TOPIC 2

The electric current and is effect on a human body

An electric current is the directed (ordered) motion of charged particles. A current must be considered **permissible,** if a person can independently release himself from an electrical circuit. Its value depends on the duration of a current passing through a human body: with a duration of more than 10 s - 2 mA, and at 120 s and less - 6 mA

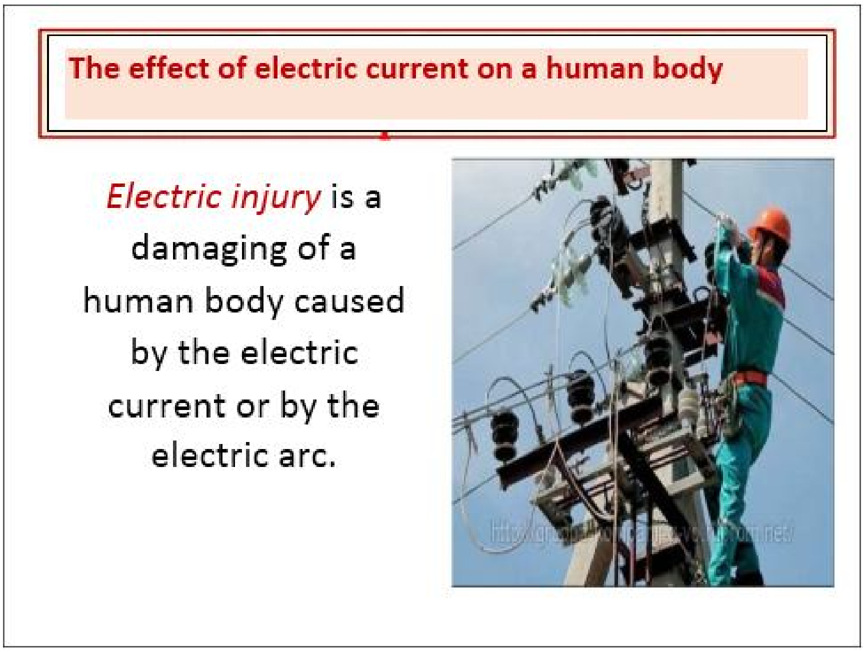
A safety voltage is a 36 V (for local stationary lights, portable lights, etc.) and 12 V (for portable lights when working inside metal tanks, boilers). But under certain conditions such voltages can be hazardous.

Safety voltage levels are obtained from a lighting network, using for this purpose the step-down transformers. It is impossible to spread the safety voltage to all electrical devices.

In industrial processes, two types of current are used - **direct and alternating**. They have different effects on the body at voltages up to 500 V. The risk of damage by a direct current is less than by an alternating one. A current of 50 Hz represent the main risk and is standard for local domestic electrical grids.

When operating and maintenance of the electrical equipment and grids, a person may find himself in an electric field coverage area or in a direct contact with a live conductors. As a result of a current passage through a person, a disturbance in his vital functions may occur.

A risk of electric shock to employees at the workplace is caused by a non-compliance with safety rules, as well as by failure or malfunction of electrical equipment. Compared to other types of industrial injuries, electrical accidents are a small percentage, but are high on the list in the number of severe injuries and fatalities. 75% of electric injuries occur at the workplace due to the non-observance of electrical safety rules.



The electric shock occurs when a human body contacts with a voltage source. By touching the conductor under voltage, a person becomes a part of the electrical circuit with a current flow. As is well known, a human body contains a lot of salts and liquid, which are good electrical conductors, so the effect of the electric current on the human body can be fatal.

In accordance with **GOST R 12.1.019-2009 "Occupational Safety Standards System. Electrical safety. General requirements and nomenclature of types of protection "** the degree of harmful effect of the electric current on a human depends on **many factors**:

- a magnitude and a type of the current flow (alternating current is more dangerous than a direct one);
- a current exposure time (the longer is the current exposure on a person, the heavier are the consequences);
- a flow path (the higher risk is represented by a current flowing through brain and spinal cord, heart and respiratory system (lungs));
- a mental state and a physical well-being of a person (the human body has some resistance, this resistance varies depending on the state of the person).

The minimum amperage that a human body can sense is 1 mA. With an increase of the amperage by more than 1 mA, a person begins to feel uncomfortable, painful muscle contractions occur; as the amperage increases to 12-15 mA, a convulsive muscle contraction occurs. The person can not control longer his muscular system and, on his own, can not break the contact with the current source.
This current is called freezing. The effect of the electric current of more than 25 mA leads to paralysis of the muscles of the respiratory system, resulting in a possible asphyxia. With the further amperage increase, a cardiac fibrillation occurs.

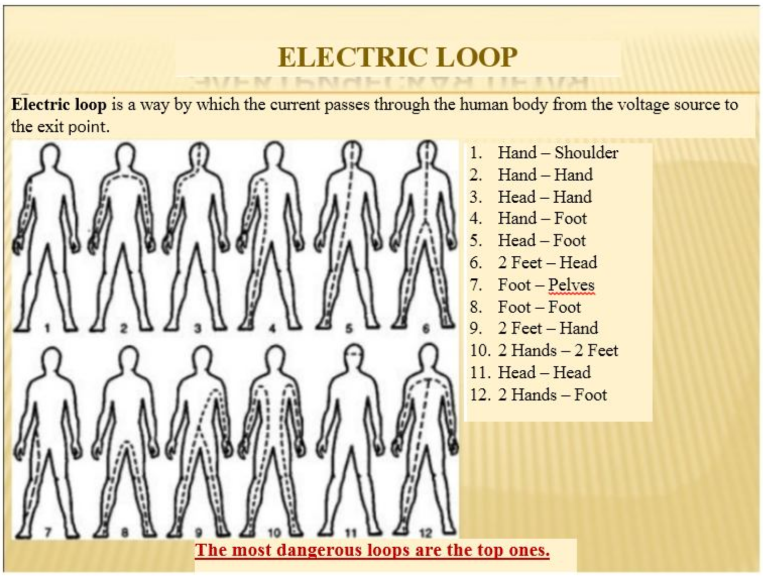
Electric current intensity (amperage) is the main factor on which the outcome of the injury depends: the higher the amperage is, the more dangerous the consequences are. The amperage (in amperes) depends on the applied voltage (in volts) and the electrical resistance of the body (in ohms).

