

**M. Yo. Fedoriv, Cand. Sc. (Tech.), Assoc. Prof.,**  
 orcid.org/0000-0002-8917-4159,  
**I. V. Hlad, Cand. Sc. (Tech.), Assoc. Prof.,**  
 orcid.org/0000-0001-6389-1742,  
**I. D. Halushchak, Cand. Sc. (Tech.), Assoc. Prof.,**  
 orcid.org/0000-0003-1209-7885,  
**I. M. Mykhailiv,**  
 orcid.org/0000-0001-9215-8654

Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine, e-mail: [fedorivm@ukr.net](mailto:fedorivm@ukr.net)

## DC LINK POWER SUPPLY SYSTEM OF ELECTRIC DRILL

**Purpose.** Selection of a rational power supply system for an electric drill based on an assessment of active power and voltage losses in a cable line.

**Methodology.** Research on active power losses in current leads is based on the use of the theory of electrical circuits. On the basis of retrospective methods of reliability study of the main elements of the electric drill power supply system, factors that affect its reliability and efficiency are determined. As a result of mathematical modeling of functioning of the electrotechnical complex of electric drill power supply system with DC link in the mathematical editor Mathcad the change in losses of active power and voltage during the transition from the “two wires – pipe” system to the system with a DC link “one wire – pipe” is investigated.

**Findings.** The influence of the structure of the power supply system of the electric drill on the level of power dissipation and voltage losses in the current lead during drilling of wells is investigated. The necessity of transition to an electric drill power supply system with DC link “one wire – pipe” is justified. This power supply system will increase reliability and energy efficiency indicators.

**Originality.** It has been shown for the first time that the active power dissipation and voltage losses in the current lead of the electric drill with the use of the power supply system with DC link “one wire – pipe” are smaller in comparison with the existing electric power supply system, especially when drilling average and lower intervals of wells.

**Practical value.** The developed mathematical models of active power dissipation and voltage losses in the current lead allow us to determine the main indicators of energy efficiency and operational reliability of the electric drill power supply system and facilitate the choice of the economic drilling process.

**Keywords:** *electric drill, energy efficiency, electrotechnical complex, dissipation*

**Introduction.** The analysis of reliability and energy efficiency indicators shows that most enterprises, institutions and organizations are equipped with morally and physically outdated technological equipment with low energy conversion efficiency. The power supply systems of the electrotechnical complexes of the oil and gas industry no longer correspond to the value of the installed capacity of consumers and are not consistent in terms of electromagnetic and mode compatibility, which causes an increase in electricity losses and a deterioration of its quality. The lack of systems for electricity technical metering and monitoring of its quality indicators often makes it impossible to analyze the power consumption of the enterprise units. The increase in the voltage level beyond the permissible value in power grids and the wrong choice of electrical equipment dramatically reduce the service life of power consumers and increase their energy consumption [1]. An adjustable electric drive for well drilling is equipped with semiconductor power converters that distort the shape of the current curve in the phase conductors of the power grid, resulting in additional losses. The power supply system of the electric drill (ED), which is currently in use, causes an asymmetry of motor currents and voltages. It results in increasing of power consumption and reducing of the system reliability as a whole [2].

**Literature review.** The questions of reliability and energy efficiency research of power supply systems and electrical equipment are considered in the works by J. Endreni, I. Sud, S. Blanter, Y. Kostyrko, and S. Shevchuk. The solution to this problem was started in the works by the authors, and the results of the research studies are presented in their publications [3].

As a result of the mathematical processing of statistical data, it is established that failures of electric drive equipment are under the Weibull-Gnedenko law, which describes both gradual and instantaneous failures. The probability of failure-free operation is determined by the formula

$$P(t) = e^{-\left(\frac{t}{a}\right)^b},$$

where  $a$  is the parameter of the distribution form;  $b$  is the parameter of the distribution scale for the elements of the power supply system of the electric drill. The parameters of the distribution law are given in [3].

The electric drill cable sections located in the drill pipes are the most frequently damaged elements, which complicates the conditions of their operation in the aggressive environment of the drilling fluid. The average failure time of the cable sections is 150 hours and their failure flow parameter is  $1.3 \cdot 10^{-4} \text{ hour}^{-1}$ .

