Electric Submersible Pumps in Oil Production and Their Efficiency Analysis

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***Abstract*—The paper describes the structure of electricity consumption of electric submersible pumps. Analyzed the loss of all elements of the pumping unit: the motor, the cable line, transformer, control stations and pump. Discusses how to optimize power consumption of oil production.**

***Keywords:* electric submersible pump, submersible motor, power consumption, power, power loss, oilwell.**

I. Introduction

At the present time issues of energy and resource saving become especially actual in almost all industries. Fuel-power complex, which are engaged in extraction, preparation, transportation and refining of oil and gas are no exception [1]. Oil and gas companies are forced to develop and implement the whole complexes of energy-efficiency measures. Energy audit of all technological processes should be performed. This helps to identify units where the efficiency of the use of energy resources is not high enough and there is the potential for savings [2].

Optimization of well pumps operation allows not only to reduce energy consumption, but also extend the life cycle of electrical equipment [3][4][5].

With this purpose automatic systems for commercial accounting of power consumption have become widely implemented at the industrial enterprises, allowing continuous monitoring of the efficiency of energy consumption by equipment.

II. The Structure of the Electricity Consumption by at the Oil and Gas Companies

The structure of the energy consumption by oil and gas companies is shown in Fig. 1. The most energy-intensive technological process in all oil and gas industry is artificial oil lift by borehole pumps - up to 55 ... 62% of the total electricity consumption [6]. The main method of oil well operation is using of electric submersible pumps (ESPs). Over 54% of all wells in Russia operated by ESP, with these oil-wells about 75% of total oil is extracted [7]. Therefore, optimization of artificial oil production process of by using ESP can provide significant energy saving effect for the enterprise.

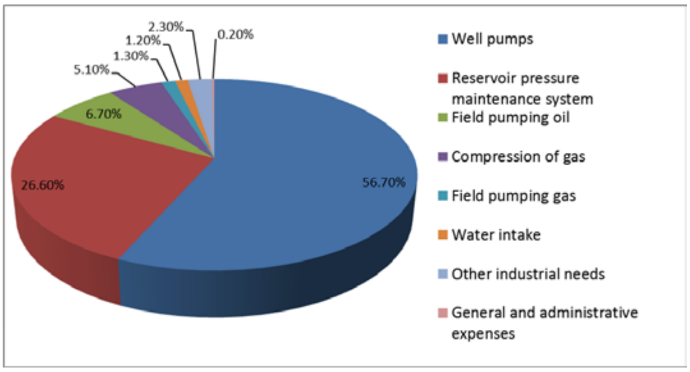

Fig. 1. The structure of the electricity consumption by various technological processes at the oil and gas companies.

III. Structure of Power Losses in Well Pump

It is necessary to analyze energy consumption by electrical drives of the submersible pumps to estimate efficiency of energy using during electricity consumption planning. For this purpose it is necessary to have a methodology for calculating the energy consumption depending on the installed equipment and technological parameters of the oilwell [8].

The structure of the electric power losses in ESP units is given in Fig. 2.

As seen in Fig. 2, the power consumption of ESP consists of useful power P_{UP} which is pump uses to lift the well fluid, as well as losses in all elements of the unit: in the pump ΔP_{CP}, in the upstream device ΔP_{UD}, in a wear sleeve ΔP_{WS}, in the submersible electric motor ΔP_{SEM}, in a cable line ΔP_{CL}, in a transformer ΔP_{TR}, in a control station ΔP_{CS}, in a line filter ΔP_{LF} and input filter ΔP_{IF} if any:

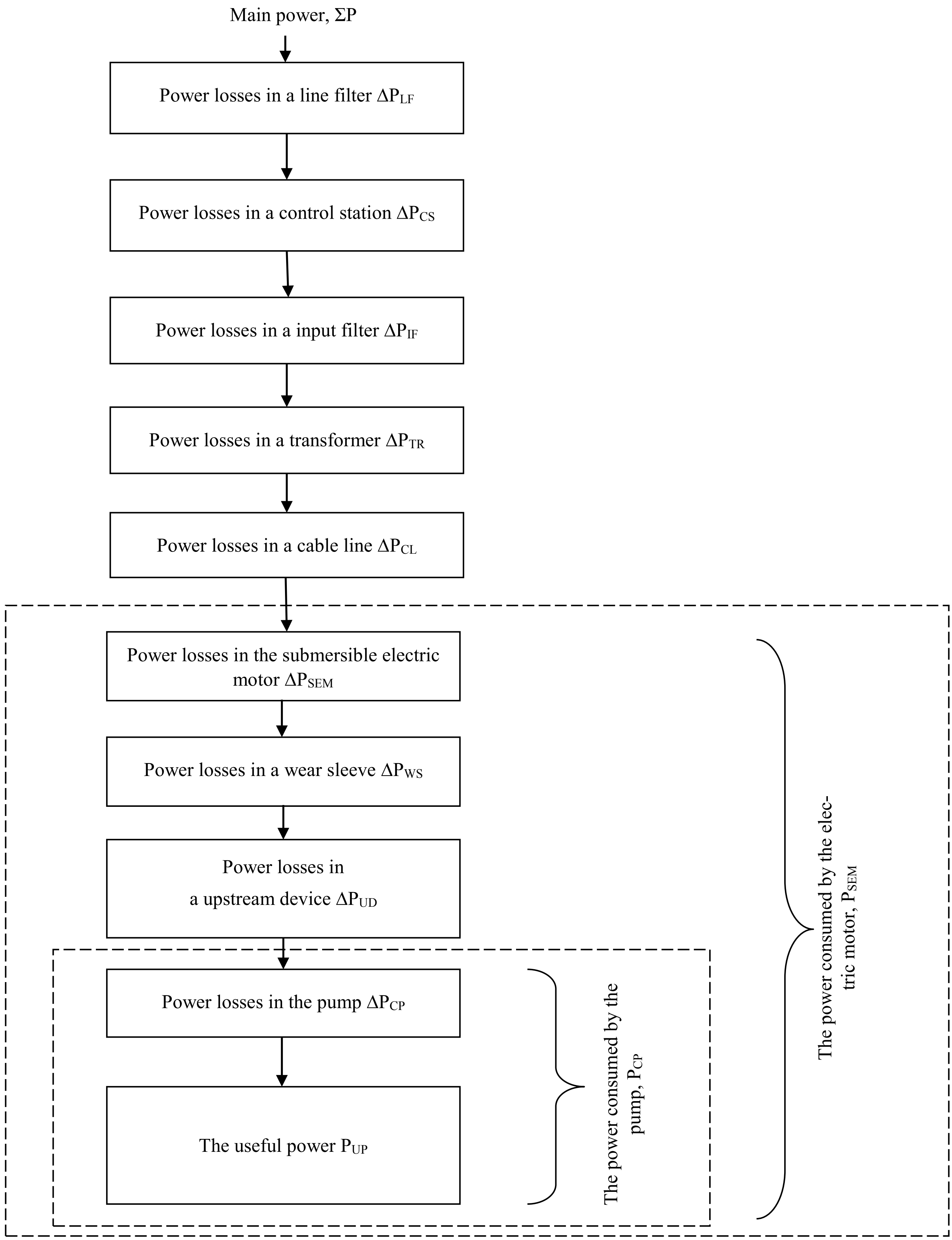

Fig. 2. Structure of power losses in ESP.

$$P_{\Sigma} = P_{UP} + \Delta P_{CP} + \Delta P_{UD} + \Delta P_{WS} + + \Delta P_{SEM} + \Delta P_{CL} + \Delta P_{TR} + \Delta P_{CS} + \Delta P_{LF} + \Delta P_{IF}. \quad (1)$$

The first five terms in the expression (1) form a power consumed by the motor:

$$P_{SEM} = P_{UP} + \Delta P_{CP} + \Delta P_{UD} + \Delta P_{WS} + \Delta P_{SEM}. \quad (2)$$

Useful power P_{UP} used by a pump to lift the well fluid depends on many factors: pump rate, liquid density, dynamic head, casing head pressure, annular pressure, hydraulic resistance of the CNT, saturation pressure, gas oil ratio and other [9]. Therefore, the accuracy in the calculation of useful power will depend on the completeness of available data on the parameters of the well and equipment operating mode.

Power loss in the pump ΔP_{CP} is determined by its coefficient of performance (COP). In this case coefficient of efficiency of the centrifugal pump varies depending on outflow performance, peaking in nominal mode. Therefore, for definition of coefficient of efficiency of ESP for this outflow performance necessary to use the pump characteristic.

The power loss in such elements as the upstream device ΔP_{UD}, the wear sleeve ΔP_{WS}, the control station ΔP_{CS}, line filter ΔP_{LF} and the input filter ΔP_{IF}, are taken from the work documents. In the absence of typical values based on the installed capacitance can be taken.

The losses in the electric motor ΔP_{SEM} are determined by its coefficient of efficiency, which varies depending on the load. The value of motor efficiency at a given load is on the running characteristic [10].

The power loss in the cable ΔP_{CL} comprise a significant part of total energy consumption in ESP. The power losses in the cable lines are proportional to the square of the current:

$$\Delta P_{CL} = \frac{1{,}732 \cdot \rho \cdot L_{CL} [1 + \alpha(t - 20)] \cdot I^2}{F}, \quad (3)$$

where ρ – electrical resistivity of the cable, Ohm·m (for copper $\rho = 0{,}0195 \cdot 10^{-6}$ Ohm·m); α – temperature coefficient of expansion of copper (for copper $\alpha = 0{,}0041$); L_{CL} – cable length, m; t – average temperature of the cable, ° C; I – operating current, A; F – area of cross-sectional, m^2.