By the degree of exposure to persons, three threshold current values are distinguished:
perceptible - an electric current, which passing through the body causes a perceptible stimulation (the minimum value of an alternating current of 50 Hz sensible for a person is 0.6-1.5 mA);
freezing – an electric current under which the irresistible convulsive muscle contractions of an arm, leg or other parts of the body do not allow the injured to detach by himself from the live-parts (10.0-15.0 mA);
fibrillation – an electric current that, when passing through the body, causes a heart fibrillation – rapid chaotic and non-simultaneous contractions of the heart muscle fibers, leading to a cardiac arrest (90.0-100.0 mA). In few seconds a respiratory failure occurs. The most common deaths come from a voltage 220 V and below. That particularly low voltage causes cardiac fibers random contraction and leads to the instant malfunction of the cardiac ventricles.

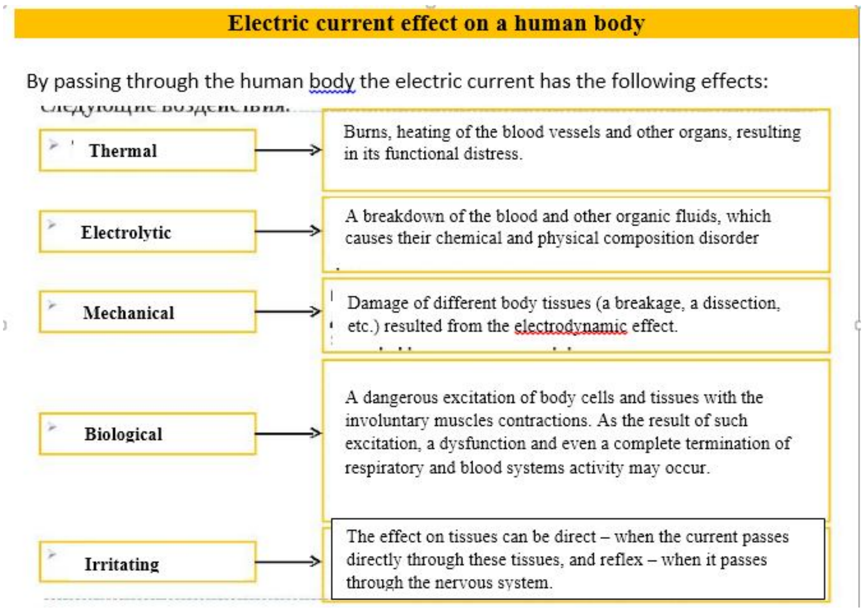
The following variants of the current flow directions along the human body are possible:

- a person touches live wires (parts of the equipment) with both hands, in this case the current flow is directed from one hand to the other, i.e. ***"hand-hand"***, this loop occurs most often;
- when touching a voltage source with one hand, the current path closes through both legs to the ground ***"hand-feet"***;
- in case of the insulation breakdown of the conducting parts of the equipment, a hand of an employee appears to be under voltage. Meanwhile the current flows from the equipment housing to the ground leading to the fact that the legs are also under voltage, but with a different potential, thus the ***"hands-feet"*** ;
- when the current flows to the ground from the broken equipment, the ground receives a varying voltage potential nearby, and a person coming with both feet on that ground becomes under a potential difference, i.e., each of his feet receives a different voltage potential, resulting in a step potential, and this electric circuit is called ***"foot-foot"***, which happens least often and is considered the least dangerous;
- a contact of a head with live parts can cause, depending on the nature of the work performed, a current path to hands or feet - ***"head-hands"***, ***"head-feet"***.

All options vary by the degree of severity. The most severe are the options ***"head-hands", "head-feet", "hands-feet" (full loop)***. This is because the vital system of a body - the brain and the heart - falls into the affected area.



The duration of the current exposure influences the outcome of the injury. The longer the electric current exposes the body, the more severe the consequences are. The conditions of the workplace environment can increase an electric shock risk. Thus, a high temperature and humidity, metal or other conductive floor increase the risk.



Several main types of injuries resulted from the electric current exposure on a person are outlined.

Electrical injuries – a local damage to the body tissues resulting from the action of the electric current or electric arc. They are divided into general (electric shock), local and mixed.

The most common electrical injury are **electric burns**, what is approximately 60% of all cases of electric shock.

Electric burns – are the most common electrical injuries, occurring as a result of a local exposure of the current to the tissue. The burns can be of two types - contact and arc.

Contact burn is a consequence of the conversion of the electrical energy into the thermal energy and occurs mainly in electrical installations with voltages up to 1,000 V.

Electric burn is similar to an emergency system protecting the body, since charred tissues, due to a greater resistance than a normal skin, do not allow electricity to penetrate deep into vital systems and organs. In other words, thanks to the burn, the current goes into a dead end.

When the body and a voltage source were not touching tightly, burns are formed at the input and exit points of the current. If the current passes through the body several times in different ways, multiple burns occur. Multiple burns occur mostly at voltages up to 380 V due to the fact that such a voltage "magnetizes" a person and it takes time to detach. The high-voltage current does not possess such "stickiness".

On the contrary, it discards a person, but such a short contact is enough for the serious deep burns. At voltages above 1,000 V, an electrical injury occurs with major deep burns, since in this case the temperature rises throughout the current path.

At voltages above 1,000 V, an arc burn may occur because of accidental short circuits.
An arc burn is caused by the action of the electric arc creating a high temperature. The arc burn occurs when working with electrical equipment of various voltages, often due to the accidental short circuits in installations of above 1000 V and up to 10 kV, or false staff operation. The injury is caused by a change in the electric arc or clothes burning from it.

