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RESONANT ELECTRIC POWER SYSTEMS

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Resonant electric power systems with the use of single-line waveguide lines at high frequency are considered. The results of comparison of classical electrical engineering with resonant electrical engineering proposed by N. Tesla 100 years ago, are given. In such characteristics as current density and line losses, energy trasmission distance, transmission capacity, the possibility of cable and wireless power transmission the Tesla electrical systems exceed the classical energy supply systems. The results of the GNU VIESH research for the development of electric power supply systems proposed by N. Tesla, are considered. The future world energy model based on solar energy and N. Tesla technologies for electric power transmission is suggested. The ten trends of the future development and application of resonant systems for electric power transmission are described. In future electrified mobile robots with external wireless electric power supply will allow to organize agricultural production on the principle "Industrial factories on the fields" with full automation of technological processes.

Keywords: *resonant electric power systems; single-line waveguide lines; wireless power transmission the Tesla electrical systems.*

At UPGrid-2012 forum Mikhail Kurbatov, RF Deputy Minister of Energy said that there exist in Russia over 2 million kilometers of overhead transmission lines more than half of which have already used their rated resource. They have to be replaced in the coming 15 years. Oleg Budarin, the head of the Federal Grid Company of the Unified Energy System of Russia (UES FGC) stated: "We are expecting new materials and technologies of power transmission over long distances. However, speaking of breakthrough solutions for electric grids, none have been demonstrated in recent years" [1]. In fact, breakthrough technologies for electric grids and systems already exist.

History of science demonstrates that very occasionally global inventions come to life that considerably change our perception of the outside world and the prospects of humanity development. As an example we can mention the discovery of electricity, the emergence of nuclear and solar energy, of aircraft and rocket engineering, computers and telecommunication technologies.

However, nowadays we witness and participate in the development of advanced technologies that change the world making it better, cleaner and safer. First and foremost we should mention technologies proposed by N. Tesla a hundred years ago. N. Tesla developed electric engineering solutions with the use of alternate current but he was not able to implement his major project of "The global system for electric power supply" for reasons described in his work [2]: … "My project was retarded by laws of nature. The world was not prepared for it. It was too far ahead of time. But the same laws will prevail in the end and make it a triumphal success".

"Perhaps it is better in this present world of ours that a revolutionary idea or invention instead of being helped and patted be hampered and ill-treated in its adolescence - by want of means, by selfish interest, pedantry, stupidity and ignorance; that it be attacked and stifled; that it pass through bitter trials and tribulations, through the heartless strife of commercial existence. ... So all that was great in the past was ridiculed, condemned, combated, suppressed - only to emerge all the more powerfully, all the more triumphantly from the struggle." It is so similar to the attitude to scientists in Russia since 1991.

N. Tesla left behind thousands of pages of his books describing the experiments results, articles and patents [2-4].

The comparison of classical electric engineering with N. Tesla electric engineering solutions

Fig. 1 demonstrates one of electric circuits of the resonant single-wire electric power supply system proposed by N. Tesla and updated at GNU VIESH [4-5].

At the beginning of the 19^{th} century there were no diodes and transistors and for pumping resonant circuit and a transformer N. Tesla used the method of impact incitation with a spark arrester with 96% transmission efficiency [2]. At the end of the 20th century we used a thyristor frequency converter with 25 kW capacity, water cooling with 86% efficiency and 400 kg weight. Currently frequency converters on silicon transistors with 97%

efficiency and 30 kg weight are applied. The ReFuSol company developed and brought to market 20 kW inverters on silicon carbide transistors with 98% efficiency.

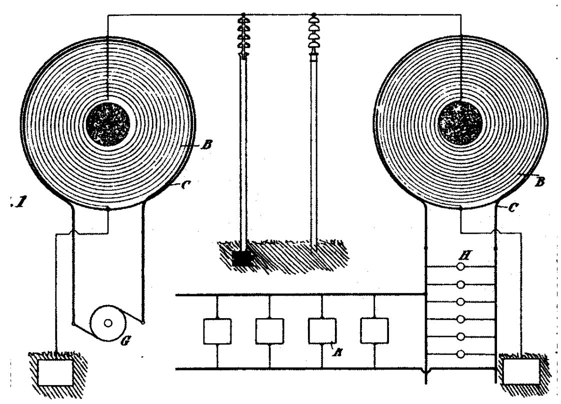

Fig. 1a. Resonant single-wire electric power supply system developed by N. Tesla (1897)

In contrast to DC power transmission lines with converting substations at a high-voltage side of transformers, we use frequency converters and inverters at low-voltage side of transformers, which reduces their price to 100-200 USD per 1 kW.

The Table 1 presents the comparison of classical electric engineering studied by future electric engineers for three terms, with N. Tesla electric engineering techique.

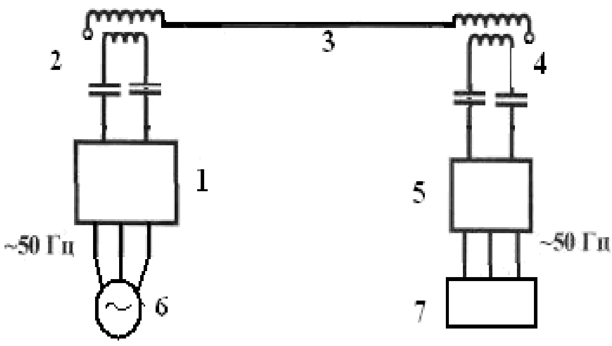

Fig. 1b. State-of-the art resonant system for electric power supply: 1 – frequency converter; 2, 4 – two resonant high-frequency Tesla transformers; 3 – single-wire high voltage line; 5 – inverter; 6 – generator; 7 – load

Table 1

The comparison of classical electric engineering with N. Tesla technique in the field of electric power transmission

№№	Classical electric engineering based on the use of alternative current in a closed circuit	N. Tesla electric engineering based on the use of reactive current in an open-circuit line
1	AC frequency – 50 Hz (Europe), 60 Hz (USA), 400 Hz (aviation)	AC frequency - 500 Hz- 500 kHz
2	The modes of quenching of resonant characteristics of the line, transformers with a closed core, three- and one-phased overhead transmission lines are used	The resonant modes of the line operation, resonant circuits, resonant transformers with an open core or without a core, waveguide single-conductor cable lines, as well as the globe as a single-conductor line are used
3	Potentials at outlets of high-voltage winding of a single-phase transformer are equal in value and opposite in sign	Potential of one of the outlets of high-voltage winding of the Tesla transformer is equal to zero and the potential of the second outlet has maximum in modulus positive or negative value
4	A single-layes electric coil is classical inductance	A single-layer electric coil in various applications is an earth loop, a time-delay circuit, a spiral waveguide, a spiral antenna or an electric resonator
5	The transformer has low-voltage and high-voltage winding made in the form of multi-layered coils with lamped parameters and there is classical theory of calculation of transformers winding	The high-voltage Tesla transformer has additional single-layer high-voltage winding which is an electric resonator with lamped parameters and it is impossible to calculate the parameters of the electric resonator using classical theory of electric circuits [5-6]
6	Loss of phase in power transmission lines is emergency for consumers	The open circuit mode of the generator is an operating mode of electric power transmission
7	Electric power from the generator is transmitted to the customer in a continuous mode	A pulse mode of energy pumping into the Tesla transformer from a transmitting resonant circuit is used.
8	The circuit must be closed to provide current flow	in closed current flows in a open-circuit line

№№	Classical electric engineering based on the use of alternative current in a closed circuit	N. Tesla electric engineering based on the use of reactive current in an open-circuit line
9	Closed current of the generator must pass through the load and return to the generator	Unclosed current flows from the generator to the load not returning to the generator
10	Current must be equal for all sections of closed circuit. It holds for direct currents and quasi-steady alternating currents with 50 Hz frequency and circuit length of up to 100 km	Current at various line sections can flow in opposite directions and assume any values from zero to maximum
11	Electric power is transmitted with the use of active current in a closed circuit	Electric power is transmitted with the use of reactive capacitance current in an open-circuit line
12	During electric power transmission in a closed line traveling current and voltage waves emerge	During electric power transmission in an open-circuit line standing (stationary) current and voltage waves emerge
13	Current and voltage waves in a line match in phase: $\varphi=0$, $\cos\varphi=1$	Current and voltage waves in a line are phase shifted by 90°: $\varphi=90^o$, $\cos\varphi=0$
14	Crests and nodes of current and voltage waves are cuncurrent and match along the line length	Crests and nodes of current and voltage waves are non-cuncurrent and are located at various sections of the line. At the moment when voltage in the whole line is equal to zero, current in the line has maximum value and vise versa
15	Crests and nodes of current and voltage move along the line	Crests and nodes of current and voltage are rigidly settled along the line
16	Maximum effective current density in the line is 1,5-3,5 A/mm^2 [7]	Maximum effective current density in the line made of copper conductor at ambient temperature is 600 A/mm^2. The parameters of the GNU VIESH operating plant are as follows: conductor diameter - 80, мкм, transmission capacity – over 20 kW, voltage – 6,8 kW
17	Losses in electric power transmission in the line are 8,5% (normative), 10-20% (actual)	Losses in electric power transmission in the line are 1-3% (N. Tesla experimental data)
18	In the mode of active power transmission voltage along the line is constant and there is an angle between voltage vectors at the sending-end and receiving end on the line	An angle between voltage vectors at the sending-end and receiving end of the line is equal to zero, and voltage value is measured over wide range and is determined by the line quality factor
19	Active transmission capacity is regulated by changing angle between voltage vectors at the sending-end and receiving end of the line, as well as voltage value	Active transmission capacity is regulated by changing voltage and frequency value
20	When frequency is changed by 2%, transmission capacity undergoes slight change	When frequency is changed by 2%, transmission capacity is reduced down to zero
21	The Umov-Poynting vector is directed along the line from the generator to the load	The Umov-Poynting vector changes its direction each quarter wave
22	Power transmission distance is 2000-3000 km [7]	Power transmission distance is limitless within the Earth bounds
23	Maximum transmission capacity of a three-phase power transmission line is limited by electromagnetic stability of the line at the level of 6 GW [7]	Maximum transmission capacity of a three-phase power transmission line is limited by electric strength of insulation and exceeds 100 GW
24	Wireless power transmission is impossible at the 50-60 Hz frequency and is economically unsound at high frequencies	Wireless power transmission is highly efficient and will be widely used in railroad and automobile transport and in rocket and space technologies
25	In DC power transmission lines 500-750 kW converting substations are used	Converting substations are used at the transformer low-voltage side with 0,4-10 kW voltage

In such parameters as current density and line losses, power transmission distance, transmission capacity, the possibility of cable and wireless power transmission N. Tesla electric systems exceed classical electric power supply systems.

In radio engineering there are examples of single-conductor power transmission systems at frequency 100 times exceeding the frequency used by N. Tesla: a beam antenna, a single-conductor wave-guide, electromagnetic and galvanic coupling between resonant circuits. The theory of coupled resonant circuits can be used in the theory of power transmission through single-conductor lines. In the theory of coupled resonant circuits power transmission efficiency tends to 100% while power transmitted between resonant circuits tends to zero. Maximum capacity is transmitted with 50% efficiency because of energy losses in circuits [8]. To raise transmission efficiency up to 96% N. Tesla used pulse mode of pumping the Tesla transformer, wherein in power transmission through a single-conductor line, transmitting circuit opened and provided infinite resistance for reflected waves, corresponding to the mode of open-circuit line of the generator [2, 6]. This provided the mode of standing waves and prevented losses in series transmitting circuit where the Tesla transformer pumping currents amount to tens of thousands of amperes at 70 kW supply voltage and idling losses power of 3 hp.

Classical electrical engineering should be supplemented by a section describing N. Tesla resonant electric engineering solutions.

Trends of future development of electric engineering and energy industry

N. Tesla has left behind the following technologies for further development:

1. Single-wire resonant technologies for power supply to stationary consumers.

2. Technologies for wireless power supply to surface and sea transport.

3. Technologies of directional electric power transmission through conducting channels in atmosphere and space.

In 21st century these technologies make it possible to develop:

1) fuel-free rockets with electric rocket motors, which increase layload mass taken into orbit, from current 5% up to 90% of the rocket total weight;

2) extremely long-range electric power transmission lines with lower losses than in superconducting cable lines;

3) a unified energy system of Russia from Chukotka to Kaliningrad;

4) a global solar energy system with terawatt transcontinental power exchange and twenty-four-hour electric power generation for million years in the amount of 20 000-50 000 TW·h, corresponding to the Earth current and future energy consumption;

5) plasma chlorine-free technologies of solar-quality silicon production in the amount of 1 mln tons per year for yearly construction of photovoltaic solar power plants with total capacity of 150 GW;

6) hydrogen energetics due to 10 times reduction of costs on water electrolysis;

7) electric cars without accumulators with limitless distance of run;

8) contactless electric power supply systems for railroad transport, trolley-cars, air and sea transport;

9) mobile electric robots providing automated soil tillage, cultivation and harvesting agricultural crops without herbicides and pesticides;

10) underground shielded cable lines that can replace all overhead power transmission lines.

All the ten directions of the development of energy technologies for future world has been developed in GNU VIESH for 20 years and are protected by fifty Russian patents. The basic content of these patents and the research results have been published in the study [4] that will be issued in the fourth edition in 2013. Over 80 experimental low-power electric devices using Tesla technologies, are described in the book [9].

Let us consider each of these trends in more detail.

N. Tesla resonant technologies for electric power transmission are based on the use of reactive currents in single-conductor open lines. In 1927 N. Tesla wrote [3]: “In 1893 I demonstrated that there is no need to use two conductors for electric power transmission… Irreversible power transmission through a single conductor was practically substantiated”.

D. Maxwell confirmed the existence of unclosed currents: “Outstanding complexity of agreeing laws of electromagnetcs with the existence of unclosed currents is one of the reasons why we should admit the existence of currents generated by displacement change”.

N. Tesla suggested power transmission through a conducting channel in atmosphere with the use of X radiation. In 1927 Tesla wrote [2]: “ More than twenty-five years ago my efforts to transmit large amounts of power through the atmosphere resulted in the development of an invention of great promise, which has since been called the "Death Ray". The underlying idea was to render the air conducting by suitable ionizing radiations and to convey high tension currents along the path of the rays. Experiments, conducted on a large scale, showed that with pressures of many millions of volts virtually unlimited quantities of energy can be projected…” .

We have obtained five patents for electric power transmission through laser, electron and microwave beams between objects in the Earth atmosphere, in space and between the Earth and space objects. Technologies of directional wireless electric power transmission develop N. Tesla technologies for using conducting channels as a guide system (single-conductor wave-guide) for transmission of electromagnetic high-potential energy at 10-500 kHz and voltage level from hundreds of kilovolts to tens of millions of volts. In this process energy transmitted through a conducting channel exceeds energy spent on formation and maintaining a conductive channel 10^2-10^6 times.

On July 15, 2012 the manned spaceship "Soyuz" was launched to perform works at the international space station. For 529 seconds of rocket engines operation 300 t of liquid fuel were consumed. This means that launch mass of the spaceship exceeded 300 t while payload mass was less than 5%. The use of electric rocket motors with wireless electric power transmission to the spaceship from a terrestrial energy system will make it possible to reduce the rocket mass and energy consumption, as well as space flights costs tens of times.

Another N. Tesla approach was to use the Earth as a single-conductor line for electric power supply to ground, sea and air electric tranport vehicles. In his speech on the occasion of receiving the Thomas Edison Award at the session of the American Institute of Electrical Engineers on May 18, 1917 N. Tesla stated: "Years ago I was in the position to transmit wireless power to any distance without limit other than that imposed by the physical dimensions of the globe. In my system it makes no difference what the distance is. The efficiency of the transmission can be as high as 96 or 97 per cent, and there are practically no losses except such as are inevitable in the running of the machinery. When there is no receiver there is no energy consumption anywhere.

When there are no receivers, the plant consumes only a few horsepower necessary to maintain the vibration; it runs idle, as the Edison plant when the lamps and motors are shut off.

The project envisaged the setting-up of a network of electric power plants equipped with the systems for power transmission to any part of the globe on the surface of ground, oceans or in atmosphere using the Earth as a single-conductor line. At the same time N Tesla suggested lighting of oceans and cities at night time due to atmosphere ionozation. Still, testing of experimental systems in Colorado Springs and near New York revealed ecological problems in the process of the system operation: sparks from water taps and horses' hooves, glowing of human hands and hair, a failure at the electric power supply station, etc.

In order to set up the global energy system developing N. Tesla ideas, we proposed electric energy transmission through high-voltage single-conductor cable gas-insulated lines and the use of three solar energy plants in deserts of Australia, Africa and Latin America as energy sources (Fig. 2, 3) [5].

Each solar energy plant size is 200×200 km, efficiency - 25%. They produce electric energy in the amount of 20 000 TW*h per year on a 24-hour basis, which corresponds to the world energy consumption in 2010.

