**DOI** *10.18454/PMI.2016.5.701*

UDC 629.563.2

# DEVELOPMENT EXPERIENCE AND DEVELOPMENT PROSPECT OF ELECTROMECHANICAL TECHNOLOGICAL COMPLEXES OF MOVEMENT AND POSITIONING OF TECHNIC SHELF DEVELOPMENT EQUIPMENT

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From the example of active semisubmersible drilling rigs it is shown characteristics of electromechanical complexes of drill rigs and anchor position control systems on the base of controlled electric drive with direct-current motors.

It is presented suggestions which allow increasing electric power and service reliability criteria through the use of semiconductor converters supplied from power semiconductor converter with active front end in technological drilling systems, propulsion and position control systems of electromechanical systems on the base of noncontact asynchronous motors. It is outlined information about experience of using such kind of electromechanical complexes at the objects of mining industry working in difficult operating conditions.

It is presented information about developing of electromechanical complexes of displacement systems, position control systems, technological and technical shelf development equipment and their characteristics. Also it is outlined structures and examples of designing modern high efficiency systems with contactless actuating motors.

***Key words*:** technical shelf development equipment, electromechanical complexes, contactless electric motors, semiconductor power converters.

***How to cite this article*:** Kozyaruk A.E. Development experience and development prospect of electromechanical technological complexes of movement and positioning of technic shelf development equipment, Zapiski Gornogo instituta. 2016. Vol.221, p.701-705. DOI 10.18454/PMI.2016.5.701

**Introduction.** Development and exploitation of offshore mineral resource fields are discussed and implemented to different extents already for fifty years.

Special technical equipment were designed, manufactured and operated to solve these tasks: mobile offshore units, drilling ships, replenishment ships and transport ships to transfer liquid and solid mineral resources.

Exploration and assessment of mineral resource deposits (oil and gas first of all) of the Arctic shelf makes extremely important the issue of development of platforms and ships for operation in severe ice and weather conditions.

Seventies-eighties of the last century were the time of development of domestic technologies (following Western technologies) to explore and produce mineral resources on the shelf. In a logical way this work was first conducted on the shelf of Caspian and Black seas, then expanded to shelves of Northern seas.

Electric power generating and electromechanical equipment is the main type of equipment to support the processes of drilling, production, moving and positioning of offshore development hardware.

First domestic floating equipment designed by Korall Central Design Bureau were SPBU – 6500/100, a jack up floating drilling rig (project 15401) and PPBU – 6000/200, a semisubmersible floating drilling rig (project 10170). Facilities to build these rigs were built (Astrakhan shipbuilding plant) and retrofitted (Vyborg shipbuilding plant) in the Soviet Union.

Technical specifications and structure of special equipment of the PPBU-6000/200 semisubmersible rig are described in detail below for example.

This rig is intended to drill offshore exploratory wells down to a depth of 6000 m with sea depth from 100 to 200 m. The rig is designed as class K✪1 – semisubmersible floating drilling rig according to the Register of Shipping of the USSR. This rig can drill in conditions of wave height of up to 6 m and wind speed of up to 18 m/s. The rig is designed to withstand wave heights of up to 16 m at wind speed of 46 m/s.

Anchor gear provides anchorage in drilling mode with accuracy of horizontal offset of the derrick centerline in relation to the well centerline equal to $\pm 4\%$ of the sea depth.

The single ship power generating plant includes five AC three-phase diesel generators with a power of 1000 kW each and provides electric power supply to AC and DC consumers in all modes of rig operation and well drilling. The use of thyristor converters for DC power supply simplifies control power circuits, allows unification of electric motor drive systems and provides good dynamic characteristics of electric motor drives thanks to fast response of thyristor converters, which is especially impor-

DOI 10.18454/PMI.2016.5.701

tant for drilling hoist and rotor. Monitoring and control systems make unnecessary permanent watch-keeping at control stations in all operation modes except for preparatory modes. The power plant is controlled from the central control station (CCS). Control panels of the ballasting system, of anchor hoists remote control, of the floating rig stabilizing measuring and control system and other navigation equipment are located in the main control station (MCS).

To monitor and control drilling and other processes driller and drilling foreman stations are provided equipped with control panels of the "M&CS-sea" special system. Drilling operations are performed by the derrick with a lifting capacity of 320 t equipped with the device to compensate for vertical oscillations of the drilling string and with the set of mechanisms for remote control of drill pipe stand running in and out. Drilling mud and cement slurry are supplied to the well by three circulating pumps and four cementing pumps with drives of 1000 kW each. Maximum pressure of cement squeezing can be as high as 700 atm. Drilling mud is prepared, reclaimed and cleaned by a closed system with necessary equipment for cleaning. The semisubmersible floating drilling rig is equipped with a compressor station of high (230 kg/cm$^2$) and low (8 kg/cm$^2$) pressure. The subsea wellhead equipment package is a new type of equipment that provides functions of wellhead control, environment protection, mud circulation, rig safety during drilling.

