Construction principle of automatic control system adjustable multi-engine drive water lift pump unit

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Abstract. The article discusses the issues of the principle of constructing an automatic control system for a multi-motor controlled electric drive with an electrical connection along the rotor chain of asyn-chronous electric motors with phase rotors and a common inverter by a driven network to control the technological process of water supply of pumping units as part of a water-lifting pumping unit. The expediency of constructing a system for automatic control of the frequency of rotation of the drive motors of a pumping unit in the form of a digital electric drive, implemented through a subordinate control system, is disclosed.

1 Introduction

In the practice of operating water-lifting pumping units (PU) equipped with the same type of AC electric drives, the most commonly used options for the structural layout of a group of pumping units (PU) for joint parallel operation in a common pressure pipeline (hydraulic pressure network). At the same time, a reduction in the cost of electrical energy and the rational use of water resources can be achieved with the help of an adjustable multi-engine electric drive, due to a consistent and proportionate change in the speeds (frequencies) of rotation of the pumping station of the water-lifting pump [1-3].

The most promising and fully meeting the requirements for a controlled electric drive system, in relation to water-lifting pumps, can be considered a multi-motor electric drive with electrical coupling (MEDEC) along a rotor circuit with a common grid-driven inverter (CGI), in which the sliding energy of the rotor circuit is transferred (returns) to the network [4].

2 The current state of the investigated problem

In order to provide the PU of the machine water lifting system (MWS) with the required supply, the following options for constructing a closed-loop automatic control system (ACS) for a multi-motor electric drive with electrical communication and a common inverter driven by a network can be applied:

- frequency of rotation of drive motors;
- consumption of each of the functioning pumping units (PU) as a part of pumping station;
- total flow rate of the common pumping system of pumping station;
- the level of the tailwater in the intake structure of the pumping station (PS);
- the options listed above or combinations thereof.

The most simple and convenient in its practical implementation is a closed automatic control system in terms of rotation frequency [5]. However, its application was difficult due to the ambiguity of the relationship between the performance of the NA and its rotational speed, which was expressed in the absence of a specific analytical dependence of the form:

$$Q = f(n, H_{CT}, N, H).$$

The mathematical descriptions of the electromechanical ratios of a multi-motor electric drive with electrical coupling along a rotor circuit proposed in the article in the mode of coordinated rotation of the drive electric motors of the PU make it possible not only to establish the indicated dependence, but also to determine, under the given operating conditions, the optimal value of the speed of rotation of the PS, ensuring that the most energy- and resource-saving modes of operation of PU MWS [6-9].

In our opinion, it is expedient to construct an automatic control system for the frequency of rotation of the drive electric motors of the PU MWS in the form of a digital electric drive (DED) implemented using a slave control system (SCS). The principle of STC is that the external control loop of a certain coordinate (for

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example, speed) is subordinated to the internal control loop (for example, current). Moreover, in one system there can be several subordinate circuits. The advantages of building a system according to the SCS principle in relation to the possibilities of forming the required static and dynamic modes, coordinate restrictions, ease of adjustment are well known, and a number of electric drive systems implemented according to the SCS and their operating modes are widely considered in the literature [10-13].

In our case, it makes sense to use an autonomous digital processor, in which a digital computer machine (DCM) serves only as a source of input information, and digital correction is carried out by a special device that operates autonomously with respect to the digital computer. It is known that in a non-autonomous digital converter, the input receives a control signal, which is a mismatch error and generated by a digital computer, which simultaneously performs the functions of a master device, a comparison element and a digital corrective device [14-17].

