheathing	x	x	-	x	-	x	-	-
	with rubber sheathing	x	x	-	x	-	x	-	-

Explanation of symbols:

x	laying not allowed	-	laying allowed
x	-, except in conduits or ducts	-	-, except in damp or wet rooms
x	-, except in water	-	-, except as extension line

x	-, except in mining, on sites and for portable equipment	-	-, however with movable laying only up to minus 5 degrees C, with proof of serviceability up to minus 12 degrees C allowed
x	-, except in assembly units and in low-voltage installations as well as for special ribbon conductor lines behind lining		

Table 16 **Not allowed laying of lines carrying voltage in operation**

4.6.3. Power cables

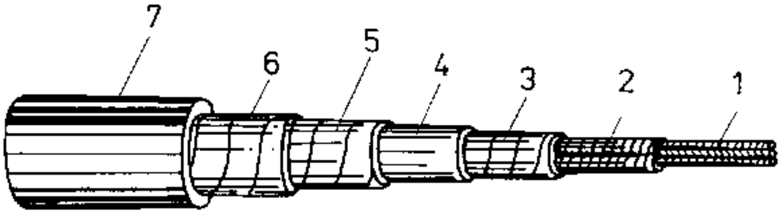


Figure 31. Power cable - 1 conductor, 2 conductor insulation, 3 belt, 4 sheathing, 5 inner protective covering, 6 armouring, 7 outer protective covering

Construction

Cables consist of one or more insulated electric conductors. They are provided with one or more protective layers with properties allowing the cables to be laid in cable trenches, cement ducts or cable ducts and water without impairing the electric function.

(The cable construction is always considered from inside to outside)

Constructional elements

- Conductor
Material: aluminium or copper.
Type of conductor: single-wire or multi-wire.
Shape of cross section: round, oval, sector-type.

- Conductor insulation
Insulating cover may be made of

- **polyvinyl chloride (PVC), for rated voltage 1 kV,**
- **polyethylene (PE), for rated voltage up to 30 kV,**
- **paper, well impregnated with cable impregnating compound up to 30 kV, impregnated with cable oil up to 380 kV (internationally)**

- Core

Conductor with insulating cover.

- Belt

Paper insulation, well impregnated with cable impregnating compound, in several layers enclosing the core as additional insulation.

- Sheathing

Seamless lead, aluminium or plastic covering, protects the interior of the cable from external mechanical and chemical effects.

- Inner protective covering

Bitumen-impregnated paper layers with fluid intermediate bituminous compound which,

in the event of mechanical stress (such as bending of the cable), permit pressure compensation between the metal sheathing or plastic sheathing and the cable armour.

- Armour

Material: steel.

Type: 2 layers of strip steel with protective coating against corrosion or round-wire armour, non-magnetized.

Type of wrapping: closed or open (round-wire armouring).

25 % overlapped (strip-steel armouring) and, against special order, anti-twist wrapping.

- Outer protective covering

Single protective covering of coarse tow yarn or textile tape with semifluid compound and non-sticking coating - A, double protective covering as above - AA, protective covering of PVC - Y. Cables with protective covering of impregnated fibre materials are allowed in rooms if impregnated against inflammability.

<u>Classification</u>

- Purpose

- **control purposes,**
- **transmission of electric power.**

- Voltage

- **low voltage: ≥ 42 V '= 1 kV**

(≤ 42 V low voltage)

- **high voltage: medium voltage 1 to 30 kV.**
extra-high voltage 110 kV.

- Construction

- **compound-impregnated cable,**
- **plastic-insulated cable,**
- **oil-filled cable for extra-high voltages,**
- **special-purpose cable,**
- **plastic-insulated cable with more than five cores.**

<u>Wire marking</u>

- Purpose

Marking of the wires largely precludes that the wires get mixed up and. therefore, is in the interest of higher reliability of service and easier installation.

Wire marking is not necessary for cable of more than 1 kV.

Up to 1 kV the wire marking corresponds, to a large extent, to that of lines. The marking of the protective conductor is of special importance.

The green-yellow wires are to be used as protective conductors.

- Type of wire marking

For the benefit of unmistakable definition of the type of wire marking (especially where two types are possible) of a multi-wire 1 kV cable, the letter code has been extended to

include 3 and 0.

Examples:

NAYY-J 4 x 25 re 1 kV four-wire plastic-insulated NAYY cable with a wire marked green-yellow or with figure code 3-1-2-3.

NAYY-0 4 x 10 re 1 kV four-wire plastic-insulated NAYY cable with a nominal conductor cross section of up to 50 mm and the colour code gnge/b1/sw/br or with figure code 1-2-3-4.

NAYY 1 x 185 sm 1 kV
single-wire plastic-insulated NAYY cable.
Table: Wire marking of 1 kV cables

Table 17 Wire marking of 1 kV cables

		Wire marking			
Type of cable		**by colours**		**by figures, colours or letters**	
		cables with green-yellow wire (letter "J")	**cables without green-yellow wire (letter "O")**	**cables with a green-yellow wire or with a wire marked with the letter J (letter "J)**	**cables without a green-yellow wire or without a wire marked with the letter 3 (letter "O")**
(1)		**(2)**	**(3)**	**(4)**	**(5)**
Compound-	single-wire	nf or sw		-	-

impregnated cables					
or plastic-insulated cable	two-wire	gnge/nf or gnge/sw	-	J-1	-
more than 35 mm^2	three-wire (also cables with concentric conductor or Al sheathing	-	nf/nf/nf or sw/sw/sw	-	1-2-3
	four-wire	gnge/nf/nf/nf or gnge/sw/sw/sw	nf/nf/nf/nf or sw/sw/sw/sw	3-1-2-3	1-2-3-4
NYY, NAYY, NYYd, NAYYd with a conductor cross section up to 2 35 mm^2	two-wire three-wire four-wire five-wire	gnge/sw gnge/b1/sw gnge/b1/sw/br gnge/b1/sw/br/sw	b1/sw b1/sw/br b1/sw/sw/br b1/sw/br/sw/sw	gnge-1 gnge-1-2 gnge-1-2-3 gnge-1-2-3 -4	1-2 1-2-3 1-2-3-4 1-2-3-4-5
Plastic-insulated cables	(2) direction wire in the outer stranding layer	gnge	br	gnge	-
with more than 5 wires	marked wire in each stranding layer	b1	b1	1 to 36(1)	1 to 37(1)
	other wires	nf or sw	nf or sw		

	other wires	nf or sw	nf or sw		

b1 blue, br brown, gnge green-yellow (for compound-impregnated cables green-natural-coloured), nf natural-coloured, sw black

(l) Sequence of figures 1 to 37 from inside to outside
(2) Seven-wire plastic-insulated cables have one gnge-wire, plastic-insulated cables with more than 7 wires do not have a gnge-wire. Deviations are possible.

Note: When using the gnge wire marking, one of these colours should cover not less than 30 % and not more than 70 % of the wire surface of each 15 mm long wire portion,

Cable designation

To get clear and full information of the specific technical construction of a cable and to avoid extensive description, standardized abbreviations for cables are also aimed at. The following markings shall also serve as an example:

- Insulating cover

Y PVC insulating cover
2Y PE insulating cover
O oil insulation

- Shield

H shield of wire

- Concentric conductor

For 1 kV cables with an electrically effective cross section of

Fa flat-wire aluminium
Fu flat-wire copper
Ra round-wire aluminium
Ru round-wire copper
For 1 kV cables with an electrically effective cross section of
Ca aluminium

Cu copper

- Sheathing

K lead sheathing
Ka aluminium sheathing
Y PVC sheathing

- Armour

B strip-steel armouring
Ba aluminium armouring
BY rigid-PVC armouring
R round-wire steel armouring
G anti-twist steel armouring

- Protective covering

A single protective covering

AA double protective covering
Y PVC protective covering

- Protection against corrosion

- K single protection
- KK double protection

(Letter is omitted for cables with sheathing or concentric conductors of aluminium.)

- Types of conductors

e single-wire
m multi-wire
r round
s sector-type

- Additional marking of constructional elements

o open-type armouring, e.g. Ro
w corrugated constructional element Kaw
z hardening additive Kz
v cross-linke
d 2Yv d twist-marked Yyd

- 1 kV cables

J with green-yellow wire or with wire figure

0 without green-yellow wire or without wire figure 0

- Examples

NYKY	plastic-insulated cable with Cu-conductors, lead sheathing and plastic protective covering
NAYKY	plastic-insulated cable with Al-conductors, lead sheathing and plastic protective covering
NAYY	plastic-insulated cable with Al-conductors and plastic sheathing
NAKY	paper-insulated compound-impregnated cable with Al-conductors, lead sheathing and plastic protective covering
•••• A	outer protective covering of coarse tow yarn or textile tape with semifluid compound and non-sticking coating
••• Y	with outer protective covering of PVC
••• BA	with strip-steel armouring and outer protective covering of coarse tow yarn or textile tape
••• RoA	with open-type round-wire steel armouring and outer protective covering of coarse tow yarn or textile tape
••• RG	with anti-twist round-wire steel armouring
NY2YHCaY	polyethylene-insulated cable with wire shields, concentric conductor of aluminium strips and flat-wire aluminium, PVC sheathing

Note:

In the case of copper conductors the A is omitted after the N in the abbreviation.

<u>Manufacturing types</u>

- Compound-impregnated cables

Paper-insulated power cables. Single-wire or multi-wire low-voltage or high-voltage cables with compound-impregnated or compound-impregnated and drained paper insulation. They may have a metal sheathing cladding all or individual wires and, in addition, special protective coverings, depending on the purpose of use.

- Belted cables

The simplest cable from the manufacturing point of view. They are produced with three or four wires.

- **Properties**

The poor thermal conductivity of the belt increases the heating of the cable. The impregnation compound presses outwards, cavities are formed inside. Increasing danger of glow discharge, enhanced by increased rated voltage.

- **Use**

In installations with rated voltages of up to 10 kV.

- Hoechstaedter cables (H-type cables)

Cables with individual shielding of the wires, without belt.

- **Properties**

The mutual contact of the wire shielding and metal sheathing (electrically conductive) restricts the electric fields to the wire insulation

- **Use**

In installations with rated voltages of up to 30 kV.

- Single-conductor cable

Differs from the normal construction of cables. Expensive manufacture.

- **Properties**

Good thermal conductivity, thus higher current-carrying capacity; high short-circuit strength (When laid on cable trays, registers etc. and on cable lifting points at terminal boxes, special measures of fixing of the cables may be required in view of the high dynamic effects of possible short-circuit currents); easy instal-lation and repair. Higher additional losses because of magnetic fields inside the cables and of mutual magnetic influence of several cables (three-phase systems)

- **Use**

In D.C. and three-phase installations of any rated voltage.

- Separate lead type cables (SL-type cables)

Combination of three single-conductor cables - without pressure protection and armouring - into one cable.

- **Properties**

The greater mass of metal (metal sheathings) results in better thermal conductivity, thus good electric shielding of the conductors against each other, reduction of losses.

- **Use**

In 20 kV and 30 kV installations.

- Plastic-insulated cables

Plastic-insulated cables are cables with plastic material used as insulating, filling and sheathing materials.

- **Advantages compared to compound-impregnated cables The costs of manufacturing and processing of plastic-insulated cables are considerably lower than those of conventional cable manufacture and processing. Advantages include: considerably smaller mass, better colour coding, higher elasticity and easier processing.**

- **Use**

In installations with rated voltages of up to 30 kV.

- **Types**

Cables with plastic-insulated cores and plastic inner sheathing, armouring and outer covering, such as NAYBY.

Cables with plastic-insulated cores, concentric outer conductor and plastic outer sheathing, such as NAYFaY.

The various plastic coverings are chemically composed according to the relevant purpose, i.e. sole purpose of insulation (dielectric strength, core insulation), sole purpose of filling (filling of cavities, filler material) as well as purposes of protection against chemical and mechanical influences (outer sheathing)

- **Polyethylene (PE) proved to be particularly suitable as raw material for core insulations**

and sheathings.

- Special-purpose cables

This term covers all cables for special purposes of use:

- **Power cables for ships NMYCY.**
- **Aerial cables NLAYYT, NLA2YvHCaeYT.**
- **Radiation-proof cables NXGG.-**

Such cables are exposed to extraordinary conditions at the place of installation, such as high thermal and chemical as well as extreme mechanical stresses.