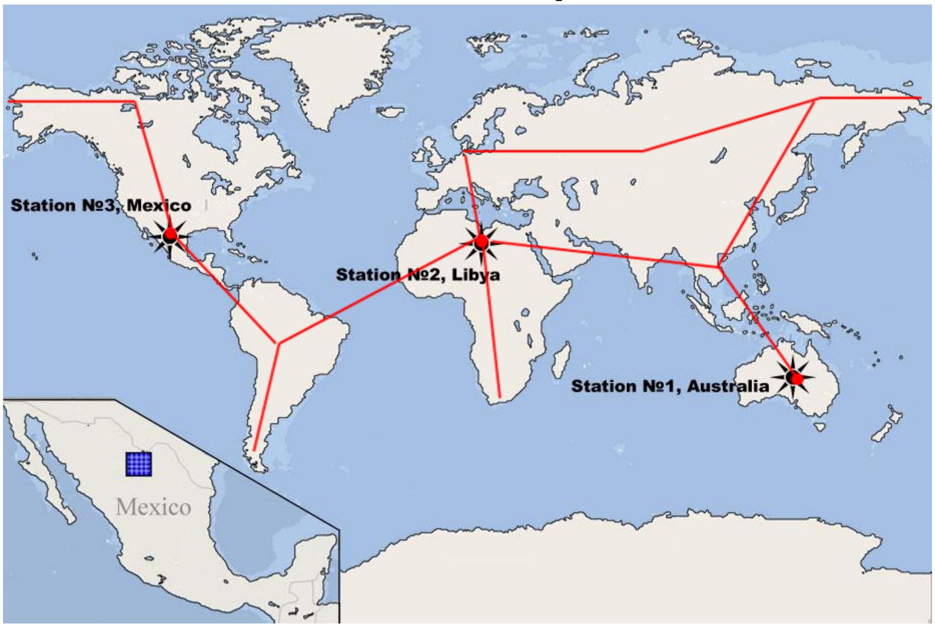

Fig. 2. The global solar energy system comprising three solar power plants

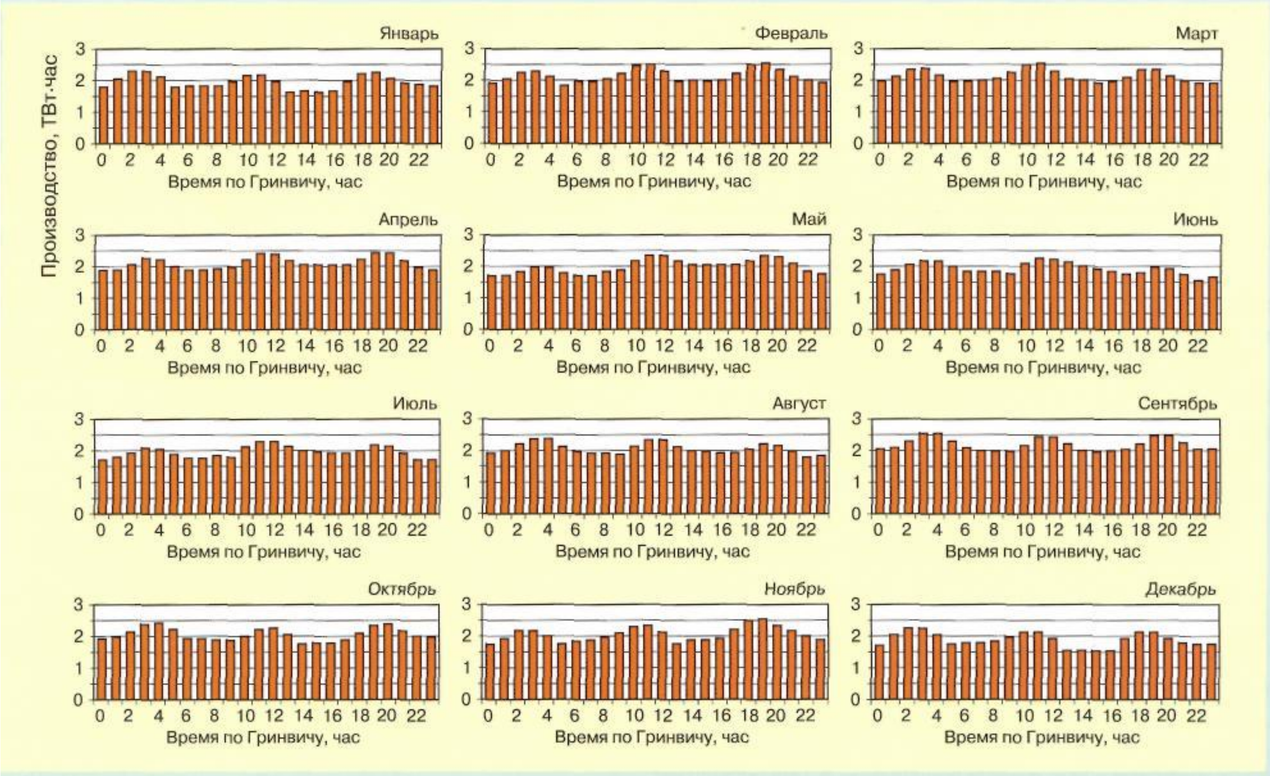

Fig. 3. Full-time production of electric energy by the global solar power system in the amount of 20 000 TW per year for millions of years

Thus Russia proposed the model of the future world development based on direct conversion of solar energy at solar power plants and transcontinental terawatt power streams with the use of resonant wave-guide technologies suggested by N. Tesla.

The use of insulated single-conductor cable lines instead of the Earth will make it possible to eliminate ecological problems related to the implementation of the N. Tesla project for the setting-up of the global power supply system. N. Tesla published two patents on cable single-wire lines [4], that can be used for the project of the unified energy system of Russia from Chukotka to Kaliningrad. The first patent suggests using cables with special shields reducing radiation losses practically down to zero. The cable conductor diameter is 1-5 mm that provides low electric capacity of the cable. In the second patent N. Tesla offered to lay wave-guide single-conductor cable lines in the permafrost zone to increase insulation strength, and to create permafrost zone around a cable with the use of electrically insulated metal pipe through which gas or liquid low-temperature refrigerant is pumped.

Single-conductor cable lines covered by N. Tesla patents will replace overhead electric power transmission lines, which will considerably increase reliability of electric power supply, reduce rate of injuries caused by electricity and free considerable areas of fields, cities and forests in Russia.

Mono-electrode high-frequency plasmatrons developed in GNU VIESH make it possible to set up solar-grade chlorine-free silicon production in the amount of 1 mln tons per year to provide the construction of solar energy plants with capacity of 150 GW, while current solar energy production is 30 GW per year. N. Tesla technologies allow to develop special mono-electrode electrolysis units and reduce energy consumption in the process of water electrolysis for hydrogen production tenfold.

N. Tesla developed the contactless method of electric power supply to railway transport from a single-conductor cable laid in the gound [4]. The GNU VIESH specialists developed and patented experimental models of cars of the future without accumulators, that are fed from an energy system through air interspace from a single-conductor cable laid near the pavement surface. Electric energy costs of a light electric car will be 1 USD per 100 kilometer of road, electromobiles price will be reduced twice due to the absence of accumulators and it will be less expensive than cars with internal combustion engines. In addition ecological problems of large cities and highways will be solved. Trolleyless systems of electric power supply will raise reliability of tramway cars and high-speed trains and will make it possible to use electric heavy-payload trucks on interurban roads. We proposed systems for electric power transmission to underwater vehicles with submergence depth of up to 10 km and to aircraft in atmosphere.

In his letters of July 14 and 17 N. Tesla wrote [3]:

“With the use of a standing waves generator and receiving equipment installed and adjusted in any distant location it is possible to transmit distincts signals, control or activate devices...

With the use of a transmitter electricity moves in all directions equally through ground and air but energy is spent only at the location where it is accumulated and used to perform operations. Though electric oscillations can be detected on the whole Earth both on the surface and high in the air, energy would actually be not consumed.

Electromagnetic energy of a transmitter is transmitted to a location of the Earth or its atmosphere where there is a receiver with resonant frequency adjusted to the transmitter frequency”.

Electric tractors and robotized mobile equipment in agriculture will get energy from a cable laid in the ground but it will be necessary to provide for a special permanent path (track) for a left ot right train of wheels of an electrified mobile vehicle. In the future electrified mobile robots with external power wireless power supply will make it possible to organize agricultural production on the principles of “Industrial Factories on Fields” with full automation of technological processes.

Humanity will be able to unify energy systems of all the countries into a global solar energy system of the Earth to provide decent living conditions for everyone and to implement large-scale scientific and technological projects both on the Earth and in space.

Conclusions

1. The results of comparison of parameters of a classical electric power supply system with an electric power supply system using single-wire wave-guide lines with high frequency, proposed by N. Tesla 100 years ago, are presented. In such characteristics as current density and line losses, energy transmission distance, transmission capacity, the possibility of cable and wireless power transmission the Tesla electrical systems exceed the classical energy supply systems.

2. The future world energy model based on direct solar energy conversion and transcontinental terawatt power transmission with the use of resonant wave-guide technology developed by N. Tesla, is proposed.

3. The trends of the future development of electric engineering and energy technologies for agriculture, space exploration, solar energy, hydrogen energy and electric transport based on resonant wave-guide methods of electric power transmission and application are suggested.

4. In future electrified mobile robots with external power wireless power supply will make it possible to organize agricultural production on the principles of “Industrial Factories on Fields” with full automation of technological processes.

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NIKOLA TESLA AND FUTURE OF ELECTRIC POWER ENGINEERING

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The methods and apparatus for the Resonant system for electric power transmission and the electrical circuit for supply of stationary consumers and mobile electric transport funds. Substantiation is given and examples of transfer of electric energy on electroconductive channels created by electron beams, laser and microwave radiation. Considered the circuit supplying power to the load on the resonance of the waveguide line.

There are presented materials on the implementation of electrotechnics, carried out on the basis of the resonance method power of different electrotechnology facilities. Given the description of experimental samples of resonant cold-plasma coagulator.

Presents the results of investigations bread and experimental samples of plant and equipment with power supply on the resonant circuit transformation and transfer of energy.

Keywords: *Resonant system for electric power transmission; resonant high-frequency Tesla transformers; electroconductive channel; resonant cold-plasma coagulator.*

If an electric engineer* had studied classical electrotechnics during three semesters and works in the field of high-power electric networks, it is rather difficult for him to accept, that an alternative electrotechnics exists, which is characterized by the following features:

- A closed circuit containing two conductors between the generator and the load is not necessary to obtain an electric current flow.
- The current can flow through a single-wire circuit, like the water flows through a pipe from the upper basin to the lower one, or like the heat flows from a hot end of a metal bar to its cold end. (W. Thomson was first to point to the analogy between thermal conduction and electrostatics, while J. Maxwell was first to show the analogy between hydrodynamics and electrodynamics).
- In a coil containing a single-layer wire winding, the phase velocity of the electromagnetic wave along the coil axes can be hundreds times lower, than in an overhead transmission line (or than the light speed in the free space).
- The current varies along the line length, in different winds of a coil, or in different sections of a single-conductor line, it can have any local value, including zero. Furthermore, the current in different segments of a single-wire circuit can flow in opposite directions.

However, such exotic behavior of the current (from the viewpoint of a classical electric engineer) does not seem strange to a radio engineer, because a beam antenna and a single-conductor waveguide are classical examples of single-conductor lines for him [1–3]. Standing waves and traveling waves of the current (and voltage) exist in such lines, and the circuit is closed by displacement currents in the space surrounding the single-conductor line. J. Maxwell wrote: "Extraordinary difficulty of coordinating the electromagnetism laws with the existence of unclosed electric currents is one of the reasons (among many other), why we must admit the existence of currents created by displacement variation". At a high frequency, the single-layer electric coil is transformed from a classical induction coil (in different application conditions) to a slow-wave structure or electromagnetic-wave delay line, to a helical waveguide, helical antenna or electric resonator with distributed parameters, which can not be determined using the classical electric circuit theory.

* The author, electric engineer, graduated from the Moscow State Agricultural Engineering University in 1959. After delivering lectures during 15 years, he has received the academic status of professor at the Open University, Chair of Fundamentals of Radiotechnics and Television. The author is grateful to professor V.M. Svistov (Chair holder of Fundamentals of Radiotechnics and Television from 1972 to 1987) for discussing waveguide systems for power transmission, to academician of the Russian Academy of Sciences Ya.B. Danilevich and to Corresponding Member of the Russian Academy of Sciences N.S. Lidorenko for fruitful discussions, recommendations and support of the work.

All the considered phenomena in a single-conductor line and in a spiral coils exist also at frequencies of 1 to 100 kHz, and they can be used for electric power transmission. Furthermore, the specified frequency range is most suitable for electric power transmission along a single-conductor waveguide in connection with limitations imposed by the radiation loss caused by the antenna effect. Unfortunately, the radio engineers have little interest in this frequency range, while the electric engineers are insufficiently prepared for working at the interface of electrotechnics and radiotechnics.

The electric power transmission along a single-conductor line at a higher frequency has been first proposed and realized by N. Tesla more than 100 years ago [4]. N. Tesla considered a resonant single-conductor system for electric power transmission as an alternative to a dc power transmission system proposed by T. Edison. The competition between dc and ac power transmission systems continues at present, however it takes place in the context of classical single-phase (double-wire) and three-phase (triple-wire) closed transmission lines.

We have shown experimentally, that a single-conductor line with a high-frequency resonant Tesla transformer at the line end can transmit electric power at any frequency, including zero frequency (i.e. using rectified current). The single-conductor resonant systems (see Fig. 1, 2) offer possibilities for designing super-long cable lines and replacing (in future) the existing overhead lines with cable single-conductor lines [5]. In this way one of major electrification problems: increasing the reliability of electric power supply will be solved.

The open-ended line shown in Fig. 1, whose length is $l = (2n + 1)\ \lambda/4$, $n = 0, 1, 2, 3, \ldots$, has a current loop and a voltage node at the generator terminals; in case of $l = n\ \lambda/2$, it is a voltage loop and a current node. In both cases the line is equivalent to a resonant oscillatory circuit.

The standing waves in the open-ended single-conductor line (see Fig. 3) arise as a result of superposing the incident and the reflected waves having equal amplitudes. The voltage and current phase values demonstrate no displacement along the line, while the phase shift between the current and the voltage is equal to 90°. The line cross-sections with voltage loops contain current nodes, while voltage nodes correspond to current loops. The mean power delivered by the generator into the open-ended single-conductor lossless line (or into a line, loaded with a capacitor) is equal to zero [2].

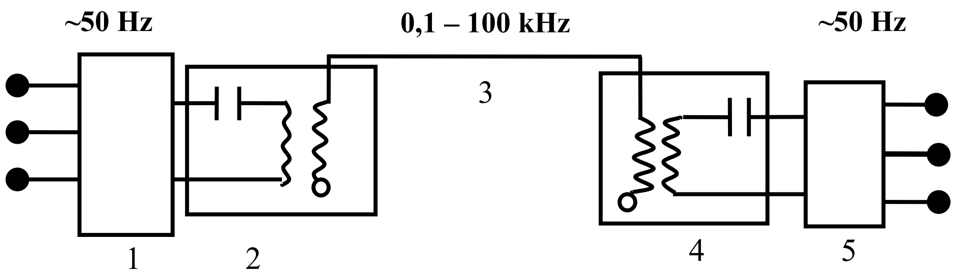

Fig. 1. Resonant system for electric power transmission:
1 – converter; 2, 4 – resonant high-frequency Tesla transformers;
3 – single-conductor high-voltage line connecting the transformers; 5 – inverter

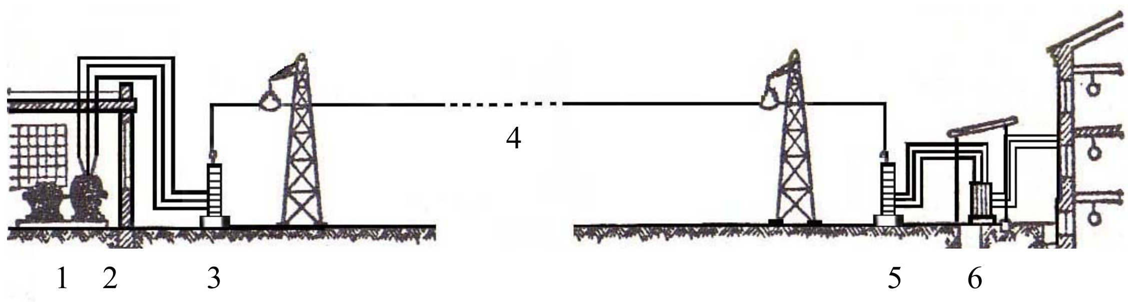

Fig. 2. Single-conductor resonant power transmission system
1 – electric generator, 50 Hz (1 to 100 kHz); 2 – frequency converter 50 Hz / 1 to 100 kHz (absent, if the generator frequency is 1 to 100 kHz); 3 – high-frequency step-up transformer 0.4 kV / 10 to 500 kV; 4 – single-conductor line 10 to 500 kV; 5 – high-frequency step-down transformer 10 to 500 kV / 0.4 kV; 6 – inverter 1 to 100 kHz / 50 Hz

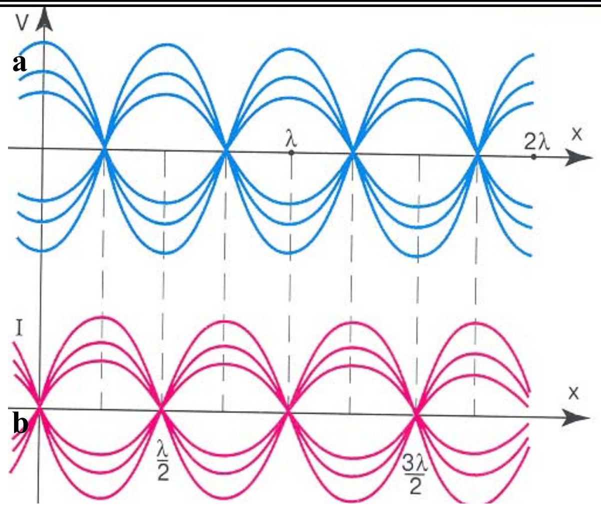

Fig. 3. Standing waves in an open-ended line at various time points: a – voltage; b – current

If the line operates in the standing-wave regime, its input impedance is reactive. If the line is lossy, a certain traveling wave from the generator compensates for the loss. If traveling and standing waves are present in the line, its input impedance contains both reactive and active components.

The single-conductor resonant line, open at the load end (or loaded with a capacitor) is shown in Fig. 4, *a*; the current and voltage distribution for the open-ended line is plotted in Fig. 4, *b* [2, 6].