However, we chose an autonomous DED as an adjustable electric drive of the PU MWS for a number of reasons. First, the dynamics of the operation of non-autonomous DEDs is directly determined by the frequency of information output from the digital computer, while autonomous DCMs are in a certain sense invariant to this frequency. Secondly, in non-autonomous DEDs, it is more difficult to control the parameters in the process of their control and adjustment, because of which the electric drive system of the PU MWS turns out to be possible to check only in combination with a digital computer. Autonomous DED requires less machine time. In addition, one of the main reasons is the fact that, according to the conditions of the technological process of water supply by the SSW pumping station, the water flow provided by it varies discretely depending on the number of working PUs in the PS, which at its stages, with unit-by-unit control of the supply, can invariably remain quite for extended periods of time, and even throughout the entire work shift. Then it is enough for the duty personnel of the pumping station only, in accordance with the water supply schedule and the energy-saving and resource-saving regime map, of the operation of the PU MWS or, by the product of the current change in the number of functioning pumps, to enter from the keyboard into the computer data on the values of the steady state operation mode of the PU according to the readings of the instruments. After that, the digital computer calculates the value of the optimal rotational speed using the developed software and outputs it in the form of a task signal [18-21].

The proposed ACS consists of digital and analog parts. The functional diagram of the specified ACS, which ensures the stabilization of the speed of rotation of the drive electric motors of the PU in the composition of the PS MWS and the equality of its optimal value, as well as that determined by the task signal, is shown in fig. 1.

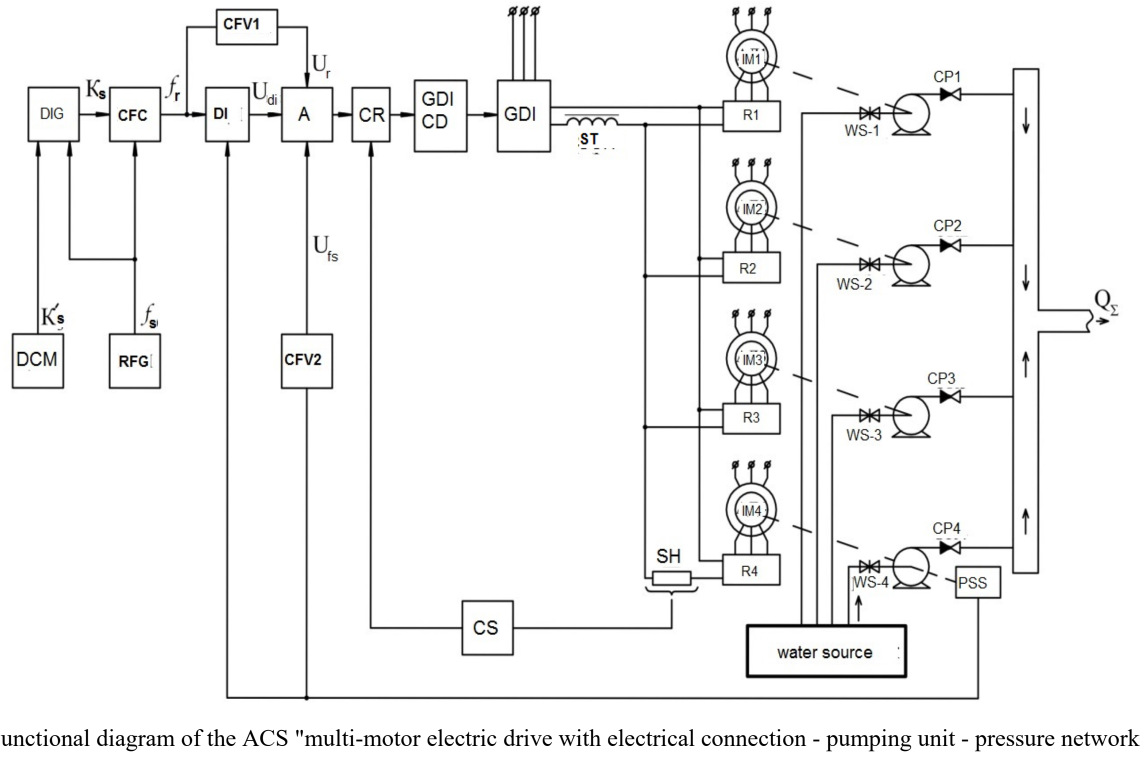

Fig. 1. Functional diagram of the ACS "multi-motor electric drive with electrical connection - pumping unit - pressure network"