- Plastic-insulated cables for control and information purposes They differ from power cables by a higher number of cores (7 to 37 cores) and a cross section ranging from 1.0 to 6.0 mm Cu and 2 2.5 to 6.0 mm Al. They are produced as plastic-insulated cables.

- **Properties**

Special colour code and a specific way of counting the cores.

Compared to multi-conductor cables of the same cross section, the load on the cores is considerably lower because of the very poor heat dissipation (massing of cores).

- **Use**

Such cables are generally produced up to a rated voltage of 1 kV only and used in heavy-current installations for measuring, signalling and control purposes.

4.7. Switching and distributing plants and accessories for the transmission and distribution of electric energy

4.7.1. Switching and distributing plants

Standard system of modular vessels

It is a modern system of modules that can be universally combined and be used in electrical and electronic engineering. Such a system enables a high packaging density in electrical installations/plants.

The vessels serve for covering and/or housing of components, modules, subassemblies, units and devices. The vessels can be classified in groups of order.

- Zeroth order vessels

Circuit cards, card plug-in units (non-protected), card inserts (non-protected)

Use:

The assembled printed circuit boards of standard sizes including plug-and-socket-connectors or terminal connectors are intended for use in vessels of 1st or 2nd order.

- First order vessels

Plug-in units and card inserts (protected), card plug-in units and card inserts (shielded), rack plug-in modules, rack inserts. Use:

As complete modules, mostly as self-contained functional units.

- Second order vessels

Sub-racks, plug-in subassemblies, subassembly inserts, card inserts.

Use:

As rigidly built-in or plug-in units they are used, for example, to complete the tiers in a cabinet. Together with the zeroth order vessels they fulfil the mechanical functions.

- Third order vessels

Built-in vessels, mounting vessels, box-type vessels, panel vessels, racks, cabinets, outdoor cabinets, control-room cubicles, consoles, desks.

Use:

They are the outer enclosure of the final product and have a decisive influence on the degree of protection, climatic class etc. Besides the front panels, they determine the shape of the final product. In connection with the 2nd order vessels they ensure the mechanical functions.

- Fourth order vessels

Subcarriers, plug-in unit carriers, insert carriers, mounting racks, swing-out racks.

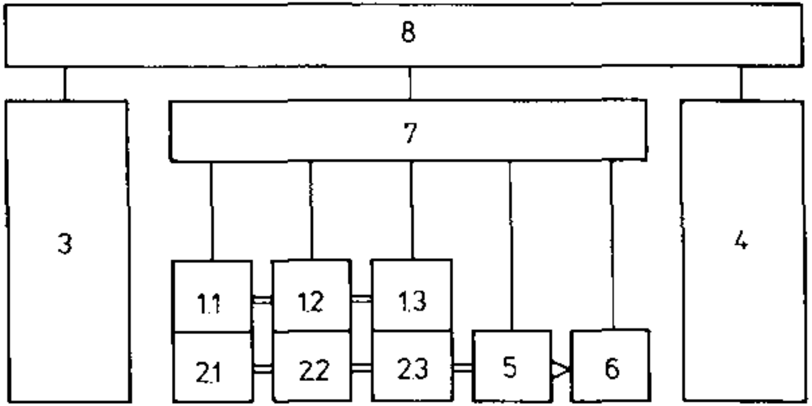


Figure 32. System structure of indoor switching plants using the standard system of modular vessels (1.1 switchboard section. 2.2 contactor section, 1.3 capacitor section, e.g. of 400 mm mounting depth), (2.1 switchboard section, 2.2 contactor section, 2.3 capacitor section, e.g. of 800 mm mounting depth), 3 subsidiary distribution, 4 energy distribution, 5 transformer box, 6 peak-load centre, 7 busbar module, 8 structural head of an indoor switching plant

<u>Indoor switching plants</u>

- Use

Switchboard sections, contactor sections and capacitor sections are intended for universal use as main and subsidiary distributions. All sections of the same mounting depth can be combined with each other. The sections of 800 mm mounting depth can be combined with transformer boxes into peak-load centres (see also Fig. 32).

- Construction

Each section has a busbar chamber, an equipment chamber and a cable termination and current bar chamber to connect the equipment modules.

- Equipment modules

Plug-in sub-units, plug-in units or inserts to be mounted in the sections. Plug-in units are connected through plug contacts, inserts are rigidly built in and connected.

- Sections

The different sections are:

- **Switchboard sections with on-load switches, power circuit breakers, fuses, contactors, no-load switches, relay modules for information processing.**
- **Contactor sections with contactor outlets for various circuits and rated currents.**
- **Capacitor sections with capacitors for power-factor compensation.**
- **Electric power distributors with power switches, NH-fuse outlets, break-jack points, busbars and/or combinations for use in power supply substations.**
- **Subsidiary distributions with current-limiting power switches, on-load switches and fuses.**
- **Transformer boxes with dry-type transformers up to 1000 kVA.**

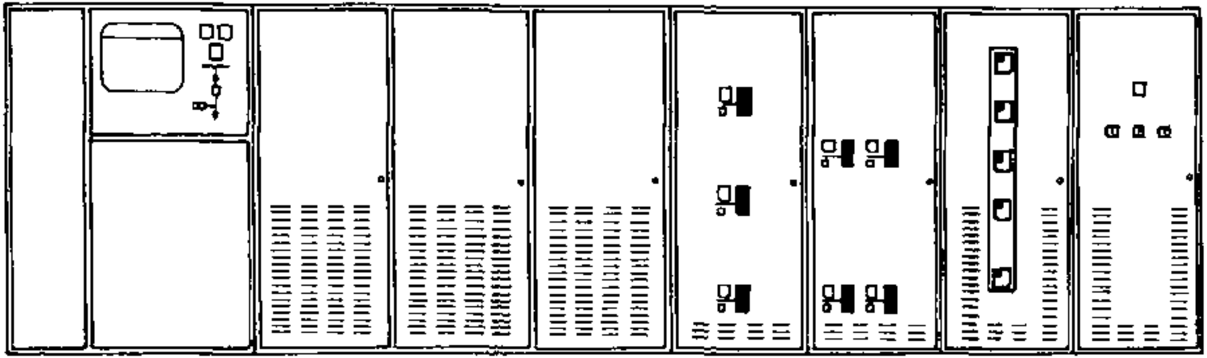


Figure 33. Front view of an indoor switching plant as peak-load centre (example)

<u>Sheet steel-enclosed low-voltage distributing plants (SLD system)</u>

The SLD system offers a variety of possible combinations with a minimum number of component parts.

- Construction

Sheet steel enclosure of standard size to house switchgear, transducers, meters, measuring instruments, transformers, pushbutton switches, signal devices and busbars. The assembled complete distributions are mounted on supporting racks.

- Use

Wherever electrical devices are to be protected against moisture, dust and mechanical damage. They are particularly suitable for industrial, mining and metallurgical operations and building sites.

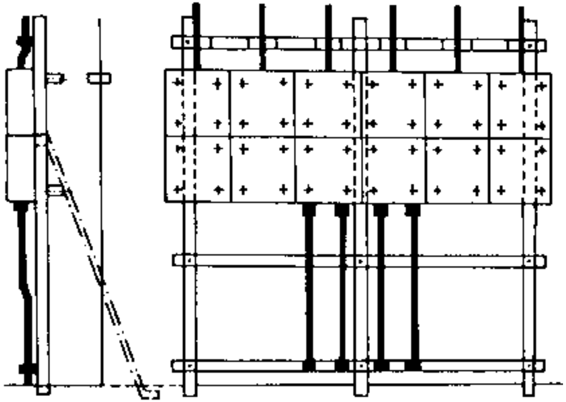


Figure 34. SLD mounted on supporting rack with connection lines

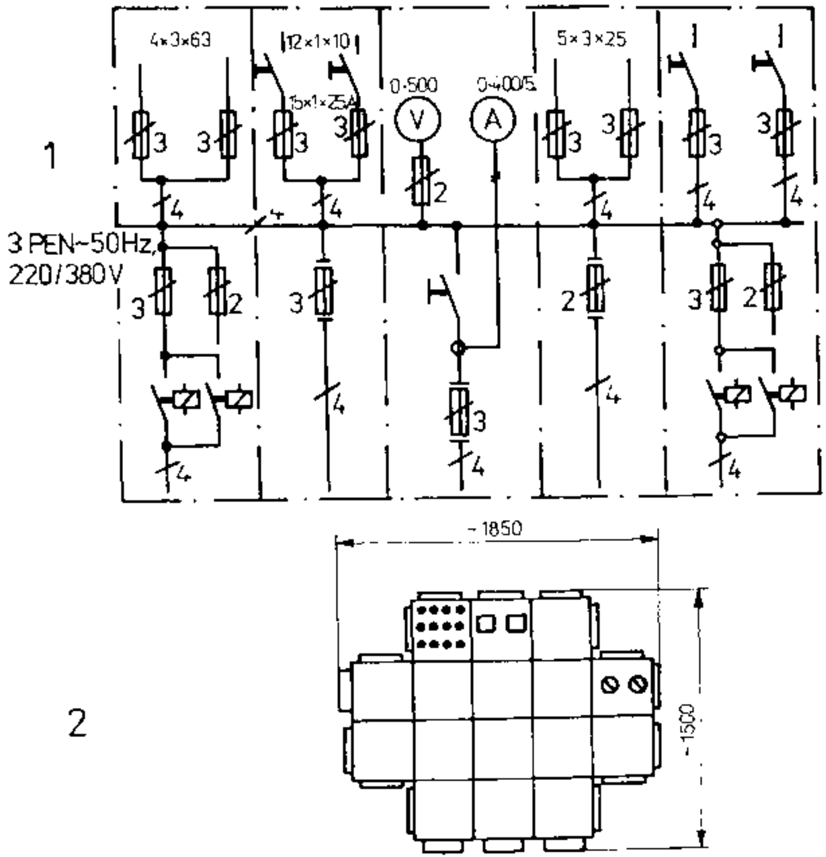


Figure 35. Example of a specifically assembled SLD - 1 general connection diagram, 2 assembly of casings

Standard Box System (SBS)

A metal (aluminium alloy) or plastic box with the relevant components already mounted by the manufacturer.

- Construction

Table 18 Metal type SBS for IP54 and partly for IP56

Empty boxes	Appliance boxes	Accessories
Screw caps (5 sizes)	Juntion boxes	Cable terminal boxes
	Fuse boxes	Flanged caps
	Barrier boxes	Insert bowls
Screw caps (4 sizes)	Switches	Sealing sheets
	Terminal boxes	Potential equalization rails
	Repair switch boxes	Quick-seal couplings
	Ballasts	Protective conductor rails
		Special accessories

Table 19 Plastic type SBS for IP 54

Empty boxes	Appliance boxes	Accessories
Screw caps (3 sizes)	Junction boxes	Cable terminal boxes
	Fuse boxes	Insert bowls
	Barrier boxes	Sealing sheets
	Terminal boxes	Protective conductor rails

	Base-mounted sockets	
	FDSP, 16 A	

- Use

- **Plastic boxes are only used in installations/plants with temperatures up to 60°C. They are very corrosion-resistant.**

- **Metal boxes are universally applicable under extreme conditions. The IP 56 version is mainly intended for use in shipbuilding.**

Low-voltage cabinet distributing system (LCD system)

- Construction

Sheet steel enclosure with mounting frame

The mounting frame serves for fixing of the devices and for holding of the device covers. After mounting and wiring it is bolted in the cabinet.

Cabinet distributors can be provided with D-fuse sockets up to B33, NH-fuse sockets up to size 1, gang switches up to 25 A, cam switches up to 100 A, air-break contactors up to IDS, motor protection switches, adapting transformers, automatic cut-outs and meter boards.

- Use

LCD systems are used in housing and social building construction, in industry and agriculture.

