INCREASE OF ENERGY EFFICIENCY OF ELECTRICALLY DRIVEN DRILLING INSTALLATIONS BY VALORISING THE BRAKING REGIME OF THE DRAW WORKS UPON DESCENDING THE PIPE LINE

CREȘTEREA EFICIENȚEI ENERGETICE A INSTALAȚIILOR DE FORAJ ACȚIONATE ELECTRIC PRIN VALORIFICAREA REGIMULUI DE FRÂNARE A TROLIULUI LA COBORÂREA GARNITURII DE FORAJ

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Abstract: *The paper provides a method and, at the same time, a solution to increase the yield of electrically driven drilling machines by efficiently implementing the technological processes specific to hydrocarbon exploratory drill. It is known that one of these technological processes refers to the execution of deep drill wells (2000-10000 m) by using diamond system drilling installed on the top of a drill pipes driven by a draw works in repeated ascending - descending marches. If, upon ascending such columns, the primary energy is consumed, upon descending in the drilling process, a large amount of potential energy of the soil is lost for many of the drilling machines. This paper presents a method and a solution to use such potential energy in the braking process irrespective of the type of electrical drilling machines.*

Keywords: Energy, oil and gas, conversion, storage

Rezumat: *În lucrare este prezentată o metodă și în același timp o soluție de creștere a randamentului instalațiilor de foraj acționate electric prin valorificarea eficientă a proceselor tehnologice specifice forajului de explorare hidrocarburi. Se cunoaște că unul dintre aceste procese tehnologice este realizarea unor puțuri de foraj de mare adâncime (2000-10000m) cu ajutorul șapelor diamantate de foraj montate în vârful unei coloane de prăjini antrenate de un troliu în marșuri urcare – coborâre repetate. Dacă la urcarea acestor coloane se consumă energia primară, la coborâre în procesul de forare o mare parte din energia potențială a solului se pierde pentru foarte multe din instalațiile de foraj. Lucrarea de față evidențiază o metodă și o soluție de a*

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folosi aceasta energie potențială în procesul de frânare indiferent de tipul instalațiilor de foraj electrice.

Keywords: Energie, petrol și gaze, conversie, stocare

1. Introduction

The structure of the electrical drilling machines is of significant complexity, but the main components are:

- Source of energy, which can be:
  - Public voltage grid;
  - Sources consisting in diesel-generator groups on a common alternative voltage bar;
- Technological equipment consisting in:
  - Draw works;
  - Mud pump;
  - Rotary drive or top-drive systems.

We state that the entire technological equipment is driven by continuous current or alternative current engines with significant power (500-1000kW).

- Equipment of auxiliary service type consisting in pumps, ventilators, lighting, kitchen etc.

From energy perspective, the source-load transfer is materialized in a balance between the primary energy which can be received from the source of energy and the energy consumed by the load.

In case of electrical drilling machines, the primary energy is the electrical energy supplied by the public energy network and/or the isolated sources consisting in thermal groups-alternative current generators, and the energy consumed by the load consists in the mechanical work of electrical engines from the technological systems, and the energy consumed for the auxiliary services.

2. Braking the draw works in the process of electric exploration drilling

Figure no. 1 shows the schematic diagram of the draw works drilling in which the notes have the following significance:

m = mass of the drill pipes bearing the drill bit

M = draw works driving electrical engine; it can be continuous current or alternative current

g = gravitational acceleration

h = drill pipes height

s = electrical separator

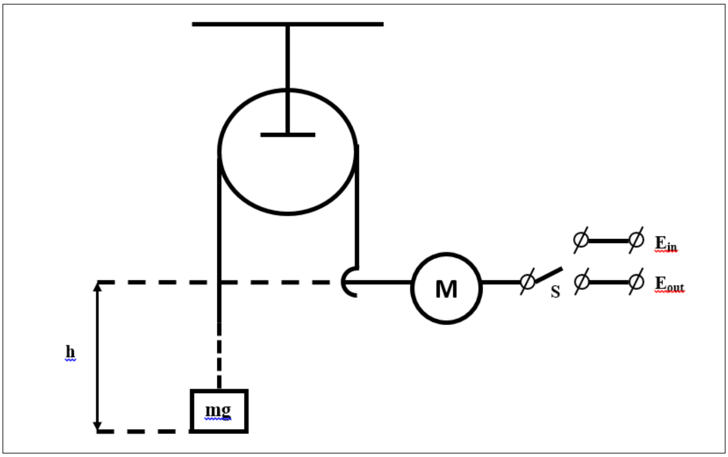

Figure 1. Principle diagram of the drilling draw works.

In the lifting regime of the mg weight of drill pipes, machine M works in engine regime, the energy necessary to the engine regime being provided by the primary energy source in point E_{in}.