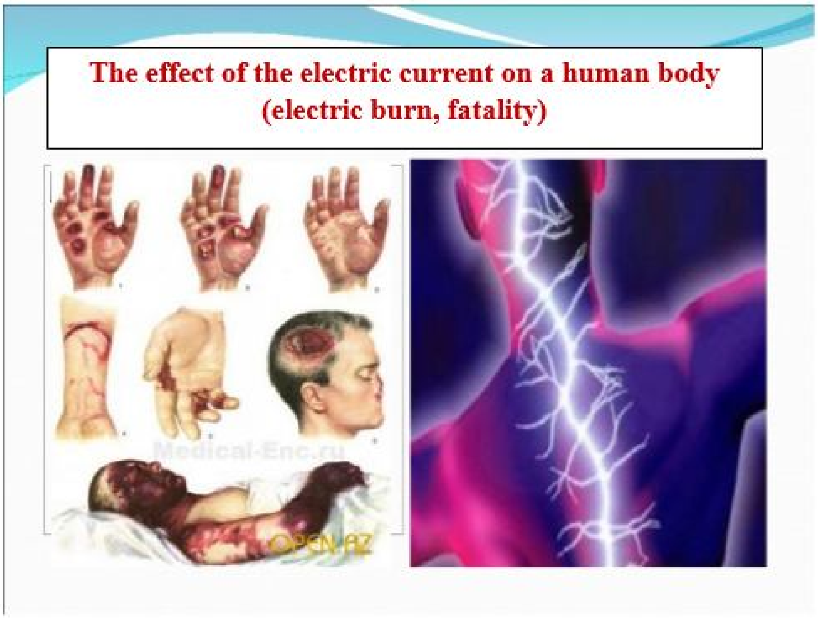
Electrical stigmas and marks - in the form of gray or pale yellow spots appeared on the skin of the person exposed to the current. Usually, electrical stigmas are round or oval with a recessed center in the size of 1 to 5 mm. As a rule, they are painless, harden like a keratoma. Eventually the dead skin layer descends on its own.

A skin metallization - results from a penetration of small metal particles melted because of the electric arc under the upper skin layer. The skin in the lesion becomes painful, hard, has a dark metallic hue.

An ultraviolet ray ophthalmia - results from an inflammation of the eyes outer coat due to the influence of the electric arc ultraviolet rays. To protect against the light effect of the electric current, it is necessary to use safety spectacles and masks with colored glasses.

A mechanical damage is represented by involuntary convulsive muscles contraction under the influence of the current. This can lead to a rupture of skin, blood vessels and nerve tissues. Such injuries occur in contact with a voltage below 380 V, when a person does not lose consciousness and tries to free himself or herself from the current source.

Of the above-mentioned injuries resulted from the electric current effect on a human body, the most dangerous are electric shocks. **The electric shock** is followed by the excitation of body tissues with a current that passes through it. At this moment, involuntary convulsive muscle contractions occur.



Depending on the aftereffect of the electric shock, **four levels of effect** are distinguished:
I - convulsive muscle contractions, a person in consciousness;
II - convulsive muscle contractions, a person is unconsciousness, breathing and heartbeat are present;
III - lack of breathing with cardiac dysfunction;
IV - clinical death, lack of breathing, cardiac arrest.

The electric shock risk is aggravated by the following facts:

- the current has no physical signs and as a rule a person without special devices can not detect in advance the danger threatening him;
- the effect of the current on a human mainly leads to serious violations in the most important vital systems, such as the central nervous, the cardiovascular and the respiratory, what increases the severity of the damage;
- the lternating current can cause intense muscle contractions, leading to the freezing effect, when the damaged person can not release by-himself from the current influence;
- the current effect causes a sharp withdrawal reaction in the person, and in some cases, also a loss of consciousness, what can lead to an injury resulting from a fall when working at height.

2.1 The effect of the electric current and electromagnetic fields on a human body

Until recently, it was believed that only the electrical component of the EMF is a hazard to a human health. However, recent studies indicate that the magnetic component has a harmful effect on biological objects.

The effect of the magnetic field of industrial frequency on a human health.

A magnetic field of industrial frequency

Functional disruption of central nervous and cardiovascular systems, changes in peripheral blood composition.

The effect increases with the increase of the field density and exposure time.

The magnetic field (MF) induces the eddy currents in the human body. They represent the main mechanism of biological effect of the MF, which depends of the eddy currents density. The biological effect of the MF depends on its density and exposure time.

The MF causes functional changes of the nervous, cardio-vascular and immune systems. There is a risk of leukemia and malign neoplasm.

The permissible levels of the magnetic field within the exposure periods are determined by interpolation.
If there is a necessity for a staff to work in zones with a diverse magnetic field intensity, the overall work duration in such zones must not exceed the maximum permissible time for a zone with the highest magnetic intensity.

The maximum permissible stay time in the magnetic field can be realized one-time or fractional during a working day. When changing the mode of work and rest (shift work) the maximum permissible level of the magnetic field must not exceed the established one for a 8-hour working day.
Measurements of the magnetic intensity (induction) must be carried out at the maximum operating current of the electrical equipment or the measured values must be recalculated to the maximum operating current (Imax) by multiplying the measured values by the ratio Imax / I, where I is the current in the magnetic field source at the time of measurement.

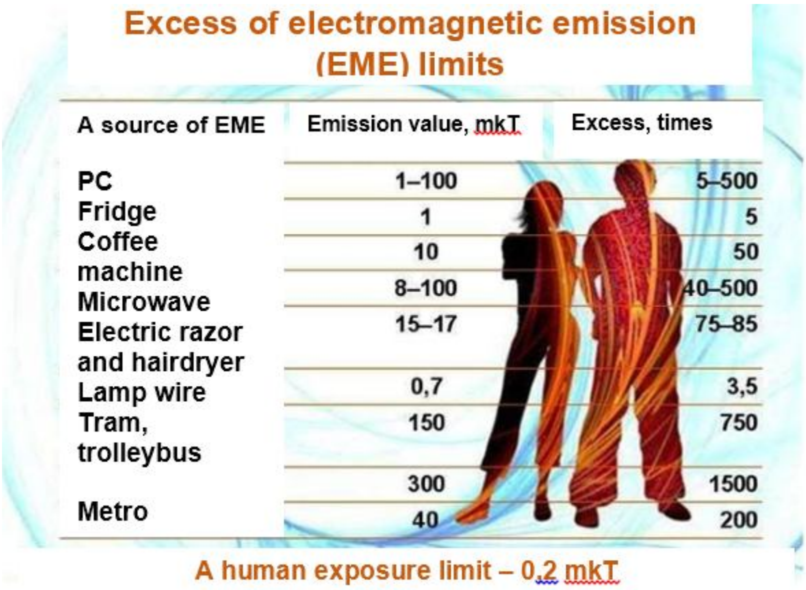
The magnetic intensity (induction) is measured in production premises with a permanent stay of personnel, which are located at a distance less than 20 m from the live parts of electrical installations, including wall separated.
The electromagnetic conditions in the residential premises are of particular concern as the least controlled. In addition, the EMF affects continuously almost all population, including children, pregnant women, patients, old people.

Usually in an apartment the level of the EF is from 5 to 80 V/m, which is much less than the remote control equal to 500 V/m.
Magnetic fields permissible levels for people in Russia are not currently standardized.

