Simulation model of the electrical complex of auxiliary equipment of an oil and gas production enterprise

D Nurbosinov, T Tabachnikova, R Bashirov, R Bashirov* and Alexander Batanin

Department “Electrical and thermal power engineering”, Almetyevsk State Oil Institute

* E-mail: bashirovramil95@gmail.com

Abstract. In this article we define the problem, formulate the theme and justify the relevance of the tasks to be solved, which depend on the object under study. The object under study was determined and the structure and basic elements were analyzed. It was found that an auxiliary transformer and from eight to ten outgoing lines are connected to one section of bus of a power transformer of the field substation. Mathematical models of electrical systems of a field substation and a pumping station for transporting oil flows with shop transformers, individual, node and centralized compensating installations have been developed. In mathematical models which take into account the change in the volume of transported oil into a common pipeline, asynchronous electric motors of pumping units with a capacity of 75, 132 and 160 kW with low-voltage frequency converter are considered. Using the MATLAB Simulink software package, we developed mathematical models for 75, 132 kW (132 and 160 kW) electric drives of pumping units. These models take into account emergency operation, i.e. when two pumping units operate from the same power source. The study of the operating modes of the electrotechnical complex of a booster pump station during direct start-up from the electrical network was carried out using its simulation model developed in the PSCAM software package. The article presents the simulation results in the form of graphs showing relationships between frequency buildup, electromagnetic and dynamic moments and the stator current of the asynchronous motor. Scientific novelty of the present work is in the developed mathematical and simulation models which take into account parametric perturbations in external and internal distribution electrical networks, and allow one to determine the energy parameters of operating modes in all sections and elements of the outgoing line, taking into account reactive power compensation in transient and steady-state conditions.

1. Introduction

This article is aimed to develop a mathematical and simulation model of the electrical engineering complex of auxiliary equipment of an oil and gas producing enterprise in order to optimize its operating modes and increase its energy efficiency.

The object of research is electrical engineering complex of auxiliary equipment of an oil and gas producing enterprise: a pumping station for transporting super-viscous oil (SVO) and high-sulfur oil (HSO) flows. Figure 1 shows the scheme of electrical complex of a field substation (ECFS) [1,2,7,15], from which the object under study receives power. This complex consists of electrical complexes of the enterprise (ECE) and auxiliary equipment (AE), which are powered from two sections of 10 kV busbars. AE is a pumping station for the transportation of SVO and HSO flows through a single pipeline over a distance of 15 km. The pumping station is equipped with four pumping units with low-
voltage frequency converters and asynchronous motors AM1 is 75 kW, AM2 and AM3 are 132 kW, AM4 is 160 kW and voltage of 0.4 kV [4, 8-11], which are connected to two step-down power transformers TM - 630/10/0.4 kV. The mode of operation of pumping units is in pairs from different transformers T3 and T4 (Table 1).

| Variant  | SVO – AM-75 kW | HSO – AM-132 kW |
|----------|----------------|-----------------|
| Variant 1| SVO – AM-132 kW| HSO – AM-160 kW |

Optimization of mode of voltage and power consumption of electric drives of pumping units provides development of mathematical and simulation models of these units. Figure 2 shows the MATLAB Simulink mathematical model of electric drives of pumping units when operating in emergency mode, i.e. when two pumping units operate from the same power source. With the help of this mathematical model, the quality of AE functioning is investigated, which includes electric drive of a pumping unit with low-voltage frequency converter with varying supply voltage and with changing of technological process. The mathematical model takes into account the process of changing the volume of SVO transportation and its temperature, as well as deviation (drops) of voltage in the distribution electric network up to 40% with a duration of 3-10 seconds [1,2,3].

Similar studies were carried out with mathematical models of electric drives of pumping units with engine capacities of 75 and 160 kW.

As a result of mathematical modeling, we obtained graphs showing relationships between frequency buildup, electromagnetic and dynamic moments and stator current (Fig. 3) of an induction motor.
Analysis of time-dependences of current of asynchronous motors stator with a power of 75, 132 and 160 kW showed that these engines are averagely loaded approximately by 61% relative to the rated currents. The starting current ratio of asynchronous motors is in the range from 5.17 to 6.35, which fully satisfies the nominal values. From the obtained dependencies of stator currents of asynchronous motors with a power of 75, 132 and 160 kW, it was established that all asynchronous motors started in a time interval of 26-35 seconds.

Figure 4 shows the simulation model of AE, developed using the PSCAM software package. This model was used to study the AE operating modes in stationary conditions, when the low-voltage frequency converter is not actively involved in the work or when it is in failure, and electric drives of the pump units are started directly from the electric network. This AE simulation model allows one to take into account the parameters of all compensating units (CU) and determine the energy parameters in all parts of the complex electrical connections. It also allows one to explore the process of starting the electric drive of pumping units (Figure 5 and 6) with voltage drops in the distribution electrical network.
Similar studies were carried out for simulation models of electric drives of pumping units with engines of 75 and 160 kW. Simulation modeling was carried out for a voltage drop of 30% in a distribution electrical network with a 3 s duration [1.5-7.12]. As a result of simulation modeling, we obtained graphs showing relationships between frequency buildup, electromagnetic and dynamic moments (Figure 5) and stator current (Figure 5 and 6) of AM [13,14].

Analysis of dependencies of the supply line current of an asynchronous motor with a power of 132 kW (Figure 6) showed that this motor, in the absence of an individual CU, is loaded averagely by 79%, and when taking into account the CU, it is loaded by 71% relative to the rated current. When using an individual CU, the supply line current is reduced by 8%. The electromagnetic moment and the moment of resistance in the steady state is 0.7 (Figure 5). The ratio of starting currents of AM is in the range of 4.0-4.26 at steady-state currents of 200 A and 185 A (Figure 6), which fully satisfies the nominal values.

Figure 4. Imitation model of 132 kW AM without individual CU (a) and with individual CU (b).

From the plots of 132 kW AM stator current, it is seen that with an individual CU, the engine starts in 9.5 seconds, and with CU it starts in 8.5 seconds. (Figure 6).
Figure 5. Graphs of dependences of voltage and current of the stator, electromagnetic moment and moment of resistance of 132 kW AM without an individual CU (a), and with an individual CU (b).
Figure 6. The graphs of dependencies (from top to bottom) of voltage at CU terminals, of supply voltage and voltage on the stator winding, the stator current, active and reactive power consumed by the 132 kW AM without an individual CU (a), and with an individual CU (b).

2. Conclusions
Scientific novelty of the proposed work are in the developed mathematical and simulation models which take into account disturbances in external and internal distribution electrical networks and allow one to determine the energy parameters of the operating mode in all areas and elements of the outgoing line, taking into account individual, node and centralized compensating installations in transient and steady-state modes.

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