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Main Types Electric Drives Marine Vessels of Russia

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Abstract

Technical excellence marine production mechanisms and their ongoing technological processes largely determined by the perfection of the respective actuator and the degree of automation. Currently and in the future the main types of drives of production mechanisms remain electrical drives (ED), which consume approximately 90 % of ship's electric energy (EE). A significant part of different ships built and put into operation at the end of the twentieth century. Despite the relatively large variety, many of the ship ED as main components include three-phase induction motors (IM). Requirements-based, various ship ED have certain sets of properties. It is known that the development of the industry of science and technology is based on the results of the research, collection and analysis of facts. Not the exception and ship ED. The article presents an overview and analysis of the main systems of the ship ED of the domestic fleet.

Keywords: Ship Electric Drive, Modes Works, Requirements To Ship Electric Drive.

Introduction

Ship ED are the major consumers of EE generated by the vessel's generators. For example, on a passenger vessel "Alexander Pushkin" (series motor vessel (m/v) "Ivan Franko", built in Germany) with a total active capacity of ship's power plant is 3200 kW (5x640 kW). From 744 power consumers 555 are ED total power 4445 kW [1]. The motorboat of the m/v "Krasnokamsk" installed 165 ED total power of 2000 kW, which amounts to 75, 6 % of the current total active power of ship's electrical equipment [2]. In general, according to the data given in [3], ship ED consume up to 90 % EE generated by the vessel's generators. In percentage terms, with one common mode of operation of the ship – way, the main part of the ship EE consume ship ED (machine and system ED [2] about 60 %, deck and side ED – about 30 %, service ED – about 10 %).

In accordance with the author's classification [4], ship ED on the modes can be grouped into three main groups.
The first group includes ED modes works with symbol S1 and S6 [5]. These include, generally unregulated ED ship machinery with "easy" transition. The dynamic work of this group ED disproportionately little time ED in the static modes. To the first group belong the tail feathers ED and marine superchargers (MS) (machine mechanisms (fuel, oil, coolant pumps, etc.), general ship systems (fire pumps, bilge blowers, etc.) and more.
The second group includes ED modes corresponding mainly with symbol S2. Such drives are in many cases "heavier" conditions of operation in transient modes. Examples ED of the second group are a number of ED lifting mechanisms (LM) (ship destination (ladder winches, boat winches, etc.), machine lifts (hoists etc), ED anchor-mooring arrangements (AMA) (anchor mooring arrangements with drums (windlasses, capstans, mooring winches)), etc.
The third group includes ED of modes that are close to the modes with the symbols S3, S4, S5, S7 and S8. A separate subgroup of the third group are ED LM (cargo winches, cranes, etc.), AMA (automatic mooring winches (AMW), etc.).
Distinctive feature of the operation of many ED of the third group is the commensurability time transient and steady-state modes of operation. ED of the third group, as a rule, should have automatic brakes normally inhibited type.
The conditions of operation of a ship ED are specific and differ sharply from the coast conditions. They are exposed to climatic (change in ambient temperature over a wide range, high salt, high humidity) and mechanical (vibration and shock, change of position of parts of electrical equipment) effects [2].

Basic Requirements to Ship Drives

Basic requirements to ship ED, and specifications governs the Russian maritime register of shipping [6], classification societies of other countries. The main technical, operational and economic requirements for most marine ED is high reliability and operational flexibility, normalized speed, sufficient overload capacity, simplicity, and serviceability.
Requirements for ED of the first group are determined depending on their functional purpose.
Many ED of the second group should have automatic brakes normally inhibited type.
Requirements for ED AMA, normalizes the Russian maritime register of shipping. Typical of these include the following.
Electric motor (EM) power the anchor mechanisms (AM) must provide continuous picking for 30 min single anchor chain to the anchor normal holding power at a speed not less than 0, 15 m/sec at a certain pulling force. Speed of veering the anchor chain should be measured by the length of the two bow anchor chain, starting from the moment the three bows are in limbo. At the approach of the anchor to hawse hole, the drive has to provide the speed of veering-in circuit is not more than 0, 17 m/sec. Recommended speed of retraction of the anchor in hawse hole – no more than 0, 12 m/sec.