In the descending regime of the mg weight of drill pipes, machine M shall be driven by the draw works cable operating as generator, if:

- ➢ The continuous current machine is excited by an external source of energy;
- ➢ The asynchronous machine has a rotation speed higher than the synchronism rotation speed.

If the rotating winding of the continuous current machine and the stator winding of the alternative current machine is not closed on a load, in other words, if the energy delivered by the generator is not consumed, machine M cannot be a brake for the draw works.

Otherwise, over 99% of the applications representing electrical hydrocarbon drill, draw works braking is done mechanically by using two methods:

- ➢ Mechanical braking with brake-bands on the engine shaft;
- ➢ Braking with electromagnetic brake with turbulent currents.

In both cases, braking energy is lost in the environment in the form of heat. Moreover, in such cases, material is lost, being necessary for it to be replaced on regular basis.

From quantitative perspective, based on an actual experience validated by practice, we can determine the braking energy upon descending the drilling tools, namely:

For an F400DEC drilling machine, we have:

m_{max} = 400t

m_{med} = 250t
h_{max} = 6000m
h_{med} = 4000m

Under these conditions, the potential energy upon descending the drilling tools is:

$$E_p = m \cdot g \cdot h = m_{med} \cdot g \cdot h_{med} = 250 \cdot 10^3 \text{ kg} \cdot 9.81 \ \frac{\text{m}^2}{\text{s}} \cdot 4000 \text{ m} = \quad = 9810 \cdot 10^6 \text{ J} \tag{2.1}$$

Considering that the power of the machines which form the draw works totalize approximately 1000kW, we can deduct that the time during which a draw works operates in descending regime, respectively the two machines totalizing 1000kW, shall operate in generating regime for $t_{average}$ equal to:

$$t_{med} = \frac{E_p}{P_M} = \frac{9810 \cdot 10^6 \text{ J}}{1000 \cdot 10^3 \text{ W}} = 9810 \text{ s} \tag{2.2}$$

In conclusion, it can be said that, during approximately three hours in the electrical drilling machines, 1000kW are lost in the drilling tool braking process.

3. Solution for energy efficiency during the operation of electrical drilling rigs

For the purpose of use occurred in machine M operating as generator upon descending the drilling pipe line, but also upon obtaining an increased redundancy for the methods of braking the drilling pipe line upon descending, we propose the following technical solution, a solution provided in Figure no. 2.

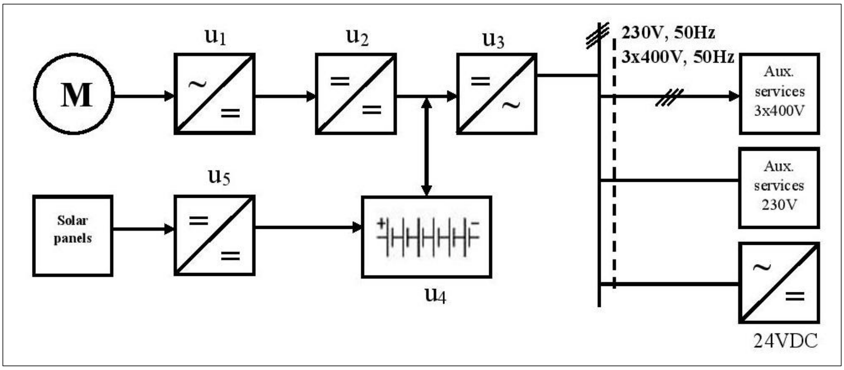

Figure 2. Solution for "braking" energy conversion into electricity:
u1 = ac/cc convertor; u2, u5 = cc/cc convertor; u3 = cc/ac convertor; u4 = battery.

The pipe line braking process is real if machine M operating as generator has a consumer from the auxiliary service area.

Moreover, we can say that we have real energy efficiency, if the energy obtained at the terminals of machine M is consumed within the area of the auxiliary services and, especially, if we provide all the energy necessary for the auxiliary services; therefore, we have chosen two supporting elements in the diagram provided in Figure no. 2:

- Battery u_4 which provides storage of surplus energy
- Photovoltaic plant in order to provide the energy requirement for the auxiliary services in case of a "braking" energy deficit.

4. Energy balance of the braking process upon descending the pipe line

According to the aforementioned aspects, the pipe line upon descending drives the electrical machine operating as generator. The voltage at the terminals of the machine is proportional with the speed for the continuous current machine and with asynchronous slide.

$$U_g = f(\Omega, s) \quad (4.1)$$

Considering that the uncontrolled movement of the pipe line upon descending is evenly accelerated, the descending speed is:

$$v_t = g \cdot t \quad (4.2)$$

It results that the voltage upon the outlet of the machine varies significantly; therefore, we have used the following constitutive blocks (see Figure no. 2).