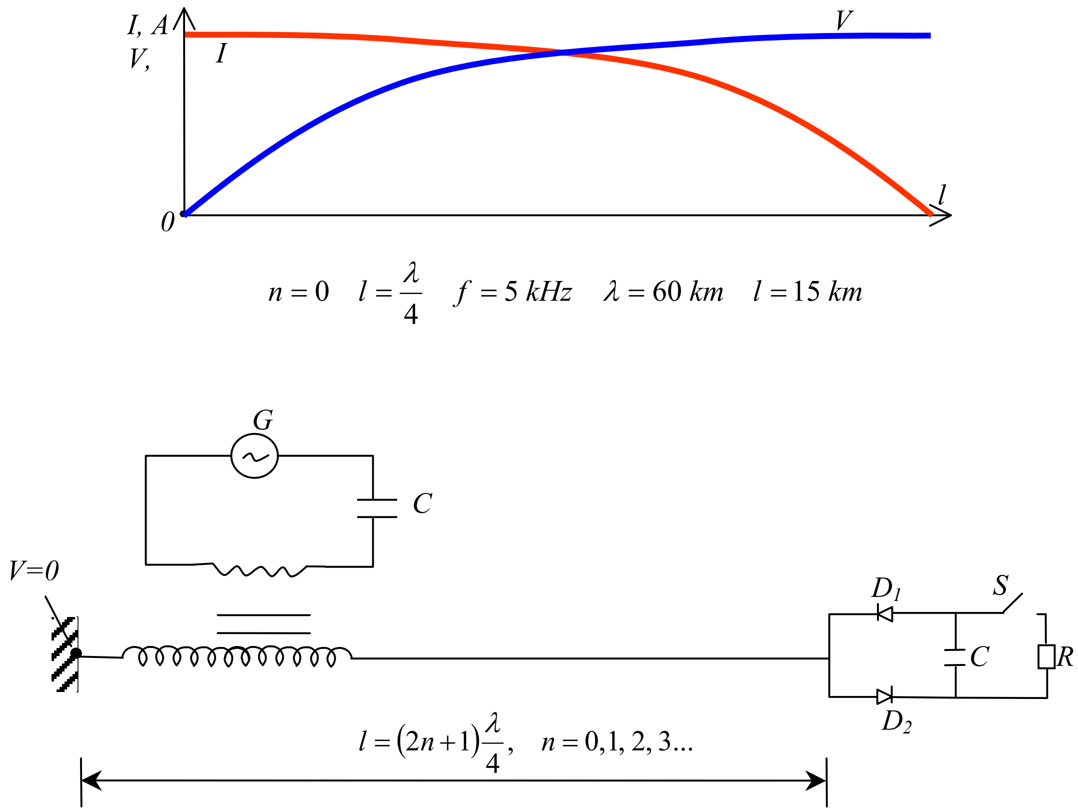

Fig. 4. Circuit representation for a single-conductor resonant line, open at the load end or loaded with a capacitor (a); current and voltage distribution (b): G – generator; C_0 – capacitance of the resonant circuit; D_1 and D_2 – diode unit; C – load capacitance; S – electronic switch; R – load resistance

The current and voltage distribution in a single-conductor line shorted to the ground at both ends is shown in Fig. 5 [5]. The classical electric engineer (mentioned at the beginning of this section) would say, looking at Fig.5, *a*, *b*, that it is a closed double-conductor transmission line using the ground as the second conductor, with the conductance current in the closed circuit. The radio engineer would give a correct explanation: it is a conventional waveguide characterized by 90° phase shift between the current and the voltage, fastened to grounded metal supports, which are connected to the line at the voltage node points. The line grounding at the voltage node points does not change the waveguide parameters and does not effect the transmitted power value.

When the line operates in the standing-wave regime, the direction of the Poynting vector $\overline{S}$ is inverted every quarter of the time period: it is directed from the generator to the load or back (see Fig.6). This phenomenon is explained in the following way. The phase shift between the voltage and the current in the line (and consequently between the values of the electric and magnetic field strength) is equal to 90°; as a result, the direction of one of the vectors: $\overline{E}$ or $\overline{H}$ is inverted every quarter of the period. This consideration confirms, that the generator spends no energy to produce standing waves in the line [2].

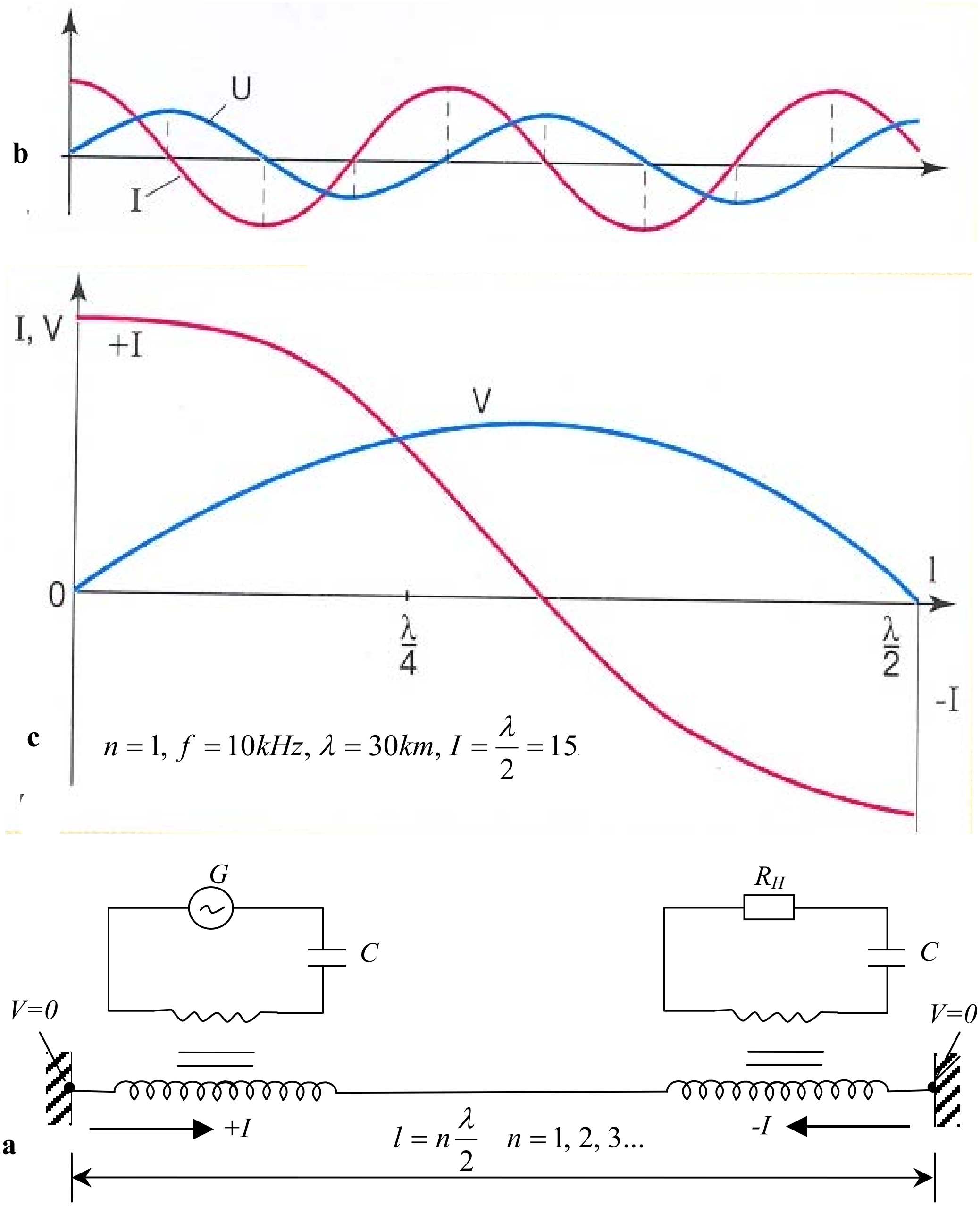

Fig. 5. Current and voltage distribution in a single-conductor line shorted to the ground at both ends:
a **– circuit representation (*G* – high-frequency generator, R_l – load resistance,**
C **– capacitance of the resonant circuit);**
b **– current and voltage standing wave distribution along a single-conductor line;**
c **– current and voltage distribution in a half-wave single-conductor line**

For the electric engineer, the stationary or standing waves shown in Fig. 6 illustrate a phenomenon, which has no real physical basis, because the length of transmission lines does not usually exceed 1000 km, while the current and voltage wavelength at a frequency of 50 Hz equals to 6000 km. A half-wave line (see Fig.5, c), 1000 km in length, can be obtained at a frequency of 150 Hz, and in this case even a conventional single-phase or three-phase line will transmit considerably more power, than at a frequency of 50 Hz.

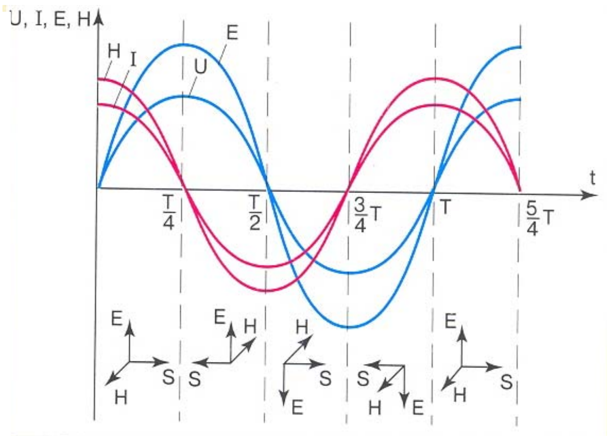

Fig. 6. Direction of the Poynting vector $\overline{S}$ along the single-conductor line in the standing-wave regime: I, H – waves of the current and the magnetic field strength; V, E – waves of the voltage and the electric field strength

However conventional transmission lines reveal resonant properties only in an emergency condition (for example, in case of line break at the consumer). In order to understand N. Tesla works and develop his ideas on resonant electrotechnics, the classical course for electric engineers shall be supplemented by a special course containing information on high-frequency resonant lines, principles of single-conductor and helical waveguides, methods for designing electric circuits with distributed components, main scientific and practical results in the field of resonant electric technologies and prospects for their application.

Several application fields for resonant single-conductor electric systems are considered below.

A 20-kW, 1-kHz resonant transmission line based on a single-conductor cable, 1.2 km in length, has been successfully developed and tested at the VIESH (Fig. 7) [6].

Application of various conducting mediums in the resonant systems for transmitting electric power has been illustrated using an electric boat model, which receives electric power from a water basin with alive fish (Fig 8, 9).

Fig. 7. 20 kW, 1 kHz resonant electric power transmission system

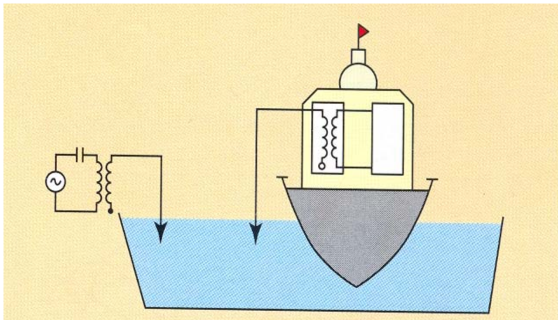

Fig. 8. Electric power transmission using water as conducting media

Fig. 9. Electric boat model receiving electric power trough the water

A wind power station, a solar battery, etc can be used as a source of electric power in a resonant electric system.

Another global application for resonant single-conductor electric power transmission systems consists in the opportunity of developing noncontact high-frequency electric transport. The well-known noncontact method for transmitting electric power to a vehicle through an air-core transformer (using the electromagnetic induction method and conventional single-phase power transmission lines) has basic limitations on the transmitted power level, the transmission efficiency and the line length; therefore, it is not used at present [7].

An experimental model of a small electric vehicle developed at the VIESH receives electric power from an isolated single-conductor cable line laid inside the roadway covering (see Fig. 10). The works on increasing the noncontact drive power and developing a commercial project of a resonant electric transport system are being carried out now. It is possible to imagine in future a big green city, full of flowers, without exhaust gases and smog. A cable transmission line will be laid in this city under each driving row along main roads, and each vehicle has an electric motor and a noncontact trolley in addition to the combustion engine. The traffic along big highways between cities can be organized in the same way, including possible use of automated vehicles controlled by robots and computers.

Fig. 10. Contactless high frequency electric vehicle

Use of an electric noncontact drive in the agricultural energetics opens the prospects for substantial fuel saving and developing pilotless automatic robots controlled by computers with satellite navigation, intended for tillage, cultivation and harvesting agricultural products. In this case the agricultural plants will turn to field factories organized according to the principles of automated industrial enterprises. Thus, three present-day electrification problems can be solved: energy saving, reducing harmful gas ejection and automation of agricultural production process.

The third application field for resonant single-conductor systems are plasma medical and technological facilities. They differ from conventional plasmatrons in having not two, but a single electrode, which is the beginning of a resonant single-conductor line, while the capacitance of any body or treated substance is used as a load. A new resonant coagulator developed at the VIESH (see Fig. 11) is used in medicine, in veterinary technique and in cosmetology [6]. Technological single-electrode plasmatrons can have pulsed power up to 10^{10} W and continuous power up to 20 MW. They can be used to eliminate weeds (instead of pesticides), to produce liquid biofuel from organic raw material, to manufacture and purify solar-grade silicon, to generate plasma in physical experiments (for example, producing artificial ball lightning [8].

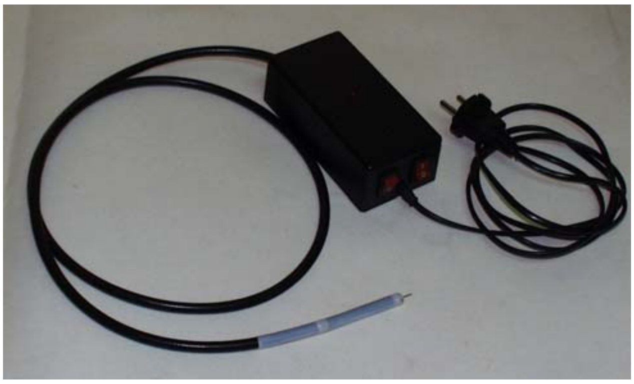

Fig. 11. Resonant cold-plasma coagulator developed by Cand. Sci. (Tech.) Veryutin V.I. (VIESH)

The fourth application field for resonant systems is creating global and local information communicating systems using single-conductor lines. Many works by N. Tesla are devoted to this application. The first devices transmitting information signals has been developed by N. Tesla in 1899, they were patented in 1901. In 1943, the Supreme Court of the USA has recognized N. Tesla priority disputed by R. Marconi in long-distant transmission of electric signals.

Each single-conductor line has several resonant waves. Therefore, the single-conductor line (as well as a fiber-optic line) may be used to transmit simultaneous different information to several users. A specialized line screening technique allows to reduce the loss in signal amplitude and quality, when it is transmitted over a long distance. N. Tesla has proposed original methods for encoding the information and protecting it against unauthorized access. The information communicating systems and power transmission systems based on modern technologies are now key factors for the social development of the country and progress in the agricultural production.

N. Tesla was an ingenious scientist, who had foreseen the development of the electrotechnics and energetics for hundreds of years. He has produced a voltage of 100 million volts using simple facilities; he has transmitted electric power over tens kilometers, using the ground as the conducting medium; he has tested a boat controlled through the water medium; he has invented the asynchronous electromotor, the multiple-phase current and has made many other inventions. N. Tesla was a brilliant designer of mechanical systems. Magnificent drawings of different mechanisms designed by N. Tesla are stored in Tesla museum in Belgrade. Some of his non-electric inventions are of interest till now: a combustion engine without a piston and a crankshaft, steam and hydraulic turbines without blades, and a mechanical analog for the electric diode (device allowing to a gas or fluid stream to flow in one direction only). In this valveless device, the hydraulic resistance values in the direct and reverse direction differ by factor of 300. Now we can fully repeat and develop Tesla resonant techniques in the field of electric power transmission using single-conductor lines and conducting mediums.

There is little information on N. Tesla works in the field of wireless power transmission methods. His last invention in this field "Device for electric power transmission" has been written in 1902, revised in 1907 and patented in 1914. At a session of the American Institute of Electric Engineers on May 18, 1917, N. Tesla received a reward named after T. Edison. His speech at the session contained the following statement:

"As to power transmission through the space, it is a project, which I consider absolutely successful for a long time. Years ago I could transmit power without wires to any distance without limitation, which was imposed by the physical dimensions of the Earth. In my system, the distance value is of no importance. The transmission efficiency can reach 96 or 97 percents, and there are practically no loss, except for the component, which is inevitable for the device operation. If there is no receiver, there is no power consumption anywhere...

When there is no receivers, the station consumes only a few horsepowers, which is necessary to maintain the electromagnetic oscillations; it is idling, like the Edison station, when the lamps and the motors are switched off...".

The high transmission efficiency may be easily explained, considering the standing waves in the conducting channel (see Fig. 6).

The journal "Time" wrote on July 23, 1934:

"Last week doctor Tesla announced a combination of four inventions, which would make the war absurd. The essence of his idea is connected with deadly rays: a concentrated beam of submicron particles moving with a speed, close to the light speed. According to Tesla, the beam, will defeat the Army during flight, causing airplane squadrons to fall down at a distance of 250 miles (400 km). The inventor will launch the rays by using the following:

- device for reducing the particle delay in the atmosphere to zero;
- method for producing high potential;
- procedure for amplifying this potential up to 50 million volts;
- producing tremendous acting electric force".

N. Tesla died on January 7, 1943 in hotel "New Yorker" in Manhattan, in the room 3327 on the 33-rd floor. Immediately after his death, his scientific works disappeared from the room; they were never found. A part of those materials contained an information on the techniques, which could be used for wireless power transmission. Methods for generating and amplifying high potential have been fully described by N. Tesla in [4]. Taking into account the present-day level of the scientific knowledge and progress in electrotechnics, N. Tesla works on resonant methods for electric power transmission give new opportunities for the development of electroenergetics, electric technologies, electric transport and communications.