The drive mooring arrangements (MA) must provide continuous picking mooring rope at the rated pulling force rated speed for at least 30 min. Speed of veering-in of the rope through the mooring head at rated traction force should be not more than 0, 30 m/sec.

To lift anchor from the ground drive AM must provide within two minutes the creation of a chain to one sprocket of traction, not less than 1, 5 calculated times the design without any demands for speed.

When the current mode of operation of MA the anchor must provide within two minutes of creating the rope on the first layer coiling on the drum traction not less than 1, 5 calculated time.

Asynchronous EM with squirrel-cage rotors ED AMA after 30 minutes of operation at rated load must provide parking under electric current at rated voltage for 30 sec for AM and 15 sec for the MA. For motors with switchable poles this requirement is really at work on the coil that generates the highest starting torque.

Anchor mechanisms not self-braking transmissions must have an automatic brake devices, triggered by the disappearance of the driving power or the drive fails.

Automatic brakes AM normally inhibited type should provide braking torque without slippage, the corresponding traction in the chain on the sprocket is not less than 1, 3 computational force, and MA – when the traction force at the drum not less than 1, 5 times the design of the traction force.

The ED AMA should be made to protect EM from overload when working on the steps of the speeds intended only for mooring operations [7].

Typical requirements and recommendations applicable to the ED LM third group are as follows.

Rated lifting speed for ship LM was adopted (0, 20-1, 00) m/sec [7]. Speed of lifting (lowering) unloaded hook shall not be less than the rated speed of the lift. Landing speed should be no more than 0, 27 m/sec [2]. The average acceleration of the lifting mechanisms of the GMP shall be 3, 0 m/sec^2 when working with nominal load [8]. The permissible acceleration mechanisms of rotation of the cranes is determined by the necessity of the automatic damping of the load and is equal to 1, 0 rad/sec^2 [7].

Capacity LM is determined by the mass to be lifted and is characterized by a pulling force corresponding to this mass. A range of lifting capacities LM is in the range of (0, 25-50, 00) ton, and pulling force – in range (0, 28-18, 00) kN.

Starting torque EM alternating current (AC) winches, powered directly from the mains at a lower speed at the rated voltage should be not less than 1, 3 times the nominal torque EM, and at all other speeds is equal to (1, 5-2, 5) moment, the corresponding nominal tractive force.

LM should have automatic brakes normally inhibited type with manual release. The brake force should be not less than 1, 5 times the nominal tractive effort [9].

Thus, due to the specific operating characteristics, due primarily to a wide range of climatic, mechanical and chemical loads, along with the general requirements for shipborne ED, to each group of marine ED in accordance with the classification developed to meet a complex of separate requirements. Requirements to ship ED dictated by the operating conditions, reveal the importance of improving the efficiency of their operation.

Researches

The majority of installed on vessels of domestic and foreign construction ED of the first group of and unregulated ED second group comprises rotary converters (EM) and a relatively simple control system (CS).

The requirements of this ED, in many cases, the answer EM direct current (DC) general ship performance "PM" series, being a sea modification of a single number of domestic universal electric DC motors series "P", three-phase IM series "4A" [10], replacing EM series "AO2-M", one speed IM of a series "MAP".

EM DC "PM" series, which implemented the key design principle of minimum mass per unit nominal torque, include 11 dimensions and cover a power range from 0. 1 kW to 210, 0 kW at the nominal angular velocities (speeds) (78, 6-314, 2) rad/sec ((750-3000) rpm). Allow extended operation at voltages up to 320 V. the Resource is up to 12000 hours.

Three-phase IM series "AO2-M" are modification EM single series "AO2". Main technical data of the motors of the series "AO2-M" is given for example in [11].

Three-phase IM series "4A" includes 25 dimensions with a power range from 0, 1 kW to 315, 0 kW at the rated speed (600-3000) rpm. They manufactured for voltages 220 V, 380 V and 660 V at the coupling circuits of the stator windings EM in a "star" or "triangle". When working in short modes (S2) power can be increased by 25% during the period of 30 min and 10% in the period of 10 min. Allow long-term operation at a reduced frequency to 65% of nominal when the proportional voltage reduction, parking under electric current for 10 sec with the set temperature. The service life of the motors reaches 20000 hours.

