ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

FAKULTA ELEKTROTECHNICKÁ

INTRODUCTION TO ELECTRICAL ENGINEERING

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PREFACE

The primary objective of this textbook is to familiarize students with the occupational safety and health concerns which should be inherent to every electrical system. In designing, operating, and maintaining electrical systems, the engineer must consider the occupational and environmental hazards associated with electrical components as well as the safety of the surrounding community from fires and explosions.

Textbook “**Introduction to Electrical Engineering**” is intended for the students of the first and the second semesters of study at Faculty of Electrical Engineering for all study programs of bachelor's degree. This book serves as educational tool to preparation for the written test "Safety in Electrical Engineering ” (in accordance with the requirements of Decree No. 50/1978.).

The purpose of the course is to give the students basic knowledge of electrical equipment and installation as to avoid danger arising from operation of it. In this way the students receive qualification of instructed persons that enables them to work on electrical equipment, which is necessary for their study.

The first edition of this textbook was published in 1994, the second in 1996.The third edition in 2003 and the new one were revised and adapted according to the current stage in the sphere of technical regulations and standards.

We wish to thank Mr. Vincent Csirik for reviewing our work.

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Authors

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1. VALID TECHNICAL RULES

There exist many spheres of human activities. Performing these activities, people come into contacts one to another as well as to the whole society. Laws, notices, directions, etc. serve for the legal arrangement of human relations. Technological and scientific activities represent a sort of very important human activities bringing a lot of important gains to the mankind.

We cannot imagine our life without products based on advanced technology. Electrical light, central or gas heating, hot water in our homes as well as the utilization of telecommunication services, computers, TV sets, etc. belong to our everyday life. Technological activity as other activities, e.g. commercial and social ones, call for a legal frame.

Following legal technical rules related to the sphere of electrical engineering and to the people working in this sphere are valid in the Czech Republic:

1) Act No. 22/1997 on the Technical Requirements for Products and on the Amendments to Some Acts.
2) Notice No. 50/1978 for the determination of qualifications for persons working in touch with electricity.
3) Notice No. 73/2010 on the important electrical equipment, installations, and plants.

1.1. The Act No. 22/1997 (Technical Requirements for Products)

deals with technical regulations, standards and obligations of producers, importers and distributors of products in its first part. Second part of this act deals with state testing which is a complex of activities the purpose of which is to ensure the assessment of conformity of products valid in the Czech Republic. The non-obligatory requirements of standards should be fulfilled as well. But there is a little difference between these two types of requirements. In this case, the producer or installer can proceed in a way different from the way complying with the requirement given in the standard. The assumption for doing that is that the solution chosen by him fulfills the aim of the standard and that all participants, i.e. the competent authority as well as customers, are satisfied with this digressed solution.

The act is based on the following principle. Everybody who has anything to do with manufacturing and distribution of any product shall care for safety of anybody who will to buy or hire it. For that reason he shall keep and maintain rules according to the Act. The basic aim of this act is to create legal conditions to distribute only safe products. For that reason it is necessary to define this aim as well as to create a system for reaching it. This system is based on **technical regulations, standards, harmonized standards and different levels of authorization**. According to this Act it is possible for the authorities to use penalties as a tool to force producers as well as businessmen and dealers to follow this act.

Act No. 22/1997 brings folloing definitions:

product - any thing that has been manufactured or otherwise gained and is intended to be placed on the market,

technical regulations - legal regulations published in the Collection of Laws of the Czech Republic which includes technical requirements for products or related mandatory production, checking, recording and other administrative procedures,

standards - documents created according to this Act and marked with letters „ČSN“ publication of which has been announced in the Official journal of the Czech Office for Standards, Metrology and Testing,

harmonized standards - standards determined for the meeting of technical requirements of technical regulations,

authorization - entrusting of a legal entity with the activities concerning conformity assessment of products specified under this Act,

product conformity assessment - a process result of which is the statement whether the properties of the product are in conformity with the requirements of the technical regulations,

declaration of conformity - a written declaration with a statement that the product conforms to the requirements of the technical regulations and that this declaration is the result of the specified assessment procedure. The producer or importer shall issue this declaration before the product is placed on the market.

According to the Act, the producer and importer is obliged to place on the market only products, which are safe.

A product is considered safe when it complies with the requirements of the respective technical regulation. The compliance of the product with this regulation is deemed to be fulfilled when it complies with standards harmonized with the technical regulation.

There exist a system supporting procedures of production and distribution of safe products. There are activities connecting with testing and certification of products. There are different rules in different technical regulations considering testing and certification. Sometimes it is obligatory to let the product test in independent and authorized testing laboratory, sometimes it is not necessary nevertheless it could be advantageous for the producer to support its own declaration of conformity of the product with the certificate of independent authorized entity.

A producer or importer may place a specified product on the market only after the assessment of the conformity of this product. Products shall comply with requirements concerning their safety. These requirements are specified in these Act and technical regulations. Requirements of technical regulations are more or less of legislative nature and of frame character. In particularities they are specified by harmonized standards. The basic difference

between technical regulations and harmonized standards is that Technical regulations constitute part of the Czech legislation and disobedience of them is to be penalized. Harmonized standards as well as other technical standards are voluntary documents. This is advantageous to keep them because when following harmonized standards relevant to technical regulation valid for product protects the producer against braking regulation. Nevertheless it is possible to manufacture the product without using harmonized standards. In this case it is necessary to prove that the product is made and distributed according to the regulation another way than prove that the product is meeting the requirements of relevant standards. This is true that it is necessary usually only in case of some accident. Then it is very difficult to show that everything was all right, only the standards were not used.

There are 14 or 16 of technical regulations according to the Act No. 22/1997 published nowadays in form of government order and number of them is increasing continually. This is not any secret that the system of technical regulations and harmonized standards was created according to the European system, i.e. system of directives of the European community and European harmonized standards. We will not speak about all of them. We will mention some of them concerning electrical engineering.

Government order No. 168/1997 on low voltage equipment

is laying down technical requirements relating to electrical equipment designed for low voltage. It is a legislative basis for the construction of the most of electrical products. This order gives particular requirements concerning assessment and declaration of conformity and in its annex is laying down principal elements of the safety objectives for electrical equipment. Shortly saying:

The **general characteristics** concerning safe use of electrical equipment as well as the manufacturers brand name shall be marked on it, and electrical equipment should be so designed and manufactured as to ensure protection against the following hazards:

Hazards arising from the electrical equipment, above all, i.e.

a) danger of physical injury or other harm which might be caused by electrical contact direct or indirect;
b) high temperatures, arcs or radiation which would causes danger;

Hazards which may be caused by external influences on electrical equipment, i. e.

a) mechanical impacts and other mechanical influences;
b) expected environmental conditions (temperature, humidity, radiation etc.);
c) foreseeable conditions of overload (overcurrent).

Government order No. 169/1997 on electromagnetic compatibility

covers nearly all kinds of electrical apparatus. The order itself does not specify emission limits and immunity levels but transfers this task to relevant standards. This order gives some principles for certification and conformity declarations. Because of a little complicated situation in the field of assessment of products according to relevant standards, cost of testing equipment, it is advisable to cooperate with the relevant authorities.

Government order No. 170/1997 on machinery

gives requirements concerning assessment and declaration of conformity, which is necessary to maintain for every machine. In its annex a long list of essential health and safety requirements to which all machines are deemed to comply. Requirements concerning electrical equipment of machines are among them. These are requirements for safety connected with reliable operation of control systems actuators. These requirements are valid preferably for electrical equipment of machines. To give the industry and users a convenient tool to cope with this order a system of European standards was developed. There exist a system of European standards for electrical equipment of machines inside of the whole system of standards for machinery.

Government order No. 178/1997 on products used in building construction industry (civil engineering)

gives a space for authorities in the process of assessment products. There exists an important clause, which assumes that all products used in the sphere of civil engineering and in building's construction shall be used in sensible manner. That means according to electrical equipment that all elements of electrical installation shall be used according to regulations for electrical installations (wiring regulations). That is the reason why among standards harmonized to this order are basic standards for electrical equipment and installations.

1.2. Notice No. 50/1978 (qualification of persons)

deals with the qualification of persons working on electrical equipment. The reason for publishing this notice was evident. When constructed or operated in an inappropriate way, electrical equipment may cause a danger for persons, livestock, as well as for property. Therefore persons immediately constructing, producing or repairing the electrical equipment, installation, etc., as well as people operating complicated electrical equipment (electrical station, substation, etc.) shall be people with definite qualification in order not to endanger themselves or other people with their activities. The qualification of persons intended for the work and operation on electrical equipment follows the rule: "the more difficult, complicated, and dangerous the work is, the higher qualification shall the competent person fulfill". There are three basic qualifications of persons in relation to the work on electrical equipment and installation. These are:

ordinary person - person who is neither a skilled person nor an instructed person - person without electrical qualification,

instructed person - person adequately advised or supervised by skilled persons to enable him or her to avoid dangers which electricity may create,

skilled person - person with relevant education and experience to enable him or her to avoid dangers which electricity may create.

The three categories of qualification mentioned above are not the Czech specialty; they are used in Europe and all over the world. But in the Czech Notice No. 50/1978 the detailed division of the qualification of skilled persons is given. Any skilled person may not do any activity in the field of electrical engineering. That is the reason why, according to the Notice No. 50/1978, the qualification of "skilled person" is subdivided into categories such as:

- skilled person determined for mounting of electrical equipment and installation,
- skilled person for designing of installations,
- skilled person supervising the work on electrical equipment,
- skilled person verifying electrical equipment and installations.

In particular cases some of above mentioned categories can be combined so that one skilled person can have the qualification for mounting of an installation as well as for verifying it.

The Notice No. 50/1978 shall also be fulfilled in case of persons educated in any electrical branch. Such persons shall fulfill the requirements for instructed persons, i.e. for persons familiar with the dangers connected with electricity and able to avoid such dangers. And that is also the purpose of this course - to give you the basic knowledge of electricity - as much as to be able to recognize the danger of electricity and to avoid it.

1.3. Notice No. 73/2010 (important electrical equipment)

There are many electrical equipment and installations used in industry, commerce, culture, and other spheres of human activities. All electrical equipment and installations are not of the same importance. Damage or failure on some installation may cause serious difficulties in industry (e.g. failure of electrical station may cause injury of electrical furnaces and material melted in them) as well as in everyday social life (e.g. failure in protection against overcurrent. Defective dimensioning of cables in installation may cause fire; the fire hazard is extremely high in buildings for cultural purposes, where many people may be gathered, i.e. in theatres etc.).

For that purpose Notice No. 73/2010 distinguishes installations according to their importance and gives the rules how to proceed in cases of installations and equipment of various importance.

Competent authority shall approve the design of the most important installations and equipment. An independent technician charged by competent authority shall verify the less important ones. For the making of installations and equipment without any particular importance, it is sufficient when done by competent electrical firm having full responsibility for making and verifying them.

2. BASIC ELECTROTECHNICAL STANDARDS

2.1. General

In the technical sphere, the legal rules obligatory given in laws, acts, notices, orders, regulations and directives cannot prescribe the detailed technical performance of an equipment, installation or appliance as to fulfill the concepts of safety, reliability, and maintainability. The described rules for the technical performance of products (e.g. machines, appliances, and devices) mounted parts, and for technological procedures are given in technical standards. Technical standards are not obligatory in the way of legal rules but the fulfillment of the requirements of technical standard can prevent from many difficulties connected with legal rules. One of the basic legal rules prescribed in many laws is the rule prescribing that nobody shall endanger anybody. And manufacturing products or assembling equipment that is not safe may endanger the purchaser. That is just the violation of law, which can be penalized.

Present-day technology as well as present-day equipment and products in the field of the electrical engineering are so complicated that keeping to the safety rules is very difficult, therefore these rules are comprehended in technical standards. If the producer keeps relevant standards, he can be almost sure that his products will not endanger any customer. Moreover - in case that a product complying with the relevant standard causes a damage, the position of the producer is much better than the position of that one whose product does not comply with the standard.

Technical standards are not papers or brochures independent one of the other. It is impossible for any standard to represent full set of technical requirements for the given type of product, equipment, or installation. Nowadays, technical products are so complicated that technical requirements for one type of equipment, device, appliance, or installation cannot be comprehended in one standard only. Technical standards form huge, more or less compact systems. Such systems are formed in electrical engineering as well. Let us investigate such systems.

Most of products of electrical engineering are to be used by persons. The utilization of it is connected with danger of harmful effects of electrical current to persons and, may be, to livestock. To prevent the danger means to fulfill respective requirements of the respective standard. Nevertheless, the standard applied for the product cannot prescribe all measures that could or should be done. The conception of safety in electrical engineering is given in basic safety standards. The rules of safety for groups of products are given in group safety standards. The standard respective for a given product does not repeat all safety requirements but it only refers to basic or group safety standards.

There is a similar situation in case of environmental or atmospheric conditions effecting the product as well as in case of electromagnetic compatibility (effects of electromagnetic fields or disturbing voltages or currents on products).

Besides these standards, there exist the so-called standards with horizontal function. Those are the standards we use - or we should use - not only in connection with the other standards but also at the usual technical work. Among these standards we can count terminological standards, standards stating nominal or rated values of voltages, currents, frequencies, standards comprising symbols for diagrams and for the use on electrical equipment, devices, or appliances.

Therefore product standards, i.e. standards immediately used for the design and construction of some products, usually consist (especially in the field of the electrical engineering) of many references to basic or group standards (for the problems of safety, electromagnetic compatibility, environmental conditions, etc.). Product standards use terminology, symbols, and nominal or rated values given in horizontally functioning standards as well.

2.2. International and European standardization

And now let us read something about the origin of standards. Standards in the sphere of electrical engineering belong to the oldest technical standards. First rules for basic use of electricity were created in the second half of the last century - at first for the use of the telegraph and then for the safe use of electrical light. Some papers unifying description of characteristics of materials used for electrical purposes were written in the second half of the last century as well. The rules for the use of electricity became the origin of a big group of standards, electrical rules (wiring regulations, electrical code - how these rules are called in some countries). The papers stating quality of materials became the origin of another big group of standards - material or product standards.

Very soon it became evident for electricians of many countries that the international exchange of information in the sphere of electrical engineering is inevitable. Many international electrical conferences took place at the turn of the 19th century. On the occasion of one of them, in the year 1904 in St Louis (USA), it was decided to establish an international organization dealing with standardization in the sphere of electrical engineering. The organization was established at the constitutive meeting in London in 1906 and it was named International Electrotechnical Commission (the internationally used abbreviation is IEC - based on the English name, or CEI - based on the French name). International standards published by IEC form the basis for regional and national standards. They may be used both directly as well as for the preparation of specifications for international trade. IEC international standards (they may be called world standards as well) cover the entire range of electrical and electronic engineering.

The IEC is composed of National Committees from about 40 countries. These countries comprise 80 % of the world 's population and consume about 95 % of the world 's electrical

energy. The IEC standards are prepared by more than 200 specialized committees and are adopted and published by the consensus of National Committees.

The Czech Republic is a member of IEC and its membership is the continuation of the membership of the previous Czechoslovak Republic since 1919.

The IEC works in close co-operation with many international organizations, including the International Organization for Standardization (ISO), which is responsible for international standards in non-electrical fields.

In some geographical regions, regional standardization organizations have developed. The development of regional standardization organizations in Europe has a long history, beginning with the year 1926, when the IFK (Installation Fragen Kommission - Installations Tasks Committee) was founded. That was the committee of European electrical testing laboratories, who prepared safety rules for electrical household appliances and installation devices as well as testing rules. The activity of the committee continued after World War Two under the new name and abbreviation: International Commission on Rules for the Approval of Electrical Equipment - CEE. Nowadays, this commission merged with IEC under the abbreviation IECEE after American, Japanese, and other laboratories joined this originally European organization. Nevertheless, the rules published by CEE are in function till now because they lay the basis for many IEC standards as well as for European Harmonization Documents serving for the unification of standards of European countries within the framework of CENELEC.

CENELEC - The European Committee for Electrotechnical Standardization (the abbreviation is from the French name - Comité Européen de Normalisation Électrotechnique) - was founded in 1973. CENELEC consists of National Electrotechnical Committees of West European countries. The Czech Republic is a member of CENELEC since 1997 (its membership followed a period of its affiliation CENELEC).

The main purpose of CENELEC is to remove any differences of technical nature among national standards of CENELEC member committees or among national measures applied to the certification of conformity which may give rise to trade barriers.

European Standards (EN) and Harmonization Documents (HD) are either endorsed or published as national standards. A stronger rule for publishing applies to European Standards so that now a pressure is made by European Community to publish almost exclusively European Standards. Nevertheless, there are fields where national traditions of European countries are so strong, e.g. in case of installation rules, that it is necessary first to bring the national rules closer to one another on the basis of Harmonization Documents. Then, after that first step, to unify the rules by European Standards that are to be published as national standards in every European country.

In many cases the development of standards unification went this way. In case of electrical installations where Harmonization Document HD 384 (based on IEC Publication 364) is applied, the development is likely to proceed similarly.

2.3. IEC Basic Standards

The list of IEC basic safety standards is shown bellow. (In the right column the number of corresponding European standard is available).

Short-time tests

IEC 60112	Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions	HD 214
ICE 60587	Test methods for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions	HD 380

Terminal marking and other identifications

IEC 60073	Coding of indicating devices and actuators by colours and supplementary means	EN 60073
IEC 60445	Identification of apparatus terminals and general rules for a uniform system terminal marking, using an alphanumeric notation	EN 60445
IEC 60446	Identification of insulated and bare conductors by colours	EN 60446
IEC 60447	Standard directions of movement for actuators which control the operation of electrical apparatus	EN 60447
IEC 60757	Code for designation of colours	HD 457

Insulation co-ordination for low-voltage equipment

IEC 60664	Insulation coordination for equipment within low voltage systems (including clearances and creepage distances)	HD 625

Tests

IEC 60068	Tests (vibration, bump, climatic tests etc.)	EN 60068

Electrical installations of buildings

IEC 60364	Electrical installations of buildings	HD 384
IEC 60364-4-41	Part 4: Protection for safety. Chapter 41: Protection against electric shock	HD 384.4.41
IEC 60364-5-54	Part 5: Selection and erection of electrical equipment.	HD 384.5.54

	Chapter 54: Earthing arrangements and protective conductors	
IEC 60449	Voltage bands for electrical installations of buildings	HD 193
IEC 60479	Effects of current passing through the human body	
IEC 60536	Classification of electrical and electronic equipment with regard to protection against electric shock	HD 366

Degrees of Protection by Enclosures

IEC 60529	Classification of degrees of protection provided by enclosures	EN 60529

Fire hazard testing

IEC 60695	Fire hazard testing	EN 60695

We shall follow basic IEC safety standards, IEC standards for electrical installations (preferably with the first number 364) and other helpful IEC materials (such as guides and reports) important for understanding of electrical safety.

3. BASIC TERMS AND DEFINITIONS FOR ELECTRICAL SAFETY AND ELECTRICAL INSTALLATIONS

Terms and definitions connected with **electric shock:**

electric shock - pathophysiological effect resulting from an electric current passing through the human or animal body

shock current - a current passing through a body of a person or animal and having characteristics likely to cause pathophysiological effects

protection against electric shock - the provision of measures reducing the risk of electric shock

cardiac fibrillation - fibrillation of muscle of one or more heart chambers leading to the disturbance of some functions of the heart

ventricular fibrillation - cardiac fibrillation, limited to the ventricles leading to ineffective blood circulation and then to heart failure

let-go-threshold-current

releasing current (deprecated)

let-go-current (USA) (deprecated) - the maximum value of current at which a person holding electrodes can let go of the electrodes

touch voltage - voltage appearing between simultaneously accessible parts

Note: By convention, this term is used in connection with protection against indirect contacts.

leakage current

earth current - a current which under normal operating conditions flows in an unintended path

short-circuit current - the current flowing at a given point of a network resulting from a short-circuit at another point of this work

residual current - the algebraic sum of the instantaneous values of current flowing through all live conductors of a circuit at a point of the electrical installation

Note: Term of the relevant protective device:

IEC: residual-current protective device.

residual current device (r.c.d.) - a mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions

direct contact - contact of persons or livestock with live parts

indirect contact - contact of persons or livestock with exposed conductive parts, which have been become live under fault conditions

hazardous-live-part - a live part which, under certain conditions, can have an adverse effect on humans and animals by electric shock

basic insulation - insulation of hazardous-live-parts providing first protection against electric shock

double insulation - insulation comprising basic insulation and a supplementary insulation in order to provide protection against electric shock if basic insulation fails

reinforced insulation - a single insulation system which provides protection against electric shock equivalent to double insulation

arm's reach - a zone of accessibility to touch extending from any point on a surface where persons usually stand or move about to the limits which a person can reach with the hand in any direction without assistance

enclosure - a housing for separating the internal and external environment

protective enclosure - an enclosure providing protection against electric shock from the internal environment

protective barrier

barrier (deprecated)

protective cover (deprecated)

shroud (deprecated) - in restricted access areas, a structure providing protection against direct contact from any usual direction

obstacle - in restricted access areas, a part preventing unintentional direct contact, but not preventing direct contact by deliberate action

earth electrode - a conductive part that constitutes an electrically conducting interface with the mass of the earth

equipotential state - the state when parts are at a substantially equal electric potential

equipotential bonding - electric connection putting various exposed conductive parts and extraneous conductive parts at substantially equal potential

protective equipotential bonding - equipotential bonding for protection against electric shock in the event of short-circuit

automatic disconnection of supply - an interruption of supply caused by a protective device

short circuit - accidental or intentional conductive path between two or more points in a circuit forcing the voltages between these points to be relatively low

fault - the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note: A fault is often the result of a failure of the item itself, but may exist without prior failure.

disabled state

outage

unavailability (deprecated in this sense) - a state of an item characterized by its inability to perform a required function, for any reason

(electromagnetic) interference - degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance

electrical equipment - any item used for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as transformers, apparatus, measuring instruments, protective devices, equipment for wiring systems, appliances

live part - a conductor or conductive part intended to be energized in normal use, including a neutral conductor, but by convention not a PEN conductor

Note: The acronym PEN results of the combination of both symbols PE for the protective conductor and N for the neutral conductor.

exposed-conductive-part - a conductive part of electrical equipment, which can be touched and which is not normally live, but which can become live when basic insulation fails

extraneous-conductive-part - a conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally that of an earthing conductor

skilled person - a person with relevant education and experience to enable him or her to avoid dangers which electricity may create

instructed person - a person adequately advised or supervised by skilled persons to enable him or her to avoid dangers which electricity may create

ordinary person - a person who is neither a skilled person nor an instructed person

environmental conditions - physical and chemical conditions external to the product to which it is subjected at a certain time and comprising a combination of single environmental parameters and their severity

Note: The environmental conditions are generally composed of environmental conditions appearing in nature and environmental conditions generated by the product itself or by external sources.

environmental parameters - one or more physical or chemical properties (e.g. temperature, humidity, acceleration)

Example: The environmental parameter Vibration is characterized by the type of vibration (sinusoidal, random), acceleration, frequency.

safety colour - a colour, of special properties, to which a safety meaning is attributed

safety sign - a sign, which gives a general safety message, obtained by a combination of colour and geometric shape and which, by the addition of a graphic symbol or text, gives a particular safety message

supplementary sign - a sign with a text only, for use where necessary in conjunction with a safety sign

dead - at or about zero voltage that is without voltage or charge present

dead working - work on electrical installations which are neither live nor charged, carried out after having taken all measures to present electrical danger

live working - all work in which a worker makes contact with live parts or can reach into the danger zone with either parts of his or her body or with tools, equipment or devices being handled

injury - death or personal injury from electric shock, electric burn, electrical explosion, or arcing, or from fire or explosion initiated by electrical energy caused by any work activity on, with or near an electrical installation

risk - a combination of the probability and the degree of the possible injury or damage to health of a person exposed to a hazard or to hazards

notification - messages or instructions which are either verbal or in writing associated with operation of any electrical installation

Note: Command B is a notification only in written form.

operation - all activities necessary to permit the electrical installation to function both under normal and abnormal conditions

These activities include such matters as switching, controlling, monitoring and maintenance as well as both electrical and non-electrical work.

maintenance - periodic visual inspections and electrical testing where necessary including after repairs and/or modification to verify the electrical integrity of the tools, equipment and devices

4. EFFECTS OF CURRENT PASSING THROUGH THE HUMAN BODY

4.1. Principles

There is a difference between the hazard associated with direct (d.c.) and that with alternating current (a.c.): a.c. is more dangerous than d.c. As regards a.c., the level of danger varies depending on the frequency: low and high frequencies are less dangerous than the technically applied frequencies of 50 Hz and 60 Hz (see Figures 4.1.1 to 4.1.4).