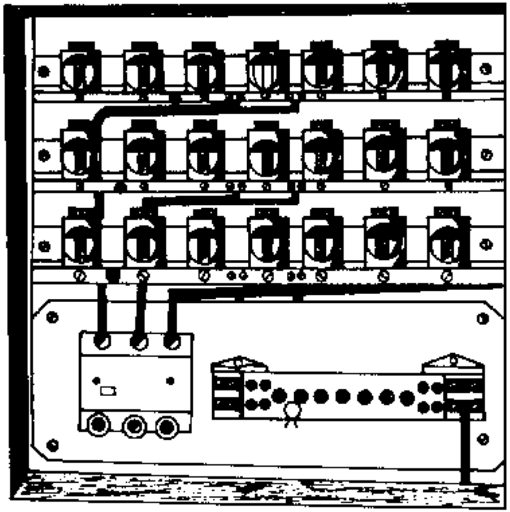


Figure 36. Example of a central house connection box

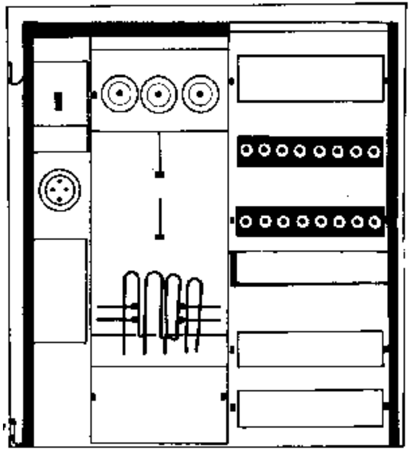


Figure 37. Example of a distributing cabinet for a house wiring system

Outdoor switching and distributing cabinets

Cabinets for switching purposes and distribution of electric energy, e.g. for use in the building industry, in traffic engineering, rail-way facilities, street lighting, agriculture, on building sites.

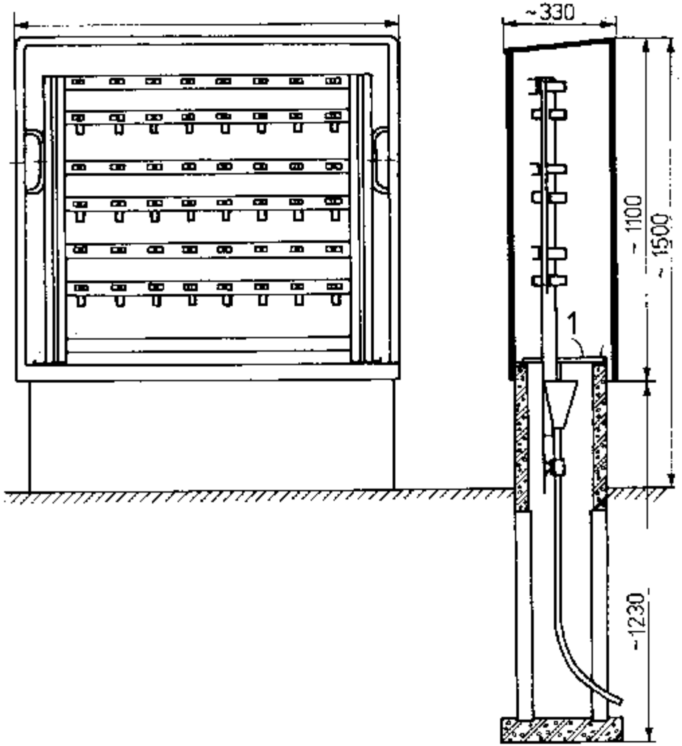


Figure 38. Example of a cable terminal box 1 equipment support

Medium-voltage switching stations, substations and transformer stations

- Switchgear cubicles (cells)

Of metal-enclosed or open (solid insulation) type, they are used as line and on-load switch cubicles, cable and measuring cubicles in switching stations for industrial power supply (metal-enclosed types) or in closed electrotechnical rooms, particularly for switching of transformers, and on heavy open-cast mining equipment (solid insulation).

Table 20 Technical data of switchgear cubicles

Switchgear cubicle	Insulation voltage		Rated current
Metal-enclosed type	12 kV		1250 A
			or 2500 A
Solid insulation type	36 kV		1250 A

- Substations

Buildings mostly constructed from industrially prefabricated assemblies, brickwork or concrete. They serve to transmit the electric energy through cables to the medium-voltage and low-voltage levels. They have separate medium-voltage and low-voltage chambers.

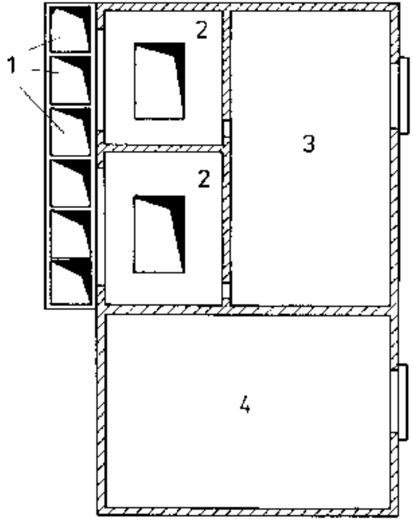


Figure 39. Example of the layout of a substation with cable connections - 1 cable entries/exits, 2 transformer chamber, 3 low-voltage switching plant chamber, 4 medium-voltage switching plant chamber

- **Equipment**

  - **• Medium-voltage switching plant 6 and 10 kV with semi-open or sheet steel-enclosed switchgear cubicles 15 and 20 kW with sheet steel-enclosed switchgear cubicles 30 kV with solid-insulation switchboard sections**

  - **• Low-voltage switching plant with indoor switching equipment having the following purposes or functions: connection of oil-filled transformers up to 1600 kVa, station service distribution, emergency power plant (accumulators),**

measuring processes, connection to earth, lighting installations.

- Transformer stations

Cable stations, overhead-line stations, pole stations and outdoor stations.

- **Cable stations**

Buildings of brickwork, concrete or industrially prefabricated assemblies. They are used as local network stations and for small or medium industrial plants.

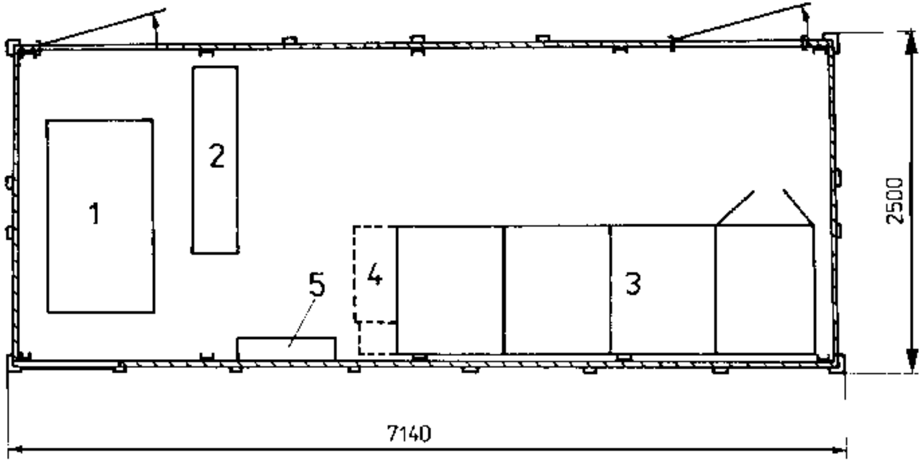


Figure 40. Example of a local network transformer station (layout) 1 transformer, 2 indoor switching plant, 3 switchgear cells. 4 relays, 5 accessories

- **Overhead-line stations Buildings like cable stations. They are used as terminal station or**

through-station for local networks and smaller industrial plants.

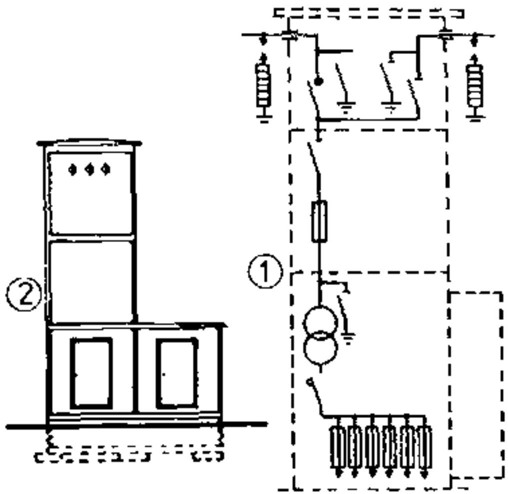


Figure 41. Example of an overhead-line through-station - (1) schematic circuit, (2) external view

- **Pole stations**

Transformers up to 160 kVA are erected on a platform at the overhead-line pole. They are used for overhead line systems in thinly populated areas with low power consumption.

- **Outdoor stations**

Transformer stations for temporary supply of electric energy for building sites, mining projects, mass events etc.

They are enclosed and can be moved on skids or wheels.

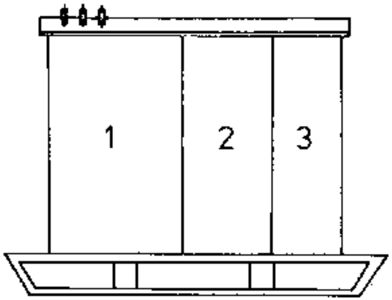


Figure 42. Schematic drawing of an enclosed outdoor station on skids - 1 medium-voltage switching plant, 2 transformer, 3 low-voltage switching plant

4.7.2. Switches

General

Switches are devices to open (break) and close (snake) current paths with all parts necessary for connecting or disconnecting firmly mounted on a joint base.

The force necessary for changing the switch position (ON/OFF) is provided by switch drives, such as

- **hand drive**
- **magnet drive**
- **motor drive**
- **compressed-air drive**

Low-voltage switches

The following types are in use:

- No-load switches

They must only be switched without load.

- On-load switches

They are designed for switching under load. Different types are:

- **Installation (or house-wiring) switches**

On-load switches designed for low-voltage electrical installations in rooms of residental buildings, industrial buildings and annexed buildings.

They are designed for a rated voltage of 250 V and for rated currents of 6 A and 10 A. They are classified according to

- • **the mode of switching (e.g. cut-out switch, two-way switch, intermediate switch), the mode of driving (e.g. toggle switch, rocker switch, rotary switch, push-button switch),**

- • **the type of installation (surface switch, flush switch, appliance switch),**

- • **the place of installation (e.g. moisture-proof switch, explosion-proof switch).**

- **Remote-controlled installation switches**

Electromagnetic switches controlled by a low voltage of 12 V or by 220 V

- **They are used in residental and social buildings.**

- Overload circuit breakers

They are mainly used as motor switches to master high starting currents. They are tested by 10 to 20 times the rated current. Different types are:

- **packet cam-operated switches,**
- **contactors,**
- **thermal relays,**
- **vacuum contactors,**
- **current-limiting power switches.**

High-voltage switches

The following types are in use:

- Disconnectors.
- Load-break switches.
- Power switches.

4.7.3. Accessories

For bare lines

- Holders:

insulated supports,
line-supporting fans or plates,
low-voltage and high-voltage overhead-line insulators,
bushing insulators.

- Line poles:

straight-line poles,
angle poles with anchors or ties,
terminal poles,
wooden poles,
reinforced concrete poles,
lattice steel poles.

- Conductor joints:

crimp joints,
screw and rivet joints,
cone joints,
seam joints,
jointing links,
jointing sleeves,
weld joints.

For insulated lines

- Holders:

clips (single and multiple types, nail, screw, louvre, spacer, series clips, anchor logs, register clips, single-tab and double-tab, with wall bolt),
supporting straps,
conduits,
duct systems,
surface sypes,
buried types,

bracing wire.

- Branch boxes, conduit boxes, switch boxes.

- Switches, sockets.

- Lighting fittings.

- Meter boards.

- Distributions.

<u>For power cables</u>

- Terminal boxes (sealing ends)

- **For plastic-insulated cables:**

  wrapping terminations (indoors),
  cast-resin terminations (outdoors).
  slip-on and casing terminations (indoors and outdoors).

- **For compound-impregnated cables:**

  cast-resin terminations (indoors),
  hose terminations (indoors),
  casing terminations (indoors and outdoors).

- Multiple-joint boxes:

For distribution of the individual cable cores of multi-core cables with joint sheathing.

Installation only in connection with single-conductor terminal boxes.