**Unsolved aspects of the problem.** To achieve this goal, it is necessary to develop a mathematical model of reliability and energy efficiency of the power supply system with DC link “one wire – pipe” and to determine the active power and voltage losses and the energy efficiency factors.

**Results.** Ukraine’s energy independence cannot be achieved without an increase in the mining of hydrocarbon energy sources – oil and gas. One of the main ways to achieve this is to increase the production rate of oil and gas during the construction of new wells and to continue the operation of conserved wells. This problem is solved by drilling obliquely directed and horizontally-branched wells. The most promising way of drilling is electrical drilling, especially in the Carpathian region.

An electrodrill is a submersible oil-filled high-voltage three-phase asynchronous motor with a squirrel cage. Electricity is supplied to it from a 6 kV power grid through a drilling transformer TMTB-630/6, a control and protection station “UZEB”, a current lead made by the “Two conductors – pipe” system and a device for controlling the insulation resistance of the motor.

The mode of operation of the electric drill practically does not depend on the amount of drilling fluid supplied by the drill

pumps into the column of drill pipes to raise the destroyed rock to the surface. Since drilling and reconstruction of existing wells are carried out at great depths of drilling, the loss of voltage in the submersible cable increases. This reduces the voltage supplied to the drive motor, which causes a softening in the mechanical characteristic of the electric drill. Resistance asymmetry of cable line and steel drill pipes leads to the creation of asymmetrical modes of the electric drill operation. Low and asymmetrical supply voltage increases the heating temperature of the electric motor winding, accelerates the degradation of the dielectric properties, the aging of the stator insulation materials and the failures of the electric drill.

The probability of the voltage decrease at the terminals of the immersion motor stator increases due to the incorrect position of no-load tap changer of the power transformer that feeds the electric drill. Currently, the secondary voltage level is changed by the switching device manually following the technological map of drilling. The parameters of the drill power circuit significantly change during these operations. However, the increase in phase resistance of the equivalent circuit of the power line due to the failure of individual conductors of the cable and after the restoration of the motor performance is not taken into account. Therefore, the electric drill operates in an asymmetrical mode and with low voltage. This reduces the efficiency of drilling and reduces the quantitative reliability indicators of the drill.

More than 14 000 meters of wells were constructed in the Drilling Department of Dolyna with the use of an electric drill, and 8 000 meters were constructed in the Drilling Departments of Boryslav and Nadvirna. During drilling, the following types of drills were used: E240, E215, and E164. They are equipped with telemetry systems and devices for changing the angle of inclination of the well. About 80 electric drills, 30 telemetry systems and current receivers with sliding contacts, 75 insulation control devices and 700 power cable sections were used throughout the year.

The study of different drilling methods shows that well drilling in difficult conditions with the use of electric drills reduces the number of complications and accidents in comparison with other methods. When drilling with an electric drill the basic parameters are higher than in the rotary or turbine drillings.

An important problem in electric drilling is to provide a power supply with low voltage and power losses. In functioning drilling machines, the electric drill is powered by three-phase alternating current according to the "Two conductors – pipe" system. The cable sections are placed inside the metal drill pipe of type H114 or H141, which is used as the third conductor. Each section consists of a segment of cable KTSHE-2P with copper cores with a cross-section  $2 \cdot 35$  or  $2 \cdot 50$  mm<sup>2</sup> (depending on the rated current of the motor) and contact connections of type KST1. Each cable segment has a pin at one end and a contact socket at the other. By using them, the continuous sealed electrical power line is made. The use of a power supply system "Two conductors – pipe" allows us to enlarge the hole for the passage of drilling fluid, reduce the overall dimensions of the contact connections and eliminate the twisting of the cable sections. But such a power supply system creates an asymmetrical electric motor mode.

As a result of the electric drill operating in an asymmetrical mode, the following factors arise:

- uneven thermal load on the motor windings;
- increased vibration of the motor;
- decreased torque on the shaft.

These factors negatively affect the energy efficiency of the motor and reduce its service life.

An unbalanced load on the winding causes the motor overheating and an increase in power consumption. Also, due to the action of a rotating magnetic field generated by inverse sequence currents, a torque is generated on the motor rotor shaft. This torque is directed against the direction of the torque created by the direct sequence currents [4].