An additional safety criterion was recommended by Swedish, US and a number of scientists from other countries – the magnetic intensity of 50 Hz for places where people stay for a long periods of time, especially for places of night rest and stay of children must not exceed 0.2 mT.

The magnetic field intensity can exceed 0.2 mT at a distance of up to 1.5 m from transformer substations, power distribution points in a house, so a place for a bed, chair, pupil workplace or a child's playing place must be chosen considering that distance.

Normally domestic electrical wiring does not have a health hazard.


Excess of electromagnetic emission (EME) limits

A source of EME	Emission value, mkT	Excess, times
PC	1–100	5–500
Fridge	1	5
Coffee machine	10	50
Microwave	8–100	40–500
Electric razor and hairdryer	15–17	75–85
Lamp wire	0,7	3,5
Tram, trolleybus	150	750
	300	1500
Metro	40	200

A human exposure limit – 0,2 mkT

A personal computer is also a source of the EMF. The PC monitor emits energy in all directions.
The overall level of the industrial frequency EMF in industrial and residential premises is constantly growing due to the expansion of the list and the growth of the amount of electrical and electronic devices. In combination with the the EPM of other frequency ranges, a new long-term impact factor for humans is emerging, which did not exist until recently for the majority of the population.

Safety methods and protective means against EMF

As protective means against electric field hazards, the following must be used:

- for an outdoor switchgear - fixed shielding devices (screens) in accordance with **GOST 12.4.154** and shielding kits in accordance with **GOST 12.4.172**, certified by the bodies of the State Energy Supervision of Russia;
- for an overhead line - shielding kits (same as for an outdoor switchgear).

Screens are made of metal in the form of flat shields - canopies, awnings, partitions. Shielding elements are metal grids with mesh size not exceeding 50x50 mm, or parallel-arranged steel cables with a diameter of 5-8 mm and with a distance between them of 10-20 cm. The shields must be properly grounded. An ungrounded screen does not provide protection.

The use of safety means is not required In the grounded vehicle cabs and bodies, mechanisms, mobile workshops and laboratories, as well as in buildings made of reinforced concrete, in brick buildings with reinforced concrete ceilings, a metal frame or a grounded metal roof as there is no electric field.

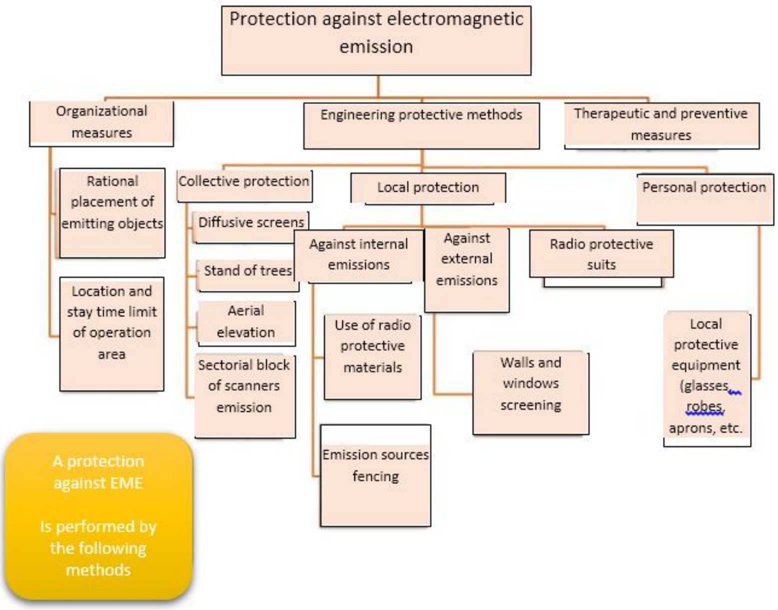
It is not allowed to use shielding kits for works that does not exclude the possibility of touching live parts under voltage of up to 1000 V, as well as when testing the equipment (for the employees conducting high voltage tests) and electric welding work.

When working in areas of switched off live parts of the electrical installations they must be grounded in order to remove the induced potential. It is not allowed to touch the switched off but not grounded live parts without protective equipment. Repair facilities and accessories that may be isolated from the ground must also be grounded.
Vehicles and mechanisms on the pneumatic wheel, located in the zone of the electric field influence, must be grounded. When moving in this area a metal chain connected to the vehicle chassis or body and touching the ground must be used in order to remove the induced potential.

It is not permitted to refuel vehicles and equipment with combustible and lubricating materials in the zone of the electric field influence.
As a safety measure to protect against magnetic field side effects, stationary or temporray magnetic shields must be used.

A system for monitoring the compliance with the state sanitary and hygienic norms is in a basis of ensuring population protection against biological effects of electromagnetic fields. In order to protect oneself to the fullest extent possible from the biological impacts of electromagnetic fields, simple safety rules must be respected.

- **protection by distance** – to stay as far as possible from electromagnetic sources.
- **protection by time** – to stay near electromagnetic sources as short as possible.
- **decrease magnetic intensity** – to use specially designed electromagnetic shields from radio-shielding materials, including radio-shielding fabric.



One of the options of a principle of the protection by distance is the establishment of safety zones of the overhead power lines with voltages above 1000 V (**GOST 12.1.051-90 .SPST**. Electrical safety: Safety distances in the safety zone of the power lines above 1000 V).

The safety zone along the overhead power lines is established as an air area, bounded by parallel vertical two-dimensional subspaces on both sides of the line at a distance from the end wires, indicated in Table. 1

Table 1

Line voltage, kV	Distance, m
Up to 20	10
20- 35	15
35 -110	20
110 -220	25
220 - 500	30
500 - 750	40
750-1150	55

The safety zone of the overhead power lines passing through water bodies (rivers, canals, lakes, etc.) is established as an air area above the water surface of water bodies bounded by parallel vertical two-dimensional subspaces on both sides of the line at a distance from the outer wires for navigable reservoirs - 100 m, for non-navigable reservoirs - at the distance indicated in Table. 1.

In the safety zone of the power lines it is forbidden to carry out an operations that could violate safety and continuity of operation, or operation hazardous for people.