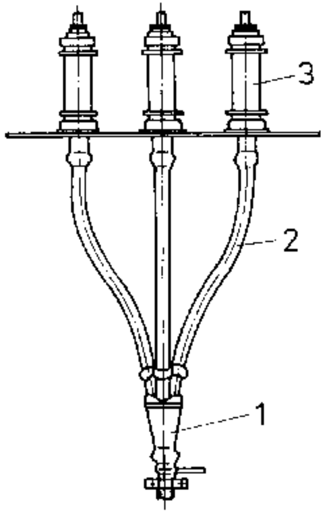


Figure 43. Multiple-joint box 1 multiple-joint box, 2 metal conduit. 3 single-conductor terminal box

- Distribution clips:

For distribution of separate lead type cables with each cable core with sheathing ending in a single-conductor terminal box.

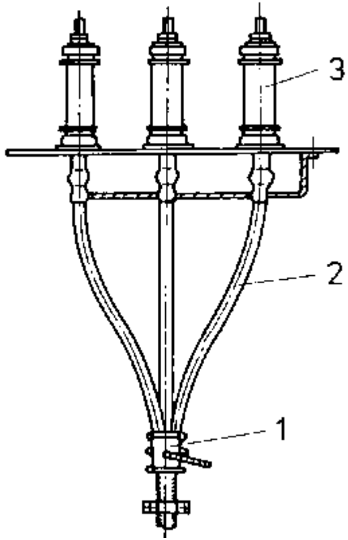


Figure 44. Distribution clip (end clip) 1 end clip, 2 metal sheathing, 3 single-conductor terminal box

- Cable sleeves.

- Compensation tanks:

For compensation of the quantity of the impregnation compound in compound-impregnated cable installations or for compensation of the oil pressure in oil-filled cables or oil-filled cable installations.

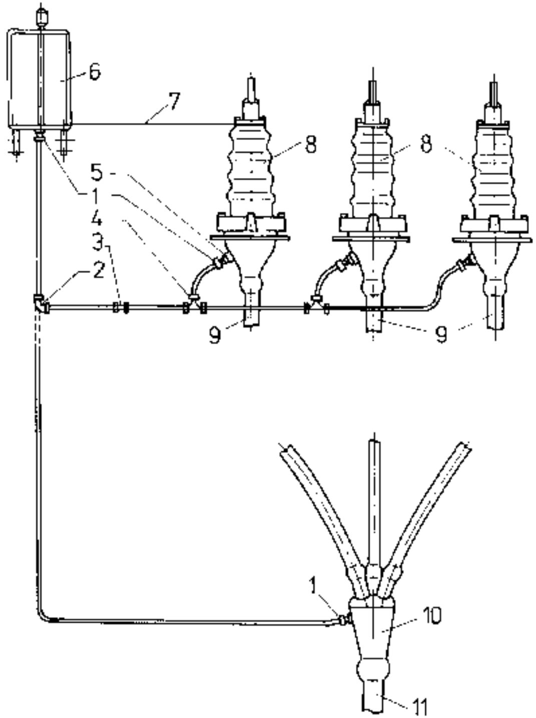


Figure 45. Example of a compound compensation tank arrangement 1 connecting piece, 2 formed bend, 3 joining piece, 4 joining T-piece, 5 connecting branch, 6 compound compensation tank. 7 minimum level of compensation tank, 8 single-conductor terminal boxes, 9 single-conductor or separate lead type cables, 10 multiple-joint box. 11 three conductor cable

4.7.4. Insulating material (insulators)

Purpose

Insulators shall insulate current-carrying electric conductors with respect to other conductive parts which are not intended for current conduction.

Materials

- Porcelain is the material mostly used. It is age-resistant, corrosion-resistant, has a high mechanical strength and is a good insulator. Porcelain is used for indoor and outdoor low-voltage and high-voltage installations.

- Thermoset plastic material is non-corrosive, has a high mechanical strength and is a good insulator but it is aging and temperature-sensitive.

- Hard paper (laminated paper) has a high mechanical strength, is a good insulator but sensitive to moisture and aging. Thermoset plastic material and hard paper are only used for indoor low-voltage installations.

Stress

- Electric stress

The insulators must be designed so as to preclude breakdown or spark-over from the electric conductor to parts of the installation which are not belonging to the electric circuit. Moisture and dirt deposit are favourable for voltage spark-over.

- Mechanical stress

The insulators in overhead-line installations are subjected to tensile stress to all sides. The tensile stress is constantly varying, depending on the weather conditions (e.g. wind,

hoar-frost, temperature variations) and the effects of electromagnetic forces between the conductors. In indoor installations there is mechanical stress only by electromagnetic effects between the conductors, i.e. by cantilever force and short-circuit force.

- Thermal stress

Temperature variations in the environment and in the lines have effects on the fastening elements between the conductor and insulator. Different heat conductivity and expansion coefficients result in mechanical stress which, in extreme cases, can destroy the insulator.

4.8. Laying of lines and cables

4.8.1. General

Damage to the conductor or insulator of any line or cable may occur as a result of improper transportation, wrong storage and inexpert laying as well as of fixing contrary to regulations. Insulated lines and cables are especially susceptible to damage.

Information required for the selection of lines or cables

Table 21 Information required for the selection of lines or cables

Type of information required	Explanation
1. Amount of load current	Operating current
2. Amount of rated voltage	Low, medium or high voltage

3. Type of laying medium	Air, water, soil
4. Type of laying	Single laying, parallel laying, bunch laying
5. Place of laying	Indoors, outdoors and in soil, in waters, in swampy ground, in corrosion-developing environment, on bridges and with altitude differences
6. Ambient temperature	Average operating values
7. Mechanical stress, if any	Impact, shock, compression, tensile or bending stress

In any laying of lines or cables it is to be guaranteed that the lines and cables are fail-safe. This includes

- protection against mechanical damage, e.g. by covering caps, conduits,
- protection against earth displacement, constant vibrations,
- protection against chemical damage,
- protection against excessive heat.

Mechanical stress

The lines and cables must resist bending, tensile and compressive stress.

To resist frequent, varying bending stress, the conductor can be divided into several partial conductors of small cross section. Bandages and armouring are measures to resist compressive stress.

Thermal stress

- Temperature

The temperature of a conductor depends on the current density (measured in A/mm). the material and the possibility of heat dissipation.

- Lines in bunches

Because of poor heat dissipation, lines laid in bunches must not be operated with the maximum admissible rated load.

- Admissible heating

Excessive temperatures cause damage to the insulation (increased brittleness, shrinkage effects and charring, considerably reduced dielectric strength) which may result in breakdown with total failure of the line or cable.

Laying temperatures

The laying temperature must not be less than the specified minimum temperature of +4 C because the cable insulation and sheathing material will get brittle at low temperatures. When the temperature of the cables to be laid is less than + 4°C, the cables must be warmed up in a 20°C to 25°C warm room, such as a preheating tent, for about 36 to 48 hours, depending on the cable length. The cables may also be preheated by resistance heating of the cores by means of a transformer suitable for this purpose. But the limiting temperature of the conductor must not be exceeded with any heating method.

4.8.2. Laying of lines

General

For fixed laying of lines (solid system of laying), types of lines intended for that purpose are to be used only.

The relevant type of line is to be selected depending on the place of laying.

Places of laying:

- **dry and sometimes damp rooms,**
- **damp or wet rooms or outdoors,**
- **in soil,**
- **in water,**
- **flush or buried,**
- **on the surface, on trays and supporting brackets,**
- **on wood, cardboard, particle board, fibre board,**
- **with the possibility of direct contact of the line.**

Laying problems

Lines, whether flush, buried or on the surface, are to be protected against mechanical damage not only during laying but especially under service conditions. Invisible lines should be laid vertically or horizontally to facilitate tracking of their course.

Mechanical protection

Uncovered lines, e.g. moisture-proof lines, must be protected by conduits at any points where mechanical damage may occur (breakthroughs in walls, ceilings/floors).

Heat accumulation

With the methods of laying in common use today, such as on trays, supporting brackets,

in ducts and conduits, the lines are laid in bunches. In each line bunch (single or multi-wire) and in each closed duct, heat may accumulate. In order to prevent accumulation of heat, the current load factor for the respective type of laying is to be taken into consideration in the selection of the line cross sections.

4.8.3. Laying of cables

Bending radii

In cable laying, when drawing off the cable from the cable drum and laying out the cable, e.g. with cable loops and cable connections the admissible bending radii are to be observed.

Table 22 Bending radii for power cables

Type of sheathing	Laying Position	Minimum bending radius
Lead and aluminium sheathing	during laying or bending final position	20 d 15 d
Plain aluminium sheathing	during laying or bending final position	25 d 20 d
Plastic sheathing	during laying or bending final position	15 d 10 d

Laying in soil

Laying of cables in the soil depends on the various different local conditions.

Table 23 Minimum laying depth with and without cable cover

Rated voltage	Type of cable	Dimensions Built-up ground with cover	Ground not built-up with cover	without cover
	-	m	m	m
up to 1000 V	with concentric conductor or metal sheathing	0.45(1)	0.7(1)	
	without concentric conductor or without metal sheathing	0.45	0.7	1.0
more than 1 kV	Compound-impregnated and plastic-insulated cables Oil-filled cables	0.7 1.0		

(1) Instead of the cover, warning tape is to be preferably used.

The minimum laying depth refers to the bottom edge of the top cable in one cable route. Laying depths of less than 0.7 m in public traffic areas are subject to the approval of the respective local authority.

Cables in cable trenches are to be arranged on a 10 cm thick coat of sand. Moreover, the cable is to be covered by another 10 cm thick coat of sand after laying. The top coat of sand is then to be covered by the cable protecting cover. The following cable protecting covers are in use:

- Cable protecting caps

It is to be ensured that the cable protecting caps covering the cable are filled with sand. Any cavity between the cable and the cable ducts will result in accumulation of heat which largely reduces the load-carrying capacity.

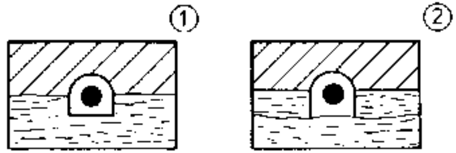


Figure 46. Cable protecting cover with cable protecting caps - (1) correct application, (2) cavity between protecting cap and cable

- Brick covers

Brick covers are low-cost protecting covers and enable quick and easy covering.

- Concrete covers

Instead of bricks, concrete slabs may be used. They should be generally used for laying of oil-filled cables.

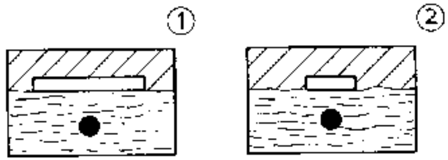


Figure 47. Cable protecting cover with concrete slabs and bricks - (1) with concrete slabs, (2) with bricks

- Cable conduits, moulded ducts

Cables run into buildings or under streets, rails and traffic-able ways require a high degree of mechanical protection. Conduits of clay, concrete or steel (not for single-conductor cables) are used for this purpose. If several cables are to be laid next to one

another, moulded ducts are used.

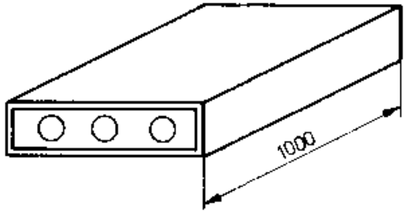


Figure 48. Moulded duct

For the transition from the covering protection to the conduit it is to be made sure that the cable is not subjected to compressive or shearing stress.

- Cable layout in the soil

If several cables are laid in one cable trench, the lateral distance between the cables should be about 7 cm. Deviations are possible.

If high-voltage and low-voltage cables are laid in one cable trench, the high-voltage cables are to be laid deeper than the low-voltage cables.

<u>Cable laying in the air</u>

Cables should be circulated by air from all sides. Complete air circulation will not always be possible, e.g. in closed cable registers and laying of cables in ducts. In such cases a reduced load is to be calculated.

- Cable runs one upon the other High-voltage cables on the lower registers, low-voltage cables on the upper registers. Cables in ducts must not be laid on the bottom since the

armouring would corrode in the event of intrusion of water. Cables intended for the protection, monitoring, control of plants or for transmission of information are to be laid separately from cables with rated voltages of more than 1 kV. Multi-conductor cables or cable systems with rated voltages of more than 1 kV should not be laid in layers one upon the other.