Setting the speed (frequency) of rotation of the K'_s in numerical form is fed to the input of the digital intensity generator (DIG), designed to generate signals for the acceleration and deceleration modes of the electric drive. The reference frequency f_r from the reference frequency generator (RFG) is also supplied to the input of the DIG. The DIG has a numerical output short circuit signal, quantized only by level, as a result of which it does not disturb the control system in the steady state. The command of the speed (frequency) of rotation of the K'_s in numerical form is fed to the input of the digital intensity generator (DIG), designed to generate signals for the acceleration and deceleration modes of the electric drive. The reference frequency f_r from the reference frequency generator (RFG) is also supplied to the input of the DIG. The DIG has a numerical output short circuit signal, quantized only by level, as a result of which it does not disturb the control system in the steady state. The principle of operation and the design of the DIG are considered in detail in. The "code-frequency" converter (CFC) converts the number of short circuits into the frequency f_s, which determines the steady rotation speed of the drive electric motors of the PU. A digital integrator (DI) and an analog proportional link combined with an analog adder make up the speed controller (SC). The reference voltage U_r is formed from the frequency f_r by means of a frequency-voltage converter (CFV1). The input of the adder also receives the output voltage from the digital integrator U_r and the feedback signal U_{fs}, which is formed from the frequency f_{fs} of the pulse speed sensor (PSS) using a frequency-to-voltage converter (CFV2). The PSS generates a speed deviation signal at the output in the form of a continuous sequence of pulses, the instantaneous frequency of which is proportional to the instantaneous speed of the sensor. The error level of the IDS is much lower than in tachogenerators, which makes it possible to ensure the most accurate coincidence of the speed of rotation of the drive electric motors of the PU with the given one [22].

The internal loop of the SPU is a current control loop in which the feedback signal is fed to the current regulator (RT) from the shunt (Sh) installed in the circuit of rectified rotor currents of induction motors (AM) by means of an analog current sensor (DT). Since in the considered MEDEC system with a common CGI, the drive electric motors of the PU and the parameters of their rotor circuits are identical, and the rotational speeds of the IM, due to the principle of constructing this system, which ensures their coordinated rotation, are maintained the same, the shunt (SH) can be installed in the circuit rectified rotor current of any of the IMs with an PSS mounted on its shaft [23]. At the same time, this IM will be the drive electric motor of the first-sequence PU, which is constantly in operation as part of the PU MWS. The diagram (Pic. 1) also shows the control unit for the inverter driven by the network (GDICD), the inverter itself driven by the network (GDI), smoothing throttle (ST), centrifugal pumps (R1 - R4) complete with drive electric motors ON (IM1 - IM4) and their uncontrolled bridge rectifiers (CP1 - CP4) [24-28].

3 Conclusion

Thus, the proposed SCS consists of two circuits: the internal one is the current regulation circuit, the external one is the regulation of the speed of rotation of the drive electric motors of the PU. In this case, the speed and current controllers are PI - controllers. The resulting doubly integrating speed control system provides astatic characteristics in terms of control and disturbing influences.