The resultant torque of the electric drill motor, which is the sum of the torques generated by the currents of the direct and inverse sequences, will be less than when the motor is powered by a three-phase symmetric current. This state of affairs reduces the mechanical power supplied to the drill bit, resulting in a reduced drilling speed for oil and gas wells [5].

Overheating reduces the insulation life of the electric motor stator winding. The peculiarity of the electric drill motor design is the large ratio of the stator length to its diameter. Therefore, the active part of the stator winding of the electric drill motor is much longer than its front part. When the temperature fluctuates, thermal expansion and narrowing of the metal parts occur and, as a consequence, mechanical stresses occur in the groove insulation of the stator winding. Over time, microcracks appear in the insulation, their size increases and a local electrical breakdown occurs [6].

Vibration leads to an increase in the aging rate of the motor components, especially shaft and housing seals, which are made of cast tungsten carbide [7]. The operation of an electric drill in an environment containing abrasive particles and corrosion-active chemicals is impossible without effective sealing of the joints of the shaft and the motor housing. The most effective way to ensure the tightness, reliability and durability of such a seal is to use cast tungsten carbide rings. Their working surfaces should be polished and fixed to each other and greased with transformer oil, which an electric motor is filled with. However, vibration causes micro-cracks in the cast tungsten carbide rings and their rapid failure, which reduces the average drilling speed of the well and the life of the rock-breaking tool.

Inadmissible asymmetry of currents on the terminals of the motor (> 5 %) is observed during the drilling of wells at medium intervals. The increase in the energy efficiency of well drilling in the Carpathian region is only possible due to the modernization of the current supply system of the electric motor.

The electric drill power supply system "Two conductors – pipe" causes asymmetry of currents and voltages of the motor, which increases power consumption and decreases the system's reliability as a whole. The voltage at the drill terminals can only be changed stepwise by changing the transformation ratio depending on the drilling depth. This state of affairs increases the losses of active power and complicates the regulation of the rotation speed of the drill bit.

Analysis of the energy characteristics of the well drilling with the use of the electric drill showed that the power and energy losses in the power supply system are significant and primarily caused due to the imperfection of the "Two conductors – pipe" system. Also, the use of a two-core cable located inside the drill pipe column reduces the hydraulic cross-section and, accordingly, increases the hydraulic resistance of the drill pipe column to the pumping of the drilling fluid.

The history of the development of electric drilling has numerous attempts to design single-phase asynchronous motors and to use the power supply system of electric drills according to the "one conductor – pipe" scheme. However, the performance of single-phase motors that were powered by this scheme was unsatisfactory. The startup of the electric drill was also difficult.

At the same time, the placement of the starting capacitors requires an additional volume in the layout of the electric drill motor. For the reasons given above, the use of single-phase asynchronous motors and a power supply system for electric drills according to the "one conductor – pipe" scheme has proved to be inefficient and unreliable.

At the Ideas Fair of the 8<sup>th</sup> International Investments Fair, the director of the innovative enterprise "Elektrobur", PhD. Oleh Kekot presented a DC electric motor for an electric drill.

Drilling rig with the use of Kekot electric motor, includes the following units: chisel, spindle, bending mechanism, gearbox, electric drill motor, telemetry system, lock, single-wire power supply, drill pipe, rotor, square rod, current collector,

swivel, hook of the hoist system, DC generator, generator drive motor, electric drill control board, drill console, and telemetry system console.

The DC electric motor proposed by Kekot is structurally designed as a non-contact valve motor. The rotary thyristor switch is provided for switching the current in its armature winding. However, the rotating semiconductor switch is mechanically coupled to the motor shaft and, therefore, does not function satisfactorily in the conditions of vibration and extreme temperatures in the borehole.

Therefore, in order to improve energy efficiency and reliability of functioning of the electrotechnical complex for drilling, the primary task is to modernize the power supply system of the drill by introducing a DC power supply system and installing an immersive frequency converter of the supply voltage of the electric drill.

