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Analysis of the adjustment of the speed of naval electric motors and its role

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Abstract. The paper presents the advantages and disadvantages of the electric propulsion and the speed adjustment of the electric motors used for it. Using the speed regulation methods of D.C. and C.A. motors, we analyze the role of physical size that appear in mathematical relations. The speed adjustment methods for three-phase asynchronous motors are: changing the number of pairs of poles; alteration the frequency of the supply voltage; turning of the slip that is realized by the variation of the rotor resistance and alteration of the supply voltage. The voltage alteration is only effective during the load operation. The speed control is analyzed by modifying the number of pairs of poles, adjusting the speed by changing the frequency of the supply voltage, adjusting the speed by modifying the supply voltage, and adjusting the speed by rheostat adjustment. The speed adjustment of synchronous motors can only be done by varying the frequency of the supply voltage or by changing the number of pairs of poles. The role of adjusting the speed of the electric motors in propulsions is presented .

1. Introduction

The electric propulsion of the ships and the adjustment of the speed of the propulsion engines are developed knowing a variety of forms and means. The choice of electric propulsion system depends on many factors including the size of the ship, the operating conditions and the importance given to the ecological and economic factor.

The electric power supply of the propulsion engine is made from the naval power station. In the case of electric propulsion between the diesel or turbine engine, which provides mechanical energy and the electric propulsion motor, the generator in the boiler is interposed with the connecting cables.The electric drive systems of naval propellers are made by using cycloconverters and synchronous motors or frequency power converters and asynchronous motors. The frequency used is 400 Hz and it has a particular importance in the economic operation of the receivers.The decrease of the frequency leads to the decrease of the engine speed, causing the failure of the parameters of the naval installations.Maintaining constant frequency, as well as voltage is done with the aid of automatic regulators [1,3,4].

The electric propulsion has a number of advantages: the rotation direction of the electric motor can be reversed; the possibility of supplying the propulsion engines from several electric generators; a smaller number of generators are used; can be ordered from several points of the ship; a more rational use of primary engines; optimal efficiency of the ship's propulsion system at low speeds; fast motors can be used that have smaller dimensions, weights and costs here; the possibility of performing repairs to the primary engines without removing the ship from operation ; better speed adjustment and more precise maneuverability can be ensured. [5,6].Vibrations during the ship's march are lower in electric propulsion than in direct propulsion through propeller. Dual propulsion engines can be used that provide the power reserve upon exit from operation of an electric motor. In the electric propulsion with two types of current, alternating current and direct current, alternating current generators are used from which, by means of rectifiers of power, controlled or not controlled, the motors of direct current are used used to drive the propellers .There are two directions of research electric propulsion: one seeks the introduction of alternating current with frequency converters and one use of generators and electric motors with windings excitation using synchronous semiconductor [2,3].The advantage of the electric propulsion system is that in order to reduce the losses due to the decrease of the speed of the ship during maneuvers, the generators and the unloaded electro-motors are disconnected.

2. Adjusting the electric motor speed

1. Speed control methods for D.C motors [6,7,8,9,13]

a-variation of voltage at the terminals of the motor, for constant voltage of the mains supply - rheostatic adjustment . Tension home network Network Power's and current excitation are constant. The useful power decreases with the speed.The voltage adjustment at the motor terminals is achieved by inserting an adjustable resistance in the circuit that can be used as a starting rheostat , but it reduces the efficiency.The speed is set below the idle speed. It is applied to the motors with separate excitation and series at which the slope of the mechanical gear decreases with the increase of the resistance of the control rheostat and the idling speed is not changed-figure 1.