- Fixing of cables

Cables are to be fixed so as to prevent any deformation which is detrimental to the service properties. For cables on ceilings and walls it is also important to ensure good appearance.

<u>Table 24</u> Distances for support and fixing of multi-conductor cables

Distances: in metres			
Metal-sheathed cables		Plastic-insulated cables	
Support horizontal	**Fixing vertical**	**Support horizontal**	**Fixing vertical**
<1	<3	<1	<1
=	=	=	=

- Distances

A minimum distance of 2 cm between the cables and between the cable and the wall is to be maintained to prevent accumulation of heat in service.

<u>Laying in water</u>

Laying of cables through inland waters (e.g. rivers, lakes and channels)

Cables in the open sea are laid by specialized companies by means of laying ships.

- Types of laying

- **Laying on the bottom of stagnant waters.**
- **Laying in a dredged channel.**
- **Laying in conduits - only in brooks, ditches and rivulets.**
- **Setting of cables or cable conduits into the water bottom.**

- Type of cable

The cable must have a strong armouring and good protection against corrosion. Plastic covering or double protective covering of impregnated fibrous material (AA) is suitable for this purpose.

4.8.4. Electric connections

General

Conductors must be connected to machines and appliances, i.e. they must have an electrically conductive connection. A connection between conductors is also necessary. The connection must enable reliable flow of current from one conductor to the other one. That means, there must be good contact between the conductors at the joint.

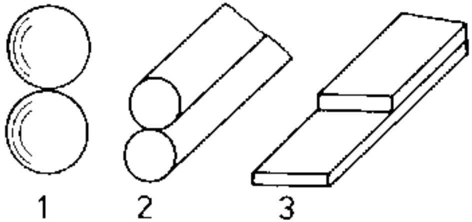


Figure 49. Types of contact - 1 point contact, 2 line contact, 3 surface contact

<u>Type of connections (joints)</u>

- Terminal connections:

- **screw terminals,**
- **spring terminals,**
- **eccentric terminals,**
- **cone-type sleeve terminals.**

- Plug-and-socket connections:

- **appliance connectors,**
- **plug-in contacts.**

- Wire-wrap connections.
- Soldered connections.
- Welded connections.
- Pressed connections.
- Sliding connections (sliding contacts).

<u>Questions for recapitulation and testing</u>

1. **What are medium-voltage systems?**
2. **What is the difference between open and closed systems?**
3. **What is the purpose of network system coding to IEC 445?**
4. **What is the importance of the voltage in plant engineering?**
5. **What are the effects of the intensity of current to be transmitted on plant engineering?**
6. **What does the term "distributing plant" mean?**
7. **How can the change of length of busbars caused by heating be coped with?**
8. **What is the basic construction of a line?**
9. **What is the basic construction of a cable?**
10. **What is the advantage of a standard system of modular vessels for electrical engineering?**
11. **What types of switching and distributing plants do you know?**
12. **What is the purpose of switches?**
13. **What materials are insulators made of?**
14. **What is generally to be taken into account in laying of lines and cables?**
15. **What is to be ensured in cable laying with cable protecting caps?**
16. **What is the purpose of electric connections?**

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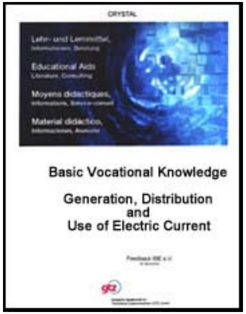


Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

5. Lighting installations and power installations

5.1. General

In practice there is a difference between lighting installations (for illumination purposes) and power installations (for driving purposes). The type of installation, the selection of the installation materials and of the protective measures to be taken against electric shock depend on the type of building and purpose of use of the building.

5.2. Classification

As a rule, the classification according to building aspects is as follows:

- Residential buildings:	Domestic facilities in individual and communal buildings.
- Industrial	Illumination and power installations of various voltage levels in plants of the light

- Industrial buildings:	Illumination and power installations of various voltage levels in plants of the light, heavy and chemical industries.
- Social buildings:	Illumination installations, scene illumination installations, advertisement illumination installations, power installations and information systems for theatres, cinemas, film and TV studios as well as electrical installations for kindergartens, schools, old-age homes, meeting rooms, department stores, etc.
- Agricultural buildings:	Illumination and power installations for livestock breeding, feed-stuff preparation, milking machines, grain drying and storage.
- Medical buildings:	Illumination installations for sickrooms, operating theatres, consulting rooms, power plants for hospitals, outpatients' departments, nursing homes.

In addition there are special installations as well as staff locator, intercom and warning systems.

Special installations They are generally classified in three fields:

- locations with explosion hazards,
- locations with explosive hazards,
- locations with fire hazards.

They include underground installations, installations in spray-painting equipment, storage rooms for inflammable liquids and gases, working rooms with heavy dust generation, such as coal crushing mills, corn mills, storage rooms for explosives, buildings of easily inflammable materials, such as wooden huts, camping houses and camping cars.

Recommendations for the specific design of the respective installations are given in national standards and international recommendations (IEC).

Staff locator, intercom and warning systems

Staff locator, intercom and warning systems are an important part with independent functions of special power electronic installations. Their main purpose is the protection of people but also of the installation equipment part of which they are. Staff locator systems are installed in hospitals, old-age homes and hotels. An indicator board, for example, indicates where help is needed.

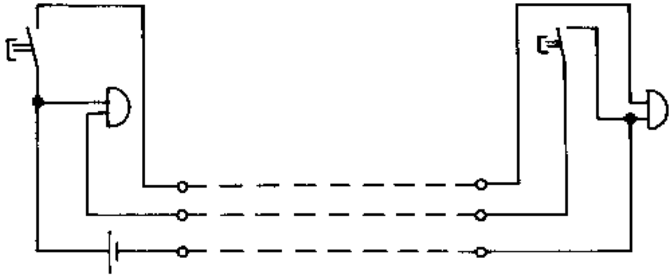


Figure 50. Staff locator system with one supply source

Figure 51. Staff locator system with two supply sources

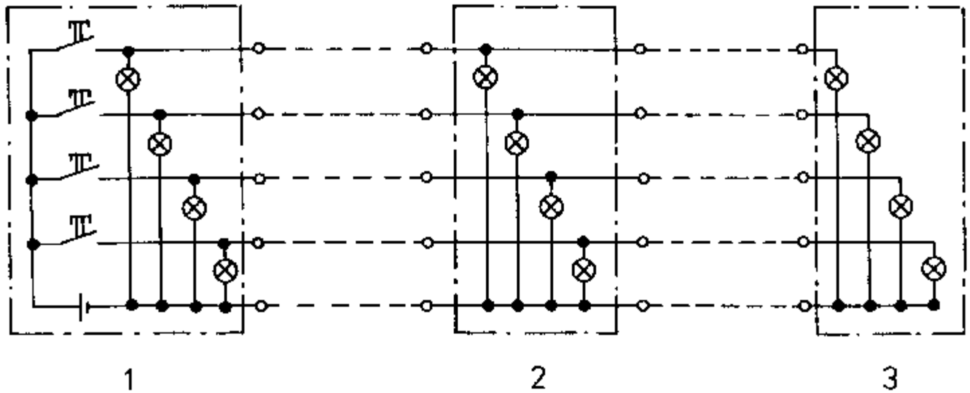


Figure 52. Light call system - 1 light call centre, 2 indicator board 1. 3 indicator board "n"

Intercom systems serve for communication in industrial plants, mines, etc. but also in residential areas.

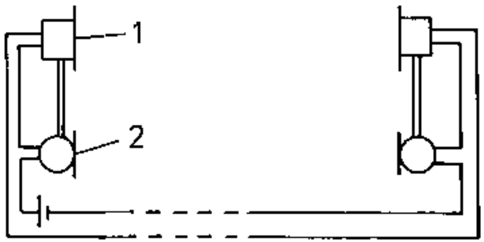
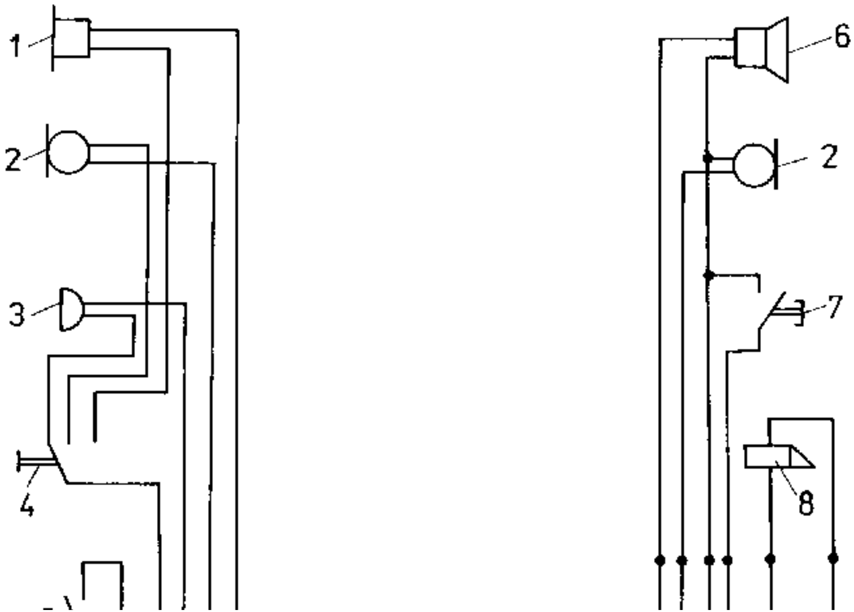


Figure 53. Intercom system (version 1) - 1 receiver, 2 microphone

Figure 54. Intercom system (version 22)



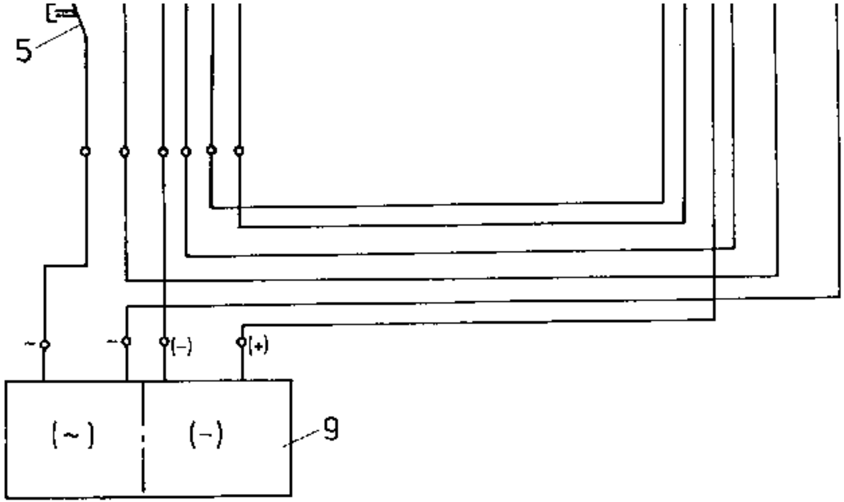


Figure 55. Intercom system with door opener - 1 receiver, 2 microphone, 3 signal transmitter, 4 change-over switch, 5 door-opening key, 6 loudspeaker, 7 calling

Warning systems are normally designed for specific purposes, such as burglar alarm, fire alarm, smoke indication, moisture indication, gas indication, etc. Figure 56 shows the basic circuit of a warning system and Figure 57 a glass door with foil strip safety system.