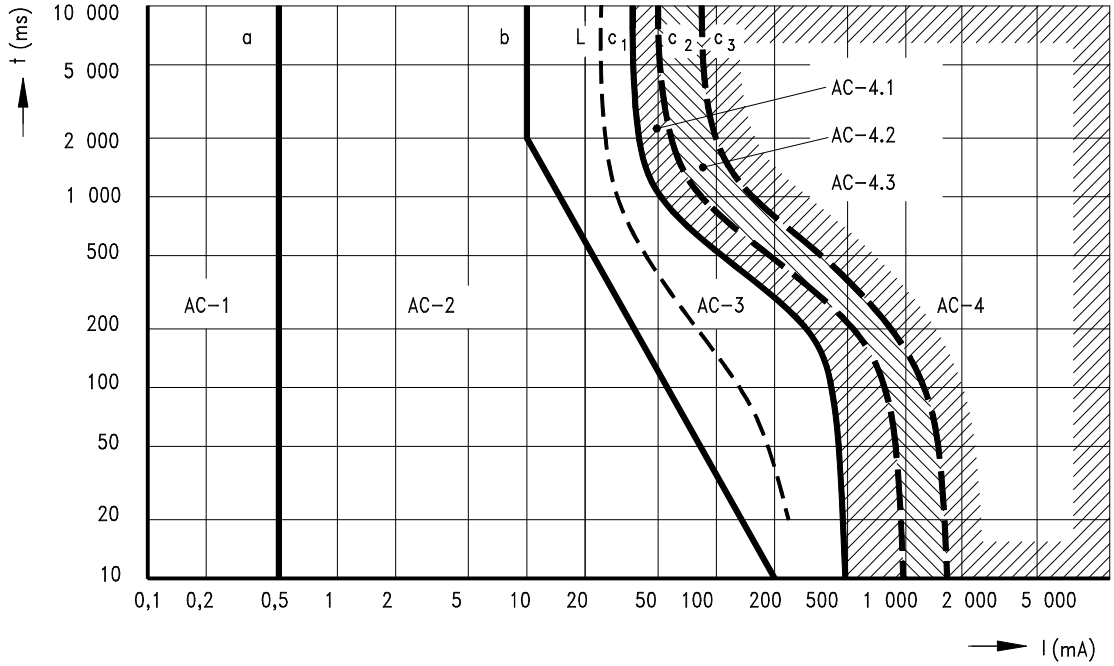


Figure 4.1.1
Time/current zones of effect of a.c. currents (15 Hz to 100 Hz) on persons Description of zones:

Zone designation	**Zone limits**	**Physiological effects**
AC - 1	up to 0,5 mA a	Usually no reaction
AC - 2	a - b 1)	Usually no harmful physiological effects
AC - 3	b - c1	Usually no organic damage to be expected
AC - 4	above c1	Dangerous pathophysiological effects: cardiac arrest, breathing arrest and severe burns
AC - 4.1	c1 - c2	Probability of ventricular fibrillation up to about 5 %
AC - 4.2	c2 - c3	Probability of ventricular fibrillation up to about 50 %
AC - 4.3	above c3	Probability of ventricular fibrillation above 50 %
1) For duration of current-flow below 10 ms, the limit for the body current for line remains constant at a value of 200 mA.		

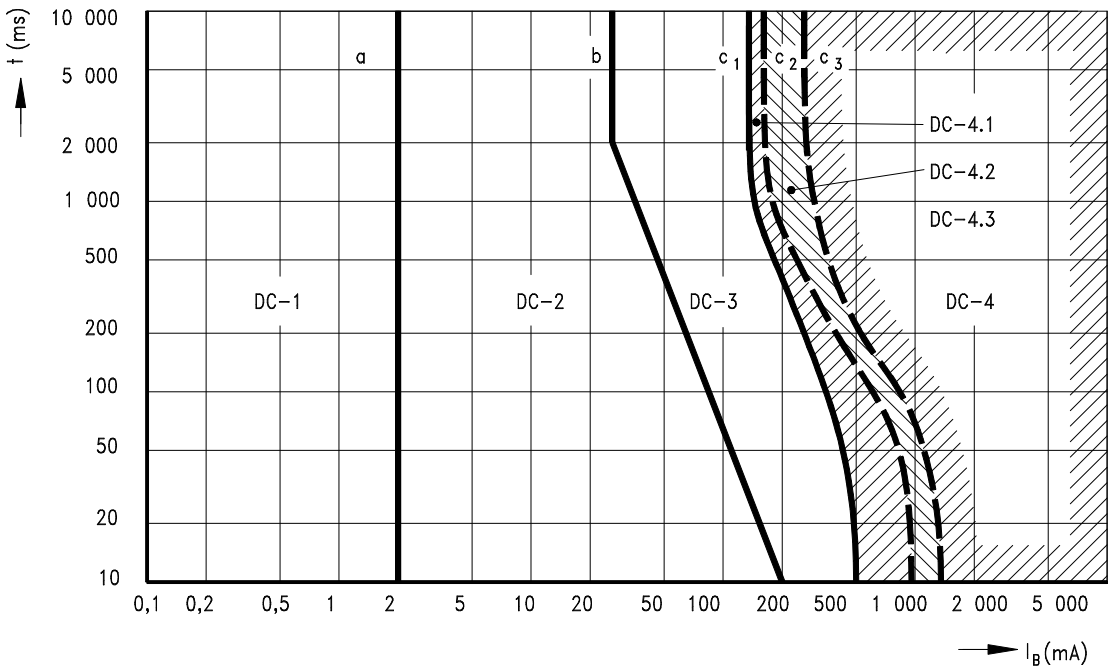


Figure 4.1.2

Time/current zones of effect of d.c. on persons.

Description of zones:

Zone designation	**Zone limits**	**Physiological effects**
DC - 1	up to 2 mA a	Usually no reaction
DC - 2	a - b 1)	Usually no harmful physiological effects
DC - 3	b - c1	Usually no organic damage to be expected. Increasing with current magnitude and time, reversible disturbances of formation and conduction of impulses in the heart may occur
DC - 4	above c1	Dangerous pathophysiological effects: severe burns, cardiac disrhythmias, unconsciousness.
DC - 4.1	c1 - c2	Probability of ventricular fibrillation up to about 5 %
DC - 4.2	c2 - c3	Probability of ventricular fibrillation up to about 50 %
DC - 4.3	above c3	Probability of ventricular fibrillation above 50 %
1) For duration of current-flow below 10 ms, the limit for the body current for line remains constant at a value of 200 mA.		

Notes: 1. As regards ventricular fibrillation, this figure relates to the effects of current, which flows in the path left hand to feet and for rising current.

2. Boundary between Zones 2 and 3 unknown for times less than 500 ms.

The hazard of electric current primarily depends on the value of the current passing through the human body and on its duration. Important parameters regarding the risk of electric shock, besides the current and time aspects, are:

- frequency of the current,
- resistance of the human body (depending on the frequency).

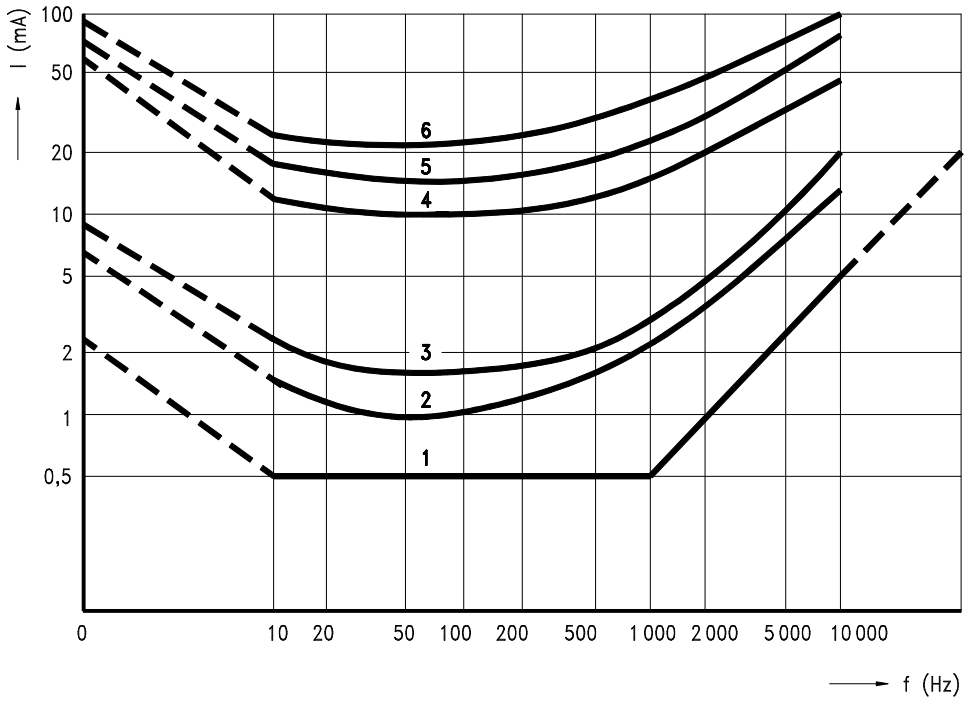


Figure 4.1.3

Influence of frequencies [according to IEC 479 (1974), First edition]. The diagram may help in the evaluation of risks for different frequencies.

Description of curves:

Curve 1: Conventional limits for current values normally not giving rise to any reaction. Based on a publication of the Association for the Advancement of Medical Instrumentation (AAMI) of July 1971.

Curve 2: Threshold of perception for 50% of persons tested, i.e. remainder felt nothing.

Curve 3: Threshold of perception for 99,5% of persons tested, i.e. remainder felt nothing.

Curve 4: Let-go-current for 99,5% of the persons tested, i.e. 0,5% could not let go.

Curve 5: Let-go-current for 50% of the persons tested, i.e. 50% could not let go.

Curve 6: Let-go-current for 0,5% of the persons tested, i.e. 99,5% could not let go.

Besides these aspects, the hazard depends on the weight of persons and on the pathway of the current through the body. (E.g. the current of 200 mA passing from one hand to the other one has the same effect as the current of 80 mA passing from the left hand to feet.)

These relationships are shown in the following figures.

Relationships of the currents causing different effects on the human body to the time for which the currents are passing through the human body are shown in Figures 4.1.1 (for alternating currents) and 4.1.2 (for direct currents). Zones of effects on the human body are shown in these figures. Any point in any zone represents one value of current and one value of time for which the current passes through the human body. All points in one zone represent values of currents and values of time that have similar effects on the human body. These zones are described bellow on the figures.

[Reference document: IEC Publication 479-2 (1987)]

Note 1: Frequency factor F_f: Ratio of the threshold current for the relevant physiological effects at the frequency *f* to threshold current at 50/60 Hz.

Note 2: The frequency factor differs for perception, let-go and ventricular fibrillation.

Note 3: Threshold of perception and frequencies between 10 kHz and 100 kHz:

For frequencies between 10 kHz and 100 kHz the threshold rises approximately from 10 mA to 100 mA (r.m.s. values).

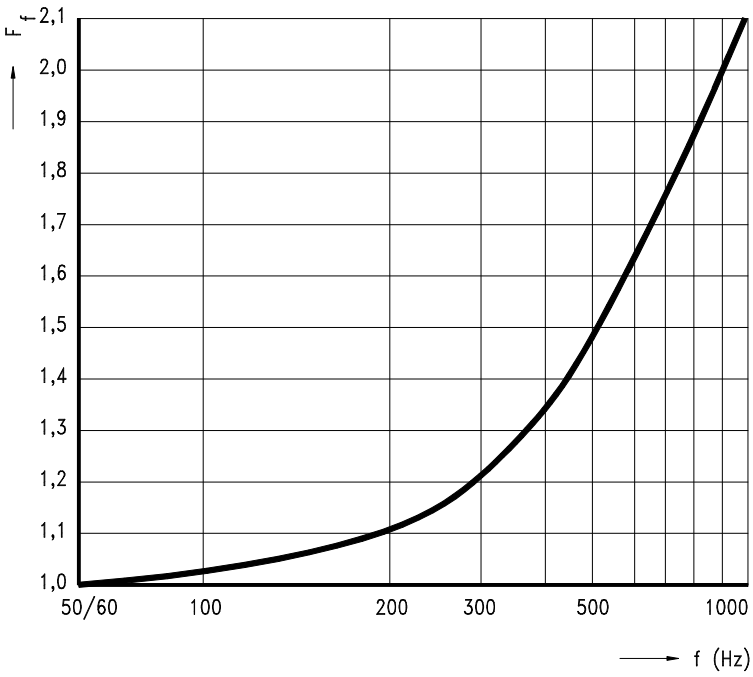


Figure 4.1.4

Variations of the threshold of perception within the frequency range 50/60 Hz to 1000 Hz.

For frequencies above 100 kHz the tingling sensation characteristic for the perception at lower frequencies changes into a sensation of warmth for current intensities in the order of some hundred milliamperes.

The threshold of ventricular fibrillation depends on physiological parameters (anatomy of the body, state of cardiac function, etc.) as well as on electrical parameters (duration and pathway of current flow, current parameters, etc.). With sinusoidal a.c. (50 Hz or 60 Hz) there is a considerable decrease of the threshold of fibrillation if the current flow is prolonged beyond one cardiac cycle. This effect results from the increase in inhomogeneity of the excitatory state of the heart due to the current-induced extrasystoles.

For shock duration below 0,1 s, fibrillation may occur for current magnitudes above 500 mA (Fig.4.1.1), and is likely occur for current magnitudes in the order of several amperes, only if the shock fall in the vulnerable period. Occurrence of vulnerable period (T - wave) corresponds to the blood - pressure maximum (Fig.4.1.5).For shocks of current above 1A and durations longer than one cardiac cycle reversible cardiac arrest may be caused.

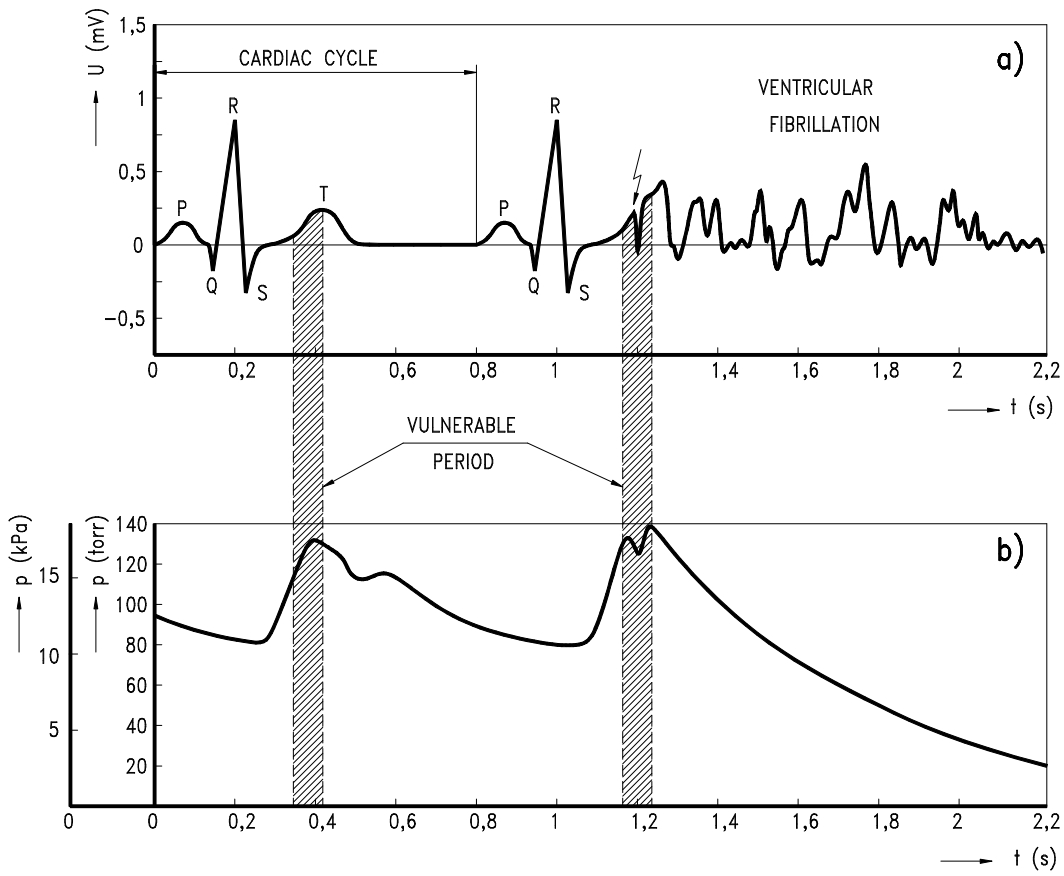


Figure 4.1.5
Ventricular fibrillation in the vulnerable period. Effects on electrocardiogram and blood pressure.

4.1.1 Requirements for characteristics of protective devices.

For a.c. (15 to 100 Hz), the curve L is situated in zone 3 (Fig.4.1.1) in which no organic damage is to be expected. The curve L is considered as reasonable for the establishment of the disconnecting times as a function of prospective touch voltage for the measure for protection by automatic disconnection of supply. It is placed with a certain margin of safety below zone 4 in which the risk of ventricular fibrillation arises, which is the main cause of death by electricity, the probability of which increased with the intensity of the current and the duration of flow.

4.2. Safety limits of current passing through the human body

Nowadays safety limits of current are not prescribed in Czech standards. The document IEC 479 is implemented as a Czech standard ČSN IEC 479 (33 2010). The informative limits which, according to this standard, can be used for electrical equipment are shown in table 4.2.1.

Table 4.2.1 Informative safety limits of current passing through the human body according to new standards

Type of equipment	**The longest duration of current (s)**	**Safety limits of current (mA) for**	
		alternating current	**direct current**
1. All equipment (except medical equipment)	permanent	0,5	2
2. Equipment assigned in relevant ČSN standard	permanent	3,5	10
3. Industrial equipment according to relevant ČSN, if it is not possible to fulfill limits for point 2	5 (exceptionally permanent)	10	30

4.3. Resistance (impedance) of the human body

The safety limits of currents (or the time current zones in Figures 4.1.1 and 4.1.2) are inconvenient for direct application to the practical design of installations. To the designer it is more useful if safey requirements are specified in terms of voltage as a function of time. For this purpose, certain values of body impedance must be taken into consideration. The relationship of current to voltage is not linear because body impedance varies with the touch voltage.

Conventional conditions in this respect mean situation where the most probable accident is hand to hand or hand to foot. In the Figure 4.3.1 the dependence of the total body impedance to the touch voltage can be seen. The sign 95%, 50%, 5% at the curves mean that the values given with the relevant curve are not exceeded for a percentage of 95%, 50% and 5% of the human

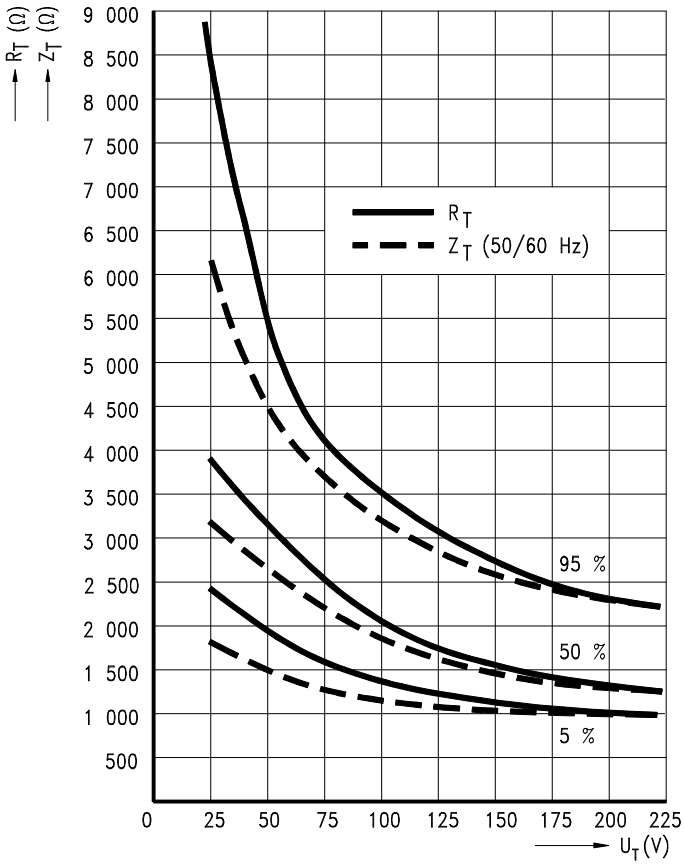


Figure 4.3.1

Statistical values of total body impedance valid for live human beings for the current path hand to hand or hand to foot, for touch voltage up to 700 V.

population. The current, which flows through the human body, depends not only on the touch voltage and body impedance but also on the impedance of the surface on which the human being stands or which is touched, and also on the conditions of the surface. The impedance of the surface, which is touched by a man, is much lower when the surface is damp or wet and also the impedance of the human body is lower when it is wet (e.g. as a consequence of perspiration). Regarding all these conditions the safety limits of the touch voltage were stated.

4.4. Conventional touch voltage limit

The highest permissible touch voltages (conventional touch voltage limits) are given in Table 4.4.1 (according to the draft ČSN 33 2000-4-41).

Table 4.4.1

Conditions	**Highest permissible touch voltage (V)**	
	a.c.	d.c.
Usual condition (dry but also a little or for a short time damp, and also with some conductive parts around)	50	120
Wet conditions or conditions with corrosion aggressiveness	25	60
Very bad conditions (a man standing in water or in metal barrels etc.)	12	25

Conventional touch voltage limits (for equipment up to and including 1000V)

It is evident that safety limits of touch voltage should depend on the duration of touch voltage similarly as limits of current passing through the human body. Nevertheless, the limits presented in Table 4.4.1 are the limits of permanent touch voltage. The limits of touch voltage dependent on time of the duration of it are given in Table 4.4.2 (according to the IEC 1200-413).

Table 4.4.2 Maximum touch voltage duration

Prospective touch voltage (V)	**Maximum disconnecting time (duration of touch voltage) (s) for**	
	usual conditions	**wet conditions**
25	-	>5
50	>5	0,47
75	0,6	0,30
90	0,45	0,25
110	0,36	0,18
150	0,27	0,10
220	0,17	0,04
280	0,12	0,02
350	0,08	-
500	0,04	-

Application of values given in the Table 4.4.2 with regard to protection against indirect contact will be discussed later.

5. FUNDAMENTAL RULES FOR PROTECTION AGAINST ELECTRIC SHOCK

As mentioned in the previous text, in case of touching a live part, that means a part with a potential different from the potential of earth, a current flows through the body from the live part to the earth.

In the course of many year 's utilization of electricity, a system of protection against electric shock has been developed. The main objective of this protection is to ensure that persons and livestock shall be protected against dangers that may arise from the contact with live parts of the electrical equipment or installation.

The protection can be achieved by one of the following methods:

- preventing a current from passing through the body of any person or any livestock;
- limiting the current which may pass through a body to a value lower than the current.

The current can pass through the human body either in case of touching live parts of different potential or in case of standing on the place with some potential and touching live part with a different potential. One of these different potentials is usually potential of earth, which we consider to be equal to zero. The other potential, i.e. the potential of the live parts, is usually potential compared with the zero potential of the earth. It is called the voltage of live parts.

For that reason the first task is to prevent anybody (persons or livestock) from touching dangerous live parts. This has to be provided during the whole life of electrical equipment (household appliances etc.) or electrical installation. This first step of protection, which has to be provided during the normal service of electrical equipment and/or electrical installation, is called **protection against direct contact** or **basic protection** or **protection under normal conditions**. This protection is usually provided by means of insulation of live parts (e.g. conductors are insulated) or by means of enclosures in which live parts are situated (e.g. live parts of electrical household appliances are covered by enclosures) or by means of barriers or obstacles around the live parts of larger equipment in electrical substations. The other possibility how to provide protection against direct contact is to situate live parts out of reach. This is the usual way of protection against direct contact to overhead transmission lines.

During the normal service it may come to such a case that the insulation may be disrupted or that the metal enclosure may come to a contact with live parts. That is so called **single fault condition** and, in such case, the so called **protection against indirect contact** has to be provided. That means contact with parts that are not live during the normal service and may become live in case of fault, i.e. under single fault condition. The conductive parts of electric equipment that can be touched and that are not normally live, but may become live in case of fault (e.g. when basic insulation fails), are called **exposed conductive parts**.

In conformity with the explanation given above, the fundamental rule for protection against electric shock is given in international standards IEC 364-4-41 and IEC 536.

The rule reads as follows:

Accessible conductive parts shall not be hazardous either

- under normal conditions (normal operating conditions and absence of a fault), or
- under single fault condition.

If sufficiently low voltage, i.e. voltage that cannot be dangerous in case of touching live parts energized with such voltage, is used, then both live parts and exposed conductive parts that may become live in case of failure of an insulation of live parts cannot be dangerous. Such type of protection that, by means of one measure (e.g. by means of sufficiently low voltage or by means of sufficiently low current), provides both protection against electric shock in case of touching live parts and protection against electric shock in case of touching exposed conductive parts in case of fault is called **protection against both direct and indirect contact**.

We can consider such case of protection both

- protection under normal conditions and
- protection under single fault condition.

In this way we can consider three types of protection against electric shock. For each type there are used several terms that, in principle, indicate the same:

1) protection ensured under normal conditions; the synonyms are:
   protection in normal service,
   protection against direct contact,
   basic protection;
2) protection ensured under single fault condition; the synonyms are:
   protection in case of fault,
   protection against indirect contact,
   supplementary protection;
3) protection ensured under normal conditions as well as under single fault condition; the synonym is:
   protection against both direct and indirect contact.