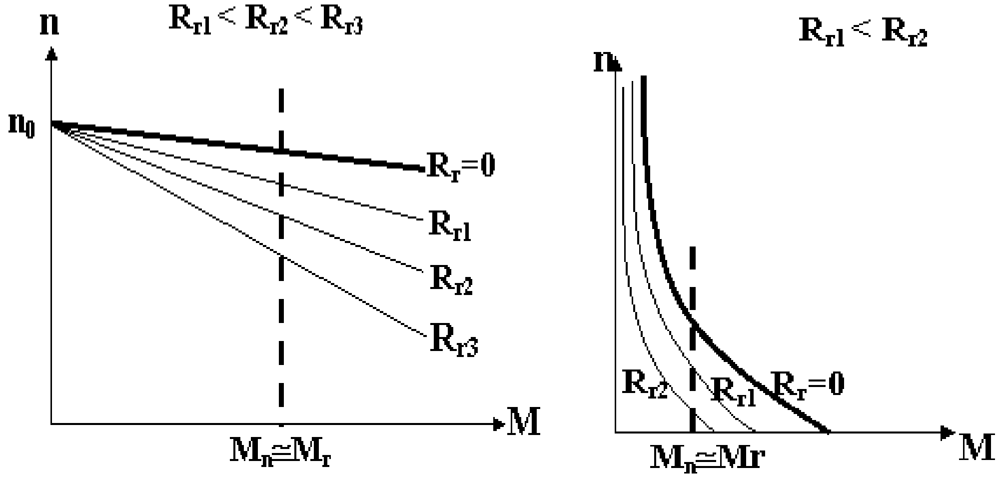

Figure 1. Motors with separate excitation and series

b- variation of the excitation flow - adjustment by slowing the flow . The speed adjustment is made by modifying the excitation current by means of an adjustable rheostat which is mounted in series with the excitation winding, when the motors with separate excitation change the running speed empty and the slope of the mechanical characteristic is modified. By slowing the flow , the reduction of the excitation current decreases stability and switching the engine speed increases , increasing the power absorbed by the central, output power increases, current increases at constant torque of the indus.Efficiency is slightly affected.The method is used to increase the rated engine speed twice.If the rheostat is mounted in parallel with the excitation winding, the excitation current is reduced, the magnetic flux is reduced and the engine speed is increased. The method allows to increase the speed of rotation The artificial mechanical characteristics of c.c. electric motors are-figure2

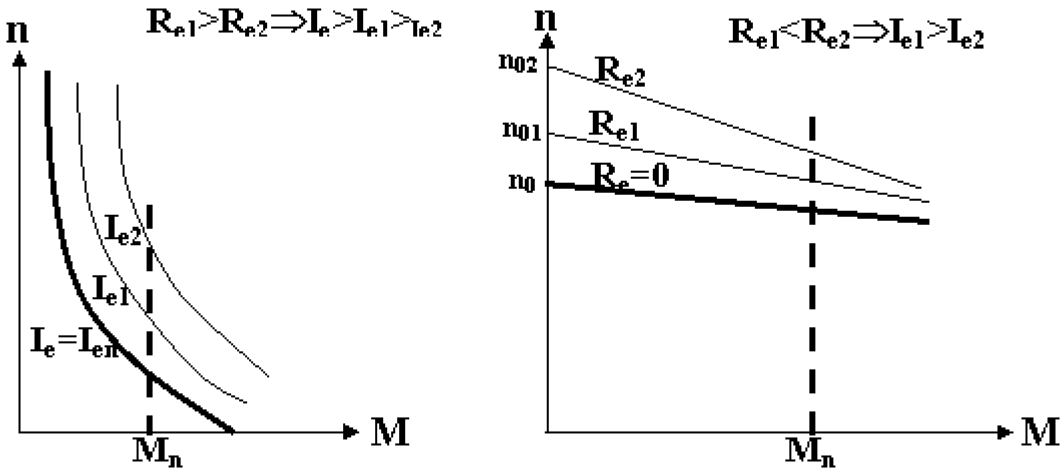

Figure 2. Serial and separate excitation motors

c- variation of the voltage of the power supply-In case of adjusting the speed of the motors with excitation bypass changes in direct proportion to the idle speed with variation of supply voltage, setting is effective at any value of the load torque and the slope of the characteristic remains constant mechanical figure 3 .At the resistant torque constant , the variation of the supply voltage leads to the variation of the engine speed. In the case of the speed control of the motors with serial excitation, it is more efficient at low values of the load torque-figure3.