In general, shipboard three-phase IM series "4A"

$$\lambda_m = \frac{M_{\max}}{M_n} \geq 2. \qquad (1)$$

In the formula (1) λ_m – overload capacity EM torque; $M_{\max}$, M_n – maximum and nominal moments EM, respectively.

In addition, the IM series "4A" minimum moments amount to at least 90 % from the nominal values [11].

Three-phase single-speed IM series "MAP" comply with International Electrotechnical Commission (IEC). The power range of single speed motors series "MAP" is in the range (1, 2-90, 0) kW at the rated speed of 880 rpm to 1475 rpm technical data is given for example in [12].

Prospects of development of IM is given in [13], etc.

CS marine ED of the first group of and unregulated ED of the second group include, as a rule, non-reversing or reversing magnetic starters, which is the complete devices designed for automatic turn on, switch off, and protection EM. The exceptions are primarily the steering tail feathers ED that includes, as a rule, computer-aided management of ship's course. The main elements of starters include contactors and protection relays.

In ED DC are used, for example, domestic non-reversing magnetic starters series "PP", which is implemented from the start in the function of the electromotive force (EMF) EM. The main power contact switching devices (PCSD) magnetic starters series "PP" are series contactors "KN". The five starters have values defined by the

rated currents from 20, 0 A to 400, 0 A, and are designed to work with voltages from 110 V to 320 V.

For reversible control EM DC ship in EP found the use of the reversible magnetic starters (magnetic station), for example, domestic production of the series "SME", which implemented the start-time functions. The main PCSD reversing magnetic starters series "SME" are series contactors "KM". The starters have four values defined by the rated currents from 25, 0 A to 150, 0 A and are designed to operate at voltages of from 175 V to 320 V.

In ship ED AC widely used domestic universal magnetic starters series "PMM" non-reversing and reversing performances. PCSD magnetic starters series "PMM" are series contactors "KM". The starters have four values defined by the rated currents from 22, 5 A to 150, 0 A and are designed to operate at voltages 220 V and 380 V [8].

The modern ship's ED is relatively large (comparable) power, including asynchronous EM with squirrel cage rotor windings, CS typically adopt start EM at low voltage (a way to switch from the "star" on the "triangle" using the system "thyristor voltage regulator – IM" (TVR–IM), etc.) [2]. The powerful ship ED, including asynchronous EM with wound rotor windings, the start is carried out most often by the introduction of additional resistance in rotor circuit.

The majority of installed on vessels of domestic and foreign construction adjustable multi-speed ED of the second and third groups working in modes that are close to the symbols S2-S5, S7 and S8, includes electric motor converters (EM) AC or DC and various technical and schematics CS.

In ship ED DC these groups have found use EM DC parallel (independent) or mixed excitation, one of the main advantages of which is the ability to smoothly and in a wide range to adjust the angular speed of the motor shaft. EM DC series excitation, due to their specific characteristics, on ships are rarely used.

In national marine ED widely used reversible EM DC short modes and intermittent modes of operation the series "DPM", which is a modification of a special series crane and metallurgical EM. Series "DPM" includes ten sizes (dimensions) EM with attached disc brakes or without. The power range EM is (1, 6-95, 0) kW at rated speeds from 615 rpm to 1850 rpm. There are two main versions of the EM series "DPM" equal the maximum permissible speed n_{max} to the nominal speed n_n (n_{max}/n_n) – high-speed and low. High-speed EM has multiplicity equal to two, and the EM low-speed performance – three. Fast EM use, as a rule, for ED with the number of starts up to 300 per hour, and the low speed – up to 500 per hour. When equal to the useful work weight EM fast execution (15-20) % less than EM low-speed performance. Current overload capacity motors "DPM" reach four-time values with respect to the nominal currents. Within handling abilities EM allow under the voltage up to 450 V. EM have high fatigue strength when the number of starts up to 10^7 per lifetime.