In particular, it is not allowed:

- to locate a storage of combustive and lubricating materials;
- to arrange landfills;
- to conduct blasting operations;
- to start a fire;
- to dump and discharge caustic and corrosive substances, as well as combustible and lubricating materials;
- to throw on wires, overhead line supports and to approach to them debris, as well as to climb on the support;
- to conduct work or to stay in the safety zone of the overhead lines during a thunderstorm or extreme weather conditions;
- without the consent of the organization operating these lines, to carry out construction, installation and irrigation works, to plant or to cut trees, to store feed stuff, fertilizers, fuel and other materials, to arrange passes for vehicles and mechanisms having an overall height with or without load from the surface roads more than 4 m;
- to place domestic buildings, parking lots and stops of all types of transport, arrange recreation facilities, sports and playgrounds.

Electromagnetic safety centers give the following recommendations:

- use models of electric appliances with a lower level of energy consumption (lower power) - they create lower level electromagnetic fields;
- place devices that are switched on frequently and continuously (electric oven, microwave oven, refrigerator, TV, electric heaters, air cleaners, air ionizers), at a distance of at least 1.5 m from the places of extended stay or night rest, especially by children;
- if your kitchen is equipped with a large number of electrical appliances, try to switch on simultaneously as few devices as possible;
- if possible, use instruments with automatic control allowing to be far from them during operation;
- purchase PC monitors with low radiation level (least radiation from monitors conforming to the Swedish standards TCO-91/92 or 95);
- be sure to ground the monitors and computers to the grounding loop of the building (it is not allowed to ground to a heating battery, water pipes, "neutral" jack);
- use additional safety equipment - grounded protective filters for the monitors, reducing the level of the electromagnetic field;
- limit the time of continuous work on the computer and the overall workday time in accordance with SanPiN 2.2.2.542-96 "Hygienic requirements for video display terminals, personal computers and organization of work"

2.2 First aid for injured by the electric current and other accidents

A first aid is a set of measures aimed at restoring or preserving life of an injured, performed by nonmedical workers at the accident scene.
The quicker and proper the first aid is rendered, the more chances for a favorable outcome there are.

The first aid must be rendered in accordance with the "**Instruction for first aid at industrial accidents**"

Sequence of the first aid:

- to release the injured person from the electric current impact and evaluate his condition;
- to take necessary measures to save the injured;
- to call an ambulance or a doctor, or to take measures to transport the injured to the nearest healthcare facility;
- to inform immediately the line manager about the accident.

The most simple and efficient way to release the injured from the current impact is switching off the electrical installation by the nearest chopper switch, the switch, the plug-and-jack connector.

If it is not possible to quickly switch of the electrical installation, it is possible to break the current circuit through the injured in electrical installations up to 1 kV by cutting the wires with an ax with a dry wooden handle or other tool with insulatied handles.

In the electrical installations with voltage above 1 kV, it is necessary to cause consciously an automatic shutdown by short-circuit the installation in accordance with the instruction.
When releasing the injures from the electric current impact, it is necessary to take precaution measures by using a proper electrical protective equipment (insulating gloves, boots, etc.).

It is allowed to touch the injured person only after he is completely released from the electric current impact.

When evacuating the injured from the zone of electric current influence, it is necessary to take him only with one hand and only by dry clothes in order not to receive an electric shock.

Under the power line, the injured must be dragged by not less than 8 meters away from the wire lying on the ground. Indoors it is enough to move the injured person by no less than 4 meters away from the power source. In order to determine the condition of the injured it is necessary to lay him on a back and to check the presence of the pulse, the state of the pupil and breathing during 15-20 s.

A pulse is a jerky rhythmic vibrations of the blood vessels walls, caused by the movement of blood in them during the work of the heart. As a rule, the presence of the pulse is checked on large arteries where it is more acute - on the radial, femoral or carotid one.
The presence of breathing is determined by lifting and lowering the chest during a spontaneous inhalation and exhalation. Normal breathing is characterized by clear and rhythmic ups and downs of the chest. In this condition, the injured does not need a rescue breathing.

Disturbed breathing is characterized by indistinct or irregular rhythms of the chest with inspiration, rare, as if suffices, air breaths or lack of visible respiratory movements of the chest. All these cases of respiratory distress lead to the fact that blood in the lungs is not saturated enough with oxygen, resulting in oxygen starvation of the tissues and organs of the injured. Therefore, in these cases, the victim needs artificial respiration.

If the injured is conscious, but before was collapsed or was under the current for a long period of time, he has to be laid comfortably on a dry bedding, covered with some warm clothes and must be kept at rest with continuous breathing and pulse check before the doctor arrival, who has to be called immediately. It is strictly forbidden for the injured be allowed to move and continue working, even if he feels well and has no visible damage. The negative effect of the electric current on a person can affect not immediately, but in a while - in few minutes, hours and even days. Only a doctor can correctly assess the state of health of the injured and decide on a help to be be given to him on the spot, as well as about his further treatment.

If the injured is unconscious (in coma), but with the surviving steady breathing and pulse, it is necessary to lay him comfortable on a bedding, to unfasten clothing and belt in order not obstruct his breathing, to ensure the influx of fresh air and to take measures to bring him to consciousness – to bring to his nose a cotton wool soaked with ammonia, to sprinkle his face with cold water, to rub and warm the body.

The injured must be kept in rest, do apply cold to his head and continuously monitor his state. He must wait for the doctor's arrival only in the "prone" position with periodic removal of mucus and stomach contents.

If the injured is breathing poorly - rarely, convulsively, as if with a sobbing, or if the injured's breathing gradually worsens, but his pulse is noticed, it is necessary to perform a rescue breathing.

In the absence of life signs, i.e. when the injured does not breath and has no pulse, painful irritations do not cause any reactions, the pupils of the eyes are dilated and do not respond to light, than the injured is considered being in a state of clinical death and needs to be immediately revitalized, i.e. a cardiopulmonary resuscitation must be conducted.

Before carrying out a cardiac compression and rescue breathing in the pulse absence, it is necessary to cover the xiphoid process with two fingers and apply a precardial punch sharply and strongly from the height to the middle third of the sternum body for hydrodynamic action on the heart and chest muscular spasm removal, with further mandatory control of the efficiency by pulse on the carotid artery.

Figure Punching on the sternum

Furthermore, it is strictly forbidden:

- to punch on the xiphoid process or on the area of the clavicles;
- to punch with a pulse on the carotid artery;
- punching the sternum and performing cardiac compression without releasing the thorax and unfastening the waist belt.

