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THE STARTER-GENERATING COMPLEX

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Abstract- The paper is devoted decision of a question of creation one machine electric network external mobile installations. Design features of new system of the starter-generating; starter and generator modes are analyzed. Electric power scheme with the analysis of transition of system in starter and a generating mode is also given. Considering the basic elements of the given complex starting generator, the switching device in many respects solves clearness and reliability between electric car and cranked shaft of an Internal Combustion Engine (ICE), deals with a question of transfer system from a reducer mode in a mode of a uniform shaft and on the contrary. The paper also shows two principles including the action and the analysis of transfer in the starter generator.

Keywords: Mobile Independent Objects, Starter-Generator, Internal Combustion Engine (ICE), External Rotating Wheel, Internal Rotating Wheel, Screw Gear, Switching Device, Pulley, Cranked Shaft.

I. INTRODUCTION

The mobile objects which are a part of the equipment in the oil and gas economy play large role in prospecting operations, experimental drillings, at restoration emergencies etc. The structure of these objects includes numerous lorries in different function which in the board have placed complex electric network where needs large electric energy and the generating knot including complex accumulator and the generator.

One of powerful consumers of the external electric power is the electric car of a direct current which is carrying out function of a starter. The external network is a basis two electric cars including the starter and the high-frequency generator is in extremely in the opposite direction regime conditions and operates in various intervals of time that leads to "infringement" of convertibility of the modes, concerning electric cars in general [1]. Currently, in this branch the numerous objects equipped with similar system of electric equipment are occupied. Input of the given design in external network of the given objects is possible to save expensive materials, and will lead to fall of the cost price of the electric equipment.

The decision of a problem of combination of the starter and generator in an electric car taking into account to increase a resource, decrease in relative density, increase the adaptability to manufacturing designing, increase the reliability maintenance at modern level and estimation of the material expenses.

II. DESIGN ELEMENTS AND FUNCTIONING PRINCIPLE

Design and project placing of «external system of one machine electromechanical transformation» [2] are considered instead of with other elements of the external complex. The starter-generating complex includes some elements including the electric car with two consistently connected anchor windings; starting the switching the device (the reducer of a special design), complex translating in the starter or the generating mode, placement between electric car and a pulley of a belt drive. It is structurally carried out as a single whole with the given electric car including a belt drive which creates communication between shaft starting the switching devices and cranked shaft ICE; the starting relay giving commands on inclusion, automation and the mode alarm system. Complex placing is provided nearby a cranked shaft taking into account balance ICE. The Belt drive is projected taking into account all expected normal moments and casual overloads.

The developed complex is projected on the basis of the engine starter in the direct current external transport systems [3]. Despite some principles of creation of contactless electric cars [4], essentially there is no replacement to the modern constructive decision which is carried out by two electric cars including starter and generator. Leaving one of them in the external electric network, in DC cars, it is possible to use it in quality of the starter and the generator [5]. For creation the function of the generator, it is necessary to displace brushes (the displacement zone corresponds to a solution of contacts) from a collector on a rack in different levels on some millimeters and being near to a collector. Displacement will not demand the big efforts, if a mechanical complex to mount on the sliding greased system is used. Considering that the system is supplied by the springs operating towards a rack, quite probably no necessity to strengthen force of a returnable spring of the relay of management. Such position will correspond to an electric contact condition collector brush systems at rotation of an anchor which the collector will be transformed to an alternating current source (in the presence of a stream).

Frequency of the induced electromotive power (e.m.p) will be certain by the known formula

$$f = \frac{p.n}{60} \quad (1)$$

where p is the number of poles and n is the frequency of rotation of an anchor.

It is considered that the idling frequency of rotation of a cranked shaft is nearby 700-800 turns/minutes, in a range of the generating mode frequency f = 50÷250 Hz. If the e.m.p. is removed from a collector in a three-phase source to straighten and submitted through contact rings to external electric system, then it will be created in the normal generating operating conditions (Figure 1).

The starter mode, being short-term, corresponds to the closed position of the main contacts of the starting relay. After a command "start-up" during time of a solution of contacts, the brushes move towards a collector and in the beginning of a failure of the contacts of brushes. Then the collector is carried out the pressure of the accumulator on an anchor winding moves. Communication e.m.p. and pressure of the accumulator at the moment of start-up it is regulated by various ways: chain rupture, application, inclusion of barrier resistance. The pressure regulator also participates in this transient. Removing the "start-up" command under the influence of returnable springs brush knot and the special lever of the relay brush in the car system comes back also a starting position to a rack. The starter - generator is adjusted on a generating mode.