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THE STATE-OF-THE ART AND PROSPECTS OF THE DEVELOPMENT OF MECHATRONICS TECHNOLOGIES AND ROBOTIZED PROCESSES IN TECHNOLOGCAL MODERNIZATION OF MILK FARMS

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The state-of-the-art and VIESH experience, as well as main trends in research in mechatronics, identification systems and robotized systems in the field of dairy cattle breeding have been analyzed.
***Keywords**: mechatronics; identification systems; precise cattle breeding; robotized systems of animal management; dairy cattle breeding.*

The RF government has included works on mechatronics technologies, identification systems and robotized systems into the list of critical technologies of the XXI century. In respect to dairy cattle breeding integration and convergence of these three components of the technological platform actually constitute the technological tool base for the realization of the concept of precise cattle breeding. In their turn, integrated local digital systems of control and management in combination with identification systems are an essential part of robotized system for animal management. The first trend – mechatronics technology remains a rather controversial concept though its standard definition exists. We are more used to the term "electromechanics". However, in order to prevent misunderstanding in our further work we shall use the term "mechatronics" mentioned in the Government decision.

Competition for innovation leadership in this sphere is only a part of more general struggle of advanced countries in the field of the so-called NBIC-technology (from initial letters: N – nano, B – bio, I – infor, C – cogno (Lat. *Cognitio* – perception, knowing, cognitive functions). The latter component means the necessity to obtain new advanced knowledge and to develop methods and algorithms for processes streamlining and management – that is what Academician N.V. Krasnoschekov urged us to do on more than one occasion.

In the present article I would like to consider in detail the state-of-the-art and VIESH experience, as well as main trends in the development of mechatronics technologies, identification and robotized systems in the field of dairy cattle breeding.

In chronological order, our department first work in this field, brought to the stage of commercial product was programmable multifunctional control unit "Fematronik-S". Theoretical basis of the offered device were results of research and simulation of a pulse converter for random milk flow at milking plants. Relation between random flow integral and pulse modulation parameters was revealed. Moreover, V. Kirsanov established the possibility and developed the algorithms for engineering diagnostics of a milking line on the basis of the analysis of pulse modulation characteristics. "Fematronik-S" was used as a basis for the development and testing of a unit for milk recording in sectors of small-size milk processing plants.

In total over 300 "Fematronic" units have been supplied to farms. During comparable testing of a milking unit with a thresher UDM-200 the representatives of the North-East Machinery Test Station mentioned "Fematronik" as one of its major competitive advantages.

For group recording a recording transportation unit with computerized control system UTB-50 has been developed. For higher measurement accuracy a new method was suggested – a measuring chamber with virtual volumes that allowed to considerably improve accuracy due to relative reduction of transients.

Currently technologies of contactless identification have become widespread in various industries in Russia and the world: access control, transport and storage logistics, health care, electronic passports, animal breeding etc. Just for regulating efforts in the field of radio frequency identification two international organizations developing standards for RFID have been set up and are functioning now. We see our goals in this direction as follows:

- constant monitoring of the situation at the market of identification systems and selection of solution with optimal mass-dimensional and price parameters, read range and reliability, as well as adaptability to farms conditions;
- higher reliability of systems operation and identification through their integration with technological equipment and software.

At present our department is developing a program method of search and restoration of data on milking in case of a transponder loss or failure. It should be mentioned that this is quiet a common situation. The following algorithm is used in this process: information on each cow including electronic and milking number, number of a technological group, milk flow parameters, time of day intervals when the group is in a milking parlor, etc., is entered into the computer; through step-by-step scanning of mass data the number of a work group where there is a cow with a failed or lost transponder and then a cow visual number are identified; at the last stage individual milking data are transferred into a corresponding file.

Information technologies in machine milking can have quite unexpected applications. In accordance with lactation theory, proper milk ejection reflex is caused by intensive udder massage. This operation quality depends only on “human factor”. To assess the quality of this operation the Bou Matic company offered a testing method based on the basic principles of lactation physiology. If an operator has adequately performed pre-milking preparation of an udder and caused proper milk ejection reflex, in the first 5 seconds milking rated must be no less than 1.5 l/min, and for the first two minutes no less than 75% of milk must be milked out. Such performance is recommended by ISO 5707-2007 standard and can be easily checked by a manager after milking, as all corresponding data is available in the computer.

Accumulated experience of the use of transponders and of the development of units for calves management, milk preparation and its distribution to them allows to develop a robot for calf rearing. (milk feeding). We are planning to carry this work with our long-standing colleagues from the Yaroslavl Institute of Animal Breeding and Fodder Production (NIIZhK). We are expecting them to develop a program for milk feeding of calves in dependence on individual peculiarities of animals.

In the early 1990-ies at VIESH a transport robot-dispenser of concentrated fodder TKR-05 was developed within the framework of the competitive project “Agronoosphere-2000”. The robot was equipped with a photooptic positioning system, an on-board controller, an independent power supply source with lead-acid accumulators, a charging device, a bin with concentrated fodder fixed at strain sensors for weighing and a volumetric screw dosing unit with a regulated drive and a tripper at the end. The robot had contactless IR-ports for communicating with the host computer. For higher dosing accuracy a special error correction algorithm was developed which depending on volume weight of concentrated fodder made corrections to the volume doser operation. During laboratory testing minimal error did not exceed 4%. The TKR-05 major drawback was the power source which had excessive mass and low capacity. At that time there were no modern lithium-polymer accumulators now used by Western companies in robots for power supply.

Over 10 years ago the first milking robot was produced by Lely and ever since such robots have been arousing interest due to their efficiency and prospects in comparison with conventional technologies. At the «Euro Tier-2010» exhibition De Laval demonstrated the carousel milking parlor for 24 boxes equipped with 5 robots. At the end of 2010 an extremely detailed article by Professor Schleitzer from Germany devoted to comparative assessment of the results of three-year operation of milking robots of the three leading companies: Lely, DeLaval and GEA (WestfaliaSurge) and the “carousel” for 48 boxes. The following conclusions were made:

- in case a milking robot performs preparatory operations according to standard, their duration per one milking is from 1.31 to 2.76 min, while a trained milker spends less that 0.5 min on these operations;
- in average, the robot milking frequency was from 2.41 to 2.74 times;
- work time expenditures (m/hr) for milking

with the use of robot were from 4.76 to 5.96 per one cow a year;

- at a 1 200-head farm expenditures when using milking robots were nearly 20% higher that when using the carousel.

Thus, at present there is no possibility to give a clear answer to the question what method is preferable. Evidently, the both milking methods will be developing in parallel.

Many year experience of using milking robots have fallen short of some expectations, notably, average frequency of cows entering boxes (2.7) proved to be lower than expected. Correspondingly milk yield increase also was about 10% which is similar to that of three-times-a-day milking. As Professor Schleitzer research demonstrated it was not possible to totally eliminate human labor in the process.

However, everybody recognize good hygienic conditions for high-quality milk production due to automation of doubling first milk jets from each udder part, washing of teats, control of electrical conductivity and temperature of milk from each udder part, switching-off of teet cups for each udder quarter. In this regard, box milking parlors equipped with such milking machines seem very promising, however, in contrast to robots, they require manual actuation of teet cups.

Due to reduced time of preparatory operations (idle run) such equipment capacity may be higher than that of multi-box milking robots.

Over 70% of cows are kept at farms with stanchion housing and pipeline milking and it is forecasted that by 2020 major part of livestock will be housed in such conditions. For such farms they envisage the development of a mobile milking machine with a flow meter and an electronic control unit with automatic or manual entry of a cow number, a data archiver and interface for communication and data transfer to the host computer in the process of washing milking machines.

Much attention has always been given to automated systems of manure removal, as this provides comfortable cattle housing and operating personnel work, as well as milk and manure organic fertilizer quality. Currently all leading companies producing manure removal equipment, alongside with conventional machinery, offer robotized equipment with high automation level in their product range (JOS, MIRO, HOUEL, DE LAVAL, LELLI). In the longer term, control systems and the development of block systems used when a scraper meets obstacles and antifreezing devices, are most promising from the practical standpoint.

In accordance with the target program for milk production, one of the ways of improvement of cows health, productivity and life time is the development of by-farm pastures is envisaged. For these purposes the development of an autonomous robot for cattle pasturing similar to the Voyager produced by the Lely company, is envisaged.

INNOVATIVE METHODS AND TECHNOLOGIES TO MAINTAIN ELECTRICAL PRODUCTION

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Innovative methods and technologies to maintain electrical production includes four groups of activities related to the intellectual organization of technology of production of electrical safety, effective constructively elements providing electrical generating sets and electrical installations, new technical means of electrical protection and personal protective equipment workers.
Keywords: *information and communication technologies of intelligent electrical safety production, formalized knowledge, expert systems, intelligent software systems to support decision-making, training and certification of personnel, new circuit breakers.*

Modern production must be equipped with appropriate means and facilities to maintain electrical work, which may be divided into groups depending on the nature of electricity consumers, the type of power supply systems, such as electrical, cost, etc., and shall meet the main requirements - demand efficiency - saving lives and normalization conditions and stay in range of the electrical installations.

Electrical injuries and morbidity in electrical work - the phenomenon of industrial and social and multi-factorial. The causes of these phenomena are interrelated and are also multifactorial. Working conditions in the electrical, like electrical injuries and disease characterized by a large number of interrelated factors. Reasons electrical injuries production and supply due to disease in electrical work, direct the prevention and prevention. There are three groups of measures to ensure the production of electrical safety:

1. Institutional, organizational and technical.
2. To provide technical and personal protective equipment.
3. Learning and achievement of professional integrity of personnel.

In accordance with measures to ensure the electrical production can be divided into four groups of innovative methods and technologies for the creation of electrical safety conditions. The first group of activities related to the organization of the production of electrical safety, the second is related to the construction of electrified vehicles, equipment, facilities, and the third sets the direction of development of means Electrical workers, the fourth relates to the field of personal protection in electrical installations.

In the area **of the organization of electrical safety of production** - is information and communication intelligent technologies for rapid decision-making error-free, the training and qualification of personnel for electrical safety in the environment of expert systems with distributed networked knowledge bases. To achieve the desired positive outcome of these technologies should be extended to all production structures.

In the area of mandatory **of constructive elements electric machines and installations** - is an effective electrical insulation and other materials, protecting the device of the new generations, including electrical and other isolation as a product of nanotechnology, and not removable plug-tech fences, enclosures and locking.

In the area **of electric technical equipment protection** - is effective stationary, portable and temporary grounding devices in electrical installations with low labor input assembly, installation, overlay and removal, the MFP to automatically disconnect the electrical power supply and circuit breakers, residual current circuit-efficient electric strand separation, separation dangerous interactions electrified technology cycles and processes.

In the area **of personal protection in electrical installations** - is efficient, insulating, anti-static, one-way or thermo impervious adjustable heat exchange materials with antibacterial properties, reinforced nanotechnology methods, comfortable and resistant to wear and use, personal protective equipment to prevent electrocution if touched the electrical and conductive parts at any voltage, light shielding kits for protection against electromagnetic and electrostatic fields in any range of frequencies and voltage levels.

No supernovae and super-efficient appliances and arrangements will not have the desired impact on the prevention of morbidity and electrical injuries working in electrical systems, if their implementation is unreasonable, if not worked out a solution for the effective deployment and operation.

A timely correct solution for prevention of morbidity and electrical injuries should be based on a real full and accurate information about these events, information on modern technological media and communication tools. Lack of reliable information on the actual production eliminates the effectiveness of seemingly reasonable and operational decisions.

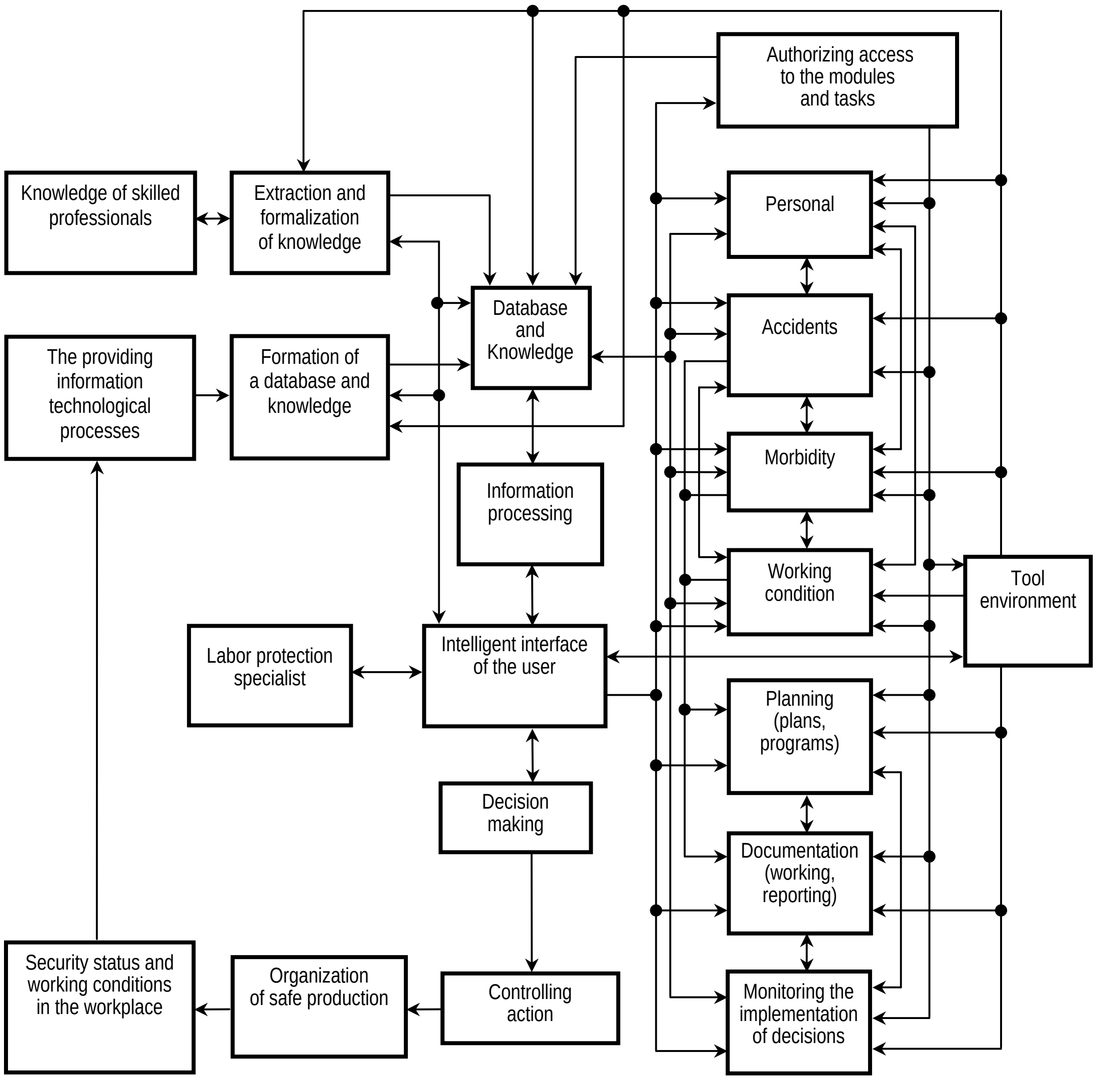

Fig. 1. Functional and technological structure IPC SDMES

Creation of the information and communication technologies which are considerably changing system of the accounting of occupational accidents, including electric traumas and occupational diseases working in electroinstallations, an order of elaboration of actions for their prevention and prevention, normalization of working conditions, and also system of preparation and certification of the personnel for electrical safety of production and certification of workplaces, allows to create necessary conditions for achievement of demanded efficiency of information and personnel, material and organizational support of a control system by labor protection in electroinstallations and moreover – will ensure necessary information resources for a correcting of levers of economic incentives and provisions of normative documents on electrical safety [1 … 4].

Innovative technologies of the organization of electrical safety working conditions have to be based on information and communication technologies with application of the formalized knowledge and the expert methods which are built in a control system of production. Information and communication technologies of providing safe working conditions (ICT PSWC) include set of intellectual program complexes of support of decision-making and preparation and certification of the personnel for electrical safety of production in computer and telecommunication networks and systems [5 … 9].