DC power transmission systems are able:

- to increase the efficiency of management of high power and lengthy power system from one center;
- to create the most favorable conditions for the functioning of interregional and international wholesale markets for electricity and power;
- to integrate AC power systems that operate with a nominal frequency of 50 or 60 Hz and different ideology of frequency support;
- to change the value and direction of the power flow in the general power system and its individual parts without any inertia, i.e. to carry out the electricity transmission according to the set program, including in the forward and reverse directions;
- to increase the efficiency of load schedules management by accumulating electricity during periods of excess generation and by giving electricity during periods of increased consumption;
- to reduce the amount of emergency equipment while maintaining high reliability and maneuverability (the expanding of the possibility of emergency mutual assistance of systems);
- to reduce the environmental burden by reducing the dimensions of the transmission towers, 1.5 times' reduction of the land exclusion zone for the DC transmission line, higher safety for humans, flora and fauna due to the absence of wave effects;
- to provide the minimum low bandwidth of interconnections, to eliminate the problem of weak connections;
- to increase the efficiency of power transmission from large and medium hydropower plants by optimizing the rotation speed of the hydropower generator rotors, which increases the energy efficiency of the power plant;
- to significantly facilitate the integration of generating equipment based on renewable DC power sources (solar panels, wind turbines of small and medium power, energy storage fuel elements) into local networks due to the lack of their mutual synchronization.

The creation and operation of DC transmission lines are connected with some technical problems that require additional financial costs. The main problems include:

- the need for compensation of higher harmonics and reactive power of converters when converting direct current to alternating current;
- the complexity of thyristor valves control (when using thyristors in converters);
- low internal resistance of power electronic semiconductor switches, which are in the open state, variation of the technical characteristics of these devices, which is the reason of uneven distribution of voltages on separate elements, which are connected in series [8];
- low stability of inverters operation in asymmetrical modes of electricity transmission (it leads to complication of the construction of substations, which reduces their reliability and increases the cost).

In recent years considerable experience has been gained in the field of DC power transmission systems. The key issues of DC transmission have been thoroughly studied in practice. They are also successfully overcome, although many design solutions remain expensive.

In a new technological environment, the use of direct current systems at the macro level is a necessary condition, and in some cases it is indispensable (i.e. when AC transmission is impractical or impossible). Such tasks are meant:

- creation of spatial active-adaptive networks, i.e. systems in which all the subjects of the electricity market participate in the processes of generation, transmission and distribution of electricity;
- formation of smart grids ("Smart Grid");
- integration of several large energy networks into a single network;
- connection of decentralized micro-energy systems (Microgrid) formed on the user side to the common power system;
- transmission of considerable electric power over long distances;
- integration into a common system of marine-based power plants (wind farms, floating solar power plants, water-using equipment), energy storage facilities, and others;
- laying of power transmission lines in rough terrain, at the bottom of rivers and seas, installation of large capacities in cities, metropolitan areas, on industrial sites of drilling rigs.

In terms of energy consumption, there are the following factors that contribute to the development of DC systems: increase in the length of rail and other contact ways; increase in the number of automobile, ship, aviation, internal (inside buildings, enterprises, drilling rigs) and special networks; widespread installation of equipment with switched-mode power supplies, industrial and domestic machinery equipped with DC motors.

Recently, the scientific community celebrated the 100<sup>th</sup> anniversary of the discovery of the phenomenon of superconductivity and the 30<sup>th</sup> anniversary of the discovery of high-temperature superconductivity, which made it possible to make the transition from expensive cooling of low-temperature superconductors with liquid helium to a fundamentally new – nitrogen temperature level. In the early 2000s, data on the successful testing of prototypes and experimental segments of superconducting DC cables began to appear in scientific articles.

At present, there are several dozens of experimental cable lines in the world designed to study the possibility of transmitting electricity using the superconductivity effect, but their length does not exceed one kilometer. Analysis of information sources shows the possibility of building energy transmission systems several kilometers long for use in real power grids. It has already been announced about the development of projects for such cable lines from one to ten kilometers long (Russia, Japan, Republic of Korea, Europe and the USA).

The interest in this direction is determined by the fact that large power sources (nuclear power plants, hydroelectric power plants, solar and wind farms) are located at large distances from large cities and electricity consumers, which leads to the need to transport large energy flows over long distances. In this case, the traditional power delivery scheme involves the use of high-voltage overhead transmission lines, which is due to the desire to minimize energy losses during its transportation. This leads to the need to create high-voltage step-up substation and, respectively, step-down substations, to significant energy losses (6–10 %) during its transportation, as well as the alienation of large areas of land.