5.1. Protection against direct contact

All electrical equipment shall be subjected to one of the protective measures against direct contact with live parts of electrical equipment by persons or livestock. All basic methods of this protection prevent from contact with live parts, only the newest one, described as additional protection, is based on limiting of current passing through the human body. From the other point of view, the protection against direct contact can be divided into:

- protection against **unintentional contact** (any contact) with live parts represented by:
- protection by insulation of live parts,
- protection by barriers or enclosures;
- protection against **intentional contact** with live parts represented by:
- protection by obstacles;
- protection by placing out of reach.

5.1.1 Protection by insulation of live parts

Live parts shall be completely covered with insulating materials which can only be removed by destruction.

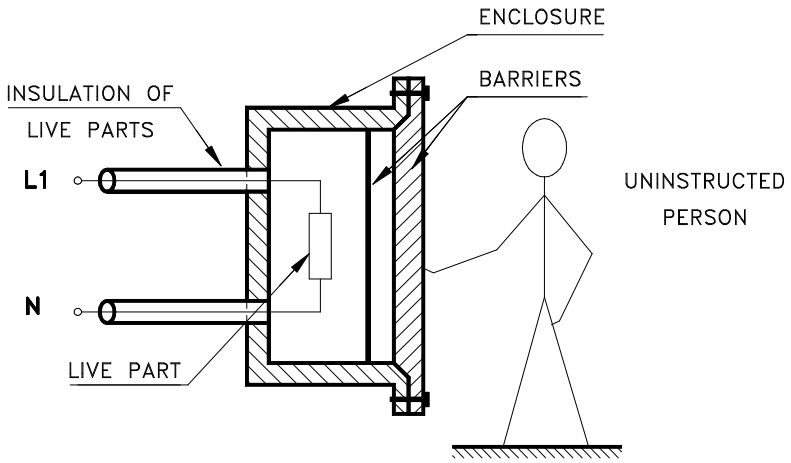


Figure 5.1.1
Protection against direct contact.
Protection in normal service.
Basic protection.
Protection by insulation of live parts, protection by barriers and enclosure,
- to prevent any contact with live parts.

5.1.2 Protection by barriers or enclosures

With this measure, the live parts are located inside enclosures or behind barriers. These enclosures or barriers shall prevent the entrance of solid object greater than 12 mm and fingers (i.e. IP 2X). They prevent from any contact with live parts.

Barriers and enclosures shall be firmly secured. Whenever it is necessary to remove barriers or to open enclosures , this shall only be possible:

- by the use of a key or tool, or
- after disconection of the power supply to live parts, restoration of the supply being possible only after replacement or reclosure of the barriers or enclosures,

or- when an intermediate barrier providing a degree of protection of at least IP 2X prevents contact with live parts, such a berier being removable only by the use of key or tool.

5.1.3 Protection by obstacles

Obstacles may include handrails, mesh-screens, railings and protective frames. Obstacles may be removed without using a key or tool but shall be so secured as to prevent unintentional removal.

5.1.4 Protection by placing live parts out of reach

With this measure, simultaneously accessible parts of varying potentials (voltages and earth potential) shall not be within arms reach. Parts are not regarded as being simultaneously accessible if they are more than 2,50 m apart. This distance shall be increased in places where bulky or long conductive objects are normally handled.

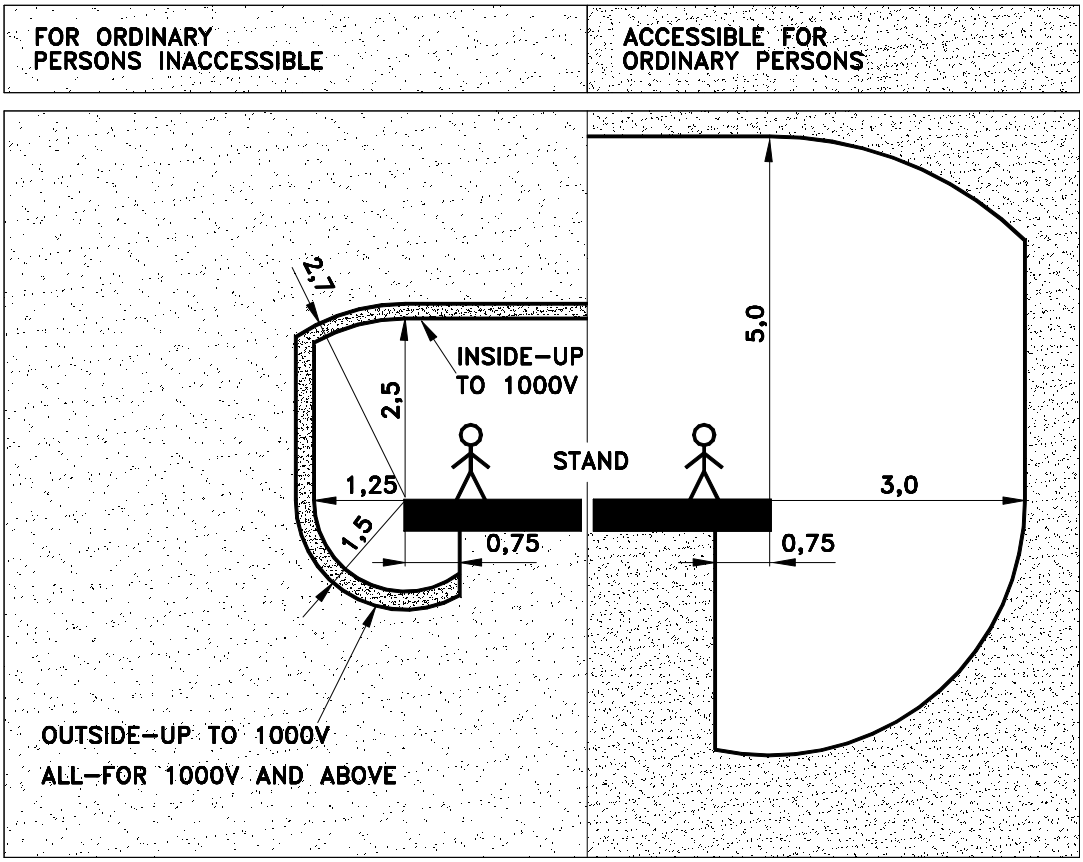


Figure 5.1.2

Protection by placing live parts out of reach - zones of arm´s reach under different conditions

Minimal distances of live parts from the stand point according to different standards are shown on the Figure 5.1.2.

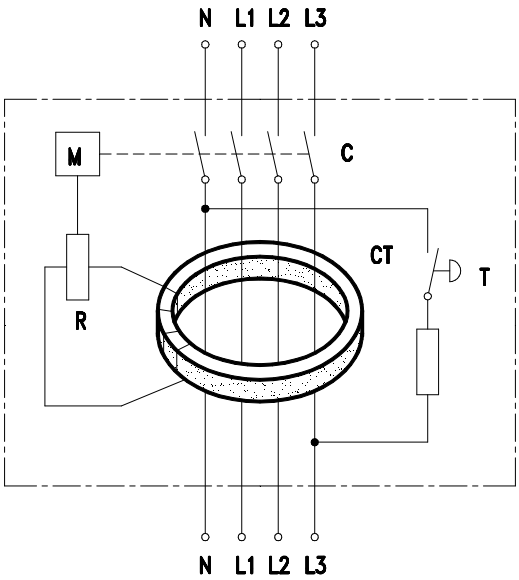
5.1.5 Use of protective measures

Protection against unintentional contact (protection by insulation by barriers or enclosures) is applied on electrical equipment, especially on household electrical appliances, used by ordinary persons without any electrotechnical qualification). Protection against intentional contact (protection by obstacles, by placing out of reach) is intended for applying in rooms with electrical equipment where only skilled or instructed persons are permitted to entry.

5.1.6 Additional protection

Besides these traditional types of protection which in international standards are considered as usual types of protection, there exists the protection by very sensitive residual-current protective devices. This protection may be used as additional protection to fundamental types shown above. The use of it is obligatory in many countries for electrical installations in bathrooms, in construction sites, and in outdoor space.

The application of **residual current protective devices** as a very important protective element leads to the necessity to show the function of these devices (see Figure 5.1.3).



T - test button

CT - current transformer

R - release, trip coil

M - mechanical lock

C - contact of switching device

Figure 5.1.3
Fundamental principle of residual-current protective device

The fundamental principle of residual-current protective device is: the total amount of current flowing to and from any electrical equipment is zero (null), that means, in normal use, no difference.

However, in the case of a fault, when current flows from the live conductors to the earthed casing, enclosure or frame, i.e. to the earthed exposed conductive parts or, in the case of very sensitive residual-current protective device when current flows through the human body to the earth or to the protective conductor, there will be a difference in current. This difference is called residual-current. The residual-current protective device must ensure the disconnection of all live conductors of the circuit, including the neutral conductor. This is ensured through the operation of a trip coil through which current from differential current transformer flows.

5.2. Protection against indirect contact

"Indirect contact" is the contact of persons or livestock with exposed conductive parts which have become live under fault conditions (see Figure 5.2.1)

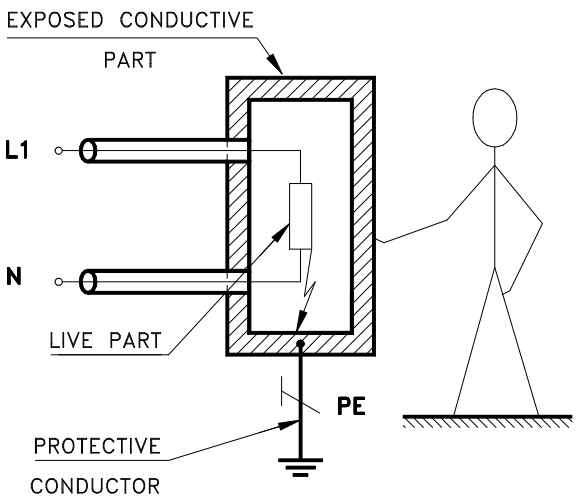
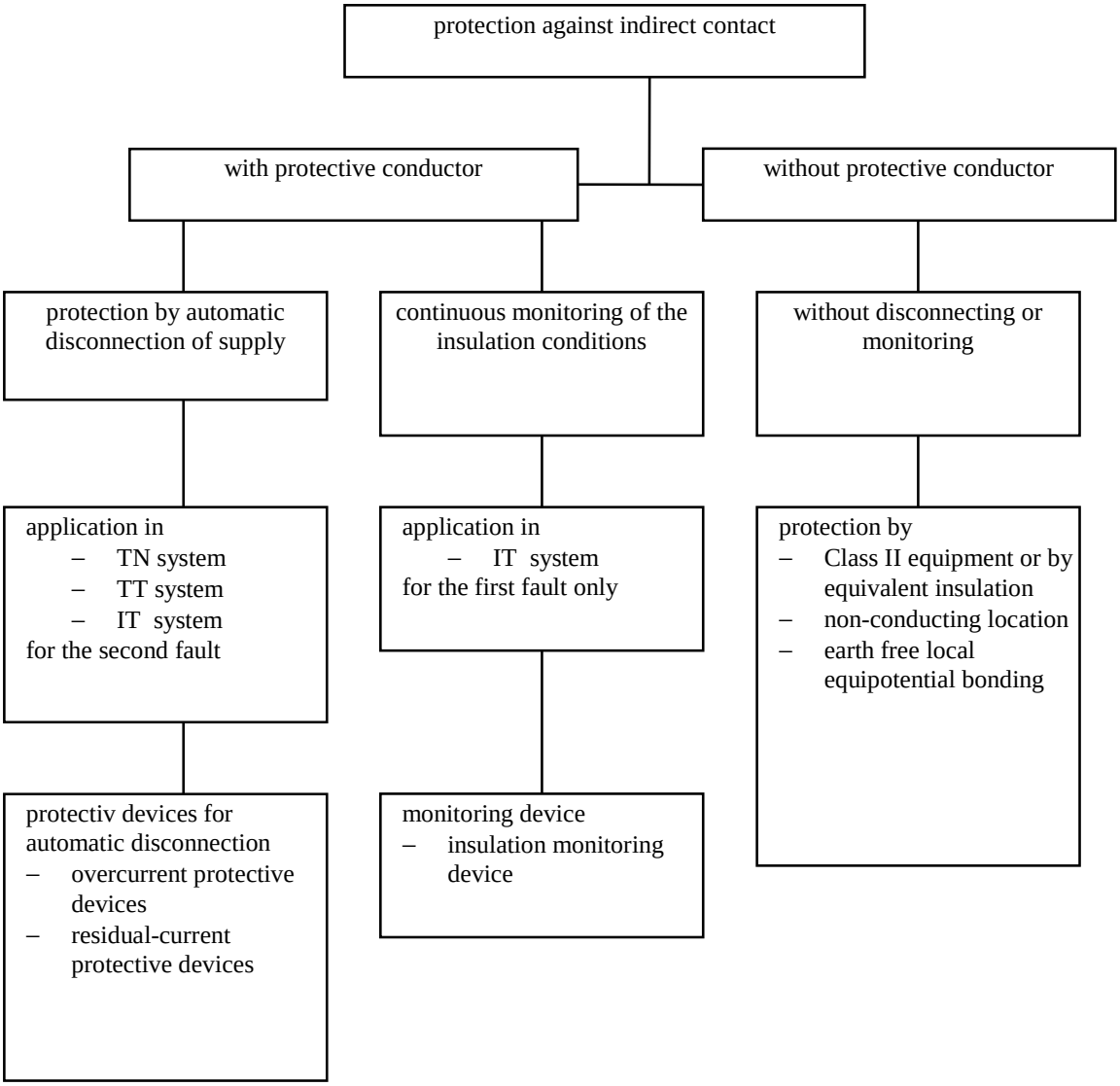


Figure 5.2.1
Indirect contact and protection in case of fault

Protection against indirect contact requires correspondence of measures on electrical equipment and measures on electrical installation (see Table 5.2.1)

All electrical equipment shall be provided with foreseen for one of the measures against indirect contact (see Table 5.2.2).

Table 5.2.1 Survey of measures for protection against indirect contact



5.2.1 Classification of electrical and electronic equipment with regard to protection against electric shock in the event of insulation fault

This classification is provided for low-voltage electrical and electronic equipment intended for connection to an external power supply (to distribution system). The classification is elaborated with regard to protection against electric shock in the event of an insulation failure. According to this classification, the protection may be provided by the environment, by the equipment itself or by the system of supply (see Table 5.2.2).

Table 5.2.2 Principal characteristics of equipment according to the classification.

	Class 0	**Class I**	**Class II**	**Class III**
Principal characteristic of th equipment	No means for protective conductor	Protective conductor (PE) means are provided	Additional insulation and no mans for protctive conductor	Desidned for supply at safety extra-low voltage (SELV)
Precautions for safety	Earth free environment	Connection to the protective conductor	None necessary	Connection to safety extra-low voltage
Usual symbols (according to IC 60417)	No symbol			
Application in installations	In non-conducting locations according to IEC 60364-4-41	With protective conductor (PE) or PEN conductor	General application	With SELV circuits

This table indicates also precautions necessary for safety in the event of a failure of the basic insulation.

Note: asic insulation: insulation applied to live parts to provide basic protection against electric shock

Classes of equipment

The class numbers are not intended to reflect the safety level of the equipment, but only the means by which the safety is obtained. Table 6 shows the principle characteristics of the classes.

Class 0 equipment

Equipment in which protection against electric shock relies upon basic insulation; this implies that there are no means for the connection of accessible conductive parts, if any, to the protective conductor in the fixed wiring installation. According to ČSN standards the use of this class of equipment is prohibited in the Czech Republic.

Class I equipment

Equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in such a way that means are provided for the connection of accessible conductive parts to the protective conductor in the fixed wiring of the

installation in such a way that accessible conductive parts cannot become live in the event of a failure of the basic insulation.

Class II equipment

Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided. There are no provisions for protective earthing (protective conductor).

Class III equipment

Equipment in which protection against electric shock relies on supply at safety extra low voltage (SELV) and in which voltages higher than those of SELV are not generated.

5.2.2 Protection by automatic disconnection of supply

The automatic disconnection of the supply on the occurrence of a fault is intended to prevent dangerous touch voltage existing for such a time as to be considered dangerous. (Disconnection must be done till the time given in Table 4.4.2. This time depends on the voltage existing on exposed conductive parts in case of failure of insulation. This voltage is not necessarily equal to the voltage of the distribution system but it is usually lower.) This protective measure necessitates co-ordination of type of system earthing and the characteristics of protective devices.

5.2.2.1 Types of system earthing

Before we start to speak about the types of system earthing we should know something about three-phase voltage system, by which almost all electric power is produced and distributed. A three phase voltage system is composed of three sinusoidal voltages agreeing in frequency and amplitude but differing in phase. Figure 5.2.2 shows a diagram of a secondary winding of a transformer as a three-phase voltage source.

The voltage exists on the output of the transformer. The voltage spreads by conductors from the output of the transformer into the distribution system (network) and through this system to electrical appliances. The voltage exists between whichever conductor L1, L2, L3 and neutral point. That is called **phase voltage.** There are three phase voltages on the output of the transformer and in the distribution system. There are voltages L1-N, L2-N and L3-N.

There are voltages between conductors (so called phase conductors) L1-L2, L2-L3 and L3-L1. These voltages are called line to line voltages or simply **line voltages**

Figure 5.2.3 shows the course of instantaneous phase and line voltages during the time of

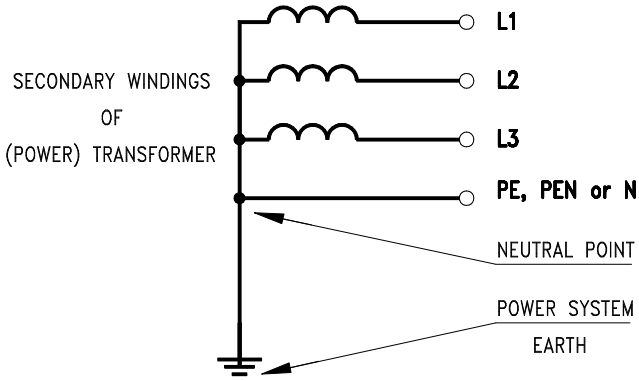


Figure 5.2.2

Diagram of a three-phase source of voltage distributed by conductors

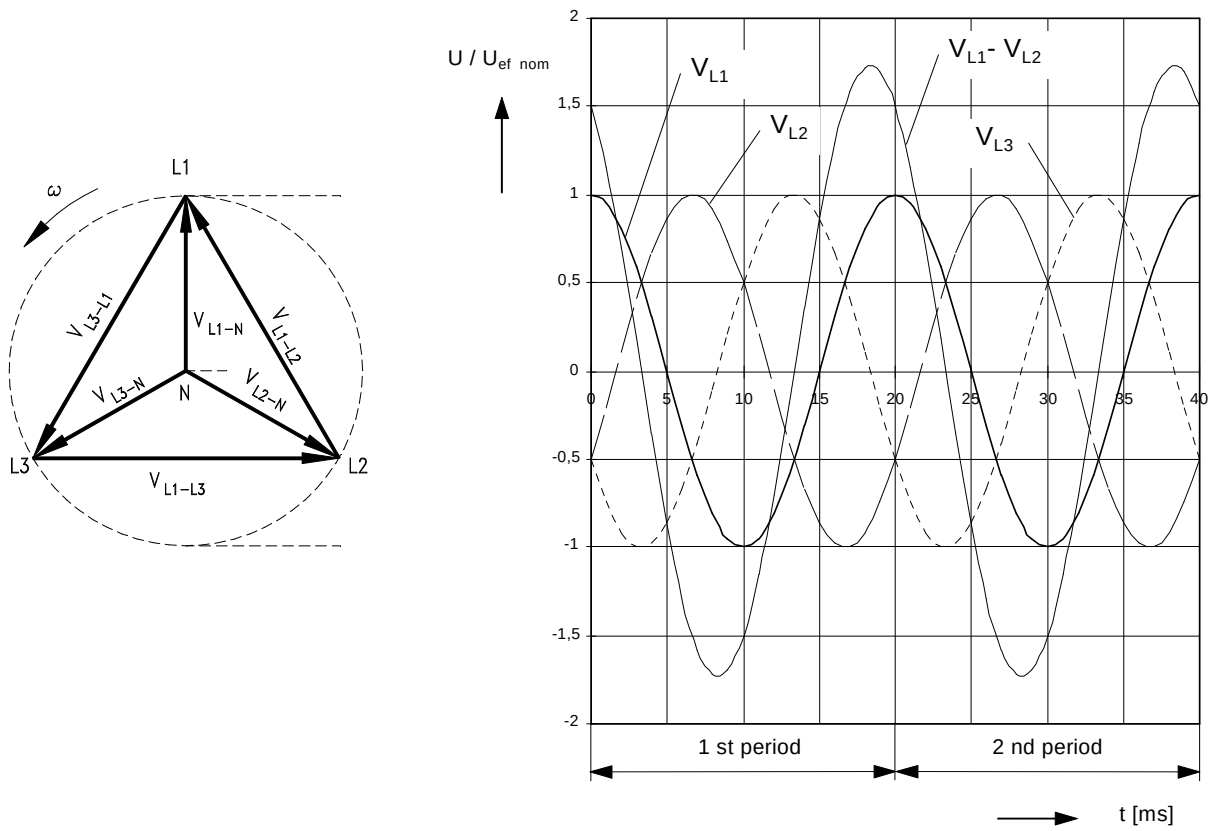


Figure 5.2.3

Course of phase voltages in three-phase voltage system.

two periods. Sinusoidal course of voltages may be derived from the rotating phasors of voltages on the lefthand-side of the Figure 5.2.3. Every phase voltage has its own course similar each

other but shifted one from another by third of period. We can see the line voltages on the Figure 5.2.3 as well. The line voltages are voltages between courses of phase voltages.

For **types** of **system earthing** following classification is applied:

- TN system;
- TT system;
- IT system.

The codes used for these systems have the following meanings:

First letter -

relationship of the supply system to earth:

T - direct connection of one point of power supply system to earth,

I - all live parts isolated from earth, or one point of power supply system connected to earth through an impedance.

Second letter -

relationship of exposed conductive parts of the installation to earth:

T - direct connection of exposed parts to earth, independent of the earthing of any point of the supply system,

N - direct electrical connection of the exposed conductive parts to the earthed point of the supply system (in a.c. systems the earthed point is normally the neutral point).

The mostly used system in the Czech Republic is the TN system. There are three different types of TN system recognized. These types differ from each other according to the arrangement of neutral and protective conductors, as follows:

TN-S system: having separate neutral and protective conductors throughout the system;

TN-C system: in which the neutral and protective functions are combined an a single conductor throughout the system;

TN-C-S system: in whitch the neutral and protective functions are combined an a single conductor in part of the system.

Subsequent letters -

arrangement of neutral and protective conductors: separate (S) and combined (C) are the words from which the letters are derived.