References

1. K.Abidov, N.Khamudkhanova. E3S Web of Conferences, 216, **01111**, (2020), https://doi.org/10.1051/e3sconf/202021601111
2. K.G.Abidov, and ofters. E3S Web of Conferences, 289, **07004**, (2021), https://doi.org/10.1051/e3sconf/202128907004
3. K.G.Abidov, O.O.Zaripov, and ofters. AIP Conference Proceedings, 2552, **030022**, (2022), https://doi.org/10.1063/5.0112384
4. K.G.Abidov, O.O.Zaripov, and ofters. AIP Conference Proceedings, 2552, **030023**, (2022), https://doi.org/10.1063/5.0112385
5. N.Khamudkhanova, and ofters. AIP Conference Proceedings 2402, **060016,** (2021), https://doi.org/10.1063/5.0071557
6. R.Karimov. AIP Conference Proceedings, 2552, **030014**, (2022). https://doi.org/10.1063/5.0111533
7. R.Karimov. AIP Conference Proceedings, 2552, **050012**, (2022). https://doi.org/10.1063/5.0111524
8. S.Dzhuraev, R.Karimov, and ofters. ElConRus, (2022), pp. 1166-1169, doi: 10.1109/ElConRus54750.2022.9755782
9. R.Karimov, A. Kuchkarov, and ofters. Journal of Physics: Conference Series 2094, **052050**, (2021). doi:10.1088/1742-6596/2094/5/052050
10. R.Karimov, N.Kurbanova, and ofters. Journal of Physics: Conference Series 2094(5), **052042**, (2021). doi:10.1088/1742-6596/2094/5/052042
11. K.G.Abidov, O.O.Zaripov, and ofters. E3S Web of Conferences, 289, **07003**, (2021), https://doi.org/10.1051/e3sconf/202128907003

12. K.G.Abidov, O.O.Zaripov, and ofters. E3S Web of Conferences, 216, **01110**, (2020), https://doi.org/10.1051/e3sconf/202021601111
13. K.G.Abidov, O.O.Zaripov. E3S Web of Conferences, 139, **01088**, (2019), https://doi.org/10.1051/e3sconf/201913901088
14. E.Kh.Abduraimov, D.Kh.Khalmanov. Journal of Physics: Conference Series, 2373(7), **072010,** (2022), DOI 10.1088/1742-6596/2373/7/072010
15. E.Kh.Abduraimov. Journal of Physics: Conference Series, 072009, 2373, (2022), DOI 10.1088/1742-6596/2373/7/072009
16. E.Abduraimov, M.Peysenov, N.Tairova. AIP Conference Proceedings, 2552, **040012**, (2022), https://doi.org/10.1063/5.0116235
17. E.Kh.Abduraimov, D.Kh.Khalmanov. Journal of Physics: Conference Series, 2094(2), **022072**, (2021), DOI 10.1088/1742-6596/2094/2/022072
18. E.Kh.Abduraimov, D.Kh.Khalmanov, and ofters. E3S Web of Conferences, 289, **07026**, (2021), https://doi.org/10.1051/e3sconf/202128907026
19. E.Kh.Abduraimov, D.Kh.Khalmanov. E3S Web of Conferences, 216, **01106**, (2020), https://doi.org/10.1051/e3sconf/202021601106
20. E.Kh.Abduraimov. E3S Web of Conferences, 216, **01105**, (2020), https://doi.org/10.1051/e3sconf/202021601105
21. E.Kh.Abduraimov, D.Kh.Khalmanov. Journal of Physics: Conference Series, 1515(2), **022055**, (2020), DOI 10.1088/1742-6596/1515/2/022055
22. K.G.Abidov, A.K.Nuraliev, and ofters. Journal of Advanced Research in Dynamical and Control Systems, **12(7)**, pp. 2167-2171, (2020).
23. A.K.Nuraliev, and ofters. E3S Web of Conferences, 216, **01108**, (2020), https://doi.org/10.1051/e3sconf/202021601108
24. M.Ibadullaev, A.Nuraliev, A.Esenbekov. IOP Conference Series: Materials Science and Engineering, 862(6), **062031**, (2020), DOI 10.1088/1757-899X/862/6/062031
25. S.Begmatov, D.Khalmanov, and ofters. AIP Conference Proceedings, 2552, **040011**, (2022), https://doi.org/10.1063/5.0130666
26. Kh.G.Karimov, M.K.Bobozhanov. Elektrichestvo, **1**, pp. 27-32, (1996).
27. M.K.Bobojanov, S.Mahmutkhonov, and S.Aytbaev. AIP Conference Proceedings 2552, **050011,** (2023), https://doi.org/10.1063/5.0113890
28. M.Bobojanov. AIP Conference Proceedings 2552, **050034**, (2023), https://doi.org/10.1063/5.0114077