# Viability of using different types of main oil pipelines pump drives

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**Abstract.** The choice of the pumping units' drive of main oil pipelines is of great importance both for design of pipelines and for modernization of existing ones. At the beginning of oil pipeline transport development, due to the limited number and types of energy sources, the choice was not difficult. The combustion energy of the pumped product was often the only available energy resource for its transportation. In this regard, the pipelines that had autonomous energy sources favorably differed from other energy consumers in the sector. With the passage of time, with the development of the country's electricity supply system, the electric drive for power-line equipment of oil pipelines becomes the dominant type of a pumping station drive. Nowadays, the traditional component is an essential factor when choosing some type of the drive. For many years, oil companies have been using electric drives for pumps, while gas transport enterprises prefer self-contained gas turbines.

## 1. Introduction

The development of transportation of the most important energy sources, such as gas, oil and electricity, makes it possible to design transport networks for the particular region, the one that is most expedient. However, when choosing a particular type of the drive for pumping units, analysis is often not conducted, because there is no alternative to using the electric drive [1, 2].

At the moment, there is no specific method for choosing the type of the pump drive. Important factors that may determine the decision-making in some cases can turn out to be unsustainable in others. Variants of technical solutions suitable for one region are inappropriate for another. The drive type accepted for the object under commissioning may be irrelevant for the reconstructed object. Detailed technical and economic analysis, conducted in two parallel directions: the ratio of calculable factors and the analysis of qualitative characteristics, should serve as a basis for rational choice [6-9]. To achieve the result, it is necessary to collect the initial data, which can be conditionally divided into several categories (technical, economic, security parameters, etc.).

## 2. Materials and methods

There are many factors influencing the choice of a particular type of drive for main pumps, and they are different for each unique case. Often, none of the factors is dominant, and then there is a need to compare several factors. Analysis of all factors seems to be quite time-consuming, so it is advisable to begin with preliminary comparative calculations to exclude obviously unsuitable options [3].

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To determine the significant factors for selecting the pump drives, as well as their ranking, it was decided to use the expert evaluation method. In the case of application of the expert evaluation method, an analysis of their objectivity is topical. There are no guarantees that the obtained estimates are reliable. It is also possible to obtain similar results, if one takes into account the assessments of experts from one scientific community [4]. Therefore, there is a need to carefully select experts, rank them in detail, and also to analyze the results of the survey. There is also a problem of insufficient stability of the experts' evaluation, i.e. the same expert can assess the situation differently in another survey after a deeper discussion. In this case, the method of expert assessments "Delphi" helps to improve the effectiveness of the research. The method allows one to conduct a survey in several stages, providing feedback to experts, introducing them to the results of the first round of the survey. Consistency of opinions, as well as detailed group assessments in each of the survey rounds is achieved through a single format that preserves the composition of the expert group, the form of the questionnaires, and the methodology for processing the results [5].

Choosing the optimal parameters influencing the selection of the drive of the main pumps by the "Delphi" method (Fig. 1) was carried out in several stages.

At the first stage of the study, the problem was formulated - "The lack of a technique for choosing the drive of the pumping unit". Preliminary preparation was carried out: the existing types of drives of the main pumping units, the factors influencing the operation of different types of drives, the world experience of their use; the advantages and disadvantages of each of them were analyzed; the questions concerning the parameters having a significant influence on the choice of the optimal drive variant were indicated. Thus, possible options for solutions that could be adopted based on expert opinion were specified.