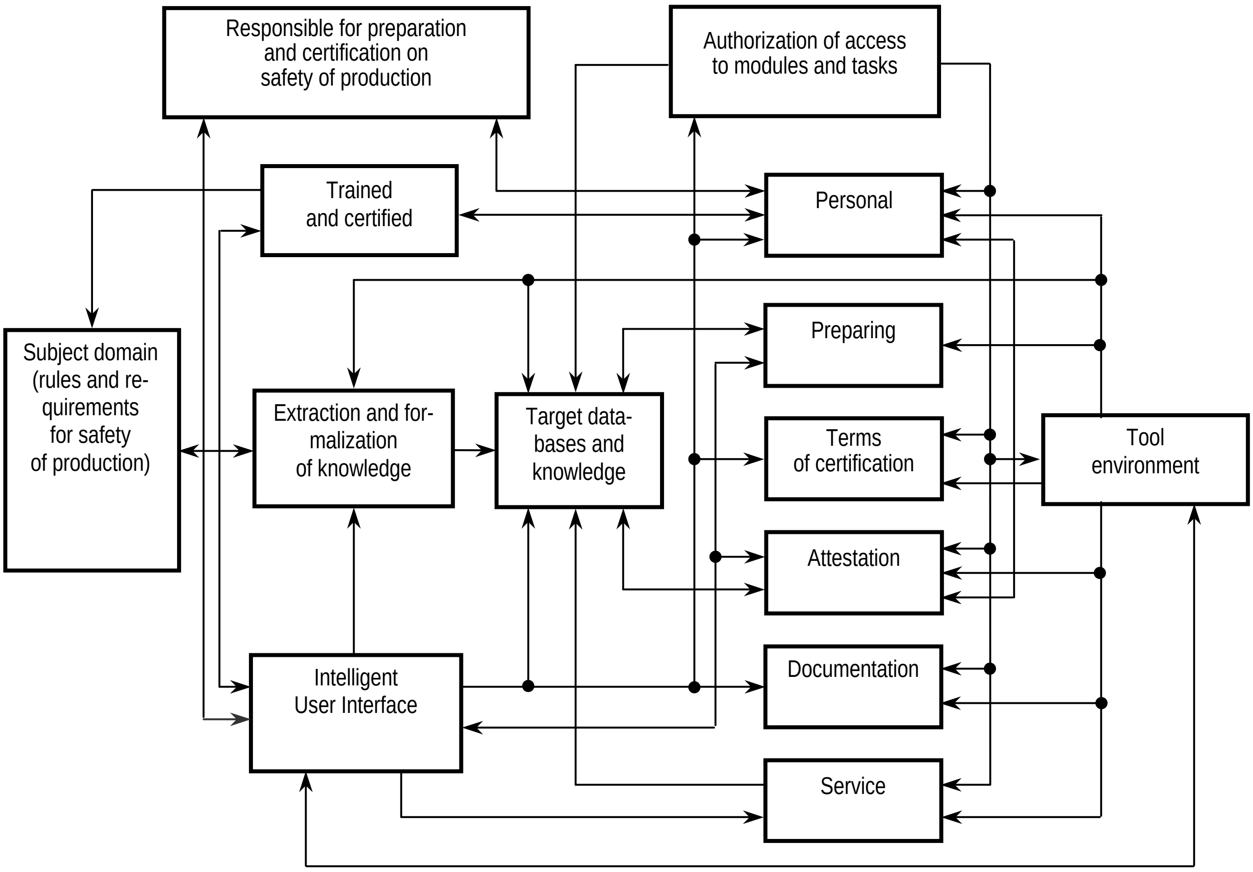

Fig. 2. Functional and technological structure IPC PCPES

The formalized knowledge is understood as in a special way structured knowledge placed in the knowledge base. Knowledge is data with the complicated structure. Knowledge unlike data possesses substantial information which of data can be taken only as a result of special additional processing, and is characterized by existence of the relations, allowing to establish relationships of cause and effect. Expert methods and systems include the software based on knowledge, supporting development of faultless decisions and qualities of decisions providing improvement taking into account experience and knowledge of the person making the decision.

Network intellectual program complexes of support of decision-making on ensuring electrical safety of production (IPC SDMES) develop faultless decisions in the environment of the expert systems founded on formalized knowledge which bases are increased and develop users. The intellectual program complex of support of decision-making on ensuring electrical safety of production is understood as the set united by infocommunication process technical and the software, capable on the basis of data and knowledge to synthesize the purposes and to develop rational faultless decisions on prevention (decrease) in production electrotraumatism, incidence prevention, improvement of working conditions.

Data (data and knowledge) about a condition of electrical safety of production are formalized and collect in databases and knowledge of dynamic expert system. The complex of the interconnected information carriers having computer screen images and the corresponding software on local personal ECM and in computer communication networks and systems is used.

Software of IPC SDMEP provide realization of basic functions, development and decision-making in the following main directions according to professional needs of experts (fig. 1):

maintaining base of professional data on the production personnel;

prevention of production electrical injuries;

prevention it is production the caused incidence working in electroinstallations;

formation of instructions (contents of documents, recommendations and urgent measures for electrical safety in concrete organizational structure);

routine and advance planning of actions for the prevention of production electrotraumatism and incidence prevention;

providing with means of individual protection;

complex assessment of workplaces on electrical safety level;

authorization of group and personal access to modules, actions and functions of program complexes.

The most important element of the organization of electrosafe production on the basis of infokomny technologies considers preparation and control of knowledge working on electrical safety with application of network intellectual program complexes of preparation and certification of the personnel for the electrical safety (IPC PCPES), containing the formalized knowledge in text and graphic representation, and bases of this knowledge also if necessary are supplemented and develop users (responsible for preparation and certification of the personnel and trainees).

As the main basic functions intellectual program complexes of preparation and certification of the personnel for electrical safety realize (fig. 2):

maintaining base of professional data on the personnel which is trained, instructing and certification for electrical safety of production, and about the personnel which is organizing and carrying out them;

input of additional target systems (subject domains), questions and comments to them, designing of graphic representations on problem area of electrical safety of production;

formation of programs of preparation, instructing and certification;

control of knowledge;

formation and press of the current worker and reporting output documentation;

the centralized updating of questions and graphic representations on electrical safety of the production, entering into industrial delivery;

authorization of group and personal access to modules, actions and functions of program complexes.

Means can be carried to innovative technical means of an electrical protection working from electrical injuries and occupational diseases during the work in electroinstallations with earlier not realized functionality. Protective shutdown as a way of protection of the person from defeat by an electric current provides automatic shutdown at the same time all phases of the electroreceiver or a network site from the power supply at achievement of controlled size (tension, current, etc.) maximum permissible value.

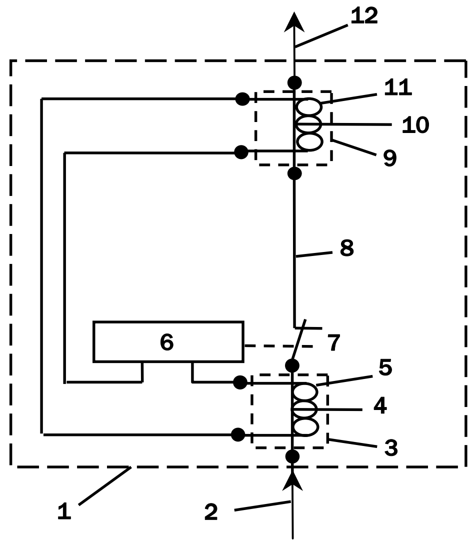

Fig. 3. The device of protection of the person from defeat by an electric current in distributive point of alternating current:
1 – distributive point; 2 – introduction wire; 3 – entrance transformer of current; 4 – primary winding of the entrance transformer of current; 5 – secondary winding of the entrance transformer of current; 6 – sensitive body; 7 – automatic switch; 8 – current carrying part; 9 – output transformer of current; 10 – primary winding of the output transformer of current; 11 – primary winding of the entrance transformer of current; 12 – output feeding wire

There are different schemes and the designs of the devices of protective shutdown (DPS) reacting to size of potential on open carrying-out parts of the electroreceiver concerning the earth, on current of zero sequence in installations with zeroing (connection with the protective zero conductor), on leak current through isolation, on differential current, etc.

New devices of protective shutdown [10 … 15] have to be in the short term allocated with additional functions (including the-others functions, executive bodies on currents of leak not only on the earth, but also between wires of an electric network in a protected zone, on wire break before its falling on the earth, operation on a radio signal, etc.), have to be coordinated if necessary from by all means mobile communication, have an independent (individual) source of power supply (fig. 3 and 4).

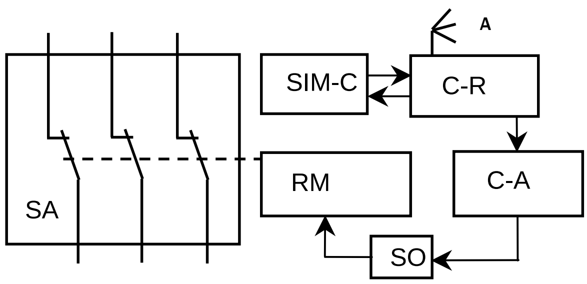

Fig. 4. Device of shutdown of electric loading to a telephone signal:
SA – the switch automatic; C-R – a chip receiver with the antenna A and sim card SIM-C; C-A – a chip amplifier, a signal from which is affected by sensitive organ SO to release mechanism RM of switch SA

To the innovative means of individual protection (MIP) working in electroinstallations easy shielding sets for works energized, executed of fabrics effective electroconductive, strong, environmentally friendly and harmless to the person with the properties strengthened by application of nanotenologichesky methods, convenient and steady in a sock and application, SIZ (dielectric gloves, mittens, footwear, helmets), preventing electrodefeats can be carried, for example, at a touch to current carrying and conducting parts under any tension, thermal burns of any character, radioactive and bactericidal influence.

One of aspects of innovative technologies of ensuring electrical safety of production should consider implementation of new ergonomic and constructive decisions at design and production of the tool and adaptations for installation and service of the equipment and units.

To achieve the required performance measures for the implementation of the integrated electrical production should be subject to innovative activities, including organizational activities, activities related to the improvement of the design of electrical equipment and electrical installations, with the extension of functionality, a high efficiency, reliability and economy of means electrical protection and personal protective equipment to employees installations.

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BASIC TRENDS OF BIOTECHNOLOGICAL DEVELOPMENT OF RENEWABLE ENERGETICS FOR PRODUCTION OF ALTERNATIVE FUELS FROM VEGETABLE RAW MATERIALS

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Analysis of the energy balance of agriculture in Russia with consideration of the development of new types of energy determines the need of using local energy resources and new energy technologies. Promising is the development of biological fuels (biomass) for the production of biofuels (bio-oil). The paper discusses the prospects for production of biofuels of the second and the third generation from non-food biomass.

The article analyzes the industrial efficiency and economic feasibility of technologies of biofuels production from microalgae in open and closed systems. It is shown that new energy technologies can effectively convert biomass and crop residues into liquid and gaseous fuels and electricity.

Keywords: *biofules, alternative energy, biodiesel, biofuels from microalgae, open and closed technologies of microalgae production.*

Current situation in the field of fuel and energy is characterized by unstable prices for fossil fuels and ever growing technogenic pressure on environment. These factors determine main political, economical, legislative and technological trends. It is well-known that in some cases a driving motive of political events is striving for control of energy markets. In legislative area considerable efforts are taken to incite replacement of exhaustible energy raw materials with renewable energy resources which are characterized by higher ecological safety. Thus, for example, in accordance with the EU Directive EC № 2003/30 of May 14, 2003, biofuel share at European transport will amount to no less than 5.75% by the next year and by 2020 this share is to increase up to 10% [1].

In scientific and technological sphere this stimulates the search for new possibilities in biofuels production, notably, the use of bioresources that do not cause considerable disbalance of the structure of agricultural production traditionally oriented at meeting demand for food products. An important trend is also the research for new methods of resource saving and reduction of harmful environmental impact of mechanical equipment using so-called conventional fuels (gasoline, diesel fuel, mazout), as well as the development of adequate technologies and equipment.

Rapid reduction of explored resources of fossil energy feedstock makes the world community intensely develop renewable energy sources, among which biomass is playing a key role. Nowadays it covers 35% of energy consumption of developing countries. Moreover, gradual replacement of coal, natural gas and refined oil products with biofuel made of vegetable biomass constantly reproduced in amounts exceeding demand, can be beneficial for maintaining carbon dioxide balance in the atmosphere. Current level of energy consumption is 12 billion tons of oil equivalents (TOE). Considering existing growth rate, by 2050 global energy consumption will amount to 15 billion tons of oil equivalent (TOE) (according to more pessimistic forecasts – 25 billion tons of TOE). As reported by the World Energy Council, the use of renewable energy sources will increase twice and reach 6 billion tons of oil equivalents and biomass share will amount to 2.6 billion TOE. Today approximately 1 billion tons of vegetable mass is used for energy generation that equals to 25% of global oil production. Potential resource of vegetable mass for energy application is evaluated at approximately 100 billion tons. In equatorial countries biomass is still used as main energy source. Its share in energy balance of developing countries is 35%, in global energy resources consumption – 12% and in Russia – only 3% [2–7].

Possible alternative energy sources that can provide stability of global energy resources are to a great extent rely on biodiesel production from plant biomass.

Plant biomass is a primary energy source on the Earth. It is formed in photosynthesis process from carbon dioxide and water accompanied by oxygen release. In formation of 1 kg of dry biomass about 1.83 kg of CO_2 is consumed and the same amount is released in the process of its decomposition. In the result, CO_2 content in the atmosphere remains invariant which is an essential factor of climatic balance (8–10). Biomass has a whole range of advantages as fuel. In particular, the use of biomass for energy production is by far more safe that the use of coal, for example, due to low sulphur content (in biomass combustion less than 0.2% of sulphur and 3-5% of ash are produced in comparison with 2-3% and 10-15% correspondingly in coal combustion). In addition, ash can be introduced back into the soil which provides continuous circulation of biogenic elements. In biomass combustion nitrogen oxides emission can be reduced with the use of advanced technologies and combustion temperature reduction. Compost production from processed biomass improves soil structure and reduces sewage and ground water contamination [11–14].

Biomass also has advantages in comparison with coal due to its higher gasification ability. Coal can be gasified at high temperature in pure oxygen which requires the use of air liquefying plants for air liquefaction and oxygen production. Biomass can be gasified at lower temperatures and heat needed to sustain the process can be transferred through heat exchangers from an external source. The product gas composition: 18–20% H_2, 18–20% CO, 2–3% CH_4, 8–10% CO_2, the rest is nitrogen. In addition energy obtained in the process of biomass processing is relatively inexpensive and there are possibilities of its accumulation. As power plants using biomass as fuel are characterized by low capacity, they have such advantages as short design and construction period, higher reliability of energy supply due to its decentralization, higher efficiency of fuel use and partial solution of the problem of waste disposal [1, 14].

The universal demand for renunciation from environmentally harmful oil products makes producers of combustive and lubricating materials develop synthetic combustive components (for example, gas from various wood species). The well-known company Shell specializing in production of ecologically safe oil products has become a pioneer in the development of such a technology. However, if so far such technologies were only a possible alternative to conventional oil and fuel, nowadays there is a visible trend to complete transition to the use of "energy plants". Notably, the German energy agency DENA declared that they have developed biofuel of the second generation with the use of the advanced technology named Biomass to Liquid (BtL). Considering raw materials amounts available and low costs of BtL production, these prospects are more than real [1].

In Norway mobile units are used at wood cutting areas where plant waste is processed by pyrolysis. Each plant capacity is from 10 to 30 tons of charcoal per day. In the pyrolysis process from 1 ton of waste (woodchips) 280 kg of charcoal, 200 kg of pyrolysis resin and about 222 kg of gas fuel are produced. Gas fuel is used for sustaining pyrolysis process. Pyrolysis resin is applied as boiler fuel or is hydroskimmed under hydrogen pressure to produce gasoline and diesel fuel. Stationary pyrolysis plants can have up to 40 furnaces and are designed for processing 300-350 thousand tons of organic waste per year.

The process of liquefying plant biomass through hydrogenation at 350° C under hydrogen pressure of 6.4 mPa has been developed. From 1 ton of biomass 24 kg of synthetic oil and 160 kg of waste of asphalt type are obtained. One of the methods of producing liquid motor fuel is thermal dissolution of wood in oil fractions at 380–450°C under 10.0 mPa. In this process wood is liquefied. There exist an experimental plant in the USA that produces 300 kg of fuel from 1 000 kg of woodchips. The process is carried out under 28 mPa pressure at 350–375°C. Sodium carbonate is used as catalyst.

In a number of countries (Italy, FRG, Argentina, etc.) special energy plantations of fast-growing wood species and other plants have been arranged on inarable lands. Willow plantations in Sweden yield 25 tons of wood per 1 hectare. Wood is harvested each 2 years by special combines in winter times when swamp land is frozen. 1 million ha yields 15 million tons of wood in the form of dry wood fuel equivalent to 20% of energy needed in this country.

Within the framework of the Western-European program of development of renewable energy resources a large-size biopower complex designed to process 300 thousand tons of fast-growing biomass and organic waste has been launched in Italy. Alongside with gas and heavy residue 20 thousand tons of liquid fuel will be produced. In Germany there are large plantations of rape whereof lubricating oils and diesel fuel are made.

In Latin America, the USA and France they produce ethanol from biomass (sugarcane, corn, etc.) traditionally using fermentation process. In Brazil over 10 million tons of ethanol are produced, which is used as basic fuel for cars (96 % ethanol) in combination with gasoline – “Gasohol” fuel (22 5 of ethanol with 78 % of gasoline). In the USA more than 3 million tons of ethanol are obtained which is used as additive to gasoline (5-10%) for octane improvement.

Among biofuels of second generation available at the market the most well-known is BioOil produced by the Canadian company Dynamotive, and SunDiesel produced by the German chemical company CHOREN Industries GmbH Industriers with the support of DaimlerChrysler and Volkswagen concerns. Raw materials for the production of the SunDeisel fuel are agricultural waste, woodchips, straw, manure, etc. After drying waste is heated up to 400–500°C and released gas undergoes a number of transmutations in the presence of catalyst and at the reactor output diesel fuel devoid of sulphur and other harmful admixtures is obtained. Besides, biodiesel fuel is CO_2-neutral in relation to environment – in the process of its combustion carbon dioxide consumed by plats in the process of their growth, is released back into the atmosphere.

Another method of biodiesel fuel production is processing vegetable raw materials. Such biofuel basic components most often are soya, rape and cotton. In the process of biodiesel fuel production from vegetable raw materials plant seeds pass through a churn, then oil is squeezed out of raw material, cleaned from meal inclusions that are waste of oil extraction. Then oil is mixed up with methanol using natrium methoxide as catalyst, cooled and distilled (Fig. 1). Fuel can be used after purification, notably, researchers from Iowa offered to use nanotechnologies for fuel purification through introduction of nanospheres whose pores are filled by catalyst accelerating the process in the course of chemical reaction.

In Table 1 [1] biodiesel fuel advantages and disadvantages of its use for economic purposes are demonstrated.