The use of superconducting cable lines will significantly reduce the voltage class and increase the single transmit power by increasing the operating currents.

This provides the ability to create transmission at low voltage, which significantly affects the cost of the entire infrastructure of the cable line. Also, there are no voltage drops along

the length of the superconducting line, which is essential for long lines. Moreover, when developing long lines, superconducting DC cable lines are considered.

For example, in Germany the proportion of cables in the low voltage lines is more than 80 % and the proportion of cables in the medium voltage lines is 65 %. Experts in Europe believe that the greater the proportion of cable networks is, the more reliable the energy supply is.

High voltage cables connect countries separated by seas. They are used for deep input of power into cities and large enterprises and connect the generator part of power plants with network substations.

Cables with cross-linked polyethylene insulation are widely used for high power transmission. They have a high throughput capacity (it is 17–25 % higher than the throughput capacity of paper-impregnated cables), thermal resistance to short-circuit currents, low mass and smaller diameter, which facilitates laying in drill pipes. Such cables are highly environmentally-friendly (no lead sheath) and have low specific damage rate (between one and two orders of magnitude lower than in oil-filled).

The share of paper-oil and thermoplastic polyethylene insulated cables is significantly reduced.

Modern cable designs include a built-in fiber module to monitor their status and power transmission parameters.

High voltage underground cable lines are an ideal option for deep input of large capacities into load centers. The electrical insulation of new cables now and in the near future is cross-linked polyethylene. The industrial development of cables with such insulation is promising. In our country, it is significantly behind the world level.

DC power transmission and inputs to the power substations will require DC cable inserts. In addition to high-power long-distance power transmission, DC cable lines are used for underwater routing.

At sufficiently high demand for DC cables, the production of extruded polymer insulated cables should be organized based on the production of high voltage AC cables together with retrofitting of the test base.

Based on the above, it is necessary to note the prospects of the development and implementation of cable sections of the electric drill power supply system using the effect of superconductivity at high temperatures. Such a design of cable sections will provide almost complete absence of active power losses during the transmission of electricity to the electric drill.

The drilling speed of solid rocks by conical bits is nonlinearly dependent on the rotation speed of the bit. Currently, the speed control is carried stepwise with the gearbox insert between the drill shaft and the bit. The gearbox is installed before the drill pipe is lowered into the well. However, the gearbox cannot change the gear ratio during the active drilling process. The gearbox also increases the length of the bottom of the drill string, which does not contribute to the drilling of inclined and horizontally branched wells.

The use of a surface frequency converter is impossible due to the capacitive component of the insulation resistance of the feeder system cable and does not lead to a decrease in the electricity losses during drilling [9].

The upgraded current lead system will include a controlled rectifier placed on the surface. The electricity from the rectifier will be transmitted to the submersible frequency converter (SFC), mounted directly above the electric drill, through cable cores, connected in parallel, and through the drill pipe column.

Accordingly, it becomes possible to adjust the rotation speed of the bit continuously and over a wide range, to reduce power losses in the drill pipe of the electric drill power supply system and to increase the reliability of the electric drive during the construction of wells [10].

Active power dissipation in the current lead of the AC power supply system, depending on the drilling depth

$$\Delta P_{AC} = I_r^2 (R_{sp\_pipe} \cdot l + 2R_{sp\_cable} \cdot l),$$

where  $I_r$  is rated current of electric drill motor;  $R_{sp\_pipe}$  is specific electrical resistance of the pipe;  $R_{sp\_cable}$  is specific electrical resistance of the cable;  $l$  is drilling depth.

Active power losses in the current lead of DC power supply system, depending on the drilling depth

$$\Delta P_{DC} = I_{DC}^2 \left( R_{sp\_pipe} \cdot l + \frac{1}{2} R_{sp\_cable} \cdot l \right), \quad (1)$$

where  $I_{DC}$  is rated current in DC link.

Let us express  $I_{DC}$  through  $I_r$ .