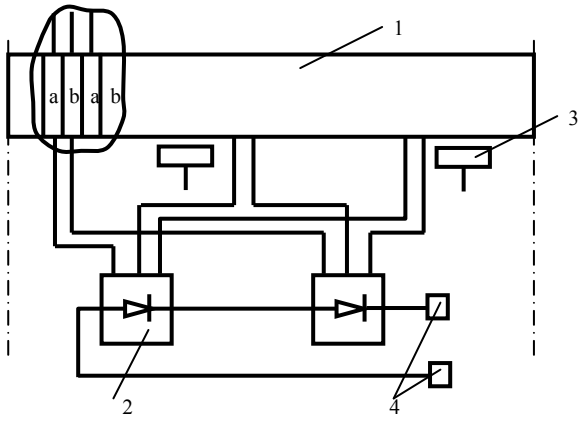


Figure 1. The electric scheme of the generating mode
1. collector; 2. rectifiers; 3. brushes on a rack;
4. contact rings; a and b are the anchor windings

III. DESIGNING AND ESTIMATION OF MATERIAL BALANCE

One of the basic questions of the given working out is the decision of elements of designing including a choice of entrance parameters and design configuration, sequence of performance of the given mode and free functioning of any mode, a tentative estimation of the expense of materials. For the purpose of rapprochement of opposite regime conditions (implementing, generating) as entrance parameters frequency of rotation of an anchor, starting capacity, external electric capacity [2] are accepted, where n_c is the frequency of rotation in starter a mode and $n_{min \cdot q}$ is the rotations in a generating mode.

Frequency of rotation, n_c, is accepted to receive the least relative density of the car that demands value increase n_c and simultaneously preserve the stability as in electric and mechanical relations. The reliability in a generator mode is in all range of frequencies (n_{min}÷$n_{max,}$ where n_{min} corresponds to frequency of rotation of idling of cranked shaft ICE) at the frequencies of rotation $n_{min.q}$. The pressure equal to rated voltage of external electric network U_b taking into account falling of pressure in system should be developed. Researchers have shown that at modern constructive decisions on execution of a winding of the anchor, comprehensible of to two modes $n_{min.q}$. It is possible to accept in 2÷2.5 time of less frequency of rotation the starter mode n_c.

The developed system is projected on the basis of the direct current car with a starter applied now external transport objects. For an estimation of the general economy of materials in comparison with an existing design, it is necessary to consider not only weight of materials of electric cars, but also weight of all communications connected with maintenance of a mode of starter and generator:

- Creation of a mode of the generator is carried out by the accepted car of a direct current (as the high-frequency generator) and for this reason the compared set of the generating weight completely acts in film;
- The new complex provides a belt drive of the moment from the electric car on cranked shaft ICE in the mode of the starter and back in the generating mode. For this reason the quantity of fixing details and accordingly decreases, the gross weight starter-generating complex decreases;
- In connection with increase of frequency of rotation of an anchor of the new car in the copper volume, weight of the electro technical steel, weight of constructive elements decreases.

IV. DESIGN ELEMENTS AND FUNCTIONS

The elements and functions are important needs of the project for creation of an intermediate element between electric car and cranked shaft ICE. It should fulfill all requirements necessary for functioning of two modes: in starter - reception starting frequency of rotation of a cranked shaft, in generating - creation of a uniform shaft between cranked shaft and electric car working as high frequency generator. The elements are starting switching devices which work without intervention from outside.

The first design for performance starting in switching operations, consisting of qipoid and screw tooth gearings, is released from muff a freewheeling. It gives the chance to increase much more the moment transferred from the engine of a direct current to cranked shaft ICE. Elements of the device with direct current engine are shown in Figure 2. Its A-A cut and lever placing on a screw wheel are shown in Figures 3 and 4, respectively. In the modes of starter-generator, lever movement (Figure 6) is limited to the support fixed on a screw wheel. The brake disk is connected to the basis (Figure 4) has communication with leading shaft and brake disk has a brake latch is connected by contact to electric scheme.

The actuating unit for the starter-generator works as follows. Start-up ICE is carried out by the direct current engine, applied for the starter-generator. For operation performance the command by means of a starting key (in drawings it is not shown) is given. At pressure giving on the coil of the starting relay (in drawings it is not shown) it works and by means of the lever connected with an anchor of the engine in direct current, establishes a brake latch to a groove of a brake disk, and a brake disk instead of with the basis creates the moment operating against rotation of cranked shaft ICE. At this time pressure on a winding of an anchor the starter-generator also moves.