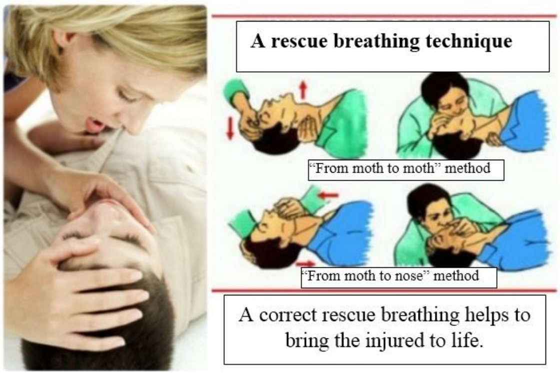
Never refuse to render first aid to the injured and do not consider him dead due to lack of breathing, pulse and other signs of life. The affected by the electric shock can be considered dead only if there are obviously visible fatal injuries, for example, in case of crushing of the skull because of a fall or because of the burning of the whole body. In other cases, only a doctor is entitled to state death.

The procedure for performing a rescue breathing.

The most effective method of rescue breathing are **"from mouth to mouth"** or **"from mouth to nose"**, which are based on a forced blowing into the respiratory tract of the injured. The air can be inflected through a gauze, a handkerchief, a special device - "airway".

Before starting a rescue breathing, it is necessary:

- to relieve the injured of the clothes shortening the breath;
- to put the injured on his back on a horizontal surface;
- to ensure the patency of the upper respiratory tract (the oral cavity is freed from a vomit, foreign objects, etc.)
- to bend the injured's head back as far as possible, by putting one hand under the back of his head and pressing with the other hand on the forehead of the injured until the chin is on the same line with the neck.



Further, the rescue provider leans over the injured person, takes a deep breath with his mouth open, and then exhales with some effort, the inflated air into the injured's mouth. The chest of the injured must up.

If the injured has a right pulse and only needs artificial respiration, the interval between rescue breathing inflation should be 5 seconds (12 respiratory cycles per minute).

When performing rescue breathing, care must be taken to ensure that air does not enter the stomach of the injured person (bloating).

Rescue breathing is stopped after regain a sufficiently deep and rhythmic self-breathing by the injured. In the absence of not only breathing, but also a pulse on the carotid artery, two successive breathing inflations are performed proceeding with a cardiac compression.

A cardiac compression procedure

The cardiac compression (artificial rhythmic contractions of the heart of the injured, imitating his own contractions) are carried out for the artificial maintenance of the blood circulation in the body of the injured and the regain of normal natural contractions of the heart.

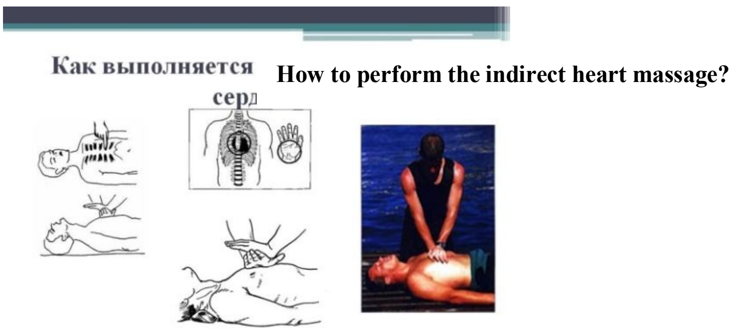
When rescuing the injured person, an indirect (external) heart massage is performed by a rhythmic pressure on the chest. As a result, the heart contracts between the sternum and the spine and pushes blood out of its cavities. After the cessation of pressure, the chest and heart are straightened, and the heart is filled with blood coming from the veins. In the person who is in state of clinical death, the chest, due to the loss of muscle tension, easily shifts (squeezes) when pressing on it, and providing the necessary cardiac compression.

To perform the cardiac compression, it is needed:

- to put the injured on his back on a hard surface,
- to bare the chest,
- to unbutton the tight-fitting clothing (belt, etc.).

When carrying out the cardiac compression, the rescuing person stays from a side of the injured and takes a position in which more or less significant inclination above him is possible.

The compression is done with a sharp pressure on the middle part of the thorax (two ribs above the end of the thorax) with both hands, with one hand being placed on the other. The hands must be straightened at the elbow when pressing. The pressing must be made by quick jerks, helping to tilt your body, so that the sternum is displaced 3-5 cm, with a frequency of at least 60 times per minute. The duration of the pressure is not more than 0.5 seconds, the interval between individual pressures is 0.5 sec. In the pauses the hands from the sternum are not removed.



Performing of the cardiac compression

The optimal ratio of chest compression and inspiration of rescue breathing is 30:2, regardless of the number of rescue participants.

A general scheme of the first aid at the scene:

1. If there is no consciousness and there is no pulse on the carotid artery - to begin cardio-pulmonary resuscitation.

2. If there is no consciousness, but there is a pulse on the carotid artery - to turn to prone position and to clean the oral cavity.
3. In case of arterial bleeding –to apply a tourniquet.
4. If there are wounds -to apply bandages.
5. If there are signs of bone fractures - to apply splints.
6. For a quick return of blood to the heart - to lift the injured's legs.
7. To save the life of the brain - to apply cold to the head.
8. To remove air from the stomach - to turn the victim to prone position and to press with fists below the navel.

2.3 Basic knowledge on electrical engineering

Electrical engineering is a field of engineering science that studies electrical and magnetic effects and their use for the practical purposes of obtaining, converting, transmitting and consuming electric energy.

Electronics is a field of the engineering science that studies electrical and magnetic effects and their use for the practical purposes of obtaining, transforming, transmitting and consuming information.

An electrical circuit is a set of devices intended for the production, transmission, conversion and use of an electric current.
All electrical devices can be divided into three large groups according to their purpose and operation and design principle.
Power sources, i.e. devices that produce electric current (generators, thermel, photocells, chemical elements).

An electomotance is an electric potential difference created by the electrical power source (electrochemical element, mechanical generator, thermel, photocell, etc.).
Receivers, or load, i.e. devices consuming electric current (electric motors, electric lights, electrical mechanisms, etc.).
Conductors, as well as various switching equipment (switches, relays, contactors, etc.).

The directional motion of electric charges is called an electric current. Electric current can occur in a closed electrical circuit. The electric current, the direction and the magnitude of which is unchanged, is called a direct current and is symbolized by a capital letter ***I***.
The electric current, whose magnitude and direction does not remain constant, is called an alternating current. The value of the alternating current at the moment is called an instantaneous current and is symbolized by a lowercase letter ***i.***

The operation of the electrical circuit requires power sources. At any source, external forces of non-electric origin create the electromotance. At supply terminals of the power source a potential difference or voltage appears which results in the electric current in the external part of the circuit connected to the source.