Power losses in double-wound transformer formed from iron loss and copper loss:

$$\Delta P_{TR} = \Delta P_L + \Delta P_{CL} = \Delta P_L + \Delta P_{SC} \left(\frac{S}{S_{NOM}} \right)^2, \quad (4)$$

where ΔP_L – no load loss given in the published data, W; ΔP_{CL} – copper losses, W; ΔP_{SC} – short-circuit losses, given in the published data, W; S – power of transformer load, V·A; S_{NOM} – nominal power of the transformer, V·A.

IV. Results of Calculation of the Power Loss

Results of calculation of the power loss in ESP elements using formulas (1), (2), (3) and (4) for the well № 1608 are shown in Table 1. Fig. 3 shows a diagram of illustrating percentage distribution of power loss between the setup items. Note that in this configuration there are no filters well.

As you can see from the diagram in Fig. 3, the useful power that is consumed on lifting well fluid, is only 22.7% of the total power consumption of ESP. Thus the loss in the centrifugal pump (47% of total consumption) is more than two times higher than the useful power. This is due to the relatively low efficiency of the centrifugal pump at rate - 32%. Also, significant part of energy consumption in the ESP comprise the motor loss (12.3%), in the cable line (6.4%) and the transformer (7.5%). The power consumed by the wear sleeve and the losses in the control station can be considered small (1.9% and 2.0%).

Table 1 - Power lost to the elements of ESP installations for the well № 1608

The element, wherein the power loss	**Designation**	**Value**	
		kW	**%**
The useful power	P_{UP}	4,77	22,7
Losses in the pump	ΔP_{CP}	9,90	47,0
Power of the wear sleeve	ΔP_{WS}	0,40	1,9
The motor loss	ΔP_{SEM}	2,60	12,3
The losses in the cable line	ΔP_{CL}	1,36	6,5
The losses in the transformer	ΔP_{TR}	1,58	7,5
The losses in the control station	ΔP_{CS}	0,44	2,1
The total power consumption of the installation	ΣP	21,05	100,0

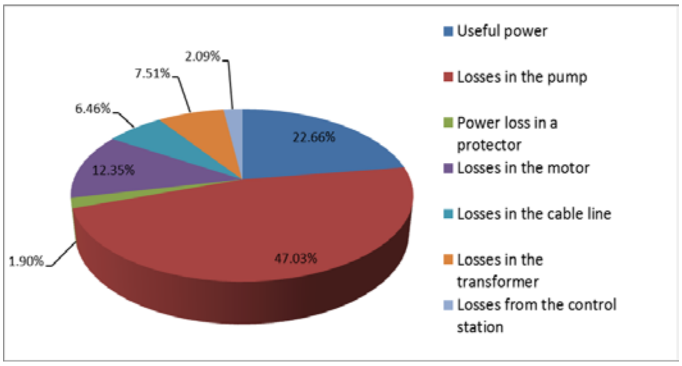

Fig. 3. Diagram of power losses on elements of ESP unit for the well № 1608.

V. Conclusion

The above distribution of power losses for the well № 1608 can be considered typical for wells operated by ESP. High electricity consumption for artificial oil lift of hydrocarbons crude are forced oil producers to look for ways to optimize energy consumption. The main areas of improvement of the ESP are the introduction variable-frequency drive, the use of the submersible telemetry units, and replacement of asynchronous motors at permanent magnet synchronous motor. Blocks submersible telemetry are transmitted to surface of the information about technological parameters on the bottom hole that allows to choose optimum operating mode for each a well. The permanent magnet synchronous motor have an efficiency of 6 ... 8% higher than asynchronous motors [11], that, respectively, reduces the losses in the motor, power consumption and current. By reducing the current is also declining and the remaining loss: in the cable, transformer and control stations.

An important factor of optimizing operating modes of ESP is using intelligent control stations with a controller [12].

Thus and so, can be drawn the following conclusions:

1. Artificial oil lift is the most energy-intensive technological process in oil and gas companies, and therefore has the greatest potential for the introduction of energy saving measures.

2. Among the methods of artificial oil lift most relevant to optimize the energy consumption is using of ESP, as this method is exploited most of the wells of the Russian Federation (over 54%), which provide up to 75% of all produced oil.

3. The useful power of ESP expended by on lifting wellbore fluid, is only 20 ... 25% of total consumption, while the losses in the centrifugal pump can reach 47% or higher. Also, considerable power losses occur in the electric motor (12%), of the cable line (6%) and the transformer (7%).

4. Reducing the power consumption of the motor reduces losses in the following elements: cables, transformers, control station due to the current reduction.

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