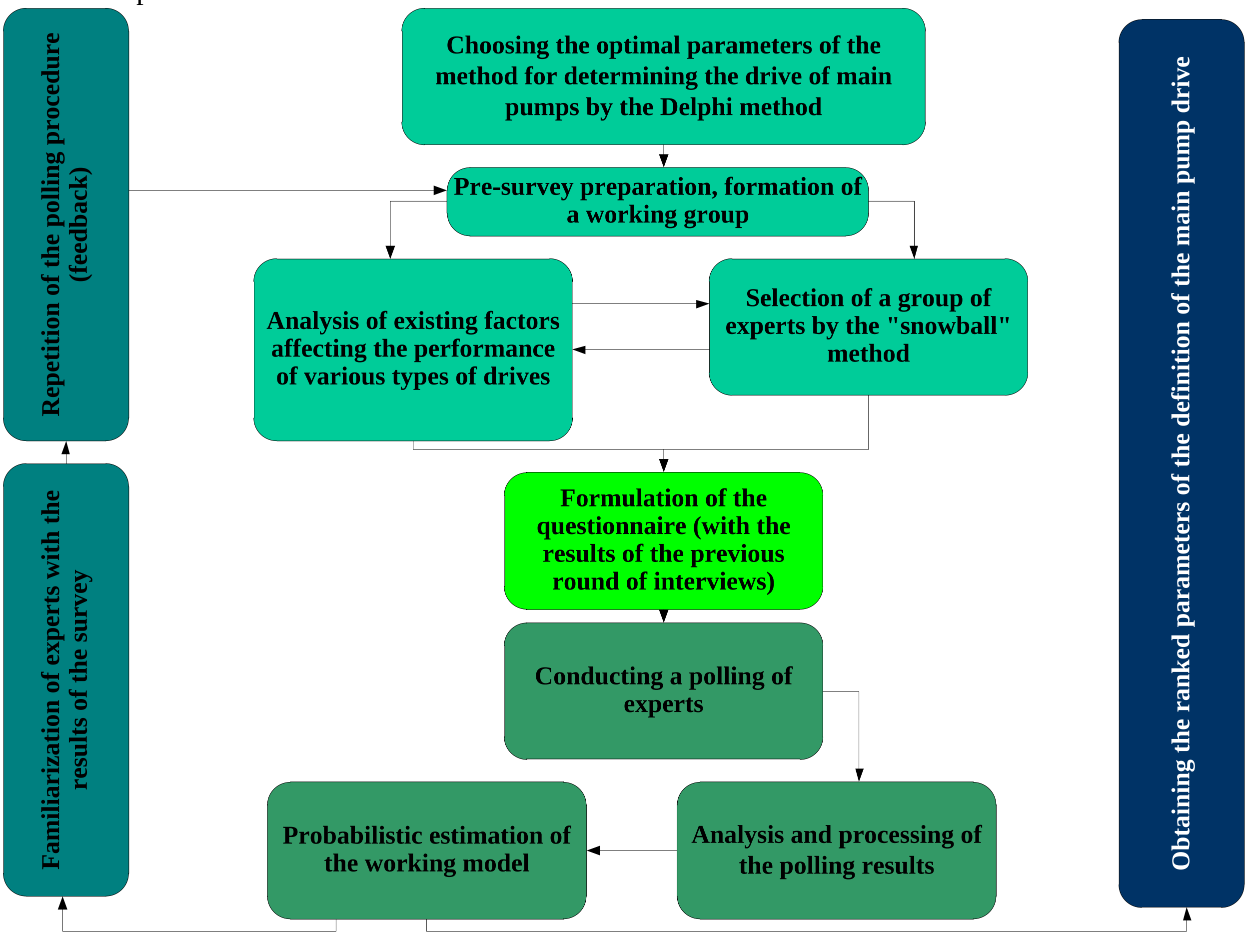


**Figure 1.** Diagram of the selection of optimal parameters by the "Delphi method"

The second stage was of an organizational nature. A group of specialists with professional polling and interviewing skills was formed. Questionnaires were prearranged, including the objectives and conditions of the survey, the procedure for processing results, evaluation criteria, and the use of survey results. At the same time, a group of experts was selected [10]. Specialists working in various oil transportation companies of the CIS (Russian Federation, Kazakhstan), specialists of design institutes, as well as the teaching staff of technical universities of the Russian Federation, were involved in the work. For the reliability of the results, specialists from various positions were involved in the work: from assistants to professors, from site masters to department heads. This allowed us to assess the situation "from different angles". The expert commission to obtain a qualitative result was formed by the method of co-nomination ("snowball method"). The essence of the method was that the first expert was asked to choose the three most competent specialists in the issue under consideration. The mentioned experts shared with the working group their list of three experts, etc. As a result, the commission selected 12 experts, whose names were often found in the questionnaire [11, 12].

At the third stage, the experts of the working group conducted a direct questionnaire. Then a statistical evaluation of the questionnaire was carried out, after which the experts were briefed on the result.

Expert analysis in the first round revealed 18 parameters (Table 1), having a significant influence on the choice of the optimal variant. The parameters were conventionally divided into four categories: functional, economic, safety parameters and infrastructure parameters.