- Rectifier u_1, irrespective of the machine, but strictly necessary if machine M is an alternative current machine, a uncontrolled rectifier at whose outlet, in point A, voltage U_A has the following value:

$$U_A = \sqrt{3} \cdot \widehat{U_e} \cdot \frac{6}{\pi} \cdot \sin\frac{\pi}{6} = 2.33U_e \quad (4.3)$$

- Continuous voltage regulator u_2, with the role of stabilizing U_A voltage, within the range necessary to charge battery u_4.

Considering that the voltage necessary for auxiliary services is 3x400V+Null, it results that the voltage in point B is:

$$U_B = U_C \cdot \sqrt{2} \ \pm 10\% = 565 \ \pm 10\% \cdot 656 \text{ V} \quad (4.4)$$

The power necessary for auxiliary services for F400DEC drilling machine is on average 1000kVA.

At an average power factor $PF_{average}$=0.8, it results that the active power requirement for auxiliary services is of 800 kW.

In chapter 2, we have shown that the average power of the machine while operating as generator is of 1000 kW, the difference of up to 800 kW being dedicated to charging the battery and maintaining it active to release energy for the auxiliary services during the period in which the draw works do not provide energy in braking regime.

Also, to ensure the energy regime in the absence of the braking energy, we have provided a photovoltaic plant which to provide for approximately 8h the energy for auxiliary services and for charging the battery. Due to technical reasons (space, transfer), the power of photovoltaic plant shall not exceed 120kW.

Under these conditions, for the power difference and emergent redundancy, it is necessary to also use a 1000 kVA 3x400 V, 50 Hz generator.

The capacity of the battery is chosen so that to ensure an approximately two hours autonomy for the supply of the auxiliary services at an average power of approximately 800 kW.

The final balance can be expressed as follows:

- Operation of auxiliary services at average power: 24 h;
- Operation of auxiliary services supplied with energy obtained upon braking the draw works: 3 h;
- Operation of auxiliary services supplied by the battery: 2h;
- Operation of auxiliary services supplied by the photovoltaic plant $\frac{120\text{ kW}}{800\text{ kW}} \cdot 8\text{ h} = 1.2\text{ h}$;
- Operation of auxiliary services independent from the primary source of energy: 6.2h;
- Relative operation of auxiliary services independent from the primary source of energy $\frac{6.2}{24} \cdot 100 = 25.83\%$;
- Knowing that the installed power represents the primary energy from four CAT 3512 groups of 1500kVA (1050kW), it can be said that the energy saving by introducing the above solution, expressed as a percentage of the total energy efficiency is:

$$\Delta E = \left(1 - \frac{4 \cdot 1050\text{ kW} - 0.2583 \cdot 1050\text{ kW}}{4 \cdot 1050\text{ kW}}\right) \cdot 100 = 6.46\% \qquad (4.5)$$

5. Costs, benefits

In order to estimate the depreciation of the investment regarding the implementation of the abovementioned solution, we initiate its conditions as follows:

- The average period for which a F400DEC machine drills at an average depth of 6000m is of approximately 18 months;
- The average power provided by the primary energy source is of 2412kW;

- The average diesel consumption in conjunction with the number of CPh is 170gr.

From the market study it turns out that the investment of implementing the solution described above amounts to the cost of 565,000 euros and implies the purchase of converters, photovoltaic power plant and battery accumulator.

Fuel costs are:

$$C_c = P_{med} \cdot D_{med} \cdot C_{med} = 2412\ \text{kW} \cdot 18\ \text{luni} \cdot \frac{30\ \text{zile}}{\text{luna}} \cdot \frac{24\ \text{h}}{\text{zi}} \cdot \frac{0.170\ \text{gr}}{\text{CPh}} \cdot \frac{5\ \text{lei}}{\text{l}} = = 8.856.864\ \text{euro} \tag{5.1}$$

Considering the above, the fuel savings due to the introduction of the proposed solution are:

$$\Delta C_c = 0.0646 \cdot C_c = 0.0646 \cong 572154\ \text{euro} \tag{5.2}$$

According to these calculations, it result that the period necessary for the depreciation of an investment for the integration of the proposed solution is the average time of work in a location, i.e. approximately 18 months. For an activity including several locations, the abovementioned calculation suggests that, starting with the 2nd location, the service provider shall save 6.46% on permanent basis.

6. Conclusions

In this paper, we have presented a technical solution for energy efficiency during the operation of electrical drilling machines, promoting one of the technological operations from the drilling process. For the equipment supplied by the public alternative voltage grid, the presented solution shall be limited to the recovery of the winch braking energy in the supply grid. For the solutions of supply by micro-power plants with electric generators, this is not possible. Today, over 95% of the electrically driven drilling machines are supplied by such power plants; therefore, the proposed solution can be part of these energy efficiency solutions, solutions which are increasingly requested in the industry.

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