The semisubmersible floating drilling rig is equipped with required sanitary and accommodation facilities for work and rest of the crew: air conditioning system; hot and cold water supply system; personal services facilities, medical module. Premises are finished and cladded with modern finishing materials.

Repair of ship and drilling equipment can be provided directly on the rig in its mechanical and electromechanical shops. Standard shipboard cranes provide for the possibility to unload and download any machine, including diesel generators and circulation pumps.

The PPBU-6000/200 semisubmersible floating drilling rig (Shelf) has technical and economical specifications comparable with that of modern foreign semisubmersible floating drilling rigs, and exceeds them in some parameters, in particular:

• the domestic rig demonstrates better hole boring rates;

• it has the first in the world set of mechanisms for remote control of drill pipe strand running in and out developed for floating structures;

• special device for deep water intake allows lower environment impact of the floating drilling rig and preventing fish and other organisms intake to the cooling system;

• functional division of the body to large unit-modules with a weight of up to 800 t each allows their separate manufacture with maximum installation of equipment, piping, cabling.

Main technical specifications PPBU-6000/200:

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|---|---|
| Overall length (with helicopter pad), m | 98.0 |
| Overall width (without brackets for anchors), m | 64.2 |
| Height from the base line to the upper deck, m | 30.5 |
| Clearance above the sea level in working position, m. | 10.2 |
| Number of lower pontoons, pcs. | 2 |
| Number of stabilizing columns, pcs. | 6 |
| Lightship weight , t. | 11500 |
| Total displacement in working position, t | 19800 |
| Weight of process and ship consumables, t | 3050 |
| Positioning system | Anchorage with chains |
| Number and weight of anchors | 8×18 |
| Power generating plant capacity, kW | 5000 |
| Ability of self-propelled movement | Not self-propelled |
| Crew, persons | 73 |
| Self-sustaining period, days | 30 |

Main power packages of equipment for shelf development – electric power generating plant, electric motor drives of drilling rigs and process systems, systems of electric propulsion and positioning systems.

**Method of analysis and evaluation of technical solutions.** During the period of rapid development of offshore exploratory drilling and production, mainly on the Caspian sea shelf, a large number of research and development projects were carried out and implemented to create self-contained electric power generating systems and electromechanical equipment for processes, propulsion and positioning.

DOI 10.18454/PMI.2016.5.701

Information on type, structure and technical specifications of electric motor drives can be found in various sources, and All-Union and international conferences discussed the problems arising in creation of special electromechanical equipment.

At the phase of creation and operation of first prototypes of domestic equipment for shelf development electromechanical equipment packages for propulsion, positioning and drilling were implemented on the basis of DC motor drives in the system of "controlled solid-state rectifier – DC motor" (CR – DCM).

Solutions of drilling rig (DR) motor drives were the same for onshore drilling rigs, and for floating drilling rigs and semisubmersible floating drilling rigs. Sufficiently complete description and technical specifications of electric motor drives for drilling rigs can be found in [5].

An extensive work to investigate, design, produce and commission DC motor drives for drilling rigs was carried out in VNII Electroprivod Institute in Moscow (by M.G. Yunkov, B.M. Parfyonov et al.).

Electromechanical equipment packages for propulsion and positioning, as well as motors of floating process drilling packages were investigated, designed and manufactured by Electrosila JSC in Saint Petersburg (now Electrosila is a subsidiary of Power Machines company).

The theory of analysis and investigation of electrical machine and electronic motor systems for self-contained rigs is quite deeply developed by author of this article [2]. Also, in the above source the information can be found on electric propulsion systems for ice-going ships and anchorage systems for stabilizing PPBU 6000/200 rigs.

Interesting theoretical and practical results of modeling, calculation and application of electric motor drives with electric machines and solid-state rectifiers are presented in [8].

All the above listed shows that by 90s domestic equipment for exploration and development of offshore oil and gas fields has been developed, designed, manufactured and put into operation. Domestic power electromechanical equipment manufacturing was mastered for these rigs. The biggest number of floating drilling rigs was operated on the Caspian sea shelf, some units were operated in the Baltic sea and in the Barents sea.

In 90s the work on improvement and creation of new types of special electromechanical equipment was reduced dramatically, the shipbuilding industry became oriented on equipment supplies from foreign companies.

It should be noted, that over the last years international companies (ABB, Siemens and others) have created and use state-of-the-art electromechanical equipment for offshore field development.

The need for new types of electromechanical equipment is defined by the market of offshore drilling rigs [1]. "The hope for gradual growth of the world economy after the crisis of 2008 – early 2009 on the background of decrease of onshore hydrocarbon reserve estimates inspired the optimistic forecasts for the market of offshore drilling rigs (especially for drilling in deep waters) for the period of 2009-2015."