**Table 1.** Pump unit drive choice parameters

| parameters | letters of references |
|---|---|
| **Functional parameters** | |
| Capacity utilization | P1 |
| Stability of modes | P2 |
| Failure statistics | P3 |
| Coefficient of extensive use | P4 |
| Mean time between failures | P5 |
| Coefficient of intensive use | P6 |
| Coefficient of starting frequency | P7 |
| **Economic parameters** | |
| Gas prices in the region | P8 |
| Electricity prices in the region | P9 |
| Payback period | P10 |
| Gas consumption | P11 |
| Electricity consumption | P12 |
| Cost of installation and operation of equipment | P13 |
| **Safety and environmental parameters** | |
| Equipment certification | P14 |
| Impact on the human body | P15 |
| Impact on the environment | P16 |
| **Infrastructure parameters** | |
| Distance to the nearest power source | P17 |
| Distance to the nearest gas supply source | P18 |

In the second round, it is proposed to rank the parameters for selecting the drive of the main pumping units according to the method proposed below.

Let $x$ experts evaluate $y$ objects with $z$ parameters. The result of the evaluation will represent quantities $Y_{h\,i}^{g}$, where $i$ is the number of the expert; $h$ is the object number; $g$ is the number of the comparison sign.

In the study, quantities $Y^{g}_{h\,i}$ ( $h$ = 1, 2… $y$ ; $i$ = 1, 2… $x$; $g$ = 1, 2… $z$) are scores. They are set by each expert individually.

In order to obtain a group estimate of each object, one can use the comparison formula:

$$Y_h = \sum_{g=1}^{z}\sum_{\text{ш}=1}^{x} q_{gi} Y^{g}_{h\,i} j_i \qquad (1)$$

where $q_{gi}$– the weights of the drive selection parameters;

$j_i$ – coefficient of the expert's competence.

Competence and weights coefficients are normalized values:

$$\sum_{g=1}^{z} q_g = 1; \quad \sum_{i=1}^{x} j_i = 1. \qquad (2)$$

The coefficients of the weights of the parameters are determined expertly. If $q_{gi}$ is the weight factor of the $g$-th parameter given by the $i$-th expert, then the average weight coefficient of the $g$-th index for all experts is equal to:

$$q_g = \sum_{i=1}^{x} q_{gi}\, j_i\ . \qquad (3)$$

Expert competence factors can be calculated from the evaluation of the objects. Given that the expert competence should be evaluated by the degree of consistency of their assessments with the group assessment of the object, the algorithm for calculating the competence coefficients of experts will take the form:

$$Y^t_h = \sum_{i=1}^{x} Y_{h\,i}\, j_i^{t-1} \quad h = 1,2 \dots y\ ; \qquad 4$$

$$\lambda^t = \sum_{h=1}^{y}\sum_{i=1}^{x} Y_{h\,i}\, Y^t_h \quad t = 1,2 \dots\ ; \qquad (5)$$

$$z^t_i = \frac{1}{\lambda^t}\sum_{h=1}^{y} Y_{h\,i} Y^t_h \quad i = 1,2 \dots x\ . \qquad (6)$$

The authors begin the calculation with t = 1. The initial values of the competence coefficients are assumed to be the same and equal to $j^0_i = \frac{1}{x}$.

At first approximation, the group estimate is:

$$Y^1_h = \frac{1}{x}\sum_{i=1}^{x} Y_{h\,i} \quad h = 1,2 \dots y\ ; \qquad 7$$

normalizing coefficient is:

$$\lambda^1 = \sum_{h=1}^{y}\sum_{i=1}^{x} Y_{h\,i}\, Y^1_h\ ; \qquad (8)$$

expert competency coefficient in the first approximation:

$$j^t_i = \frac{1}{\lambda^1}\sum_{h=1}^{y} Y_{h\,i} Y^1_h\,. \qquad (9)$$

The ranking of experts is planned to be carried out in accordance with the weighting factors (Table 2).

**Table 2.** The weighting coefficients of experts

| Indicators | weighting coefficient | | |
|---|---|---|---|
| Academic degree | Without a degree | Candidate of Sciences (PhD) | Doctor of Science |
| | 0 | 0,5 | 1 |
| Work experience in the sphere of an electric drive use | X =n/N | where x – weighting coefficient<br>n - expert's work experience<br>N – experience of the most experienced expert in the sphere | |
| Work experience in the use of a gas turbine drive | X =n/N | where x – weighting coefficient<br>n - expert's work experience<br>N – experience of the most experienced expert in the sphere | |
| Availability of scientific works of Higher Attestation Commission (VAK), SCOPUS, WoS for the last 5 years | None | Up to 5 articles (inclusive) | Over 5 Articles |
| | 0 | 0,5 | 1 |

**3.Conclusion**

Thus, the ranking of the parameters for selecting the drive of the main-unit pumps should form the basis of the methodology, which in turn will allow rational selection of the most economically, technically advantageous types of drives based on the initial parameters.

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