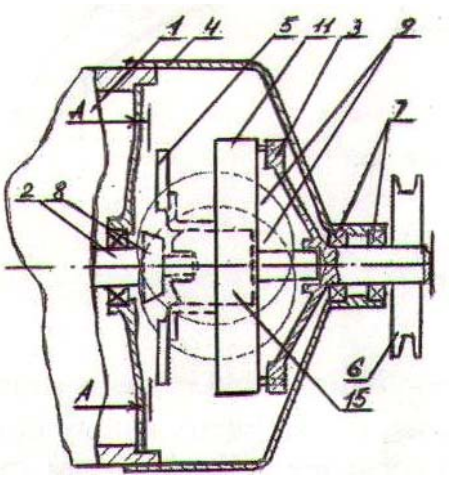


Figure 2. The constructive scheme of actuating unit for starter-generator
1. direct current engine; 2. leading shaft; 3. conducted shaft; 4. cover; 5. brake disk; 6. Pulley; 7. bearings; 8. small cogwheel qipoid transfers; 9. big cogwheel qipoid transfers; 10. screw gear cogwheel; 11. screw wheel

The rotating moment of the engine shaft in direct current, having mechanical communication with qipoid transfer and target shaft of the actuating unit, screw and belt transfers are transferred to cranked shaft ICE. The screw gear wheel is made of two parts (semi wheels have sliding possibility among themselves round relative to an axis) and regarding to the sum of forces F_1 and F_2 translate on a conducted shaft (Figure 4.a) the moment, operating in starter a mode.

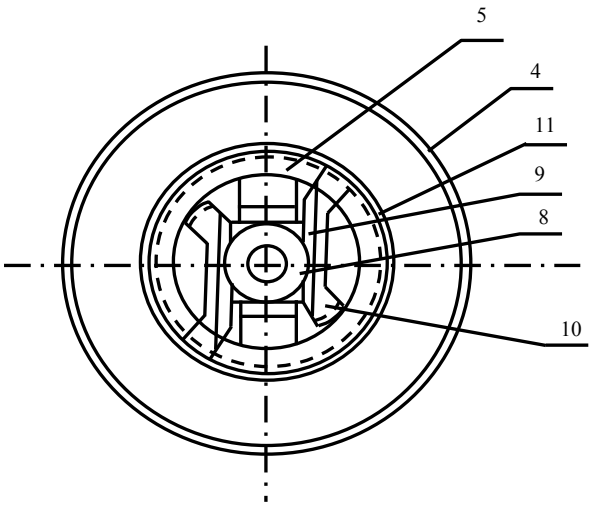
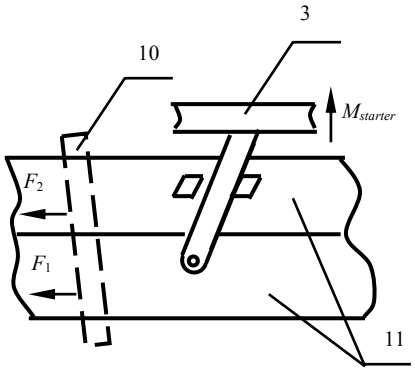
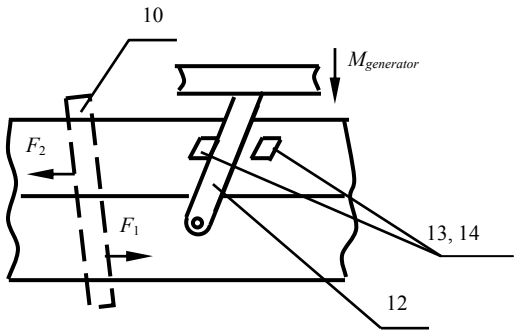


Figure 3. A-A cut of the scheme of the actuating unit



a)



b)

Figure 4. Lever placing on a screw wheel
12. lever; 13, 14. support

Frequency of rotation in the anchor shaft of the engine in direct current the ω_1 decreases to starting frequency of rotation of cranked shaft ICE taking into account three numbers of transfer:

$$\omega_p = \omega_1 \frac{1}{K_0} \tag{2}$$

where $K_0 = K_r.K_s.K_p$ is definitive number of transfer, K_r is number of the relation of quantity of a teeth qipoid transfers, K_s is number of transfer of the screw and K_p is number of transfer of a belt.

Depending on entrance parameters of the project and the put requirements value K_0 can be regulated by means of making K_c, K_p and K_r.

Some reasoning and the resulted analytical researches have shown that the design executed with use qipoid and screw transfers gives the chance increases of the transferred moment. In each transfer the moment is translated by means of linear communication between teeth that promotes fall of noise to the bottom level. The safe load on the moment is high enough that decrease weight dimensional parameters, and it in turn leads to reduction of total amount of placing of elements. As soon as it is started ICE preparation and transition in a generating mode begins. At the moment of starting the direct current of the engine sharply decreases and also a latch is released from a brake disk and then the actuating unit passes in free position. The moment created by cranked shaft, with high frequency of rotation is transferred on conducting shaft (in starter mode - conducted).