For powerful ship ED (LM, fishing mechanisms etc.) are special EM direct current, such as a sea modification domestic EM crane series "D800", "DP", etc.

EM independent of excitation series "D800" cover a power range from 80 kW to 350 kW at the rated speeds (900-1000) rpm. EM allow operation at voltages up to 600 V. Overload capacity EM current is equal to two.

Motors with separate excitation series "DP" cover a power range from 125 kW to 608 kW. They allow for work at voltages up to 320 V. Overload capacity EM current is equal to two [11].

Technical realization of the CS is determined by the purpose and functional features of ED. Comparison of various ship systems ED performance indicators allows you to more objectively determine the scope of their application, to predict likely directions in the development of this group of marine ED. Feasibility assessment and field of application of various systems of ED is given for example in [8], [14].

Most CS marine ED DC contain a controller or relay-contactor system "generator – motor" (G–M), "controlled rectifier – motor" (CR–M) and others [2].

Various adjustable multi-speed ED (windlasses, cargo, trawl and mooring winches, capstans, etc.) with EM DC and the controller or contactor-relay schemes mainly equipped ships built in the Soviet Union (SU) and abroad up to 60 years inclusive, who had a ship power system DC. These include: the m/v "Tartu" (1960, Hungarian People's Republic (HPR)); m/v "Simferopol" (1962, Polish People's Republic (PPR)), etc [2].

The number of such ship ED is constantly decreasing due to the decommissioning of obsolete vessels, and in connection with the introduction on most modern ships in AC. Theory and variations of different circuit solutions drives with EM DC adequately covered in the literature [7], [15].

With the 60-ies of XX century on ships in regulated ED (steering gears, LM, AMA, trawl winches, etc.) began to be actively implemented system of G–M ("Ward-Leonard" or "Shubina") [2]. System G–M were installed in the tail feathers ED – the series ships "Povenets" (1963, German Democratic Republic (GDR)); in ED LM (cargo winches) – some ships series m/v "Belomorskles" (PPR) (m/v "Amurskles", 1963; m/v "Angarales", 1963); in ED AMA (windlasses) – on a number vessels of series m/v "Sibirles" (SU) (m/v "Verhojansk", 1965; m/v "Jana", 1966); m/v "Novgorod" (1967, Finland); in ED AMA (AMW) – m/v "Sovfracht" (1967, Socialist Federal Republic of Yugoslavia (SFRY)); m/v "Novgorod"; in ED trawl winches – seiner-trawlers refrigerated (STR) m/v "Alpinist" (1971, SU), and others [2].

Currently not justified promising systems G–M ship's ED due to a number of disadvantages, which primarily include: low coefficient of performance (COP); the relatively low reliability and increased operating costs due to the presence of DC machines; relatively high mass-dimensional indicators. Only at some powers, in particular, (40-60) kW or greater (for steering ED), 70 kW and above (for ED AMA), the mass of the ED electrical system G–M is comparable with the mass of the electrical drives with EM DC and relay-contact circuits. Power installed on many vessels of the adjustable multi-speed ED below appropriate powers for the use of G–M. In addition, it should be noted that despite the ability of systems G–M ED to ensure high smoothness of control of operating speeds in wide ranges in ship controlled ED is used, typically no more than five sustainable speeds throughout the range of regulation.

Exceptions include, for example, ED trawl fishing systems, including systems G–M, which are currently widely used on ships of the fishing fleet. A circuit diagram ED