The apparent power in the current lead is equal to the motor power

$$S_{CL} = S_M. \quad (2)$$

We take into account that

$$S_M = \sqrt{3} U_r I_r; \quad (3)$$

$$S_{CL} = U_{DC} I_{DC}. \quad (4)$$

If we substitute (3) and (4) into (2), we get

$$U_{DC} I_{DC} = \sqrt{3} U_r I_r.$$

Therefore,

$$I_{DC} = \frac{\sqrt{3} U_r I_r}{U_{DC}}. \quad (5)$$

The level of DC voltage in the current lead is determined by the amplitude value of the sinusoidal AC voltage of the motor

$$U_{DC} = \sqrt{2} U_r. \quad (6)$$

From expressions (6) and (5) we obtain

$$I_{DC} = \frac{\sqrt{3} I_r}{\sqrt{2}}. \quad (7)$$

Substituting (7) in (1), we determine the active power loss in the DC link of the electric drill power supply system

$$\Delta P_{DC} = \frac{3}{2} I_{DC}^2 \left( R_{sp\_pipe} \cdot l + \frac{1}{2} R_{sp\_cable} \cdot l \right).$$

A comparison of the results of calculations of active power dissipation in the current lead of DC and three-phase AC power supply system of the electric drill is illustrated in Fig. 2.

The use of the DC link power supply system of the electric drill can significantly reduce power losses in the current lead. When drilling oil and gas wells in the Carpathian region at a depth of more than 2 km, the predicted decrease in power losses will be 25 %.

The supply voltage of the electric drill motor is an important indicator. Reducing the voltage drop in the current lead will allow works to be carried out at greater depth.

Since the resistance values of the cable and the pipe are different, the voltage drop is calculated separately in phases.

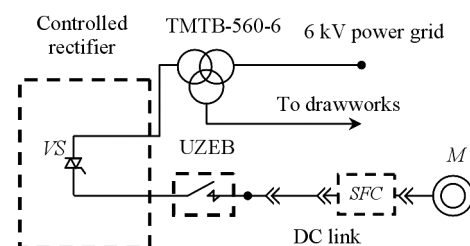


Fig. 1. Modernized power supply system of an electric drill with DC link

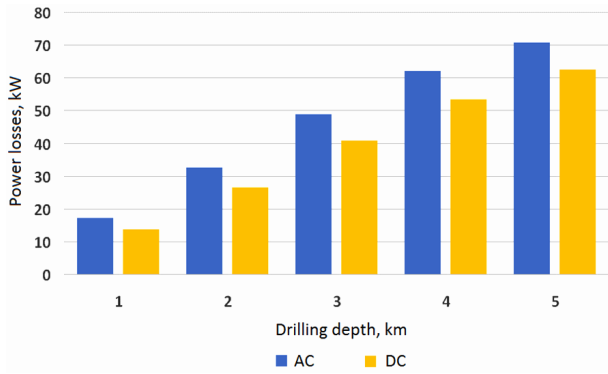


Fig. 2. Dependence of power dissipation in the current lead of DC and three-phase AC power supply system

Voltage drop in the current lead pipe of the AC power supply system depending on the drilling depth is

$$\Delta U_{AC\_pipe} \% = \frac{I_r I (R_{sp\_pipe} \cos \varphi + X_{sp\_pipe} \sin \varphi)}{U_{ph}} 100.$$

Voltage drop in the core of current lead cable of the AC power supply system depending on the drilling depth is

$$\Delta U_{AC\_cable} \% = \frac{I_r I (R_{sp\_cable} \cos \varphi + X_{sp\_cable} \sin \varphi)}{U_{ph}} 100,$$

where  $I_r$  is rated current of electric drill motor;  $R_{sp\_pipe}$  is specific electrical resistance of the pipe;  $R_{sp\_cable}$  is specific electrical resistance of the cable;  $X_{sp\_pipe}$  is specific electrical reactance of the pipe;  $X_{sp\_cable}$  is specific electrical reactance of the cable;  $I$  is drilling depth;  $U_{ph}$  is phase voltage.

Voltage drop in the current lead of the DC power supply system depending on the drilling depth

$$\Delta U_{DC} \% = \frac{I_{DC} \cdot \left( R_{sp\_pipe} + \frac{1}{2} R_{sp\_cable} \right) \cdot I}{U_{DC}}, \quad (8)$$

where  $I_{DC}$  is current in the DC link at rated load of the electric drill motor.

If we substitute (7) into (8), we get

$$\Delta U_{DC} \% = \frac{\frac{\sqrt{3}}{\sqrt{2}} I_r \left( R_{sp\_pipe} + \frac{1}{2} R_{sp\_cable} \right) I}{U_{DC}}.$$

A comparison of the results of calculations of voltage drop in the current lead of DC and three-phase AC power supply system of electric drill is illustrated in Fig. 3.