The wheel of a screw gear, wheel qipoid transfers and connected to them and the internal screw will rotate in a rotation direction. If frequency of rotation of the leading shaft ω_1 (ω_2 in starter mode) is above frequency of rotation ω_2 (ω_1 in starter a mode), then the starter-generator will not be connected with the moment which at the time free the untied movement will proceed to $\omega_1=\omega_2$.

The transfer of the moment from the leader to a conducted shaft begins at equal frequencies ($\omega_1=\omega_2$). Transfer is carried out by braking of two screw wheels (Figure 4.b) under the influence of the generating moment of $M_{generator}$ with forces F_1 and F_2. The operating on semi wheels by means of the lever try to shift them in on the contrary located a direction and the screw wheel is exposed to full braking. Change of forces F_1 and F_2 is proportional to value of the moment of $M_{generator}$ gives the chance to create reliable mechanical communication on all range of a generating mode.

V. DESIGN FEATURES

The constructive scheme is given in Figure 5. This design also takes places between car direct current and the belt drive pulley. For performance of function, a reducer two complete sets of tooth gearings are used.

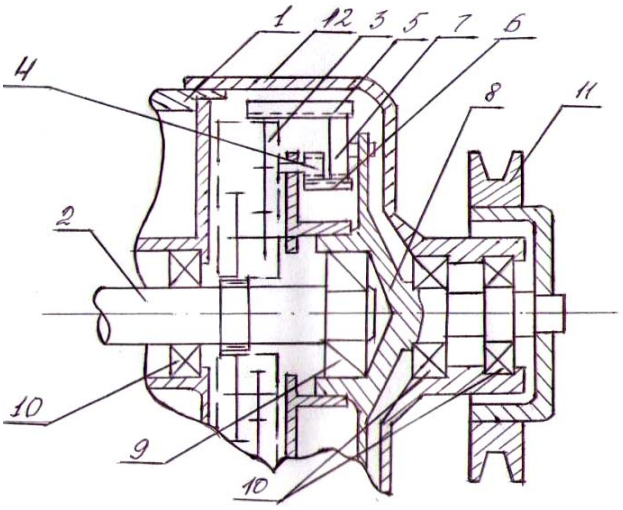


Figure 5. The constructive scheme starting the switching devices 1. direct current car; 2. shaft of the car of a direct current; 3. block of tooth gearings; 4. exit of the block of tooth gearings; 5. rotating the external cogwheel; 6. rotating internal cogwheel; 7. leading cogwheel; 8. pulley shaft; 9. freewheeling muff; 10. bearings; 11. pulley; 12. cover

In design of the tooth gearings block, connected with direct current car, three cogwheels with their placing through 120° on two diameters are entered. For reduction of width and weight of a wheel in the second diameter mechanical connection the wheels have the first diameter in two points.

The second complexity includes two cogwheels with big diameter and three wheels connected with them. The last complication takes place between the big wheels through 120° .

VI. STARTER MODE

The direct current car and the block of cogwheels are connected for planting on the car shaft. The block of cogwheels has two exits including the big diameter of the cogwheels located on the second diameter which are connected with outwardly rotating wheels, and internal rotating wheels have connection with wheels of small diameter. The wheels are rotating on external diameter n_1 and on internal diameter n_2, the frequency of the car n_c decreases. On request as the project the internal rotating wheel can rotate in the required party during calculations can be accepted $\pm n_2$. Between wheels with external and internal rotation, the gear is established for the driving wheel at required frequency of rotation which is defined taking into account frequencies of rotation n_c, n_1 and n_2.

For the analysis and redesigning of starting process in Figure 6, the placing of wheels of an external and internal wheel is shown. At calculations given starting the switching devices, the basic settlement parameters are accepted diameters D_1, D_2 and D_3. Basically, the given sizes are defined frequency of rotation ICE.

Frequency of rotation of the external wheel is defined taking into account the number of transfers as follows:

$$n_1 = \frac{n_c}{k_1 k_2 k_3} \tag{3}$$

where k_1, k_2 and k_3 are the number of transfer of the first, second radiuses and transfer number between outwardly rotating and conducting wheels.