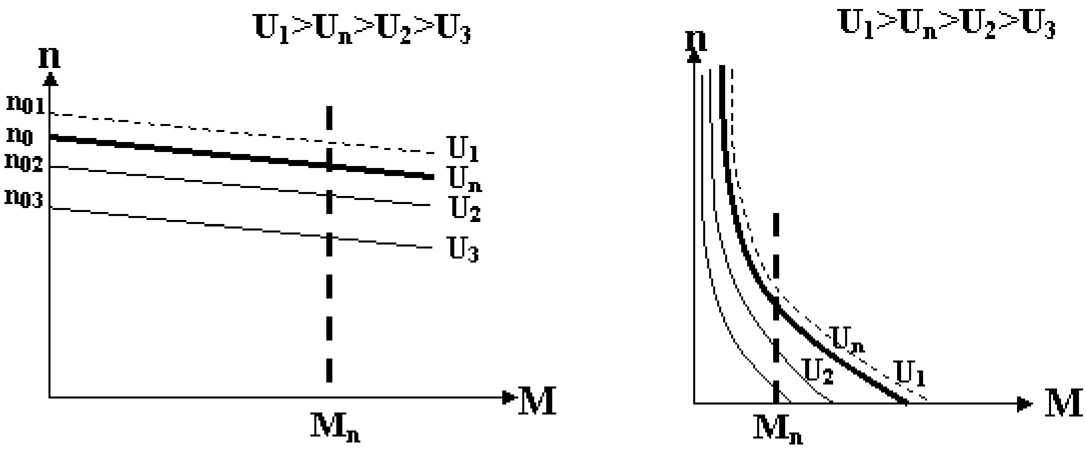

Figure 3. The artificial mechanical characteristics of the motors with serial and separate excitation

The method is used to adjust the speed below and above the rated speed, within wide and continuous limits, but requires a controlled rectifier.

d- use of static converters . Electric motors can be powered from variators or rectifiers. Depending on the type of rectifier, electric motors can operate in one direction - we have a rectifier controlled with a single polarity of the rectified voltage or we have a two-way rectifier . The speed of the electric motor can be adjusted to a large extent with a direct current voltage regulator or the motor is powered by the induced and the excitation from the rectifiers ordered.

2. Methods for adjusting the speed take three-phase motors:

a- change the number of pairs of poles - it is applied to the asynchronous motors with the rotor in the short circuit and it is possible to realize the variation in steps of the synchronization speed depending on the number of pairs of poles in the stator. The change of the number of pairs of poles is realized by means of two windings or with a winding.

b- change the frequency of the supply voltage - allows the speed adjustment to any load of the motor. The ratio of voltage to frequency must be constant. The magnetic flux determines the saturation state of the magnetic core of the asynchronous motor. If the voltage is kept constant and the flux decreases, the magnetic flux increases, the saturation of the magnetic core increases, the losses increase, the magnetization current increases. The magnetic flux must be kept constant at the nominal value. Static frequency converters are required. When changing the frequency of the supply voltage, the critical slip and the synchronization speed change, and the maximum torque remains constant - figure 4. At low frequencies, the stator resistance has a high value in relation to the dispersion reactance, and when the frequency increases above the nominal value, the voltage is kept constant in order to avoid iron losses and to further isolation.

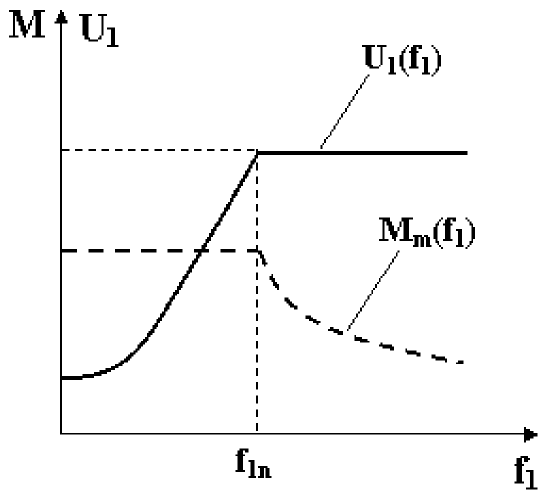

Figure 4. Artificial mechanical characteristics – maximum torque dependence on frequency and speed

c- adjusting the speed by changing the supply voltage - causes the synchronization speed and critical slip to remain constant and the torque to change - figure 5. As the supply voltage decreases, the motor overload capacity decreases .