Trends and restrictions in the field of supply of special equipment by Western companies connected with sanctions and the need to provide readiness to the work on shelves of Northern seas make especially important the task of development, design and creation of special electromechanical equipment packages.

Electric power generating equipment packages to support process plants of offshore drilling rigs and ships. As in 80s, the main development works in the field of electric motor drives of drilling rigs are carried out by an organization formed on the basis of VNII Electroprivod Institute. Up to now this work is related mainly to packaged DC motor drives.

Arkticheskaya (project 15402 M) drilling rig is the most advanced among the rigs being commissioned. It is intended to drill exploration and production oil and gas wells on the shelf of Arctic seas of the Russian Federation. Unfortunately electromechanical equipment of this rig is oriented to the use of imported components to a significant extent.

Let us review in brief (without diagrams and specific features) the structure and composition of process package equipment for high-performance controlled drives with asynchronous motors. Rationale and implementation examples are given in [3].

Electric power generating plant of self-contained equipment for shelf development is composed of a single electric power generating system including n synchronous generators (driven by diesel engine or turbine), m solid-state power switches (frequency converters) and k contactless asynchronous motors of appropriate design.

DOI 10.18454/PMI.2016.5.701

The experience of DC motor drives operation (in the system of controlled rectifier and motor) has revealed an energy-related problem caused by comparable capacities of load and source. (Power factor of the mains and the independent sources, and quality of the electric energy in case of "deep regulation" of power converters.)

Development of power electronics and improvements in control systems of solid-state converters (switches) allowed creation of structures of multimotor electromechanical packages providing power factor in the mains of $K_M \approx 1$ and harmonic distortion factor (HDF) of mains voltage within requirements of GOST and Rules of the Register of the RF.

Recommended structure of electric power generating plant (EPGP) including a single active rectifier (AR) that provides regulation of $K_M$ and HDF (thus controlling energy saving and electromagnetic compatibility) and m invertors with controlled pulse-width modulation (PWM) and ensured electromechanical compatibility is given in [9].

So, functionally the electric power generating plant for process equipment package of the rig includes:

Single electric power generating system – AR – Invertor with PWM (m) – AM (k) $\Rightarrow$ Working mechanism (WM).

This principle of EPGP building was applied and demonstrated its positive effect in terms of reliability and energy saving to the fullest possible extent during operation on such machine as mining excavator of EKG – 32R/35 type manufactured by KARTEX Izhorsky Plant. Structure, circuit diagrams of the power part and specifications are presented in [6].

The second important electromechanical package providing availability of shelf development equipment is electric propulsion and positioning systems [4, 7]. The main feature of modern positioning and electric propulsion systems is the use of AC propulsion motors (AC electronic motors with electromagnetic excitation and permanent magnet excitation and switched reluctance motor (SRM), asynchronous motors).

There is an extensive positive operation experience of electric propulsion system with synchronous motor power supplied through cycloconverter on Taimyr and Vaigach ice-breakers (electric equipment supplied by foreign manufacturers)

Leading electrical engineering companies (Siemens, ABB and others) have developed steerable thrusters (ST) with propulsion motor accommodated in the submersible pod (Azipod propulsion system) for propulsion and positioning systems. Rotation speed of the propulsion motor is controlled by solid-state frequency converter. Azipod propulsion system uses synchronous or asynchronous propulsion motor. Azipod (Azimuting Podded Drive) systems can be used on ice-breakers and ice-going ships – tankers, cargo and research ships specially intended for operations in ice covered waters, i.e. for vessels of Arctic shelf development.

Propulsion electric systems are created and operated on a floating drilling rig where 8 Azipod CZ systems are installed providing drilling rig movement and its stabilizing during drilling. Synchronous motor with permanent magnets is used as propulsion motor.

As for domestic electric propulsion systems being created, the electric propulsion system of ice-breaker project 22220 is worth to note. The electric propulsion systems shall contain main generators with capacity of 36 MW each – 2 units; 16 MW static frequency converter – 6 units; 20 MW tandem propulsion motors – 3 units.

## Conclusion

1. Electric power generating systems and electromechanical propulsion, positioning and process equipment packages for shelf development technical means were actively and fruitfully created in the USSR and in Russia in 70-80s and were used for exploration and production operations on offshore fields.

2. To carry out prospective works in the field of shelf development, including the Arctic shelf, technical means (floating drilling rigs, drilling and transport ships) which require high-performance electromechanical equipment packages. These are electromechanical equipment packages with contactless (first of all asynchronous) frequency-controlled driving motors. Rotation speed must be controlled

**DOI** *10.18454/PMI.2016.5.701*

through power solid-state frequency converters with intermediate active rectifier providing high power factor of the electric power generating system and acceptable harmonic distortion factor (electromagnetic compatibility).

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*The paper was accepted for publication on 25 April, 2016.*