Frequency of rotation in the internally rotating wheels is also defined by the parameters of the block of tooth gearings.

$$n_2 = \frac{n_c}{k_1 k_2 k_3'} \tag{4}$$

where k_3' is the transfer number between internally rotating and the leader wheels. If to consider that $D_2 < D_1$ $k'_3 > k_3$ that $n_1 > n_2$, then

$$n_2 = n_1 \frac{k_3}{k_3'} \tag{5}$$

and difference between $n_1 > n_2$:

$$\Delta n = n_1 - n_2 \tag{6}$$

Frequency of rotation of a driving wheel:

$$n_3 = \frac{D_1}{D_3} \Delta n \tag{7}$$

Frequency of rotation of a shaft of a pulley:

$$n_{fr} = \frac{D_1 - D_2}{D_3} n_3 \tag{8}$$

Frequency of rotation of a cranked shaft:

$$n_c = n_{fr} . K_p \tag{9}$$

VII. GENERATOR MODE

As ICE is started the starting pulley of the switching devices will start to rotate with frequency above on K_p (number of transfer belt) and all elements of the device connected to it will rotate with the same frequency. This process will continue until the rotation frequency will not be equal to shaft rotation frequency the direct current car.

At this time the freewheeling muff will begin and the uniform force between cranked shaft and the direct current engine is created. At occurrence in connection of these elements no blow or mechanical overload is observed. The rotation frequency of cranked shaft ICE can be unstable during transition. But the freewheeling muff is provided with a special clamp which creates the additional moment of the uniform shaft maintenance. At sharp reduction of rotation frequency, the cranked shaft can be an infringement of the uniform shaft, but further the anchor of the direct current car and starting elements of the switching devices are adjusted with the uniform shaft.

VIII. CONCLUSIONS

The research is developed for a starter-generator system connected to an external electric network which covers the following results:

- The scheme of one machine system including a transformation, a starter is developed to connect to a generator;
- The analysis is given the principles of functions to the constructive complex system in two modes of the starter and the generator;
- Placing of the developed designing system in a complex with ICE is also underlined;
- It is estimated that technical and economical parameters at replacement of a complex operating are including the starter and the generator;
- The analyzed two designing systems are given as starting switching devices; full concepts of the system, an action principle, and system transfer in different modes.

It is established that the cost of the power equipment of mobile installations in oil and gas economy will go down at the expense of economy of materials with such complex electric equipment elements.

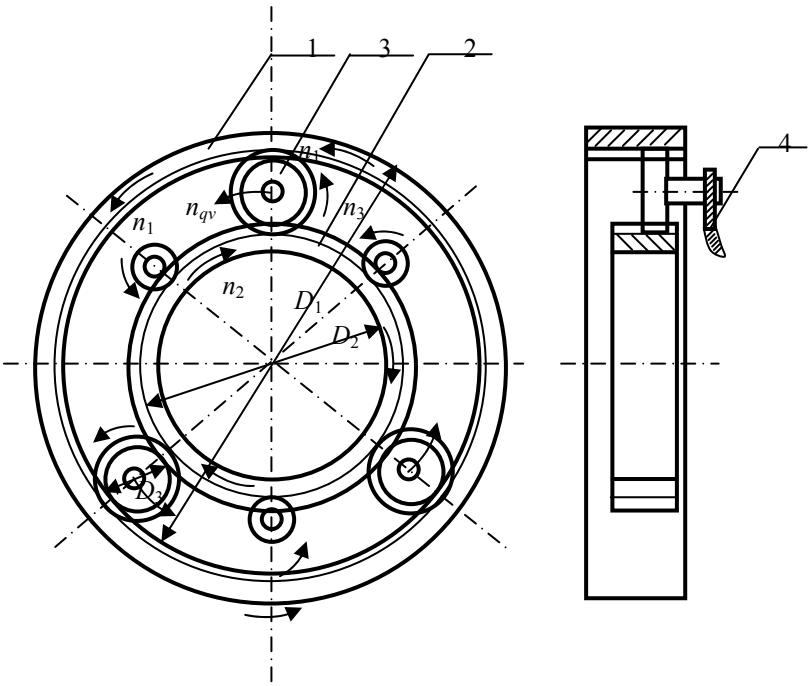


Figure 6. The scheme of placing of external, internal and leading wheels
1. external wheel, 2. internal wheel, 3. driving wheel, 4. pulley shaft

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BIOGRAPHY

Zabulla Nureddin Musaev was born in Azerbaijan, 1939. He has ended the Power Faculty, Azerbaijan Institute of Oil and Chemistry (nowadays Azerbaijan State Oil Academy) in 1962. He received the M.Sc. degree in 1969. Now, he works as the senior lecturer of chair of "Electric the Equipment and Automation of Plants" in Power Faculty of Azerbaijan State Oil Academy, Baku, Azerbaijan.