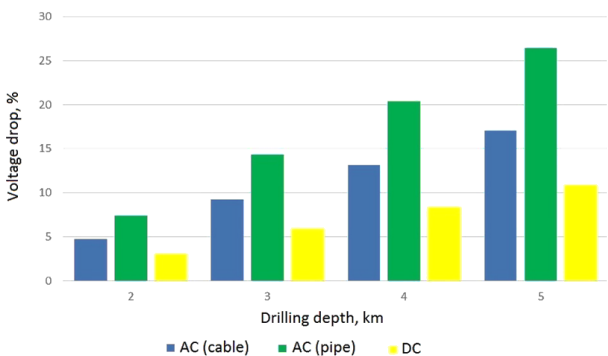


Fig. 3. Dependence of voltage drop in the current lead of DC and three-phase AC power supply system

The use of a DC link can significantly reduce the voltage drop in the current lead system.

**Conclusions.** Using the developed mathematical model of an electric drill power supply system with a DC link, the losses of active power and voltage in the current lead of existing and proposed electric drill power supply systems are determined by the calculation method.

The scientific and methodological base has been created for choosing a rational power supply system of the electric drill according to the level of active power and voltage losses in the current lead.

#### References.

1. Braslavskiy, I. Ya., Metelkov, V. P., Esaulkova, D. V., & Kostylev, A. V. (2017). Some peculiarities of the simulation of electric drives with random mode loading. In *Conf. Rec. 2017 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, 16–19 May 2017. St. Petersburg, Russia. <https://doi.org/10.1109/ICIEAM.2017.8076306>.
2. Braslavsky, I. Ya., Metelkov, V. P., Valtchev, S., Esaulkova, D. V., Kostylev, A. V., & Kirillov, A. V. (2016). Some Aspects of the Reliability Increasing of the Transport Electric Drives. In *IEEE Int. Power Electronics and Motion Control Conf. (PEMC)*, Sept 2016, (pp. 706-710). Varna, Bulgaria. <https://doi.org/10.1109/EPEPEMC.2016.7752080>.
3. Fedoriv, M. Y. (2017) Increasing reliability and energy efficiency of electric driven boring units. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (2), 93-98.
4. Plakhtiy, A. (2018). Analysis of power loss caused by higher harmonics in electrical supply systems. *Bulletin of NTU "KhPI". Series: New solutions in modern technologies*, 26(1302), 1, 126-134, <https://doi.org/10.20998/2413-4295.2018.26.18>.
5. Zaikin, D. I. (2015). Round and tubular wire skin effect modeling and usage SPICE as Maxwell's equations solver. In *23rd Telecommunications Forum Telfor (TELFOR)*, (pp. 650-653). <https://doi.org/10.1109/TELFOR.2015.7377551>.
6. Dias, R. A., Lira, G. R. S., Costa, E. G., Ferreira, R. S., & Andrade, A. F. (2018). Skin effect comparative analysis in electric cables using computational simulations. In *Simposio Brasileiro de Sistemas Eletricos (SBSE)*, (pp. 1-6). <https://doi.org/10.1109/SBSE.2018.8395687>.
7. Braslavskiy, I. Ya., Metelkov, V. P., Kostylev, A. V., & Esaulkova, D. V. (2017). Features of Electric Drive Simulation at Random Loading. *Bulletin of the South Ural State University. Ser. Power Engineering*, 17(1), 69-76. <https://doi.org/10.14529/power170110>.
8. SEMIKRON IGBT modules (n.d.). Retrieved from <https://www.semikron.com/products/product-classes/igbtmodules.html>.
9. Braslavsky, I. Ya., Metelkov, V. P., Valtchev, S., Esaulkova, D. V., Kostylev, A. V., & Kirillov, A. V. (2016). Some Aspects of the Reliability Increasing of the Transport Electric Drives. In *IEEE Int. Power Electronics and Motion Control Conf. (PEMC)*, Sept 2016, (pp. 706-710). Varna, Bulgaria. <https://doi.org/10.1109/EPEPEMC.2016.7752080>.
10. Motors in Random Mode Loading. In *23rd Int. Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*, June 2016, (pp. 447-451). Anacapri, Italy. <https://doi.org/10.1109/SPEEDAM.2016.7525821>.