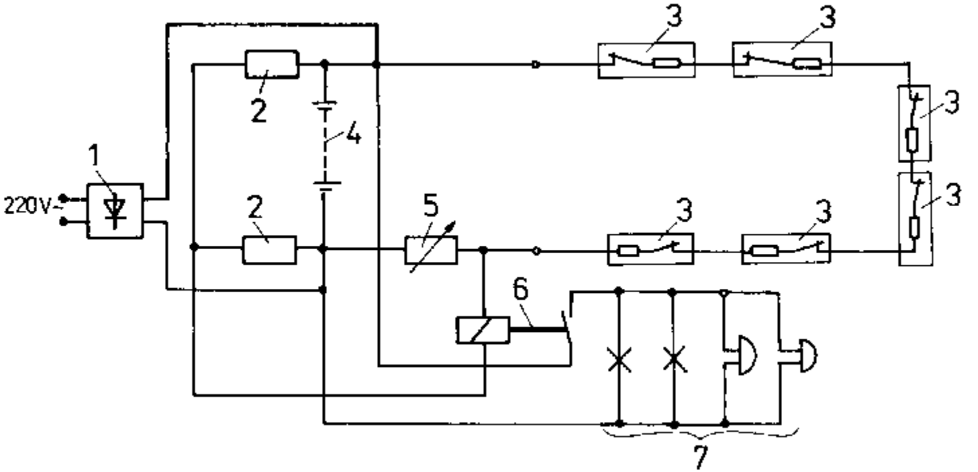
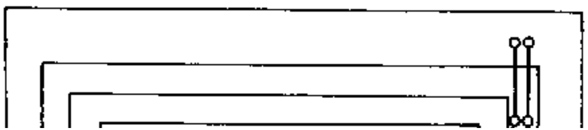


Figure 56. Warning circuit (schematic circuit) - 1 power supply unit. 2 bridge resistors, 3 door contacts with resistors, 4 buffer battery, 5 bridge adjusting resistor, 6 contactor, 7 optical and sound signal transmitters

Explanation of Figure 56:

The resistance bridge is tuned to balance with the bridge adjusting resistor. No voltage is applied to contactor (6) and the contactor does not pull up. If, for example, a burglar bridges a door contact (3), the balance is changed, the contactor will close the circuit and operate the signal transmitters. The same applies to any line interruption.



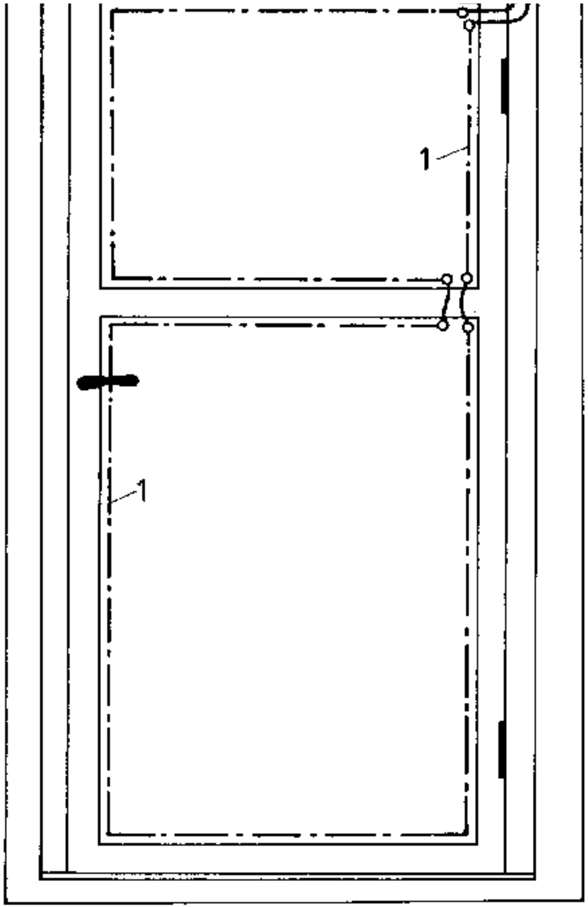


Figure 57. Glass door with foil strip safety system - 1 foil strip (conductive)

5.3. Installation types and systems

Once the application as differentiated under subsection 5.1. above is known, the type of installation and installation materials are to be selected. There is a difference between

- **installation in the building and**
- **installation at the building.**

Installation in the building

Installations in walls, ceilings, floors, machines and equipment. In this case, mechanical protection is provided by the building. Specific installation types or systems are applied, depending on the type of building and the relevant purpose of use.

Installation at the building

Installation types and systems to meet the requirements of environmental conditions, electric load, aesthetical aspects, specific purpose of use and laws of economical use of material. Nowadays solutions for repeated application are aimed at because production changes by the user of the plants call for variable installations.

Internationally there is but little standardization of the variety of installation types and systems. Normally there are only national specifications. The following list shall give a survey of different installation types and systems:

Installations

- Fixed installations

- **Conventional installation**

- • **Buried (concealed)**
installation The installation material is embedded in the brickwork and covered by plasterwork.

- • **Flush installation**
The installation material lies on the brickwork and is enclosed by plasterwork (flat lines).

- • **Surface installation**
Plastic-insulated cables in clips on the plasterwork, pipe installation on the plasterwork, plastic ducts on the plasterwork (see systems).

- • **Bracing wire installation**
Plastic-insulated cable wound around bracing wire and fixed to the bracing wire at certain intervals.

- **System engineering**

- • **Current bar systems**

- • • **Bar duct systems**

Bare conductors insulated against each other and mounted in a sheet metal duct. Current tapping is easy through so-called adapters at certain intervals.

- • • **Current paths**

Enclosed system for electric energy transport in the form of a contact line. “Intervention” is not possible. The trolley is movable along the system.

• • • Plug-in lines

Enclosed current-carrying system in a rigid duct at the front of which tapping of electric energy from the inside of the duct is possible through plug-in units (adapters).

Cable and line systems

Underfloor systems

screed-covered systems
screed-flush systems
concrete-embedded systems
feeding systems
connection systems
steel cell systems
hollow ceiling systems
double floor screed systems
double slab systems
ceiling duct systems

• • • Surface-type systems
wiring duct systems
strip duct systems
wall duct systems
parapet duct systems
column installation systems
light fitting installation systems

- Movable installations

• Installations subjected to low mechanical and thermal stress. Base material: plastic hose lines.

• Installations subjected to high mechanical stress. Base material: rubber sheathed cables (cab-tyre lines)

• Installation subjected to high mechanical and chemical stress.

Base material: rubber sheathed cables (cab-tyre lines), (oil-resistant)

• Installations subjected to high mechanical and thermal stress.

Base material: silicone rubber sheathed cables.

5.4. Installation technology

The installation types and systems need to be mounted by various mounting technologies. Processing differs internationally and largely depends on the existing possibilities.

<u>Mechanical fixing of the components</u>

- Doweling techniques

- **screwing**
- **nailing**

- Bolt firing and setting techniques
- Cementing techniques

- **epoxy resin adhesives**
- **other highly volatile adhesives**

- Screwing and welding techniques
Mechanical engineering techniques to process cable trays.

Electric connections

- Soldering techniques

- **soldering-iron soldering**
- **blow-pipe soldering**

- Pressing techniques

- **notch-type connection**
- **hexagon connection**
- **flat plug connection**

- Screw terminal connection as conventional connection technique.

5.5. Cost/benefit and environmental considerations in the technological preparation of electrical installations

The preparation of a basic decision as to the erection of an electrical installation must include studies of the external conditions, such as

- system solutions at choice,

- environmental influences on the plant (e.g. temperature, moisture, vibrations),

- influences of the plant on the environment (e.g. noise by transformer plants, deforestation for overhead-line routes, hazards of contamination of drinking water catchment areas by the use of oil-filled cables where oil may penetrate in the

event of failure),

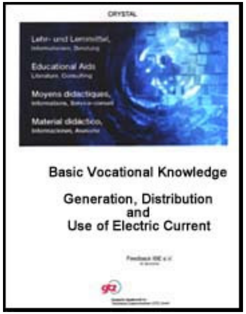
- qualification of the installer and future user of the plant,

- use of existing technologies and working tools.

The development of sites is also an important cost consideration, such as transportation routes, power supply, storage facilities, etc. The electrification of a relatively small town/village or factory in an undeveloped terrain, possibly even a well-wooded area, for example, will be less expensive and less harmful to the environment if isolated operation is envisaged. That means, the erection of a diesel-electric station (so-called mini power plant) avoids the deforestation (which is of heavy ecological impact) for an overhead-line route for external power supply which itself would be very costly. Today it is not enough to decide just on the basis of the costs involved in the erection of an electrical installation but the operating expenses and possible consequential damage are also major considerations. The operating expenses also include costs of service and qualification of personnel. In other words, the more intricate the erection of an installation, the higher the current costs and the total costs at the end.

Questions for recapiutlation and testing

1. How are electrical installations classified?
2. What are installation systems (system solutions)?
3. What is the prevailing technique of connecting aluminium conductors?



6. The use of electric current by the various groups of consumers (assignment)

This section does not deal with the current simply as dimensioning quantity but with the basic quantity for the consequences caused by the various consumers in the different networks, such as conduction losses with the specific conductor heating, voltage drops as well as electromagnetic effects on the immediate environment of the line system carrying the current. The current networks are either D.C. (direct current) or A.C. (alternating current) systems. A.C. systems may have different frequencies, such as 16 2/3 Hz, 50 Hz and 60 Hz to name only the most usual ones. The D.C. and A.C. voltage levels differ very

much nationally and internationally with only a few equal international levels. In addition to the known A.C. voltage levels of 220 V. 380 V. 500 V and 600 V and D.C. voltage levels of 220 V, 440 V, 600 V, 850 V, there is a great number of other voltages. However, there is a move towards international standardization. The assignment of consumers is always to be seen in connection with the type of current concerned. Basically, four different effects of the electric current are used:

- **heat effect (heating/cooling),**
- **light effect (lamps, projectors, tubes),**
- **magnetic effect (electromagnet, electric motor),**
- **chemical effect (accumulator, electrolysis, melting furnace).**

A very low percentage of the electric energy generated by power stations can be stored in pumped storage power stations. Most of it is to be supplied to immediate consumption otherwise it will get lost. It is the task of the electric power industry to match the quantity of electric energy to be produced with the consumers demand for electric energy at any moment. This is done by switching on and off generators in the power plant. The available service energy is used by public, private, industrial, agricultural and cultural consumers.

Public consumers include:

- **local traffic and long-distance traffic including industrial railways,**
- **street lighting including illumination of buildings, monuments and advertisement spaces,**
- **municipal water supply and disposal with all electrotechnical equipment, e.g. pumps, compressors, valves and gates,**
- **postal service including communications, broadcasting service and newspaper service.**

Private consumers use electric energy primarily for

- **illumination and cooking (lamps, stoves, ranges),**
- **washing (washing machines),**
- **cooling (refrigerators, freezers),**
- **heating (smoothing irons, hair dryers),**
- **entertainment (radios, TV sets, sound equipment),**
- **medical purposes (infrared radiators, solar radiators etc.),**

The industrial consumers are the biggest group of consumers, such as

- **transformers, electric motors, converters,**
- **annealing furnaces, melting furnaces, welding equipment,**
- **machines, controls, hoisting machinery,**
- **electroplating equipment, electrolysis,**
- **data processing equipment, information equipment, etc., etc.**

The agriculture has also a high degree of electrification by

- **pump and compressor equipment for irrigation and drainage,**
- **fodder preparation equipment, harvesters and threshers,**
- **milking machines, incubators,**
- **hot-house and greenhouse equipment (illumination, special radiators),**
- **air conditioning plants,**
- **grain draying plants.**

The cultural sphere consumes a considerable quantity of electric energy for representation and scene illumination purposes. Air conditioning plants, hoisting machinery, transport equipment, water supply and disposal as well as advertisement are the main applications.

The afore-mentioned list indicates the variety of consumers within the individual groups of consumers. And, moreover, the habits, production cycles, national time cycles and climatic conditions as well as the relevant rates/charges have a decisive influence on the daily routine and load cycles within each group of consumers. The energy consumption is not continuously distributed over the whole day! So the consumers are also to be actively influenced to reasonably use electric energy!

Question for recapitulation and testing

1. Why is it difficult to calculate the consumer's behaviour?

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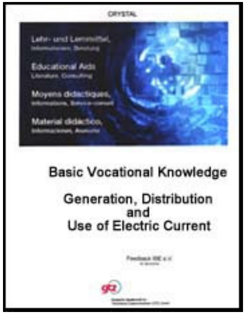

Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

Generation, Distribution, Use of Electric Current - Basic vocational knowledge (Institut fr Berufliche Entwicklung, 141 p.)

7. Measuring technology of checking electrotechnical installations and equipment and of permanently controlling the main parameters in operation (I, U, P, Wh, Q,)

7.1. Measuring and testing methods applied before and during the installation

Before any plant is installed, i.e. before lines or cables have a fixed location within the installation, and before the plant is put into operation, the lines and cables are tested for their "insulating property" and for continuity. Such measuring and testing methods are applied to find out, before and during the installation, any insulation defects and line interruptions.