The meaning of the letters used in the symbols:

PEN stands for a conductor with protective (PE) and neutral (N) functions. Alphanumeric notations for particular conductors applied in following figures:

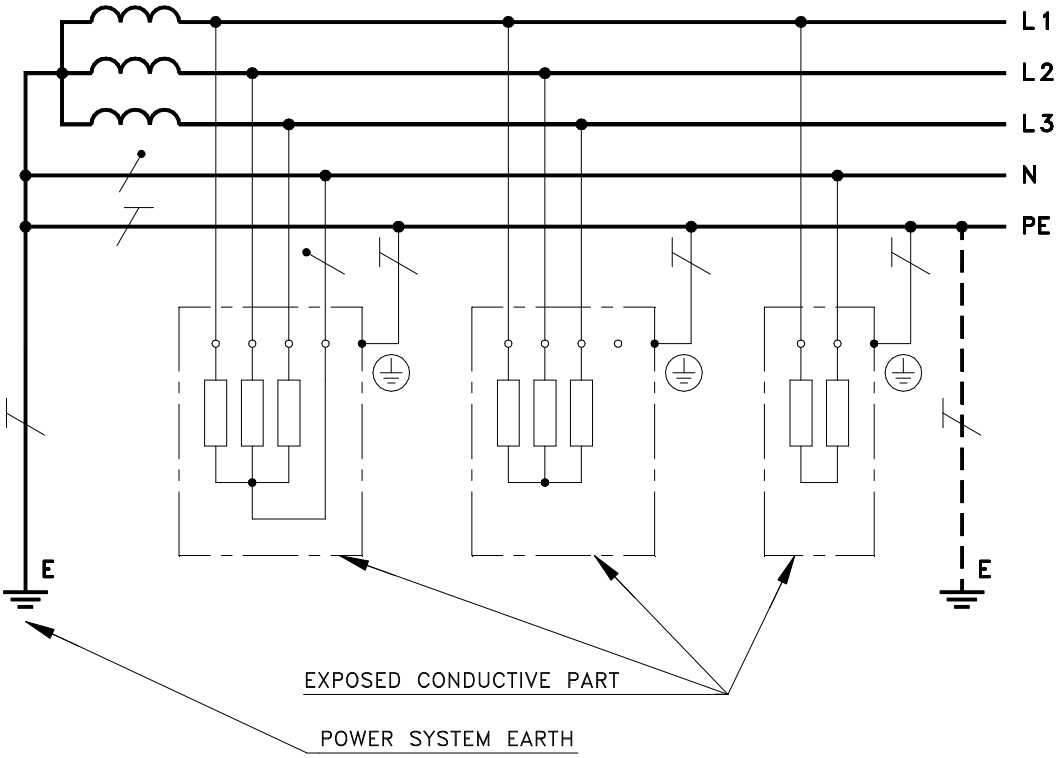


Figure 5.2.4

TN-S system: separate neutral and protective conductors throughout the system

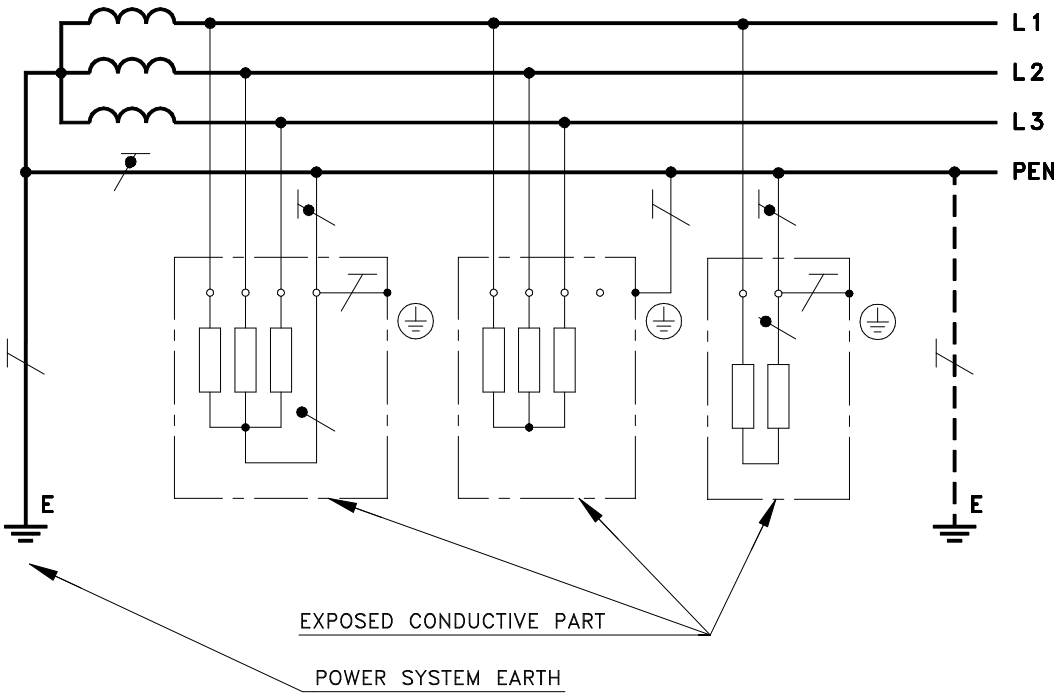


Figure 5.2.5

TN-C system: neutral and protective functions are combined in a single conductor throughout the system.

L1, L2, L3	Phase conductors 1,2,3 or Line conductors 1,2,3	Symbols for conductors according IEC 617 (1983):
PE	Protective conductor;	protecctive conductor (PE)
N	Neutral conductor;	neutral conductor (N)
PEN	PEN conductor.	PEN conductor (PEN)

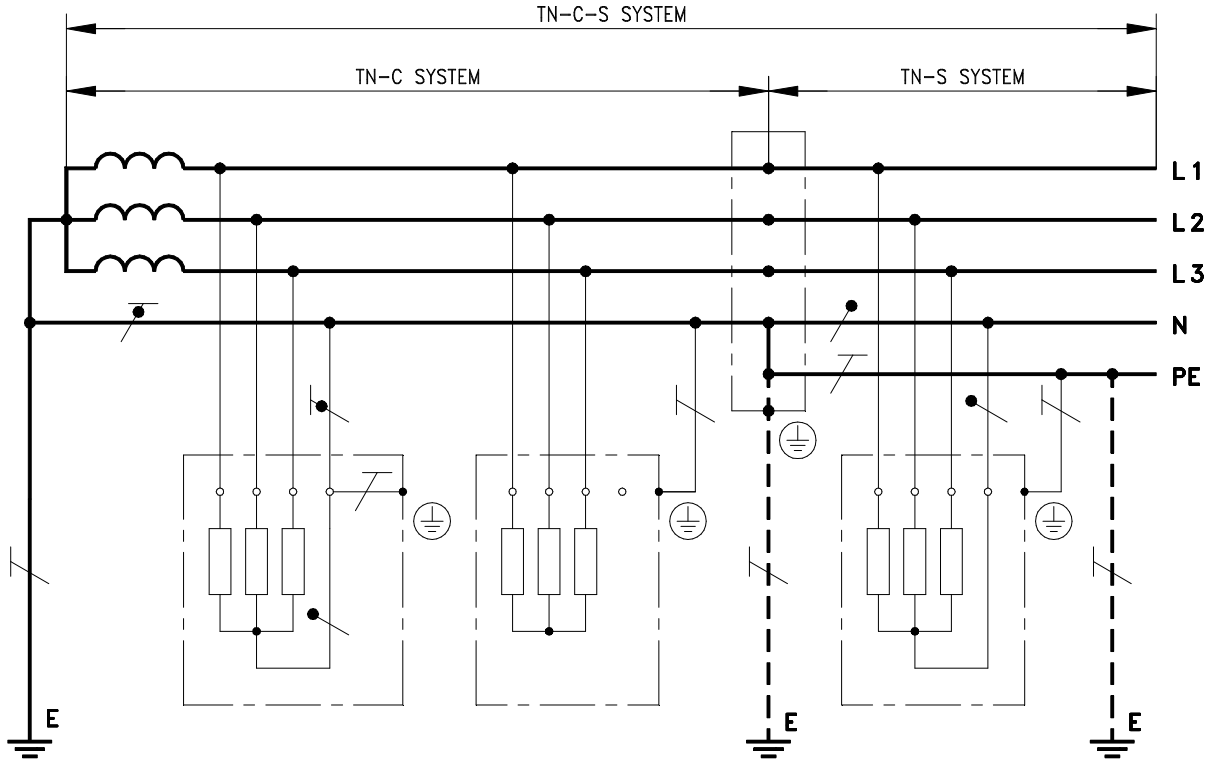


Figure 5.2.6

TN-C-S system: in one part of the system neutral and protective function are combined in a single conductor, in another part of the system there are separate neutral and protective conductors.

5.2.2.2 Measures for protection by automatic disconnection of supply

For all types of systems earthing following fundamental principles shall be applied:

a) Earthing

Exposed conductive parts shall be connected to the earth by means of protective conductor.

b) Conventional voltage limit

The conventional voltage limit U_L equal to 50 V a.c., r.m.s. or 120 V ripple-free d.c. is the maximum prospective touch voltage which can occur on exposed conductive parts under usual conditions for indefinite time.

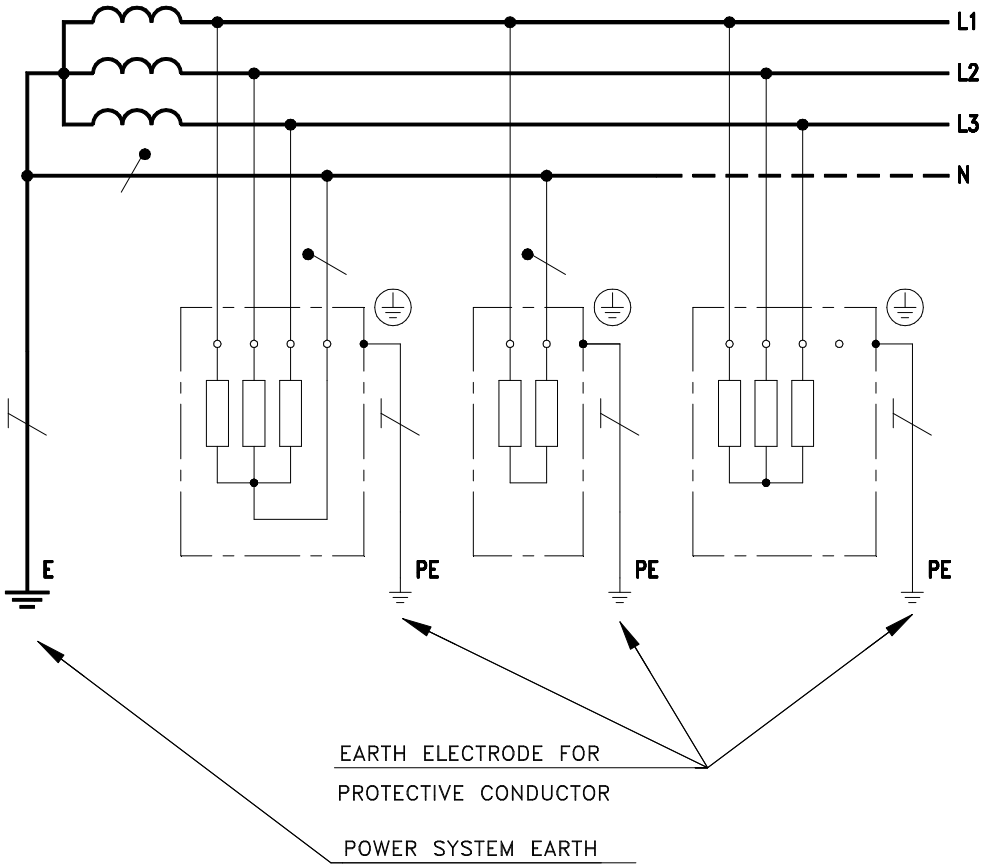


Figure 5.2.7
TT system

c) Disconnection of supply

A protective device shall automatically disconnect the supply to the part of the installation protected by that device, so that, following a fault in that part, a dangerous touch voltage cannot be maintained at any point of the installation.

5.2.2.3 Main equipotential bonding

According to the international standards a main equipotential bonding conductor shall interconnect at the entrance point of the supplies of each building the following conductive parts:

- main protective conductor,
- main earthing conductor or main earthing terminal,
- PEN conductor,
- metal pipework (water pipes, gas pipes, central heating etc.),
- metallic parts of building structure.

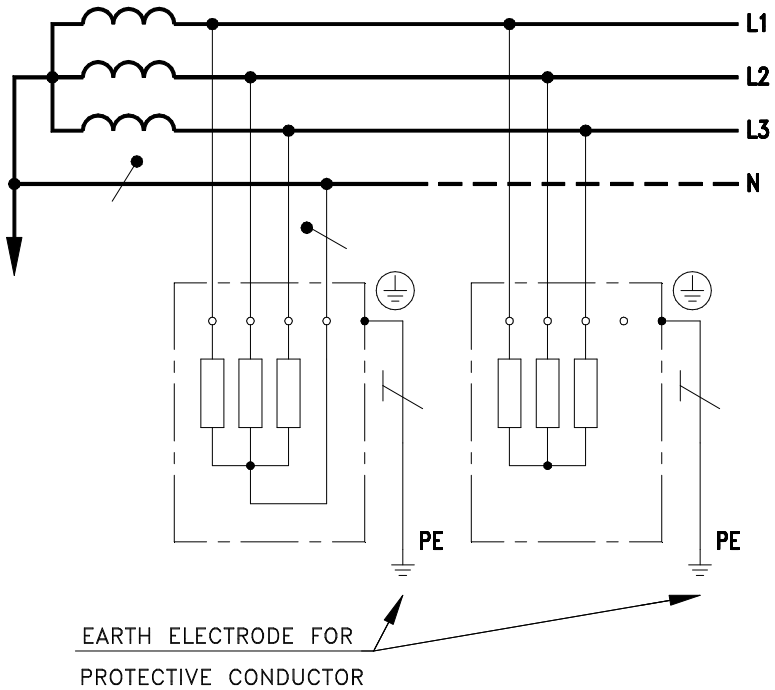


Figure 5.2.8
IT system

5.2.2.4 Supplementary equipotential bonding

It is the equipotential bonding that is usually necessary for special locations, for instance for bathrooms or swimming pools. This measure can be applied also when the conditions for disconnections of supply cannot be fulfilled in some part of the installation.

The above mentioned measures are more or less applied in all three basic systems. TN, TT, and IT.

5.2.2.5 Protective measures in TN system

a) The characteristics of protective devices

and the cross-sectional areas of conductors shall be selected so that, if a fault of negligible impedance occurs anywhere between a phase conductor and a protective conductor or exposed conductive part, automatic disconnection of the supply will occur within the specified time (see Table 5.2.3).

b) The fault loop impedance Z_S

(Figure 5.2.9) shall be lower than the phase voltage U_O divided by the current I_a ensuring the automatic disconnection within the specified time:

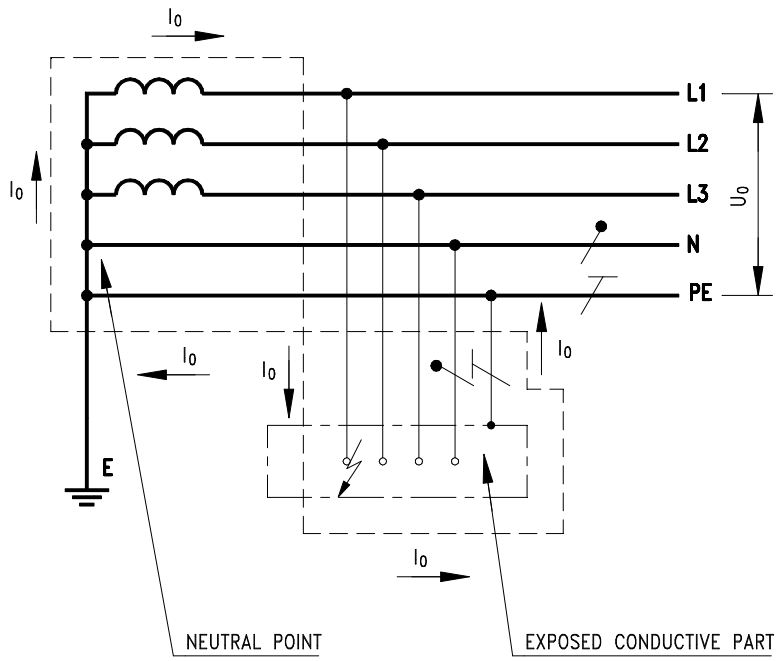


Figure 5.2.9

Fault loop Z_S and fault current I_a in TN-S system

c) The maximum disconnecting time

shall comply with Table 4.4.2 the voltage which reasonably can occur on the exposed conductive parts shall not occur for a longer time than the time given in Table 4.4.2 (E.g. the voltage on the exposed conductive part in case of fault in TN system with phase voltage 230 V may be reasonably 90 V; maximum duration of this voltage shall not be - according to Table 4.4.2 - longer than 0,45 s.) Because it is impracticable to determine the time duration in such a way, the maximum disconnecting time is given for the used phase voltages of supply system in Table 5.2.3.

It is necessary to make a note about Czech standards. The condition mentioned above is introduced in the ČSN 33 2000-4-41:1996. The value of fault loop impedance Z_S shall be so low that the short circuit current in case of failure would cause functioning of protective device in a time shorter than that one prescribed in table 5.2.3.

Table 5.2.3 The maximum disconnecting time in case of a fault in TN system

U_o (V)	t (s)
120	0,8
230	**0,4**
277	0,4
400	**0,2**
>400	0,1

d) Earthing of protective conductors

The international standard requires earthing of the protective conductor or PEN conductor near each power transformer or generator of the installation and wherever in the supply system where other effective connections exist. Czech standards require earthing in defined distances of the length of the line.

There are many other conditions which are to be fulfilled for the right function of protection in TN system, but we cannot pay attention to them for the shortage of time and space.

5.2.2.6 Protective measures in TT systems

In TT system the following electrical condition shall be fulfilled:

$$R_A \cdot I_a \leq U_L$$

where

R_A is earthing resistance of the earthing of exposed conductive parts,

I_a is the operating current of the protective device in the disconnecting time (which is for overcurrent protective devices, for residual current protective devices),

U_L is the conventional voltage limit, e.g. 50 V a.c.

In TT system the use of the residual-current protective devices is preferably recognized and also the overcurrent protective devices may be used.

5.2.2.7 Protective measures in IT systems

The IT systems shall be built up in such a way as to comply with the following conditions: In case of occurrence of a first fault (on insulation of electrical appliance), when the fault current is low the following condition shall be fulfilled:

$$R_A \cdot I_d \leq U_L$$

where

R_A is the earthing resistance of the earthing of exposed conductive parts,

I_d is the fault current of the first fault of negligible impedance between phase conductor,

U_L is the conventional voltage limit, i.e. 50 V a.c. for normal condition.

According to Czech standards the highest earthing resistance is firmly given as 20 Ω (exceptionally in small systems 100 Ω).

An insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. The device shall release an acoustic and/or optical signal, or automatically disconnect the supply. It is recommended that a first fault be eliminated within the shortest possible time.

After the occurrence of a first fault (in case when the supply is not automatically disconnected) conditions for the disconnection of the supply in the event of a second fault as specified for TN and TT systems shall apply, depending on whether all the exposed conductive parts are interconnected by a protective conductor (collectively earthed) or are earthed in groups or individually. In case of interconnection of all exposed conductive parts with earthed protective conductor TN system arises after the occurrence of first fault. For such TN system the maximum required disconnecting time depends on whether in this system the neutral conductor is distributed or not according to Table 5.2.4.

Where exposed conductive parts are earthed in groups or individually, the conditions of a TT system are to be considered.

Table 5.2.4 The maximum disconnection time in case of second fault in IT system

Installation nominal voltage	**Disconncting time *t* (s)**	
U_0 / U (V)	**Nutral not distributed**	**Nutral distributed**
120-240	0,8	5
230/400	**0,4**	**0,8**
400/690	**0,2**	**0,4**
580/1000	0,1	0,2

Other conditions for the case of second fault in IT system are similar to the ones of TN or TT systems.

In IT systems, the use of the following monitoring and/or protective devices is recognized:
- insulation monitoring devices,
- overcurrent protective devices,
- residual current protective devices.

Inspite of rare use of IT systems this systems are unavoidable in cases when it is necessary to finish some work, operation etc. when the first fault occurs (e.g. for operation rooms in hospitals, for heavy industry machinery).

Protection without automatic disconnection of supply - measures without application of protective conductors (PE)

The most common protective measures without automatic disconnection of supply are:

- protection by the use of Class II equipment,
- protection by electrical separation.

5.2.3 Protection by use of Class II equipment or by equivalent insulation

(see Figures 5.2.10 and 5.2.11)

This measure is the most recommended one for electrical equipment, in particular for domestic appliances.

Protection shall be foreseen by:

- the use of Class II equipment (identified by the symbol).
- supplementary insulation applied to electrical equipment having basic insulation only,
- reinforced insulation applied to uninsulated live parts.

This insulation shall be equivalent to basic plus supplementary insulation.

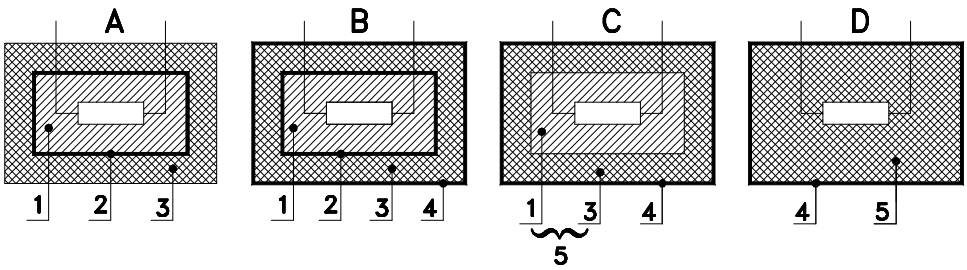


Figure 5.2.10

Principle diagrams for Class II equipment; three examples and symbol

1 basic insulation
2 internal metal part
3 supplementary insulation
4 outside metal part
5 reinforced insulation

5.2.4 Protection by electrical separation

Electrical separation of an individual circuit prevents flowing of shock currents through contact with exposed conductive parts, which may be energized by a fault in the basic insulation of the circuit. In unearthed circuit separated from the distribution system by isolating transformer is not possible at the first insulation fault for the current to come through this insulation fault because of lack of another point of circuit through which the current could come back.

Protection by "electrical separation" is applied under certain environmental conditions, e.g. in restrictive conducting locations, tools in wet conditions.

Although there are other protective measures for protection against indirect contact, we will not deal with them for the lack of space here and because these measures are not so important and not used so often as the measures mentioned above.

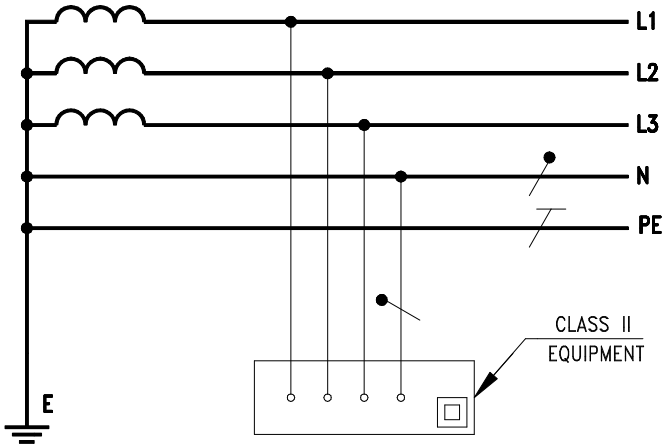


Figure 5.2.11

Class II equipment (current using equipment) in TN-S system. The protective conductor is not connected with the Class II equipment.

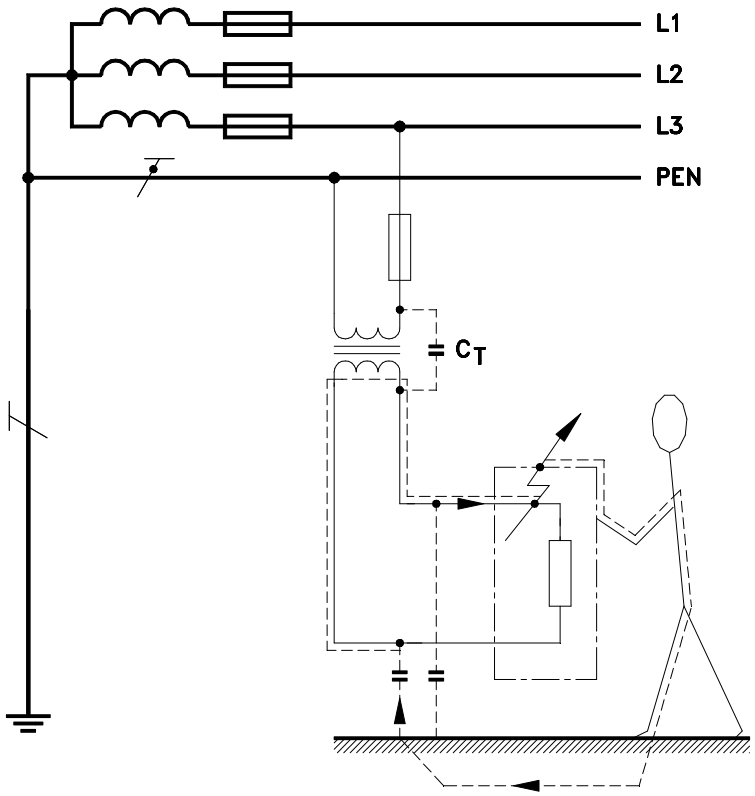


Figure 5.2.12

Protection by electrical separation. Isolating transformer with one equipment.