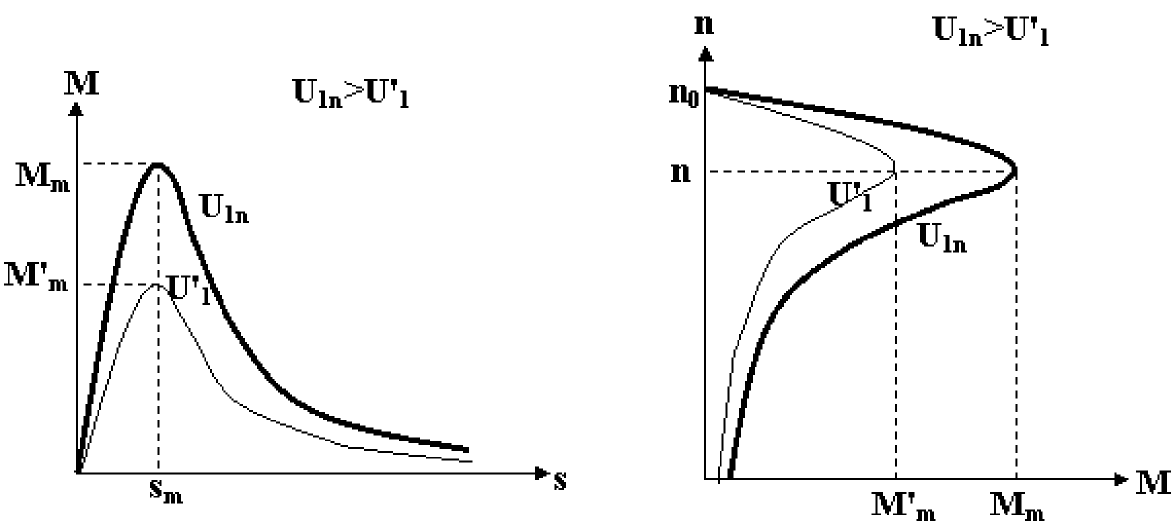

Figure 5. Artificial mechanical characteristics

d - adjusting the speed of the variation in rotor resistance – it is used and in the case of three-phase asynchronous motors with wound rotor and is recommended for short-term operation, the load of the engine speed control is made by. The speed adjustment is made by inserting an adjustable resistance in the rotor circuit. As the rotor resistance increases, the synchronization speed remains constant, the critical slip increases, the starting torque increases and the maximum remains constant - figure 6.

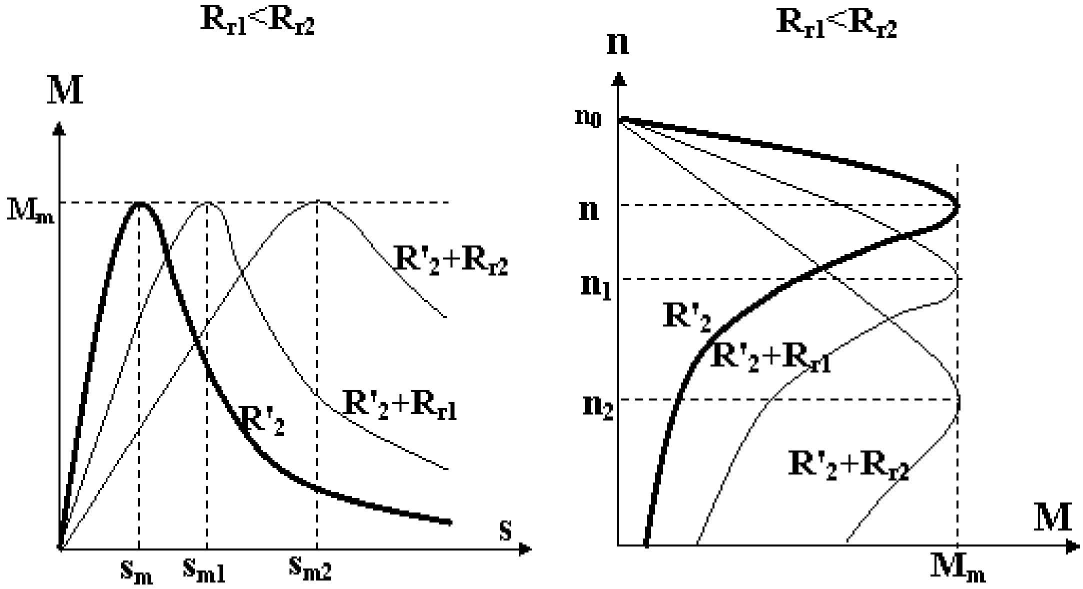

Figure 6.Artificial mechanical characteristics

3.The methods of adjusting the speed of synchronous motors can be realized by varying the frequency of the supply voltage with the help of static frequency converters or by changing the number of pairs of poles.The voltage adjustment fan is limited by the maximum and minimum voltages at the output of the inverter and the voltage allowed at the motor terminals.Knowing that the angular velocity varies by a sinusoidal law, must not exceed it the magnetic request accepted, and the excitation current varies according to the magnetic induction