Table 1. Analysis of biodiesel fuel made of conventional vegetable raw materials

Advantages	Disadvantages
Economical aspect. Countries lacking oil or having small amounts of oil are ready to pay with green raw material for their energy independence;	Production cost is higher than that of gasoline and mineral diesel fuel;
Biodiesel fuel practically does not contain sulphur and cancerogenic benzol. This fuel is decomposed in natural conditions without any harm for environment, and in combustion process in engines CO_2 emission into the atmosphere is 50–80% lower than when using conventional mineral diesel fuel.	Additional agricultural lands are required;
Biomass fuel is characterized by high inflammability, as its cetane number amounts to 58 while this value for conventional diesel fuel does not exceed 52. In other words, it is easier to ignite biodiesel fuel but it combusts with lower heat transfer;	Rape oil ethers have high corrosive activity which can reduce durability of rubber pads and seals and cause formation of solid deposits in injectors and nozzles, clogging of fuel filters and failures of high-pressure pumps;
Raw materials reserves can reproduce themselves every year; the crops do not require any special care in cultivation process;	High NOx content in “vegetable” emission: in comparison with conventional diesel fuel it is by 10% higher and in the course of an experiment Volvo engineers demonstrated that this difference can reach 40 %;
In oil processing additional products (glycerine, sodium sulphate) are obtained	Toxicity control results in capacity loss which is compensated by higher fuel consumption.

Table 2. Comparable characteristics of mineral diesel fuel and biodiesel fuel produced from conventional vegetable raw materials

Characteristic	Mineral DF	Biodiesel fuel
Cetane number	42-52	47-58
Solidification temperature, °C	-10	-9
Sulphur content, %	0.2	-
Ash content, %	0.03	-
Viscosity at 20 C, mm²/c	3.8	7.5
Calorific efficiency, kJ/kg	42 000	37 000

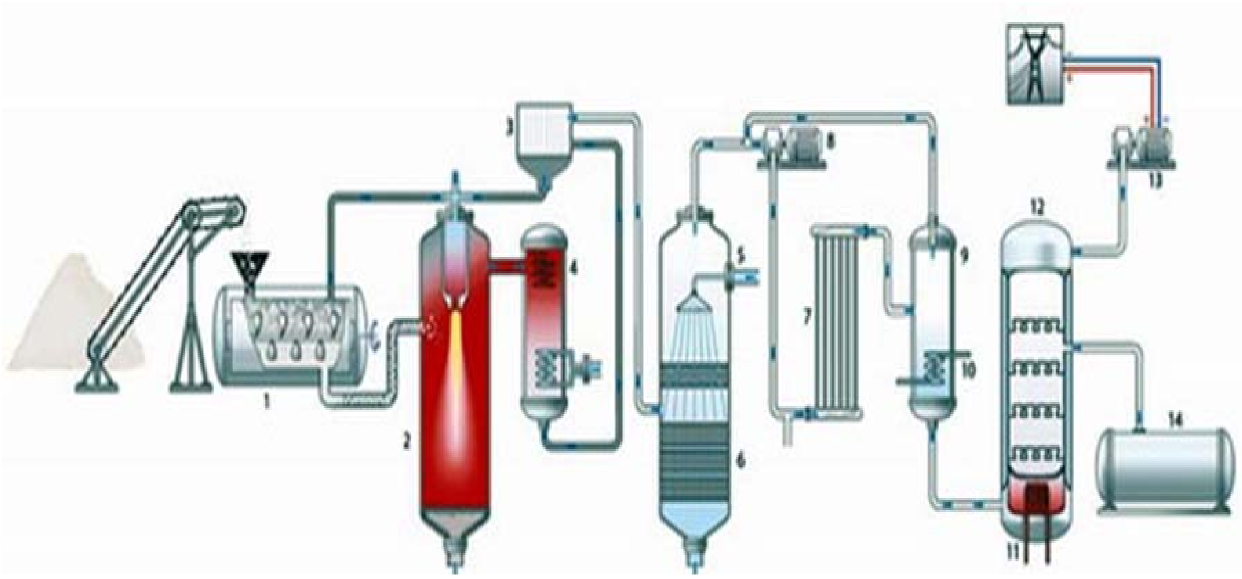

Fig. 1. Process diagram of biodiesel fuel production from vegetable material:
1 – low-temperature gas generator; 2 – high-temperature reactor; 3 – dust filter; 4 – heat exchanger; 5 – water supply; 6 – separator; 7 – multitube reactor; 8 – gas compressor; 9 – condenser; 10 – cooling system; 11 – heater; 12 –distillation tank; 13 –gas power generator; 14 – tank with finished fuel

Conventional raw material for biodiesel production is rape. Rape yield amounts to 20-25 centners per 1 hectare. However, so far it has been added to diesel, as pure rape oil is not used as fuel. Because of higher viscosity (almost 20 times higher in comparison with diesel fuel) different fuel equipment is required and combustion chambers should be changed. Oil is mixed with methanol and methyl ether is obtained, which is also known as “oil-methanol mixture”. 1 ton gives 350 kg of such mixture. To produce biodiesel, 30% of oil-methanol mixture is added to diesel fuel. Instead of toxic methilic alcohol, rape oil can be mixed with ethyl (food grade) alcohol. In the course of processing oil into biodiesel a number of additional marketable products (for example, glycerine, potassium sulphate) are obtained.

In Table 2 [1] comparative characteristics of mineral and biodiesel fuel are given.

In recent years, due to considerable increase of biomass use for energy purposes, serious problems emerge related to deforestation and transfer of considerable part of agricultural products from food and forage industries to energy area. Intensive wood procurement for biodiesel production leads to failure of ecosystems that nave been formed through geological time and comprise a great variety of plant and animal species. It is evident that the use of plant oil for energy purposes is by far not the best way of utilization of resources that could be otherwise used for food purposes. There exist tens of technologies of biodiesel production using palm oil, soya and other plant components as basic raw materials that are mixed with oil products. Many specialists consider that the solution of the energy crisis problem lies in cultivation of large amounts of oil crops [15, 16]. Nevertheless, this approach has at least two disadvantages:

- cultivation of considerable amounts of oil crops can oust food crops grown for satisfying human nutritional needs;
- conventional oil crops are not the most productive sources of plant oils.

In this connection the search for alternative vegetable raw materials and their commercial use are of extreme importance. In this context microalgae are most promising [1, 17–20]. It is assumed that these organisms were basic components of fossil fuel [21–22].

Fig. 2. Comparative data on raw oil production per 1 hectare of area allocated for crops cultivation

In biomass production rate algae many times exceed the most productive land plants and, moreover, produce more useful products per unit area. Thus, grain crops contain only 2% of oil by weight, in oil seeds there are more vegetable oil – from 20% in soya beans to 50% in fruits of the Australian variety of canola. Sunflower seeds contain up to 55% of oil, safflower (Carthamus tinctorius) – up to 40%, cotton seed – about 20%, hemp (Cannabis sativa) – up to 35% and peanuts and palm core – up to 50% of oil (dry residue). Average content of oil in mustard is approximately 40%, in flaw seed – about 45% and in tropical plant jatropha – 35-40% in seeds and 50-60% in pith. On this background algae advantages are evident, as their oil content per unit of cultivation area exceeds the above-mentioned plants 10-15 times (Fig.2).

Biofuels made of algae oil are termed third generation biofuels. Raw material for them is inedible biomass. According to analysts, these biofuels are very promising in terms of technical characteristics of finished product and savings related to their production [23, 24]. In 1978–1996 the US Department of Energy invested over 20 million dollars into the Aquatic Species Program (ASP). This was done to promote the idea of production of biologically pure fuel made of algae instead of conventional soya and palm raw materials, which was not realized because of low oil prices making production of conventional diesel fuels more profitable. The Program was aimed first of all at the search for the most oleiferous strains and determination of cultivation conditions most beneficial for oil production, and secondly, at the development of technological lines for large-scale production of these strains. The ASP goals were not attained, as the prices of produced alternative fuel exceeded the existing diesel fuel prices at least twice.

In 2006 after a sharp rise of oil prices research was carried out that demonstrated that as the technology advances, the use of algae raw material will allow not only to considerably reduce prices for fuel but will also to guarantee its high quality and proper level of ecological safety. Further development of renewable energy sources was determined by the interest to that issue shown by the *IPCC* (*Intergovernmental Panel on Climate Change),* set up in 1988 [2–5]. The technology for fuel production from algae oil was the subject of a whole range of research and commercial studies. It attracted attention of some research and industrial organizations, notably, fuel corporations, such as the Canadian Global Green Solutions, Spanish Bio Fuel Systems and New Zealand Aquaflow Bionomic Corporation, that declared their intention to construct new industrial sites for bio oil and diesel mixtures production from algae.

Currently research aimed at the determination of the role and scale of algae use as an alternative energy source is still in development stage [25]. Thus, the National Renewable Energy Laboratory (NREL) at the US Department of Energy is thoroughly developing the methodology for industrial-scale production of fuel from microalgae rich in triglycerides. The Sandia National Laboratories in Albuquerque (USA) carried out a number of studies that demonstrated that the potential of using algae for bioenergetics is so high as to be able to replace all diesel fuel with biodiesel fuel obtained from algae.

The problem of using algae oil for energy purposes has two principal aspects determining the scale of use and applications of this raw material [26]. They are 1) the search for species of oil-containing algae most suitable for cultivation and 2) development of optimal cultivation technology allowing to produce industrial-scale amounts of oil-containing biomass.

Abundant data on the biology of algae species suitable for renewable energy production, and the research of their use as alternative energy raw materials fostered the development of technologies and methods of microalgae production. Still the technologies of biofuel production from algae require further improvement in order to provide industrial efficiency and economic feasibility.

Fig. 3. Industrial cultivation of microalgae in open ponds

Fig. 4. Cultivation of microalgae in photo bioreactors

There exist two methods of microalgae cultivation that radically differ from each other – in open and closed systems [1]. In the first case algae are cultivated in ponds and basins of various design and solar light is used as lightning source (Fig. 3). The other method involves closed photo bioreactor system with artificial illumination (Fig. 4).

For large-scale biomass production attempts are made to integrate both open and closed cultivation methods [27]. There is a whole variety of designs of photo bioreactors using electric light for illumination. Such photo bioreactors are closed systems allowing to control and optimize cultivation parameters [28]. Stable yield of high-quality microalgae with high protein and vitamins content is obtained through maintaining optimal composition of culture medium (Fig. 5, 6).

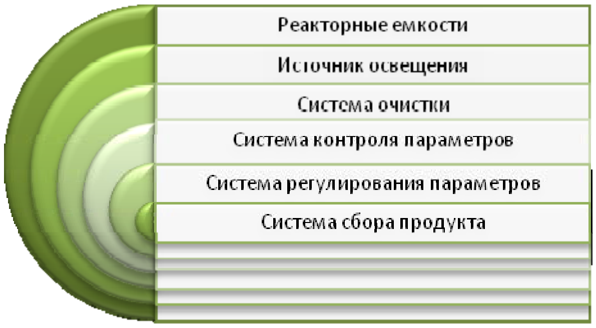

Fig. 5. Basic components of closed photo bioreactor systems

Rather high design and operation costs are limiting production and use of large-scale industrial systems of photo bioreactors. In recent years ideas of two-phase technology of microalgae cultivation for biodiesel production combining closed (photo bioreactor) and open (basins and ponds) methods of cultivation has been developed. In this case closed photo bioreactors can be effectively and economically used for production of high-quality inoculum – cell suspension used as feedstock for cell culture cultivation (phase 1) with further introduction to nursery ponds for open cultivation (phase 2).

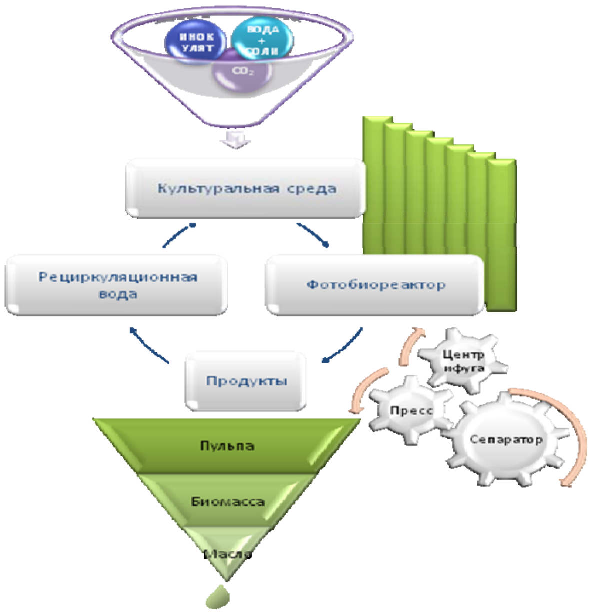

Fig. 6. The diagram of the photo bioreactor operation

It can be concluded that at the present stage of the world economic and technological development there are great opportunities of microalgae use as alternative vegetable raw materials for biodiesel production. Further progress is determined by 1) finding fast-growing and resistant microalgae strain with high oil content and algology development with the use of a whole range of biotechnological, genome and biochemical methods; 2) improvement of cultivation process using benefits of open methods of growing large amounts of biomass and photo bioreactor cultivation of strains with specified technological properties. This is possible through combination of open and photo bioreactor cultivation. Open ponds that are cost-efficient and can be used to produce large amounts of biomass, are polluted with undesirable species of main oil-containing culture. This is explained by the fact that various strains have similar requirements for cultivation parameters and main culture productivity is lowered in the course of competition. In their turn photo bioreactors allow to obtain pure monoculture with required properties but they are too expensive to be used for full cultivation cycle. The use of combined open and photo bioreactor technology with maximum use of benefits of each of them and minimization of disadvantages (cultivating pure monoculture in photo bioreactors with further completion of growing in open ponds) will make it possible to economically and technologically streamline the process of production of energy algae biomass.

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ENERGY-SAVING EQUIPMENT FOR COLD ACCUMULATION AND EFFECTIVE USE OF ICE ENERGY

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The energy saving equipment for accumulation of cold, effective use of ice energy and free cooling is presented in article.

Key words: *energy saving, accumulation of cold, ice energy, free cooling.*

Recently in connection with constant growth of prices for conventional energy sources they have been actively searching for the ways of power costs reduction, notably, through the use of alternative energy sources.

One of such ways is cold accumulation and free cooling.

The use of water ice for cold accumulation is extremely efficient, because ice melting heat is very high (about 333 kJ/kg) and allows to apply water having high heating capacity (1.0 kcal/kg.degree) as cooling medium. Water is safe, harmless, nontoxic and is widely used in everyday life and agricultural technologies. Natural cold accumulation in the form of ice and ice water provides considerable saving of electric power and reduction of related costs. Moreover, in systems with ice accumulators freezing of products is impossible, as cooling water temperature is in the 0…+1° C range.

At VIESH research in this area was initiated in 1979. The first project for large-scale use of natural cold was implemented at the animal-breeding complex "Golyevo" at the collective farm "Zavet Ilyicha" of the Krasnogorsk area of the Moscow region. At this farm in 1983-1984 the first pilot production units for cooling milk obtained from the 1.000 head herd, came into operation.

Considering positive experience of the Zavet Ilyicha" collective farm, in 1984 large-scale research of the use of natural cold for cooling milk and other agricultural products was for the first time initiated in Russia by the USSR State Planning Committee (Gosplan) decision (record of the meeting №3 of 14.12.84).

GNU VIESH developed energy-saving equipment allowing to effectively accumulate natural and artificial ice, to freeze ice and cool agricultural products. This equipment can be operated on both seasonal and year-round basis [1…11].

For cooling agricultural products in cold season accumulators of various design for seasonal operation were developed, that can be set up outside and allow to effectively freeze ice [1, 2].

Fig. 1 demonstrates a seasonal multi-section accumulator that was tested for a long time at the animal-breeding complex "Golyevo" (ZAO "Krasnogorye" of the Krasnogorsk area of the Moscow region). Testing results demonstrated that specific electricity consumption for milk cooling in winter period approximately was 2 kW·h per 1 ton.

Fig. 1. Multi-section receiver-accumulator of seasonal action

For cooling agricultural products all the year round ice accumulators with high capacity, using natural cold have been developed (hereinafter - ice storage) (Fig. 2). They can operate with all types of heat exchangers using water as cooling medium for cooling liquid food products and refrigerating chambers. To raise ice storage efficiency they developed equipment for layered ice freezing and ground cooling thermal units (GTU) for cold accumulation in grounds adjacent to underground part of ice storage houses [3].

Fig. 2.Year-round icehouse

GNU VIESH in cooperation with the Moscow Specialized Integrated Plant of Refrigerating Equipment (OAO "MSKKhO) developed the energy-saving refrigerating chamber for cooling and storage of agricultural products using both natural and artificial cold.

The basic idea of using refrigerating chambers for cooling and storage of agricultural products is based on the use of low potential energy of natural cold of atmosphere air and water in combination with artificial cold depending on operating modes. The use of natural cold makes it possible to quickly reconstruct refrigerating systems of enterprises of the agro-industrial sector and to increase general amount of technological cold used by farms for their own needs by no less than 25-30 % without considerable growth of capital costs. Such works can to a large extent be carried out using farms own resources [1].

A refrigerating chamber is operating in the following way (Fig. 3). Products being cooled and stored are placed in thermally insulated premises 1. Water is supplied into the cold accumulator 5 through the valve 17.

In cold season the hatch 5 of the cold accumulator 5 is open. Water is frozen under the action of cold air supplied by the pressure fan 4 and ice is accumulated in the cold accumulator 5. For cooling agricultural products the pressure fan 4 (ventilator or compressor) is switched on and cold air from the atmosphere (in cold season) or the cold accumulator 5 through the air filter 9, the heating device frame 10 and the distributor 16 is supplied to the thermally insulated room 1. Heated air from the thermally insulated room 1 through pipeline 7 is supplied to the cold accumulator 5 where it is cooled, fed into the pressure unit 4 and the cycle is repeated again.

The use of the suggested system provides considerable reduction of energy consumption and annual operation costs in agricultural production.