5.3. Protection against both direct and indirect contact

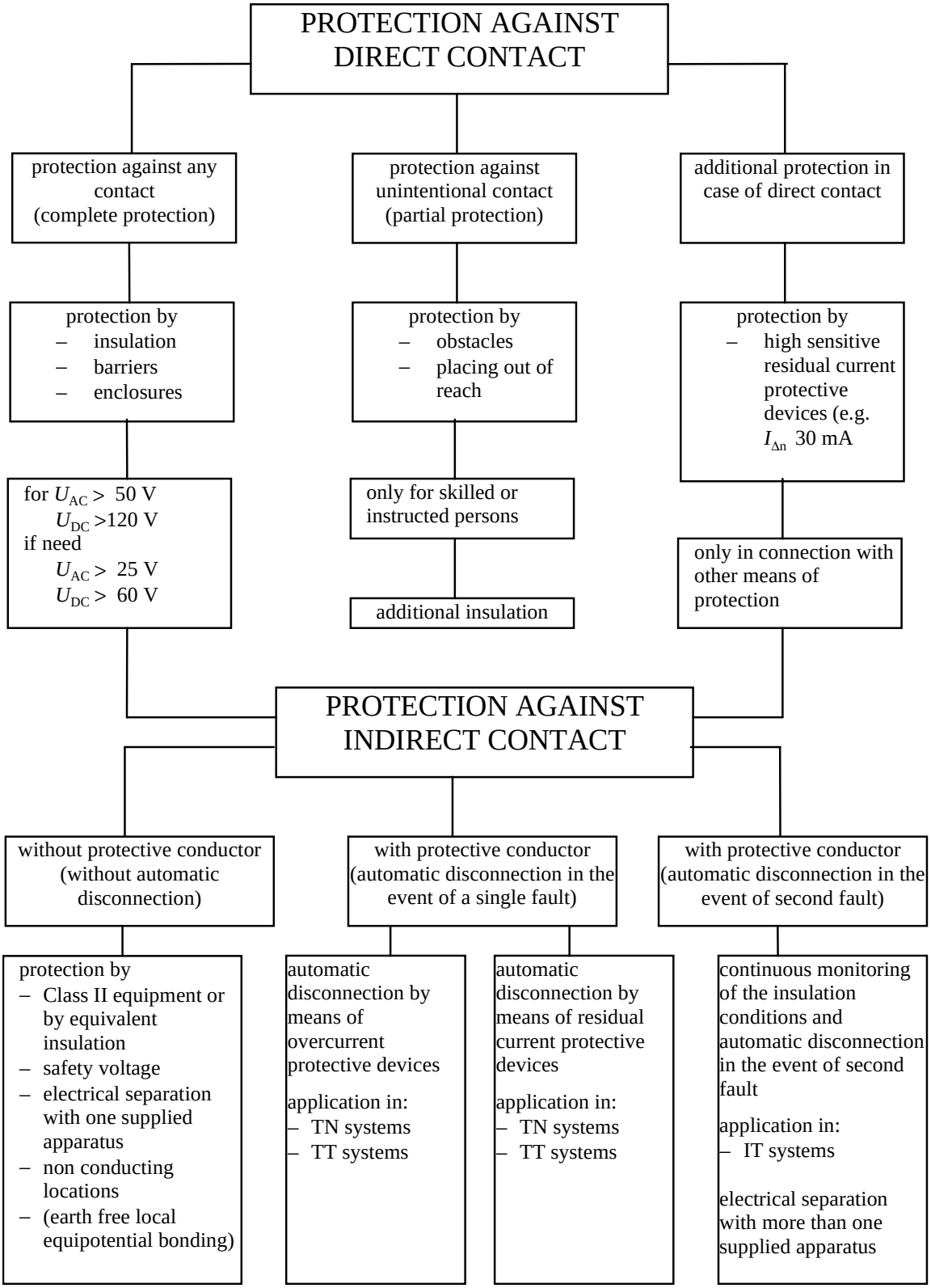
The idea of application safety limits of touch voltage can be seen just at the protection both during normal service and in case of fault. This type of protection is regarded as being ensured when the highest voltage cannot exceed 50 V a.c. or 120 V d.c. (For wet and very bad condition the highest voltage must exceed the limits according to Table 4.4.1). There are many other conditions, which shall be fulfilled in this type of protection. (According to these conditions the protection is divided into three basic types:

SELV - safety extra low voltage,

PELV - protective extra low voltage,

FELV - functional extra low voltage.

Table 5.3 Survey of measures for protection against electric shock



6. CONSTRUCTION OF ELECTRICAL INSTALLATION AND EQUIPMENT

Electrical installation and electrical equipment shall be provided with regard to safety of persons and property and shall be protected against external influence, against harmful effects of other equipment and shall be made in such a way not to effect harmfully on other equipment or other installation.

Following measures are applied on electrical equipment to fulfill above mentioned principles:

- protection provided by enclosures,
- proper installation of protective conductor,
- proper installation of electrical equipment.

6.1. Degrees of protection provided by enclosures (IP Code)

The European Standard EN 60529: 1991 and ČSN EN 60529: 1993 describes a system for classifying the degrees of protection provided by the enclosure of electrical equipment.

The type of protection covered by this system of classification is as follows:

1) protection of persons against access to hazardous parts inside the enclosure;
2) protection of the equipment inside the enclosure against ingress of solid foreign object;
3) protection of the equipment inside the enclosure against harmful effects due to the ingress of water.

This standard applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV.

Enclosure is a part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.

IP Code is a coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection.

Tab 6.1.1 IP Code (short description)

6.1.1 Elements of the IP Code and their meaning

Arrangement of the IP Code: the IP Code indicates the degree of protection provided by an enclosure in the following way:

IP 2 3 C H

Code letters (international protection)

First characteristic numeral (numerals 0 to 6, or letter X)

Second characteristic numeral (numerals 0 to 8, or letter X)

Additional letter (optional) (letters A, B, C, D)

Supplementary letter (optional) (letters H, M, S, W)

Where a characteristic numeral is not required be specified, it shall be replaced by the letter "X" ("X X" if both numerals are omitted).

Additional letters and/or supplementary letters may be omitted without replacement.

Table 6.1.2 Degrees of protection against access to hazardous parts indicated by the first characteristic numeral

First characteristic numeral	**Degree of protection**	
	Brief description	**Definition**
0	Non- protected	-
1	Protected against access to hazardous parts with the back of hand	The access probe, sphere of 50 mm∅ shall have adequate clearance from hazardous parts
2	Protected against access to hazardous parts with a finger	The jointed test finger of 12 mm∅ , 80 mm length, shall have adequate clearance from hazardous parts
3	Protected against access to hazardous parts with a tool	The access probe of 2,5 mm∅ shall not penetrate
4	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm∅ shall not penetrate
5	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm∅ shall not penetrate
6	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm∅ shall not penetrate

Table 6.1.3 Degrees of protection against solid foreign objects indicated by the first characteristic numeral

First characteristic numeral	**Degree of protection**	
	Brief description	**Definition**
0	Non-protected	-
1	Protected against solid foreign objects of 50 mm ∅ and greater	The object probe, sphere of 50 mm ∅ shall not fully penetrate [1)]
2	Protected against solid foreign objects of 12,5 mm ∅ and greater	The object probe, sphere of 12,5 mm ∅ shall not fully penetrate [1)]
3	Protected against solid foreign objects of 2,5 mm ∅ and greater	The object probe of 2,5 mm ∅ shall not penetrate at all [1)]
4	Protected against solid foreign objects of 1,0 mm ∅ and greater	The access probe of 1,0 mm ∅ shall not penetrate at all [1)]
5	Dust- protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust-tight	No ingress of dust
[1)] The full diameter of the object probe shall not pass through an opening of the enclosure		

Table 6.1.4 Degrees of protection against water indicated by the second characteristic numeral

Second characteristic numeral	**Degree of protection**	
	Brief description	Definition
0	Non-protected	-
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops shall have no harmful effects when the enclosure is tilted at any angle up to 15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects

6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7

An enclosure designated with second characteristic numeral 7 or 8 only is considered unsuitable for exposure to water jets (designated by second characteristic numeral 5 or 6) and need not comply with requirements for numeral 5 or 6 unless it is dual coded as follows:

Table 6.1.5

Enclosure passes test for		**Designation and marking**	**Range of application**
water jets second characteristic numeral	temporary/continuous second characteristic numeral		
5	7	IPX5/IPX7	Versatile
6	7	IPX6/IPX7	Versatile
5	8	IPX5/IPX7	Versatile
6	8	IPX6/IPX8	Versatile
-	7	IPX7	Restricted
-	8	IPX8	Restricted

Enclosures for "versatile" application indicated in the last column shall meet requirements for exposure to both water jets and temporary or continuous immersion.

Enclosures for "restricted" application indicated in the last column are considered suitable only for temporary or continuous immersion and unsuitable for exposure to water jets.

This standard provides for an optional extension of the IP Code by an additional letter A, B, C, or D if the actual protection of persons against access to hazardous parts is higher than that indicated by the first characteristic numeral.

Table 6.1.6 Degrees of protection against access to hazardous parts indicated by the additional letter

Additional letter	**Degree of protection**	
	Brief description	**Definition**
A	Protected against access with the back of the hand	The access probe, sphere of 50 mm ∅ shall adequate clearance from hazardous parts
B	Protected against access with a finger	The jointed test finger of 12 mm ∅, 80 mm length, shall have adequate clearance from hazardous parts
C	Protected against access with a tool	The access probe of 2,5 mm ∅, 100 mm length, shall have adequate clearance from hazardous parts
D	Protected against access with a wire	The access probe of 1,0 mm ∅, 100 mm length, shall have adequate clearance from hazardous parts

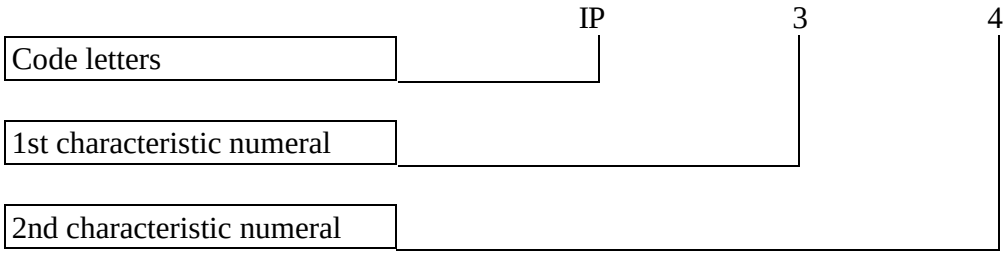
In the relevant product standard, a supplementary letter following the second characteristic numeral or the additional letter may indicate supplementary information.

Table 6.1.7 Supplementary letters

Letter	**Significance**
H	High-voltage apparatus
M	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (e.g. the rotor of a rotating machine) are in motion
S	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (e.g. the rotor of a rotating machine) are stationary
W	Suitable for use under specified weather conditions and provided with additional protective features or processes

6.1.2 Examples of designations with the IP Code

1) IP Code not using optional letters:



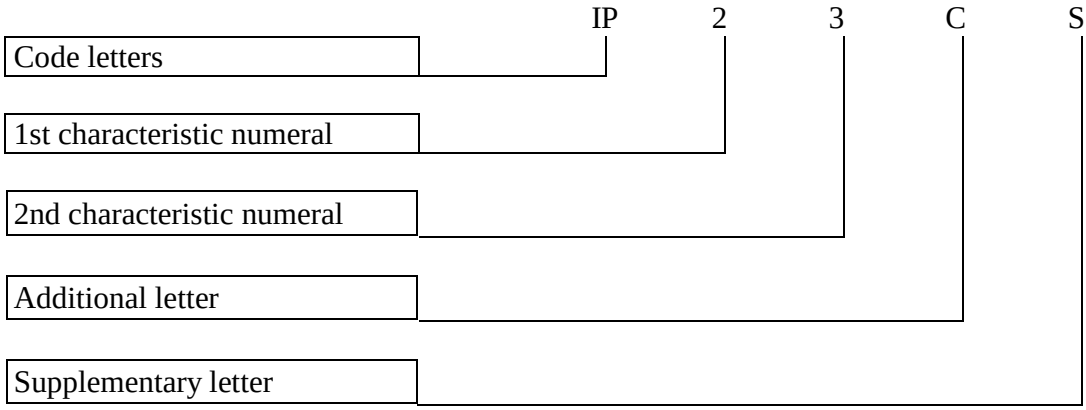
An enclosure with this designation (IP Code)

(3) - protects persons, handling tools having a diameter of 2,5 mm and greater, against access to hazardous parts;

- protects the equipment inside the enclosure against ingress of solid foreign objects having a diameter of 2,5 mm and greater;

(4) - protects the equipment inside the enclosure against harmful effects due to water splashed against the enclosure from any direction.

2) IP Code using optional letters:



An enclosure with this designation (IP Code)

(2) - protects persons against access to hazardous parts with fingers;

- protects the equipment inside the enclosure against ingress of solid foreign objects having a diameter of 12,5 mm and greater;

(3) - protects the equipment inside the enclosure against the harmful effects due to water sprayed against the enclosure;

(C) - protects persons handling tools having a diameter of 2,5 mm and greater and a length not exceeding 100 mm against access to hazardous parts (the tool may penetrate the enclosure up to its full length);

(S) - is tested for protection against harmful effects due to the ingress of water when all the parts of the equipment are stationary.

6.2. Rules for installation of electrical equipment (apparatus and appliances)

By designing and mounting any electrical installation some basic rules shall be followed.

For the design of the electrical installation the main aspects are subordinated to the aim to provide:

– the protection of persons, livestock, and property,
– the proper functioning of the electrical installation for the use intended.

We shall pay attention to the prevention of danger that may arise when the installation is not designed and mounted properly.

In electrical installation, two major types of risk exist:

– shock currents,
– excessive temperatures likely to cause burns, fires, etc.

The protection against shock currents or, in another words, the protection against electric shock, was mentioned in the preceding part. Let us remind of it here:

6.2.1.1 Protection against direct contact

Persons and livestock shall be protected against dangers that may arise from contact with live parts of the installation.

This protection can be achieved by one of the following methods:

– preventing current from passing through the body of any person or any livestock;
– limiting the current which can pass through a body to a value lower than the shock current.

6.2.1.2 Protection against indirect contact

Persons and livestock shall be protected against dangers that may arise from contact with exposed conductive parts in case of a fault.

This protection can be achieved by one of the following methods:

– preventing a fault current from passing through the body of any person or any livestock;
– limiting the fault current which can pass through a body to a value lower than the shock current;
– automatic disconnection of the supply in a determined time on the occurrence of a fault likely to cause a current to flow through a body in contact with exposed conductive parts, where the value of that current is equal to or greater than the shock current.

In connection with the protection against indirect contact, the application of the method of equipotential bonding is one of the important principles for safety.

The protection against electric shock shall be provided in case of high voltage equipment and devices as well as in case of low voltage equipment. Even insulated parts of high voltage equipment shall be protected against direct contact in order to avoid danger from leakage currents or dangerous electric charge on these parts. This protection may be achieved by suitable

locating of devices. In case of conductive floor around the high voltage device, the floor shall be connected with the exposed conductive parts of the device.

6.3. Proper installation of protective conductor

It follows from the principles mentioned above that almost in every electrical installation the conductor for mutual connection of exposed conductive parts, extraneous parts, and earth, besides the live (phase) conductors, shall be installed. This conductor is called **protective conductor** and is identified by letters **PE**. Protective conductors as well as terminals for protective conductors shall fulfill certain rules. These rules follow from the purpose of protective connection provided by them.

Protective conductors as well as the terminals connecting them shall be of sufficient cross-sectional area for conducting of fault currents, usually short circuit currents, caused by failure of installation and consequently by short connection between live parts and exposed conductive parts in the point of failure. The terminals for protective conductors shall be much more reliable than terminals for other conductors. It is necessary because protective conductors have safety function. It means that the safety depends in electrical installation more or less on protective conductors.

The cross-sectional area of the protective conductor shall be not less than the appropriate value shown in Table 6.3.1. If the application of this table produces non-standard sizes, conductors having the nearest standard cross-sectional area are to be used.

Table 6.3.1

Cross-sectional area of phase conductors of the installations S (mm^2)	**Minimum cross-sectional area of the corresponding protective conductor (PE) S_p (mm^2)**
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	S/2

The values in Table 6.3.1 are valid only if the protective conductor is made of the same material as the phase conductors. If this is not so, the cross-sectional area of the protective conductor is to be determined in a manner which produces a conductance equivalent to that which results from the application of Table 6.3.1.

The cross-sectional area of every protective conductor, which does not form a part of the supply cable or cable enclosure, shall be, in any case, not less than:

– 2,5 mm^2 if mechanical protection is provided,

- 4 mm^2 if mechanical protection is not provided.
- Protective conductor may comprise:
- conductors in multicore cables;
- insulated or bare conductors in a common enclosure with live conductors;
- fixed bare or insulated conductors;
- metal coverings, e.g. the sheaths, screens and armouring of certain cables;
- metal conduits or other metal enclosures for conductors;
- certain extraneous conductive parts, e.g. metal constructions of buildings, metal tubes, pipes, metal enclosures or frames.

6.3.1 PEN conductor

In TN systems, for cables in fixed installations having a cross-sectional area not less than 10 mm^2 for copper and 16 mm^2 for aluminium, a single conductor may serve both as protective conductor and neutral conductor. This conductor is identified by the letters **PEN** (PE - as for protective conductor, N - as for neutral conductor). It shall be considered that a residual current-operated device can not protect parts of installation where PEN conductor is used.

If from any point of the installation separate conductors provide the neutral and protective functions, it is inadmissible to connect these conductors to each other from that point. At the point of separation, separate terminals or bars shall be provided for the protective and neutral conductors. The PEN conductor shall be connected to the terminal or bar intended for the protective conductor.

Extraneous conductive parts shall not be used as PEN conductor.

6.3.2 Preservation of electrical continuity of protective conductors

Protective conductor shall preserve its ability to conductively connect exposed conductive parts, extraneous conductive parts with earth under any circumstances when electrical equipment and appliances are connected to the installation. For that purpose:

- protective conductors shall be suitably protected against mechanical and chemical deterioration and electrodynamic forces;
- no switching device shall be inserted in the protective conductor;
- switching or disconnecting of protective conductor is permitted only in case when all conductors of relevant circuit are disconnected at the same time;
- when disconnecting the protective conductor in socket outlet, this conductor shall be disconnected later and connected sooner than other conductors of the circuit passing through the socket outlet;

– where electrical monitoring of earth-continuity is used, the operating coils shall not be inserted in protective conductors.

6.3.3 Terminals for protective conductors

According to the purposes of connection of protective conductors we can distinguish:

– inward terminals,
– outward terminals.

The **inward protective terminal** is situated close to the phase terminals and is determined for the protective conductor, which is the part of the supply cable. It is reliably conductively connected to the exposed conductive part of the supplied appliance or equipment.

The outward **protective terminal is** determined for the connection of separate protective conductor for equipotential bonding. It is situated on the outer surface of the exposed conductive part of equipment and is used for connection with exposed constructive parts of other equipment and with extraneous conductive parts. Conductive connection of these parts by the separate protective conductor represents equipotential bonding (main or supplementary).

According to the way of connecting protective conductors there are:

– separable terminals,
– inseparable terminals.

The **separable terminal** for connecting the protective conductor to the exposed conductive part is made as a screw terminal. One part of separable terminals shall be made of corrosion resisting material, preferably of brass.

A washer or ring shall be inserted into the screw terminal for carrying over the contact pressure effecting on the conductor. For screw terminals determined for higher values of current than 25 A the springy element shall be used.

Inseparable terminals could be made by soldering, welding or moulding.

All exposed conductive parts of electrical equipment in mounted stage shall be durably and reliably connected to the terminal for protective conductor.

The reliability of conductive connection between the main part of the equipment and the separable part of the equipment (lids or doors) shall not be influenced by ageing or deformation of packing between both parts.

6.4. Proper installation of electrical equipment

As for the danger of excessive temperatures, following measures shall be carried out.

6.4.1 Protection against thermal effects

The electrical installation shall be so arranged that there is no risk of ignition of flammable materials due to high temperature or electric arc. In addition, during normal operation of the electrical equipment, there shall be no risk of persons or livestock suffering burns.

To protect persons as well as property against danger from electricity, the installation as well as the equipment used shall fulfill following conditions:

6.4.2 Type of wiring and methods of installation

The choice of the type of wiring and the methods of installation depend on:

- the nature of the locations;
- the nature of the walls or other parts of the building supporting the wiring;
- accessibility of wiring to persons and livestock;
- voltage;
- the electromechanical stress likely to occur due to short-circuits;
- ther stresses to which the wiring can be exposed during the erection of the electrical installation or in service.

With respect to expected utilization of the installation and to the danger that may arise in the course of its utilization, the installation shall be divided into circuits.

6.4.3 Nature of demand

The number and type of the circuits required for lighting, heating, power, control, signaling, telecommunication, etc. are to be determined by:

- location of points of power demand;
- loads to be expected on the various circuits;
- daily and yearly variation of demand;
- any special conditions;
- requirements for control, signaling, telecommunication, etc.

If a great danger for human lives or property may arise as a consequence of interrupting of the electrical supply (e.g. in hospitals, in theaters), the installation shall be equipped with emergency supply. For the purpose of safety it is necessary to determine and design:

- the source of emergency supply (nature, characteristics) and
- circuits to be supplied by the emergency source.

6.4.4 Selection of electrical equipment

Every item of electrical equipment used in electrical installations shall comply with such standards as are appropriate.

6.4.5 Characteristics

Every item of electrical equipment selected shall have suitable characteristics appropriate to the values and conditions on which the design of the electrical installation is based. Every electrical equipment and device connected to the supply shall comply with following characteristics:

Nature of current of available supply: a.c and/or d.c.

Nature and number of conductors:

- for a.c.: phase conductors,
- neutral conductors,
- protective conductor;
- for d.c.: conductors equivalent to those listed above.

Values and tolerances:

- voltage and voltage tolerances,
- frequency and frequency tolerances,
- maximum current allowable,
- prospective short-circuit current.

Voltage: Electrical equipment shall be suitable with respect to the maximum steady voltage (r.m.s. values for a.c.) likely to be applied, as well as overvoltages likely to occur.

For certain equipment, it may be necessary to take account of the lowest voltage likely to occur.

Current: All electrical equipment shall be selected with respect to the maximum steady current (r.m.s. value for a.c.). It is the current, which the equipment has to carry in normal service. Above that the equipment shall be selected with respect to the current likely to be carried in abnormal conditions and the period (e.g. the operating time of protective devices if any) during which it may be expected to flow.

Devices are allowed to be loaded according to their ratings.

Frequency: If frequency has an influence on the characteristics of electrical equipment, the rated frequency of the equipment shall correspond to the frequency likely to occur in the circuit.

Power: All electrical equipment selected on the basis of its power characteristics shall be suitable for the duty demanded on the equipment, taking into account the load factor and the normal service conditions.

Protective equipment: When there is any danger of changing of characteristics of supply, the protective equipment preventing from the consequences of it shall be used.

The **characteristics of protective equipment** shall be determined with respect to their function, which may be, e.g., protection against the effects of:

– overcurrent (overload current, short-circuit current),
– earth-fault current,
– overvoltage,
– undervoltage and no-voltage.

The protective devices shall operate at values of current, voltage and time, which are suitably related to the characteristics of the circuits, and to the possibilities of danger.

6.4.6 Cross-section of conductors

The cross-section of conductors shall be determined according to:

a) their admissible maximum temperature,
b) the admissible voltage drop,
c) the electromechanical stress likely to occur due to short-circuits,
d) other mechanical stresses to which the conductors can be exposed,
e) the maximum impedance with respect to the functioning of the short-circuit protection.

The above-listed items concern primarily the safety of electrical installations. Cross-sectional areas greater than those required for safety may be desirable for economic operation.

6.4.7 Protection against overcurrent

Persons or livestock shall be protected against injury and property shall be protected against damage due to excessive temperatures or electromechanical stresses caused by any overcurrents likely to arise in live conductors.

This protection can be achieved by one of the following methods:

– automatic disconnection on the occurrence of an overcurrent before this overcurrent attains a dangerous value, taking into account its duration;
– limiting the maximum overcurrent to a safe value and duration.

6.4.8 Protection against fault currents

Conductors, other than live conductors, and any other parts intended to carry a fault current shall be capable of carrying that current without attaining an excessive temperature.

Particular attention should be given to earth fault currents and leakage current.

6.4.9 Protection against overvoltage

Persons or livestock shall be protected against injury and property shall be protected against any harmful effects as a consequence of a fault between live parts of circuits supplied at different voltages.

Persons or livestock shall be protected against injury and property shall be protected against damage as a consequence of any excessive voltages likely to arise due to other causes (e.g. atmospheric phenomena or switching overvoltages).

6.4.10 Disconnecting devices

Disconnecting devices shall be provided so as to permit disconnection of the electrical installation, circuits or individual items of apparatus as required for maintenance, testing, fault detection or repair.

6.4.11 Emergency control

Where, in case of danger, immediate interruption of supply could be necessary an interrupting device shall be installed. It should be installed in such a way that it can be easily recognized and effectively and rapidly operated.

6.4.12 Conditions of installation

All electrical equipment shall be selected so as to withstand safely the stresses and the environmental conditions characteristic of its location and to which it may be exposed. If, however, an item of equipment does not have by design the properties corresponding to its location, it may be used on condition that adequate additional protection is provided as a part of the completed electrical installation.

6.4.13 Prevention of mutual influence

The electrical installation shall be arranged in such a way that no mutual detrimental influence will occur between the electrical installation and non-electrical installations of the building.

All electrical equipment shall be selected so that it will not cause harmful effects on other equipment or impair the supply during normal service including switching operations. In this context, the factors, which can have an influence, include, e.g.

- power factor,
- inrush current,
- asymmetrical load,
- harmonics.

6.4.14 Accessibility of electrical equipment

* sufficient space for the initial installation and later replacement of individual items of electrical equipment;
* accessibility for operation, testing, inspection, maintenance, and repair.

6.5. Erection and initial verification of electrical installations

6.5.1 Erection

For the erection of the electrical installation, good workmanship by suitably qualified personnel and the use of proper materials shall be provided for.

The characteristics of the electrical equipment, as determined according to the rules mentioned above, shall not be impaired in the process of erection (e.g. by connecting them to the electrical circuit, by fastening them or by locating them to the place of function).

Conductors shall be identified in accordance with IEC 446:1989, Identification of conductors by colours or numerals (see the chapter 7.1).

Connection between conductors and between conductors and other electrical equipment shall be made in such a way that safe and reliable contact is ensured.

Connections shall be done in such a way that conductors are sufficiently insulated one from another as well as from other parts and that the protection against electric shock and against external influences is not impaired.

All electrical equipment shall be installed in such a manner that the designed cooling conditions are not impaired.

All electrical equipment likely to cause high temperatures or electric arcs shall be placed or guarded so as to eliminate the risk of ignition of flammable materials. Where the temperature of any exposed parts of electrical equipment is likely to cause injury to persons, those parts shall be so located or guarded as to prevent accidental contact therewith.