7.1.1. Visual inspection

Line material and switching devices are visually inspected to find out any damage to the insulation material (damaged insulators, hair cracks in varnished and glazed surfaces, spark-overs and breakdowns, inexpertly installed switching and measuring devices, manufacturing faults, wrong safety distances, etc.).

7.1.2. A.C. voltage testing

The dielectric strength (insulating property) of the plant is tested by means of a high test voltage. The level of the test voltage depends on the insulation group and purpose of testing.

Table 25 Test voltages and testing times for installations up to 1000 V

Rated test voltage of installation			Testing time
	up to 100 V	500 V	2 s
120	up to 300 V	1500 V	2 s
300	up to 1000 V Un + n	1000 V	2 s

The testing time depends directly on the purpose of testing and on the faults to be found out, such as:

- smaller distances than the minimum specified,
- air inclusions and impurities in insulating material,
- mechanical defects of insulating parts.

The tests are carried out with A.C. voltage testers.

7.1.3. Lightning-stroke voltage testing

The insulation of the electrical installation is exposed to the operating voltage ranging from 80 to 120 % of the rated voltage on the one hand and to external overvoltage (so-called lightning-stroke voltage or lightning surge) and internal overvoltage (so-called switching surge) on the other hand. These two voltages enormously differ from the operating voltage with respect to the voltage increase and frequency. Spark-overs and breakdowns in ths insulation result in considerable voltage stress of the installation.

The tests are carried out with so-called lightning-stroke voltage testers which can generate voltages of up to 10 kV, in exceptional cases up to 20 kV.

Electric power supply plants must be subjected to a so-called type acceptance test including A.C. and lighting-stroke voltage tests. During the final acceptance test, when the plant is to be put into operation, it can be decided on the basis of the plant type and location whether A.C. voltage testing and/or lightning-stroke voltage testing is to be carried out.

7.1.4. Measuring of the insulation resistance

The quality of the insulation of a product depends on the value of the insulation resistance. Reduced insulating capacity is detrimental to the function of a product as well as to the safety of the user of a plant. An insulation resistance of 50 is ths admissible minimum. A product with a lower insulation resistance is fit for limited use only (dry rooms, site insulation). Measuring of the insulation resistance can be applied instead of insulating property tests as per subsections 7.1.2. and 7.1.3. above.

Normally the insulation resistance is measured by way of a hand generator or electronic insulation measuring device.

The recommended values for the insulation resistance "Riso" are:

- For new installations or parts of installations $10\frac{K\Omega}{V}$

- For installations in operation $1\frac{K\Omega}{V}$

- For installations with rated voltage of 100 V or less, 100 Ωm, if the total line section is 100 m. For greater lengths the insulation resistance R_{Ired}= 1005 Ω m is reduced to the following formula:

$R'_{Ired} = R_{Ired} \frac{100}{1_G}$ (G: total length)

- Moreover, $50 \frac{\Omega}{V}$ applies to damp installations in operation

7.1.5. Testing of single parts of installations, such as cables, for their insulating property

Cable installations are generally subjected to insulation tests on completion of the installation. The tests are carried out with rated voltages of up to 1000 V for information cables and power cables as well.

A minimum resistance of 5 megaohms per km of cable is to be measured for the cores to each other and for each core to earth. The testing times differ, depending on the cable capacity saturation. The insulation test should be carried out with lightning-stroke voltage. Cables with Un of more than 1 kV are to be tested with testing voltage. D.C, voltage is applied. The testing time is 10 minutes. A sheathing-earth test is necessary for checking the cable sheathing in the case of plastic covering.

7.2. Measuring and testing methods during operation

Electrical installations must be checked for their parameters in regular intervals (prophylactic service) or in the case of need (faults). Specific measuring and testing methods are applied for this purpose. Commercially available measuring devices are suitable for direct measurement, i.e. measurement without converter, only for the

parameters of up to 100 V, up to 6 A and up to 1 kW.

In the interest of the size and weight of the devices, they are not designed for higher measuring values. Any quantities of higher value to be measured are to be adapted through converters, multipliers or shunts.

7.2.1. Testing methods (examples)

- Conductor break or conductor interruption is signalled at the end of the cable by means of indicator lights.

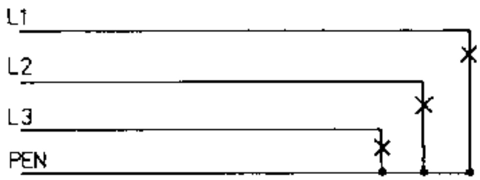

Figure 58. Test circuit with indicator lights

- A supervisory relay automatically cuts off the installation in the event of failure of an outer conductor.

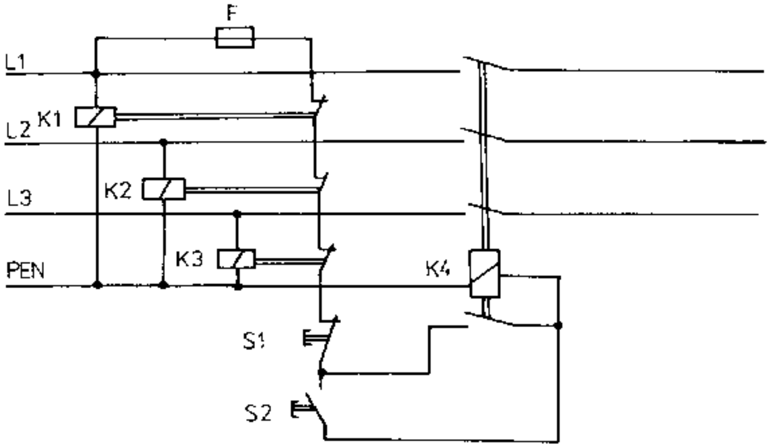

Figure 59. Supervisory circuit with relays K1...K3 supervisory relays, K4 contactor, F fuse, S1 off-key, S2 on-key

- When a neutral fault-voltage switch is used, the installation is cut off in the event of earth leakage of the neutral conductor (7 V or more) because of heavy asymmetry of load.

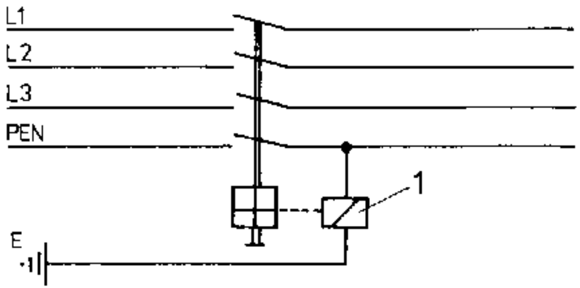

Figure 60. Neutral fault-voltage circuit 1 neutral fault-voltage switch

7.2.2. Measuring methods

Laboratory measurements

Laboratory measurements are carried out to determine parameters (e.g. resistance, power) of consumers with no indication of electric quantities. In this way, the actual electric quantities are determined.

Specific circuits are used, depending on the size of the test object and on the amount of the measured value to be expected.

The following circuits are prevailing:

- **Direct correct-voltage measurement For a voltage of 380 V or less since the multiplier is built into the device as standard. A current of up to 6 A can be measured.**

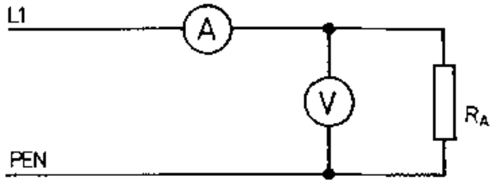

Figure 61. Direct correct-voltage measurement - A amperemeter, V voltmeter, R_A load resistance (consumer)

- Direct correct-current measurement

Unlike correct-voltage measurement, the current is measured here without the instrument current of the voltmeter. That means the consumer current or correct current is measured exclusively. The amounts of voltage and current are the same as above.

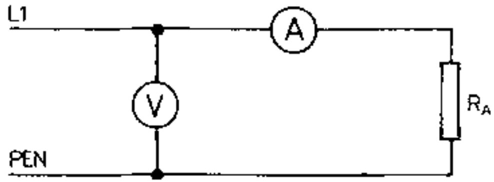

Figure 62. Direct correct-current measurement legend like Fig. 61

- Semi-indirect correct-voltage measurement For a voltage of up to 380 V and currents of more than 6 A.

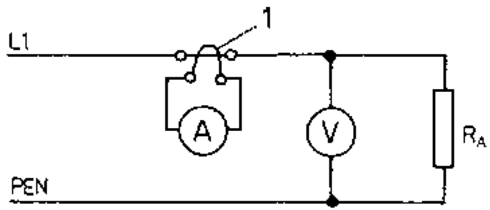

Figure 63. Semi-indirect correct-voltage measurement legend like Fig. 61, 1 current transformer

- Semi-indirect correct-current measurement
For currents of more than 6 A and voltages of up to 380 V.

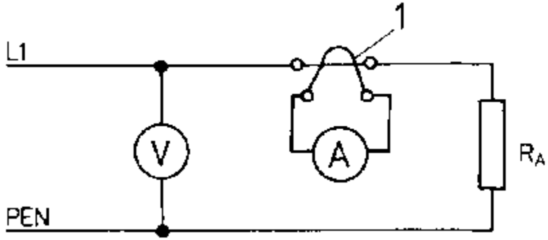

Figure 64. Semi-indirect correct-current measurement legend like Fig. 63

- Indirect correct-voltage measurement
For voltages of more than 380 V and currents of more than 6 A.

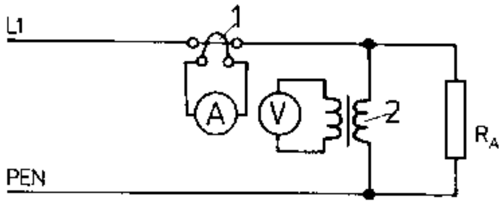

Figure 65. Indirect correct-voltage measurement legend like Fig. 63, 2 voltage transformer

- Indirect correct-current measurement
For currents of more than 6 A and voltages of more than 380 V.

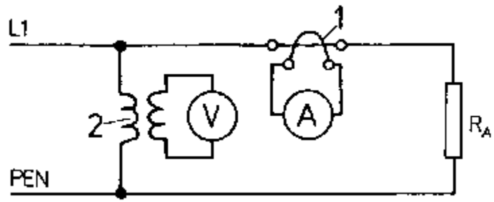

Figure 66. Indirect correct-current measurement legend like Fig. 65

Operational measurements of voltage

The mains voltage is measured in two circuit configurations, i.e. conductor voltage (conductor to conductor)

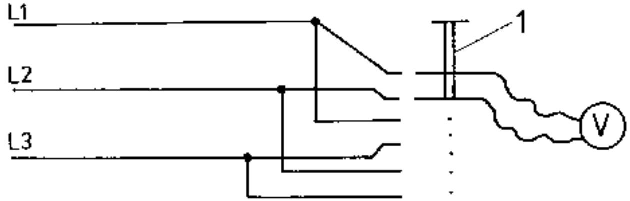

Figure 67. Conductor-to-conductor voltage measurement 1 change-over switch

- conductor-earth voltage (conductor to earth and conductor to zero).

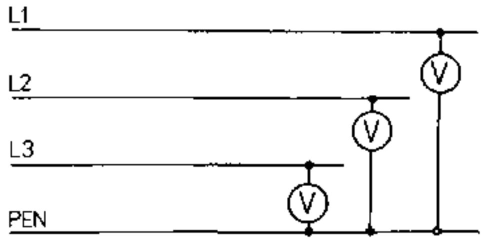

Figure 68. Conductor-to-earth/zero-voltage measurement

In symmetrically loaded sections of lines (such as motor taps) it is sufficient to use one instrument with change-over, if necessary.