There are active and passive circuits, sections and circuit elements. Active circuits are
electrical circuits containing power sources, passive circuits are electrical circuits without power sources.

A linear electric circuit is a circuit where no circuit parameter depends on the value or the direction of the current, or on thevoltage.

A nonlinear electrical circuit is an electrical circuit that contains at least one nonlinear element. Parameters of nonlinear elements depend on the value or the direction of the current, or on the voltage.

An electrical diagram is a pictorial representation of an electrical circuit, including components symbols and showing a connection of these components.

Fig. 1.1 shows the electrical diagram of a circuit consisting of a power source, electric lamps 1 and 2, an electric motor 3.

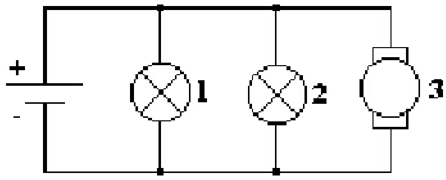


Fig. 1.1

To facilitate the analysis, the electrical circuit is replaced by an equivalent circuit.
An equivalent circuit is a graphic representation of the electrical circuit using ideal elements with parameters equal to parameters of the replaced elements.
Figure 1.2 shows the equivalent circuit.

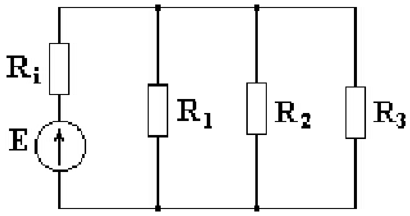


Fig. 1.2

Passive components of the equivalent circuit
The basic passive components of the equivalent circuit are resistor, inductor and capacitor.

In the real circuit, not only the rheostat or resistor possesses electrical resistance, but also conductors, coils, capacitors, etc. A common property of all devices having resistance is the irreversible conversion of electrical energy into heat energy. The heat energy released in a resistor is used or spilled. In the equivalent circuit, a resistor is included in cases when it is necessary to consider an irreversible energy conversion.

The conductor resistance is determined by the following formula

$$R = \rho \frac{l}{S}, \quad (1.1)$$

where l is the length of the conductor;
S – a cross sectional area;
ρ – a resistivity.

Conductance is the reciprocal of the resistance.

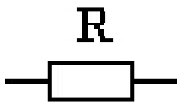
$$g = \frac{1}{R}.$$

The resistance is measured in ohm (O), and the conductance is measured in Siemens (S).
The resistance of the passive circuit component is generally determined by the following formula:

$$R = \frac{P}{I^2} ,$$

where P – is an import power;
I - a current.

A resistor in the equivalent diagram is represented as follows:

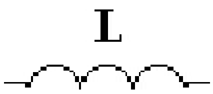


Inductance is the ideal component of an equivalent circuit, characterizing the circuit ability to accumulate a magnetic field. It is assumed that only inductive coils have the inductance. The inductance of other elements of the circuit is neglected.
The inductance of a coil is measured in Henery [H], is determined by the formula:

$$L = \frac{W \cdot \Phi}{i} ,$$

where W – number of turns in wire coil;
Φ - is a magnetic flux of the coil excited by the current i.

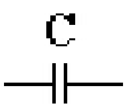
The figure shows the inductance pictorial representation in the equivalent diagram.



Capacitance - this is an ideal element of an equivalent scheme, characterizing the ability a circuit part to accumulate an electric field. It is assumed that only capacitors have capacitance. The capacity of other elements of the circuit is neglected.
Capacitor capacitance, measured in Farad (F), **is determined by the formula**:

$$C = \frac{q}{U_C} ,$$

where q is the charge on a capacitor plates;
Uc is the capacitor voltage.



The figure shows the capacitance pictorial representation in the equivalent diagram.

Active elements of the equivalent scheme

Any source of energy can be represented as an electromotance or a power source. The electromotance is a source characterized by electromotive force and internal resistance. The source of EMF is called ideal when its internal resistance is zero.
Fig. 1.3 shows the source of EMF, to the terminals of which the resistance R is connected.
Ri is the internal resistance of the EMF source.
The arrow of the EMF is directed from the point of the lower potential to the higher one, the voltage arrow at the supply terminals U12 is directed in the opposite direction from the point with a high potential to the point with a lower potential.

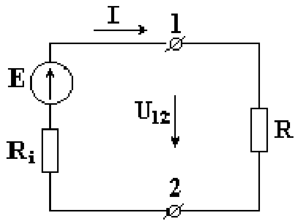


Fig. 1.3

$$I = \frac{E}{R_i + R},$$

Ток

$$E = R_i \cdot I + I \cdot R = R_i \cdot I + U_{12}, \quad (\mathbf{1.2})$$

$$U_{12} = I \cdot R = E - I \cdot R_i \quad (\mathbf{1.3})$$

At the ideal EMF source the internal resistance is Ri = 0, U12 = E.
The formula (1.3) shows that the voltage at the terminals of the real EMF source decreases with the increasing current. For the ideal source, the voltage at the terminals does not depend on the current and is equal to the electromotive force.
There is one more way of the source idealization: its representation in the form of a current source.

A current source is a power source characterized by an almost constant current value and low internal conductivity.

An ideal current source is a current whose internal conductivity is zero, and the resistivity is infinite.
We divide the left and right sides of the equation (**1.2**) by Ri and obtain

$$\frac{E}{R_i} = U_{12}\frac{1}{R_i} + I,$$

where $\frac{E}{R_i} = J$ - is the current from a currents source;

$\frac{1}{R_i} = g_i$ - internal conductance.

$$J = U_{12} \cdot g_i + I$$

For the ideal current source g_i = 0 и J = I.
The current of the ideal source is independent from the resistance of the external part of the circuit. It remains constant regardless of load resistance. A drawing of the current source is shown in **Fig. 1.4**.

Any real EMF source can be converted to a current source and vice versa. A power source, whose internal resistance is low in comparison with the load resistance, approximates its properties to an ideal EMF source.

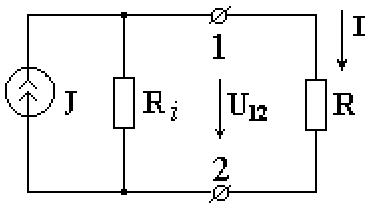


Fig. 1.4

If the internal resistance of a source is high in comparison with the resistance of the external circuit, it approximates its properties to an ideal current source.