Where the protection against external influences provided by enclosures of equipment is not sufficient, supplementary measures like placing out of reach of harmful influence or providing with supplementary enclosure shall be done when mounting the equipment.

6.5.2 Initial verification

Electrical installations shall be tested and inspected before being placed in service and after any important modification to verify proper execution of the work in accordance with the standard.

A test report shall be worked out on verification. The report shall comprehend the description of the verified installation or equipment, the list of measuring equipment used, the list of measurements and test, and the list of defects found. As a result of the verification, the test report shall announce whether the equipment or installation is able to be safety operated.

The keeper of the installation or equipment shall keep the verification report.

7. SAFETY SYMBOLS AND SAFETY IDENTIFICATION FOR USE ON ELECTRICAL EQUIPMENT

7.1. Identification of conductors and terminals

For the purpose of identification of the use of conductors in electrical distribution system, the insulation of conductors in the system (in one cable or in one line) is identified by colours. The terminals on electrical equipment are identified for the same purpose. The identification is placed either directly on the terminal or near to it. The identification is provided by the combination of letters and numbers (alphanumeric notation) or by symbols. The same identification of terminals as used on electrical equipment (appliances, devices, etc.) is used in electrical diagrams. The identification of conductors by the combination of letters and numbers (alphanumeric notation) is used in diagrams in the same way as the identification of terminals.

Table 7.1.1 Correlation between alphanumeric notations and colours of insulated and bare conductors and symbols for identification of relevant terminals

Designation of conductors		**Identification**		
		Alphanumeric notation	**Colour**	**Symbols (for terminals)**
Supply a.c. system	Phase 1	L1	Not specified 1)	
	Phase 2	L2	Not specified 1)	
	Phase 3	L3	Not specified 1)	
	Neutral	N	LIGHT BLUE	
Equipment terminal a.c. system	Phase 1	U	Not specified	
	Phase 2	V	Not specified	
	Phase 3	W	Not specified	
Supply d.c. system	Positive	L+	Not specified 1)	
	Negative	L-	Not specified 1)	
	Mid-wire	M	LIGHT BLUE	
Protective conductor		PE	GREEN-AND-YELLOW	
Earthing conductor		E	Not specified	
Noiseless (clean) earth		TE	Not specified	
PEN conductor		PEN	GREEN-AND-YELLOW with LIGHT BLUE markings or LIGHT BLUE with GREEN AND YELLOW markings	

1) Preferred colours used for identification of conductors in installations are black and brown.

7.2. Graphical symbols for use on electrical equipment

According to the **way of connection** of electrical equipment to the electrical system, following symbols are used:

Table 7.2.1 Graphical symbols for Class I, Class II and Class III

	This symbol is situated on the terminal or near to the terminal for connection of equipment to the protective conductor of the system. This symbol marks the equipment of **Class I** which is to be except for live conductors connected to the protective conductor (PE) of the system
	This symbol, usually situated on the enclosure of the electrical equipment, marks the equipment of **Class II**. This equipment shall only be connected to the live conductors of the system and it is not provided (but for exceptional cases) with the terminal for protective conductor
	This symbol, usually situated on the enclosure of the electrical equipment, marks the equipment of **Class III.** This equipment is designed only for supply at safety extra - low voltage (SELV).

According to the **external influences** which electrical equipment is to sustain, following symbols are used:

Table 7.2.2 Graphical symbols for external influences

	symbol used on electrical equipment protection of which provided by enclosures (IP Code) is IP 21
	symbol used on equipment protected against humidity
	symbol used on equipment designed for outdoor conditions
	symbol used on sealed equipment
	symbol used on sealed closed equipment
	symbol used for water tight equipment

7.3. Safety information on electrical equipment and devices

To recognize what an electrical equipment or device is for and whether it may be used for the intended purpose, the identification or coding is used.

To understand this identification or coding, the basic principle of them should be learned. Such principle are given in the international standard ISO 3864: 1984.

The safety colours and safety signs on equipment and devices are used to give basic safety information. The purpose of such information is to prevent accidents and health hazards. safety colours and safety signs are chosen and designed in such a way as to draw attention rapidly to objects and situations affecting safety and health. Safety signs shall be used only for instructions related to safety and health.

7.3.1 Safety colours

The general meaning assigned to safety colours shall be as given in Table 7.3.1.

Table 7.3.1 General meaning of safety colours.

Safety colour	Meaning of objective	Example of use
Red	Stop Prohibition	Stop signs Emergency stop Prohibition signs
	This colour is also used for fire-prevention and fire- fighting equipment and its location	
Blue 1)	Mandatory action	Obligation to wear personal protective equipment
Yellow	Caution, risk of danger	Indications of dangers (fire, explosion, radiation, toxic hazards, etc.) Warning for steps, low passages, obstacles 2)
Green	Safe condition	Escape routes Emergency exits Emergency showers First aid and rescue stations

1) Blue is considered a safety colour only if used in a circular shape.

2) Fluorescent orange-red may be used in place of safety yellow except on safety signs. This colour is very conspicuous, especially in conditions of poor natural lighting.

7.3.2 Example of use of safety colours and contrast colours

The following combination of safety yellow and black may be used to indicate temporary or permanent risk locations such as:

– locations where is a risk of collision, falling, stumbling or falling objects;

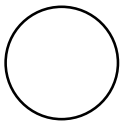
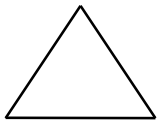
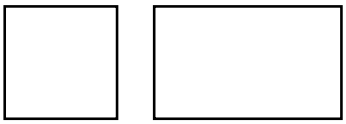
– steps, holes in floors, etc.

Figure 7.3.1 Safety yellow and black

Yellow shall cover at least 50% of the area of the sign.

7.3.3 Geometric form and meaning of safety signs

Table 7.3.2 Geometric form and meaning of safety signs

Geometric form	Meaning
	Prohibition or mandatory action
	Warning
	Information (including instructions)

7.3.4 Safety signs

The safety colours and contrast colours (foreground/background) and geometric form shall be used only in the following combinations to obtain the four basic types of safety signs (Tab. 7.3.3).

Tab. 7.3.3 Four basic types of safety signs

Sign	Safety colour		Symbol or text
	Background colour	Foreground colour	
Prohibition	**white**	**red** circular band and crossbar	black 1)
Mandatory action	**blue**		white 2)
Warning	**yellow**	**black** triangular band	black 2)
Information	**green**		white

1) The symbol or text shall be placed centrally on the background, and shall not obliterate the cross bar.
2) The symbol or text shall be placed centrally on the background.

7.3.5 Examples of safety signs

Tab 7.3.4 Examples of safety signs

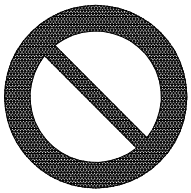
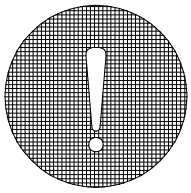
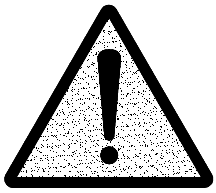
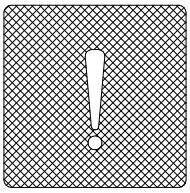
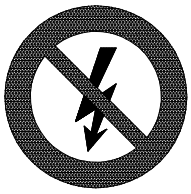
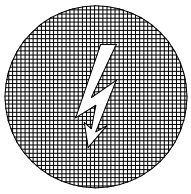
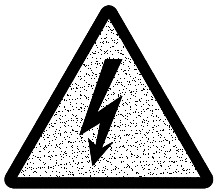
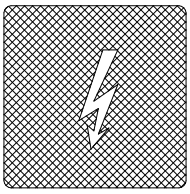
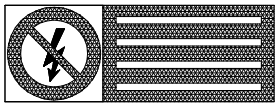
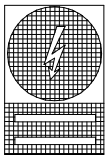
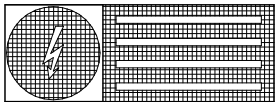
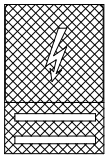
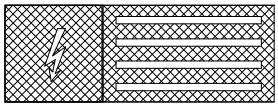
Meaning of sign	**Symbol**	**Type of safety sign**			
		Prohibition	Mandatory action	Warning	Information
General expression of safety meaning	Without symbol or exclamation mark				
Manipulation with electrical equipment	Broken arrow				

Table 7.3.5 Survey of four basic safety signs in Czech Republic (ČSN ISO 3864)

	Vertical format	**Horizontal format**
Prohibition signs		
Mandatory action signs		
Warning signs		
Information signs		

RED BLUE GREEN YELLOW

7.4. Coding of indicating devices and actuators by colours (IEC 73)

The general principles for the meaning of colours for the coding of information on electrical equipment are given in Table .4.1

Table 7.4.1 Meaning of colours for coding - General principles

Colour	**Meaning**		
	Safety of persons or environment	Conditions of process	State of equipment
RED	Danger	Emergency	No general meaning
YELLOW	Caution	Abnormal	No general meaning
GREEN	Safe	Normal	No general meaning
BLUE	Mandatory significance		
WHITE GREY BLACK	No special meaning assigned		

7.4.1 Indicating devices

The meaning of colours used for coding indicating devices shall be as given in Tab. 7.4.2 to 7.4.4 Table 7.4.2 gives the meaning of colours of indicating devices with respect to the safety of persons and/or environment.

Table 7.4.2 Meaning of colours of indicating devices with respect to the safety of persons *), property and/or the environment.

Colour	**Meaning**	**Explanation**	**Action by**		**Examples of application**
			the operator	other persons	
RED	Danger	Dangerous situation or imperative order	Immediate response to deal with a dangerous situation	Escape or stop	Prohibited entry
YELLOW	Caution	Out of order Faulty situation Permanent or temporary risk (e.g. accessibility to live or moving parts)	Intervention to prevent a dangerous situation	Evacuation or restricted access	Restricted access
GREEN	Safe	Indication of a safe situation Safe to proceed Way clear	No action demanded	No action demanded	Escape route
BLUE	Mandatory	Indication of a need for mandatory action	Mandatory action	Mandatory action	Mandatory route
WHITE GREY BLACK	No specific meaning assigned	General information	No action demanded	No action demanded	Explanation of route

*) Persons who are in the vicinity of the plant or process, but who are not themselves operators.

Table 7.4.3 gives the meaning of colours of indicating devices with respect to the condition of the process.

Table 7.4.4 gives the meaning of colours of indicating devices with respect to the state of equipment.

The use of the colour RED, YELLOW and GREEN in place of the

preferred colours WHITE, GREY and BLACK in Table 7.4.4 is permitted only, if no risk of confusion arises with the meaning of Tables 7.4.2 and 7.4.3 and the colours are supplemented with graphical symbols and/or by written information provided on near the indicating devices.

Table 7.4.3 Meaning of colours of indicating devices with respect to the condition of the process.

Colour	Meaning	Explanation	Action of operator	Examples of application
RED	Emergency	Dangerous conditions	Immediate action to deal with a dangerous condition, e.g. by: - operating emergency stop - opening safety valve - starting cooling pump	- Pressure temperature out of safe limits - Voltage drop - Break down of a main unit - Stoppage of necessary machines, service systems - Deep-freezer temperature too high - Over-travelling of a stop position of a hoist
YELLOW	Abnormal	Abnormal conditions Impending critical condition	Monitoring and/or intervention (e.g. by re-establishing the intended function)	- Pressure/temperature different from normal level - Tripping of protecting device or of an auxiliary unit - Conveyor overloaded - Over-travelling of a limit switch - Position change of a valve or a conveyor belt - Deep-freezer on super freezing
GREEN	Normal	Normal conditions	Optional	- Authorisation to proceed - Indication of normal working limits
BLUE	Mandatory	Indication of a condition which requires action	Mandatory action	- Instruction to the operator to enter preselected values
WHITE GREY BLACK	No specific meaning assigned	Any meaning, may be used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE	Monitoring	- General information, (e.g. confirmation of a command, indication of measured values)

Table 7.4.4 Meaning of preferred colours of indicating devices with respect to the state of the equipment

Colour	Meaning	Examples of application
BLUE	Mandatory	Indication of need to enter - present values - other modes of control
WHITE GREY BLACK	No specific meaning assigned	Status indication, e.g.: - switch OPEN/CLOSED - valve CLOSED/OPEN - motor STOPPED/RUNNING

7.4.2 Marking of actuators

In case where suitable graphical symbols are standardized in IEC 417 mechanical actuators shall be marked with those symbols. If no suitable symbol is standardized, the indicator may be marked in complete words or recognized abbreviations.

Table 7.4.5 Graphical symbols for marking pushbuttons according to the IEC 417.

Meaning	**Symbol**
START or ON	
STOP or OFF	
push-buttons which act alternatively as START and STOP or ON and OFF	
push-buttons that cause a movement while they are pressed and stop the movement when they are released	

7.4.3 Colours of actuators

The meaning of the colours used for the coding of actuators shall be as given in Table 7.4.6.

Table 7.4.6 General meaning of colour of actuators

Colour	**Meaning**	**Explanation**	**Example of application**
RED	Emergency	Action in case of danger or emergency	- Emergency stop - Stop or off with emergency stop - Initiation of emergency function (see note 1)
YELLOW	Abnormal	Action in abnormal condition	- Intervention to suppress abnormal condition - Manual intervention to restart an interrupted automatic cycle
GREEN	Safe	Action in case of safe situation or to prepare normal condition	(see note 1)
BLUE	Mandatory	Condition which requires action	- Reset functions
WHITE GREY BLACK	No specific meaning assigned	General indication of functions	- May be used for any function, except for emergency stop, e.g. OFF/ON, STOP/START (see note 2)

Notes:

1) For normal STOP/OFF see next

START/ON see next

2) If supplementary means of coding (e.g. shape, position) are used for identification of actuators, the same colour WHITE or GREY or BLACK may be used for various actuators, e.g. WHITE for

START-actuators and WHITE for STOP-actuators.

Emergency actuators

The colour used for EMERGENCY-STOP/OFF actuators shall be RED.

STOP/OFF actuators

WHITE, GREY and BLACK are the preferred colours for STOP/OFF actuators, with the main preference being for BLACK, RED is also permitted. GREEN shall not be used. In the case of the same actuator used for the emergency and normal STOP/OFF operation, the colour shall be RED.

START/ON actuators

WHITE, GREY and BLACK are the preferred colours for START/ON actuators, which cause the closing of switching devices and the equipment to start, with the main preference being for WHITE, GREEN is also permitted. RED shall not be used.

8. EXTERNAL INFLUENCES EFFECTING ELECTRICAL EQUIPMENT AND INSTALLATION

Electrical equipment and electrical installations are exposed to external influences, not only during their use, but also during transportation, storage, and erection. Such external influences may be: ambient temperature, humidity, altitude, water, mechanical stresses, flora, fauna, etc.; but also utilization of equipment or the construction of buildings (e.g., material, design) may influence the installation.

All these external influences may hamper the safety of electrical installations. Therefore IEC has issued relevant standards for classification of external influences and environmental conditions, e.g.:

IEC Publication 364-3 (1977) **Electrical installations of buildings**.

Part 3: Assessment of general characteristics.

Chapter 32: Classification of external influences

IEC Publication 721 **Classification of environmental conditions**.

Chapter 32 of IEC 364-3 establishes the classification of external influences which require assessment in the design and erection of electrical installations. Table 8.1 shows a list of external influences.

Explanation of the codification for external influences in Chapter 32 of **IEC 364-3 (1977):**

Each condition of external influence is designed by a code comprising a group of two capital letters and a number as follows:

The **first letter** relates to the general category of external influence:

A environment

B utilization

C construction of buildings

The **second letter** relates to the nature of the external influence:

A ...

B ...

C ...

The **number** relates to the class within each external influence:

1 ...

2 ...

3 ...

For example the code AC2 signifies:

A environment

AC environment-altitude

AC2 environment-altitude > 2000 m.

Note: This classification is not intended to be used for marking equipment.

Table 8.1 Concise list of external influences according to IEC 364-3

A	**AA**	**Ambient temperature**	**AF**	**Corrosion**	**AM**	**Radiation**
	AA1	-60°C +5°C	AF1	Negligible	AM1	Negligible
	AA2	-40°C +5°C	AF2	Atmospheric	AM2	Stray currents
	AA3	-25°C +5°C	AF3	Intermittent	AM3	Electromagnetic
	AA4	-5°C +40°C	AF4	Continuous	AM4	Ionization
	AA5	+5°C +40°C			AM5	Electrostatics
	AA6	+5°C 60°C	**AG**	**Impact**	AM6	Induction
	AB	**Humidity**	AG1	Low	**AN**	**Solar**
			AG2	Medium		
	AC	**Altitude**	AG3	High	AN1	Negligible
					AN2	Significant
	AC1	≤ 2000 m	**AH**	**Vibration**		
	AC2	> 2000 m			**AP**	**Seismic**
			AH1	Low		
	AD	**Water**	AH2	Medium	AP1	Negligible
			AH3	High	AP2	Low
	AD1	Negligible			AP3	Medium
	AD2	Drops	**AJ**	**Other mechanical stresses**	AP4	High
	AD3	Sprays				
	AD4	Splashes	**AK**	**Flora**	**AQ**	**Lightning**
	AD5	Jets				
	AD6	Waves	AK1	No hazard	AQ1	Negligible
	AD7	Immersion	AK2	Hazard	AQ2	Indirect
	AD8	Submersion			AQ3	Direct
			AL	**Fauna**		
	AE	**Foreign bodies**			**AR**	**Wind**
			AL1	No hazard		
	AE1	Negligible	AL2	Hazard		
	AE2	Small				
	AE3	Very small				
	AE4	Dust				
B	**BA**	**Capability**	**BD**	**Evacuation**	**BE**	**Materials**
	BA1	Ordinary	BD1	(Low density/easy exit)	BE1	No risk
	BA2	Children	BD2	(Low density/difficult exit)	BE2	Fire risk
	BA3	Handicapped	BD3	(High density/easy exit)	BE3	Explosion risk
	BA4	Instructed	BD4	(High density/difficult exit)	BE4	Contamination risk
	BA5	Skilled				
	BB	**Resistance**				
	BC	**Contact with earth**				
	BC1	None				
	BC2	Low				
	BC3	Frequent				
	BC4	Continuous				
C	**CA**	**Materials**	**CB**	**Structure**		
	CA1	Non combustible	CB1	Negligible risk		
	CA2	Combustible	CB2	Fire propagation		
			CB3	Structure movement		
			CB4	Flexible		

IEC 721 presents a number of classes of environmental parameters and their severities covering the conditions most frequently met by electrotechnical products and equipment while being:- transported, stored, installed,used.

The classification is presented in such manner that Standard Committees or other users concerned can select from the classes proposed those which are appropriate for the case of application. Table 8.2 shows a list of the Parts of IEC 721.

Table 8.2 List of Parts of the IEC Publication 721 "Classification of environmental conditions" (collated 1.7.1989)

IEC No.	Classification of environmental conditions
721-1	**Part 1**: Classification of environmental parameters and their severities
721-2	**Part 2**: Environmental conditions appearing in nature
721-2-1 1)	Temperature and humidity
721-2-2	Precipitation and wind
721-2-3	Air pressure
721-2-4 2)	Solar radiation and temperature
721-2-5	Dust, sand, salt, mist, wind
721-2-6	Earthquake vibrations and shocks
721-2-7	Fauna and flora
721-3	**Part 3**: Classification of groups of environmental parameters and their severities
721-3-0 3)	Introduction
721-3-1	Storage
721-3-2	Transportation
721-3-3 4)	Stationary use at weatherprotected locations
721-3-4 4)	Stationary use at nonweatherprotected locations
721-3-5	Ground vehicle installations
721-3-6 4)	Ship environment
721-3-7	Portable and nonstationary use

1) IEC 721-2-1 (1982) with one amendment (Appendix A and B):

- Amendment No.1 (1987) "Geographical survey of statistical open-air climates" with two coloured maps "Open-air climates of continents and large islands" and "Constitutional

diagram for humid air".

2) IEC 721-2-4 (1987) with one amendment:

- Amendment No.1 (1988) "Appendix A: World distribution of daily global irradiation".

3) IEC 721-3-0 with one amendment:

- Amendment No.1 (1987) "Applies to the duration and frequency of occurrence".

4) For these Publications exists a corrigendum.

8.1. Climate

The climate as an influential factor on electrical equipment is the physical and chemical atmospheric condition, outdoors or indoors, **including daily and seasonal alterations,.**

With regard to this definition, by "atmosphere" is meant the combination of dry air with water vapour, dust and/or corrosive components. Climate takes into account both natural and technical influences (Figure 8.1).

The two influences should not be handled separately, since they will always occur combined where technical equipment is concerned.

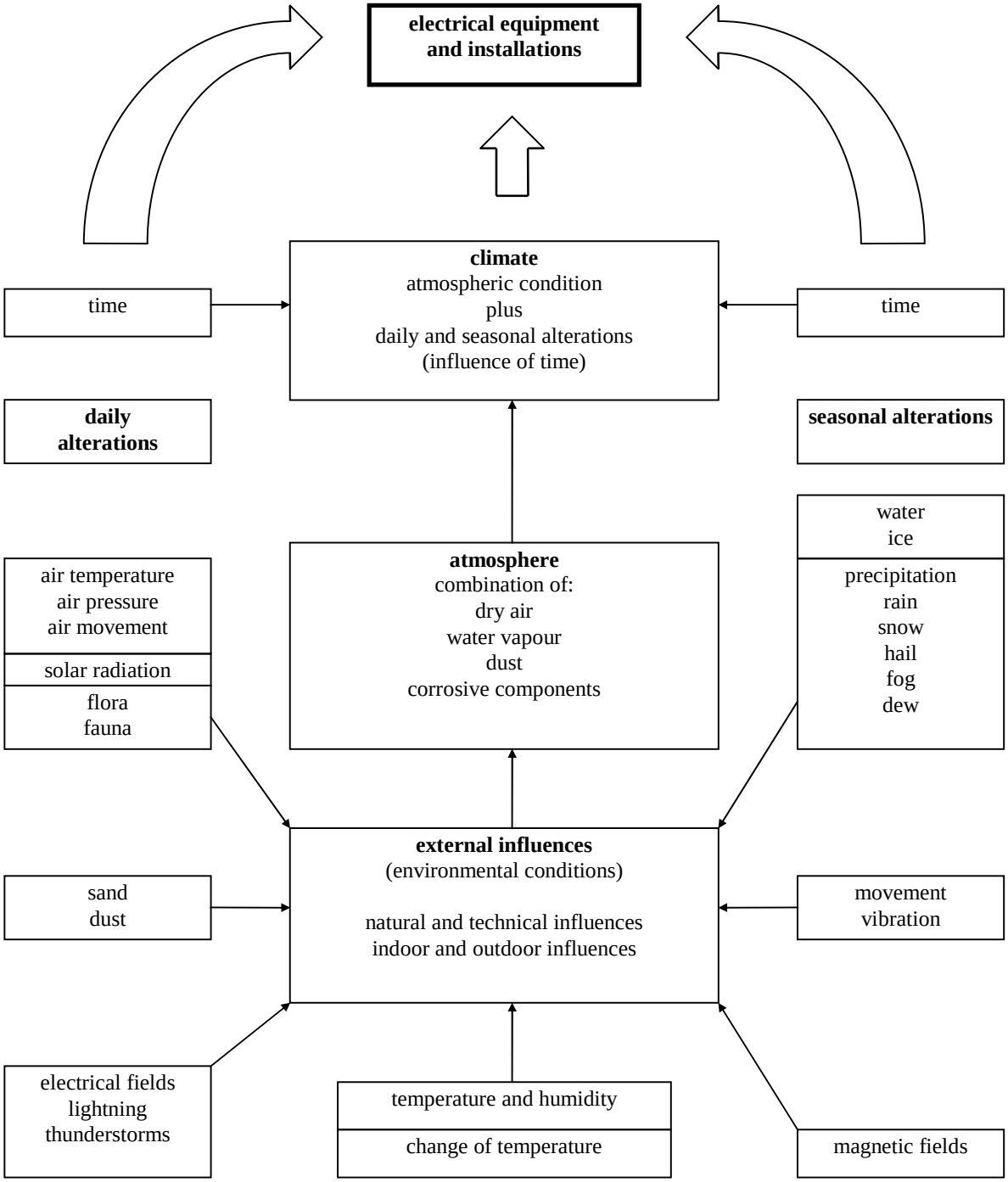


Figure 8.1

Climate and atmosphere, with examples or relevant parameters of external influences (environmental conditions).