### Система електропостачання електробура з ланкою постійного струму

М. Й. Федорів, І. В. Гладь, І. Д. Галушак,  
І. М. Михайлів

Івано-Франківський національний технічний університет нафти і газу, м. Івано-Франківськ, Україна, e-mail: [fedorivm@ukr.net](mailto:fedorivm@ukr.net)

**Мета.** Вибір раціональної системи електропостачання електробура на підставі оцінки втрат активної потужності та напруги в кабельній лінії.

**Методика.** Дослідження активних втрат у струмопроводах виконане на підставі використання теорії електричних кіл. Ретроспективними методами дослідження надійності основних елементів системи електропостачання електробура встановлені фактори, що впливають на його надійність і ефективність роботи. У результаті математичного моделювання в математичному редакторі Mathcad функціонування електротехнічного комплексу системи електропостачання електробура з ланкою постійного струму досліджено зміну втрат активної потужності й напруги при переході від системи «два проводи – труба» до системи з ланкою постійного струму «один провід – труба».

**Результати.** Досліджено вплив структури системи електропостачання електробура на рівень дисипації потужності та втрати напруги у струмопідводі під час буріння свердловин. Обумовлена необхідність переходу до системи електропостачання електробура з ланкою постійного струму «один провід – труба», що підвищить показники надійності та енергоефективності.

**Наукова новизна.** Уперше показано, що дисипація активної потужності та втрати напруги у струмопідводі до електробура з використанням системи електропостачання з ланкою постійного струму «один провід – труба», у порівнянні з існуючою системою електропостачання електробура, зменшуються, особливо при бурінні середніх і нижніх інтервалів свердловин.

**Практична значимість.** Створені математичні моделі дисипації активної потужності та втрати напруги у струмопідводі дозволяють визначати основні показники енергоефективності та експлуатаційної надійності системи електропостачання електробура та полегшити вибір економічного процесу буріння.

**Ключові слова:** *електробур, енергоефективність, електротехнічний комплекс, дисипація*

## **Система электроснабжения электробура со звеном постоянного тока**

*М. И. Федорив, И. В. Гладь, И. Д. Галушак,  
И. Н. Михайлив*

Ивано-Франковский национальный технический университет нефти и газа, г. Ивано-Франковск, Украина, e-mail: [fedorivm@ukr.net](mailto:fedorivm@ukr.net)

**Цель.** Выбор рациональной системы электроснабжения электробура на основании оценки потерь активной мощности и напряжения в кабельной линии.

**Методика.** Исследование активных потерь в токопроводах выполнено на основании использования теории электрических цепей. Ретроспективными методами исследования надежности основных элементов системы электроснабжения электробура установлены факторы, влияющие на его надежность и эффективность работы. В результате математического моделирования в математическом редакторе Mathcad функционирования электротехнического комплекса системы электроснабжения электробура со звеном постоянного тока исследовано изменение потерь активной мощности и напряжения при переходе от системы «два провода – труба» к системе со звеном постоянного тока «один провод – труба».

**Результаты.** Исследовано влияние структуры системы электроснабжения электробура на уровень диссипации мощности и потери напряжения в токоподводе при бурении скважин. Обусловлена необходимость перехода к системе электроснабжения электробура со звеном постоянного тока «один провод – труба», что повысит показатели надежности и энергоэффективности.

**Научная новизна.** Впервые показано, что диссипация активной мощности и потерь напряжения в токоподводе к электробуру с использованием системы электроснабжения со звеном постоянного тока «один провод – труба», в сравнении с существующей системой электроснабжения электробура, уменьшается, особенно при бурении средних и нижних интервалов скважин.

**Практическая значимость.** Созданные математические модели диссипации активной мощности и потерь напряжения в токоподводе позволяют определить основные показатели энергоэффективности и эксплуатационной надежности системы электроснабжения электробура и облегчить выбор экономичного процесса бурения.

**Ключевые слова:** *электробур, энергоэффективность, электротехнический комплекс, диссипация*

*Recommended for publication by V.S. Kostyshyn, Doctor of Technical Sciences. The manuscript was submitted 05.12.18.*