widely used trawl-seiner winch "ЛЭТрС-2", are G–M in the form of a single multi-drum mechanism, and installed, for example, on STR, m/v "Alpinist", is given in [2].
Reasonable competition on a number of technical characteristics of the ED, including EM DC system and G–M actuators are performed by the system CR–M. Such adjustable multispeed ED installed, such as: m/v "Volgoles" (1960, PPR) – for the mechanism of the spire; the m/v "Severoles" (1960, PPR) – for cargo winches; m/v "Alexei Kosygin" (1983, SU) – for litery crane, etc. However, their implementation in marine electrical engineering limited because not entirely exclude the presence of DC machines. The scope and technical characteristics of the ship ED system CR–M is given in [8], [16].
Option scheme and the test results of the ED, including a system CR–M, developed "Central research and engineering institute of marine fleet" (CREIMF) and installed in ED LM on the m/v "Severoles" presented in [17].
Currently most ships are equipped with power three-phase alternating current, among other reasons, predetermined widespread use on ships ED AC.
In accordance with the classification provided in [2], ship ED type gear device is divided into hydraulic and mechanical.
The hydraulic reversible adjustable ED AC second and third groups include generally single-speed asynchronous EM with squirrel-cage windings of the rotor and relatively simple relay-contact circuits. For reverse and regulation of the working speed used variable displacement pumps and valve box.
Hydraulic adjustable ED AC second and third groups installed on ships series: m/v "Zoya Kosmodemyanskaya" (1973, SU), m/v "Izvestiya" (1978, Denmark), m/v "Mechanik Garownik" (1986, Japan) – at the steering gear; m/v "Magnitogorsk" (1976, Finland), m/v "Igor Ilyinski"" (1990, Spain) – in AMA; m/v "Engineer Machulski" (1974, Finland) – in AMA and thrusters; m/v "Posyet" (1988, Greece) – in AMA and LM; m/v "Pioneer of Moscow" (1973, SU), m/v "Norilsk" (1982, Finland), m/v "Argun" (1991, Romania), diesel-electric (d/e) "Vitus Bering" (1986, SU) – LM [2], [18], etc.
When used in marine ED AC second and third groups of mechanical gear transmission devices, the composition of the ED includes a multi-speed EM with one poles switchable winding or with some multiple stator windings and a squirrel-cage or wound rotor windings. CS include a controller or relay-contactor system "inverter frequency converter – induction motor" (IFC–IM), "direct frequency converter – induction motor" (DFC–IM), TVR–IM and others.
ED with multi-speed IM, which have a phase rotor winding and a controller or relay-contactor, have found application mainly in the mechanisms of AMA series of vessels built in the GDR (m/v "Dzhankoy", 1960; m/v "Vyborg", 1963; m/v "Povenets", 1963), Denmark (m/v "Beloretsk", 1962), and others. On m/v series "Stakhanovec Cotov" (1978, Finland) and some others, multispeed EM with slip-ring rotors installed in ED LM [19].
In most reverse ED ship mechanisms with variable speed and mechanical (geared) transmission devices of the second and third groups are established and operated multispeed IM, having separate or poles switchable stator winding and a squirrel cage rotor winding. This is due, above all, rational solutions for EM in ratios of the

numbers of poles of the stator winding, the multiplicities of the starting and maximum moments, flywheel weights, etc. Such ED includes, for example: the structure of AMA series of ships m/v "Omsk" (1961, Japan), d/e "Sakhalin-1" (1972, SU), m/v "Vasily Shukshin" (1977, SU); LM series of ships m/v "Krymsk" (1967, Romania), m/v "Warnemunde" (1972, GDR), m/v "Leninskaya gvardiya" (1972, PPR) and many others [2].

A circuit diagram of a reversible multi-speed (three speed) ED LM with relay-contactor control scheme that best reflects the features of the ship ED with multi-speed asynchronous EM and relay-contactor control circuits presented in [2].

Widely used in ship ED AC second and third groups of a uniform number of national multi-speed three-phase asynchronous squirrel-EM with an increased rotor resistance series "MAP", meets the requirements of IEC.

Basic series motors "MAP" includes nine sizes. Provides manufacturer EM with attached disc brakes or without brakes. Power range two-speed ED series "map" is (0, 3-100, 0) kW at rated speeds from 385 rpm to 1410 rpm, and a three-speed – (2, 5-90, 0) kW at rated speeds from 175 rpm to 1495 rpm. Number of start EM for the service life is 10 years make $2x10^4$-$10x10^6$ [12], [20].

CS reversible ED with multispeed IM contain in most cases of relay-contactor comprising a magnetic controllers (MC) (magnetic station) and controllers (CC), or controller circuits, including power controllers [2]. According to the data given in $10x10^6$ [8], the cam controller CS used with the installed capacity of the EM to 22 kW, contactless controller CS – to 30 kW, and relay-contactor – up to 100 kW. The greatest distribution was received relay-contactor CS [21], mainly due to the increasing capacity of the ship ED.