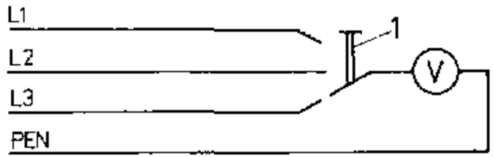

Figure 69. like Fig. 68 but with one voltmeter 1 change-over switch

<u>Power measurements</u>

The electric power of consumers is measured by means of power meters with the following circuit configurations:

- Measurement in a single-phase A.C. system

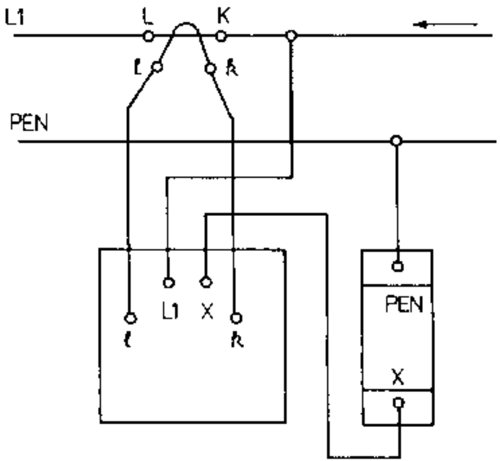

Figure 70. Power measurement in a single-phase A.C. system

- Measurement in a symmetrically loaded three-wire system

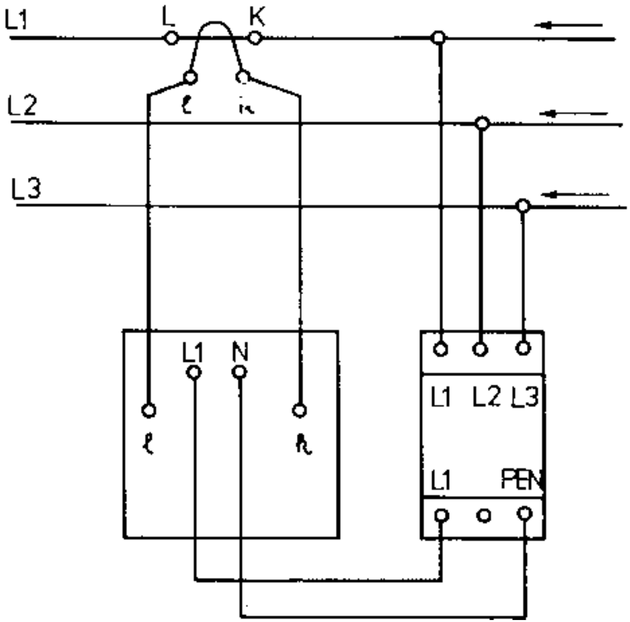

Figure 71. Power measurement in a symmetrically loaded three-wire system

- Measurement in an asymmetrically loaded three-wire system

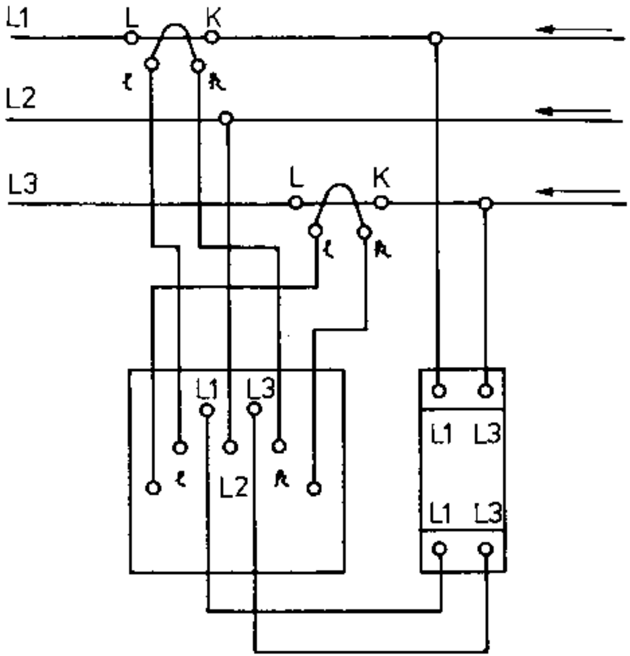

Figure 72. Power measurement in an asymmetrically loaded three-wire system

- Measurement in an asymmetrically loaded four-wire system

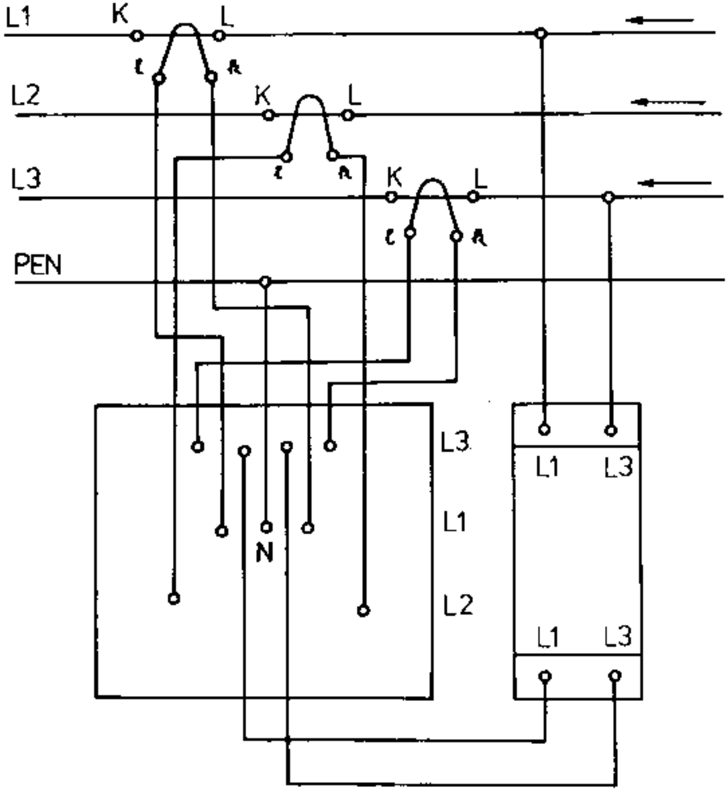

Figure 73. Power measurement in an asymmetrically loaded four-wire system

Measurement of electric work (energy)

For the energy generating (supplying) industry it is important to know the electric energy

taken by the consumer from the supply mains.

It is the basis for active-energy meters (which do not take into account the reactive energy).

Examples of circuits:

- Circuitry of a single-phase A.C. meter

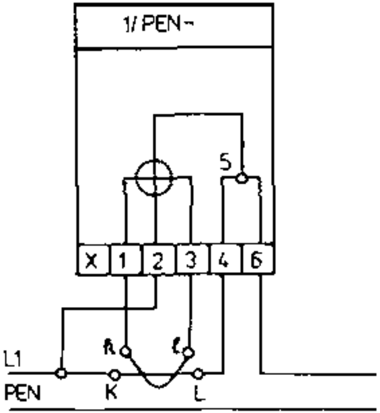

Figure 74. Circuit of an A.C. meter

- Circuitry of a three-phase meter with two measuring systems.

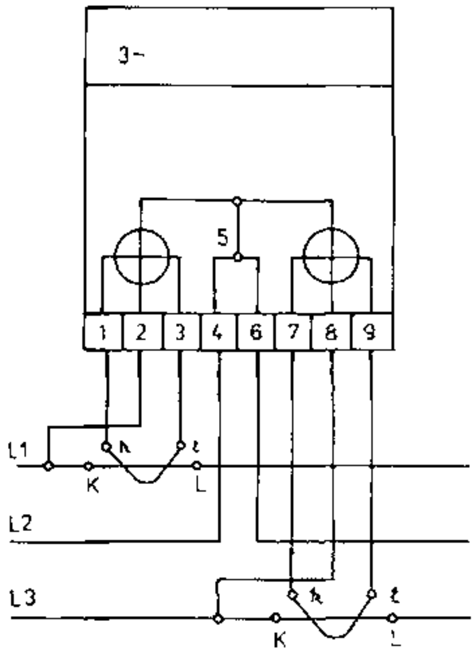

Figure 75. Circuit of a three-phase meter with two measuring systems

- **Circuitry of a three-phase meter with three measuring systems.**

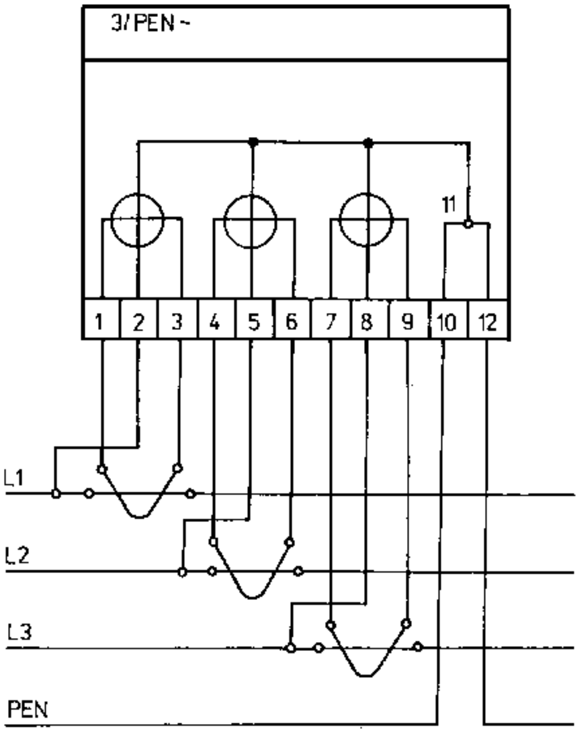

Figure 76. Circuit of a three-phase meter with three measuring systems

<u>Measurements of the power factor</u> p The ratio of active power to total power (y) is indicated by the cos- -meter (or power-factor meter). Circuit examples:

- Circuitry in an A.C. system

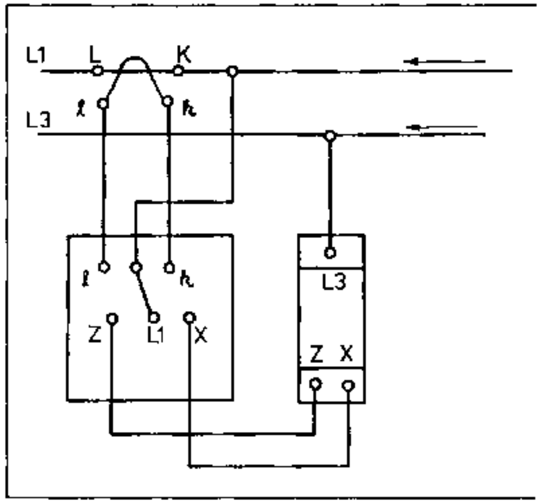

Figure 77. cos- -measurement in an A.C. system

- Circuitry in a three-phase system

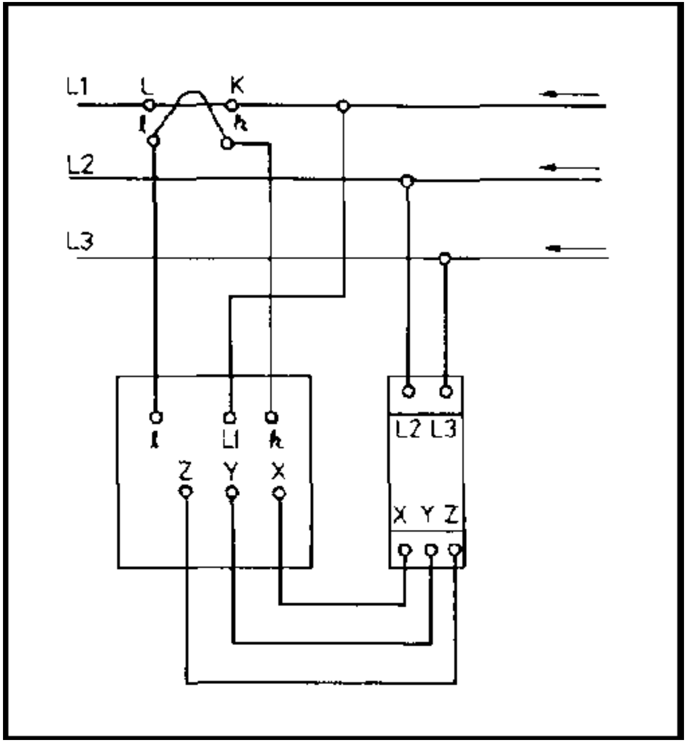

Figure 78. cos- -measurement in a three-phase system

Questions for recapitulation and testing

1. What tests are to be carried out in an installation before it is put into operation?
2. What devices can be used for insulation resistance tests of an installation?
3. What are the recommended values for the insulation resistance?