The analysis of the development of refrigerating systems for all types of farms demonstrated that now the use of combined accumulators able to accumulate both natural and artificial cold is the most promising solution. Such accumulators can be used on the all-year-round basis and allow to accumulate cold at nighttime when reduced electricity tariff is applied. Therefore, electricity consumption and its costs are reduced. In central areas of Russia electricity consumption is reduced by 25-30% and related costs – 3-4 times.

A combination cold accumulator is a tank with cooled water or ice providing accumulation of natural or artificial cold. The cold accumulator design ensures its operation at all outside air temperatures all the year round.

To raise energy efficiency of equipment and additional cooling of refrigerant at capacity of over 30 000 kcal/h barbotage can be used. For this purpose cold outside air is supplied through a distribution header under ice accumulating sections, which improves intermixing of ice water and raise intensity of cooling and ice formation, as well as of ice thawing.

GNU VIESH in cooperation with продукции с использованием как природного, так и искусственного холода. GNU VIESH in cooperation with the Moscow Specialized Integrated Plant of Refrigerating Equipment (OAO "MSKKhO) initiated work for the development of combined accumulation refrigerating units using natural cold. At present this work is continued with the participation of the "Kholodprom" Association, OOO "Ortex" and OOO "Kasimovkholod".

The developed systems include: receivers of natural cold of outside air and accumulators of artificial and natural cold of outside air and ground (Tables 1, 2). Air, water or ecologically safe refrigerant with low freezing temperature (ecosol, ecofrost, water solutions of calcium or natrium chloride) are used as cooling media.

Table 3 presents technical characteristics of standard line of combined refrigerating units for cooling milk at farms.

Components of such energy-saving cooling systems can be installed both in the open air and in the production premises of agricultural enterprises.

Table 1. Accumulation refrigerating units

Characteristics	Type				
	MO-2Skh	MO-3Skh	MO-4Skh	MO-5Skh	MO-6Skh
Refrigeration capacity, kW Packaged version Version using a remote air condenser	 14 16	 21 24.2	 28 32.2	 35 40.3	 70 80.mil5
Milk productivity, t/h Packaged version Version using a remote air condenser	 0,4 0.46	 0,6 0.69	 0,85 0.98	 1,0 1.15	 2,0 2.3
Compressor	K150Skh	K300Skh	K400Skh	K500Skh	K600Skh
Remote air condenser	KГ-12G	KГ-22G	KГ-27G	KГ-35G	KГ-57G
Receiver capacity, l	10	12	12	16	30
Evaporators surface area, m^2	6	10	12	14	20
Cold accumulator capacity, m^3	0.9	1.1	1.2	1.3	2.0
Frozen ice mass, t	0.34	0.48	0.5	0.75	1.7
Installed capacity, kW	2.0	3.0	4.0	5.0	10.0

Table 2. Receivers-accumulators of natural cold

Characteristics	type			
	PA-1	PA-2	PA-3	PAG-1
Cooling medium	water	water	water	water
Heat load, kW	15…30	15…30	10…20	10…20
Refrigerating temperature of cooling medium, ºC	2…3	2…3	2…3	7…8
Accumulator capacity, m^3	0.8	0.5	0.3	0.8
Cooling medium consumption, m^3/h	1.5…3	1.5…3	1.5…3	1.5…3
Type	film	ejector	rotor	ground
Air consumption, m^3/h	1700	1700	1700	–
Installed capacity, kW	0.97	0.97	0.97	0.6

Table 3. Technical characteristics of the standard series of accumulation refrigerating units

Characteristic	Unit of measurement.	AKKhM-4	AKKhM - 8	AKKhM - 14	AKKhM - 20	AKKhM - 35
Refrigeration capacity at t_0 = -10ºC; $t_к$ = +30ºC	kW	4	8	14	20	35
Milk productivity* (minimum)	kg/h	115	230	400	570	1000

* - considering frozen ice.

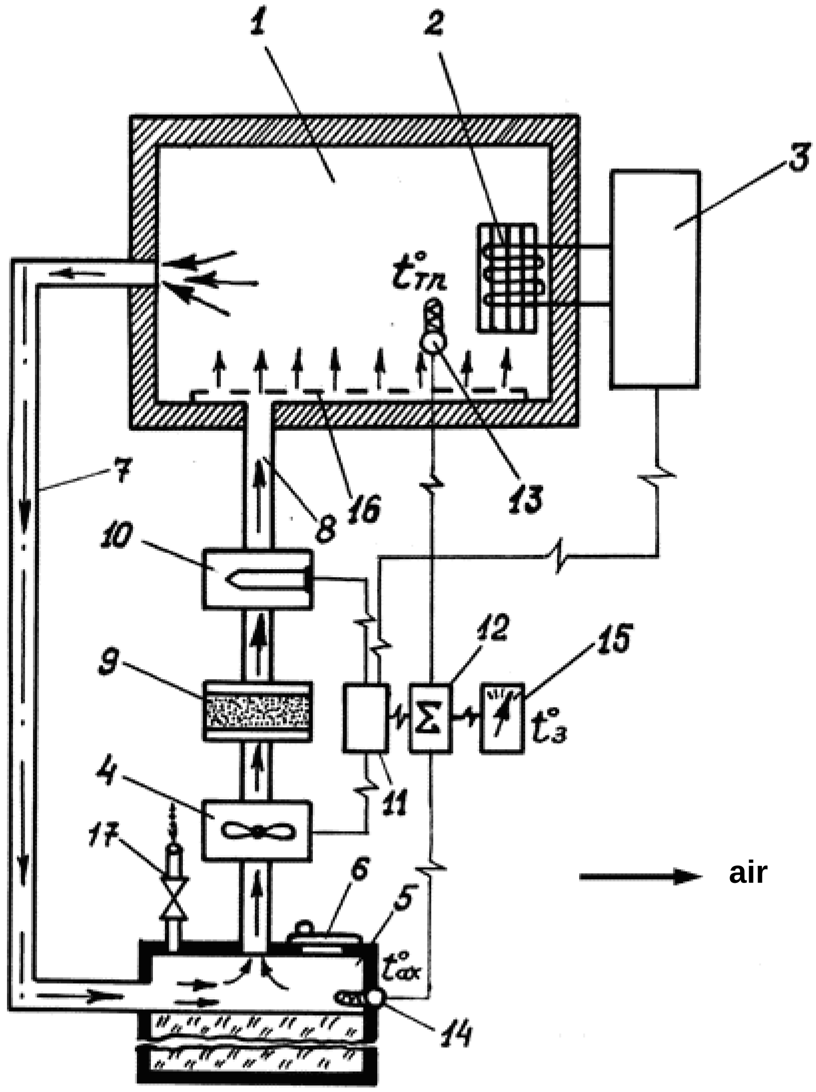

Fig. 3. The functional block diagram of the energy saving refrigerator for cooling and storage of agricultural products:

1 – thermally isolated room; 2 – refrigerating unit with an evaporator; 3 – compressor-condensation unit; 4 – air fan (ventilator or compressor); 5 – cold accumulator; 6 – opening hatch; 7, 8 – pipelines; 9 – air filter; 10 – heating device; 11 – amplifier unit; 12 – comparator; 13, 14 – temperature sensors; 15 – setup unit; 16 – distributor; 17 – valve

A specific version of a combination refrigerating system using natural cold should be selected with due consideration for natural cold potential at location area.

Fig. 4 and 5 present the block schematic diagram of the two versions of developed equipment.

Fig. 4 demonstrates diagram of equipment for milk farms where developed units are installed in production premises.

In cold season cold atmosphere air is supplied by the air fan 11 into thermally insulated water-ice accumulator 6 through the open hatch 9 and goes out through the open hatch 10.

In the accumulator 6 filled with water, natural cold in the form of ice and ice water is accumulated.

Artificial cold generated by the refrigerating machine 2, 4, 5 is accumulated in the water-ice accumulator 1 in the form of ice frozen on the surface of the evaporator 2 of the refrigerating unit. The condenser 5 of the refrigerating unit is cooled by natural cold of outside air supplied through the open hatch 13 and goes out into the atmosphere through the air duct 7.

The refrigerant pump 8 supplies ice water from the water-ice accumulator 1 or 6 into the heat exchanger for milk 3 wherefrom is comes back to the water-ice cold accumulators for cooling.

The control panel 12 provides effective interaction of artificial and natural cold sources in the cooling process and the system proper functioning at low temperatures.

Fig. 2 presents the diagram of the solution using combination cold accumulator of water-ice type (outdoor installation).

In the thermally insulated water-ice accumulator 1 there is the evaporator 14 made in the form of a tube sheet with ribs immersed into water. Ice is frozen on its surface. The condenser 2 and the compressor 3 are fixed to the ice accumulator case. The air fan 5 supplies outside air into the sprayer 6. Ascending air is intensively mixing water cooling it. He refrigerant pump 7 supplies ice water into the heat exchanger for milk 8 installed in production premises, and heated water is supplied into the cold accumulator 1 through the distribution pipe 13.

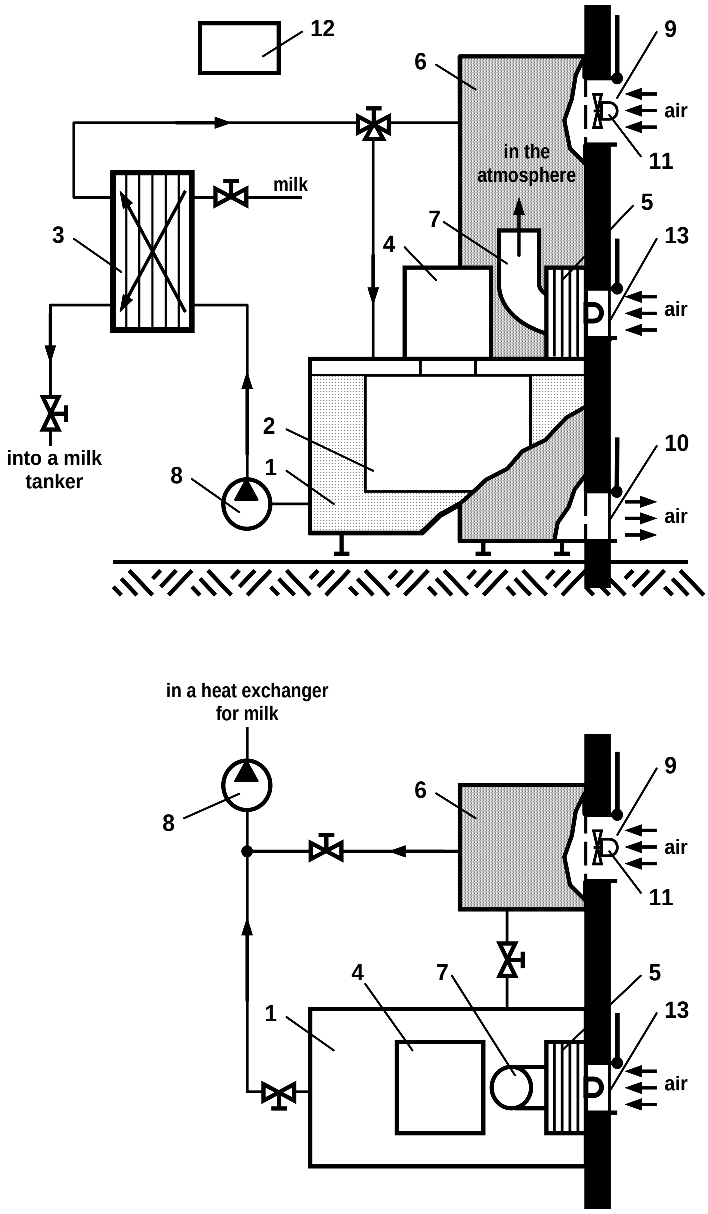

Fig. 4. The block schematic diagram of equipment with additional accumulators of natural cold:

1 – artificial cold accumulator; 2 – evaporator; 3 – heat exchanger for milk; 4 – compressor; 5 – air-cooled condenser; 6 – water-ice accumulator of natural cold; 7 – air duct; 8 – refrigerant pump; 9, 10, 13 – hatches; 11 – ventilator; 12 – control panel

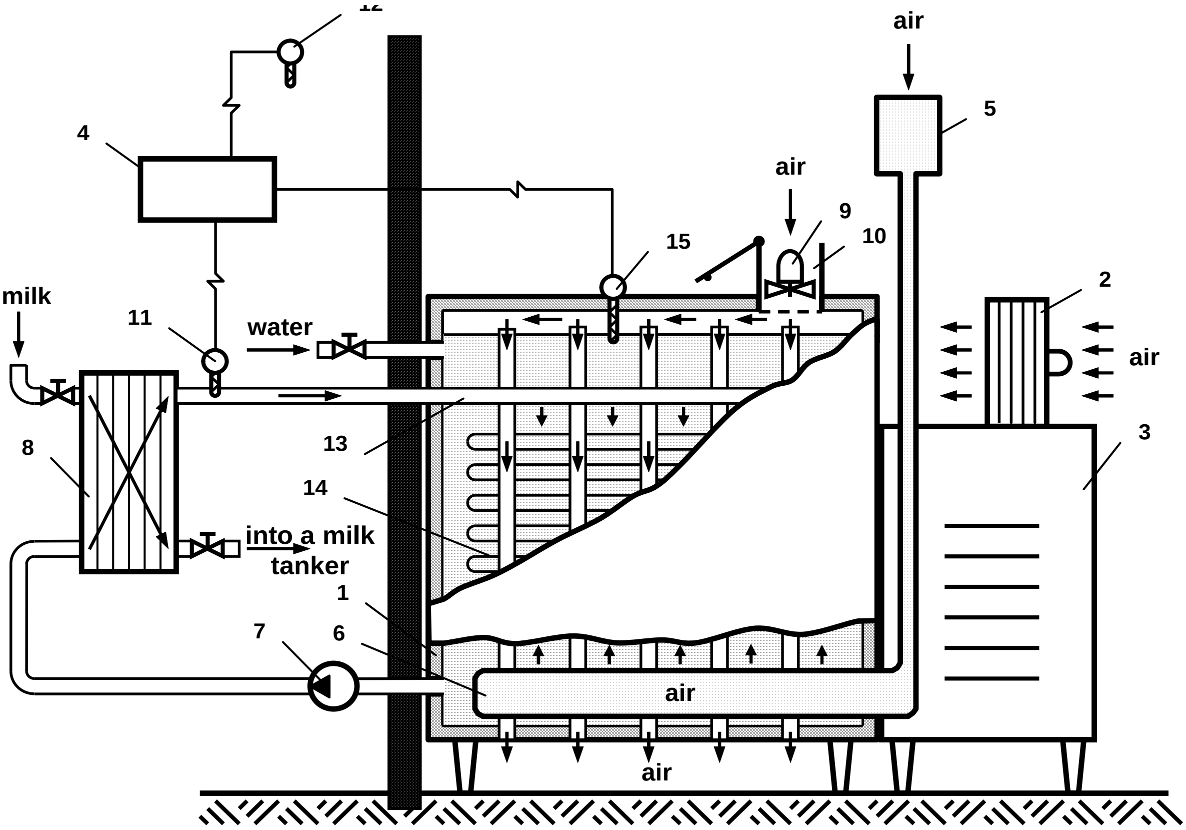

Fig. 5.The principle diagram of the equipment for production of ice-cold water with use of the accumulator of ice of the outdoor installation:
1 – ice-water cold accumulator; 2 – condenser; 3 – compressor компрессор; 4 – control panel; 5 – air fan; 6 – sprayer; 7 – refrigerant pump; 8 – heat exchanger for milk; 9 – ventilator; 10 – air hatch; 11 pressure sensor; 12 – outside air temperature sensor; 13 – distribution pipe; 14 – evaporator; 15 – refrigerant temperature sensor

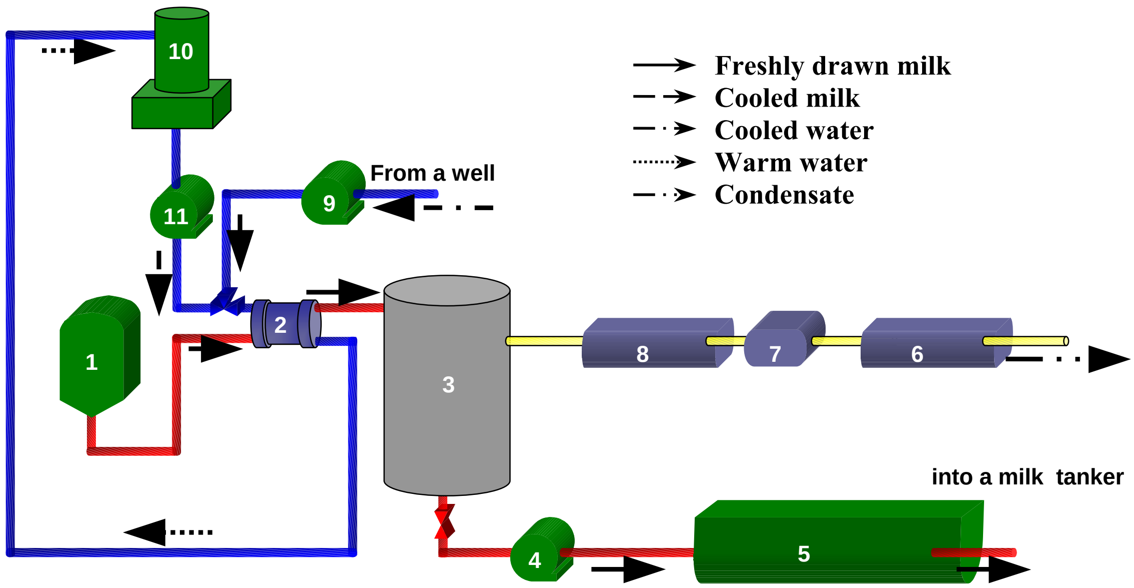

Fig. 6.Energy-saving CFC-free unit for cooling milk:
1 – releaser; 2 – heat exchanger; 3 – vacuumized tank; 4 – milk pump; 5 – storage tank; 6 – additional vacuum pump; 7 – condenser; 8 – main vacuum pump; 9 – ground water pump; 10 – receiver-accumulator of natural cold; 11 – refrigerant pump

In cold season outside air is supplied through the open hatch 10 with the ventilator 9 into the ice accumulator 1, the combined evaporator pipes 14 and cools water through freezing ice on the pipes surface and the combined evaporator ribs 14. Air goes out from the ice accumulator 1 or through its bottom part.