At some ships have found the use of four-speed ED with IM and relay-contact circuits (ED aft cargo winches on large freezer fishing trawler "Hermes", "Persei" (PPR), etc.). On some vessels, particularly fish meal factory mother ships, to increase the number of speeds installed five-speed domestic ED, which includes two IM (basic and speed) and relay-contactor control [2].

Increase of requirements to ship EP for different purposes leads to necessity of search of new technical solutions. To a new level of ship EP came with the development of the theoretical development and practical implementation of solid-state, microprocessor and other equipment.

Since the 80-ies of XX century to promising areas began to relate the development of ship ED on the way of expanding the field of use of asynchronous frequency-controlled ED with squirrel-cage motors [22], [23].

For ship ED with frequency variable speed used one-, two-and three-speed EM special design. The power range of domestic EM series "MAP" for frequency variable speed ED is equal (1, 2-52, 0) kW. Single-speed EM used in ED with changing frequency in the range (5-80) Hz, and two and three speed – change frequency in the range (from 5 to 20) Hz on the low speed winding [8], [20]).

Frequency ED, including systems IFC-IM, with thyristor frequency converters of series "SAMI" (Finland) installed in ED cargo pumps [24], [25] on ships of series m/v "Grigory Nesterenko" (1986, SU) [2]. Most of the logical functions CS ED exercise microprocessors [24]. System IFC–IM equipped transistor frequency converters

"FREQROL-Z200" (Japan) [26], are part ED of the production mechanisms of supertrawlers type m/v "Cooperaciya" (1991, Spain) [2].
Ship frequency ED system DFC–IM on the basis of domestic frequency converters of series "TTS" [27] was installed and tested on a fishing freezer trawler (super) "Horizont" (1974, SU). ED with systems DFC–IM, including modification of domestic frequency converters, used, for example, in ED LM on the universal fish meal factory mother ship series "Kamchatsky bereg" – "Tausky shelf" (1991, SU) [2].
In CS ship ED found limited application and voltage regulators. For example, in LM series of vessels "Cheremkhovo" (1984, Germany) installed system TVR-IM includes three-phase IM with phase rotors [2].
Most ED of different modern ships for domestic and foreign vessels (cargo ships (ro-ro) "Midnight Sun", "North Star" (2002, United States of America (USA)); container ships – "Norilsk Nickel" (2006, Finland), "Monchegorsk" (2008, Germany), "MSC Beryl" (2010, South Korea (SK)); icebreakers – "FESCO-Sakhalin" (2005, Finland), "Vladislav Strizhov" (2006, Ukraine), "Moscow" (2008, Russia); gas carriers – "British Emerald" (2008, SK), "Castillo de Santisteban" (2010, SK); vessels for fisheries research [28] have no significant difference with ED vessels earlier buildings. A typical trend of modern shipbuilding is the introduction of the main propeller-rudder speakers, combining the functions of the main propulsion vessel and steering ED.

Conclusion

It is proved that the main consumers of ship electric energy are electric drives that consume most of the electricity generated by the vessel's generators. The number of installed on ships electric motors, which are the main converters of electrical energy into mechanical energy is typically hundreds of units.
Specific conditions and modes of operation of a ship electric drives, significantly different from the coast and due to high climatic and mechanical loads, reduce their reliability, the need for increased attention to maintenance and repairs of electric drives, their components and elements.
Despite the relatively great diversity, many of the ship's electric drives as the main components include three-phase asynchronous motors, thanks to their constructive simplicity, adaptability, high energy and operating indicators. For electric drives with adjustable working speed of widely used multi-speed (three speed) asynchronous motors with separate windings or switchable poles the stator windings and relay-contactor control systems. Developed and implemented a frequency-controlled electric drives.
The probable directions of development of ship drives that meet modern requirements include: theoretical studies and practical implementation of new technical solutions; modernization of existing systems primarily for vessels in operation.

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