Table 8.3 Characteristics of electrical equipment regarding t**emperature, altitude, presence of water, foreign solid bodies and corrosive substances.**

Code	External influences	Characteristic required for selection and erection of equipment
A	Environmental conditions	
AA	Ambient temperature	
AA1	-60°C to +5°C	
AA2	-40°C to +5°C	Specially designed equipment or appropriate arrangements
AA3	-25°C to +5°C	
AA4	-5°C to +40°C	Normal (in certain cases special precautions may be necessary)
AA5	+5°C to +40°C	Normal
AA6	+5°C to + 60°C	Specially designed equipment or appropriate arrangements
AB	Atmospheric humidity	Under conditions
AC	Altitude	
AC1	< 2000 m	Normal
AC2	> 2000 m	May necessitate special precautions such as the application of derating factors Note: For some equipment special arrangements may be necessary at altitudes of 1000 m and above
AD	Presence of water	
AD1	Negligible	IP X0
AD2	Drops	IP X1
AD3	Sprays	IP X3
AD4	Splashes	IP X4
AD5	Jets	IP X5
AD6	Waves	IP X6
AD7	Immersion	IP X7
AD8	Submersion	IP X8
AE	Presence of foreign solid bodies	
AE1	Negligible	IP 0X
AE2	Small objects (2,5 mm)	IP 3X
AE3	Very small objects (1 mm)	IP 4X
AE4	Dust	IP 5X if dust penetration is not harmful to functioning of equipment IP 6X if dust should not penetrate equipment
AF	Presence of corrosive or polluting substances	
AF1	Negligible	Normal
AF2	Atmospheric	According to the nature of substances

8.2. Selection and erection of electrical equipment according to external influences

Electrical equipment shall be selected and erected in accordance with the requirements of

Table 51A in IEC Publication 364-5-51 (1979), parts of which are quoted in Tables 8.3 and 8.4. of this Commentary. Table 51A of IEC 364-5-51 indicates the characteristics of equipment necessary according to the external influences to which the equipment may be subjected. as such influences are defined in Chapter 32 of IEC 364-3.

Equipment characteristics shall be determined either by a degree of protection or by conformity to tests.

If the equipment does not, by its construction, have the characteristics relevant to the external influences, it may nevertheless be used on condition that it provided with appropriate

additional protection in the erection of the installation. Such protection shall not adversely affect the equipment thus protected.

When different influences occur simultaneously, they may have independent or mutual effect and the degree of protection shall be provided accordingly.

The selection of equipment according to external influences is necessary not only for proper functioning, but also to ensure the reliability of the measures of protection for safety complying with the rules for "Protection for Safety" in IEC 364, Chapters 41 to 46. Measures of protection afforded by the construction of equipment are only valid for the given conditions of external influence if the corresponding equipment specification tests are made in these conditions of external influence.

Table 8.4 Characteristics of electrical equipment regarding the presence of flora and fauna

Code	External influence	Characteristics required for selection and erection of equipment
AK	**Presence of flora and/or moulds growth**	
AK1	No hazard	Normal
AK2	Hazard	Special protection, such as: - increased degree of protection (see AE) - special materials of protective coating of enclosures - arrangement to exclude flora from location
AL	**Presence of fauna**	
AL1	No hazard	Normal
AL2	Hazard	Protection may include: - an appropriate degree of protection against penetration of foreign solid bodies (see AE) - sufficient mechanical resistance (see AG) - precaution to exclude fauna from the location (such as cleanliness, use of pesticides) - special equipment of protective coating of enclosures

9. VERIFICATION OF ELECTRICAL EQUIPMENT AND INSTALLATION

Electrical equipment and installation shall be tested and inspected before being placed in service, after any important modification and in appropriate periods to verify proper and safe execution of the work.

The purpose of the verification of electrical equipment and installation is to verify their condition and to find defects, which have to be removed.

9.1. General

Every installation shall, during erection and/or on completion before being put into service by the user, be visually inspected and tested to verify, as far as practicable, that the requirements of this standard have been met.

The documentation shall be made available to the persons carrying out the verification.

Precautions shall be taken to avoid danger to persons and to avoid damage to property and installed equipment during inspection and testing.

Where the installation is an extension or alteration of an existing installation, it shall be verified that the extension or alteration complies with this standard and does not impair the safety of the existing installation.

9.2. Visual inspection

Visual inspection shall precede testing and normally be done with the whole installation dead. The visual inspection shall be made to confirm that permanently wired electrical equipment is:

- in compliance with the safety requirements of the relevant equipment standards;

Note: - This may be ascertained by examination of marking or certification.

- correctly selected and erected according to this standard;
- not visibly damaged, so as to impair safety.

Visual inspection shall include at least the checking of the following, where relevant:

- method of protection against electric shock, including measurement of distances, concerning, for example, protection by barriers or enclosures, by obstacles

or by placing out of reach

- presence of fire barriers and other precautions against propagation of fire and

protection against thermal effects;

- selection of conductors for current-carrying capacity and voltage drop;
- choice and setting of protective and monitoring device;
- presence of suitable isolating and switching devices correctly located;
- selection of equipment and protective measures appropriate to external influences;

- neutral and protective conductors identification;
- presence of diagrams, warning notices or other similar information;
- identification of circuits, fuses, switches, terminals, etc.;
- adequacy of connection of conductors;
- accessibility for convenience of operation and maintenance.

9.3. Testing

The following tests shall be carried out where relevant and should preferably be made in the following sequence:

- continuity of protective conductors and of the main and supplementary equipotential bonding;
- insulation resistance of the electrical installation;
- protection by separation of circuits;
- automatic disconnection of supply;
- polarity test;
- electric strength test;
- functional tests.

In the event of any test indicating failure to comply, that test and any preceding test, the

results of which may have been influenced by the fault indicated, shall be repeated after the fault has been rectified.

The test methods described in this chapter are given as reference methods; other methods are not precluded provided they give no less valid results.

9.3.1 Continuity of the protective conductors, including the main and supplementary equipotential bonding

A continuity test shall be made. It is recommended that the test be carried out with a supply having a no-load voltage of 4 V to 24 V, d.c. or a.c., and with a minimum current of 0.2 A.

9.3.2 Insulation resistance of the electrical installation

The insulation resistance shall be measured:

a) between live conductors taken in turn two by two;

Note: - In practice, this measurement can only be carried out during erection of the installation before the connection of the appliances.

b) between each live conductor and earth.

Notes: 1. - In TN-C systems, the PEN conductor is considered as part of the earth.

2. - During this measurement, phase and neutral conductors may be connected together.

The insulation resistance, measured with the test voltage values indicated in Table 9.1, is satisfactory if each circuit, with the appliances disconnected, has an insulation resistance not less than the appropriate value given in Table 9.1.

Table 9.1 Minimum value of insulation resistance

Nominal circuit voltage (V)	**Test voltage d.c. (V)**	**Insulation Resistance (MΩ)**
SELV and functional extra-loe voltage, when the circuit is supplied froma safety transformer and also fulfils other requirements	250	≥0.25
Up to and including 500 V, with the exception of the above cases	500	≥0.5
Above 500 V	1000	≥1.0

Measurement shall be carried out with direct current. The testing apparatus shall be capable of supplying the test voltage specified in Table 9.1 when loaded with 1 mA.

When the circuit includes electronic devices, only the measurement between phases and neutral, connected together, to earth shall be made.

Note: - This precaution is necessary because carrying out the test without a connection between live conductors could cause damage to electronic devices.

9.3.3 Protection by separation of circuits (electrical separation)

The separation of the live parts from those of other circuits and from earth shall be verified by a measurement of the insulation resistance. The resistance values obtained shall be in accordance with Table 9.1, with the appliances, as far as possible, connected.

9.3.4 Polarity test

Where the rules forbid the installation of single pole switching devices in the neutral conductor, a test of polarity shall be made to verify that all such devices are connected in the phase only.

9.3.5 Automatic disconnection of supply

The verification of the efficacy of the measures for protection against indirect contact by automatic disconnection of supply is effected as follows:

a) For TN systems

Compliance with the rules for TN systems shall be verified by:

1) measurement of the loop impedance. As an alternative compliance may be verified by measurement of the resistance of protective conductors.

Note: - The above measurements are not necessary where the calculations of the fault loop impedance or the resistance of the protective conductors are available and when the arrangement of the installation permits measuring

of the length and cross-sectional area of the conductors. In that case the verification of the continuity of the protective conductors is sufficient

2) verification of the characteristics of the associated protective device (i.e. by visual inspection of the nominal current setting for circuit-breakers and the current rating for fuses and also by test for residual current protective devices).

In addition, the effective earthing resistance R_B of the system shall be verified where necessary.

b) For TT systems

Compliance with the rules for TT systems shall be verified by:

1) measurement of the resistance of the earth electrode for exposed conductive parts of the installation;

2) verification of the characteristics of the associated protective device. This verification shall be made:

- for residual current devices by visual inspection and by test;
- for overcurrent protective devices by visual inspection (i.e. current setting for circuit-breakers, current rating for fuses);
- for the protective conductors by inspection of their continuity.

c) For IT systems

Calculation or measurement of the first fault current.

Notes:

1. This measurement is not necessary if all exposed conductive parts of the installation are connected to the power system earth in the case where the system is connected to earth through impedance.

2. The measurement is made only if the calculation is not possible, because all the parameters are not known. Precautions are to be taken while making this measurement in order to avoid the danger due to a double fault.

Where conditions, which are similar to conditions of TT systems, occur in the event of a second fault, verification is made according to point b) of this clause.

Where conditions similar to conditions similar to conditions of TN systems occur, verification is made according to point a) of this clause.

Note: - During the measurement of the loop impedance, it is necessary to establish a connection of negligible impedance between the neutral point of the system and the protective conductor at the origin of the installation.

Measurement of the resistance of the earth electrode

Measurement of the resistance of an earth electrode, where prescribed, is made by an appropriate method.

Measurement of fault loop impedance

Measurement of the loop impedance shall be effected at the same frequency as the nominal frequency of the circuit.

9.3.6 Measurement of the resistance of protective conductors

Verification consists of measurement of the resistance R between any exposed conductive part and the nearest point of the main equipotential bonding.

Note: - Protective conductors include metal conduits and other metal enclosures for conductors in defined conditions.

It is recommended that the measurement be carried out with a supply having a no-load voltage of 4 V to 24 V, d.c. or a.c., and with a minimum current of 0.2 A.

The measured resistance R shall meet the following condition:

$$R \leq 50/I_a$$

where

50 means 50V, which is the prospective touch voltage under normal conditions,

I_a is the current (in A) causing the automatic operation of the protective device within 5s.

10. OPERATION OF ELECTRICAL INSTALLATIONS

The operation of electrical installations includes all activities necessary to permit the electrical installation to function both under normal and abnormal conditions. These activities include tending of equipment and devices such as switching, controlling, monitoring, as well as work on electrical installation such as maintenance and repairing it and verification of it.

The principles for work activity on or near electrical installation do not apply to ordinary persons for their own domestic electrical installation in private dwellings and when using equipment designed and installed for use by ordinary persons which complies with relevant standards.

From the basic principles of operation of electrical installation we choose following rules:

All activities on or in the vicinity of electrical installation shall be subjected to the preparation and agreement of the nominated person in control of the work activity and the nominated person in control of the electrical installation.

The preparation of the work activity, except for simple and often repeated works, shall be made in a written form (**Command B** - according to ČSN 34 3100).

Persons who are required to work on or in the vicinity of electrical installations shall be provided with training and information so that they are able to give appropriate first aid treatment for electric shock and/or burns.

Before any work activity starts, the nominated person in control of the electrical installation shall be informed of the intended work. (This person, according to ČSN 34 3100, signs the Command B.)

All necessary information such as network arrangement, state of switchgear (on, off, earthed), position of safety device to permit safe operation of the electrical installation shall normally be transmitted by Command B.

The next information which Command B according to ČSN 34 3100 further contains are the workplace, time and type of work activities, name and signature of person who gives the order and names and signatures of persons providing the safety stage of workplace (switching off, isolating and earthing of it).

Any tools, equipment, and devices provided for the purpose of safe operation on or in the vicinity of electrical installation shall be suitable for that use, be maintained in good order and properly used.

Examples of tools, equipment and devices are:

- insulating boots, gloves and overshoes;
- eye or face protection;
- insulating mats, platforms and stands;
- insulated flexible and rigid screening materials;

- insulated and insulating tools;
- operating poles and rods;
- lock, notices, signs;
- voltage detectors and indicating devices;
- cable locating equipment;
- earthing and short-circuiting equipment;
- barriers, flags, supports.

The most of work activities are being provided as dead working. The following five essential requirements:

- disconnect completely,
- secure against re-connection,
- verify that the installation is dead,
- provide earthing and short-circuiting,
- provide protection against adjacent live parts,

shall be undertaken in the specified order. Permission to start work shall be given (after checking all above mentioned measures by the person responsible for control of work activity.

From the view of the ability to work on electrical installation, the qualification of persons is divided in the following way:

ordinary person

a person who is neither a skilled person nor an instructed person - person without any electrical qualification,

instructed person

a person adequately advised or supervised by skilled persons to enable him or her to avoid dangers which electricity may create,

skilled person

a person with relevant education and experience to enable him or her to avoid dangers which electricity may create.

There are different sorts of work activities related to electrical equipment or installation which persons can do according to their electrical qualification. Work activities mentioned above depend on qualifications and they are defined in ČSN 34 3100.

10.1. Standard operational procedures

The following procedures shall be carried out by skilled or instructed persons using, where appropriate, suitable tools and equipment so that danger to persons is presented.

Operating activities

Operating activities are designed to change the electrical state of an electrical installation.

There are two kinds of operating activities:

- operations intended to modify an electrical installation, to use an equipment, connect, disconnect, start or stop equipment designed to be used for this purpose without risks so far as is reasonably practical.

- disconnecting or reconnecting installations for working.

Operating activities may be carried out locally or by remote control.

Only skilled or instructed persons shall carry out disconnecting or reconnecting before or after dead working.

Measurement

Measurement is defined as activities to measure physical data. Measurement may be required to check the correct functioning of equipment or to ensure that safety precautions are adequate.

Testing

Testing includes all activities designed to check the operation or the electrical, mechanical, thermal condition of an electrical installation. Testing includes also activities to prove the effectiveness of e.g. protective devices and safety circuits.

Testing may include measurement activities.

Inspection

The purpose of inspection is to verify that an electrical installation is in accordance with specified technical and safety regulations of the relevant standards and may include verification of the normal state of that installation. New electrical installations as well as modifications and extensions to existing installations should be inspected prior to their being brought into operation.

Electrical installations shall be inspected at suitable intervals.

Defects, which constitute an immediate danger, shall be rectified without delay.

10.2. Working procedures

General

According to the basic principles, the nominated person in control of the electrical installation and the nominated person in control of the work activity shall both ensure that specific and detailed instructions are given to the personnel carrying out the work before starting the work.

The most of work activities are being provided as dead working. The following five essential requirements:

- disconnect completely,
- secure against re-connection,
- verify that the installation is dead,
- provide earthing and short-circuiting,

- provide protection against adjacent live parts,

shall be undertaken in the specified order. Permission to start work shall be given (after checking all above-mentioned measures) by the person responsible for control of work activity.

Protection against adjacent live parts

If there are parts of an electrical installation in the vicinity of the work location that cannot be made dead, then special additional precautions are necessary and shall be applied before work starts.

Re-energizing after work

After the work has been completed, inspected and tested, persons no longer required shall be withdrawn. All tools, equipment and devices used during the work shall be removed. Only then shall the procedure for re-energizing be commenced.

10.3. Maintenance procedures

General

The purpose of maintenance is to keep the electrical installation in the required condition.

Maintenance may consist of " preventive maintenance" which is carried out on a routine basis with the intention of preventing breakdown and keeping equipment in good condition, or "corrective maintenance" which is carried out to repair or replace a defective part.

There are two types of maintenance work:

- work where the risk of electric shock or arcs is present and therefore the appropriate working procedures have to be applied,
- work where the design of equipment enables certain maintenance) e.g. replacement of fuses or light bulbs) to be undertaken without full working procedures having to be applied.

Repair work

Repair work may consist of the following stages:

- fault location,
- fault rectification,
- verification of the repaired part of the installation.

Different procedures may need to be applied at each stage of the work.

Specific working conditions shall be defined to allow fault location and confining defects under the presence of voltage.

Elimination of defects shall normally be carried out in accordance with the rules of dead working.

Appropriate tests and adjustment shall be performed to ensure that the required parts of the installation are suitable for re-energization.

10.4. Personnel

The nominated person in control of the electrical installation shall approve all activities carried out.

Personnel in control of maintenance shall be nominated to carry out maintenance work on a defined part of an electrical installation.

Personnel who are to carry out the work shall be adequately instructed or skilled and be equipped with appropriate tools, measuring and testing devices in a required condition.

All necessary precautions to prevent danger to other persons.

11. ERECTION AND OPERATION OF ELECTRICAL TEST EQUIPMENT

11.1. Electrical test equipment

Electrical test equipment is the entirety of all the test appliances and devices combined for test purposes, by means of which electrical tests are performed on test objects. Test equipment may be designed and erected or installed as:

- test station
- test laboratory or experimental station
- temporary test equipment

A **test station** denotes appropriately identified test equipment within a defined area in which only one or two persons are generally employed on test work, e. g. in the line of series production or in electric workshops, repair and service shops.

A **test station with automatic protection against direct contact** denotes a test station in which the test object and all live parts of the test apparatus have automatically activated full protection against direct contact in an energized condition.

A **test station without automatic protection against direct contact** denotes a test station in which parts of the test object or live parts of the test apparatus are not fully protected against direct contact during testing. This includes, for instance, test areas in electric workshops, laboratories, measurements and experimental areas.

A **test laboratory** denotes test equipment in securely enclosed space or within an area separated from adjacent work areas, in which several persons are generally employed on test work on larger test objects remaining there for a longer period of time.

A test laboratory may be subdivided into test areas in which mutually independent tests are performed.

An **experimental station** denotes test equipment for performing experiments or tests within the scope of research and development work. In general, no routine tests are performed in experimental stations. A variety of tests assemblies as well as different hazards shall therefore be anticipated.

An experimental station may be subdivided into sections in which mutually independent experiments or tests are carried out.

Temporary test equipment denotes test equipment erected for a short time in order to perform tests on individual test objects.

Prohibition zone denotes an area around live parts which should not be breached if full protection against direct contact with these parts is not provided.

Test area denotes the area around the test assembly which is separated from the surrounding area.

Signal lights are lights which are clearly visible from outside the boundaries of the test area giving red or green signals to indicate the operational status inside the test area.

Indicator lights serve to indicate the switching status on the control panels. They are not an alternative to required signal lights.

Risk is a combination of the probability and the degree of the possible injury or damage to health of person exposed to a hazard or to hazards.

Electrical hazard is a source of possible injury or damage to health in presence of electrical energy from an electrical installation.

Nominated person in control of a work activity is that person who has been nominated to be the person with direct management responsibility for the work activity. Parts of this responsibility may be delegated to others as required.

11.2. Operational status

Out of operation status is given when:

a) all power supplies, signalling and control circuits are switched off and secured against unauthorized switching on

b) all safety precautions necessary before entering the test area (for voltages exceeding 1 kV, e.g. earthing, short circuiting) have been taken

Ready for operation status is given when :

a) the power supplies for switchgear signalling and control circuits of the test equipment are switched on

b) the green signal lights are on

c) all the power supplies for the test voltage are switched off and secured against unintentional switching

d) the safety precautions specified in („Out of operation“ status) are in force

Ready to switch on status is given when:

a) all power supplies for the test voltage are switched off

b) all entries to the test area are closed

c) the red signal lights are switched on

d) the safety precautions specified in („Out of operation“ status) are no longer in force

In operation status is given when:

a) all entries to the test area are closed

b) the red signal lights are switched on

c) one or more power supplies for the test voltage are switched on

11.3. Protection against electric shock

The test assembly shall be so arranged and designed that the protection against direct contact is secured by insulation of live parts, covers, enclosures, obstacles or safe distances. A safe distance is ensured, when the person carrying out of tests cannot reach the prohibition zone with parts of his/her body or tools. Safety can also by means of a two-hand control device or the use of two safety probes to apply the test voltage. Where several persons are involved in a test, a two-hand control device shall be provided for each person of the personnel and which are so connected that all the two hand controls are required to be operated before the test supplies can be energised.

Safety test probes shall have the adequate insulation level for the applied test voltage. No clamping devices shall be permitted for this purpose.

In case of measuring instruments and auxiliary appliances of protection Class I (cathode ray oscilloscope, sine wave generator), where the protective conductor is interrupted to facilitate testing, e.g. because the enclosure has to be isolated from earth potential, the appliance shall be supplied from an isolating transformer .

If a circuit and/or the enclosure of measuring instrument or an auxiliary appliance designed for mains connection is connected to live parts of the test assembly which can carry voltage to earth, then the internal insulation of the supplying isolating transformer shall be rated at least to

this voltage.

An effective protective measure for protection in case of fault (protection against indirect contact) shall be provided.

The test assembly shall be so designed and arranged in order to prevent the transfer of voltage to extraneous conductive parts.

The test equipment controls and test circuits shall be clearly identified. Test equipment shall have devices which indicate the operational status, e.g. **indicator lights**. Test equipment and test areas shall be clearly and visibly indicated by means of warning signs.

11.3.1 Emergency switching off

Test equipment shall be provided with means for emergency switching off in order to cut off all electrical energy which could result in danger. An adequate number of manual controls shall be provided inside and outside the test area as appropriate to the size of the area and complexity of layout. Connection points, e.g. outlets of the general power supply within the test area, shall be identified accordingly, if they are not interrupted by the emergency switching off equipment.

11.3.2 Preventing unauthorised and unintentional switching -on

Test equipment shall be secured against unauthorised and unintentional switching-on of test circuits. Manual controls shall be clearly correlated to the respective test circuits.

11.3.3 Preventing automatic energizing

Automatic energizing of test circuits shall be prevented when mains voltage recovers after a power failure.

11.3.4 Protection against residual voltages and transfer of voltages

If there is likelihood of danger due to residual voltages after switching-off test circuits, suitable devices or equipment shall be provided for a safe discharge of energy.

Transfer of voltage to accessible conductive parts outside the test area shall be prevented by adequate measures - e.g. earthing, shielding, appropriate cable routing - or these conductive parts shall be protected against direct contact.

Protective measures against other hazards

Appropriate means of protection shall be provided, in cases where in addition to dangers due to voltages other hazards are to be expected, e.g. due to arcs, noise, explosion, radiation, flying parts, formation of gas, fire, dangerous substances.

11.4. Test stations with automatic protection against direct contact

The protection against direct contact must be satisfied by insulation of live parts, covers or enclosures. The means of protection against direct contact shall guarantee at least the defined degree of protection IP3X.. in accordance with EN 60529 and include all parts of the test object.

It shall not be possible to switch on the test voltages until the means of protection are fully operational and functioning correctly. Opening the means of protection must disconnect the test voltage automatically. Residual voltages shall be automatically reduced to a non-hazardous level before live parts can be touched.

Single fault conditions shall not prevent the test voltages from being switched off when the means of protection are opened. The occurrence of the fault shall ensure that it is impossible to switch the test voltages on again. It must not be possible to bypass the means of protection in an easy way.

Mechanical means of protection shall be adequately strong.

In the case of test station with automatic protection against direct contact, barriers and emergency switching off devices may be omitted.

11.5. Test stations without automatic protection against direct contact

Test stations without automatic protection against direct contact shall only be installed if the erection of test station with automatic protection against direct contact is not practicable, e.g.

- due to frequently changing test duties
- in case of varying types of test objects
- in case of serious difficulties in performing the work
- when test duties occur only occasionally

The barriers may be e.g. walls, grids, ropes, chains or bars. They shall be so designed that visual contact with the operator can be maintained from outside at all times.

At least one emergency switching device shall be installed outside the test areas.

An adequate number of red signal lights, indicating the operational status, shall be installed.

If the test circuits are electrically connected to the general power supply system, additional protection shall be provided by means of RCD with rated difference current ≤ 30 mA. If the residual current includes d.c. components, an appropriate RCD shall be used.

The working area of test stations shall be such that movement of test personnel is not impeded.

11.6. Test laboratories and experimental stations

The barriers shall be solid walls or grids at least 1 800 mm high. Entrances shall be provided with a warning sign „No unauthorized persons beyond this point“

A sufficient number of red and green signal lights shall be installed to indicate the operational status; green signal lights are not required in case of voltages up to 1 000 V.

When there are separate test areas within the test laboratory

- the operational status of each of the test areas shall be indicated by means of signal lights
- red signal shall indicate „ danger“ for the entire test laboratory whenever the operational status **ready for operation** or **in operation** exists in at least one of the test areas.

Emergency escape doors, gates, etc. shall be able to be opened from the inside of the test area.

In test laboratories measures are required to prevent unauthorized entry and shall not hinder persons from leaving.

11.7. Operation of test equipment

11.7.1 General

Test equipment may only be operated under the control and supervision of a skilled person.

Test equipment shall be provided with operating instructions. These shall contain the information required for safe operation.

The test equipment used shall be inspected for externally visible damage or defects before use.

Test equipment shall not be operated if there are signs of damage or defects liable to cause danger.

Only skilled persons shall be employed to maintain the test equipment.

The proper condition and efficiency of the safety devices shall be checked by a skilled person at suitable intervals of time. The result on these inspections shall be recorded.

11.7.2 Personnel

Only skilled or instructed persons may work with test equipment. All personnel involved shall be instructed in the safety requirements, safety rules and company instructions applicable for their work. These instructions shall be repeated as necessary. The personnel shall be required to comply with the requirements, rules and instructions. The complexity of the work activity shall be assessed before the activity starts such the appropriate choice of a skilled or instructed person is made for carrying out of activity. A written record of the training shall be kept.

Personnel using safety probes shall receive additional training regarding special risks involved.

Personnel working in test laboratories, experimental stations and temporary test stations may work only under overall supervision of nominated person in control of the work activities.