Basic definition related to circuits
There are branched and unbranched circuits.
Fig. 1.5 shows an unbranched circuit.
Fig. 1.6 shows a branched circuit containing two EMF sources and 5 resistors.

The resistivity of the connecting wires is assumed to be zero.
A branched circuit is a complex combination of connections of passive and active components.
Fig. 1.6 shows a branched circuit containing two EMF sources and 5 resistors.
The resistivity of the connecting wires is assumed to be zero.

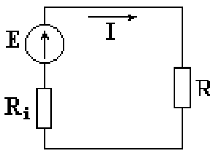


Fig. 1.5

A branch is a part of the electrical circuit through which the same current passes.
A node is the junction of three or more branches of athe electrical circuit.

A node connecting two branches converge is called removable, that is, topologically it is not a node. A topological, real, or irremovable node is the one connecting three or more branches. The node on the diagram is represented by a dot.

A tandem is the connection of circuit sections through which the same current passes. In a bridge connection, all sections of the circuit are connected to a pair of nodes under the equal voltage.

Any closed path, including several branches, is called a contour.

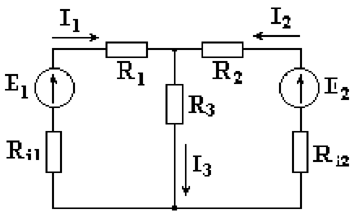


Fig. 1.6

Conditions of circuit operations

Depending on the load, the following operation conditions are distinguished:

- nominal,
- idling,
- short-circuit,
- coordinated.

Under nominal conditions, electrical devices operate under the conditions specified in the manufacturer's specifications. Under normal conditions, the values of the current, voltage, and power do not exceed the indicated values.

The idling conditions occurs when the circuit breaks or the load resistance is switched off. The idling condition is upset for the current sources.

A short-circuit condition is obtained with a load resistance equal to zero. A short-circuit current is several times higher than a nominal current. The short-circuit condition is upset for the voltage sources.

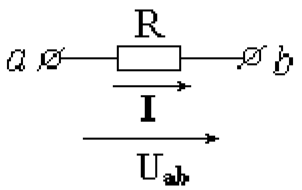
The coordinated conditions is the mode of transmission of the maximum power from the source to the load resistance. The coordinated condition occurs when the load resistance becomes equal to the internal resistance of the source. In this case, the load has the maximum power.

Basic laws of electrical circuits

Fig. 1.7 shows a part of a circuit with the resistance R. The current flowing through the resistance R is proportional to the drop in the voltage on the resistor and is inversely proportional to the magnitude of this resistance. **This is the Ohm's law**.

$$I = \frac{U_{ab}}{R}.$$

The voltage drop on resistor is the product of the current flowing through the resistor by the value of this resistance.



Pic. 1.7

The main laws of electrical circuits, along with the Ohm's law, are the laws of the balance of currents at nodes (**Kirchhoff first law**) and the law of resistivity balance in closed-loop (**Kirchhoff second law**). In accordance with Kirchhoff's first law, the algebraic sum of the currents at any chain node is zero:

$$\sum \mathrm{I} = 0.$$

Take the circuit on **Fig. 1.8** and write for it the equation according to **the first Kirchhoff law**. For currents directed to the node, we assign a plus sign, and the currents directed from the node are a minus sign. We obtain the following equation:

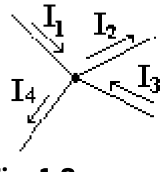


Fig. 1.8

$I_1 - I_2 + I_3 - I_4 = 0$ or $I_1 + I_3 = I_2 + I_4$

According to the **Kirchhoff second law**, the algebraic sum of the EMF along any closed circuit is equal to the algebraic sum of the voltage drops at this circuit

$$\sum E = \sum U$$

Take the circuit on **Fig. 1.9** and write the equation for the external contour of this circuit according to **the second Kirchhoff law**.

For this, we choose arbitrarily the direction of traversal of the contour, for example, clockwise. EMFs and voltage drops are written to the left and right sides of the equation with a plus sign if their directions coincide with the direction of circuit bypass, and with the minus sign if they do not coincide.

When determining the current in the branch containing the EMF source, Ohm's law is used for the active branch.

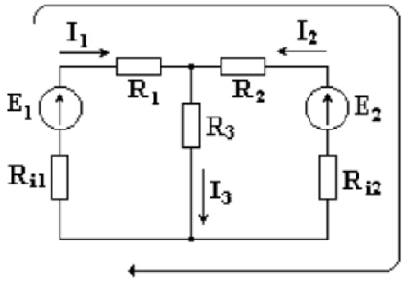


Fig. 1.9
We take a branch containing resistors and EMF sources. The branch is connected to the nodes a-b, the direction of the current in the branch is known (Figure 1.10).

We take a closed loop consisting of an active branch and a voltage arrow Uab, and write for it the equation according to **the second Kirchhoff law**. We choose the direction of the circuit bypass clockwise.

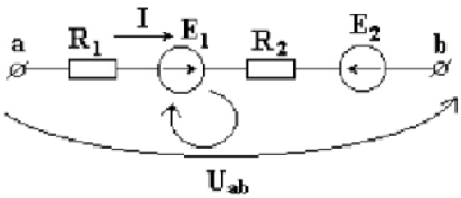


Fig.1.10
We get

$$I \cdot R_1 + I \cdot R_2 - U_{ab} = E_1 - E_2$$

From this equation we derive the formula for the current

$$I = \frac{U_{ab} + E_1 - E_2}{R_1 + R_2}$$

In general:

$$I = \frac{U_{ab} + \sum E}{\sum R},$$

where Σ R is the sum of the branch resistances;
Σ E is the algebraic sum of the EMF.

The EMF in the formula is written with a plus sign, if its direction coincides with the direction of the current and with a minus sign, if it does not coincide.

The results of electrical engineering are seen every day everywhere. This is the domestic electrical equipment: lighting and electric cookers, televisions and telephones, vacuum cleaners and fans. This is the industrial equipment of factories and plants: electric drive of machines and other equipment, devices for measuring and controlling production processes, enterprises power supply.

The energy in our human society is transmitted mainly by electric grids ensuring the maximum process speed and efficiency, and therefore there is a whole industry producing, transporting, converting electricity. In the field of communications and data processing, electrical devices and processes have virtually no alternative.