3. Power supply of asynchronous engines from indirect frequency converters

The use of static converters with power semiconductors in the electric propulsion of alternating current and alternating current-direct current allows to obtain characteristics similar to the generator-motor diagram in direct current and the realization of comparison schemes allow the constant maintenance of the frequency of the main generators what creates the possibility of using a parts of their power to feed consumers from the general network of the ship. The supply voltage is regulated continuously. The converters are divided, according to the operating principle, into frequency converters with intermediate circuit and without intermediate circuit. The converters are divided, according to the operating principle, into frequency converters with intermediate circuit and without intermediate circuit. The indirect frequency converter, depending on the type of the filter, can be with intermediate voltage or direct current circuit. The inverter changes both voltage and frequency to the indirect voltage converter with non-rectified rectifier. At the indirect voltage converter with non-controlled rectifier and current with controlled rectifier, the direct current voltage is adjustable and the inverter only changes the frequency [2,8,9,10,11,12].

4. Conclusions

When choosing the type of current, we took into account that the electric propulsion in direct current and in alternating current-dirrect current allows to obtain higher torques at propellers, compared to the electric propulsion in alternating current. Also the speed of the primary engines is independent of the propeller speed, while at the electric propulsion in alternating current (without the use of static converters) the speed control is obtained by modifying the frequency achieved by adjusting the primary engine speed.

Alternating current electric propulsion eliminates some of the deficiency of direct current propulsion, such as the presence of the collector which limits the speed, voltage and power of the direct current generator.

Through the use of modern frequency converters and filtering techniques, alternative current motors have become more feasible for the high demands in the domain being used on most recently built vessels . The operation of the entire electric propulsion system is carried out with the help of electronic computers that monitor and provide reference signals both in current and voltage based on specialized programs. The intensive development of the technique led to the construction of static converters that allowed the unification in the system of naval electric propulsion of the alternative current and direct current. The synchronous generator-non-controlled converter-propulsion electromotive system has the following advantages:

-synchronous generators can be directly connected to the their primary motors;

-use of the primary engine speed and power with the high;

-direct coupling of the alternating current generators avoiding the reducer which leads to the reduction of the gauges and the pulses of the rectified voltage;

-to ensure a safety of the system diagram by using alternating current generators;

-the automatic value in a wide range of the moment of the electromotor propulsion at the constant speed and power of the primary engines

-the independence of the propeller speed and its adjustment from that of the primary drive motor.

If the rectified voltages and currents are given by the electromotor parameters then the voltage and current of the synchronous generator depend on the converter scheme.

In the propulsion electromotor, within a synchronous generator-converter system controlled electric motor, the losses increase and the switching is made worse. At angular speeds and low powers mechanical vibrations proportional to the frequency of pulsations may occur. The degree of loss increase mainly depends on the current pulses in the windings. The pulses of the current depend on: the frequency of the network; the number of phases of the rectifier; winding inductance; the voltage supplied to the rectifier; the average value of the tension per winding; the average value of the winding current. Due to the size of the losses the heating of the electric motor takes place.

The controlled converter is characterized by two operating regions: rectifier and inverter. The control of the converters is carried out by several methods.

The principle of phase-impulse control is limited to the fact that thyristor control electrodes deliver positive polarity pulses. The frequency of the command impulses is divisible by the frequency. The angle measured from the moment of the normal opening of the thyristor (at natural switching) until the moment of supply of the command pulse is called the adjustment angle(α).

The basic requirements of the command pulse parameters are: duration, amplitude and slope. When choosing the control system of the recovery, the following indicators are taken into account: the voltage and frequency of the power supply network; number of command channels; adjustment range; the power consumed; the working temperature range; command impulse parameters; the factors that determine the security of the system.

The instability of the output parameters of the control system (ambient temperature, variation of values and shape of voltage and frequency, asymmetry of impulses) can influence the symmetrical operating mode of the converter.

The existence in the schemes of the electric propulsion systems of the ordered, non-controlled or frequency converters leads to the appearance of high harmonics in the alternative current circuit and influences the functioning of the synchronous generators and the consumers connected to the bars. The converters, like any non-linear installation, consume the non-sine current from the network, generating harmonics.

The disturbances in the electrical propulsion system of the converters are also related to the fact that they consume reactive power at which the deformation coefficient of the first harmonic of the current, in relation to the voltage of the synchronous generator, varies proportionally with the variation of the output voltage of the converter.

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