Test areas shall only be entered by the personnel employed there and other persons who have received adequate instruction regarding the hazards.

If other persons have to enter these areas, they shall be accompanied by a skilled person and their attention shall be drawn to the risks. In case of the test stations with voltages exceeding 1 kV, the permission of the nominated person in control of the work activities is also required.

Any person working in test laboratories, experimental stations or in areas with temporary test stations shall be fully aware of the existing hazards and has the duty to take safety precautions in his/her work in order to protect both himself/herself and other persons against hazards.

11.8. Preparation of tests, switching operations in test stations

If the enclosure of a measuring instrument or an auxiliary appliance is connected to live parts of the test assembly and if as a result the enclosure can be exposed to a voltage exceeding 25V a.c. or 60V d.c. to earth, then adequate external insulation of the enclosure including the control mechanism shall be provided. In special cases, procedures for live working shall be used.

When using safety test probes, the person carrying out the test shall visually check the test probes and their leads before starting work to ensure that they are safe to use.

If there is a likelihood of danger due to arcing, adequate measures shall be taken for the protection of personnel.

If other risks are likely to occur during test and experiments, e.g. noise, explosions, radiations flying parts, gas formation, fire or hazardous materials, additional safety measures shall be taken to ensure adequate protection.

The nominated person in control of the work activity shall make sure that their instructions are carried out correctly before the experiment:

- is switched on, in case of voltages up to 1000V
- is made **ready to switch on** in case of voltages exceeding 1 kV

Orders for switching operations may only be given by a nominated person in control of the work activity. In test laboratories, experimental stations and temporary test equipment with voltages exceeding 1kV, switching operations may only be performed upon the personal order of the nominated person in control of the work activity, when he/she does not perform this duty himself/herself.

The persons mentioned above shall ensure that all persons other that persons have left the test area before the test equipment is:

- switched on, in case of voltages up to 1000 V
- made in case of voltages exceeding 1 kV

In case of test stations all persons must have leave the test area before the test station is switched on.

In case of test laboratories, experimental stations and temporary test equipment with voltages exceeding 1 kV, all persons must leave the test the test area before the test equipment is made .

The person carrying out the test shall be able to recognize the operational status at any time, especially when several voltages are supplied.

Before leaving the test equipment, the out of operation condition shall be established. This does not apply when endurance tests have to be left running in the test equipment.

11.9. Test procedure

Assembly work and tests shall not be performed simultaneously if this could result in danger.

In exceptional cases skilled persons may enter the test area in the operational status **ready to switch on** or **in operation**. .Measures shall be taken to ensure that the prohibition zone is not reached.

Work activities carried out in the prohibition zone (live working) shall comply with the requirements EN 50110-1.

In the event of a fault during tests, parts of the test object and test equipment which are not live during normal operation can be subjected to dangerous voltages. If , in exceptional cases, work has to be carried out on these parts, suitable insulating devices and auxiliary means shall be used.

In a test station without automatic protection against direct contact, as a safety measure during the operational status **ready to switch** on and **in operation**, at least one person shall be present in visual and audible contact with the person carrying out the test and be in the position to recognize any dangerous conditions in the test station immediately and eliminate the danger by actuating the emergency switching off device.

If a temporary station is separated from generally accessible areas only by means of ropes, chains or bars, the following conditions apply in addition to the other requirements:

a) The entire test assembly shall be under surveillance during the test procedure. If this cannot be ensured by the person carrying out the test, a sufficient number of at least instructed persons shall be present to supervise the entire test area and to take immediate action in the event of danger.

b) In case of test assemblies with several separate test areas, e.g. when testing installed cables, one person is required to guard each area. Communication with the responsible skilled person shall be ensured.

Before touching test objects which have been switched off, it shall be ensured that no dangerous voltages are present on the accessible parts by earthing and short circuiting.

Emergency routes and exits shall always be kept clear.

11.10. Electrical work activities in school laboratories

These rules are applicable to all operation of and work activity on , with or near electrical installations in laboratories of Faculty of Electrical Engineering CTU in Prague.

General requirements for the safe operation of and work activity on electrical equipment are:

1) Students in school laboratories may work only under the overal supervision of a nominated person in control of the work activities (teacher). The number of students who are liable to the supervision of one nominated person in control of the work activities is 10 or less. Where the work activity is more complex it may be necessary to nominate person to be responsible for the safety of smaller groups of students.
2) School laboratory shall be provided with means for emergency switching off in order to cut off all electrical energy, which could result in danger. An adequate number of manual controls shall be provided inside the laboratory. Connection points, e.g. outlets of the general power supply within the laboratory shall be identified accordingly, if they are not interrupted by the emergency switching off equipment. Before starting work in laboratory the nominated person in control of the work activities (teacher) must verify means for emergency switching off.
3) All students shall be instructed in the safety requirements, safety rules and laboratory instructions applicable to their work. Students shall be required to comply with the

requirements, rules and laboratory instructions. The complexity of the work shall be assessed before the activity starts. A written record of the instructioning shall be kept.

4) Students who are to carry out the work activity shall adequately instructed or skilled. They shall be equipped with and use appropriate tools, measuring and testing devices and individual protective equipment, which shall be maintained in a good condition.
5) All students shall be provided with training and information so that they are able to give appropriate first aid treatment for electric shock and/or burns.
6) Any tools, equipment and devices provided for the purpose of safe operation of, or work on, with or near electrical installations shall be suitable for that use, be maintained in a condition suitable for that use, and be properly used.
7) During any work or operations adequate signs shall be displayed to draw attention to any relevant hazard. The signs shall comply with relevant standards where there exist.
8) All students involved in a work activity on, with or near an electrical installation shall be instructed in safety requirements, safety rules and laboratory instructions applicable to their work in lessons of safety courses for basic stage of study.
9) Nominated person in control of a work activity in school laboratory (usually teacher) is skilled person with direct responsibility for the work activity of students. The competence of nominated person (qualification) is periodically verified (Notice No. 50/78).

12. FIRST AID TREATMENT OF THE ELECTRIC SHOCK

Through great effort for making all work on electrical installation safe has been made and many safety measures at work are ensured, some accidents at work caused by mistake or by carelessness may happen. Electrical current is usually the main cause of an injury in such accidents. The main characteristics of the injury in such accidents are effects of electrical current to the human being. The usual effects are **electric shock** or **burns.** The treatment of the electric shock or burns issues from the characteristic of electric current.

It is necessary to act fast but without haste at rendering first aid after the electric shock. The **proceeding of the rescue of afflicted person** is following:

a) to set afflicted person from the range of current,

b) to start artificial respiration immediately in case when afflicted person does not breathe,

c) to start indirect heart massage if the pulse is not palpable,

d) to call for a doctor,

e) to let know the person responsible for the workplace.

The afflicted person can **be set free from the range of current** with one of the following proceedings:

a) switching off the current,

b) shifting the conductor aside or back,

c) pulling the afflicted person away,

d) breaking off the conductor.

It is necessary to be conscious of the afflicted person not being able to release the hand gripped on the object with current because of the convulsion of muscles.

If the afflicted person is in such a position, that he or she would after the breaking of the current fall down, there shall be done measures to prevent from it.

When there are more people present, the best thing to do is to bind their clothes together to form something like emergency fire. Otherwise, the afflicted person shall be protected against the fall by supporting by dry wooden things, such as planks, beams or ladders, as long as possible, or by ropes, belts, dry towels, etc., pulled under shoulders and properly fastened or held. Metal parts or web things shall be never used. In case of injuries caused by low voltage in housing or workshop installation it is necessary first to switch off the current by emergency stopping or supply disconnecting device or by pulling the plug of the defective equipment out of the socket outlet.

If it is not possible to switch off the current promptly, the afflicted person shall be set out of the range of current by shifting the conductor aside or back or by pulling him or her away. The rescuer must come to the contact with the current circuit by touching the conductor or the

afflicted person. He or she shall stand on an insulated surface, e.g. on the wooden board, chest, table or on the rubber (tyre), or shall be provided with rubber shoes, The rescuer shall avoid touching metal things, wet walls etc.

The non-conductive object (e.g. wooden stick or bar) shall be used for shifting the conductor. When pulling the afflicted person away, the rescuer shall stand on the insulated surface and work, as far as possible, only with one hand, which is, protected (e.g. by insulating rubber gloves or dry towel or clothes).

Immediately after the setting the afflicted person out of the range of current, the duty of the rescuer is to render the afflicted person **first aid treatment** till the doctor comes.

In case of injury caused by electricity, the main principle is not to transport the afflicted person, when he or she is not burned on the large surface of the body or does not bleed unstoppable, and not to have the afflicted person alone.

It is necessary to find out, immediately after the injury, whether the afflicted person:

a) is in the conscious state,

b) is breathing,

c) has tangible pulse,

d) is hurt (bleeding, burns, fractured bones).

If the afflicted person is in **conscious state,** he or she should be lain comfortably, with released clothes in a warm room and a warm beverage (tea) should be given to him or her.

If the afflicted person is in the state of **unconsciousness**, but **is breathing** and is not seriously injured, he or she shall be lain in horizontal position on the side of his body with his or her head bend backward and with released clothes as to make the breathing free. No beverage shall be given to the afflicted person.

If the afflicted person **does not breathe**, or if he or she stops breathing, an **artificial respiration** shall be applied immediately. The artificial respiration continues till the afflicted person does not start breathe by himself or herself or till the doctor does not stop it.

The **indirect heart massage** shall start when artificial respiration does not give any effect.

13. VOCABULARY

A	
actuator	ovládač
afflicted person	postižená osoba
alternating current (a.c.)	střídavý proud
artificial respiration	umělé dýchání
arm's reach	dosah ruky
automatic disconnection (of supply)	samočinné odpojení (od zdroje)
B	
barrier	přepážka
basic insulation	základní izolace
C	
cardiac fibrillation	srdeční fibrilace (chvění srdečního svalu)
caution	upozornění (pro případy menších rizik)
classes (of equipment)	třídy (bezpečnosti elektrických předmětů)
Class I	třída I
Class II	třída II
Class III	třída III
conventional touch voltage limit	dovolená mez dotykového napětí
D	
danger	nebezpečí (pro upozornění na vážné riziko)
dead	bez napětí
direct contact	dotyk živých částí
direct current (d.c.)	stejnosměrný proud
disabled state	vyřazení z provozu
disconnecting time	čas odpojení
double insulation	dvojitá izolace
E	
earth	země
earth current	unikající (poruchový) proud
earth electrode	zemnič
effects of current	účinky proudu
electric shock	úraz elektrickým proudem (elektrický úraz)
electrical equipment	elektrické zařízení
electrical separation	oddělení obvodů (elektrické oddělení)
emergency control	nouzové ovládání
enclosure	kryt
environmental conditions	vnější vlivy (prostředí)
equipment	zařízení (vybavení)
equipotential bonding	pospojování (vyrovnání potenciálů)
erection	montáž
exposed conductive part	neživá část
extraneous conductive part	cizí vodivá část
F	
fault	porucha
fault loop impedance	impedance smyčky (poruchového proudu)

fault of negligible impedance	porucha o zanedbatelné impedanci
first aid	první pomoc
H	
harm	škoda
hazard	nebezpečí
hazardous live part	nebezpečná živá část
I	
identification (of conductors)	označování (vodičů)
indication (of direction)	určení (směru)
indirect contact	dotyk neživých částí
indirect heart massage	nepřímá srdeční masáž
information sign	značka upozornění (informační)
initial verification	výchozí revize
injury	zranění
inspection	prohlídka
installation	instalace (zařízení)
insulation failure	porucha isolace
insulation monitoring device	hlídač izolačního stavu
instructed person	poučená osoba
intended use	předpokládané použití
interference	rušení
inward protective terminal	vnitřní ochranná svorka
isolating transformer	oddělovací transformátor
L	
leakage current	unikající (svodový, poruchový) proud
let-go-threshold-current	proud odpovídající mezi uvolnění
level of safety	úroveň bezpečnosti
line (line to line) voltage	sdružené napětí
live part	živá část
live working	práce pod napětím
M	
mandatory action sign	značka příkazu
main equipotential bonding	hlavní pospojování
maintenance	údržba
N	
neutral conductor	střední vodič
notification	příkaz k práci
O	
obstacle	zábrana
operation	obsluha (práce)
operation of electrical installation	obsluha (a práce) na elektrickém zařízení
ordinary (uninstructed) person	osoba bez (elektrotechnické) kvalifikace
outward protective terminal	vnější ochranná svorka
overcurrent	nadproud
overcurrent protective device	nadproudový ochranný přístroj
overvoltage	přepětí
P	

pass through (the body)	procházet (tělem)
PEN conductor	vodič PEN
performance	provedení, funkce
phase (line to neutral) voltage	fázové napětí
prohibition	zákaz
prohibition sign	značka zákazu
prospective touch voltage	napětí před dotykem
protection	ochrana
protection against electric shock	ochrana před úrazem elektrickým proudem
protective	ochranný
protective conductor (symbol PE)	ochranný vodič (symbol PE)
protective equipotential bonding	ochranné pospojování
protective measures	ochranná opatření
R	
re-energizing	znovuuvedení pod napětí
reinforced insulation	zesílená izolace
residual current	rozdílový proud
residual-current protective device	proudový chránič
risk	riziko
S	
safety	bezpečnost
safety aspects	hlediska bezpečnosti
safety colour	bezpečnostní barva
safety sign	bezpečnostní značka
SELV (safety extra-low voltage)	bezpečné malé napětí
shock current	proud způsobující úraz
short circuit current	zkratový proud
short circuit	zkrat
simultanously accessible parts	části současně přístupné
skilled person	znalá osoba
supplementary equipotential bonding	doplňující pospojování: (doplňující vyrovnání potenciálů)
supplementary sign	doplňující značka
system (system TN, TT, IT)	síť (síť TN, TT, IT)
stop	stůj, stát
T	
terminal	svorka
tool	nástroj
touch voltage	dotykové napětí
V	
ventricular fibrillation	fibrilace (chvění) srdečních komor
W	
warning	výstraha (pro upozornění na riziko středního významu)
warning notices	varovná upozornění
warning sign	značka výstrahy
wiring	elektrický rozvod

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60073Colours of indication lights and push-buttons
60364 series Electrical installation of buildings
60479 Effects of current passing through the human body
60536 Classification of electrical and electronic equipment with regard to protection against electric shock

Czech national standards

The most important chapters of
ČSN 33 2000 series Electrical equipment and installations (the Czech equivalent of the IEC 60364) i. e.
ČSN 33 2000-4-41 Part 4: Protection for safety. Chapter 41: Protection against electric shock
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ČSN IEC 73:1993 Colours of indicator lights and push buttons (33 0170)
ČSN 33 0160:1989 Identification of apparatus terminals and general rules for a uniform system terminal marking, using an alphanumeric notation
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ČSN IEC 38:1993 IEC standard voltages (33 0120)
ČSN EN 60617 series Graphical symbols for diagrams

15. Occupational Safety and Health Regulations

Observing the rules and regulations governing Health and Occupational Safety is considered one of the basic duties of all employees, students and all other persons who enter the premises with the prior consent of the employer, and those who have already been trained. The knowledge of Health and Occupational Safety regulations forms an integral and permanent part of qualification requirements.

15.1. Basic Training Guidelines

1. System of safety courses during the study
2. Legal Basis for Health and Occupational Safety
3. General principles for ensuring of Health and Occupational Safety
4. Duties of the Employer
5. Duties of the Employee
6. Decree of the Czech Occupational Safety Office
7. Safety of work with electrical equipment. Decree
8. Accident at work, recording and registration
9. Security of work with computers
10. First Aid – traumatological plan
11. Emergency calls
12. Laboratory rules (example), fire protection

15.1.1 System of safety courses during the study

Safety courses are compulsory for all students and are defined in accordance with the recommended curriculum of Bachelor's and Master's studies.

Safety course	Symbol	Date	Program	Study
Basic health and occupational safety regulation	**BPZS**	At the beginning of the 1st semester	All programs	Bachelor
Safety in Electrical Engineering 1	**BP1**	1st semester	EEM, KME, KYR	
		2nd semester	OI, STM	
Safety in Electrical Engineering 2 + Repeated BPZS	**BP2**	4th semester	All programs	
Safety in Electrical Engineering 3 + Repeated BPZS	**BP3**	1st semester	All programs	Master

15.1.2 Legal Basis for Health and Occupational Safety

Basic documents:

1. Constitution of the Czech Republic – Charter of Rights and Liberties
2. Instruction of the European Community Council ”On taking measures to increase health and occupational safety of employees on the premises”
3. Civil Code
4. Labour Code

5. Decrees embedded in Codes of Law issued by the Czech Office of Occupational Safety
6. Czech standards

15.1.3 General principles for ensuring of Health and Occupational Safety

Everyone is obliged to proceed with caution so as not to cause damage to health, property, nature, and the environment.

Anyone breaking the law will be held responsible for any caused damage.

Caring about the safety, knowledge of regulations to ensure Health and Occupational Safety is a permanent and integral part of performing work tasks.

15.1.4 Duties of the Employer

The employer is obliged to provide safe and healthy work conditions in the area under his/her responsibility:

- search for, consider and assess hazards (risks) of a possible danger to workers´ health and safety, keep them informed, and take proper safety precautions;
- operate machines and equipment complying with Health and Occupational Safety regulations;
- introduce, maintain and improve protective devices and equipment;
- acquaint workers with the labour law and other regulations governing Health and Occupational Safety;
- prevent employees from doing activities that are beyond their abilities or health conditions;
- check the quality of state of health and safety regularly;
- immediately determine and do away with causes of accidents at work;
- check the quality of state of health and safety on the premises at least once a year.
- employer is obliged to provide the employees with the free use of indispensable personal protective aids and equipment.
- workers´ health must not be endangered by smoking on the premises.
- managers and respective heads at all levels are responsible for performing Health and Occupational Safety tasks of the employer.

15.1.5 Duties of the Employee

The employees are entitled to the maintaining of Health and Occupational Safety, information on work risks, and information on measures taken to prevent them. Employees can refuse to perform the work, for which there is good cause to believe it could imminently and seriously threaten their life and health ,or the life and health of other physical persons. The employee is obliged to care, according to his or her capacities, of his/her own safety and health and those of other people namely:

- to stick to legal and other regulations relating to the Health and Occupational Safety, to principles of safe behaviour, and prescribed working procedures with which s/he has been properly acquainted
- to use, when working, personal protective working tools and protective equipment

- to participate at instructive workshops for Health and Occupational Safety, to undergo tests, and medical check ups
- not to use alcoholic drinks and misuse other drugs at the workplace, and during working hours outside the workplace, not to start work under the influence of drugs, stick to ban on smoking at the workplace
- to notify the supervisors and other supervising bodies of the shortcomings and defects of Health and Safety principles, and participate in their disposal
- to undergo the medical tests to determine whether s/he is not under the influence of drugs

15.1.6 Decree of the Czech Occupational Safety Office

Basic regulations:

- technical documentation for production, assembly, operation, maintenance and repair of machines, facilities and technology must contain requirements for ensuring the safety of labour, principles for control, tests and revisions
- on machinery, technical facilities and technologies there must be kept the prescribed operational technical documentation into which all the changes must be recorded
- machines and technical equipment can start their operation only if they correspond to pertaining regulations and after the prescribed tests, controls and revisions have been performed
- machines and technical equipment must be submitted during their operation to regular prescribed checks, test revisions, maintenance and repairs
- workplaces, machinery and technical equipment which can endanger people must have safety designation (colours, signs, tables, light and acoustic signals)

This regulation further contains basic requirements to ensure work safety and safety of the technical facilities during the work and services on the premises.

15.1.7 Safety of work with electrical equipment

Threatening danger: accident by electric current, fire, explosion

Every employee must get at least the lowest qualifications according to Decree no. 50/78 Law code: Acquainted persons (§3 Decree no.50/78 Law code).

These are the employees (ordinary persons) acquainted with regulations on treatments with electric current and aware of the possible danger of electric current

Allowed activities:

- they can independently manipulate only electrical equipment of a safety extra low voltage SELV (up to 50V) and low voltage (up to 1000V) but only if they cannot touch the life parts (parts under voltage) during a normal operation
- switching on and off, plugging into the socket, moving connecting cables, exchange of bulbs when switched off and exchange of safety fuses
- they can perform maintenance work without the dismantling with instruments (dry cleaning) when the equipment is switched off
- must be a safe distance from unprotected working parts under voltage up to 1 kV at least 1 meter

Forbidden activities: (for acquainted persons- according to §3 of Decree no. 50/78 Law Code)

- to repair electrical appliances and distribution
- to work on parts of electrical equipment under voltage
- to use electrical equipment suspected of damage
- to move electrical appliances connected to the network (computers, electrical typewriters, calculators etc.) unless they are intended for such usage - (electrical hand tools) - unplugging of the socket
- to touch electrical equipment by wet parts of the body
- to clean the surface of electrical equipment by wet means

15.1.8 Accident at work, recording and registration

Any harm to health or death inflicted upon the employee independently of his will by temporary, sudden and violent incidents of external circumstances when fulfilling his or her working tasks or in direct connection with them, if the incapacity of work lasts at least one day, except the day of injury, is considered to be work accident.

Direct connection with fulfilling working tasks:

- work resulting from the job, from prescribed tasks during the work, tasks necessary for starting and finishing work and for performance of the work
- medical examination on the employer 's order, first aid treatment including the journey there and back to workplace
- training organized by the employer
- activity stimulated by the trade unions, other employees, or on one's own initiative if there is not required any special authorization for it, or if it is not directly forbidden by the employer.

However connection with fulfilment of working tasks is not considered:

- journey to work and back
- meals, medical treatment or check ups in medical centres, including the journey there and back, if they are not performed on the premises.

Recording and registration of work accidents: Report the accident immediately to the closest supervisor!

Recording of accidents where there was no resulting incapacity of work it lasted less than one day it is necessary to record the accident into the book of accidents for future recording of protocol on the accident if need be.

Registration - the supervisor is obliged:

- to ensure responsible and reliable investigation of causes as well as other circumstances of work accident occurrence
- to make report on work accidents according to investigation findings - up to 2 days- the supervisor is obliged to immediately sent the report to the health safety official in charge of the faculty of electrical engineering
- to formulate the necessary regulations to prevent similar accidents

15.1.9 Security of work with computers

Risks of common users regarding Health and Occupational Safety and occupational disease occurrence:

Increasing eye-strain (brightness, blinking)

- the worker at the screen shall have neither the light source nor its reflection (a window, lamp etc.) in the range of view
- the brightness of the objects in the neighbourhood of the screen shall be balanced so as not to produce big contrasts
- the artificial lighting of the room shall not form dark nooks and overlighted places the upper margin of the active area of the screen shall be on the eye level at maximum.
- the distance of the screen shall be at least 40 cm

Electromagnetic radiation

- If possible, place a monitor in such a way as to prevent the people from having access from its sides

Strain to the neck-spine

- the placement of the keyboard : if sitting straight, the arms, placed with their palms on the keyboard, shall be perpendicular at the elbows
- the height of the seat : if the soles are fully tread-down on the floor, the legs shall be perpendicular at the knees

15.1.10 First Aid – traumatology plan

Directions for the first aid after an electrical shock-proceeding of the rescue of afflicted person:

- to extricate afflicted person from the range of electric current
- to start artificial respiration immediately in case when afflicted person does not breathe
- to start indirect heart massage if the pulse is not palpable
- to call for a doctor
- to inform the person responsible for a workplace(supervisor)

Extrication of afflicted person from the electric circuit under voltage by:

- switching off the current (in laboratories use a push-button switch)
- replacing the conductors (wires) with an appropriate non-conductive object
- pulling away the affected person
- breaking the conductor

First aid treatment

- do not move him/her, do not leave the person alone

It is necessary to find out whether the afflicted person:

- is in the conscious state
- is breathing
- has tangible heartbeat
- is injured (bleeding, burns, fractured bones etc.)

Cardiopulmonary resuscitation contains:

- Artificial respiration (by mouth – to - mouth method, by T-tube)
- Indirect heart massage

Indirect heart massage

- put the person onto a hard mat
- the rescuer puts his/her left hand across his/her right hand and by the weight of the whole body with great force, he/she compresses rhythmically the rib bones of the affected person in the direction to the spine to the depth of 4-5 cm, approximately 60 times a minute.
- after every five compressions one inhalation by mouth-to-mouth method follows

15.1.11 Emergency calls

Emergency (universal)	**112**
Ambulance	**155**
Fire Brigade	**150**
Police – emergency	**158**
Municipal Police	**156**

15.1.12 Laboratory rules (Example)

- All of the activity in laboratory is permitted only if the teacher is in laboratory.
- In laboratory can work only students, who were before the entrance acquainted with regulations on treatments with electric equipment and aware of the possible danger of electric current. (Decree No. 50/78 Law Code, §3).
- Laboratory appliance (within sources) may operate only teacher, or student with declaratory agreement of teacher.
- Students are obliged in case of danger turn off with emergency button mains of electric energy.
- Defect on appliance students must report teacher immediately.
- When stay and work in laboratory, students are obliged to observe all of the directions of work security and other teacher instructions.
- Students are simultaneously obliged to observe directions of fire security.
- Damages, caused of not observe laboratory rules, will be solved according to the valid law precept.
- In laboratory mobiles must be turn off.
- In laboratory is prohibited food consummation.