The control panel 4 electrically-connected with the pressure sensor 11, the outside air temperature sensor 12, the ice temperature sensor 15 and the ice thickness sensor is able to control refrigerating equipment at all temperatures of outside air.

In recent years vacuum came to be used for freezing ice. Research carried out at the Moscow State University of Ecological Engineering (MSUEE) demonstrated that the use of vacuum-evaporation units for cooling and ice freezing allows to considerably reduce energy consumption [11].

Fig. 6 presents the principle diagram of the combined energy-saving CFC-free system for cooling milk with the use of natural cold and vacuum developed by the GNU VIESH researchers in cooperation with MSUEE.

Fig. 7. General physical configuration of the energy-saving CFC-free system for cooling milk (the animal-breeding complex "Golyevo" (ZAO "Krasnogorye" of the Krasnogorsk area of the Moscow region).

The system operates in the following way. In cold season cooled water is supplied by the pump 9 from the receiver-accumulator of natural cold 10 into the heat exchanger 2 wherein it cools milk down to 4…6ºC . Heated water is fed back into the receiver-accumulator of natural cold 10. Cooled milk is pumped out by the pump 4 into the storage tank 5 wherefrom it is supplied into a milk tanker.

In warm season ground water is supplied by the pump 11 from a well into the heat exchanger 2 wherein it cools milk down to 13±1ºC. Then cooled milk is pumped out by the pump 4 into the storage tank 5 wherefrom it is supplied into a milk tanker.

Research and preliminary experiments on cooling products with the use of the new technology of cold generation have demonstrated the possibility of energy costs reduction down to 12…15 kW per 1 ton of product, time of cooling to 4…6 C° being less than 2 hours. Such combined refrigerating systems (Fig. 7) using energy-saving technology, can be operated all the year round practically in all regions of Russia. They can generate cold for storage houses designed for other agricultural products: fruits, vegetables, flowers, etc.

Conclusion

The developed equipment has the following major advantages in comparison with conventional refrigerating systems:

- electric power, water and expendable materials saving, as well as capital and operational costs reduction;
- high reliability of refrigerating systems due to ice reserve in accumulators, as well as to ease of maintenance and repair;
- the possibility to use reduced night electricity tariff in the process of ice freezing;
- environmental improvement due to reduction of freon and freon oils.

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THE PROSPECTS FOR THE DEVELOPMENT AND USE OF ENERGY-SAVING ELECTRIC TECHNOLOGIES IN AGRICULTURE

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In the article the prospects for the development and use of energy-saving electric technologies in agriculture are shown.

Key words: *optical radiation; electromagnetic field; electric field; electric impulses of high voltage; magnetic field.*

For the last 20 years the reduction of agricultural products production was accompanied by decrease of electricity and energy consumption. Electricity consumption in various branches of agriculture has been reduced from 103 to 62.5 billion kW*h (2011). Electric power per worker in agricultural production has also decreased from 8 000 to 5 450 kW*h per 1 worker (2011).

At the same time the production of practically all agricultural products in Russia is very energy-consuming and in comparison with the advanced countries energy and electricity consumption here is 2-5 times higher. Considering faster growth of electricity tariffs and prices in comparison with prices for agricultural products energy consumption share in their production cost has sharply increased from 3-8 % to 10-20% and for some kinds of products – up to 30-50% and more (greenhouses, poultry farms).

Thus, for example direct electricity costs are as follows: milk production – 340 kW.h/t; beef – 1700 kW.h/t; pork – 2500 kW.h/t and eggs – 95 kW.h/1000 pieces.

To solve the problem of food supply security in Russia it is necessary to reduce import and increase domestic production of agricultural products, which will require additional energy resources. The analysis of the current state of agricultural production, prospects for the development of all its forms – collective, farm and personal subsidiary economy, and for large scale implementation of advanced technologies of primary processing of agricultural products in the field, the necessity to improve working, social and living conditions, as well as comfort of rural population, have demonstrated that energy consumption will increase by 20-25% by 2020.

On the other hand, growing electricity tariffs and rather low efficiency of its use require active measures for energy saving,

Considering the current situation, the State Program of the Development of Agriculture and Regulation of Market of Agricultural Products, Raw Materials and Food Supplies was adopted in Russia, one of its major goals being the agro-industrial complex modernization through the use of energy-saving equipment meeting the requirements of current level of scientific and technological development, and relevant energy policy is pursued (Decree of the RF President № 889 of 04.06.2000, the RF Law № 261-FZ of 23.11.2009) setting-up the challenge of economical use of electric energy in agriculture and energy consumption reduction by 49%.

One of effective measures for electricity saving is a wide use of energy-saving technologies in agricultural production [1, 2]. The development and implementation of electric technologies and building new equipment for production, storage and processing agricultural products on their basis is a scientific and technological challenge demanding the solution of the following interconnected fundamental and application problems:

- substantiation of economically feasible applications of electric technologies;

- comprehensive study of electrophysical and thermophysical properties of agricultural products and raw materials in dependence on physiological processes and climatic effects, as well as determining of interrelations among them;
- study of heat and mass exchange processes in concentrated electrophysical effect on agricultural raw materials and products;
- development of methods of determining of technological modes of electrophysical impact on agricultural materials and food products;
- development of theoretical foundations of management of technological processes and implementation of technical means of automation.

For wide application of combined energy-saving technologies in technologial processes of agricultural production it is necessary to continue the studies aimed at:

- determination of optimal doze of elecrophysical effect, design of technical means, problems of labor protection and reliability of equipment operation both in steady-state and in field conditions;
- development and implementation of new energy-saving electrical technologies based on the realization of effective electrotechnical processes, advanced methods of electrophysical effect on biological objects;
- implementation of automatic technical means for complex electro-mechanization of production, processing and storage of agricultural products, introduction of automatic process control systems.

When substantiating prospective lines of development of energy-saving electric technologies in agriculture it is also necessary to consider that currently approach to quantitative indices of electrification – electricity consumption, has changed: if before electrification indices and success were considered only in terms of growth of electricity consumption, nowadays a major criterion is real production and social effect obtained by each kilowatt·hour consumed.

Considering the above-mentioned, in proposals on the development of energy-saving technologies in agriculture accent should be shifted to energy consumption efficiency, rational use and electricity saving. Of special importance are the development and implementation in agriculture of energy-saving electric technologies in agriculture, based on the use of optical emission, electromagnetic and magnetic field, electric impulses, etc.

Optical emission. In agriculture a whole range of optical emission is used – visible, ultraviolet and infrared. Depending on emission spectrum, unit or individual radiators are used for various technological operations: lighting of houses, animal breeding premises, storage houses, various production facilities and utility areas; ultraviolet and IR radiation of animals; radiation of plants in protected ground; presowing seeds radiation; elimination of pathogenic microflora (disinfection of water, air, agricultural products, packages, etc.); processing of plant and animal products (pasteurization of milk, juices and other liquids), products drying and disinfection; flying pests control, etc.

One of perspective lines of development of lighting systems is the use of a new generation of light sources – light emitting diodes. LED are characterized by low energy consumption, allow to smoothly regulate the lighting level, have improved color rendering not depending on illumination level and extremely prolonged service life (up to 100 thous. hours) with replacement period up to 400 months.

For lighting animal and poultry breeding premises GNU VIESH has developed electric equipment on the basis of LED lamps.

The advanced LED system for lighting a poultry house (8x70 m) comprises 44 lamps for work lighting and 11 lamps for technological passage. Lamps are composed of a plastic case inside of which 0.5 W CLP-6 12 LEDs are installed. These LEDs provide even illumination and stroboscopic effect is totally excluded; in addition installed capacity of the lighing system has been reduced from 980 to 370 W.

For illuminating calf houses for 200 and 300 heads sets of equipment using LEDs with 120 lumen per watt light efficiency have been developed at GNU VIESH. Lamps capacity is 9 W. Energy consumption of the system for lighting a calf house for 200 heads is 250 W, and of the system for 300 heads – 360 W.

Economic efficiency calculation demonstrated that in spite of high initial costs for installation of new equipment its payback period does not exceed 2 years.

For protected ground GNU VIESH hase developed a universal wideband LED lamp using light sources of various spectrum that can be effectively used it in plant cultivation.

Timely disinfection of agricultural premises is also of great importance in production of high quality products.

It should be considered that the process of air disinfection in poultry houses usually has to be carried out in presence of operating personnel and poultry. In this case the following basic requirements are specified for disinfecting means: they should have strong bactericidal effect, be harmless for people and birds even when used for a long time; must not pollute environment, cause corrosion and equipment failure; their use must be cost-effective and technology-savvy.

The new UV units developed at GNU VIESH have higher capacity (up to 95 W) in comparison with standard units using low-pressure UF lamps. Their efficiency is 3 times higher in comparison with bactericidal ozon-producing lamps with 36 W capacity and 15 times in comparison with 30 W bactericidal lamps. In the result of the use of these advanced irradiation units considerable energy saving is achieved.

UF units are also widely used in animal breeding. Short-wave ultraviolet bactericidal radiation is used in animal breeding for air disinfection in maternity barns, prophylactic centers, artificial insemination departments, veterinary clinics, in storage premises, as well as for disinfection of water, dishware, equipment, clothes, etc.

Considering its comprehensive effect on plant cells, UF emission is used in plant cultivation. It is applied for selection purposes and for presowing seeds processing. Acting directly on plants, this emission can be an effective regulator of major processes in biological objects. Research has demonstrated that ultraviolet radiation of perishable goods prolongs their storage time. There are positive results in the development of methods of controlling pests of agricultural plants and of soil denitration with the use of UF emission.

The development and application of energy-saving electric technologies based on the use of infrared emission are of extreme importance.

Research in this field carried out by VIESH scientists has made it possible to substantiate standard series of thin-layer IR-pasteurizers with various capacity. It was decided to develop the following equipment:

- low capacity units (100…250 l/h) designed for individual households and farms;
- medium capacity units (500…1 000 l/h) designed for use at farms and enterprises specialized in processing agricultural products;
- high capacity units (up to 3 000…5 000 l/h) designed for integration with production lines at enterprises specialized in processing animal and plant products.

The equipment operating principle is based on short-wave infrared emission effect on open surface of continuous liquid flow specifically formed and flowing down relatively cold internal surface of a cylinder. Products are processed with the use of IR-radiators installed coaxially with the pasteurization chamber cylinder.

Short-term contactless effect of high-density IR-radiation leads to rapid heating of flowing liquid layer and creates conditions for microflora elimination and ferments inactivation, thus providing products pasteurization.

Pilot pasteurizer models with 1 000 l/h capacity have been developed.

Production testing confirmed high technological efficiency of thin-layer IR processing of milk and juices. In their quality milk and juices met all necessary requirements and were characterized by high organoleptic qualities. Absence of direct contact of product with heating body allows to pasteurize products preserving their high nutritional and taste properties. In addition, energy consumption in pasteurization process is consumption in pasteurization process is considerably reduced.

Infrared radiation is also successfully used for local warming of young animals and poultry in initial growing period. The use of infrared heating is very effective in terms of heating costs as it allows to create comfortable local zones for young livestock.

For these purposes, VIESH researchers have developed the IKUF-1 and IKUF-1 radiators providing combined IR and VF radiation, as well as the set of lighting equipment "Komfort" designed for IK-heating, UV radiation and air ionization.

Electromagnetic field. The use of energy of electromagnetic field of currents of various frequency (ultra-high frequency, extremely high frequency, ultrahigh frequency range and laser emission) considerably expands electric technologies possibilities. This kind of energy is widely used in agricultural production as sources of heat used for warming, heating water and vapor, drying and electrothermal processing of materials and food products, control of qualtitative and qualitative parameters of products, non-drug therapy of livestock, presowing processing of seeds, etc. [1 … 5, 7]. The use of these electric technologies will allow to considerably reduce energy consumption not only in agricultural production but also in food industry, catering and daily life.

Basic advantages of microwave heating in comparison with heat passage into material trough heat conduction are its instantaneous character – the possibility to immediate turn heat action on and off, as well as high efficiency of conversion of microwave energy into heat. GNU VIESH in cooperation with the Scientific-Production Association "Impulse" has developed the microwave plant for thawing of products, the microwave dryer for granular material and a whole range of other equipment [7].

At present GNU VIESH is carrying out research for the development of complex equipment for drying grain through active aeration with the use of microwave fields allowing to considerably reduce energy consumption in grain processing [3].

Electric field. The use of electric field is an extremely promising way of using electric energy in agriculture. Research carried out in this field has made it possible to develop new flowcharts of separation process. In these flowcharts grain mixtures are separated in dependence on grain parameters determining its behaviour in electric field: grain dielectric capacity, electric conductivity, polarization ability, as well as ability to receive and emit electric charge.

So far various types of electric seed cleaners have been developed and made. In the process of seed cleaning with the use of these equipment stimulating effect is observed, that is, germinative energy and capacity, as well as yield level are increased. Thus, for example, through processing in the field of corona discharge seeds germinative capacity is increased by 15-200%, germinative energy – 2-3 times and yield – by 25% [6]. The processing with 200-400 kW/m electric field for 10-30 sec effectively stimulates rooting of fruit and berry shoots [5].

Electric field is also used for chemicals sedimentation for plants protection, for air ozonation and aeroionization at livestock breeding farms, for drying of agricultural products, for post-treatment and disinfection of manure liquid fraction, as well as for other purposes. It has been proved that if in the process of drying agricultural products electric field is generated in the grain dryer chamber, moisture separation from seeds is accelerated due to electrokinetics (electroosmosis and electrophoresis), energy consumption is reduced by 25 % and drying period is shortened.

High voltage electric impulses. The use of impulse energy in high voltage charges allows to intensify many technological processes in agricultural production and obtain results that cannot be achieved by conventional electromechanical methods, for example, water lifting from great depth and processing food waste containing solid admixtures due to electrohydraulic effect. The electrohydraulic method of cleaning wool from contamination allowing to reduce wool bacterial number, to lower water consumption twice and detergent consumption three times, has been developed. Electric pulse charges are used for grinding lime fertilizers, presowing seeds processing, disinfection and pasteurization of liquid agricultural products, elimination of weeds and pests in hothouses soils, electrospark threshing, as w ell as for other purposes.

As research carried out at VIESH demonstrated, the use of electromagnetic impulses for intensification of herbage dehydration in the process of fodder briquetting, energy consumption in drying processes is reduced more than 2 times.

Magnetic field. Magnetic field is used in agriculture both directly (cleaning of seeds and fodder from metal objects, reduction of crust formation in internal combustion engines, ect.) and in special equipment designed for stimulating development and raising yield of vegetable crops trough seeds processing by magnetic field, plants treatment with magnetized water, as well as for other purposes.

It is known that application of water processed with magnetic field provokes nitrogen, phosphorus and potassium transition to a state more suitable for absorbtion by plants. However, these characteristics remain unchanged only for a short time period (no more than one day) so it is necessary to treat water directly before using it.

Now at VIESH relatively simple equipment for processing water and seeds with magnetic field with permanent magnets and electromagnets making it possible to increase yield in protected ground by 15-20% practically without electricity consumption, has been developed.

Electric technologies allowing to produce activated liquid with the use of electric, magnetic, ultrasonic and other effects also seem very promising. Various filters for activating water solutions, fat emulsion, solvents and other liquids, and for pasteurization of liquid food products when it is necessary, are being developed. At the Saint-Petersburg State University of Low Temperature and Foodstuff Technologies units for magnetic processing of raw milk especially effective at milk farms located far from diary plants are being developed. On the basis of experimental research it has been established that magnetic processing allows to preserve milk quality without any changes for several days. Raw milk activation reduces microorganiss content, moreover, it has been noted that its pH is lower than in raw milk [8].

Conclusion

For higher efficiency of production of high quality agricultural products at the first stage it is necessary to implement already developed electric technologies and electrotechnological processes based on energy-saving methods of affecting plants, animals, seeds, fodder and agricultural products, including electric heating and radiation of plants and animals; sorting and pre-sowing processing of seeds; electrophysical methods of grain and soil processing; weeds elimination; disinfection of premises, water, fodder and air; storage of potatoes, vegetables and fruits, notably through micro current stabilization; drying of agricultural products; plants electro plasmosis; treatment of animals, etc. Their implementation will make it possible to expand the use of electric energy directly in technological processes with high technological and energy effect.

Of special importance in the development of this trend is the implementation of electric technologies and electrified processes of initial processing and storage of agricultural products (milk, potatoes, vegetavles, fruits) with due consideration to their biological characteristics and peculiarities of their production and selling, that can be determined with the use of automatic electronic-optical system developed at VIESH. With the use of the developed algorithms of transformation of color images and optical characteristics bio-ecological reactions of seeds (temperature, light, defects and other stresses), assessment of grading factors, diagnostics of quality and forecasting of parameters change will be carried out.

It is also necessary to widely use ozone generators and units on their basis designed for pests elimination in hothouses, for drinking water purification instead of harmful chlorine, disinfection of premises, air, fodder, clothes at farms, etc.

On the basis of new electric technologies high-voltage energy supply sources and plasmatrons for electro technologic processes will be developed:

electric weeding machine for eliminating weeds, units for sewage water purification systems, veterinary and medical cold plasma coagulators, etc.

The implementation of energy-saving electric technologies in agriculture will allow to reach the following major parameters by 2020:

- electric energy saving – no less than by 40%;
- 1.5-2 times reduction of agricultural products losses sustaining their quality and increasing storage term;
- 2-2.5 times reduction of electric energy consumption for lighting and radiation.

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